IFIP TC 13 SEMINAR
TRENDS IN HCI

PROCEEDINGS

March 26, 2007. Salamanca (Spain)

PROCEEDINGS

IFIP TC 13 SEMINAR: TRENDS IN HCI

March 26, 2007. Salamanca (Spain)

Edited by Ana B. Gil, Julio Abascal and Francisco J. García

This publication has been produced with the assistance of:

Ministerio de Educación y Ciencia (MEC): Proyects TSI2005-00960 and TIN2006-27687-E
International Federation for Information Processing (IFIP)
Universidad de Salamanca
Universidad del País Vasco
GRupo de investigación en InterAcción y eLearning (GRIAL)

Published: June 2007

Proceedings of the:

IFIP TC 13 SEMINAR: TRENDS IN HCI
March 26, 2007.

University of Salamanca - Spain

I.S.B.N.: 978-84-690-6531- 0
Depósito Legal: S·1005-2007

Ana B. Gil, Julio Abascal and Francisco J. García (Eds.)

Program:

IFIP TC 13 SEMINARTrends in HCI. March 26, 2007. Salamanca (Spain)

9:00-9:15 Welcome speech and introduction to the workshop Annelise Mark Pejtersen. IFIP TC13 Chairperson. Centre for HumanMachine Interaction (DANFIP). Denmark.

9:15-10:15 *Toni Granollers* (University of Lleida).HCI in Spanish speaking countries
Paula Kotzé (University of South Africa).Cultural Factors in a Mobile Phone Adoption and Usage Model.

10:15-10:45 Coffee break

10:45-11:45 *G.C. van der Veer*. (Open University Netherlands).Cognitive Ergonomics in Interface Development - A Brief Discussion of a Moving Science.
José Cañas. (University of Granada).Cognitive Ergonomics in Interface Development Evaluation.

11:45-12:45 *Gitte Lindgaard* (Carleton University). Intelligent Decision Support in Medicine: Back to Bayes?
Myriam Arrue (University of the Basque Country).Development of Accessible Web Applications: Highlights and Trends.

13:00-14:30 Lunch

14:30-16:00 *Ana B. Gil* (University of Salamanca).Learner Course Recommendation in e-learning Based in Swarm Intelligence.
Annelise Mark Pejtersen (Centre for Human Machine Interaction, Denmark).Evaluation of a Collaborative Annotation System.
Manuel Ortega (University of Castilla-La Mancha).Developing Collaborative and Ubiquitous applications using CIAM.

16:00-16:30 Coffee, open discussion and conclusions

16:30 Closure of the workshop Francisco J. García-Peñalvo (University of Salamanca) and Julio Abascal (University of the Basque County)

21:00 Dinner

Table of Contents:

HCI in Spanish speaking countries

Toni Granollers
GRIHO, HCI research group
Computers Department - Escola Politècnica Superior - University of Lleida
Lleida (Spain)
tonig@diei.udl.es

Abstract: As easy to use the computers were, as fast they introduced at every house, every work and everyday people lives. Nowadays nobody doubts about the importance of attributes such as usability when talking about interactive systems.
Human-Computer Interaction (HCI) is the recent but growing related discipline concerned with the design, the evaluation and the implementation of interactive systems for human use and with the study of major phenomena surrounding them.
Even though, HCI related topics are not consolidated enough in university (and not university) studies. Moreover, its interdisciplinary nature and underdevelopment of teaching resources makes assimilation by students difficult. Teachers and researchers have a situation of poor consolidation, shortage of material, little methodological development, and also with the dilemma of situating the educational paradigm in a formal academic model similar to that of other disciplines, or that used in the area of courses given in the industry for HCI professionals.
This contribution presents the domain of HCI as it has been developed in Spanish speaking countries from its beginnings up to the present. It focuses on the current situation at different study levels, from university carriers, to ad hoc short courses or specialized industry instruction. It also shows the context created in these countries (AIPO society and other related communities and companies that work in this field) that makes to look the near future situation to be success.
CHIJOTE, held in July 2005 in Puertollano (Ciudad Real) was the 1rst workshop about teaching HCI in our country. Different academic people from Spain exposed and shared the situation with international teachers that came from Netherlands (representing Europe), Chile and Colombia (in representation of South America) and US. Also an important group of professionals were worried about their HCI-specialized people needs. The idea was to have the "current HCI teaching snapshoot" and underline the future curricula of the discipline.
The paper also explains an educational experience based on a constructivist learning model of problem solving methodology when teaching the subject of HCI at the University of Lleida (Spain). We've been experimenting during the last 15 years and represent a good and experienced example.
The exposition analyzes known important initiatives such as the 1rst workshop about teaching HCI (CHIJOTE), the situation in the universities where HCI is taught, the revision of last Interacción proceedings, the books published and different Internet sources. The advances in professional companies also are exposed to give the widest as possible real situation and try to imagine the next future when talking about HCI in Spanish speaking context.

Keywords: HCI teaching, HCI companies, Spanish speaking context.

1 Introduction

Human-Computer Interaction (HCI) is a recent area of development with a strong interdisciplinary character and which has experienced a spectacular growth over recent years. This growth has occurred as a result of the generalization of computer use and of problems which originate from use by people who are not specifically trained in these appliances. Despite this growth, presence of HCI in Spanish universities is still scarce. This is especially true at undergraduate level, owing, in part, to the difficulty of introducing new subjects into university study schemes. It performs a scenario with shortage of competent people prepared to assume the HCI real industry needs.

This scenario presents us, as university tutors, a situation of poor consolidation, shortage of material, little methodological development, and also with the dilemma of situating the educational paradigm in a formal academic model similar to that of other disciplines, or that used in the area of courses given in the industry for HCI professionals. Moreover, in many universities the HCI contents are placed inside programming courses, this could instigate problems of credibility and confusion in the students.

This situation was analyzed for first time in July 2005 by professional and academic people belonging to the most important HCI Spanish speaking society AIPO[1] in the 1rst workshop about teaching HCI in those countries. This paper summarizes the main contributions and conclusions from that workshop. It also analyzes the situation from that workshop up today.

The contribution also gives the widest as possible real situation of all the factors related to human-computer interaction and tries to imagine the next future when talking about HCI in Spanish speaking context.

2 Teaching HCI: Justification and Context.

For many years major scientific societies have emphasised the importance of HCI training for engineers, incorporating it into programmes of study. The report by ACM/IEEE-CS Joint Curriculum Task Force Computing Curricula of 1992 [ACM, 92] establishes new thematic areas to cover subject matter from the discipline of computer science.

HCI is one of the nine thematic areas defined in the ACM curricula, an important aspect when situating its education in programmes of study of Spanish universities.

In 1988 the Special Interest in Human-Computer Interaction Group (ACM-SIGCHI) put into practice a group with the objective of composing a curricular proposal. The committee's task was to draw up a series of recommendations for education in HCI. This committee drafted the document ACM SIGCHI Curricula for Human-Computer Interaction in 1992 [ACM curricula], which contain a series of recommendations for the realization of HCI courses. To be able to cover all aspects of definition and the objectives, HCI must be comprised of a large number of different

[1] AIPO website: http://www.aipo.es

areas, which include different aspects of human beings and computers: computer science, psychology, sociology, anthropology, industrial design and fine arts.

3 Starting points for the analysis of the Spanish HCI context

One of the conclusions of the 5th HCI Spanish annual conference, Interacción, was the maturity of HCI discipline at scientific level in Spanish speaking countries [Interacción, 04]. But, the situation was not the same when talking about the teaching of this discipline.

Next sub-sections will show the initiatives looked for this analysis as a basis to be able to show the "current HCI teaching snapshoot" and underline the future curricula of the discipline.

3.1 Chijote workshop.

With the European Higher Education area (also knows as Bologna process) [Bologna, 00] as a main goal, it is necessary to assure that the curricular contents that in the HCI subject are taught in the university centres, also the pedagogical methods and the educational paradigms that are used fit to the demand that is observed in the society in general, and the company in individual.

Having this objective in mind, the AIPO society organized (in July 2005) the 1rst workshop about teaching HCI in our country [Chijote, 05]. These days tried to take advantage of the maturity in the investigating plane the Spanish groups to constitute a point of contact and discussion where educators from different knowledge areas could share their experiences in the matter of HCI teaching.

The main goal of the workshop was to have the opportunity, in a multidisciplinary context, to discuss, determine, to share and, mainly, to underline the future curricula of the discipline (the fundamental formative lines in degree, post-degree and doctorate in matter of HCI teaching) [Chijote goals, 05].

Different academic people from Spain exposed and shared the situation with international teachers that came from Netherlands (representing Europe) [G.C. van der Veer, 05], Chile [Baeza-Yates, 05] and Colombia [Collazos, 05] (in representation of South America) and US [Puerta, 05]. Also an important group of professionals were worried about their HCI-specialized people needs.

3.2 HCI Educators Workshop.

In March 2006 another important and similar experience was carried out in Limerick (Ireland). It was the first *HCI Educators' Workshop* denominated "HCIEd.2006-1 inventivity: Teaching theory, design and innovation in HCI" [HCIEd, 06] organized by important societies such as IFIP TC.13 (IFIP Technical Committee on Human Computer Interaction)[2], the British HCI Group[3], the CONVIVIO Network (the

[2] IFIP TC-13 web page: http://www.ifip-hci.org
[3] British HCI Group web page: http://www.bcs-hci.org.uk

European network for Human-Centered Design of interactive Technologies)[4] and the Irish Computer Society[5].

The purpose, as the organizers defined, was *to discuss and explore methods and best practice for helping our students learn about and apply inventive thinking when designing systems, visualisations and interaction for human use*. To share the understandings of how theories in the HCI curriculum can be taught to encourage inventive and innovative thinking among our students or usability evaluation in practice were some of the most important topics of the workshop.

In that workshop J. Lorés, representing the University of Lleida (as the oldest to offer HCI subject in Spanish universities) explained the InIPO (Introduction to Human-Computer Interaction in Spanish) course [Lorés et. al, 06]. It is given in the fourth semester of the degree course Technical Engineering in Management Computer Science of our university and it has been undertaken with Audiovisual Communication students.

The objective of this course is to introduce the future engineer to methodological teaching and basic concept knowledge of the discipline.

4 Current HCI state of art in Spain

4.1 AIPO master HCI commissions

One of the most important topics discussed during the above mentioned Chijote workshop was about the lack, in Spanish University, of studies in the HCI field. At that time most of universities that offered these matters (only a few) did it at an introductory level and, usually, such as a non mandatory subject within other subject in the curriculum degree.

During the last session of these days, the creation of a curricular proposal of a HCI Master was decided. The objective was to serve as orientative model for those universities and centers that wish to offer this type of formation. With that goal two commissions were created. One, formed by four people form academia and four from HCI industry, to be in charge of the curricular contents and, other, to be in charge to the legal, administrative and academic aspects necessary to start inter-university HCI masters in the Spanish university [AIPO HCI Master].

The curricular commission was the most active. They started the activities in a meeting held in Granada during the *VI Congreso Interacción Persona Ordenador* and, having virtual monthly meetings (every last Friday of the moth) finished their work in December 2006. It was more that one year of hard work where they analyzed other HCI masters around the world, they interviewed people to get the student profile, they debated every step with AIPO community[6] and, also, they held meetings with HCI companies responsible to debate the document they were preparing.

---

[4] CONVIVIO Network web page: http://convivionetwork.net
[5] Irish Computer Society web page: http://www.ics.ie
[6] HCI Spanish curricullar commission Blog: http://griho.udl.es/master-ipo

The final report [Master IPO, 06] is open and free, and serves as curricula for the universities that desire to develop an HCI Master. Figure 1 shows the general schema that defines the curricula.

Figure 1: Structure of the curricular HCI Master defined by AIPO society.

4.2 Consultation to AIPO members

When I was asked for writing this article I started to collect as much information I had. I gathered a big amount of information; however I didn't have all the HCI subjects. I started surfing the university WebPages, but, the information I got was not enough. Then, I decided to ask for information to the AIPO list (as I mentioned, this society groups all the teachers involved in HCI teaching in Spain and Spanish speaking countries).

I conducted a small questionnaire asking for suitable information that allows me to give the most accurate snapshot of teaching HCI in Spanish universities. The questionnaire was:

- The *Center* (Faculty, Universitary School,) and University.
- Kind of *Studies* (Informatics, Psychology, …).
- The *Subject Name*.
- Credits of the Subject (*#CR*). To know, 1 credit refers to 10 hours.
- Credits of HCI within the Subject (*#HCI CR*).
- Subject *Type* (Mandatory –*M*–, Non Mandatory –*NM*– or Doctorade –*D*–).
- The course that the subject started (*SC*).

The questionnaire was answered by twenty-one people and figure 2 shows all of them. The figure also shows information collected by other ways.

Centre/University	Studies	Subject Name	#CR	#HCI CR	Type	SC
ETSde Ing. Informática. Universidad de Sevilla.	- Ing. Informática - Ing. Técnica en Inf. de Sistemas - Ing. Técnica en Inf. de Gestión	Diseño de Interfaces Hombre-Máquina	6	6	NM	1997/98
EPS de Albacete. Univ. Castilla-La Mancha.	- Ing. Técnica en Inf. de Gestión	Multimedia, Hipermedia y Realidad Virtual	6	6	NM	2000/01
	- Ing. en Informática	Informática Gráfica	6	3	M	2000/01
ETS de Ing. Informática. Universidad Rey Juan Carlos.	- Ing. Técnica en Inf. de Gestión	Interfaces Gráficos	6	6	NM	1999/00
	- Ing. Técnica en Inf. de Sistemas	Sist. Multimedia Distribuidos	6	6	NM	1999/00
	- Ing. Informática	Interfaces de Usuario	6	6	M	2004/05
	- Ing. Informática	Multimedia e Hipermedia	6	6	NM	2001/02
	- Master Oficial en Sistemas de Información en Ing. Informática	Seminario de SW Avanzado para la Sociedad de la Inform.	5	3	NM	2006/07
Universitat Oberta de Catalunya (UOC)	- Ing. Técnica en Inf. de Gestión - Ing. Técnica en Inf. de Sistemas	Interacció Humana- amb els Ordinadors	6	6	NM	?
	- Ing. Técnica en Inf. de Gestión - Ing. Técnica en Inf. de Sistemas	Final Degree Projects				?
	- Ing. Informática	Interfícies Multimèdia	6	6	NM	2004/05
	- Ing. Informática	Final Degree Projects				
	- Documentación	Interac. de Humanos con Ord.	4,5	4,5	NM	2003/04
EPS de Elche. Univ. Miguel Hernández	- Ing. de Telecomunicaciones	Diseño de Sistemas de Información Web	6	6	NM	2004/05
Fac. de Ciencias Sociales y Jurídicas de Elche. Univ. Miguel Hernández	- Licenciatura en Periodismo	Comunicación e Internet	4,5	2,5	M	2006/07
Fac. Informática de Barcelona. Univ. Politéc. de Barcelona (UPC)	- MSc in Computing	Realidad Virtual y Aumentada, Usabilidad y Presencia	3	1,5	NM	2006/07
Escola Universitària Politècnica Mataró (UPC)	- Eng. Tècnica en Informàtica	Interacció Persona Ordinador	7,5	7,5	NM	2002/03
EPS d'Enginyeria de Vilanova i la Geltrú (UPC)	- Ing. Técnica Industrial	Sistemas de Teleoperación	6	2	NM	2006/07
	- Ing. en Automática y Electrónica Industrial (segundo ciclo)	Sistemas de Producción Integrados	6	2	M	2004/05
	- Control, Visión y Robótica (Doct.) - Automática y Robótica (R. Master)	Teleoperación e interfaces hombre-máquina	4,5	2	D	2004/05
Fundació Politécnica de Catalunya (UPC)	- Master Eng. Informática	Diseño de Interfaces	3	3	M	2002/03
ETSde Ing.s. Universitat de Valencia	- Ing. Informática	Entornos de Usuario	6	6	NM	2000/01
ETSde Ing. Informática. Universidad de Alcalá	- Ing. Superior en Informática	Interacción Persona-Ordenador	6	6	NM	2004/05
	- Información, Documentación y Conocimiento	Interacción Persona-Ordenador en Sistemas de Información Avanzados	6	6	D	2005/06
Fac. de Biblioteconomía y Documentación. Univ. de Barcelona	- Máster en Gestión de Contenidos Digitales	Interacción y Visualización	5	5	NM	2005/06
Fac. de Informática. Universidad del País Vasco	- Ing. Informática	Sistemas de Interacción Avanzados	6	6	NM	2001/02
Centro Politécnico Superior. Univ. Zaragoza	- Ing. Informática	Interacción Hombre-Máquina	6	6	NM	1996/97
	- Posgrado en Servicios Web	IPO	5	5	-	-
	- Doctorado en Ing. Informática	Diseño y evaluación de interfaces	3	3	D	-
EPS. Universidad de Lleida	- Ing. Técnica en Inf. de Gestión	Introducción a la IPO	6	6	M	2001/02
		IPO (especialización)	9	9	NM	2001/02
	- Programa Doctorado en Ing.	Despliegue de la Accesibilidad y de la Usabilidad en Sist.Interact.	3	3	D	2005/06
		Diseño de Interfaces Físicas	3	3	D	2005/06
		Internacionalización y Modelos Culturales en las Comunidades Digitales	3	3	D	2005/06
		Ing. de la Usabilidad	3	3	D	2003/04
		Aprendizaje Colaborativo Asistido por Ordenador	3	3	D	2005/06
	- Master en IPO	Todas las asignaturas	60/120	60/120	-	2007/08
Facultad de Informática. Univ. Politécnica Madrid	- Ing. en Informática	Usabilidad y Diseño de Interfaces de Usuario	4,5	4,5	NM	2005/06
E.T.S.I. Telecomunicación. Universidad de Málaga	- Master oficial de postgrado en Tecnología de Telecomunicación	Ing. de la Interacción Hombre-Máquina	5	5	NM	2003/04
	- Ingeniero de Telecomunicación	BioIng.	4,5	0,5	NM	2005/06
Facultad de Bellas Artes. Universidad de Málaga	- Licenciado en Bellas Artes	Tecnología de Realidad Virtual para el Arte Interactivo	6	6	NM	2007/08
E.T.S. de Ingeniería Informática y de Telecomunicaciones. Universidad de Granada	- Ing. Técnica en Inf. de Gestión	Diseño de Inter. de Usuario	6	6	NM	
		Ing. del Software I	7,5	0,5	M	2000/01
		Ing. del Software II	7,5	0,5	M	2000/01
	- Master en Desarrollo de Software	Ing. de la Usabilidad	3	3	NM	2006/07
EPS. Universidad Autónoma de Madrid	- Programa Oficial de Postgrado - Master en Ing. Infor. y Telecos.	Interacción Persona-Ordenador	6	6	NM	1994/95
Dpto. de Sist. Informáticos y Computación. Univ. Politécnica de Valencia	- Máster en Dirección y Gestión de Sistemas de Información (Informática)	Presentación e Interfaces de Usuario	1,6	1,6	M	2003/04
	- Ingeniería en Informática	Interfaz Gráfica de Usuario	6	6	M	2004/05

Figure 2. State of teaching HCI in Spanish Universities (February 2007).

The table of the figure shows that HCI is taught in 16 universities (of 69) involving 21 different Faculties. Figure 3 summarizes the Studies where HCI is taught. It is easy to observe that, even knowing that HCI is a multidisciplinary subject, computing studies still are the most important when teaching this discipline.

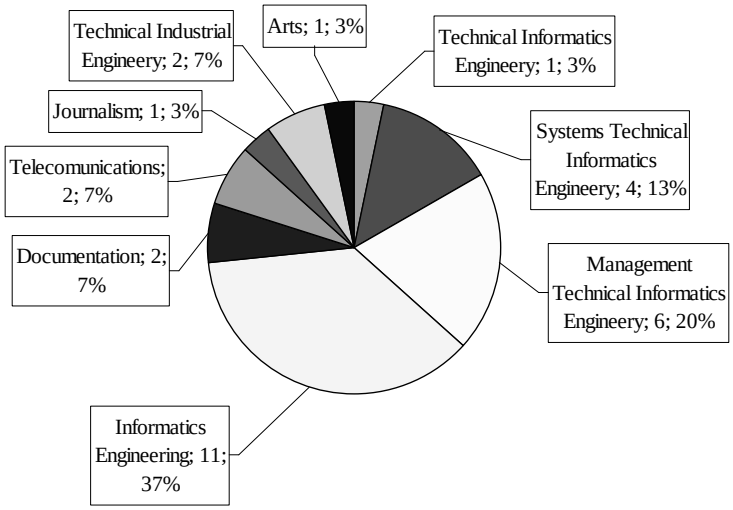


Figure3. Grade University Studies that offer HCI in their docent plans.

If we analyze the HCI in Post Grade and Masters, the HCI situation is thirteen subjects offered in eleven different studies. Those numbers do not reflect the University of Lleida case. This university offers fifth doctorade subjects and next academic course will start the first HCI Master in Spanish language. This master is structured following the European directives (120 ECT credits) and will count with multidisciplinary participation from seven universities (aside of Lleida U.) and four teachers coming from companies working with HCI field.

The study of the questionnaire also reveals that all the subjects that offer HCI in Spain have 175.6 credits in total, where 143.6 are "pure" HCI (it represents the 81.77%) grouped in 9 Mandatory (M), 26 Non Mandatory (NM) and 8 in Doctorate subjects.

Academic course	Number of HCI Subjects started	Academic course	Number of HCI Subjects started
1996/97	1	2002/03	1
1997/98	1	2003/04	4
1998/99	-	2004/05	7
1999/00	2	2005/06	8
2000/01	5	2006/07	5
2001/02	4	2007/08	2

Table 1: This table shows when the academic HCI Subjects started.

Finally, table 1 shows that first HCI university course started ten years ago and, since then, noticeable increasing has been carried out; mainly last tree years.

4.3 Main HCI societies

The Association for Human Computer-Interaction AIPO has been the tool that enabled the organization of, basically, the HCI *Spanish speaking academic world*. AIPO arises in November '99 with the objective to promote and to spread the HCI in all its slopes (organization of scientific and technical activities) and to establish agreements with other national and international societies [Lorés, 05].

From its foundation the association served for organize an annual congress, several workshops and conferences, or sponsored visits of international experts are organized, to publish books.

During the 5th conference edition (celebrated in Lleida [Interacción, 04]) the first university-company day served to present AIPO to the companies that have HCI their most important business. The necessity to create a common forum between the industry and the university started the *company AIPO branch* and, from then, the website shows the new elements of interest for the companies.

In the professional side, important Spanish HCI communities and initiatives are:

- Cadius[7], community focused to usability, information architecture and interaction design. The community is structured around an online discussion-list and periodic meetings in the most important cities. Founded on 2001, today it counts on more than 1,500 members worldwide, in special of Spain and Latin America.
- Alzado[8] is an independent online publication founded by E. Manchón, L. Villa and C. Martin. The idea to create Alzado was born in October '02 and appeared to Internet in February '03 with the objective to share real cases about information design, Web development, multimedia, usability and data representation and to divulge theory that help the development of future projects. To put the user in the centre of the development is its other important goal.
- Telefónica (one of the most important communication companies) publishes the *human factors* bulletin[9] since April '93.
- Dnx[10] since 2004 offers from its website ides organized as articles, newsletters, jam sessions, and a specialized blog.
- "No Solo Usabilidad" is an electronic multidisciplinary journal started in 2003 with the objective to serve for diffusion, spreading and interchange of knowledge between Web developers and investigators[11].

Other important HCI related societies are the Spanish sections of significant worldwide associations:

- upaSpain[12], Spanish part of the Usability Professional Association, and

[7] Cadius English website: http://www.cadius.org/english.html
[8] Alzado website: http://www.alzado.org
[9] Human Factors bulletin: http://www.tid.es/html/boletin/articulos_boletin.html
[10] DNX English website: http://www.dnxgroup.com/english/index.html
[11] No Solo Usabilidad Web journal: http://www.nosolousabilidad.com
[12] Asociación Española de Profesionales de la Usabilidad: http://www.upaspain.org

- CHISPA[13], the Spanish chapter of ACM SIGCHI –the Association for Computer Machinery's Special Interest Group on Human-Computer Interaction–.
- AIPO Colombia[14], at the beginning of current 2007 the Colombian AIPO members started its own activities.

4.4 HCI in Spanish companies

In the last years, diverse symptoms elucidate that the Spanish market is growing very fast to incorporate the Usability Engineering and User Centered Design (UCD) methods when developing software or interactive devices.

Important companies (Telefónica, Bankinter, La Caixa, Indra, …) have created internal specialized usability and UCD groups.

An emergent usability consultancy market has caused the birth and consolidation of specialized companies around HCI scope. It is the case of Claro Studio, Xperience Consulting, Usolab, DNX, The Cocktail, to mention some of most well-known.

At the same time, the current CHI restlessness of the companies has generated the necessity of formation in usabilidad and UCD of the professionals, as much of the own companies as of its suppliers, being translated in a demand of internal formation [Perdrix, 05].

Next list serves as representative example:

- The *Use Enginering Group*[15] within the Methodology and Engineering Software Division of Telefónica I+D, is a multidisciplinary team formed by specialists in cognitive psychology, ergonomics, and UCD methodology specialists. It's main objective is to assure the usability of the products in the different development phases, and also lend consultancy to companies of Telefónica Group on these subjects.
- Claro Studio is a company that conducts usability-tests and other user research for global companies that wish to test their products in Spain and South America. All research is conducted by facilitators skilled in psychology and advanced usability techniques. Since 1995, Claro has tested and optimized high-profile web sites, software and mobile applications for the Spanish, North American and South American markets. Since the end of 2005 Claro Studio joined its activity with Multiplica company, offering HCI services integrated with greater interactive solutions[16].
- Xperience Consulting[17] is a company settled in Madrid and Barcelona that, since 2001, offers consultancy, online measurement (e-Metrics), investigation and training around the user experience field.

---

[13] http://www.chispain.org
[14] http://www.usarte.org
[15] Telefónica I+D Usability website: http://www.tid.es/html/boletin/usabilidad.html
[16] Claro Studio into Multiplica website: http://www.multiplica.com/experiencia.asp?idioma=ESP
[17] Xperience Consulting english website: http://www.xperienceconsulting.com/eng

- Dnx is a company dedicated to the investigation and consultancy for new markets, specialists in the analysis of user experience and in online investigation.
- The Cocktail[18] is a consultant of user experience and interaction design that thinks that to develop a digital product or service (web, mobile, pda, tv, ...) implies to face a user that, through an interface, has total control of the relationship.
- Usolab[19] is a consultancy specialized in usability and UCD initiated at the end of 2001. Usolab has been centered mainly in analyzing the usability, doing recommendations and redesigning for websites of financial organizations. They also offer usability training (internal courses for companies and open seminaries).

4.5 Publications and online-blogs

Because of its short number, mention a part is for the HCI books. At this moment there are only four books written in Spanish language:

1. "*La interacción Persona-Ordenador*". Jesús Lorés and other university teachers involved in the creation of AIPO, in December 2001 wrote the first multidisciplinary and multiuniversitary HCI Spanish book. The book is available by CD and free downloadable from the Internet AIPO website [Lorés, 02].
2. "*Interfaces de recuperación de información: conceptos, metáforas y visualización*". Mari C. Marcos describes the concepts of HCI discipline from its documentation and information retrieval perspective [Marcos, 04].
3. "*Personas y Maquinas: el diseño de su interacción desde la ergonomía cognitiva*". Profesor J. J. Cañas explains how to desing the interaction process from a cognitive point of view [Cañas, 04].
4. "*Diseño de sistemas interactivos centrados en los usuarios*". The authors describe a particular UCD process that is used in the HCi teaching coursesd where they are [Granollers, 05]. The authors also have developed a website[20] describing the UCD process explained in the book. This website is actualized with examples and research advances with the objective to serve as learning support for HCI teachers and students.

Finally, another parameter that shows the emergence of HCI thematic in Internet is the numerous persona and corporative blogs dedicated to it. It is not the objective of this paper to give all of them, but, here we can see a list of the most representative HCI related blogs: Cadius webblog[21] , Usalo[22], E. Gutierrez y Restrepo personal accessibility webblog[23], E. Manchón personal webblog[24], biguel[25], Accessibility

[18] The Cocktail website: http://www.the-cocktail.com/en
[19] Usolab website: http://www.usolab.com
[20] Website related: http://www.mpiua.net
[21] http://www.cadius.org/weblog
[22] http://usalo.es
[23] http://bitacoras.sidar.org/emmanuelle
[24] http://eduardomanchon.com

webblog[26], G4: the Usability Sidar group (G4)[27], J. L. Velázquez personal webblog[28] or H. Matas personal webblog[29] (as part of Dnx website).

5 Current HCI state of art in Latin America

The objective of this paper tries to give a widest as possible state of HCI in all Spanish speaking countries. Previous paragraphs have focused on Spain case, and now the centre the attention will be in Latin America case, having the papers [Baeza-Yates, 05] and [Collazos, 05] the main information source.

Baeza-Yates describes an abstract about teaching human-computer interaction discipline in Latin American context. In particular, he presents the case of Brazil, México and Chile, as they are the most advanced and representative[30] South American countries.

This paper concludes that HCI, excluding Brazil, is still incipient in South America. It minds that at formative level they have a lack of people interested in the field. The article explains some problems in the Brazilian case such as: the lack of qualified teachers, the lack of educational material and the lack of well-equipped usability labs and lecture settings. Those problems are greater in the rest of countries.

Collazos explains his vision in Colombian case. There HCI formation started in 2004 with a non mandatory subject in the Systems Department of the University of Cauca (where he teaches HCI and computing technology). From then, other subjects have been initiated and he thinks that the situation is changing. Some teachers begin to participate in international events and the discipline acquires relevance in Systems Engineering formative programs.

Nowadays talented HCI research groups with formative vocation are emerging in Colombian universities and forming people in more consolidated HCI groups in Spain. This is the case of the new usability research group in the University of Quindio, they have two teachers/researchers in PhD programs in Castilla-La Mancha and Lleida universities with the objective to be a referent in the field.

6 Conclusions

This paper gives an extensive vision about HCI discipline in Spanish speaking countries. We have seen the main research and formative actions carried out to give the state of the art in Spain and the revision of some papers that gives the state in Latin America.

To complete the work a questionnaire has been carried out. It asked for information to present the current view of teaching HCI in Spanish universities. From

---

[25] http://www.biguel.com
[26] http://accesibilidad.blogspot.com
[27] http://www.bitacoras.sidar.org/g4
[28] http://www.jlvelazquez.net
[29] http://www.dnxgroup.com/humberto/index.php
[30] Baeza-Yates explains this countries classification, based in an interest HCI index.

that study we can conclude that teaching HCI in our context is very recent but a significant growth can be observed during last 5 years. To highlight, the HCI curricula developed by AIPO society and its first implementation, the HCI specific master following the European Higher Education directives (the Bologna process) with the participation of teachers from diverse universities mixed with professional HCI people.

The work also explains the situation in Latin American countries, where the relevance of our discipline has strongly raised during last years.

Finally the paper offers the industrial vision and on-line. It configures the current real sate of Human-Computer Interaction discipline in Spanish speaking countries.

Acknowledgements

In memoriam of Jesus Lorés, who founded our research group and gave us the human vision of the computers technology.

I would also to be thankful with all the AIPO members that answered my questionnaire request. They facilitated some of the results here presented.

References

[ACM, 92] ACM/IEEE-CS joint Curricullum Task Force Computing Curricula. 1992.

[ACM curriculla] ACM SIGCHI Curriculla for Human-Computer Interaction.

[Marcos, 04] Marcos, Mari Carmen. Interfaces de recuperación de información: conceptos, metáforas y visualización. Gijón: Trea, 2004. ISBN 84-9704-118-6.

[Interaccion, 04] V Congreso Interacción Persona Ordenador. http://griho.udl.es/i2004

[Bologna, 00] The Bologna Process. Towards the European Higher Education Area. http://ec.europa.eu/education/policies/educ/bologna/bologna_en.html

[Chijote, 05] I JOrnadas de Trabajo sobre Enseñanza de CHI. Universidad de Castilla - La Mancha. Puertollano (Ciudad Real). http://chico2.inf-cr.uclm.es/chijote2005/index.htm

[Chijote goals, 05] http://chico2.inf-cr.uclm.es/chijote2005/objetivos.htm

[G.C. van der Veer, 05] Veer, Gerrit C. Van der. HCI in Europe. Presente y Futuro de la Docencia en Investigación en Interacción Persona-Ordenador. I Jornadas de Trabajo sobre Enseñanza de CHI (CHIJOTE 2005), Puertollano (Espanya), 2005.

[Baeza-Yates, 05] Baeza-Yates, R.; Sieckenius de Souza, C.; Rivera, C. Enseñanza de Interacción Humano-Computador en Latinoamérica. Presente y Futuro de la Docencia en Investigación en Interacción Persona-Ordenador. I Jornadas de Trabajo sobre Enseñanza de CHI (CHIJOTE 2005), Puertollano (Espanya), 2005.

[Collazos, 05] Collazos, César Alberto. La Enseñanza de CHI en Colombia. Presente y Futuro de la Docencia en Investigación en Interacción Persona-Ordenador. I Jornadas de Trabajo sobre Enseñanza de CHI (CHIJOTE 2005), Puertollano (Espanya), 2005.

[Puerta, 05] Puerta, Angel. The Teaching of Human-Computer Interaction at US Universities. Presente y Futuro de la Docencia en Investigación en Interacción Persona-Ordenador. I Jornadas de Trabajo sobre Enseñanza de CHI (CHIJOTE 2005), Puertollano (Espanya), 2005.

[HCIEd, 06] First Joint BCS/IFIP WG13.1/ICS/EU CONVIVIO HCI Educators' Workshop "HCIEd.2006-1 inventivity: Teaching theory, design and innovation in HCI", (2006).

[Lorés et. al, 06] Lorés, J.; Granollers, T.; Aguiló, C. An Undergraduate Teaching Experience in HCI at the University of Lleida. The First Joint BCS/IFIP WG13.1/ICS/EU CONVIVIO HCI Educators' Workshop. "HCIEd.2006-1 inventivity: Teaching theory, design and innovation in HCI". Limerick (Ireland), 2006.

[AIPO HCI Master] Masters en Interacción Persona-Ordenador. At http://griho.udl.es:8080/aipo/formacion.jsp (information available only in Spanish).

[Master IPO, 06] AIPO curricular commission. Master en Interacción Persona-Ordenador. v.3 (11-dec-2006). At: http://griho.udl.es/toni/MASTER-IPO/Propuesta_Master_IPO_v3.pdf

[Perdrix, 05] Perdrix, F.; Granollers, T.; Lorés, J. Necesidades docentes en IPO fuera del ámbito universitario". I Jornadas de Trabajo sobre Enseñanza de CHI (CHIJOTE 2005), Puertollano (Spain). 2005.

[Lorés, 02] Lorés, J. (editor) [cdrom]. Introducción a la interacción persona-ordenador. AIPO. ISBN: 84-607-2255-4. 2002. Downloadable from http://www.aipo.es/ipo

[Granollers, 05] Granollers, T; Lorés, J; Cañas, J. Diseño de sistemas interactivos centrados en el usuario. Editorial UOC. 2005.

[Cañas, 04] Cañas, J. J. Personas y Maquinas: el diseño de su interacción desde la ergonomía cognitiva. Pirámide Editions. 2004.

[Intertacción, 04] Interacción 2004. V congreso annual AIPO. http://www.aipo.es/i2004

[Lorés, 05] Lorés, J. El despliegue de la Ingeniería de la Usabilidad en España. Online paper available at http://griho.udl.es/publicacions/2005/desingusab.pdf

Cultural Factors in a Mobile Phone Adoption and Usage Model

Judy van Biljon
(School of Computing, University of South Africa, South Africa
vbiljja@unisa.ac.za)

Paula Kotzé
(School of Computing, University of South Africa, South Africa
kotzep@unisa.ac.za)

Abstract: In human-computer interaction and computing, mobile phone usage is mostly addressed from a feature-driven perspective, i.e. which features do a certain user group use, and/or a usability perspective, i.e. how do they interact with these features. Although the feature driven and usability focus carry value, it is not the full picture. There is also an alternative or wider perspective: mobile phone users are influenced by demographic, social, cultural, and contextual factors that complicate the understanding of mobile phone usage. Drawing on concepts and models from sociology, computer-supported cooperative work, human-computer interaction and marketing, we researched the influence of culture on mobile phone adoption. The contribution of this research is a model that includes culture as one of the factors that influence mobile phone adoption and usage. The proposed model combines the influence of mediating factors (personal, demographic and socio-economic) and determining factors (social influence, perceived ease of use, perceived usefulness, facilitating conditions and behavioural intention) on actual system use. The proposed model has been evaluated from both a qualitative and quantitative perspective.

Keywords: Mobile phone usage; mediating factors; determining factors; usage intensity, usage variety and usage breath; sociology, computer-supported cooperative work, human-computer interaction and marketing.
Categories: H.1.2, J.4,

1 Introduction

Mobile communications, including mobile phones, is a complex and rapidly changing industry consisting of hardware, software, network and business aspects. Mobile phone usage involves the mobile phone, the telecommunications system, the mobile phone users, the adoption, and the use of the system. People have adopted mobile phone technology with almost unprecedented enthusiasm [Keshav 2005] to the effect that the status of a mobile phone has changed from an unknown device to an essential device in the span of less than ten years. Therefore it is necessary to reflect on the factors that influence mobile phone adoption and use. Past research has focused on researching mobile phone adoption and usage from a variety of divergent perspectives. For example, in sociology the user has been researched as a social entity

and in marketing the focus has been on the user as an economic entity. In human-computer interaction (HCI) and computing, mobile phone usage is mostly addressed from a feature-driven perspective, i.e. which features do a certain user group use, and/or a usability perspective, i.e. how do they interact with these features. One of the aims of the field of HCI is to add value to the user interaction. Although the feature driven and usability focus carry value, it is not the full picture. There is also an alternative, or wider, perspective: mobile phone users are influenced by demographic, social, cultural, and contextual factors that complicate the understanding of mobile phone usage.

This paper is our response to taking a wider perspective on modelling mobile phone usage, while paying special attention to the cultural perspective. We focus on two research sub-questions: does culture influence mobile phone use and adoption and how can the influence of culture be included in a model on mobile phone adoption and usage? The contribution of this paper is a set of cultural dimensions that were found to influence mobile phone usage and a model of mobile phone adoption and usage that include the influence of cultural factors on such adoption and usage. This paper should be of interest to a wide audience since it aims to integrate the views on mobile adoption from social, cultural and marketing perspectives.

1.1 Investigative stance

The aim of our research is to understand the factors that influence mobile phone adoption and usage therefore the epistemology is mainly interpretivistic. However, since the theoretical framework provides some existing models for technology adoption and use there is the objective of finding whether these models apply to mobile phone adoption and use and this leads to positivist outcomes as well. The study evolved from an interpretivist, qualitative study aimed at understanding the factors that influence mobile phone adoption and usage to a positivist, quantitative study where specific questions about mobile phone adoption and usage were investigated. The findings were then triangulated with the qualitative data to propose an answer to the original question on the factors that influence mobile phone adoption and usage.

1.2 The scope and approach of this research

The scope of this paper is limited to addressing mobile phone adoption and usage from a cultural perspective using cultural dimensions as a starting point. Our research involved structured interviews and three surveys (a pilot survey, a data gathering survey and a verification survey). Although our interviews focused on a variety of age groups, our surveys mainly yielded data about mobile phone usage of university students under the age of 30 in South Africa. The proposed model was evaluated qualitatively with different age groups.

We analysed the research literature for concepts, theories and models that could help to understand the factors that influence mobile phone adoption and usage. Since we were specifically interested in looking at the cultural aspect of mobile phone adoption and usage, we also considered literature on the culturalisation of computer technology.

1.3 Organisation of this paper

This paper is organised as follows. [Section 2] summarises the research design that is structured around two questions, where the answer to the first question leads to the second question. The first question asks if culture influences mobile phone adoption and usage. [Section 3] provides the theoretical background for this question and describes the interviews, the pilot survey and the data gathering survey conducted to investigate this question. The analysis of the results and the response to the first question is also dealt with. Having established that culture influences mobile phone adoption and usage, [section 4] considers how this finding can be represented in the bigger picture of mobile phone adoption and usage. The section starts with a theoretical foundation for technology adoption models, and then integrates this knowledge on existing models with the findings of our research to propose a new model for representing the factors that influence mobile phone technology adoption models. The section concludes by discussing the evaluation of the proposed model. [Section 5] reflects on our finding and also notes some of the factors that influenced our research. [Section 6] concludes with the notion that since mobile phones, are the ultimate, personalised, personal computer, mobile phone adoption and usage seem to differ from other technology adoption and use in ways we are only beginning to understand.

2 Research design

The research reported on in this paper focuses on two sub-questions:

- Does culture influence mobile phone adoption and usage?
- How do cultural factors fit into the bigger picture of mobile phone technology adoption and usage?

The research design consisted of four phases. The first phase was explorative and consisted of literature reviews and questionnaire based interviews with participants from different ethnic and age groups. The aim was to gain some understanding of the factors that influence mobile phone adoption and usage and the focus was on gathering qualitative data. The output of this phase was a basic understanding of the issues involved in mobile phone adoption and usage and a refined questionnaire. The second phase was a pilot survey where the main aim was to test the questionnaire and gather data in order to refine the questionnaire. The results of the pilot survey was analysed against research findings from literature in order to finalise a survey questionnaire aimed at capturing the cultural dimensions that influence mobile phone adoption and usage. The third phase involved the data gathering survey that was conducted to capture quantitative data on mobile phone adoption and usage for statistical analysis. The findings of the survey were combined with research literature on technology adoption and usage to propose a model for mobile phone adoption and usage. The fourth phase was the evaluation of the model which included both a qualitative and a quantitative evaluation. Each of these phases will now be discussed in more detail in the sections to follow. [Section 3] primarily focuses on the first research question and [section 4] on the second.

3 Culture and Mobile phones

This section deals with the question: does culture influence mobile phone adoption? [Section 3.1] provides the theoretical foundation by reviewing existing research on culture and the influence on interactive systems, and specifically mobile phone usage and adoption. [Section 3.2] discusses the research we conducted to find out what aspects of culture, if any, affects mobile phone adoption and usage. It included a discussion on the structured interviews conducted to form an understanding of the factors that influence mobile adoption and usage, the pilot survey to test the questionnaire that was based on the outcomes of the structured interviews, the data gathering survey and the findings from this survey on whether or not cultural factors influence mobile phone adoption and usage.

3.1 Theoretical Foundation

The mobile device market has widened to a global scale and consequently mobile devices are distributed throughout the world [Kim and Lee 2005]. As the use of mobile phones pervades the world, the globalization of mobile device user interfaces design is becoming more crucial to business success and building a loyal customer base. Communications technologies are entirely dependent on a social network for adoption and use, and therefore the diffusion of these technologies within a culture should be studied [Urbaczewski, Wells et al. 2002]. The context of the mobile user includes user culture and the influence of culture on mobile phone use [Urbaczewski, Wells et al. 2002; Teo and Pok 2003a; Jones and Marsden 2005]. This necessitates a review of culture as an essential part of understanding users and the factors that influence mobile phone usage.

The word ‘culture’ originally stems from an agricultural root: ‘culture as cultivation of the soil and plants’ [Hartley 2002]. Applying this to people offers a metaphor for the cultivation of products, minds and social relations. There are various definitions of the term ‘culture’. Culture can be seen as the social production of sense, meaning and awareness [O'Sullivan, Hartley et al. 1994]. Culture can also be seen as learned behaviour consisting of thoughts, feelings and actions [Del Gado 1996], while Hall [1990] describes culture as communication through words, material things and behaviour. Honold [2000] notes that it is more meaningful to find a definition of culture that suits the specific area of research than to produce a general definition. Ford [2005] defines culture in the context of HCI as ‘the patterns of thinking, feeling, and acting that influence the way in which people communicate among themselves and with computers’. This definition is also applicable to mobile interaction and we consequently adapted it for the purpose of this study to consider culture as ‘the patterns of thinking, feeling, and acting that influence the way in which people communicate among themselves and use mobile devices’.

The basic models of culture are mostly based on some form of ethnic culture even though they may apply to the business environment, the work environment or peer group culture. The term ‘ethnic’ is defined as ‘relating to a group of people having a common national or cultural tradition’ [Oxford 1999]. Nevertheless, business and other organizations also have cultures that have an impact on a range of micro and macro-organisational phenomena [Boyancigiller and Adler 1995]. Hofstede [1995]

uses the word ‘culture’ in the sense of ‘collective programming of the mind’ when referring to organisational culture.

Organisational culture is based on the organisation’s sense of identity, its goals, core values, primary ways of working and shared assumptions [Scott and Gable 1997]. Membership of organisations and social groups is usually partial and voluntary, while the association with a nation is permanent and involuntary. National cultures differ at the level of basic values while organisational and group/peer cultures are composed of practices (like symbols, heroes and rituals) rather than values [Scott and Gable 1997].

According to Palen et al. [2000], deployment of mobile telephony varies noticeably internationally and even among western countries. In general, usability studies aim to make technology more useful. Cultural usability goes further and aims to make technology fit in with the user’s lifestyle [Sun 2004]. In order to be effective, designers therefore have to understand and be aware of the cultural priorities and the value system of users, i.e. they must identify factors that are relevant and sensitive to cultural differences. This necessitates a closer look at the concepts of cross-cultural diversity and organisational culture, and examples of acculturation.

Fitzgerald [2004] presents four models used for managing cross-cultural software:

- Cultural dimensions, measuring different cultures according to a number of cultural variables or factors [Marcus and Gould 2000].
- Cultural markers, use cultural dimensions in measuring interface design elements that are prevalent and possibly preferred within a particular cultural group [Badre 2002].
- Cultural behaviours, measuring on-line behaviour of web site users in terms of a four-factor model [Fitzgerald 2004].
- Activity theory, viewing people’s activities as ‘an object-oriented and tool-mediated process in which actions are mediated through the use of artefacts (including tools and languages) to achieve a transformative objective’ [Sun 2004].

Many anthropologists have researched the field of cultural dimensions and one of the best known and most cited studies was done by Geert Hofstede [Hofstede 1995; Marcus and Gould 2000; Hofstede 2001; Baumgartner 2003]. Hofstede conceptualized culture as ‘programming of the mind’ and focuses on determining the patterns of thinking, feeling and acting that form a culture’s mental programming. In the 1970s and 80s he did a survey at IBM that dealt with ‘the employee’s personal values related to the work situation’ and investigated cultural variations within five different dimensions. Each of these dimensions (or ‘international variable’ as coined by Hoft [1996]) is a dichotomy, in that there are two opposing sides to each dimension. The dimensions are [Hofstede 1995; Hoft 1996; Hofstede 2001]:

- Power distance, denoting the extent to which less powerful members expect and accept unequal power distribution within a culture, and scaling from high-power-distant to low-power-distant.
- Masculinity vs. femininity, referring to gender roles, not physical characteristics, as commonly characterized by the levels of assertiveness or tenderness in the user, and scaling from masculine to feminine.

- Individualism vs. collectivism, referring to the role of the individual and the group, and is characterized by the level of ties between an individual in a society, and scaling from individualistic to collectivistic.
- Uncertainty avoidance, referring to the way in which people cope with uncertainty and risk, and scaling from high-uncertainty-avoidant to low-uncertainty-avoidant.
- Time orientation, referring to people's concerns with the past, present and future and the importance they attach to each, and scaling from short-term orientation to long-term orientation.

The other three approaches are not investigated further since cultural markers are based on cultural dimensions, cultural behaviours apply mostly to web-sites and activity theory does not support a quantitative approach. In the context of mobile phone design and usage existing research into the effects of culture has been aimed at the culture-based preferences for specific design attributes [Choi, Lee et al. 2005; Kim and Lee 2005] and the distinction between universal and to-be-localised components [Lee, Ryu et al. 2005a]. The following studies represent the general trends, all using Hofstede's premises:

- Choi et al. [2005b] looked at cultural influences on functionality design of mobile data services by comparing 24 Korean, Japanese and Finnish users. They found 52 attributes considered important by mobile data service users and identified 11 critical attributes related to the user interfaces of mobile data services devices. The critical attributes such as minimal keystrokes, iconic menu style, logical ordering of menu items, variety of fonts and font colours, etc., all showed a clear correlation with characteristics of the culture of the user's country (as identified by Hofstede).
- Kim & Lee [2005] investigated cultural influence and mobile interface design to clarify the relationship between cultural traits and mobile phone interfaces. Their subjects came from the USA and Korea. The results suggest a possibility of cultural impact on icon recognition. They found that Korean subjects performed better using concrete representations, while American users preferred the abstract icon representations.
- Lee et al. [2005a] studied multi-cultural usability in mobile phone navigation in a laboratory-based usability experiment with participants from the USA, West Africa, Eastern Europe and South America. They collected cross-cultural usability information in the product development process to determine universal and to-be-localized components, detect mistakes that lead to critical miscommunication, and assess the usability of cross-cultural user interfaces. Their study was again based on Hofstede's premise, but combined with the work of Jordan [1998] on pleasurable products. They found no real differences between the various cultures for the issue of supportiveness, but found evidence that the perception of the same icons differs across cultures.

Based on the findings of these studies it can be argued that culture and mobile phones have been researched to some extent, but what we found to be lacking is a model to integrate the findings on culture with the other factors that influence mobile phone adoption and usage.

In order to come up with such a model it is necessary to clarify the relationship between the social and the cultural aspects of mobile phone usage. Socially the emphasis seems to be on finding new ways to use mobile phones in enhancing socialisation [Jones and Marsden 2005; Schiphorst 2006] and the use of mobile phones to eliminate physical location as a determinant of communication [Geser 2004]. For the purpose of this study, culture is seen as a specific manifestation of social behaviour so that social influence will encompass cultural influence .

[Section 4] will address the issue of developing a model for including cultural issues with mobile phone adoption, but before we could address this aspect, we had to determine for ourselves whether cultural factors indeed affect mobile phone adoption and usage, and whether these cultural factors correspond with the dimension proposed by Hofstede, as proposed and used by all the studies mentioned above. [Section 3.2] focuses on this issue.

3.2 Researching Cultural Influence

As stated before, our research involved four phases: structured interviews, a pilot study, a data gathering survey and finally an evaluation phase as described in [section 4.3]. The first three phases were used to determine the influence of culture on mobile phone usage (amongst other issues) and will now be discussed by describing the approach and then summarising the main findings of each phase.

3.2.1 Structured Interviews

In the context of our research question (does culture influence mobile phone adoption and usage) the initial interviews were directed towards:

- Eliciting verifiable facts and 'reality out there' through questions on basic issues such as frequency and duration of communication interaction, breadth of interaction (how many communication partners) and variety of tasks.
- Eliciting social and cultural perceptions that could influence mobile phone adoption and usage.
- Uncovering participant's perceptions about mobile phone adoption and usage and reflections about their experience of using a mobile phone.

When researching a common phenomenon such as mobile phone usage it is necessary for the researcher to focus on eliminating all preconceived issues from their mind. This was found to be easier if the researcher is not of the same age group, since age influences mobile phone adoption and usage [Kwon and Chidambaram 2000; Kleijnen, Wetzels et al. 2004]. The researcher who conducted the interviews was over the age of 40 and therefore the selection of participants under the age of 30 helped to create the necessary distance in terms of age.

No appropriate, standardised questionnaire could be found and therefore the questions for the interviews were compiled from existing questionnaires [Kiljander 2004; Ford and Kotze 2005], a literature review on related research [Marcus and Chen 2002] and commercial information on mobile phone functions and services. Apart from biographic information, the questionnaire captured priorities in using mobile phones and frequency of feature usage.

The 10 participants for the interviews were selected with a gender balance, from the age groups 20-29, 30-39, 40-49 and 50-59, representing three different ethnic

groups. The pre-defined questions were followed by a short interview to give participants the opportunity to respond outside the structured format of the questions. The capacity of their phones used was gauged by going through all the sub-menus with them and counting the items used.

The following observations were made based on the outcomes of the interviews:

- Participants *over* the age of 30 used less than 40% of the available features on their phones; thought of a mobile phone mostly as a mobile version of the traditional phone; identified relationship building and security as the highest priorities; questioned the value of a feature before being willing to consider using it; and often preferred to keep the old phone when their mobile phone contracts were renewed.
- Participants *under* the age of 30 used between 40% and 50% of the features on their mobile phones; viewed the phone as a tool for communication, organization and entertainment; and demonstrated a keen interest in exploring all the features available, but were inhibited by cost.

Reasons for not using certain features included ignorance on the availability of features, cost, unavailability on a specific phone model and personal preference.

After the interviews the questionnaire was revised and we again studied existing research to guide the way forward. The cultural dimension approach was chosen to guide our further research into cultural factors since it can be used in quantitative studies. Quantitative research was preferable in order to be compatible with the technology usage models proposed by marketing, though qualitative observations were made, when possible, as the qualitative findings were needed to provide explanations for some of the quantitative findings. Based on these findings a questionnaire was compiled for the pilot survey.

3.2.2 Pilot survey

Following our extensive literature review on past research and the findings of our interviews at this stage, we knew that demographic variables such as age [Kwon and Chidambaram 2000; Teo and Pok 2003a; Kleijnen, Wetzels et al. 2004], education and socio-economic status [Ho and Kwok 2003; Bina and Giaglis 2005] influence mobile phone adoption and usage. We therefore controlled the demographic variables by selecting participants in the same age, education and socio-economic group for our further research.

The participants were a group of 40 third-year computer science students, 65% male and 35% female, from Monash University (South African campus). They were all under the age of 30 but from a variety of nationalities. Most students at the University are from an above-average socio-economic background. This was important as to ensure that they would be in possession of a mobile phone with average or above-average functions and services, and could afford mobile phone services.

The questionnaire was a refined version of the questionnaire used in the interviews. It captured biographic details and mobile phone usage behaviour in a way that could be coded for statistical analysis. The analysis sought to distinguish the participants based on technological development, a dimension from Baumgartner‘s set of cultural dimensions [Baumgartner 2003], and four of Hofstede’s cultural

dimensions and then relate this to mobile phone usage preferences. Therefore the first priority was to see if the cultural dimensions were measured consistently.

The Cronbach's alpha values were computed as listed in [Table 1]. It follows that only the dimension of technological development had a correlation above 0.7., but uncertainty avoidance at 0.65 came close to 0.7 and warranted further investigation.

Dimension	**Cronbach's Alpha Coefficient**	
	Variables	*Alpha*
Technological development	Raw	0.731244
	Standardised	0.731047
Time-perspective	Raw	0.250291
	Standardised	0.182336
Uncertainty avoidance	Raw	0.654830
	Standardised	0.679292
Time-orientation	Raw	-0.732048
	Standardised	-0.873414
Individualism	Raw	-0.086748
	Standardised	-0.057296

Table 1: Reliability of cultural dimensions

All the questions in the questionnaire were reviewed to see if they captured the cultural dimensions as intended. In the case of the individualism dimension, it was found that the questions focused on the individual versus a group, while they should have focused on the individual versus relatives and family in order to represent collectivism. These questions were adapted accordingly. No content changes were made to the questions for the other dimensions. Based on the results of the pilot study and the support in literature for the difficulties in identifying time-orientation [Ford and Kotze 2005], only the dimensions of technological development, uncertainty avoidance and individualism/collectivism were retained in the survey questionnaire (with a revised set of questions for the latter).

3.2.3 Data Gathering Survey

Our data gathering survey involved 138 participants of whom 64 (46%) were male and 74 (54%) female, 69% attended urban schools, while 31% completed their matriculation in a rural area. All participants have successfully completed the matriculation examination and were third-level (third-year) students from two universities in Pretoria, namely the Tshwane University of Technology (60 students) and the University of Pretoria (78 students). Mother-tongue was captured as an indicator of ethnic distribution, as depicted in [Figure 1].

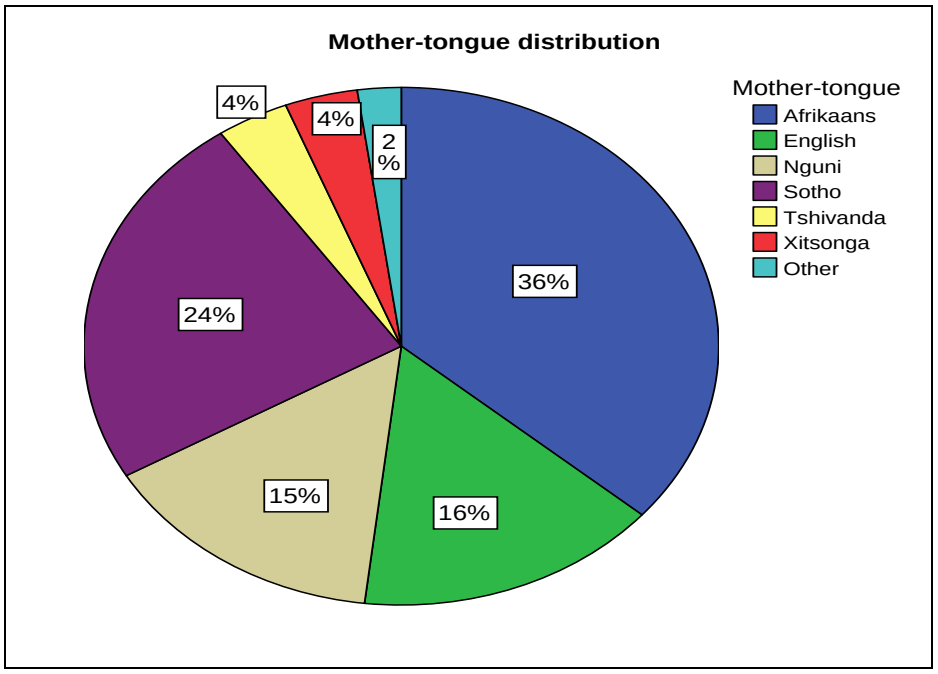


Figure 1: Mother-tongue distribution

The questionnaire was a refined version of the questionnaire used in the pilot survey. The demographic data was analysed with descriptive statistics to verify that the participants fitted the target group, i.e. university students under the age of 30. Hofstede's dimensions [Hofstede 1995] as well as a study by Ford [Ford 2005], based on Hofstede's dimensions, were used as the point of departure for designing the questionnaire. Apart from the cultural dimensions, the priorities on buying was captured and coded to ascertain if infrastructural variables have a significant influence on mobile phone adoption.

In the end the participants were not grouped by language (ethnic) group. Categorisation according to ethnic culture was found problematic for three reasons.

- Firstly, it was observed in the interviews that some people marked English as their mother-tongue although it was known not to be, and this invalidated any ethnic classification based on mother-tongue.
- Secondly, many of the participants across the interviews, pilot survey and survey were found to be bi-cultured or multi-cultured.
- Thirdly, even if these problems could be overcome the division into ethnic culture groups would result in small samples of unequal size.

The reliability of the analysis (Cronbach's Alpha values) was less than 0.7 for the individual cultural dimensions of uncertainty avoidance, individualism/collectivism and time-orientation but 0.83 on the combined data set. This implied that all the questions were consistently measuring the same construct but the measurement of the

individual dimensions (done be grouping questions together according to the Hofstede classification) was not consistent.

In order to explore alternative grouping of the questions the method of optimal scaling was then employed. Optimal scaling, like factor analysis, is a data reduction method to identify clusters within a data set. Optimal scaling was done on the entire data set and from inspection of the plot (not depicted here) certain responses clustered together. The groups of responses that correlated significantly were grouped together into new variables that were identified as follows:

- Variable 1 - Uncertainty avoidance.
- Variable 2 - Independence from assistance.
- Variable 3 - Independence to explore and solve problems.
- Variable 4 - Efforts to maximise time and technology.
- Variable 5 - Family orientation.

These five variables describe various distinct aspects of behaviour and attitude towards mobile phone usage. Variable 1 confirmed the dimensions of uncertainty avoidance as proposed by Hofstede, while variables 2, 3 and 5 seem to the support individualism/collectivism dimension, although not being directly equivalent to the definitions as put forward by Hofstede. Variable 4 pointed towards a need to optimise and explore.

Hofstede proposed that on each of the dimensions, people from both sides of the scale would be found, but that one side would be more prevalent for each ethnic culture [Hofstede and McCrae 2004]. We thus found that some of the dimensions identified by Hofstede do play a role in mobile phone usage and adoption, and also that there may be other dimensions not identified by Hofstede that should be explored.

Our findings suggest that mobile phone use might have a unique set of cultural dimensions not necessarily directly corresponding to those proposed by Hofstede, and also that the concept of a ‘unique mobile phone usage culture’ may exist that does not necessarily correspond to the culture that exist in human-human relations. This has been identified as a major future research project to pursue.

These combined findings affirm the first research question on whether culture influence mobile phone adoption and usage, though not necessarily in the expected way, and leads to the second question on how this can be related to mobile phone adoption and usage.

4 Cultural Factors and Technology Adoption and Usage Models

We will now address the second research question, namely ‘how do cultural factors fit into the bigger picture of mobile phone technology adoption and usage’. In order to do this it is necessary to look at the literature on technology adoption and therefore this section starts with an overview of the existing research on technology adoption and use.

4.1 Theoretical Foundation

Technology adoption involves the user, the technology and the context [Humphreys 2005]. Various models for understanding technology adoption have been proposed.

Pedersen [2005] lists Roger's innovation diffusion model, the domestication model and the technology acceptance model (TAM) as the three most commonly applied.

- Roger's innovation diffusion model is founded in sociology but has also been applied to the world of marketing where users are seen as economic entities. The model provides an approach to understanding how innovations are adopted by a particular population [Rogers 2003].
- Silverstone and Haddon [1996] proposed the domestication model where users are seen as social entities and the model aims to provide a framework for understanding how technology innovations change and are changed by their social contexts.
- The technology acceptance model was developed by Davis [1989] to explain the determinants of computer acceptance and usage behaviour.

While Rogers' innovation diffusion model focuses on marketing and sales processes, the domestication approach deals with a more global analysis of adoptions ex post facto and the TAM focuses on information technology adoption in organisations [Ling 2001].

This paper focuses on understanding the cultural factors that influence mobile phone adoption and usage and we therefore consider all three adoption models in more detail in order to establish their applicability.

4.1.1 Domestication theory

The domestication theory was founded by Silverstone and Haddon [1996] who viewed technologies as social, cultural, political and economic products that play a symbolic and aesthetic as well as material and functional role. The domestication approach aims to discern the interaction between the innovation and the context in which it is being placed. Therefore contexts are often contrasted, for example work versus leisure, private versus public, and contrasts between users in different demographic groups [Ling 2001].

The concept of domestication is derived from the British studies on consumption [Sun 2004]. It refers to the taming of innovation by the individual and focuses on the process that integrates technology into everyday domestic life [Sun 2004; Pedersen 2005]. The domestication approach considers the following phases in the adoption process [Silverstone and Haddon 1996; Ling 2001; Habib 2003]:

- Commodification: the way a technology is designed to give it an image with a number of functional, aesthetic and symbolic claims.
- Imagination: the way in which an innovation enters our consciousness.
- Appropriation: the actual purchase of the technology.
- Objectification: the phase in which the technology is made acceptable and familiar in the daily life of the consumer.
- Incorporation: integrating the technology with daily use.
- Conversion: the technology becomes fitted into routines and is seen by others as part of the individual's identity.

Pedersen et al. [2002] distinguishes between the first purchase decision, which refers to adoption, and post-decision buying behaviour. They recommend that usage be seen as a transition between stages of increasing consumer sophistication in the consumer life cycle rather than a specific event. This is in line with the domestication

approach which considers consumption rather than mere use, and views adoption as a process rather than a specific event [Ling 2001; Haddon 2003].

Brown and Randell [2004] uses the term 'dwelling' with technology to describe the study of technology use over a long period of time where the context in which technology is used may change. Domestication studies do ex post facto examination of technology adoption to understand why a technology has been adopted and why not [Pedersen 2005]. It is therefore intended as a tool for observing adoption rather than a tool for the prognosis of an adoption [Ling 2001].

Our research views users as social entities, which is in accordance with the domestication approach. The acknowledgement of the importance of context and the post-adoption focus make the domestication approach relevant to understanding the factors that influence mobile phone usage variety. Given the widespread adoption of mobile phones, they are already in the appropriation phase and beyond. Therefore our study will not consider specific phases in the adoption process, but rather the factors relating to adoption and post-adoption usage.

4.1.2 Rogers Innovations of Diffusion

Rogers, a sociologist, developed the innovation diffusion model to explain how an innovation diffuses through a society [Geoghegan 1994; Rogers 2003; Walton and Vukovic 2003; Kiljander 2004]. The innovation diffusion model has been used extensively to explain the acceptance or rejection of IT innovations in an organisation or society [Urbaczewski, Wells et al. 2002].

According to Rogers [Rogers 2003] 'an innovation is an idea, a practice, or object that is perceived as new by an individual or another unit of adoption'. Diffusion is defined as the process by which an innovation is communicated by means of certain channels over a period of time between the members of a social system.

Rogers' adoption/innovation curve divides adopters of innovations into five categories each representing a unique psychographic profile based on the idea that some individuals are more open to adoption than others are. The categories can be described as follows [Geoghegan 1994; Leung, Chan et al. 2003; Rogers 2003; Walton and Vukovic 2003; Kiljander 2004]:

- Innovators (± 2.5% of the adopter population): These are the 'techies', the experimenters who have technology as a central interest in their lives and pursue new technology as soon as it appears, no matter what the function is.
- Early adopters (± 13.5% of the adopter population): They are the 'visionaries' who blend an interest in technology with a concern for significant professional problems and tasks. They are mostly not technologists but exploit the new capability.
- Early majority (± 34% per cent of the adopter population): They are the 'pragmatists'. Although fairly comfortable with technology in general, their focus is on concrete professional problems rather than on the tools (technological or otherwise) that might be used to address them.
- Late majority (± 34% per cent of the adopter population): They are the conservatives or 'sceptics'. They share the attitude of the early majority, though being less comfortable with technology.

- Laggards (± 16% per cent of the adopter population): They are the most likely never to adopt at all. They are not interested in new technology and they generally buy technology products only when these are buried inside other products.

A successful innovation will be adopted in this order, beginning with the innovators, followed by the early adopters, the early and late majority, and perchance the laggards. A new technology is best focused on innovative adopters since they do not insist that the technology should have a track record, as they value a product on the basis of the latest technology built into it [Leung, Chan et al. 2003].

Ling [2001] notes the following problems with Rogers's model:

- The model assumes that users behave in a rational way by weighing positive and negative factors. This does not acknowledge the influence of broader social processes.
- The model assumes the ideal Gaussian adoption curve, which is rarely achieved in reality.
- The model stops with the adoption of the innovation and does not consider ex post facto analyses of adoptions. This may not be a problem from the marketing and sales perspective, but in HCI and sociology research, both the adoption and rejection of innovations are of interest.

Other models that deal with technology diffusions are the Bass diffusion model [Ali-Vehmas and Luukkainen 2005], the product life cycle by Levitt and the Positioning model by Trout and Reis [[2006]. According to all these models, the number of success factors are limited [Ali-Vehmas and Luukkainen 2005]. The fact that there are a limited number of factors determining the success of technology adoption makes it more feasible to model technology adoption.

The Rogers Innovation Diffusion Model focuses only on adoption and therefore it cannot be used to represent mobile phone usage. However, the innovation diffusion model has implications for mobile phone usage since adoption is a prerequisite to usage.

4.1.3 Technology adoption models

The Technology Acceptance Model (TAM) proposes that beliefs about usefulness and ease of use are essential elements in determining user attitude towards using a new technology [Davis 1989; Malhotra and Galletta 1999; Kleijnen, Wetzels et al. 2004]. The theoretical foundation for TAM is based on Fishbein and Ajzen's [1975] theory of reasoned action (TRA) model.

TRA is a widely studied model in social psychology [Malhotra and Galletta 1999; Kwon and Chidambaram 2000]. It attempts to explain why people behave as they do in situations of 'reasoned action' by identifying causal relations between beliefs, attitudes, intentions and behaviour [Kwon and Chidambaram 2000; Barnes and Huff 2003; Pedersen 2005]. Attitude is defined as the individual's positive or negative feelings about enacting a target behaviour [Uzoke, Seleke et al. 2006]. TRA is illustrated in [Figure 2] and has the following components [Fishbein and Ajzen 1975; Malhotra and Galletta 1999]:

- Actual behaviour: According to TRA a person's performance in a specified behaviour is determined by the behavioural intention (BI) to enact the behaviour.
- Behavioural intention (BI): BI is jointly determined by the person's attitude (A) and the subjective norm (SN) concerning the behaviour in question, with relative weights estimated by regression [Davis, Bagozzi et al. 1989]:

$$BI = A + SN$$

- Attitude towards behaviour (*A*): A person's attitude towards behaviour is determined by their salient beliefs (b_i) about the consequences of performing the behaviour multiplied by the evaluation (e_i) of those consequences.

$$A = \sum_{i=1}^{n} b_i e_i \quad \text{where } n \in N$$

- Subjective norm (*SN*): Subjective norm refers to the social pressure exercised on the person to either enact or not enact the behaviour [Kwon and Chidambaram 2000] and is expressed as the sum of all the person's normative beliefs (nb_i), which consists of the perceived expectations of specific significant individuals or groups' reaction, multiplied by the person's motivation to comply (mc_i).with these expectations:

$$SN = \sum_{i=1}^{n} nb_i mc_i \quad \text{where } n \in N$$

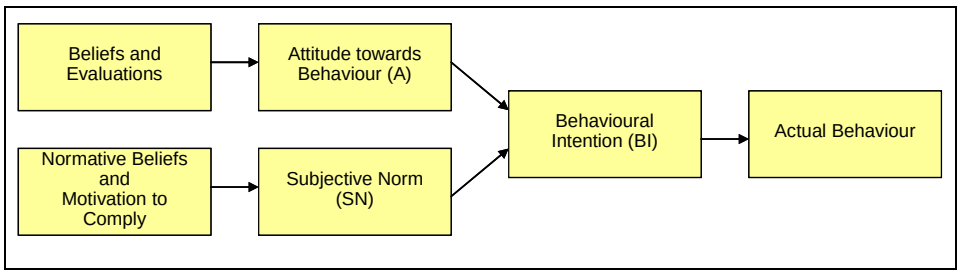


Figure 2: Diagrammatic representation of the TRA adapted from [Davis, Bagozzi et al. 1989]

TRA is a general model and it does not specify the active beliefs for a specific behaviour. Therefore a researcher using TRA has to identify the beliefs that are relevant for subjects regarding the behaviour under investigation. For example, if TRA is applied to mobile phone use, people's beliefs regarding the benefits or liabilities of mobile phone use have to be identified by the researcher.

The Technology Acceptance Model (TAM) is a special case of TRA for modelling technology adoption in organisations [Pedersen 2005]. TAM, as illustrated in [Figure 3], includes six concepts [Davis, Bagozzi et al. 1989; Malhotra and Galletta 1999; Urbaczewski, Wells et al. 2002]:

- External variables (*EV*): External variables influence perceived usefulness (*PU*) and perceived ease of use (*PEU*), for example demographic variables (as discussed in Chapter 3).
- Perceived usefulness (*PU*): Perceived usefulness is defined as 'the extent to which a person believes that using the system will enhance his or her job performance' [Venkatesh and Davis 2000].
- Perceived ease of use (*PEU*): perceived ease of use is 'the extent to which a person believes that using the system will be free of effort' [Venkatesh and Davis 2000].
- Attitudes towards use (*A*): Attitude towards use is defined as 'the user's desirability of his or her using the system [Malhotra and Galletta 1999]. Perceived usefulness (*PU*) and perceived ease of use (*PEU*) are the sole determinants of attitude (*A*) towards the technology system. Perceived usefulness and perceived ease of use is determined by external variables (EV) and attitudes toward use (A) can therefore be defined as:

$$A = PU + PEU + EV$$

- Behavioural intention (*BI*): Attitude (*A*) combined with perceived usefulness (PU) predict behavioural intention (*BI*):

$$BI = A + PU$$

- Actual use: Behavioural intention (*BI*) in turn predicts actual use.

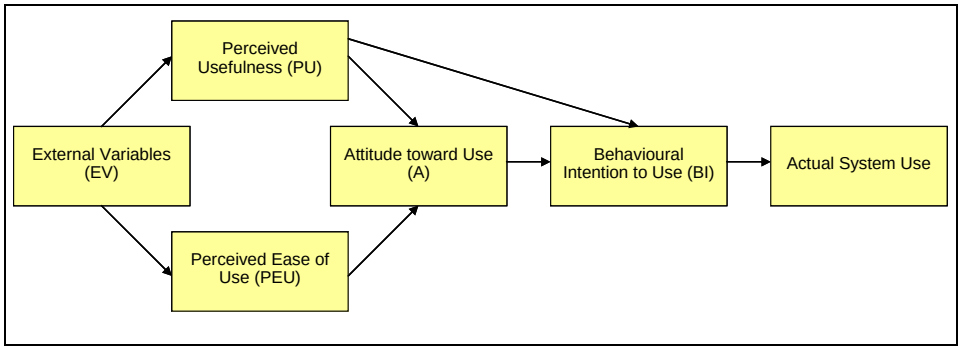


Figure 3 : Technology Adoption Model (TAM) [[Davis, Bagozzi et al. 1989]

TAM is noted as one of the most influential models in technology adoption research and represents an important theoretical contribution towards understanding information system usage and information system acceptance behaviour [Malhotra and Galletta 1999]. While the TAM model is mainly applied to explaining the adoption of technology within organizations, the constructs of the model are meant to be fairly general and universal to different types of computer systems and user populations. Attitude towards adopting a technology is believed to be influenced by personal and social influences and the fact that TAM does not account for social influence has been identified as a limitation [Davis, Bagozzi et al. 1989; Malhotra and Galletta 1999].

In addressing this problem, Malhotra and Galetta [1999] established a theoretical and empirical base for the introduction of social influence through the processes of internalization, identification and compliance with the TAM model. According to their findings, users' attitudes are directly affected by social influence, while behavioural intentions are indirectly affected. This supports our argument that social and cultural factors should be represented in a technology adoption model. Several other studies have applied TAM to research mobile phone technology adoption, notably Kwon and Chidambaram [2000], Lee et al. [2002], Pedersen [2005], Teo and Pok [2003b], Kleijnen et al. [2004] and Roberts [2004].

Two of the findings regarding mobile phone adoption have special significance for this the inclusion of cultural factors:

- Given that cultural factors are encompassed in social factors, the finding that social factors influence mobile phone adoption [Peterson 1994; Urbaczewski, Wells et al. 2002; Teo and Pok 2003b] provides justification for investigating cultural factors as an influence in mobile phone adoption and usage.
- The importance of infrastructural factors in mobile phone adoption [Kleijnen, Wetzels et al. 2004] means that infrastructural factors will have to be taken into account during our research, e.g. selection of participants with access to similar infrastructure, etc.

The TAM model is based on the assumption of the availability of basic infrastructure and organisational context for the adoption of new technology. If this is not the case then conditions facilitating infrastructure become important in technology adoption.

Venkatesh [2003] developed the Unified Theory of Acceptance and Use of Technology (UTAUT) model to explain user intentions to use an information system and subsequent usage behaviour and included facilitating conditions as a component determining technology adoption and use. The UTAUT was developed through a review and consolidation of the constructs of the following models [Venkatesh, Morris et al. 2003]: theory of reasoned action [Fishbein and Ajzen 1975], technology acceptance model [Davis 1989], motivational model [Davis, Bagozzi et al. 1992], theory of planned behaviour [Ajzen 1991], a combined theory of planned behaviour/technology acceptance model [Taylor and Todd 1995], model of PC utilization [Thompson, Higgins et al. 1991], innovation diffusion theory [Moore and Benbasat 1991] and social cognitive theory [Compeau and Higgins 1995].

According to UTAUT [Venkatesh and Davis 2000; Venkatesh, Morris et al. 2003] as depicted in [Figure 4], performance expectancy, effort expectancy, social influence and facilitating conditions are the four key constructs that determine usage intention and behaviour. Gender, age, experience, and voluntariness (i.e. the degree to which use of the innovation is perceived as being of free will) are mediating factors in the impact of the key constructs on usage intention and behaviour. An important contribution of UTAUT is to distinguish between mediating factors and determining factors.

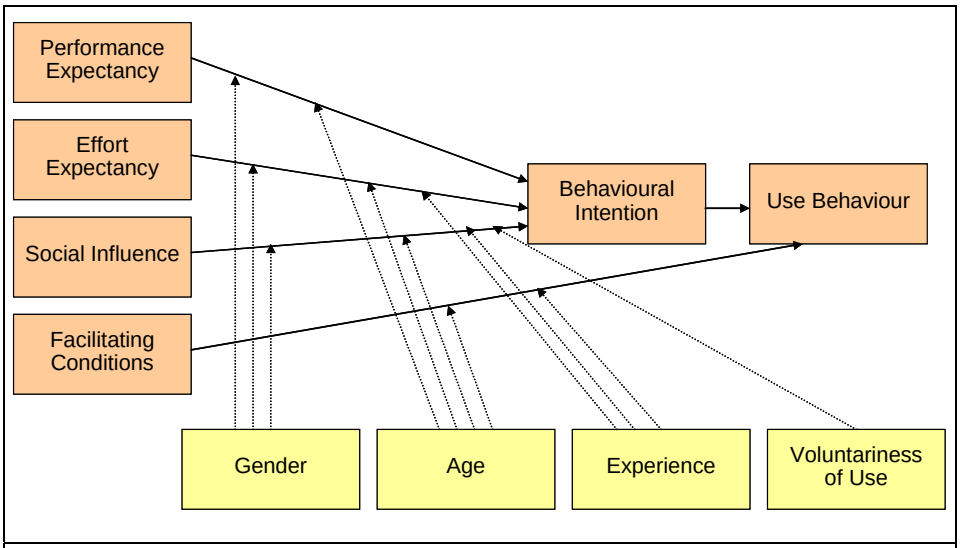


Figure 4: Diagrammatic representation of the UTAUT adapted from [Venkatesh, Morris et al. 2003]

4.2 Proposed model

Considering research on culture and mobile phones as discussed in [section 3] and research on technology adoption, as discussed above, it follows that mobile phones and culture as well as technology adoption have been well researched. What is lacking is a model to integrate the findings on culture with the other factors that influence mobile phone adoption and usage.

To address the second research question, we integrate the findings on the cultural factors that influence mobile phone usage from [section 3] with the extant models on technology adoption as discussed in [section 4.1]. The finding that cultural factors do influence mobile phone usage was synthesized with the technology adoption models to create the model presented in [Figure 5]. Like UTAUT this model is structured to have two groups of components namely the determining factors as discussed in [section 4.2.1] and the mediating factors as discussed in [section 4.2.2].

4.2.1 Determining factors

The determining factors are the basic constructs that influence mobile phone usage. In our model they consist of social influence (SI), facilitating conditions (FC), perceived ease of use (PEU), perceived usefulness (PU) and behavioural intention to use (BI). The external variables component in TAM has been replaced with two components namely social influence (SI) and facilitating conditions (FC). These components are now described in more detail together with the evidence from literature to support their inclusions in the model:

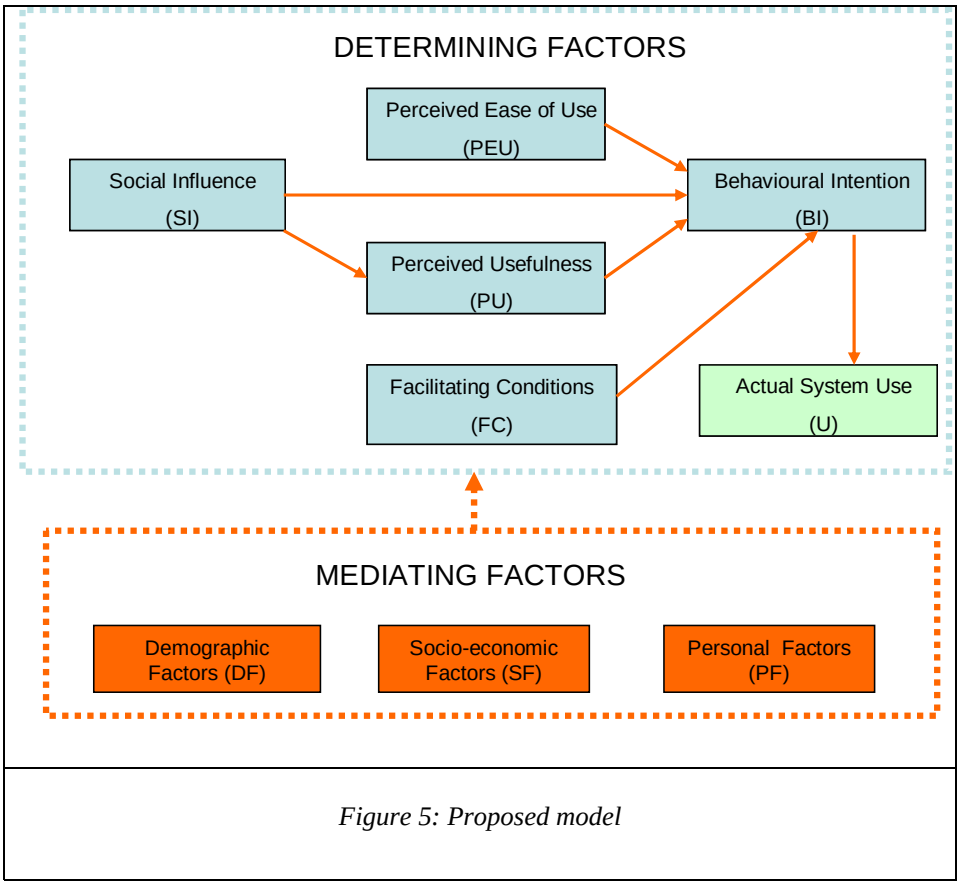


Figure 5: Proposed model

- Social influence (SI) (also referred to as subjective norm (SN) in the TRA [Fishbein and Ajzen 1975]). This encompasses the social pressure exerted on the individual by the opinions of other individuals or groups. Culture influences are included as part of social influence also as recommended by Urbaczewski [2002] and is therefore not represented as a separate component. SI is a component of the mobile phone technology adoption and use model by Kwon and Chidambaram [Kwon and Chidambaram 2000] and UTAUT [Venkatesh, Morris et al. 2003]. SI is also a component of the TRA [Fishbein and Ajzen 1975] but not of TAM. The need to add social norm to the TAM has been recommended by several researchers [Malhotra and Galletta 1999; Urbaczewski, Wells et al. 2002; Teo and Pok 2003b; Pedersen 2005].
- Facilitating conditions (FC): TAM was developed for organisations where the infrastructure and cost did not concern the user [Pedersen 2005]. Other studies on technology adoption and use have noted the need to recognise system factors notably security, reliability, digital standards and web connectivity [Kleijnen, Wetzels et al. 2004; Roberts 2004; Meso, Musa et al.

2005], while Uzoke et al. [2006] added the importance of management factors.

- Perceived usefulness (PU): The extent to which a user believes that he or she will benefit from using the mobile phone. PU is a component of the TAM. The importance of this component was also observed in the interviews we conducted.
- Perceived ease of use (PEU): The extent to which a user believes that using the mobile phone will be free of effort. PEU is a component of the TAM and the model by Kwon and Chidambaram [Kwon and Chidambaram 2000], while UTAUT [Venkatesh, Morris et al. 2003] refers to effort expectancy. The importance of PEU was verified in our interviews, observations and the quantitative findings of our study.
- Behavioural intention (BI): The intention to enact the behaviour of using the phone. BI is a component of both TAM and UTAUT.
- Actual usage (U) : The actual use of the phone, can be measured in terms of frequency of use, usage breadth (i.e. how many contacts) and usage variety (i.e. how many different applications) [Geser 2004].

Additional influences are represented by the mediating factors as discussed below.

4.2.2 Mediating factors

Mediating factors influence the determining factors. For example, a person may find a mobile phone useful and easy to use but socio-economic status (mediating factor) may inhibit the adoption and use for financial reasons. Based on the existing models for technology adoption as described in [section 4.1.3] and the findings from our study, demographic, socio-economic and personal factors have been selected as the most important aspects for technology adoption and usage. Each of these factors is now explained together with some evidence from the literature for including the specific factors.

- Personal factors (PF): Refers to personal preference and user's beliefs about the benefit of technology including relative advantage, compatibility, complexity, trialability, observability, image and trust. Personal factors encompass individual beliefs (IB) which are included in the external variables (EV) component of the TAM model and explicitly noted by Barnes and Huff [2003]. Since it involves 'beliefs' it also subject to cultural influence.
- Demographic factors (DF): Variables like age, gender, education and technological development.
- Socio-economic factors (SF): Described by variables like job status, occupation and income. SF is a component of the mobile phone technology adoption and use model by Kwon and Chidambaram. Socio-economic status has been found to influence mobile phone usage in other studies [Rice and Katz 2003].

UTAUT listed age, gender experience and voluntariness as mediating factors. Arguably gender, age and experience can be grouped under demographic factors but voluntariness is relevant only to technology use in organisations since all personal

mobile phone use is voluntary. The addition of socio-economic factors are necessary since a person's job status often determines what kind of phone the person has and what they use it for. Due to the possibilities to customise mobile phones and the fact that the device is mostly with the person and switched on, personal factors have been introduced as a factor that influences mobile phone usage.

4.3 Evaluation of the Proposed Model

The proposed model is based on qualitative as well as quantitative findings and hence it needs to be tested both qualitatively and quantitatively.

A qualitatively evaluation was done in one-to-one interviews with the same set of participants as those from the first round of interviews. The model was evaluated against the criteria of simplicity, comprehensiveness, generality, exactness and clarity [Olivier 2004].

According to the results from the evaluation interviews the model is simple, comprehensive and exact. There were some suggestions about improving clarity by colour coding the determining factors and the mediating factors appropriately. The model was found to be general enough to capture influences applicable to all age groups, but the strength of the influence would probably vary between age groups. During the initial interviews we noted how personality differences could influence mobile phone adoption and usage. This notion was strengthened in the evaluation interviews.

To evaluate the proposed model quantitatively a survey was conducted with 59 students from the university where the pilot survey was done. The participants in the validation survey were undergraduate university students, 39 (66%) of who were male, 16 (27%) female, while 4 (7%) did not indicate their gender. Considering age, 95% of the participants were between 18 and 30 years of age. The remaining 5% were under the age of 35, with a mean age of 23. The ages in the survey ranged from 17 to 27 with a mean age of 21. The students in the validation questionnaire were thus slightly older on average than those for the survey. The ethnic distribution (based on mother tongue) indicates that Setswana (48%) and English (29%) are the biggest groups. The quantitative evaluation was aimed at verifying the importance of the components and the relationships between the components of the model, i.e. between the different determining and mediating factors.

A multi-variant correlation was done between factors representing the components namely the social influence (SI), perceived ease of use (PEU), perceived usefulness (PU), behavioural intensity (BI), actual usage (U) as depicted in [Table 2]. The Pearson correlation coefficient was used and the significant two-tailed values at 0.05 level are indicated by one asterisk (*) and those at 0.01 by two asterisks (**).

On vertical inspection of [Table 2] it follows that SI has a significant positive correlation (0.05 level) with PU and BI and a highly significant positive correlation (0.01 level) with FC. This verifies that SI affects PU and BI as proposed in the model. The correlation between SI and FC had not been anticipated and can possibly be attributed to the target group of students exposed to the same student culture and facilitating conditions. PEU influences BI as proposed in the model but there also seems to be a correlation between PEU and PU. BI influences U as proposed by the model, while BI is influenced by FC. The correlation between BI and FC is important

in distinguishing mobile phone adoption and usage from other technology adoption and usage where facilitating conditions are not as important.

Regarding mediating factors, the socio-economic factors were partially controlled for by selecting students. Correlations were found between demographic variables on the one hand and SI, PEU, BI and usage on the other. Having controlled for age and education, the variable of technological development was used to represent the demographic influence. Using one variable to represent the concept of demographic influence is limiting and therefore we do not present these correlations, but rather conclude with the notion that the influence of technological development warrants further investigation.

The same applies to PF which was based only on the variable of technical orientation i.e. Rogers's scale which goes from laggard to innovator. Correlations were found between PF and SI, PU, PEU and BI but we can only conclude that there is at least one personal factor which mediates mobile phone adoption.

		SI	PEU	PU	BI	Usage	FC
SI	Pearson Sig.	1					
PEU	Pearson Sig.	.255 .058	1				
PU	Pearson Sig.	.325(*) .015	.503(**) .000	1			
BI	Pearson Sig.	.277(*) .039	.549(**) .000	.293(*) .024	1		
U	Pearson Sig.	.082 .547	.051 .703	.018 .893	.288(*) .027	1	
FC	Pearson Sig.	.430(**) .001	.126 .350	.220 .101	.292(*) .027	.141 .294	1
	N	56	57	57	57	57	57

Table 2: Correlation between components of proposed model

5 Discussion

The findings of our study support the fact that cultural dimensions play a role in mobile phone adoption and usage. But in doing this research on cultural issues affecting mobile phone use, we encountered several problems. We briefly outline the most prominent of these:

- The first issue is the fact that ethnic culture is a sensitive issue, and that many people are multi-cultured, which means that they do not identify with any one specific ethnic culture. As noted, categorisation according to culture in our studies was problematic due to participants selected to represent non-English cultures, did select English as their mother-tongue. In South Africa, English has a higher status than most other languages in the working environment and this may explain this selection. Another problem with cultural categorisation is that many of the participants were found to be bi-cultured or multi-cultured.
- The lack of suitable standardised questionnaires to research the influence or effect of culture is a problem. The questionnaires on cultural awareness are often aimed at measuring human-human interaction which is quite different from human-computer interaction. For example, when answering a question on time-orientation, one participant noted that in human-human interaction he tends to be long-term oriented but in human-computer interactions he is short-term orientated.
- Furthermore, when analysing data from questionnaires it is important not to analyse them from given perspectives only. Data captured from these surveys had to be analysed in detail to see if the questionnaire design was not masking alternative possibilities or findings. For example, in our data collection survey analysis the grouping of the questions, as planned, did not provide consistency in measuring the dimensions. However, alternative groupings of cultural dimensions did emerge from the optimal scaling method. This implies that the support for cultural dimensions was in the data but could only be extracted by applying an alternative method.

Considering the second research question, the evaluation interviews provided evidence that the proposed model is useful in representing the factors that influence mobile phone adoption and use. The inclusion of social (encompassing cultural) influence in technology adoption has been recommended in the literature as discussed in [section 4.1.3]. The main contribution of this research is to provide evidence that SI (which encompasses culture) influences PU and BI and then to represent the social influence together with the other determining and mediating factors. A secondary contribution is the identification and positioning of facilitating conditions and personal factors in the mobile phone model adoption and usage scenario.

When we compare the proposed model with previous models, we find that UTAUT did include SI but limited the influence of SI to BI. Furthermore UTAUT represented facilitating conditions but noted only the relationship between facilitating conditions and actual use whilst we found that facilitating conditions also influence BI. Like TAM this model has PEU and PU as components that influence BI and eventually actual use. Unlike TAM the relationships between the basic elements are mediated by demographic factors, socio-economic factors and personal factors.

Like UTAUT the proposed model makes a distinction between determining factors and mediating facts but the mediating factors, namely demographic, socio-economic and personal differ from the factors proposed by UTAUT. This difference in mediating factors reflects the nature of the mobile phone scenario. Facilitating factors which include cost, infrastructure and service emerged strongly from the

qualitative observations although they may not be important in technology adoption within organisations.

Apart from acknowledging that personal factors mediate mobile phone adoption and usage, a detailed investigation of personality has been excluded from the scope of our study. However, the personality attributes of nervous, enthusiastic, original, appreciative and controlled, as noted by Hofstede and McCrae [2004], could possibly be useful in understanding user behaviour not accounted for by this model. The fact that the mobile phone is the ultimate, personal computer supports the idea that personality should be included as a mediating factor.

The proposed model could be useful in bridging the gap between research from the fields of HCI, marketing and sociology as it integrates factors investigated in these different fields. Finally, the development of a set of questionnaires to capture mobile phone usage needs and behaviour is seen as a major contribution of this research.

6 Conclusion

Based on the findings of our study we conclude that cultural dimensions do influence mobile phone adoption and usage. Our findings may also suggest that mobile phone use have a unique set of cultural dimensions not necessarily corresponding to those proposed by Hofstede or other researchers. This would imply that the concept of a 'unique mobile phone usage culture' may exist that do not necessarily correspond to the culture that exist in human-human relations. This issue has been identified as a major future research project to pursue.

The second important contribution of this paper is a model that explicitly includes social influence in representing the factors that influence mobile phone adoption and usage, where social influence encompasses cultural influence. The model combines the influence of mediating factors (personal, demographic and socio-economic) and determining factors (social influence, perceived ease of use, perceived usefulness, and facilitating conditions) on behavioural intention and actual mobile phone usage.

Given the individual's vulnerability to infrastructural factors, the effect of facilitating conditions on behavioural intention, as well as on actual use, distinguishes personal mobile phone usage from technology used in organisations. We also found that given the personal nature of mobile phones, and the many possibilities for personalising such devices, and mobile phone usage, the influence of personality warrants further investigation.

This paper makes a contribution on integrating research from sociology, computer -supported cooperative work, marketing and HCI. However, there is a need for more debate on integrating research on mobile phone adoption and usage across fields.

References

[12Manage 2006] 12Manage: "Rigor and Relevance"; (2006), Retrieved 2006/08/25, from http://www.12manage.com/methods_rogers_innovation_adoption_curve.html.

[Ajzen 1991] Ajzen, I.: "The Theory of Planned Behavior"; Organizational Behavior and Human Decision Processes 50, 2 (1991), 179 - 211.

[Ali-Vehmas and Luukkainen 2005] Ali-Vehmas, T., Luukkainen, S.: "Service Diffusion Strategies for Push to Talk over Cellular"; International Conference on Mobile Business (ICMB'05), edited, IEEE, (2005)**:** 427- 433.

[Badre 2002] Badre, A. N.: "Shaping web usability"; Addison-Wesley, (2002).

[Barnes and Huff 2003] Barnes, S., Huff, S. L.: "Rising sun: iMode and the wireless Internet"; Communications of the ACM 46, 11 (2003), 78-84.

[Baumgartner 2003] Baumgartner, V.: "A practical set of cultural dimensions". S. J. Masood Masoodian, Bill Rogers. FH Joanneum, Graz, (2003): 76.

[Bina and Giaglis 2005] Bina, M., Giaglis, G. M.: "Exploring Early Usage Patterns of Mobile Data Services"; International Conference on Mobile Business (ICMB'05), edited, IEEE, (2005)**:** 363-369.

[Boyancigiller and Adler 1995] Boyancigiller, N. A., Adler, N. J.: "The parochial dinosaur: organisational science in a global context"; Cross-cultural management, edited by T. Jackson, Oxford: Butterworth-Heinemann, London (1995)**:** 9-37.

[Brown and Randell 2004] Brown, B., Randell, R.: "Building a context sensitive telephone: some hopes and pitfalls for context sensitive computing "; CSCW Journal 13, 3-4 (2004), 329-345.

[Choi, Lee et al. 2005] Choi, B., Lee, I., Kim, J.: "A qualitative cross-national study of cultural influences on mobile data service design"; SIGCHI conference on Human factors in computing systems, edited, ACM Press, Portland, Oregon (2005), 1**:** 661-670.

[Compeau and Higgins 1995] Compeau, D. R., Higgins, C. A.: "Computer Self-Efficacy: Development of a Measure and Initial Test"; MIS Quarterly 19, 2 (1995), 189 - 211.

[Davis 1989] Davis, F. D.: "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology"; MIS Quarterly 13, 3 (1989), 319-340.

[Davis, Bagozzi et al. 1989] Davis, F. D., Bagozzi, R. P., Warshaw, P. R.: "User acceptance of computer technology: A comparison of two theoretical models"; Management science 35, 8 (1989), 982-1003.

[Davis, Bagozzi et al. 1992] Davis, F. D., Bagozzi, R. P., Warshaw, P. R.: "Extrinsic and Intrinsic Motivation to Use Computers in the Workplace"; Journal of Applied Social Psychology 22, 14 (1992), 1111 - 1132.

[Del Gado 1996] Del Gado, E. M.: "Culture and Design"; International User Interfaces, edited by E. M. Del Gado and J. Nielsen, Wiley, New York (1996)**:** 276.

[Fishbein and Ajzen 1975] Fishbein, M., Ajzen, I.: "Belief, Attitude, Intention and Behaviour: An Introduction to Theory and Research"; Addision-Wesley, Reading, MA. (1975).

[Fitzgerald 2004] Fitzgerald, W.: "Models for Cross-Cultural Communications for Cross-Cultural Website Design." National Research Council Canada, Institute for Information Technology, (2004).

[Ford 2005] Ford, G.: "Researching the effects of culture on usability". MSc Dissertation. University of South Africa, Pretoria, (2005).

[Ford and Kotze 2005] Ford, G., Kotze, P.: "Researching culture and usability - a conceptual model of usability"; People and computers XIX: the bigger picture: proceedings of HCI 2005, edited by T. McEwan, J. Gulliksen and D. Benyon, London: Springer, Edinburg (2005)**:** 317-333.

[Geoghegan 1994] Geoghegan, W. H.: "What ever happened to instructional technology?" Paper presented at the 22nd Annual Conference of the International Business Schools Computing Association, (1994), Baltimore, Maryland.

[Geser 2004] Geser, H.: "Towards a Sociological Theory of the Mobile Phone"; (2004), Retrieved 2006/03/21, from file:///C:/aPhD/Referenced_Mobile/Geser.pdf.

[Habib 2003] Habib, L.: "Domestication of e-learning technologies: A preliminary conceptual framework"; (2003), from http://home.hio.no/~laurence/NOKOBIT2003.doc.

[Haddon 2003] Haddon, L.: "Domestication and Mobile Telephony"; Machines that Become Us: The Social Context of Personal Communication Technology, edited by J. Katz, Transaction Publishers, New Brunswick, New Jersey (2003)**:** 43-56.

[Hall and Hall 1990] Hall, E. T., Hall, M. R.: "Understanding Cultural Differences"; Intercultural Press Inc., Yarmouth, Me (1990).

[Ho and Kwok 2003] Ho, S. Y., Kwok, S. H.: "The Attraction of Personalized Service for Users in Mobile Commerce: An Empirical Study"; ACM SIGecom Exchanges 3, 4 (2003), 10-18.

[Hofstede 1995] Hofstede, G.: "The business of international business is culture"; Cross-cultural Management, edited by T. Jackson, Butterworth-Heinemann, London (1995)**:** 150-154.

[Hofstede 2001] Hofstede, G.: "Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations"; Sage Publications Inc, Thousand Oaks, CA (2001).

[Hofstede and McCrae 2004] Hofstede, G., McCrae, R. R.: "Personality and culture revisited: Linking traits and dimensions of culture"; Cross-Cultural Research 38, 1 (2004), 52-88.

[Hoft 1996] Hoft, N.: "Developing a Cultural Model"; International User Interfaces, edited by E. d. G. a. J. Nielsen, John Wiley and Sons, New York (1996)**:** 41-72.

[Honold 2000] Honold, P.: "Culture and Context: An Empirical Study for the development of a Framework for the Elicitation of Cultural Influence in Product Usage," International Journal of Human-Computer Interaction 12, 3-4 (2000), 327 - 345.

[Humphreys 2005] Humphreys, L.: "Cellphones in public: social interactions in a wireless era"; News Media & Society 7, 6 (2005), 810-833.

[Jones and Marsden 2005] Jones, M., Marsden, G.: "Mobile Interaction Design"; John Wiley and Sons, Hoboken, NJ (2005).

[Jordan 1998] Jordan, P. W.: "Designing Pleasurable Producs"; Taylor & Francis, London (1998).

[Keshav 2005] Keshav, S.: "Why cell phones will dominate the future internet?" ACM SIGCOMM Computer Communication Review, edited, ACM Press, New York (2005), 35**:** 83-86.

[Kiljander 2004] Kiljander, H.: "Evolution and Usability of Mobile Phone Interaction Styles". Department of Computer Science and Engineering. Helsinki University of Technology, Helsinki, (2004): 238.

[Kim and Lee 2005] Kim, J. H., Lee, K. P.: "Cultural difference and mobile phone interface design: Icon recognition according to level of abstraction"; Proceedings of the 7th International Conference on Human-Computer Interaction with Mobile Devices & Services, edited, ACM Press, New York (2005)**:** 307 - 310.

[Kleijnen, Wetzels et al. 2004] Kleijnen, M., Wetzels, M., De Ruyter, K.: "Consumer acceptance of wireless finance"; Journal of Financial Services Marketing 8, 3 (2004), 206-217.

[Kwon and Chidambaram 2000] Kwon, H. S., Chidambaram, L.: "A test of the technology acceptance model: The case of cellular telephone adoption"; Proceedings of the 33rd Hawaii International Conference on System Sciences, edited, IEEE Computer Society, Hawaii (2000), 1**:** 1-10.

[Lee, Kim et al. 2002] Lee, W. J., Kim, T. U., Chung, J. "User acceptance of the mobile Internet"; M-Business 2002, Athens, Greece, (2002).

[Lee, Ryu et al. 2005a] Lee, Y. S., Ryu, Y. S., Smith-Jackson, T. L., Shin, D. J., Nussbaum, M. A., Tomioka, K. "Usability Testing with Cultural Groups in Developing a Cell Phone Navigation System"; HCI International - 11th international conference on Human-Computer Interaction, Las Vegas, Nevada, USA, (2005a).

[Lee, Ryu et al. 2005b] Lee, Y. S., Ryu, Y. S., Smith-Jackson, T. L., Shin, D. J., Nussbaum, M. A., Tomioka, K.: "Usability testing with cultural groups in developing a cell phone navigation system"; Proceedings of HCI International 2005 - 11th International Conference on Human-Computer Interaction, edited by C. Stephanidis, Las Vegas, Nevada, USA (2005b), 10.

[Leung, Chan et al. 2003] Leung, C. H., Chan, Y. Y., Chan, C. S. C.: "Analysis of Mobile Commerce Market in Hong Kong"; Proceedings of the 5th international conference on Electronic commerce, edited, ACM Press, Pittsburgh, Pennsylvania (2003), 50**:** 408-412.

[Ling 2001] Ling, R.: "The diffusion of mobile telephony among Norwegian teens: A report from after the revolution". Telenor R&D, Paris, (2001).

[Malhotra and Galletta 1999] Malhotra, Y., Galletta, D. F.: "Extending the Technology Acceptance Model to Account for Social Influence: Theoretical Bases and Empirical Validation"; Proceedings of the Thirty-Second Annual Hawaii International Conference on System Sciences, edited, IEEE, (1999), 1**:** 1006.

[Marcus and Chen 2002] Marcus, A., Chen, E.: "Designing the PDA of the future"; Interactions 9, 1 (2002), 34 - 44.

[Marcus and Gould 2000] Marcus, A., Gould, E. W.: "Crosscurrents: cultural dimensions and global Web user-interface design"; Interactions 7, 4 (2000), 32 - 46.

[Meso, Musa et al. 2005] Meso, P., Musa, P., Mbarika, V.: "*Towards a model of consumer use of mobile information and communication technology in LDCs: the case of sub-Saharan Africa*"; *Journal of Information Systems* **15**, 2 (2005), 119-146.

[Moore and Benbasat 1991] Moore, G. C., Benbasat, I.: "Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation"; Information Systems Research 2, 3 (1991), 192 - 222.

[O'Sullivan, Hartley et al. 1994] O'Sullivan, Hartley, J., Saunders, D., Montgomery, M., Fiske, J.: "Key concepts in communication and cultural studies"; Routledge, London and New York (1994).

[Olivier 2004] Olivier, M. S.: "Information technology research: a practical guide for computer science and informatics"; Van Schaik, (2004).

[Oxford 1999] Oxford: "Concise Oxford Dictionary", edited by J. Pearsall, Oxford University Press, New York (1999).

[Palen, Salzman et al. 2000] Palen, L., Salzman, M., Youngs, E. "Going wireless: behavior & practice of new mobile phone users"; Proceedings from the 2000 ACM conference on Computer supported cooperative work., Philadelphia, Pennsylvania, ACM Press, (2000).

[Pedersen 2005] Pedersen, E.: "Adoption of Mobile Internet Services: An Exploratory Study of Mobile Commerce Early Adopters"; Journal of Organizational Computing and Electronic Commerce 15, 3 (2005), 203 - 222.

[Pedersen, Methlie et al. 2002] Pedersen, P. E., Methlie, L. B., Thorbjornsen, H.: "Understanding mobile commerce and user adoption: a triangulation perspective and suggestions for an explanatory service evaluation framework"; Proceedings of the 35th Hawaii international conference on system sciences, edited, (2002).

[Peterson 1994] Peterson, R. A.: "A Meta-Analysis of Cronbach's Coefficient Alpha "; Journal of Consumer Research 21, 2 (1994), 381-391.

[Rice and Katz 2003] Rice, R. E., Katz, J. E.: "Comparing internet and mobile phone usage:digital divides of usage, adoption, and dropouts". Pergamon. Rutgers University, New Brunswick, (2003): 597–623.

[Roberts 2004] Roberts, K. J.: "Technology factors in Corporate Adoption of Mobile Cell Phones: A Case Study Analyses"; Proceedings of the 37th International Conference on System Sciences, edited, IEEE, (2004), Track 9**:** 90287b.

[Rogers 2003] Rogers, E. M.: "Diffusion of Innovations"; The Free Press, New York (2003).

[Schiphorst 2006] Schiphorst, T.: "Affectionate Computing: Can we fall in love with a machine"; IEEE MultiMedia, edited by F. Nack, IEEE, (2006), 13**:** 20-23.

[Scott and Gable 1997] Scott, J. E., Gable, G. "Goal congruence, trust, and organizational culture: strengthening knowledge links"; Proceedings of the eighteenth international conference on Information systems, Atlanta, Georgia, Association for Information Systems, Atlanta, GA, (1997).

[Silverstone and Haddon 1996] Silverstone, R., Haddon, L.: "Design and the Domestication of Information and Communication Technologies: Technical Change and Everyday Life"; Communication by Design: The Politics of Information and Communication Technologies, edited by R. S. a. R. Mansell, Oxford University, Oxford (1996)**:** 44-74.

[Sun 2004] Sun, H.: "Expanding the Scope of Localization: A Cultural Usability Perspective on Mobile Text Messaging Use in American and Chinese Contexts". Communication and Rhetoric. Rensselaer Polytechnic Institute, New York, (2004): 287.

[Taylor and Todd 1995] Taylor, S., Todd, P. A.: "Assessing IT Usage: The Role of Prior Experience "; MIS Quarterly 19, 2 (1995), 561 - 570.

[Teo and Pok 2003a] Teo, T. S. H., Pok, S. H.: "Adoption of the internet and WAP-enabled phones in Singapore"; Behaviour & Information Technology 22, 4 (2003a), 281-289.

[Teo and Pok 2003b] Teo, T. S. H., Pok, S. H.: "Adoption of WAP-enabled mobile phones among Internet users"; Omega: The International Journal of Management Sciences 31, 6 (2003b), 483-498.

[Thompson, Higgins et al. 1991] Thompson, R. L., Higgins, C. A., Howell, J. M.: "Personal Computing: Toward a Conceptual Model of Utilization"; MIS Quarterly 15, 1 (1991), 124 - 143.

[Urbaczewski, Wells et al. 2002] Urbaczewski, A., Wells, J., Sarker, S., Koivisto, M. "Exploring Cultural Differences as a Means for Understanding the Global Mobile Internet: A

Theoretical Basis and Program of Research"; Proceedings of the 35th Hawaii International Conference on System Sciences, Hawaii, IEEE Computer Society, (2002).

[Uzoke, Seleke et al. 2006] Uzoke, F. M. E., Seleke, G. G., Shemi, A. P.: "Infrastructural and behavioural influences on the adoption of ecommerce in developing countries"; IST-Africa, edited by P. Cunningham and M. Cunningham, IIMC International Information Management Corporation, Pretoria (2006).

[Venkatesh and Davis 2000] Venkatesh, V., Davis, F. D.: "A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies"; Management Science 46, 2 (2000), 186-204.

[Venkatesh, Morris et al. 2003] Venkatesh, V., Morris, M. G., Davis, G. B., Davis, F. D.: "User acceptance of information technology: Toward a unified view"; MIS Quarterly 27, 3 (2003), 425-478.

[Walton and Vukovic 2003] Walton, M., Vukovic, V.: "Cultures, Literacy, and the Web: Dimensions of Information "Scent""; Interactions, edited by S. M. Dray, D. A. Siegel and P. Kotzé, ACM Press, New York (2003), March-April**:** 64-71.

Cognitive Ergonomics in Interface Design – Discussion of a moving science

Gerrit C. van der Veer
Open University Netherlands

Introduction: positioning the discipline

In many cases we label our discipline "Cognitive Ergonomics". We obviously view our domain as an applied science. We apply knowledge, methods, techniques, and tools from human sciences towards problems of human use of artifacts. Ergonomics, in general, seems to focus on several directions of application. At the one side, artifacts are considered in an existing situation of use, and actual problems of use are approached local to that situation. This type of application I label "curing". At another, in fact opposite, site, problems are approached from the point of view of human needs and design of a solution includes design of a new situation and envisioning new artifacts in context. This type of application I will label "envisioning design". Obviously, ergonomic practice often can be located somewhere between these extremes.

Cognitive Ergonomics as a discipline is a restriction of Ergonomics, where "Cognitive" as a label indicates the focus on human knowledge and understanding. Both curing and envisioning design mainly consider cognition: either trying to help users of artifacts solve their problems of understanding, or designing artifacts that fit human cognitive competences and needs. But cognition as such should not be interpreted too narrow. Immediately related to understanding the aspects of acceptance, emotion and behavior have to be considered. And, moreover, cognition should be understood in a broader sense than (only) the Psychological meaning of the concept. In that respect, labels like "social ergonomics" and "distributed cognition" have been applied, indicating the variety of human science disciplines that should be considered basic to the applications in our domain. A general characteristic of Cognitive Ergonomics is the focus on information systems, information technology, and, more recently, multimedia as the core of the artifacts considered.

The label "Cognitive Ergonomics" seems to be used mainly in Europe. For the same domain of applied science several alternative labels prevail in the Western world, like "Human-Computer Interaction", "User Centered Design", and "Usability Engineering". Depending on who is using any of these labels, there may be subtle differences in meaning. Again, there are extremes that aim at curing local problems (e.g., focusing on help systems or instruction), or, alternatively, at envisioning and designing future smart, or adaptive, environments. In this sub-domain of Ergonomics, however, envisioning design seems to be more on the forefront of state of the art approaches, in comparison to curing efforts. The rapid development of technology seems to have forced a choice here.

Cognitive Ergonomics, with whatever name, is a rather young discipline. Both in Europe and in North America professional organizations celebrate this year their 25th anniversary (ACM SIGCHI, EACE), and INTERACT (IFIP TC13's "pre-marital" child) is not far behind. Systematic attention for the human user of interactive systems seems to be an accepted value. Look at the titles of educational volumes that have been published during these years (Norman & Draper, 1986; Vredenburg et al., 2001; Garrett, 2002; Holzblatt et al., 2004; Lazar, 2006; Lambropoulos & Zaphiris, 2006), and look at names of courses in Computer Science Curricula and at keywords in Computer Science conferences. But we are not there yet. On of my colleagues, Computer Science Professor, recently told me:

"My students do not need to talk to people".

What is the discipline of Cognitive Ergonomics, or Human-Computer Interaction, in 2007? The year should be mentioned since the domain is being redefined continuously and the methods change as well. Technical possibilities of information technology still grow according to Moore's Law (and are applied by industry immediately before optimal application for human users has been considered). The application domains broaden: more people, more non-experts, more applications in complex social and organizational settings, more application outside the work situation.

I will show what is changing and what should be changing and I will point to relevant new approaches. And I will focus mainly on the prevailing efforts of design, leaving curing to "traditional" Ergonomists. In addition, I will omit in my analysis the development in the basic sciences that contribute towards Cognitive Ergonomics: the experimental Psychologists that study the characteristics of human behavior in relation to information technology and the requirements for usable multimedia based on human information processing. I expect the next presentation (by José Cañas) will cover some of these developments.

Users and the design of interactive systems

Let me sketch a brief history of design of interactive systems from the point of view of the human partner. The main issue is the location of the user in the design process.

1. participatory design

Enid Mumford (1924-2006) was one of the pioneers. In the 70s she was a member of the Quality of Working Life Group, in 1983 she won the American Warnier Prize for her contribution to Information Science. Mumford's ETHICS approach (1983) towards software development is based on user participation. She mainly intended to solve the problem of introducing new systems. She advocated a holistic vision on the organization resulting in both a social and a technical solution. Mumford made a distinction between three categories of user participation:

- consulting, where the user was interviewed for each decision but the responsibility for design was left with the analyst;
- representational, where users are allowed a vote for each decision;

- consent, where employees of each department participate and where the workers in decide.

Mumford's approach was an evident success at a time where computers were used by computer experts and task professionals, e.g., at the introduction of the first stand-alone word processors, early applications of computer technology in offices. IBM invented the concept in the 60s and discovered that the introduction in its own offices was only successful after the users were involved from the start. These users were experts in their task domain and they knew the previous technology first hand. For the introduction of spreadsheets in the domain of professional accounting the same was found to be true. Nardi & Miller (1990) in this case refers to "end user programming".

An import development, at least partially derived from Mumford, is often labeled the "Scandinavian approach" (Suchman, 1988; Bødker, 1996). The user should be included in all phases of the design and introduction, and in some cases this developed into a political right (Bjerkness & Bratteteig, 1995). With the broader introduction of information technology in society, however, the "extreme" variant of user participation collided with the need for systematic analysis and specification of functional requirements and user interfaces, even though the need for consulting users in all phases of the design process remains (Carroll, 1996).

2. user centered design

In the 80s world wide attention developed for user centered design, an approach the can be characterized by systematic design methods applied by expert designers, from the point of view of the user. I will mention two important aspects:

Modeling the user interface

Design is based on systematic (more or less formal) modeling the user relevant aspects of the system. Moral (1981) was one of the pioneers. Tauber (1988) build on his ideas and introduced the concept of the "User Virtual Machine" (UVM) that referred to the total of relevant user *knowledge* of the technology:

- the task world – what are the goals of the prospective user of the system, what are the tasks to be delegated to the system;
- the semantics – what is the system offering the user to delegate tasks, in terms of system objects and actions on these;
- the syntax – how may tasks be delegated and how will the system provide feed back to the user;
- the representation – how does the information from user to system look like and vice versa (Moran labels this level as "key strokes").

The designer models everything the user needs to know or to understand. In this respect I like to point to a plethora of academic work on cognitive task analysis (Hollnagel, 2003), user-interface specification en modeling (Pfaff, 1985; Card, Moran & Newell, 1983; Baumann & Thomas, 2001), en systematic evaluation techniques (Jordan et al., 1996). Even though the label UVM never was adopted worldwide, the four aspect (levels) are:

pragmatics (user task world); functionality (semantics); dialogue (syntax); and representation.

Systematic design process

The process mostly starts with a user and task analysis. Next steps are generally an iteration of envisioning of the future task world, and of specification, evaluation, and implementation phases (van der Veer & van Welie, 2003). I will only focus on task analysis here, since this is the first phase where the user is in focus. Whatever the remainder of the process looks like, the task analysis phase aims at: mapping the users, their organization, the social and group structure, and task relevant individual differences. In addition, a detailed overview needs to be developed on the goals and tasks for using technology. A main issue in this process is the acquisition of all knowledge needed.
The user will know only fragments of what is relevant. Jordan en Henderson (1995) show that we need to approach four sources: only part of the knowledge is the expertise of the people concerned (all users and stakeholders should be considered experts in their own domain) and part of the knowledge is in the situation (post-it notes around the screen, memos on the poster board, how-to-use-it notes with the coffee machine). Moreover, only part of this knowledge is explicit (an expert will speak about it, or it can be read somewhere), and part is implicit (the expert shows evidence of expertise without being able to explain this, the team shows a "silent" division of tasks). Figure 1 is an adaptation of Jordan & Henderson (1995), where the cells show the main techniques for acquisition of knowledge.

[figure 1 about here]

For all techniques the best approach is to find an analyst who is not an expert in the domain. Otherwise there is a risk of knowledge being unnoticed. This is more so for implicit knowledge. Ethnography will takes most time since the analyst is a "participant observer" who participates as an apprentice in "normal" activities. To start with the ethnographer will have to register everything that is surprising and not understandable. If one waits till things are clear, there will be nothing that seems worth while to register.

Only after collecting and understanding all relevant knowledge of users and stakeholders and the situation, the systematic design may continue. From this moment the client of design will be a partner to negotiate with. And in many cases this is not the main "end user". All users and stakeholders will have to be considered further during all phases of design, especially when design decisions have to be made.

The methods and techniques sketched in this section on "user centered design" will remain to be relevant in the future.

3. contextual design

This label has been coined by Beyer & Holtzblatt (1997), who continue in the direction pointed to by Jordan and Henderson. They show that expert knowledge only gets its meaning in an actual context. Only is a situation people decide on their goals and on what

they consider their actual task. It is interesting to note the full title of their book is: "Contextual Design: a Customer-Centered Approach to Systems Designs". However, in practice "customer" may be read as "user or stakeholder". This broad approach is currently developing into a mainstream design vision.

Misunderstandings

In the world of design for users there are still some common misunderstandings:

1. the user can do it

Since many years not all users are experts or nerds. And even if they were they do not want to be. Systems are increasingly complex and users do not get extra memory. The dispatchers of the service desk of our University keep statistics of calls received regarding basic services. For 2005 Figure 2 provides the statistics.

[figure 2 about here]

The highest frequency is for category "reset of a password". And all those poor users are convinced of the need to protect the security of their boss' system.

2. if you are user friendly

The label "user friendly" did not die, and to many customers of design it seems that a system that looks "nice" to its user is easy to use. The best known is Microsoft's paperclip (Figure 3).
[figure 3 about here]

But this is not a single incident. Recently a web search with the term "user-friendly" resulted in an unexpected series of companies that advertised with this label, including universities! Some authors of this prose refer to representation, lay out, or usability tests. But in many cases one should wonder what are the methods that are responsible for accrediting this label.

3. all users want the same thing

When we really start with a user and task analysis we find a different situation (Norman, 2005). I will show some examples of research we did with PhD students in various European countries (Chisalita, 2006):

- The Dutch police force new information systems were designed. Ethnographic studies showed a large difference between the category "cops" and the category "detectives". The former were obliged to collect all kinds of information and put this in a system (a time consuming task they hated) without knowing the purpose. The second group was allowed to decide what information was relevant to input, and had access to all kinds of additional sources. In the first group this lead to resistance to the system, in the second group this resulted in a negative image of the ethics of the other group.

- In an international bank the business goals changed from client centered to maximizing profit. This changed the goals of the stakeholders in the central management, and sometimes, but not always, of the branch managers. A new intranet based systems was implemented that offered, among other things, functionality for desk-tasks. Many desk clerks, however, kept their service oriented approach and were in some cases passively supported by their branch managers who allowed the old desk systems to be kept available.
- For a government body in a European country we analyzed the directorate that controlled the expenses of other directorates. Transactions were supported by a system that reported the state of the process. Based on this negotiations were initiated to change budgets. Decisions were made by managers who themselves did never touched the system. The actual users implemented the decisions and collected information for reports. When these users made a mistake (and subsequently had to correct their actions) the system kept traces of this. For many of these users the system was an archive of errors. Others reached a level of expertise that allowed them to program around these problems, which the management was unable to detect or control.

Analyzing complex systems shows that it serves different goals for different people in different situations. And not all goals are explicit and clear to all stakeholders.

Who are the users?

Managers are users as are desk clerks and back customers, cops are users as are detectives. But their goals differ. Design should take all different user groups and different goals into account. Moreover, a client of design does not necessarily wish to support all types of users and their goals. I will point to an interesting example from the domain of games. The free of charge available computer game "America's Army" (Figure 4) reached in 2005 6 million registered players (Boyd, 2005) with 100,000 new registrations a month. The original goal, different from many popular games, was not commercial. America's Army intended to be an advertisement and at the same time a selection instrument to solicit recruits for the American army (Observer, 2005).

[figure 4 about here]

In the meantime it is, in addition, considered a serious training tool for the army focusing on "teamwork, integrity and leadership". Most players consider it a challenge or just fun, in many cases in (geographically spread) teams. The designers aimed at selection and advertisement, and the owner currently aims at preparation for actual combat. It seems that now Taliban, Sunnite and Shiite groups should be considered additional stakeholders. This points to interesting ethic aspects of modern design.

Norman (2006a) criticizes the concept of "user centered design" for still different reasons: it concerns multiple people that use a system in actual situations. These people are alive; they are not stuck in a single location and a single role. Consequently, they might, over time, want to use the same system for different purposes: internet banking,

watching a movie, communicating with friends). The term "user" suggest too simple a world with a single environment and culture.

Activity centered design – a new paradigm

We need to keep the approach to analyze all kinds of goals for the system and to detect who are the stakeholders. With existing modern interactive systems there is often nobody who knows precisely and completely what the possibilities are and what purpose these serve. The analyst will have to use all of the aforementioned knowledge acquisition techniques to get an overview.

Organizations have business goals, which change, and which will not, by default, be shared (or even known) by all stakeholders in the organization.

Humans have goals, often several at any time, and in natural situations these might well be implicit. Goal priorities depend on:

- the individual history (do I know the customer at my desk?);
- the culture that is experienced as actual (do I consider myself an employee of bank X, or do I consider myself a tem member of bank branch Y?);
- the context (my branch manager aims at keeping a client friendly image);
- actual needs (how can I get rid of the cue at my desk).

Norman (2006b) introduces the label "activity centered". In an actual situation people choose what goal is most important and aim at performing activities that support that support that goal.

A designer should aim at detecting what may be needed for supporting / mandating / delegating stakeholder activities, and combine this into a design space:

- what are the opportunities of available or expected technology;
- what does the client of design want to pay for;
- and sometimes: does the designer want to participate in this.

Balancing of stakeholder interests cannot be avoided (an issue already with user participation). And each solution will have to be validated in the actual use of context because only there the user or stakeholder will decide on actual goal priorities.

Techniques for activity centered design

Even though the unit of analysis is changing from "the user" to the situated activity, we still need the same well established techniques. Their aim may change somewhat, so I will provide a sketch of "old techniques for new purposes". It makes sensed to recollect the general design process:

1. if at all possible, start with an analysis of the current task situation including the users and stakeholders;
2. envision the future task world for the case where the new technology-to-be-designed is implemented and in use;

3. specify details of the technology in the sense of the UVM (task delegation, functionality, dialogue, and representations);
4. early, as well as late, evaluate design decisions against understanding and acceptance of users and other stakeholders and against established knowledge of usability experts and state of the art design patterns.

Designers, of course, will keep in mind that each of the mentioned processes might trigger a (new) phase of any other one. Overall the design of interactive systems is an iterative process, though there should be a generic start in task analysis and finally a well assessed set of specifications that will function as requirements for the engineers implementing the design.

1. We did mention already the four groups of techniques needed for acquisition of task knowledge. In the new era of activity centered design the techniques are still valid, but the focus does change:
    - Interviewing task experts should preferably take place at the actual location of task performance, where the situation will trigger the relevant knowledge of the situated activities. Recording the physical environment may well add to understanding, and, at the same time, trigger the analyst to probe for additional information about details and conditions for action.
    - Hermeneutic understanding will, as in the old days, require the analyst to picture the situation as well as the stakeholder background and current motives. Not too much will change here. Especially mental model analysis, like using teach back procedures (van der Veer & Puerto Melguizo, 2004), needs to explicitly refer to stakeholder history and context of use.
    - Registering and analyzing documents and other artifacts needs a clear focus on validity of the information. A major question to ask is in what situation of use and what type of user (culture and motives) the meaning should be understood.
    - Ethnography will, in all cases, consider the situation as a whole, from the viewpoint of the "aboriginals". This technique needs to be kept as it is, even though time and opportunity are a condition of application. As a last resort, techniques of ethnography by proxy might be applied, where original stakeholders are asked to keep a diary, collect stories, or take pictures in well specified original situations, and feed back the data collected to the analyst. Obviously, the specification of the situation to collect material is crucial here, and should aim at understanding the precise context of activities to be understood. Even if by proxy, this type of ethnography will result in an iterative process of deeper understanding.
2. Envisioning the future task world should be based on a task model approach that allows for activities as a unit. Approaches like GTA (van Welie & van der Veer, 2003) serve the purpose, allowing roles to be defined in relation to a responsibility to perform each activity. Roles (and activities) can be mandated or delegated to agents (people, groups of people, or interactive systems). This leads to a finer grained task model and a view on the task world that allows freedom to consider role allocation in relation to (situational) conditions for starting or stopping

activities. Obviously, the modeling of the situation should be considered a major aspect of task modeling.

3. Specification of technology will, as previously, consider the various users as well as the context of use.
    - Functionality will in most cases be defined separately for different roles, even if many users and other stakeholders may take various roles in different occasions. Sometimes a wrist watch is a device to delegate time telling, at another moment is takes the role of a stop watch, or a device to alert me on an appointment. Separating the functionality aspects of system objects (pre set clock times, pre set periods, running clock times in relation to time zones) as well as operations on these objects will help the user to easily understand when delegating various tasks to various roles.
    - Dialogue means the physical exchange of information between an inactive system and a user. The relevance and feasibility of the physical exchange depends heavily on the actual situation (noise, light conditions, presence of other people, current occupations of the user including attention, requests to senses and physical behavior). In many cases multiple dialogue styles (commands versus choice of options versus "direct" manipulation) as well as physical actions should be provided. Increasingly technical developments allow devices to be context aware and help users to choose the optimal settings depending on the context.
    - Representation indicated the actual shape of the physical signals exchanged, including language, sound, visuals, gestures and tactile feedback. Both the conditions for feasibility and the growing possibilities for context aware support of the user are comparable to what has been indicated after the previous bullet.
4. Evaluation should consider the context as well as the situation of the user (current needs, history, and actual cultural identity). The well known standard evaluation techniques in fact serve this purpose well (e.g., Jordan et al., 1996). In most cases of expert evaluation it just requires the analyst to keep the right mind set. We give an example:
    - Cognitive walkthrough is best performed by a small (3 – 4) usability experts, who consider an early prototype of a mock-up that simulated the intended interactions. They should start with understanding the goal and relevant characteristics of the user. For each user step in a dialogue process they answer a small number of questions, considering (a) what would be the user's next goal; (b) what would be the user's next action; (c) what would be the actual reasons for the user to make decision b; and (d) what would the user expect the system to do. The main "change" (or fine tuning to activity centered design) would be to start with including the actual context of use and the actual needs and goal priorities of the user. Subsequently, in step (a) they need to consider explicitly the goal for an activity, in step (c) the context as possible trigger for a reason, and in step (d) the meaning of system state in relation to this context and to the user's current needs.

In cases where early evaluation requires confronting stakeholders (including users) with the system under construction, we need to represent our preliminary design ideas to them. In an early stage a static "sketch" is the only possibility, and it makes sense to show the sketchy character, in order to elicit free comments and allow multiple interpretations of specifications that are not fixed yet.

[figure 5 about here]

Figure 5 shows a 2-dimensional drawing (Vyas & van der Veer, 2006), but 3-D representations of foam and cardboard are relevant as well and allow actual handling in simulated activities.

In a later stage, when preliminary decisions of the dialogue need to be assessed, an interactive representation makes sense, whether this is in fact a powerpoint simulation or an early prototype, see Figure 6.

[figure 6 about here]

Once there has been a first set of decisions on the technology, the prospective application in context can be illustrated and assessed with stakeholders. The well known techniques of scenario analysis remain a good choice:

- A set of personas will be a first requirement. In the case of activity centered design we may well need to start with a list of all types of human agents that might be candidates for taking a role to perform (or delegate to interactive systems) an activity. "Types" refers to types of agents that can be distinguished from other types by characteristics relevant for performing or delegating activities we consider. As an example, take the domain of scientific authoring. In a current research (Vyas, de Groot & van der Veer, 2006) project we identified several types of human agents:
    - Expert authors, like full professors;
    - Knowledgeable authors who are expert on certain sub-domains and tend to write guided my an expert;
    - PhD students;
    - Support staff with relevant supporting expertise, like librarians, graphic designers, or statisticians.

  In addition there are "non human" agents like "the library", "the secretariat" and Google. These agents tend to perform activities less situation dependent. For each of the human agent types it makes sense to analyze relevant characteristics and "picture" persona to provide guidance for stakeholders to consider the people that would use the system in their context.

  The first step in developing personas is to survey the task and domain model for identifying relevant distinct types of users and other stakeholders. With the distinction the relevant variables will emerge that can be used to describe the various personas. Figure 7 provides an example of sets of characteristics that emerged in our example domain,

and figure 8 shows a representation of one of the personas that we used in our assessment study.

[figure 7 and 8 about here]

- Scenarios allow early confrontation of users with design ideas. In the case of modeling the future task domain scenarios will be global and focus on context and stakeholder understanding and goals. Later in the design process scenarios can be based on actual activities, and, in the case of delegating these to interactive technology, on "use cases" as used in Software Engineering. In all cases, scenarios could be based on the personas that have been identified and recognized by the stakeholders. In fact, a scenario is a description of the intended delegation of activities, or interaction in the course of activities, dressed with a description of an actual context and an actual agent (or multiple agents) with an indication of current needs.

[figure 9 about here]

Figure 9 (Vyas & van der Veer, 2006) shows fragments of a scenario where stakeholders can help evaluate understanding, acceptance, and experience related to future implementation.

We provided just examples of design techniques that can, and should, be adjusted to the new paradigm. For other techniques similar arrangements should be made, but in fact the general purpose, as well as the procedures, will not change too much. Designers should be aware of the fact that a new unit of analysis, the activities, should be considered in all aspects and all phases of design. And clients of design need to be convinced of this finer grain of analysis that will bring additional negotiation and choices to be made.

References

Baumann K. & Thomas B. (2001) User Interface Design for Electronic Appliances. Taylor & Francis.

Beyer H. & Holtzblatt K. (1997) Contextual Design: A Customer-Centered Approach to Systems Designs. Morgan Kaufman.

Bjerkness G. & Bratteteig T (1995) User participation and democracy: a discussion of Scandinavian research on system development. Scandinavian journal of information systems, 7(1): 73-98.

Boyd C. (2005) US army cuts teeth on video game. BBC news 25 November 2005, bbc.co.uk.

Bødker S. (1996). Creating conditions for participation - Conflicts and resources in systems development. Human-Computer Interaction 11 (3): 215-236.

Card S.K., Moran T.P. & Newell A. (1983) The psychology of human-computer interaction. Hillsdale, NJ: Erlbaum.

Carroll J.M. (1996). Encountering Others: Reciprocal openings in participatory design and user-centered design. Human-Computer Interaction 11: 285-290.

Chisalita C.M. (2006) Contextual issues in the design and use of information technology in organizations. SIKS Dissertation Series No. 2006-02.

Garret J.J. (2002) The Elements of User Experience: User-Centered Design for the Web**.** New Riders Publishing

Hollnagel E. (ed) (2003) Handbook of Cognitive Task Design. New Jersey, NJ: Lawrence Erlbaum Associates.

Holtzblatt K., Burns Wendell J. & Wood S. (2004) Rapid contextual design: a how-to guide to key techniques for user-centered design. Morgan Kaufmann Publishers

Hoorn J.F. (2006) Software requirements: update, upgrade, redesign. SIKS Dissertation Series No. 2006-14.

Jordan B. (1997) Transforming Ethnography - Reinventing Research. CAM (Cultural Anthropology Methods Journal): 9:3: 12-17

Jordan B. & Henderson A. (1995) Interaction Analysis: Foundations and Practice. The Journal of the Learning Sciences: 4(1): 39-103.

Jordan P.W., Thomas B., Weerdmeester B.A. & McClelland I.L. (1996) Usability Evaluation in Industry. Londen: Taylor & Francis.

Lambropoulos N. & Zaphiris P. (2006) User-centered Design of Online Learning Communities**.** Hershey, PA: Idea Group, Inc.

Lazar P. (2006) Web Usability: A User-Centered Design Approach. Addison-Wesley

Manser T., Howard S.K. & Gaba D.M. (2006) Self-regulation as a central mechanism to collaboratively manage unexpected events in complex work environments. In Proceedings of ECCE13 Trust and control in complex socio-technical systems, ETH Zurich: 162-169.

Moran T.P. (1981) The command language grammar: a representation for the user interface of interactive computer systems. International journal of man-machine studies, 15: 3-50.

Mumford E. (1983) Designing human systems for new technology: The ETHICS method. Manchester, UK: Manchester Business School.

Nardi B.A. & Miller J.R. (1990). The Spreadsheet Interface: A basis for end user programming. Human-Computer Interaction - INTERACT'90. Amsterdam: Elsevier: 977-983.

Norman D.A. (2005) Human-centered design considered harmful. Interactions 12(4): 14-19.

Norman D.A. (2006a) Words matter. Talk about people – not customers, not consumers, not users. Interactions 13(5): 49, 63.

Norman D.A. (2006b) Logic versus usage: the case for activity-centered design. Interactions 13(6): 45, 63.

Norman D.A. & Draper S.W. (eds) (1986) User Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum Associates, 1986.

Observer C. (2005) Video game used to lure new recruits. Military Headlines, March 4, 2005, military.com.

Pfaff G.E. & ten Hagen P. J. W. (eds) (1985) User Interface Management Systems. Berlin: Springer Verlag.

Suchman L. (1988). Designing with the User: Review of "Computers and Democracy: A Scandinavian challenge". ACM Transactions on Information Systems 6 (2): 173-183.

Tauber M. (1988) On mental models and the user interface. In: G.C. van der Veer, T.R.G. Green, J.-M. Hoc & D. Murray (eds) Working with computers: theory versus outcome. Academic Press, London.

.

Van der Veer, G.C. & Puerta Melguizo, M.C. (2004) Specifying User's Knowledge – A Cognitive Ergonomic View on Designing Information Technology. International Journal of Cognitive Technology, 9(1), 14-23.

Van der Veer G.C. & and van Welie M. (2003) Chapter 7 - DUTCH – Designing for Users and Tasks from Concepts to Handles. In: Dan Diaper & Neville Stanton (eds) The Handbook of Task Analysis for Human-Computer Interaction. New York, NY. Lawrence Erlbaum, Inc. 155-173.

Van Welie M. & van der Veer, G.C. (2003) Chapter 19 - Groupware Task Analysis. In: Handbook of Cognitive Task Design. Erik Hollnagel (Ed). Erlbaum, Inc. pp 447-476.

Vredenburg K., Isensee S. & Righi C. (2001) User-Centered Design: An Integrated Approach**.** Upper Saddle River, NJ: Prentice Hall.

Vyas D., de Groot, S. & van der Veer, G.C. (2006) Understanding the Academic Environments: From Field Study to Design. Proc. of ECCE-13. ACM Press: NY, 119-120

Vyas D. & van der Veer, G.C. (2006) Experience as Meaning: Some Underlying Concepts and Implications for Design**.** Proc. of ECCE-13. ACM Press: NY, 81-91.

sources of knowledge	(individual) expert knowledge	group knowledge, knowledge in situation
explicit knowledge	interviews with different types of users and stakeholders	analysis of documents, stories, and artifacts
implicit knowledge	registration of expert behavior, interview based on this, hermeneutic interpretation	ethnography, interpretation through interaction analysis

Figure 1. Sources of task knowledge and knowledge collection techniques (after Jordan & Henderson, 1995).

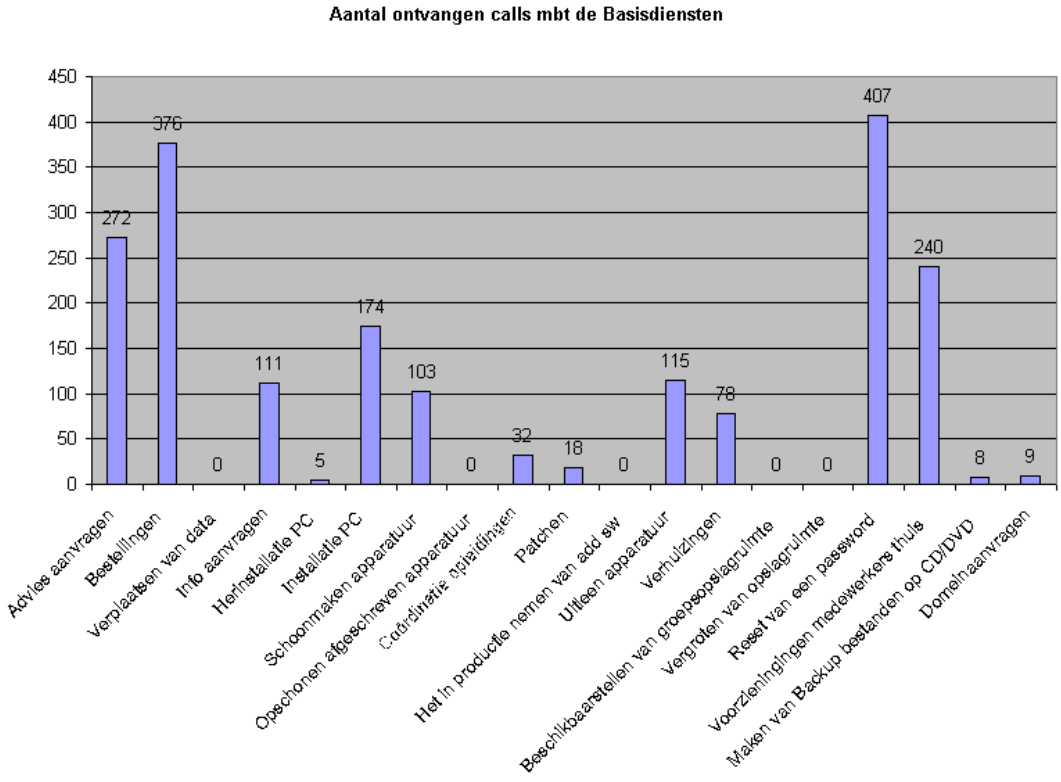


Figure 2. Overview of calls for basic services received by the Service Desk of the Open University Netherlands in 2005.

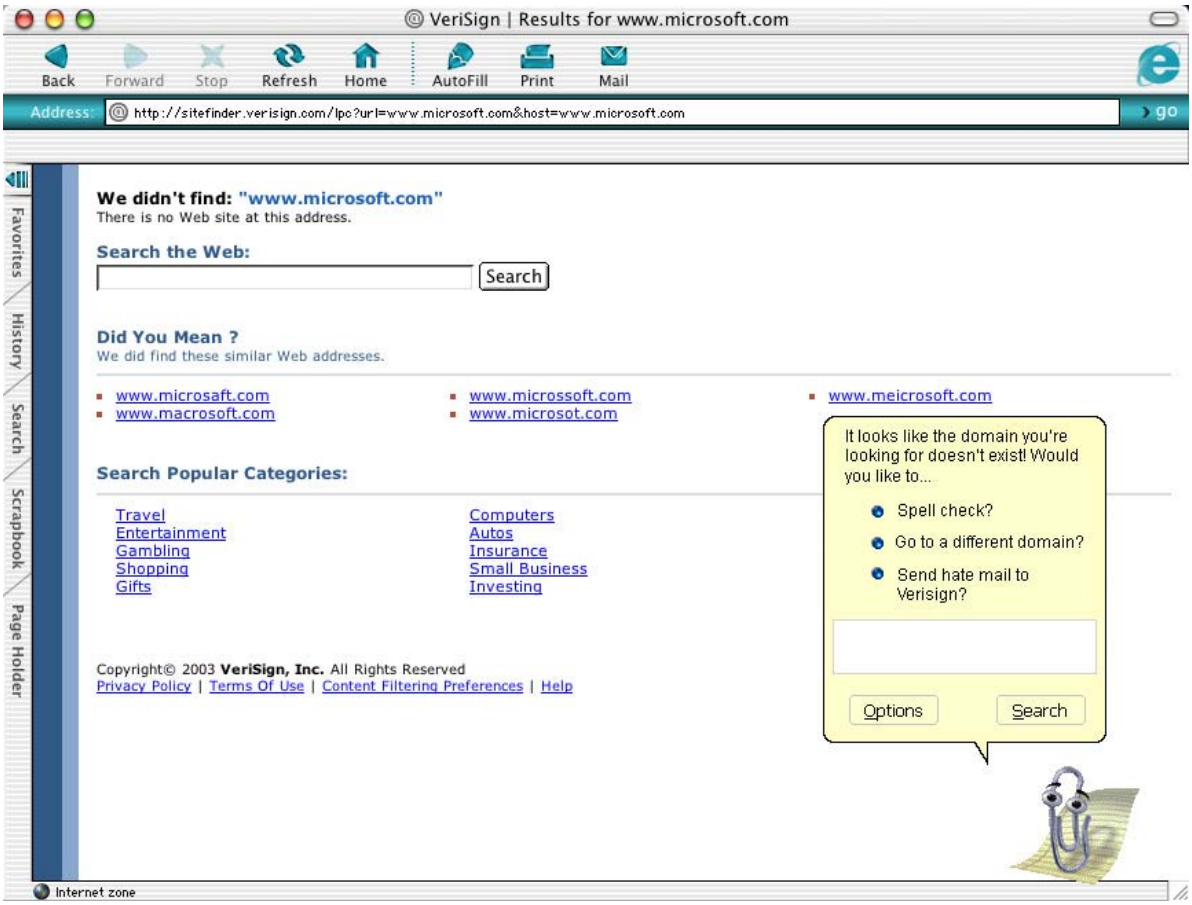


Figure 3. Clippy, the suggestion of a user friendly interface.

Figure 4. America's Army.

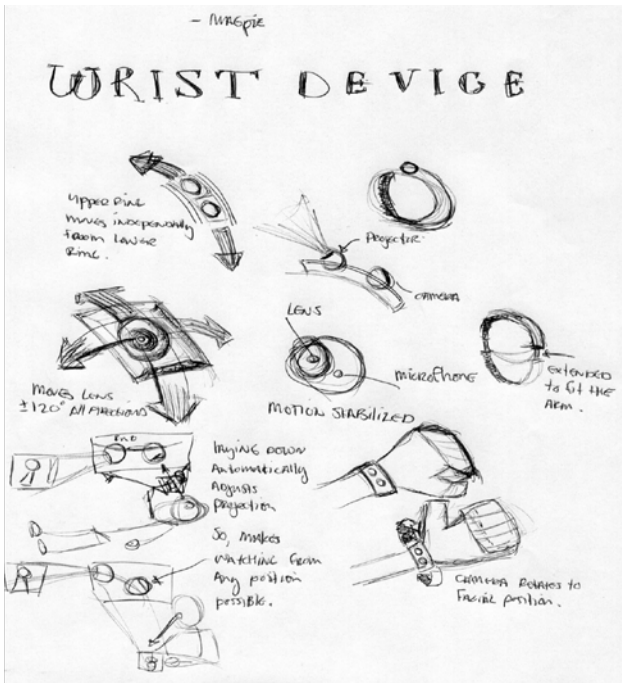


Figure 5. 2-D sketch of a wearable communication device.

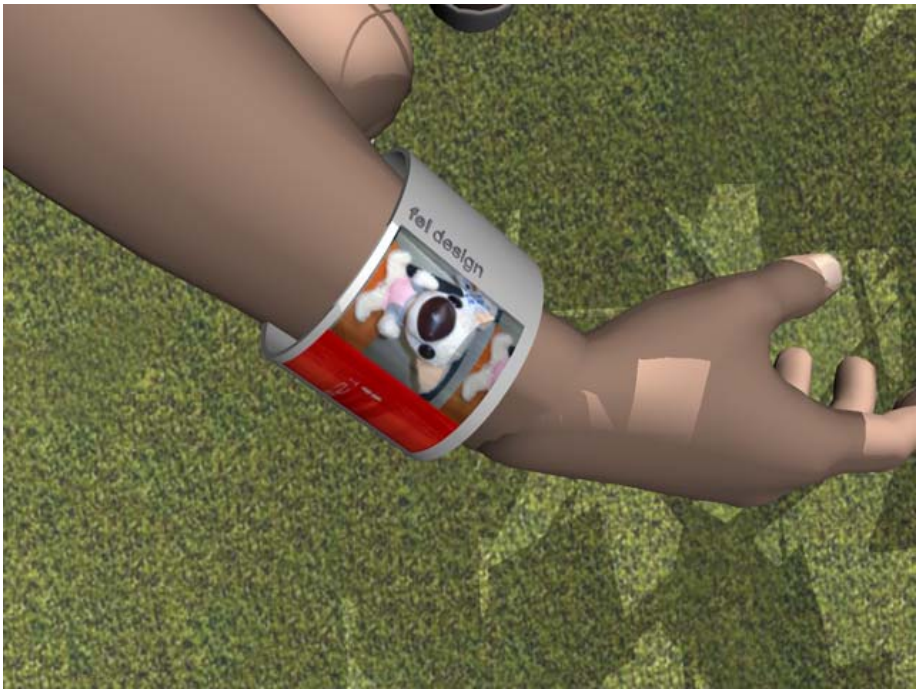


Figure 6. Slide from a powerpoint “interactive” simulation.

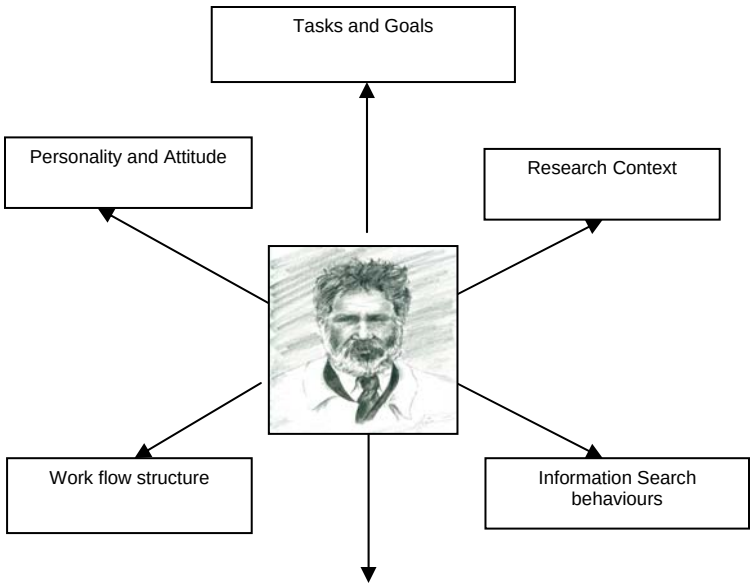


Figure 7. Example of persona construction elements for the domain of scientific authoring.

John

Professor (55) – molecular biology

Goals:

1. Have higher academic accreditations
2. Get acceptance on research grants
3. Getting recognized for his research

Tasks:

1. Supervise 3 PhD student
2. Writing research grants
3. Carrying out experiments
4. Editorial works
5. Administrative works for faculty
6. Teach a class of MSc Students

John's Personality:

- John cares a lot about his academic credits – publications, teaching, grants, etc.
- He prefers collaborating with reputed researchers
- He doesn't like change in his day-to-day activities
- He always tries to finish his work quickly (*"Automation that would eliminate laborious tasks"*)
- Based on experience, he has developed his own ways of working
- He thinks that he doesn't need to be up-to-date with the latest information of his field.

John's Work Information:

- John has been a professor of Molecular Biology at the University of Toronto, Canada, for 6 years.
- He supervises 3 PhD students and teaches and advises a class of MSc students
- He collectively has up to 10 projects running concurrently
- John is an experienced Mac User. He has one PC for writing papers and other for running experiments in his office; However he is not a great surfer of the Internet
- His main work is to research and develop new molecules in software. He then compares them with different published work. He does bench-working with a research assistant.
- His secondary work includes editorial and some faculty teaching and administrative works

John's Context of Work:

- On campus he has a faster Internet connection. From home he can logon to the University server to get the campus access.
- For reminders, he makes notes on pen and paper.
- He has folders in outlook for each of his PhD student and their associated information.
- He spends 40% of time on bench-working (in lab) & 60% on writing papers & other admin things. He has one assistant researcher who does bench-work for him, but he is now on holiday so he's doing most the work. He sometimes feels shortage of equipments in the lab.
- To him, the most tedious tasks are getting recognized for his work, the grant process, getting a paper accepted and getting comments.
- He says, *"Besides measurements and experiments, it is finding scientific papers on specific topic or author experiments is much more complex, it needs great effort"*
- John has collaborators all around the world. He mainly uses e-mail for communication. He prefers going to some relevant conferences. He says, *"I see colleagues at conferences and meetings (2-3 times per year) and I use these as opportunities to keep in touch and collaborate"* He rarely uses phone for collaboration purposes. He also asks advice from professional consultants regarding his work.
- While bench-working he uses his lab notebook. He does data processing of data in Excel files and in Origin. He creates images in PowerPoint and Adobe Photoshop. He also uses Kodak camera and software for cells. He sometimes uses scanner for data that are not digitized.
- John uses PowerPoint as a file organizer. He keeps figures, text, and annotations in it. He has one PowerPoint file that is strictly for figures and one PowerPoint file that has everything. He uses Word for the actual authoring of the manuscript.

John's Problems with Current Search Engine:

- He uses his old search engine almost everyday
- One of the problems for him with his old search engine is that it often gives hits over 100, which are no good for him.
- He feels that his old search engine doesn't provide him flexibility and control over search. His search engine has some predefined criteria for search. This sometimes distracts him from his initial search. He prefers to be able to bookmark interesting keywords to go back to them later.
- His search engine provides documents from only specific journals. He some times avoids going to different publishers to get relevant documents.
- His work includes drawing structures for molecules and he has to use CrossFireBeilstein to draw a structure and then search for documents in his search engine. He wishes to have both facilities in a single search engine.
- His search engine doesn't provide email addresses of authors of papers. So he uses Google to find author and affiliation information.
- He thinks that the Alert function in his search engine doesn't perform well. E.g. alerts on "water" gives him a lot of material, which is not very relevant to what he does. This requires detailed scanning from him to identify relevant papers from the emails alerts. He has a special folder for alerts.
- Sometimes old documents aren't available online and the library is the only way he can get those article.

A Positive Scenario:

John uses a new search engine – recently bought by his University. He knows that it includes almost all the publishers and the search engine only offers peer-reviewed documents. He says, *"A problem with Google is that it has a mixture of all good and bad papers and the good ones are difficult to extract"*. His new search engine has bibliographic searching, which he thinks is better then only abstract searching.

He gets some results on some keywords. While scanning through the record-page he says, *"Absorbing the key components of what is in the contents of the paper that is very relevant to the research and setting some direction for the PhD students on those basis."* He selects a document and downloads the PDF in an appropriate folder (sorted on author name, then year, journal, and some keyword). He says, *"I often print the documents to read. I cannot always get access to the computer (e.g. while travelling). I also read on screen, when I am in office."* He adds, *"Occasionally I download HTML to use the figures. I sometimes use fulltext + links, when I need to read in real-time"*. He saw a basket on the screen that would allow him to store interesting references from several different searches within a session. This new search engine allowed him to group the results and annotate them and then export to endnote. John uses endNote also to keep track of his articles. With a smile he says, *"I have a big filing cabinet at home where they all eventually go."*

Figure 8. Example of a persona representation.

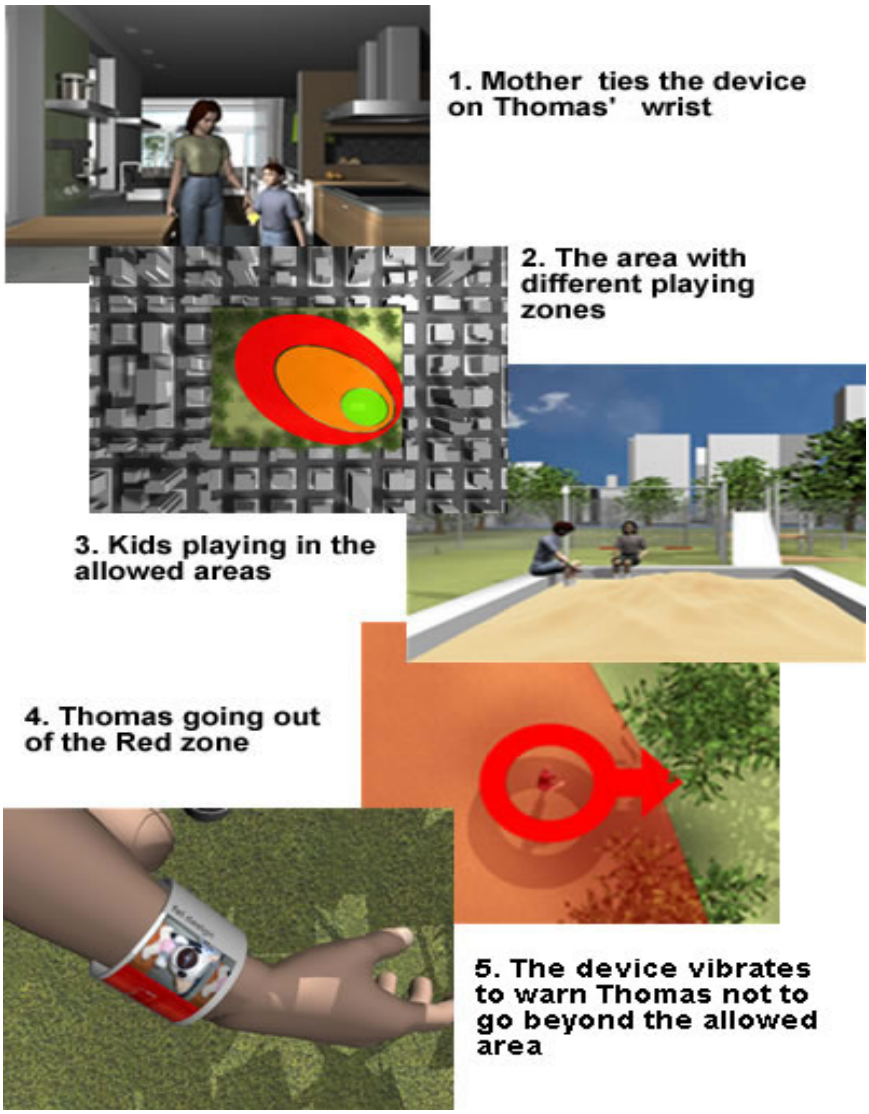


Figure 9. Fragment of a scenario.

.

Cognitive ergonomics in Interface development evaluation.

José J. Cañas

Cognitive Ergonomics Group
University of Granada

Abstract

Cognitive Ergonomics is a discipline that contributes with its knowledge to construct better machines in the sense of being easier to use by human beings. Cognitive Ergonomists perform a cognitive analysis de interaction to: (1) shorten the time to accomplish interaction tasks; (2) reduce the number of mistakes made by humans; (3) reduce learning time; and (4) improve people's satisfaction with a system. An appropriate methodology for performing this cognitive analysis of interaction should be based on what I call the "Principle of Mutual Dependency" (Cañas, et al, 2004). This principle determines that:

- The optimal interface functions that will be those that fit the human cognitive functions involved in the task.
- The human cognitive functions that are involved in the task depends on the interface functions.
- The modification, replacement, or introduction of a new interface function implies the adaptation of the human cognitive functions to them.
- The development (e.g., learning) or limitation (e.g., Elderly users) of the human cognitive functions will imply limitations on the possible interface functions.

I will describe this principle with examples from research projects in which our research group participates.

Index

Cognitive Ergonomics: The Cognitive Analysis of Interaction

Cognitive Ergonomics (also called Cognitive Engineering or Psychological Engineering; Wickens y Hollands, 2000) is the scientific discipline that studies the cognitive processes in the design of technology and the environment in which this technology is used by people. Cognitive ergonomists analyze human work in terms of representations and cognitive processes. When we combined the terms Cognition and Ergonomics we make it to indicate that our objective is to study the cognitive aspects of the interaction between the people, the work system and the artefact that we find in it, with the intention of designing them so that the interaction is effective. The cognitive processes like perception, learning or problem solving play an important role in the interaction with artefacts and they must be considered to explain cognitive tasks that people perform with them.

We might say that the goals of cognitive ergonomists are the same as those of any other discipline related with Human-Computer Interaction. Those goals are to: (1) shorten the time to accomplish tasks; (2) reduce the number of mistakes made; (3) reduce learning time; and (4) improve people's satisfaction with a system. However, what particular to Cognitive Ergonomics is the methods they use to reach those goals. Cognitive Ergonomics perform what we might call a “cognitive analysis of the interaction”.

Traditionally, cognitive analysis of interaction has been done by applying theoretical models of human cognitive processes proposed by cognitive psychologists. However, this approach is now facing an important problem, predictions made from these models developed in laboratory settings with particular materials, tasks and people are not confirmed when we have to predict how a person interacts with an artefact. This failure could be explained by recognizing that these theoretical models incorrectly assume that the human cognitive processes work independently of context. Furthermore, traditional analysis of interaction has also incorrectly assumed that the human being is the only cognitive agent in the interaction. We propose to replace this analysis by another one in which interaction design should be based on the idea that human cognitive processes adapt their operations to contextual changes to interact with other cognitive agents, devices, to perform jointly the task at hand.

In the current thought in the Cognitive Ergonomics it is considered that to find a complete explanation of the human behaviour is necessary to consider the interaction between the human being and its environment. In our case the environment is what a "Joint Cognitive System" has begun to be called within a determined partner-technical context. This proposal is being defended by a group of authors who group themselves around which she has come in calling the "Engineering of Cognitive Systems" (Hollnagel and Wood, 1983; Woods, Johannesen, Cook, and Sater, 1994; Wood and Roth, 1988; Rasmussen, Pejtersen and Goodstein, 1994).

What is "cognitive analysis of interaction"?

Cognition is the processing of environmental information to act on the environment. Therefore, we could say that any system that process information available in its environment to act upon it could be called "Cognitive System" and performs "cognitive work". Therefore, we can consider artefacts also as cognitive agents. Technological development, mainly of Computer Science, has made that the devices designed today have a level of automatism that makes them candidates to be considered as cognitive systems by themselves. These are almost at the same level than human beings, in the sense that they have their own dynamics many times independent of human performance. That is, although the human being does not perform any action, the artefact continues running and producing changes in the environment. The

fundamental difference between the human being and the device, considered both as cognitive systems, is that the artefact is designed by the human being, while the human being is not designed but modified by a process that we call learning. Cognitive artefacts provide us with representations of the work domain, with processes to transform these representations and with means to express these transformations (Simon, 1969; Dowell and Long, 1998). For example, a radar in the domain of air traffic control provides representations that allow the controller to reason on the state of the domain (for example, height and distances among airplanes), and to transform these representations into transmitting orders to pilots. Theerefore, today in Cognitive Ergonomics we talk about "Joint Cognitive System"(Dowell and Long, 1998; Hollnagel and Wood, 1983) to refer to a cognitive system formed by the artefact and the human being. The cognitive functions performed by the Joint Cognitive Systems are distributed between the human being(s) and the artefact(s) (see Figure 1).

Insert Figure 1 about here

There are many definitions of Interaction. For Cognitive Ergonomics, interaction means "Collaboration to perform a task, to do Cognitive Work". Interaction is not the goal. The goal is to perform a task. For example, when describing the task of driving a car we would say that: "My goal is not to sit in my car and play with the equipment. My goal is to sit in my car, so that both together get from one point to other in space, safely and as fast as possible". This collaboration is done through the interface. To analyze the interaction that occurs between a person and a device, or between a person and other people through devices within the Joint Cognitive System one can follow Hutchins' proposal of basically broadening cognitive analysis used by cognitive psychologists to study human information processing, to describe how the information is processed by the whole system formed by human beings and the devices within a certain socio-technical environment (Hutchins, 1996).

Therefore, for cognitive ergonomists cognitive analysis of interaction is:

1. The allocation of functions to both humans and artefacts
2. The design of the interface through which humans and artefacts communicate while collaborating in performing the task.

By "Functions" we mean a information processing procedure. Therefore, when we talk about functions we mean: Perceiving, attending, memorizing, decision making, cooperating, etc. Both humans and artefacts have "cognitive" functions. Human and artefact interact to perform a task by performing cognitive functions. Therefore, the design of interaction is to describe how these cognitive functions are allocated to humans and artefacts. But, we mean something more than traditional "function allocation". Today Cognitive Ergonomists talk about **"Adaptive function allocation"** to mean that functions could be re-allocated through the interaction.

When we speak of an interface we must include the means by which the artefact presents/displays information to the person and the means by which the person introduces information in the artefact. We would say that the design of the interface depends on the particular functions done by the artefact, and those done by the human being. The interface should

How function allocation works and how it affects the design of the interface?

First, we need a principle to investigate on the relationship between interface functions and human cognitive functions. This principle, that we could call "The Principle of Mutual Dependency" would serve to define functions that are adaptively allocated to the artefact and the human being. Then we need to identify which "cognitive" functions should be allocated. To this aim, we can propose a framework for identifying the level of functional analysis.

The Mutual Dependency Principle

This principle means that (see Figure 2) :

1. The optimal interface functions will be those that fit the human cognitive functions involved in the task.

2. The human cognitive functions that are involved in the task depends on the interface functions.
3. The modification, replacement, or introduction of a new interface function imply the adaptation of the human cognitive functions to them.
4. The development (e.g., learning) or limitation (e.g., Elderly users) of the human cognitive functions will imply limitations on the possible interface functions.

Insert Figure 2 about here

Levels of functional analysis

The interaction considered as a cognitive unit of analysis would be a complex activity. Therefore, it would be of much help to have a way of describing it to facilitate its analysis. With this goal in mind, Cañas and Waern (2001) have proposed a framework of reference that allows us to describe the interaction at several levels making the stress in the relationship between particular cognitive processes and types of artefacts that when introduced would affect the human cognitive agent. An adaptation of this framework can be seen in Table 1. In the left column of the table there are examples of cognitive artefacts. Each cognitive level represents a level of analysis. In the right column of the table we have the aspects of human cognition and behaviour affected by the introduction of one artefact.

Starting from the bottom of the table, the first cognitive level that we find is the sensory-motor. In this level interaction is described from the point of view of the characteristics of the human sensorial and motor systems. Interaction occurs when the output of the device, be this visual, auditory, or of any other physical type, is captured by human sensorial receivers. In the same way, human behaviour would be given through the motor system, and it is necessary that the device has the necessary input systems to receive it in the appropriate way. For example, we can be interested here on how people learn to adapt and to use neuronal implants cognitively. When a person receives an implant of an artificial motor organ, a hand for example, his actions are not

the same as they were before, fundamentally because he doesn't have direct sensorial feedback. Since many motor functions are dependent on sensitive feedback, any device that compensates for the loss of a motor organ would have to be designed with this in mind. Therefore, it is a challenge for Cognitive Ergonomics to consider how a compensatory type of feedback could be designed, how a person could learn to manage the device as well as his compensatory feedback, and the possible secondary effects of such feedback. Another possible example that is of enormous interest today in this level is “Virtual Reality", where people are provided with a three-dimensional experience of the world and where at least some motor actions are allowed to change the experience of the world. Topics of interest for Cognitive Ergonomics are, for example, the real sensations in the virtual world, and the interactions between virtual reality and natural reality.

Going up a step in the table we find the individual information processing level. In this level we can begin to speak about symbolic information processing. The aspects of devices that are important in this level are related with their performance. The cognitive aspects refer to how the objects are presented by the device (on the screen for example) and how they are perceived by the user. It is important to know, for example, if the objects indicate the pertinent action in a unique way, and the interpretations that the objects confront. The "affordance" concept taken from Gibson (1979) is useful to analyze the difficulty that the user has to understand what will happen when certain actions act on certain objects (also see Norman, 1986).

An important part of the work done in Cognitive Ergonomics has been developed in this level. For example, when we are studying how people understand items on a menu, whether verbal, or represented as icons, or when we are answering questions with regards to how much information can be put on the screen, we are in this level. The necessary attention to carry out a task as well as information overload, are also aspects that are considered in this level

---

Insert Table 1 about here

In the following level we find the topics that concern complex individual information processing. The devices that are important in this level are, for example, knowledge management systems, and those that support the decision making and complex problem solving.

New topics that are of interest in this level refer to knowledge awareness, mental models, and situational awareness. For example, it is important to know how the conceptual model of a computer system should be presented so that the user can form a corresponding mental model that allows him to work correctly with it (Cañas, Bajo and Gonzalvo, 1994). To make decisions and to solve problems people develop heuristics, that is to say, strategies of information processing that allow them to solve problems efficiently (Newell and Simon, 1972).

Cognitive Ergonomics studies how people can understand the concepts and principles used in support systems, to solve a problem or to elaborate a decision. For example, the heuristic of search used by the computer can be different from that used by the human user. It is possible to wonder then, if it will be necessary that the device be transparent, that is to say that the human user will be able to understand the heuristic of search that it uses, or that it is enough that it carries out some algorithms correctly without revealing them (Waern and Hägglund, 1997).

Next, we meet with higher topics, when people cooperate to perform a task. Many tasks require cooperation for reasons of effectiveness. For example, in some occasions, it would take a person too much time to make all the decisions for the design of a mechanical device. Many tasks require cooperation because the knowledge of several people is needed. For example, medical work in a hospital uses the abilities of laboratory personal, medicine, surgery and psychiatry, sometimes applied to one patient alone.

In this level, individual information processing covered in inferior levels should be considered from the point of view of the communication and the coordination that takes place amongst the participants of a task. Of course, individual information processing is still important, but the result of team information processing will be different and will depend on interactions within the team.

Devices that are good for communication and coordination belong to the category called, with its English initials, "CSCW" (Computer Supported Cooperative Work). They can vary from the simple support of communication, such as e-mail, to complex systems of support in coordination, such as systems of work flow.

In this level, topics of interest for Cognitive Ergonomics are, for example, studying how CSCW systems affect the habits, strategies or styles of people's communication, how to adapt such systems to the ways of working that have developed in a work place, and how to allow them to organize tasks flexibly and to distribute the tasks efficiently.

Finally, the level with a wider reach is the one that covers the socio-cultural aspects of knowledge. In this level it is recognized that actions of people, as well as their expectations are built on historical tradition, where the mutual social influences as well as the devices that are used jointly, play an important role. The devices in this level can help to build a community and keep the historical memory of it. For example, we could discuss at this level how people who use the Internet extensively form a virtual community, with similar effects to a community in real life, from the point of view of traditions and expectations, but where the rules for interaction and action can be different from his.

This level is so high that it is debatable if it can really affect the design. A community is not designed, but develops over a long period of time. Its members can experience problems and make errors, and they can try to find for themselves the different ways to overcome them. Solutions are given based on mutual agreements without external advice, and built on general cognitive or social principles in general.

Topics of interest for Cognitive Ergonomics in this level are then, more to do with analysis than with design. Methods and concepts of Cognitive Ergonomics could help participants to meditate its practices, and allow them to choose solutions that favour its goals and own values. For example, some problems can be solved with purely social action, while other problems can be solved technically (O'Day, Bobrow, Shirley, 1996).

This reference framework, therefore, offers us three or four levels where Cognitive Ergonomics can offer very pertinent explanations. Although levels overlap, interaction problems can be considered in any single level. An analysis in a higher level does not exclude problems in a different one. It is obvious that solutions at the organizational level are not sufficient to solve perceptual problems and vice versa. In this way, a wider level will also be required to consider other levels.

How to apply this principle in the analysis of interaction?

This principle of mutual dependency is applied to solve design problems by looking at the relationship between interface functions and human cognitive functions in two directions: (1) From the human cognitive functions to the interface functions; and (2) from the interface functions to the human cognitive functions.

From Human Cognitive Functions to Interface Functions

The functions of the interface that help to perform a task will be those that are more appropriate to the human cognitive functions that are implied in the task. For example, appropriate interface functions will be those that correspond to the structure and function of the human working memory. We can find good examples of this situation when the human congitive functions suffer from some kind of limitation that would determine the interface functions that we can design.

Design problems: Deaf users interacting with the WEB

Insert Figure 3 about here

The Web is becoming the more important media for communicating and accessing information in today world. However, it is not equally accessible to all its users. There are many people that have problems interacting with the web due to some kind of sensorial or motor disabilities. Therefore, the definition of design guidelines to make Internet accessible to all users is an important area of research for cognitive ergonomists. Deaf people are among those users that have problems interacting with the WEB.

Contrary to what we might think intuitively, it is not easy for deaf people to interact with Internet. Since Internet is mainly visual, it should not be a problem for them. However, the auditory deficit of deaf people not only makes difficult or prevents the compression of the speech in the oral communication for them, but also that it is also true that there is a remarkable deficit in the processing of any verbal information, either oral or written (see Figure 4). This fact means a disadvantage to them at the time of interpreting written language that, as we can observe analyzing any page Web, is strongly implied in the communication via Internet. For that reason it is considered necessary to describe the profile of the cognitivo system of the deaf people so that it can serve as guide of design of Web destined these users.

Insert Figure 4 about here

When we apply the Mutual Dependency Principle to this design problem, we start by considering a series of aspects: (1) the amount and the type of information that the deaf people process; (2) the strategies of cognitive processing of deaf people; and (3) the cognitive activities that the Web demands. The first two aspects make reference to the characteristics of cognitive processes like attention, memory and language, that is to say, to basic cognitive processes of the deaf people that could be different from basic cognitive processes of listeners. The third aspect is related to the levels of functional analysis, and it makes reference to what type of task a person performs when interacting with the Web to reach some goal (to purchase something, to obtain data on certain subject or to send an electronic mail). These tasks would be, for example, tasks that imply attention and perception, like visual searches of elements in a menu, tasks that imply memory like recall, recognition or generation of a mental model, tasks that imply language like reading and text understanding or tasks that imply motor processes like movements of the mouse (tracking) and writing by means of the keyboard. If we know these tasks, we will be able to adapt them to the basic capacities of the deaf people and to facilitate its navigation and understanding of the Web.

Several recommendations of design of Web for deaf people can be done following the logic of this principle. Sometimes, these recommendations are a logical deduction of the cognitive limitations of the deaf people already researched empirically; and in other occasions the recommendations leave more from empirically demonstrated hypotheses about facts related to the deaf people, thus opening possible and interesting lines of investigation.

A priori we might think that a person with auditory deficiency should not have problems remembering information. What deafness has to do with memory? However, it is the case that the structure and functioning of memory is to a great extent dependent on the type of information that need to be stored and retrieve. The experimental data seem to indicate that the organization of Working memory can determine the advantages and disadvantages of deaf people with respect to the listeners. It is evident that deaf people do not have the possibility of processing phonological information (the sonant forms of the words). Therefore, the phonological loop develops deficiently and the viso-spatial component of Working memory would assume its functions (Wilson and Emmorey, 2000). The fact that this structure is implied means that the task is

becoming of controlled way more, investing more atencionales resources, which can suppose more effort for the person. Furthermore, considering that the viso-spatial tasks demands more attentional resources than the verbal taks (Miyake, Freidman, Rettinger, Shah and Hegarty, 2001) we could assume that it is more difficult to process verbal information for deaf people than for listeners.

Deaf people that use Sign language develop good visuo-spatial abilities. Experimental data have shown that they are better at generating, maintaining nad transforming images Enmorey, Kosslyn and Bellugi (1993). Research done by Arnold and Mills (2001) showed that the deaf people seem to better than listeners recognizing complex stimuli like faces and shoes.

In addition, Sign language depends more on the spatial aspects of the information that of the temporary aspect, contrary to what happens with oral language. For that reason, deaf people are worse than the listeners in tasks of serial memory (to remember the words in the presentation order) (Rollman and Harrison, 1996). That is to say, deaf people not only process a type of material (visual) better than other (phonological), but also process it in different ways (they base the processing on visual aspects rather than on temporal ones).

Given the differently developed cognitive abilities of the deaf people, we can derive hypotheses about how to improve the design of the pages Web accessible for them. Fajardo, Cañas, Salmerón, and Abascal (2006) have conducted an experiment to test some of these hypotheses. In their experiment, two groups of subjects, one with deaf people and another one with hearing non signers, performed a navigation task in a Web designed to manipulate their visuo-spatial characteristics by means of the depth and the width of the menus (see Figure 5). The objective of the investigation was to verify the hypothesis that the effectiveness and efficiency of navigation it would be affected by the complexity of the Web more for the deaf people than pear the listeners.

Insert Figure 5 about here

The authors designed three versions of a digital newspaper with the same content but with different degrees of depth. The subjects had to look for a series of holders of the news that were indicated to them (See Figure 6). The results showed that the deaf users found more targets, were faster, got disoriented less and learnt less than hearing non signers (see Figure 7). But more important than that was the effects that the different Web structures had on the performance of both groups of subjects. As can be seen on Figure 7, the advantage that wide structure had on response time and lostness for hearing people disappeared for deaf people. There was a tendency for deaf people to be faster, got disoriented less and learnt more on the deep structure.

Insert Figure 6 about here

In order to interpret these results the authors consider that it is necessary to begin recognizing the role that Working Memory plays in navigation through each type of structure. On the one hand, the verbal component of Working Memory has a more important role in a superficial menu since the users must process greater number of categories with these menus. Due to the smaller span the verbal store of the deaf people, these superficial structure are difficult to use for them than for hearing people. On the other hand, the visuo-spatial store is more important when navigating thorugh a deep structure since it is more complex one. For that reason, the deaf users improve their performance in this type of structures, whereas hearing people perform worse on them. Therefore, the results show that the greater space ability than has the signed deaf users, due to the use of sign language, can facilitate navigation in the Web when the verbal content is distributed in many pages.

Insert Figure 7 about here

The design guideline that we recommend from these results is this: To make Web pages more accessible to deaf people you should reduce the information in each page and increase the number of pages (less text in each page and more visual complexity). The reduction of information by page is at the cost of increasing the number of pages, but there are many advantage as the smaller degree disorientation. Figure 8 summarizes this design guideline. We should point out that we have reached this conclusion an design guideline by applying the Mutual Dependency Principle at the appropriate level of cognitive analysis, individual complex information processing.

Insert Figure 8 about here

From Interface Functions to Human Cognitive Functions

We can express the idea that is behind this proposal by taking what Dix, Howes and Payne (2003) have said about the relation between human intelligence and the use of artefacts: “Human intelligence is based on the capacity to process, store, and retrieve information that is relevant to social, emotional, and cognitive needs. This capacity has developed and exists through interaction with an information-bearing environment, which itself is created and evolving. Human intelligence both shapes and is shaped by the information processing tools that it has created (p. 1) ”.

Design problem: Is hypertext really better than lineal text?

The human cognitive system is characterized by its capacity to acquire, to store and to retrieve information. Throughout the evolution human beings have acquired information from the environment directly or through systems (devices) where that information previously has been stored by other human beings (p.e books). Nowadays, hypermedia systems have become one of the more important sources from which human beings acquire information. A hypermedia system is that in which the information is contained in a set of pieces of information connected by links that represent the relations among them. The information can be in any format (text, images, etc). In the special case in which it contains only textual information we call it hypertext system instead of hypermedia system. The most important example of hypermedia system is Internet.

Insert Figure 9 about here

Hypermedia navigation faces two problems that limit their utility and that have interested many researchers: (1) When the goal is to look for information, people undergo a phenomenon that we called disorientation. Disorientation happens when a person does not remember the visited information and loses the sense and the objective of its search; (2) When the goal is to learn and to understand, it does not exist conclusive experimental evidence of what is learned and of whether people learn more from hypermedia system than from what we call systems linear (the traditional book). It do not exist conclusive experimental results that demonstrate that hypermedia systems are superior to the linear systems in any learning criterium that we might consider (Chen and Road, 1996; Dillon and Gabbard, 1998). These two problems are related. For example, there is some empirical evidence of which disorientation entails a worse learning (Ahuja and Webster, 2001). For that reason several solutions are being considered that would avoid disorientation as for example the use of content maps.

In any case, to avoid the problems associated to navigation and to design the hypermedia systems in such a way that they are really an alternative that improves searching, understanding and the learning, it is necessary to conduct research to study as the human cognitive system interacts with these systems to search and to find information. Also we needed to propose theoretical models that could allow us to make predictions on the effectiveness in the tasks of searching and learning.

According to the Mutual Dependency Principle, we should start from analysing the activity that a person performs to acquire information contained in hypermedia system is navigation (see Figure 9). In order to navigate a person begins by a unit of information (page) and continuous through the links that lead to other units of information. Navigation can have two objectives. In the first place, a person might want to find a particular unit of information, in which case we speak of searching task. But also, very frequently, a person navigate with goal of understanding the information found and acquiring knowledge, and in that case we speak of learning or understanding tasks. For example, in the case of hypermedia systems used in the educative environment, navigation has the goal of understanding and learning.

From that analysis, we should identify the critical difference between the hypertext and the lineal text is that readers in hypertext have to navigate in hypertext to find and read the information. The special characteristic of the reading in Hypertext and that it is not present in lineal text it is the particular order in which the reader accesses to the different contents. Therefore, navigation in hypertext requires many cognitive resources to plan the search, to determine if the found information is the one looked for, to understand its content and to integrate this content with the knowledge stored in the long term memory (as show the results on the differences in the different people with previous knowledge. see Salmerón, Kintsch and Cañas, 2006). In a recent revision, DeStefano and LeFevre (in press) indicate that due to the characteristics of the hypermedia system, the tasks of reading and comprehension require a greater number of Working Memory resources, decision making and understanding processes. In addition this excessive demand of resources cannot easily be palliated by some of the characteristics that have been introduced by the designers to improve navigation. For example, the semantic maps designed in some systems, that supposedly must facilitate navigation, increases the demand of spatial cognitive resources and negatively affect

understanding. Therefore, the most important factor when deciding the best hypertext design is the selection of a optimal strategy that would allow the effective reading, because a strategy of inadequate reading that leads readers to a bad understanding (Salmerón, Kintsch and Cañas, 2006).

In the present state of the investigation in this topic, it is considered that it is necessary now to investigate about the factors that determine the strategy that a person adopts for navigation. In this sense, researchers who worked in this topic think that the adoption of a particular strategy depends on several factors that concern both to the structure of the system and the characteristics of human cognitive system. Nevertheless, the complexity and the number of these determining factors of the strategies can make difficult the investigation and take to confusing results and to erroneous conclusions. Therefore, Madrid and Cañas (in press) have proposed a scheme that can allow us to identify those factors and their interactions. In this theoretical scheme, the adoption of a particular strategy of navigation must be explained based on the characteristics of human cognitive system and the characteristics of the hypermedia system (see Figure 10). This scheme derives directly from the Mutual Dependency Principle.

Insert Figure 10 about here

At the moment we have been investigating the factors that depend on the structure of the system. For example, Salmerón, Baccino, Cañas, Madrid and Fajardo (in revision) have found results that demonstrate that when the readers have a semantic map (overview) of the structure of the hypertext, an interaction takes place between the reading strategy, previous knowledge and coherence of the text at the time of determining the time dedicated to the processing of the map and text itself which affects the result of the understanding. The time of processing is greater for the map and the text when this one is unfamiliar or no coherent.

In relation to the characteristics of human cognitive system, Juvina and va Oostendorp (2004) have conducted an experiment to determine the cognitive predictors of navigation behavior in hypertext systems. The results showed that the space abilities, the capacity of Working Memory and Episodic Memory are related to navigation behavior. Concretely, a low Working Memory capacity is a good predicting factor of disorientation problems, whereas the space abilities are predictors of the performance in the task. In the same line, Madrid, Salmerón, Cañas and Fajardo (2005) have examined the role of nine cognitive factors in the determination of the navigation strategy. The results showed that the space abilities are related to the amount of information read and that the level in which the reader follows the structure shown in a map was affected by the capacity of Working Memory. The authors interpreted these results from the concept of cognitive load. Navigation is a task that exceeds our cognitive resources, fundamentally because the reader must perform two simultaneous tasks, she must decide what she wants to read next and to understand what she is reading.

Conclusions

We might conclude that what is unique to Cognitive Ergonomists is the stress that we make on the cognitive analysis of the interaction between human being and the artefacts that are designed for performing tasks. The idea leads our work when we analyse the interface is based on the mutual dependency between interface functions and user functions and the cognitive level of interaction. From this we recommend that designers should consider that any modification, substitution or introduction of a new function in the interface will imply a change in the human cognitive functioning that intervene in the task. Furthermore, anything that is particular or constraining in the characteristics of the hunman cognitive functions that are present in some or in all users will imply a limitation in the posible functions that are included in the interface.

References

Ahuja, J.S. and Webster, J. (2001). Perceived disorientation: an examination of a new measure to assess web design effectiveness, *Inte-acting with Computers*, 14(1), pages 15-29.

Arnolds, P., y Mills, M. (2001) Memory for faces, shoes and objects by Deaf and Hearing Signers and Hearing Nonsigners. *Journal of Psycholinguistic research*, *30*, 185-195.

Cañas, J.J., Bajo, M.T. y Gonzalvo, P. (1994). Mental Models and computer programming. *International Journal of Human-Computer Studies,* 40, 795-811.

Cañas, J.J. y Waern, Y. (2001). *Ergonomía Cognitiva. Madrid: Editorial Médica Panamericana.*

Chen, C. y Rada, R. (1996). Interacting with hypertext: A meta-analysis of experimental studies. Human- Computer interaction, 11, 125-156.

DeStefano, D. and LeFevre, JA. (en prensa). Cognitive load in hypertext reading: A review. *Computers in Human Behavior*.

Dillon, A. y Gabbard, R. (1998). Hypermedia as an educational technology: A review of the quantitative research literature on learner comprensión, control, and style. Review of Educational Research, 68, 322-349.

Dix, A., Howes, A., and Payne, S. (2003) Post-web cognition: evolving information environments. *International Journal of Web Engineering Technology*, 1, 1-12.

Dowell, J., y Long, J.B. (1989). Towards a conception for an engineering discipline of human factors. *Ergonomics*, *32*, 1513-1535.

Dowell, J., y Long, J.B. (1998). Conception of the cognitive engineering design problem. *Ergonomics*, *41*, 126-139.

Emmorey, K., Kosslyn, S., y Bellugi, U. (1993) Visual imagery and visual-spatial language: Enhanced imagery abilities in deaf and hearing ASL signers. *Cognition*, *46*, 139-181.

Fajardo, I, Cañas, JJ, Salmerón, L. and Abascal, J. (2006). Improving deaf users' accessibility in hypertext information retrieval: Are graphical interfaces useful for them? *Behaviour and Information Technology*, *25, 455-467.*

Gibson, J.J. (1979). *The ecological approach to visual perception*. Houghton Mifflin.

Hollnagel, E. y Woods, D.D. (1983). Cognitive systems engineering: New wine in new bottles. *International Journal of Man-Machine Studies*, *18*, 583-600.

Hutchins, E. (1996). How a cockpit remember its speeds. *Cognitive Science*, *19*, 265-288.

Juvina, I. y van Oostendorp, H.(2004). Individual differences and behavioral aspects involved in modeling web navigation. En *Proceedings of The UI4ALL Conference*. 2004.

Madrid, R.I., and Cañas, J.J. (in press). How reading strategies affect the comprehension of texts in hypertext systems. In D. Alamargot, P. Terrier, and J.M. Cellier (Eds) Improving the production and understanding of written documents in the workplace. Elsevier]

Madrid, R.I., Salmeron, L., Cañas, J.J. & Fajardo, I. (2005). Cognitive factors related to text comprehension with hypertext overviews. In G. Chiazzese, M. Allegra, A. Chifari & S. Ottaviano (Eds.). Methods and technologies for learning. Southampton: WIT Press. (pp. 597-598)]

Miyake, A, Freidman, N, Rettinger, D, Shah, P., y Hegarty, M. (2001). How are Visuospatial Working Memory, Executive Functioning and Spatial Abilities Related? A Latent Variable Analysis. *Journal of Experimental psychology: General*. *130,* 621-640

Norman, D.A. (1986). Cognitive engineering. En D.A. Norman y S.W. Draper (Eds.), *User Centred System Design*. Hillsdale, NJ: Erlbaum.

O'Day, V.L., Bobrow, D.G., and Shirley, M. (1996). The socio-technical design cycle. In *Proceedings from CSCW 1996,* pp. 160-169.

Rasmussen, W.B., Pejtersen, A., y Goodstein, L. (1994). *Cognitive Systems Engineering*. New York: Wiley.

Rollman, S., y Harrison, R. (1996). A comparison of deaf and Hearing subjects in Visual Nonverbal sensitivity and Information 21. Processing. *American Annals of the Deaf*, *141*, 37-41.

Salmerón, L., Cañas, J.J., Kinstch, W. and Fajardo, I. (2005) Reading strategies and hypertext comprehension. Discourse processes ,40, 171-191.

Salmerón, L., Baccino, T., and Cañas, J.J. (under review). How overview processing strategies affect comprehension in hypertext: an eye-tracking study

Simon, H. (1969). *The Science of the Artificial*. Cambridge, MA: MIT Press.

Waern, Y y Hägglund, S. (1997). User aspects of knowledge systems. En I. Helander, M.G. Landauer, y T.K. Prabhu (Eds) *Handbook of Human-Computer Interaction*, 2ª edción*. Amsterdam, The Netherlands: Elsevier Science.*

Wickens, C.D., and Hollands, J..D. (2000).*Engineering psychology and human performance*. Upper Saddle River, NJ : Prentice Hall, 2000.

.Wilson, M., y Emmorey, K. (2000). When Does Modality Matter? Evidence from ASL on the nature of Working Memory. En K. Emmorey y H. Lane (Eds.), *The signs of language revisited*. London: LEA.

Woods, D.D., Johannesen, L.J., Cook, R.I., y Sater, N.B. (1994). *Behind human error: Cognitive systems, computers and hindsight*. Columbus, Ohio: CSERIAC.

Woods, D.D., y Roth, E.M. (1988). Cognitive systems engineering. En M.Helander (Ed.) *Handbook of Human Computer Interaction*. Amsterdam: Elsevier North-Holland.

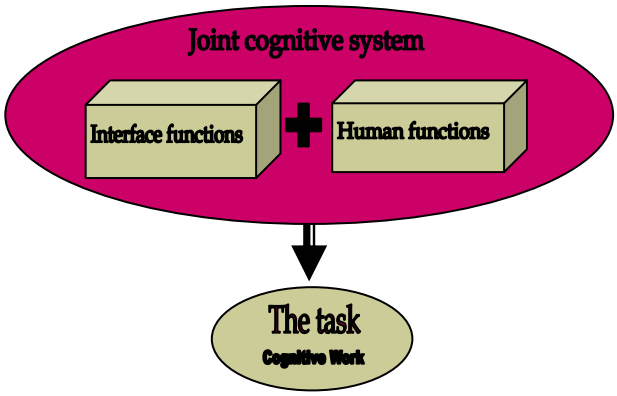


Figure 1. The Joint Cognitive System

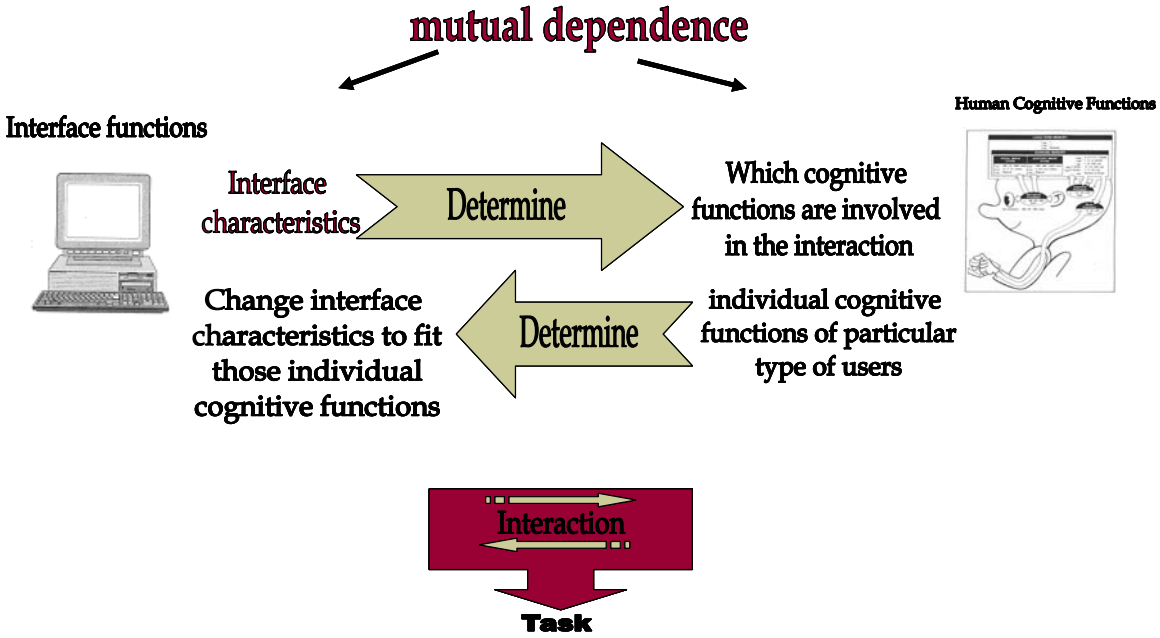


Figure 2. The Mutual Dependency Principle

Task	Examples of artefacts involved in the tasks	Levels of functional analysis	Psychological knowledge
Virtual Communities virtual, teleworking,	CMC, e-mail, e-conferences, MUD	Socio-Cultural	Organization, History, Culture
Virtual Communities virtual, teleworking,	CSCW, workflow	Cooperation	Communication y coordination
Ubicous computing	Emotional interfaces	Emotional context	Theories of emotion
Interpretation, search, decision making, problem solving	Knowledge-based systems, decision making support systems	Individual complex information processing	Memory, mental representation, thinking, etc.
Reading, comprehension, writing, etc.	Displays, voice recognizer, voice synthesizers	Perception	Gestalt laws, Attention, Affordance, etc.
Manual and voice control	Input and output component of interfaces, virtual reality systems, etc.	Sensory-Motor functions	Psychophysiology of sensory and motor systems

Table 1. Levels of functional analysis

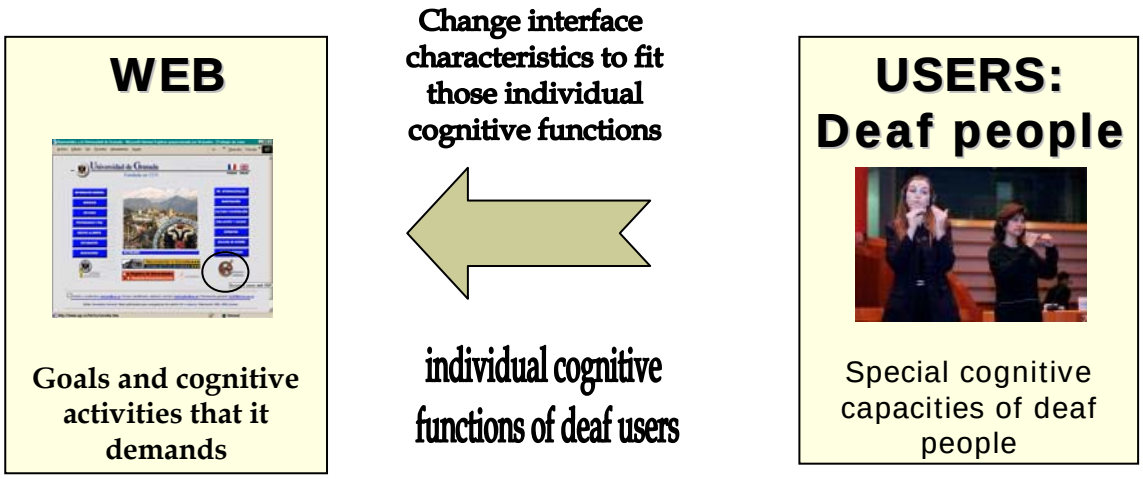
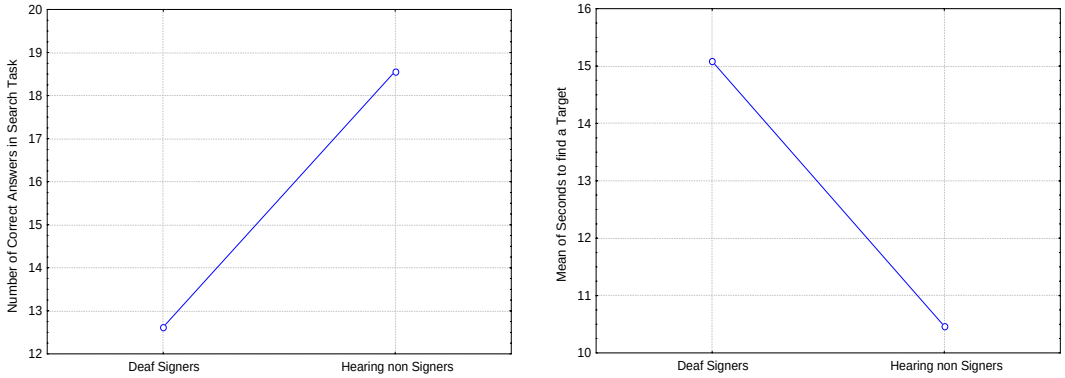
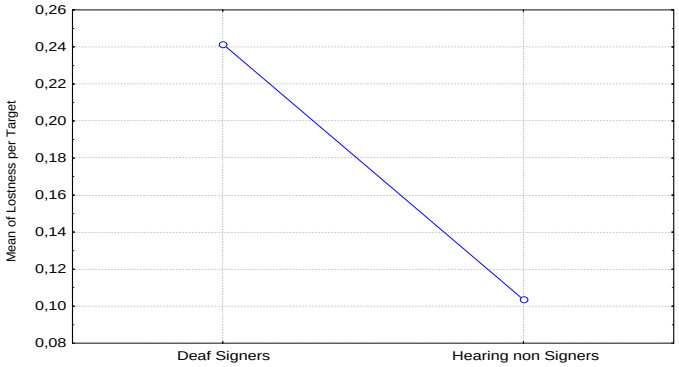


Figure 3. Deaf users interacting with the Web



Average of correct answers hearing non signers and deaf signers users

Average of response time to find a target for hearing non signers and deaf signers users



Average of lostness to find a target for hearing non signers and deaf signers

Figure 4 : Performance of deaf and hearing non signers users in the search task (data from Fajardo, Cañas, Salmerón, and Abascal, 2006)

Dense and space simple Web structures

Fluid and space complex Web structure

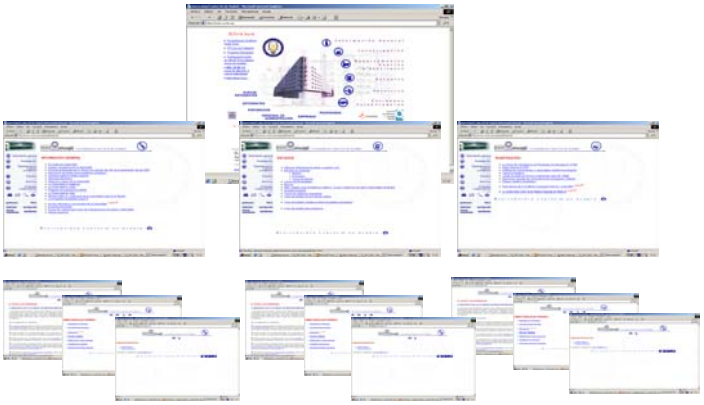


Figure 5. Two Web sites that differ on complexity

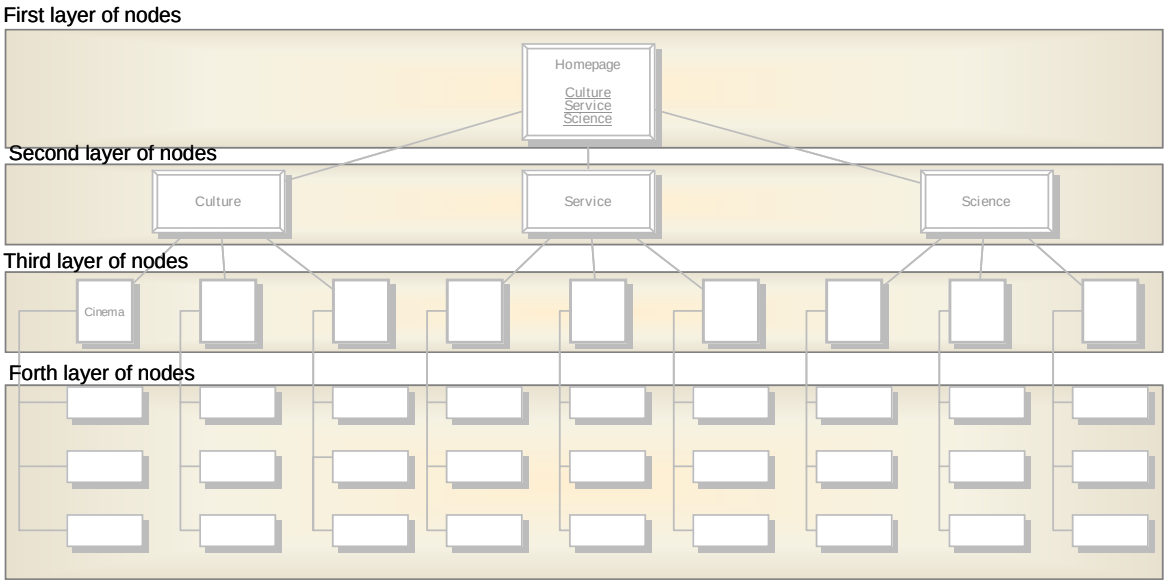


Figure 6. Three different hierarchical structures of the online newspaper containing the 90 sections: Wide, Mid Wide and Deep

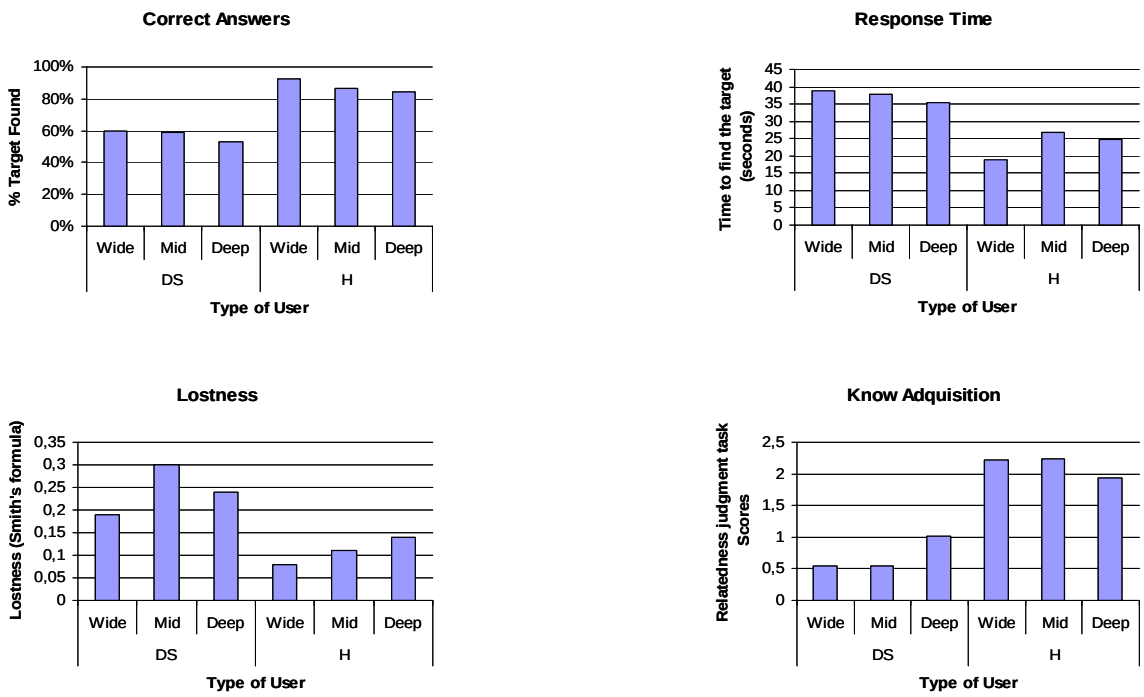


Figure 7. Effect of web structures for deaf and hearing non signers people

	Web structure	
	Wide (Verbal demand)	Deep (Visual demand)
Signer Deaf people	X	√
Hearing No signer People	√	X

Figure 8. Different Web structures for Deaf and hearing people

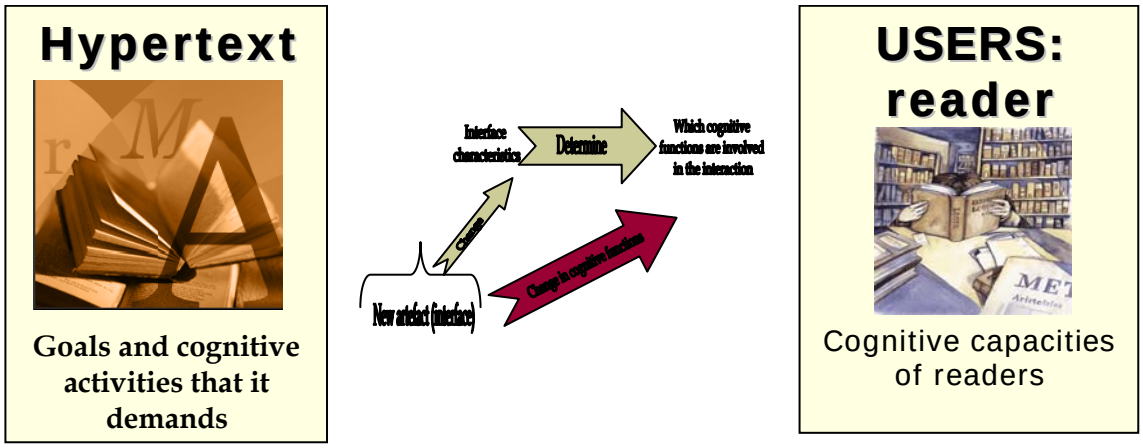


Figure 9. Interacting with hypertext systems

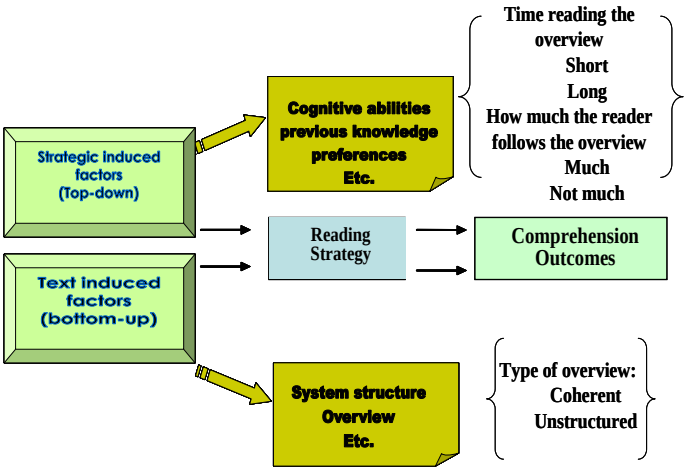


Figure 10. Scheme to explain the factors that determine the selection of a particular reading strategy

Intelligent decision support in medicine: back to Bayes?

Gitte Lindgaard
(Carleton University, Ottawa, Canada
gitte_lindgaard@carleton.cat)

Catherine Pyper
(Carleton University, Ottawa, Canada
cpyper@connect.carleton.ca)

Monique Frize
(Carleton University, Ottawa, Canada
mfrize@connect.carleton.ca)

Robin Walker
(IWK Health Centre, Halifax, Canada
Robin.Walker@iwk.nshealth.ca)

Craig Boutilier
(University of Toronto, Toronto, Canada
chair@cs.toronto.edu)

Bowen Hui
(University of Toronto, Toronto, Canada
bowen@cs.toronto.edu)

Sheila Narasimhan
(Carleton University, Ottawa, Canada
snarasim@connect.carleton.ca)

Janette Folkens
(Carleton University, Ottawa, Canada
lu-lu@rogers.com)

Bill Winogron
(S4Potential, Almonte, Canada
bwinogron@s4potential.com)

Peter Egan
(S4Potential, Almonte, Canada
pegan@s4potential.com)

Colin Jones
(S4Potential, Almonte, Canada
cjones@s4potential.com)

Abstract: Decision Support Systems are proliferating rapidly in many areas of human endeavour including clinical medicine and psychology. While these are typically based on Artificial Neural Networks, this paper argues that Bayes' Theorem can be applied fruitfully to support expert decisions both in dynamically changing situations requiring the system progressively to adapt, and when this is not the case. One example of each of these two types is given. One provides diagnostic support for human decision makers; the other, an e-health mental intervention system provides decision rules enabling it to respond and provide the most appropriate training modules to input from clients with changing needs. The contributions of psychological research underlying both systems is summarized.

Keywords: Bayes' Theorem, Decision Support Systems (DSS), diagnostic error, individuating information, base rates, e-health intervention
Categories: H1.2, H4.2, I2.1

1 Introduction

Decision Support Systems (DSSs) are proliferating at an increasingly rapid pace in many areas of human endeavor including clinical medicine and psychology. These DSSs are typically based on Artificial Neural Networks (ANNs), many of which have been shown to perform very well (e.g. Ennett, 2003). This paper attempts to show that Bayes' Theorem can offer an alternative approach to the design of DSSs. One of the strengths of Bayesian models is that they are adaptive; that is, they are able to 'learn' iteratively from 'experience'. This enables such models to become customized to individual users' needs, which is very important in the context of clinical psychology. We also argue that Bayesian models can be usefully applied even in situations in which the DSS relies on a static, finite database and where opportunities for these models to adapt are absent. Two examples of DSSs currently under development are presented. One, using a static database, aims to support a particular class of medical diagnostic decisions for resident pediatricians. The other, which is adaptive, will provide psychological e-health services to clients in a variety of clinical settings and skill-training programs. The contribution of psychology varies between the two systems: in one, it applies lessons learned from empirical research into certain judgmental biases found systematically to impact diagnostic decisions, aiming to raise awareness of those biases and support human decisions. In the other, it provides the relevant variables and decision rules for the computer to select the most suitable teaching modules for clients whose needs change dynamically through the skill-training course. In both cases, the contribution of psychology to the background justification, design, and the evaluation of DSSs is discussed.

Bayes' Theorem and the notion of probability are discussed in the next section, in which the concept of diagnosticity is also introduced. A brief summary of the most important flaws marring people's ability to integrate information correctly in Bayesian tasks is then presented, followed by a summary of empirical research showing a predominant and robust tendency of expert nurses and medical practitioners to pay disproportionately more attention to the first item than to later presented items in Bayesian diagnostic tasks. Section 4 begins with a discussion of the magnitude of the problem of diagnostic error in medicine. This is followed by an outline of the DSS intended to support resident pediatricians faced with particular diagnostic decisions and ambiguous symptoms. The DSS user interface is presented,

and the relevant validation studies are introduced. Finally, the e-health system is discussed, and conclusions are drawn.

2 Bayes' Theorem and the notion of probability

The notion of probability is connected with the degree of belief warranted by evidence (epistemic probabilities) on the one hand, and with the tendency, displayed by some chance devices, to produce stable relative frequencies (aleatory probabilities) on the other. Whereas the statistical probability concerns the way evidence from various sources is combined into a numeric statement irrespective of the judge's belief, the epistemic probability incorporates an assessment of the judge's personal belief as well, generated from autobiographical experience and state of knowledge about the evidence. The human-generated probability reflects both arithmetic calculations and degree of belief - it is an epistemic probability. By contrast, a computer-generated probability is a sheer arithmetic computation of given numeric values – it is a statistical probability. Consequently, it is unrealistic to expect the two to be identical. Not surprisingly, computer-generated probabilistic judgments are most accurate: subjective beliefs are more likely to attenuate rather than increase judgmental accuracy because beliefs are derived from a judge's understanding of her autobiographical experience.

From the Bayesian perspective, knowledge is represented in terms of statements, or hypotheses, H_i, each of which is characterized by a subjective probability $p(H_i)$, representing one's confidence in its truth [De Finetti, 1976]. The output of a Bayesian analysis is a distribution of probabilities over a set of hypotheses. These probabilities can be used in combination with information about payoffs associated with various decision possibilities and 'states of the world' to implement any number of decision rules. It is a normative model in the sense that it specifies certain internally consistent relationships among probabilistic opinions that prescribe how opinions should be revised as new information becomes available. Existing knowledge is summarized in prior (aleatory) probabilities also called the base rates, and incoming case-specific evidence is provided through subjective assessment of the so-called individuating information. The outcome of a Bayesian analysis, the posterior probability, is calculated by combining the base rates and the individuating information. The model is iterative in the sense that a posterior probability becomes the prior probability in the next calculation as more individuating information becomes available. Two hypotheses, H and $\hat{H}$, are assessed against one another, expressed in the base rates such that $P(H) + P(\hat{H}) = 1.0$. The model demands that the individuating information be considered in terms of its support for both hypotheses, the weighting of which leads to the posterior probability, which in turn results in a revision of the opinion contained in the original base rates. When the evidence supports both hypotheses H and $\hat{H}$ to an equal extent, no revision of opinion should occur. The resulting posterior probability is therefore identical to the base rate representing the hypothesis in terms of which the judgment is made.

2.1 Diagnosticity

Diagnosticity refers to "how much potential impact a datum should have in revising one's opinion without regard to what the prior odds are" ([Wells, Lindsay, 1980], p. 778). A component that should have no impact on the judgment is thus, by this definition, nondiagnostic. In order to determine the informativeness (diagnosticity) of the entire individuating information in cases where it consists of several items, a value must be assigned to each item. The combined value of items then determines the degree of importance and hence its support, for the hypothesis being entertained.

Early studies of subjective probability assessments analyzed from a Bayesian perspective found consistently that subjects tended to adjust their probabilities less than required by Bayes' Theorem. That is, subjects' confidence in the apparently correct hypothesis did not increase as quickly as the accumulating evidence indicated it should; they were 'conservative' ([Phillips,Edwards, 1966]; [Edwards, 1982]). The ensuing debate on conservatism eventually led to Peterson and Beach's (1967) optimistic claim that "man is an intuitive Bayesian", arising from their extensive review of the literature at the time. As a consequence, the line of research into conservatism was "quietly abandoned" ([Fischhoff, Beyth-Marom, 1983], p. 248) with the rise of research into the so-called "base-rate fallacy" phenomenon [Bar-Hillel, 1980].

This line of research, inspired by Kahneman and Tversky (1972), provoked the bold claim that "man is apparently not a conservative Bayesian; he is not a Bayesian at all" (p. 450). One of the most famous cases tested by Kahneman and Tversky was the lawyer-engineer problem in which subjects were provided with several descriptions of people under high (70/100 lawyers in a particular sample of lawyers and engineers) or low (30/100 lawyers) base rate conditions. The individuating information exerted a large effect on subjects' judgments, whereas base rates exerted virtually no effect. Each vignette describing an individual was intended to be nondiagnostic, being equally descriptive of a lawyer or an engineer. Thus, the posterior probabilities should have been identical with the prior probability of lawyers, either .70 or .30. Yet, subjects consistently were found to evaluate the individuating information in terms of the degree to which it was believed to represent the stereotype of a lawyer; in other words, subjects were prone to the representativeness bias [Kahneman, Tversky, 1982]. Hundreds of laboratory studies conducted since then have replicated this robust finding but have not shed much light on the phenomenon other than to confirm that "base rates are universally ignored" ([Koehler, 1996], p. 2).

Studies of nondiagnosticity of individuating information and its impact on base rate usage have primarily focused on outcome probability estimates rather than on the fate of individual items in the individuating information in the final judgment. However, the psychological research underlying the justification for ReDDS described later in this paper, focused on the integration of items in the individuating information instead. This research is summarized next.

2.2 Potential causes of flawed information integration

Anderson (1982) claims that "[serial] order effects are clearly important in any attempt to study integration processes" (p. 15). In particular, research into primacy

effects has supported the attention decrement hypothesis, in which the weighting of later presented items decreases due to a progressive reduction in attention over a number of items. In recency effects this process is reversed: later items receive more attention than earlier presented items. By contrast, the presence of an anchoring effect can be distinguished from a serial order effect because the item weighted most heavily and thus serving as an anchor, may be presented in any serial position in the stimulus array [Lopes, 1983]. Anchoring may result if diagnosticians fail adequately to adjust their opinion in the light of other items of information. If a certain item is deemed particularly important and is selected as an anchor, the resulting judgments should be very similar regardless of the serial position in which that item is presented.

A confirmation bias ([Wason, 1960]; [Wason, 1968]; [Klayman, 1995]) exists when subjects systematically display inappropriately high confidence in one hypothesis [McKenzie, 2004]. Confirmation biases can be inferred from a failure to change one's opinion in the face of nonsupporting or contradictory evidence, or selection of data favoring one's hypothesis while ignoring data that would contradict it [Klayman, Ha, 1987]. If diagnosticians are found systematically to weight symptoms confirming a disease in terms of which a subjective probability is made when the overall case information is carefully balanced equally to support the competing hypotheses in a Bayesian decision task, the probability estimate should consistently be higher than justified by the evidence.

A confirmation bias or use of an anchor may affect judgments in which the individuating information is nondiagnostic in a very similar manner. If the item selected as an anchor also confirms hypothesis H, an anchoring strategy would be indistinguishable from a confirmation bias. In either case, the individuating information, $P(D \mid H)$, would affect the judgment more than warranted by the evidence. If however, the judgment is dominated by the evidence in support of the alternative hypothesis, $\hat{H}$, in nondiagnostic cases, the denominator term, $P(D \mid \hat{H})$, would suggest anchoring.

Graber (2007) claims that "knowledge deficits are rarely the cause of cognitive errors in medicine; these errors more commonly involve defective synthesis of the available data" (pp. 1-2). This concurs with Eddy and Clanton's (1982) suggestion that medical diagnosticians select a single, very salient symptom and use it as a pivot around which they collect additional information. Such a strategy could bias the integration of information in ambiguous cases, leading to "premature closure" whereby possible diagnoses are not considered once a hypothesis has been identified [Graber, 2007]. For example, the diagnostician may ignore available data that conflict with the current hypothesis or the fact that the selected pivot may point to different diseases may not be detected if only one hypothesis is entertained. The psychological studies summarized very briefly here explored the information integration strategies employed by nurses and physicians in the face of very limited amounts of ambiguous information. Ambiguity was maximized by balancing the case-specific information such that it equally supported two different diseases.

3 Summary of the studies on nondiagnosticity

A series of five experiments are summarized briefly in this section. Experiment 1 explored the use of nondiagnostic individuating information in a set of different

medical conditions. The three medical conditions, arranged in a within-subject Latin-square design, were tested on a sample of 80 specialist nurses. Each condition, checked with a cross-reference of several medical texts, was causally related to two diseases, each with unique symptoms, and also sharing certain symptoms. Four symptoms were presented in a set of eight vignettes each describing an individual patient: one confirmed the hypothesis in terms of which the overall judgment was made, one disconfirmed it, one was neutral (it could occur in either of the two diseases), and one was irrelevant. The diseases were presented as base rates – for example Acute abdomen caused either by diffuse peritonitis (29/100 cases) or bowel obstruction (71/100 cases). Most importantly for the present argument, the data yielded no serial order effects. Weightings of each symptom were invariably highest for the confirmatory, and lowest for the disconfirmatory symptom regardless of their serial position, suggesting that the nondiagnosticity of the individuating information as a whole was not recognized.

Experiment 2 determined if the vignettes could have been perceived to be diagnostic, and also to select a small pool of symptoms with control for diagnosticity to be used in subsequent experiments. Using the symptoms from Experiment 1, a list of 12 symptoms was prepared for each medical condition. Four symptoms confirmed the disease in terms of which the expected frequency rating was made, four confirmed the opposite disease, and four symptoms were neutral. Each list was presented twice – once for each disease belonging to a medical condition. Thus for the 'acute abdomen' condition, judgments were made in terms of 'diffuse peritonitis' in one, and 'bowel obstruction' in the other list. Symptoms were arranged in different random orders for each disease, and always presented such that the same list was not seen twice in a row. Subjects were asked to assess the frequency with which they expected each symptom to be present in a sample of 100 patients, all diagnosed with the disease in question.

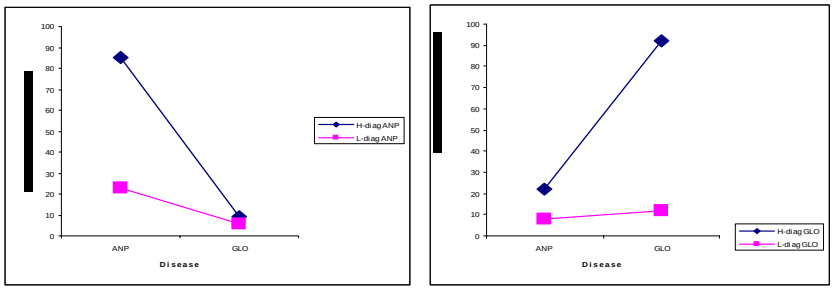


Figure 1: (a, left) Mean weightings for the H- and L-diagnostic symptoms supporting angina pectoris and assessed under both ANP and GLO, (b, right) mean weightings of the H- and L-diagnostic symptoms supporting GLO and assessed under both GLO and ANP.

The perceived frequency of occurrence varied greatly within and between diseases, suggesting that the four symptoms indicative of one of the diseases were not perceived to be equally diagnostic. The procedure did, however, allow us to identify

high- and low-diagnostic symptoms characteristic for each disease. Figure 1 shows the mean perceived frequency of occurrence of the two symptoms selected for the angina pectoris and glomerulonephritis disease-pair, both indicative of 'essential hypertension'. The high-diagnostic symptom received the highest mean weighting under the disease for which it was characteristic and a very low rating for the alternative disease, whereas the mean rating for the low-diagnostic symptom differed slightly when presented in the two contexts.

Experiment 3 presented vignettes belonging only to one disease-pair and each requiring a single probability estimate. The many combinations of symptoms, diseases, and medical conditions in Experiment 1 precluded a detailed analysis of the possible effect of individual symptoms. Some 44 expert nurses each judged all the 24 vignettes arising from the factorial combination of the six symptoms (2 neutral, 1 high-diagnostic, 1 low-diagnostic confirming each disease in the pair) presented in all possible sequences. All judgments were made in terms of the probability that the patient described in each had angina pectoris; one half of the subjects were assigned at random to the low-base rate group (28/100 patients with angina pectoris), and the other half to the high-base rate group (72/100 patients with angina pectoris). Base rates did not affect the probability ratings at all. To simplify the present discussion, only the key finding for the nondiagnostic cases comprising both the high-diagnostic symptoms are discussed, and judgments are collapsed across both base-rate groups. Figure 2 shows a clear primacy effect: a high-diagnostic confirmatory symptom presented first in a vignette resulted in higher probability estimates compared with later presentation of the same symptom, indicated by the descending slope. Similarly, a high-diagnostic disconfirmatory symptom resulted in lower probability estimates when presented first than when presented later in the sequence, indicated by the ascending slope.

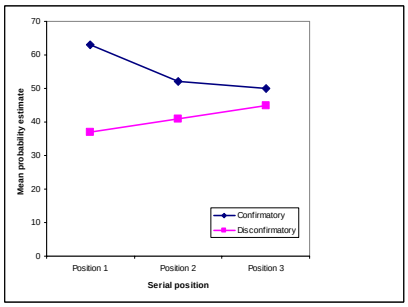


Figure 2: Mean probability estimates by serial position for confirmatory and disconfirmatory symptoms high in diagnosticity

Experiment 4 was designed to assess the generalizability of the above results using a second disease-pair from Experiment 1, treated exactly as the above data and employing the same factorial design as well as a new sample of 44 expert nurses who had not taken part in any earlier experiments. The results resembled those obtained in

Experiment 3 and are therefore not discussed further here. Assuming that nurses generally do not propose medical diagnoses in their clinical work, the vignettes used in Experiment 3 were again tested in Experiment 5 on a sample of 32 medical practitioners. Again, the results yielded a highly significant serial order effect consistent with the same primacy effect as shown for the nurses' data in Figure 2. This supports the robustness of the primacy effect.

Nondiagnosticity of conflicting information which, when summed, equally supports both competing hypotheses can only be detected if both of these are considered. The persistent presence of a primacy effect in three experiments suggests that the symptoms were not weighted according to both hypotheses: subjects apparently failed to detect the nondiagnosticity of the cases. The primacy effect also excludes the possibility that subjects selected an anchor in any of the three experiments. Had they done so, all the probability estimates shown in Figure 2 should have been virtually identical. A confirmation bias was said earlier to exist if subjects favor one hypothesis over another regardless of the weight of evidence pointing to the alternative hypothesis. The results did not support a tendency to favor either hypothesis; the presence of a confirmation bias cannot therefore be entirely refuted. However, they all suggest that items were processed in the order in which they were seen: the mean estimates in Figure 2 were consistently closer together in the third than in the first serial position due to a progressive increase in disconfirmatory estimates and a progressive decrease in confirmatory estimates. This is consistent with the attention decrement hypothesis.

The extent to which subjects' understanding of diagnosticity concept may have been correct is not entirely clear from the above results. They could have relied either on the absolute frequency of occurrence of the symptoms in the to-be-evaluated disease, or on the relative difference in frequencies of occurrence of symptoms under H and $\hat{H}$. Either approach could affect the estimates in a similar manner because high- and low-diagnostic symptoms differed along both dimensions: a high-diagnostic symptom was high in absolute frequency of occurrence under hypothesis H as well as in the difference in frequency of occurrence under both hypotheses H and $\hat{H}$.

To the extent that the above experimental findings may be indicative of the way diagnosticians process information in practice, a DSS based on such research should support diagnostic decision making. However, such a DSS would only be worthwhile if it can be shown that a relevant problem actually exists. That is explored next.

4 Diagnostic Decision Support in medicine: is there a problem?

According to certain patient safety research reports, between 98,000 [Hughes et al., 2000] and 195,000 [Miller et al., 2003] hospitalized people die every year in the United States due to some kind of medical error. While there is some dispute about the figures ([McDonald et al., 2000]; [Leape, 2000]) as well as about the definition and calculation of "preventable error" [Hayward, Hofer, 2001], the number is very high. One recent review of some 14 studies of general medical errors published between 1991 and 2004, Schiff and his colleagues [Schiff et al., 2006] found that diagnosis-related errors accounted for 10-30% of all errors recorded; other researchers have estimated that such errors account for up to 76% of medical errors [Amy et al.,

2006], and that the 'gold standard' of misdiagnosis obtained from autopsies has consistently yielded a misdiagnosis rate of 40% over the past 65 years [Croskerry, 2006]. With increasing pressure on medical personnel to attend to ever more patients in shorter time frames, it is safe to predict that the problem of misdiagnosis is likely to increase.

Online resources providing both more general medical information, for example, PubMed (www.pubMed.(http://www.pubmedcentral.nih.gov/), eMedicine (www.emedicine.com) and SearchMedica (www.SearchMedica.co.uk), as well as specialized applications such as DermConsult (www.dermconsult.com.au) are proliferating; some are enjoying heavy usage by medical practitioners (Chamberlain, 2006). One popular diagnostic web-based DSS, Isabel, provides information in the form of additional diagnoses which the practitioner may or may not have considered in the assessment of a given patient (e.g. [Ramnarayan, 2005]; [Ramnarayan et al., 2006]; [Bavdekar, Pawar, 2005]. Isabel draws on cross-references from a range of medical textbooks; it has been found to perform quite well in terms of "including [73%] of all key diagnoses" [Ramnarayan, 2005] as well as including the "single expected" diagnosis in over 90% of cases in various validation studies [Ramnarayian, Cronje, 2005]. It is able to parse both keyboard entries and unformatted, spoken natural language; its output is a list of 10-15 possible clinical conditions [Bavdekar, Pawar, 2005] in addition to a short list of up to three possible diagnoses. The conditions are listed in ten clinical categories, namely: Gastrointestinal Disorders, Nervous System Disorders, Shock States, Urologic Disorders, Infection Diseases, Neoplastic Diseases, Endocrine System, Metabolic Diseases, Respiratory System Disorders, Cardiac Disorders, Liver Disorders, Nephrology, Hematology, Allergic Disorders, and Toxicology. In particular, when patients present with ambiguous symptoms that may point to several possible diseases, the output can thus be overwhelming and very time-consuming to process. Because Isabel's data are derived from medical texts, it cannot provide probabilities associated with each of the possible conditions; it merely aims to "remind" the medical practitioner of alternative possibilities. By contrast, ReDDS does provide such probabilities based on the relative frequency of occurrence of signs and symptoms in different diseases.

4.1 Creating ReDDS (Resident Decision Support System)

The summary of the five laboratory experiments presented earlier suggests that the task of diagnosing may proceed in the manner described by Eddy and Clanton (1982), by generating a hypothesis from a single salient, easy-to-observe, symptom, and weigh additional information according to its support for that hypothesis. A DSS may thus improve diagnostic decision making simply by providing alternative possible hypotheses, which would encourage the diagnostician to widen the range of hypotheses to be pursued. In essence, that is precisely what Isabel does. However, Isabel does not provide the relative probability associated with each potential output condition. Therefore, it does not facilitate differentiation between the proposed hypothetical conditions even when the probability associated with each varies widely. Nor does it afford a better general understanding of the concept of symptom diagnosticity. In order to achieve this, the diagnosticity of each sign, symptom, and laboratory finding must be quantified in relation to each possible outcome.

ReDDS is a proof-of-concept tool based on a subset of actual data from a database of 1200 infants admitted to the neonatal intensive care unit at the Children's Hospital of Eastern Ontario. It aims both to facilitate the diagnosis of respiratory distress in infants and to teach residents the concept of diagnosticity. Respiratory distress was selected as the target condition in this because it occurs relatively frequently and because the signs and symptoms are ambiguous, generally pointing to different possible causes.

An experienced medical records librarian was first given a list of signs, symptoms, and laboratory findings related to respiratory distress with which to select relevant cases from the database. One hundred cases fulfilling these criteria were thus identified. Clinical information missing from the database, such as working- or final diagnoses and patient outcome, was obtained by consulting the relevant patient records. The completeness of the 100 cases enabled accurate quantification of the relative diagnosticity of each sign and symptom associated with every causal condition which, in turn, enabled the calculation of the terms $P(D|H)$ and $P(D|\hat{H})$ for any combination of symptoms. However, rather than providing all possible conditions, the ReDDS output rank orders and presents the five most probable conditions based on the collection of signs and symptoms entered by the physician. By contrast, Isabel's suggested conditions appear implicitly to be equiprobable because it lacks quantified information about the diagnosticity of each datum in the database relative to each condition.

Ideally, a DSS should be able to calculate posterior probabilities, $P(H|D)$. However, because the base rates, $P(H)$ and $P(\hat{H})$, will vary depending on the reference groups chosen for comparison, this is not possible. Say, for example, a male infant is admitted with symptoms X, Y, and Z. Should the reference groups be male ($P(H)$) versus female ($P(\hat{H})$) infants, all infants displaying symptoms X, Y, and Z versus all infants ($P(H)$) displaying symptoms X, A, and Y ($P(\hat{H})$), or yet other groups? Each calculation would clearly result in different posterior probabilities, thereby confusing rather than assisting the diagnostician.

Interaction with ReDDS is via a very simple GUI comprising two main sections: a data input and a data output section. This is shown in Figure 3a. To enter a case, the diagnostician selects each relevant sign or symptom from a drop-down menu that appears upon a left mouse click in the 'symptom' field. As a symptom is selected, the field changes colour and, depending on the type of symptom, it enables the diagnostician to describe it in more detail or to select the relevant value from a drop-down menu in the column labeled 'Description'. Tooltips guide the nature of descriptive data required. The button labeled 'Diagnose' may be pressed upon each entered symptom and description, as shown in Figure 3b. If a single symptom suffices to provide possible diagnoses as in the Figure, the five most likely diagnoses are shown in the date output section at the bottom of the screen. To narrow the search, more symptoms may then be entered, and the diagnose button pressed repeatedly to display the progressively changing diagnostic probabilities. The most desirable output is, of course, a single probability, given in percent below, with a value of 100.00. Alternatively, if several probabilities result from the input, it is naturally best if only one has a value of 100.00. In the example below, two possible diagnoses both show

100.00, suggesting that the 'Apgar1'[1] score of '2' on its own does not allow discrimination between those two most likely diagnoses. As more data are entered, these probabilities will automatically be adjusted. The 'History' field is populated progressively every time the 'Diagnose' button is pressed, enabling the diagnostician to review the symptoms entered and the chronological order in which these were entered. The 'Delete' button deletes whichever datum is pointed at, and the 'DeleteAllButton' deletes all entries while retaining the history, thus allowing multiple data entries and review of each.

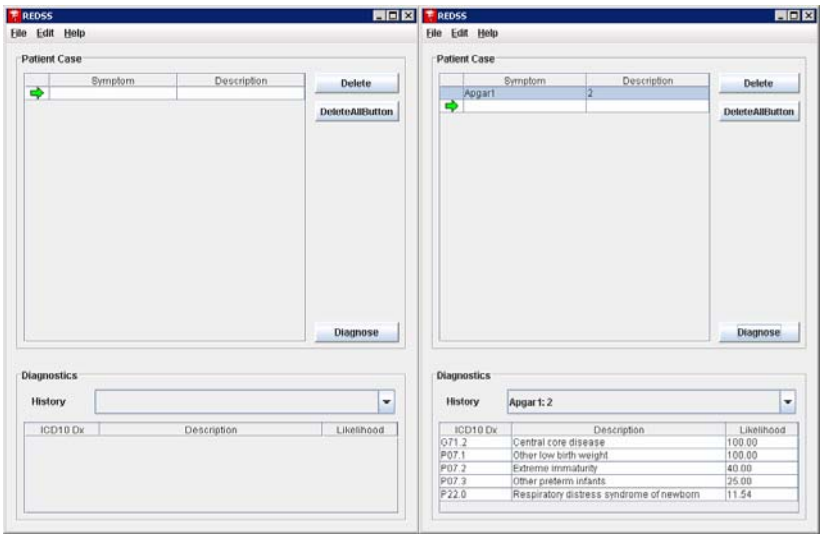


Figure 3: ReDDS screen prior to data entry; 3b: output probabilities upon entry of an 'Apgarl' score of '2'

4.2 Validation of ReDDS

One important purpose of the proof-of-concept ReDDS is to demonstrate that diagnostic performance can improve by encouraging the diagnostician to widen the range of hypotheses to be pursued when diagnosing ambiguous cases. This is consistent with the aim of Isabel, except that the number of potential conditions

[1] Apgarl is a mnemonic for pediatricians referring to Appearance (skin color), pulse (heart rate), grimace (reflex irritability), activity (muscle tone), and respiration. Each variable is scored on a scale 0-2, and the five scores are summed to yield the final Apgarl score. The test is generally done at one and five minutes after birth, and may be repeated later if the score is, and remains, low. Scores below 3 are generally regarded as critically low, with 4 to 7 fairly low and over 7 normal.

provided by Isabel can be overwhelmingly large, whereas ReDDS only provides the five most likely conditions. More importantly, we also aim to demonstrate that appreciation of quantified diagnosticity is transferable to diseases not covered by the DSS. Let us assume that Graber's (2007) assertion is correct, that defective synthesis of available data rather than knowledge deficits are the underlying cause of cognitive errors in diagnosis. The sheer realization that one is prone to fall victim to primacy effects when generating and testing diagnostic hypotheses should help physicians to consider both alternative diseases and also the likelihood associated with each. On the one hand, the initial search should thus be widened to include alternatives not otherwise considered, and on the other hand, it should also be narrowed only to consider the most likely alternatives. Furthermore, to the extent that ReDDS does enhance residents' understanding of the concept of diagnosticity, such understanding should generalize to diagnostic decision tasks not associated with the conditions catered to in ReDDS. To test these possibilities, a series of controlled laboratory validation studies are currently being planned.

We argued earlier that Bayes' Theorem could be successfully applied even in situations in which the model relies on a static database. We are confident that our validation studies will lead to a better understanding of diagnosticity as well as to better diagnostic performance. Whereas ReDDS will thus support human decision making, the 'psychologist in the box' project discussed next will enable the computer to customize training programs to the needs of individual users whose needs change dynamically in the course of the particular training program.

5 Psychologist in the box: an e-health mental intervention system

The ultimate purpose of the 'psychologist in the box' project is to relieve clinical psychologists of routine work that currently consumes a large proportion of the one-on-one consultation time spent with clients in order to leave the clinician free to address more serious underlying issues in the precious face-to-face client time. The aim of this routine work is to teach certain types of client particular social skills through relatively simple messages conveyed via a wide range of stored video scenarios. The task of the system is to select the most appropriate scenarios for the client, and adapting to the client's changing needs as she learns the different lessons in the program.

Based on the psychological literature and a set of experiments currently being performed, the system will 'know' about certain personality characteristics, such as cognitive and sensory learning styles. It is also able to ascertain motivation for change, certain performance characteristics, and characteristics of the nature and severity of the client's condition, for example, 'anorexia nervosa, diagnosed 2 years ago, single condition, male university student, early twenties'. The user model for such a client will differ qualitatively along some dimensions from that of, say, a 'middle-aged woman without a college degree, just diagnosed with bulimia nervosa and acute endogeneous depression'. The language used by the program, the scenarios selected, and the ways questions to the user are phrased, will vary considerably for these two types of client. The level of motivation, the learning style, and the nature of the individual's psychological needs will all dictate the type and amount of course content displayed and the ways in which the content will be presented. The necessary

diagnostic characteristics will be captured and measured via informal conversation between each individual client and the computer.

Current e-Learning models for adaptive learning provide a solid base of technology on which to build such an e-health system. These models describe and categorize knowledge such that it may be adapted to individual users' needs. The models use well-structured metadata regarding content, as well as expert systems to identify the best material for each user. The rules of the expert systems in e-Learning models use first-order data, such as the results of a test or a response to a scenario just played to the user, to make decisions. However, the e-Learning model is not sufficient to enable the 'psychologist in the box' system to understand the user to the degree necessary for developing a sound, customized intervention plan. In order do this, the system must deal with both first-order and second-order metadata. Second-order data can be thought of as patterns of behaviour. In order to develop a sound intervention plan consisting of psychological content and process variables, the system must discern the relevant user- and disease-characteristics.

In addition to requiring metadata, an e-intervention system differs from an e-learning system in the types of interactions that occur between the user and the system. In an e-Learning environment (e.g. [Winzelberg et al., 2000]), knowledge is made available for the user to investigate in a manner best suiting the user's learning needs. The investigation is all user-driven and user-oriented; the onus is on the user to identify his or her learning needs. In an e-intervention environment, the system adapts to the client's needs in an effort to convey a sense of the material being customized and targeted specifically to that individual. To achieve this, the capture of purely first-order data is inadequate. Two tools are currently being developed to overcome this imitation: one is an intelligent agent that will perform data mining on various first-order data items to derive second-order data. The integration of second-order data defines a user model. The second tool is an expert system that will apply the user model and rules based on the most empirically validated approaches to psychological intervention – namely Rational-Emotive Behavioural Therapy (REBT) and Cognitive Behavioural Therapy (CBT) [Roth, Fonagy, 2004]. The rules attempt to determine a sound intervention plan based on the input user model.

Figure 4 below shows the relationships between these two tools and the e-Learning platform. A client interacts with the user interface to generate first-order data by responding to specific questions and challenges played out in scenarios presented to the user. The user interface sends the first-order data to the intelligent agent, which processes these into second-order data. The intelligent agent sends the second-order data to the expert system, which makes recommendations based on rules applied to the second-order data. The expert system, based on Bayes' Theorem, generates recommendations for the adaptive e-Learning system, which, in turn, chooses specific content elements as well as presentation styles and tactics based on the recommendations, and presents the material to the client via the user interface. The purpose of this rather complex interaction is to convey to the end user a sense that the program is adapting its intervention to suit them personally – that they are being listened to and understood.

In order to select appropriate scenarios, the expert system applies its 'knowledge' of the relevant personality and other characteristics that distinguish extraverts (P(H)) from introverts (P($\hat{H}$)) in the client population. It also 'knows' the likelihood that the

client's preferred learning style will be X if tend more toward extraversion than toward introversion as ascertained through informal conversation as well as through their feedback on, and responses to, scenarios already shown, as well as to questions, small tests, and the like. Through continual evaluation of the client's feedback, the expert system progressively adjusts its knowledge about the client simply by calculating the posterior probability, $P(H \mid D)$. It uses each such outcome as the base rate, $P(H)$, for the next calculation, based on further client input, comprising $P(P(D \mid H)$ and $P(D \mid \hat{H})$. Since $P(H) + P(\hat{H}) = 1.0$, adjustments to $P(H)$ automatically updates the value of $P(\hat{H})$ as well. This way, the system 'learns' to fine-tune its selections to the needs of the client. Thus, the customized user model evolves during continued client-computer interaction.

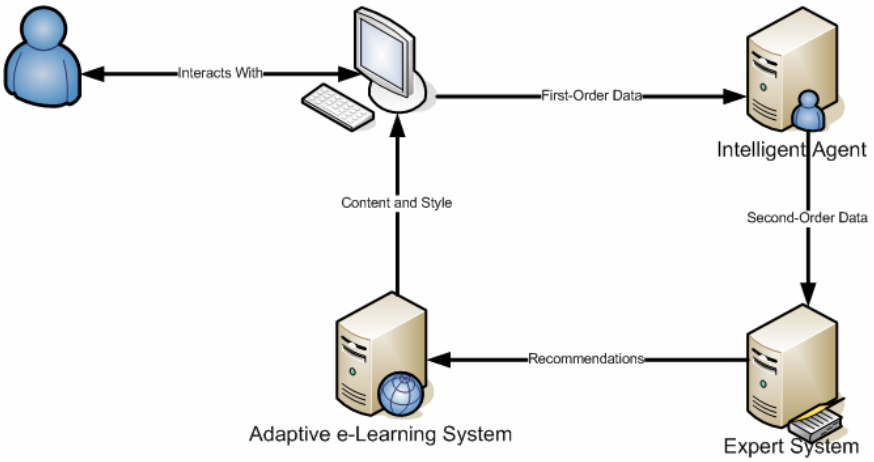


Figure 4: The 'psychologist in the box' system

6 Conclusion

In this paper we have attempted to show that Bayes' Theorem can be applied successfully to DSSs, even in circumstances requiring no adaptation once the basic database and decision rules are in place such as in ReDDS. We also attempted to show that Bayes' Theorem can be successfully applied to machine-based learning in a dynamically changing environment. The psychological contribution to ReDDS is an understanding to information integration, whereas to the 'psychologist in the box' project, it provides the initial knowledge of the distribution of base rates of the important variables comprising the individuating information, $P(D \mid H)$ and $P(D \mid \hat{H})$, as well as providing the selection rules based on evaluation of the different kinds of human input. We thus maintain that Bayesian models can be applied usefully to different kinds of decision problems, and that psychological research can successfully contribute to the background justification, the definition, design, and evaluation of

DSSs in the medical and psychological arenas, regardless of whether the system is intended to support human- or machine learning.

References

[Amy et al., 2006] Amy, L.R., Lyman, J., & Borowitz, S.: "Impact of a web-diagnosis reminder system on errors of diagnosis"; Proceedings American Medical Information Association (AMIA) annual conference, 11-15 November, Bethesda, MD, 2-6.

[Anderson, 1982] Anderson, N.H.: „Methods of information integration theory"; Academic Press / New York, NY (1982).

[Bar-Hillel, 1980] Bar-Hillel, M. I.: „On the subjective probability of compound events"; Organizational behavior and human performance, 9, (1980), 396-406.

[Bavdekar, Pawar, 2005] Bavdekar, S.B., Pawar, M.: "Evaluation of an internet[-delivered pediatric diagnosis support system (ISABEL®) in a tertiary care center in India"; Indian pediatrics, 42, November, (2005), 1086-1091.

[Chamberlain, 2006] Chamberlain, A.J.: „The internet as a clinical aid for the dermatologist"; British Medical Journal (BMJ), 333, (2006), 1143-1145.

[Crosskerry, 2006] Crosskerry, P.: „Diagnostic failure: A cognitive and affective approach"; Advances in patient safety, 2, (2006), 241-254.

[De Finetti, 1976] De Finetti, B.: „Probability: Beware of falsifications!" Scientia, 3, (1976), 283-303.

[Eddy, Clanton, 1982] Eddy, D.M., Clanton, C.H.: „The art of diagnosis: solving the clinicopathological exercise"; New England journal of medicine, 306, (1982), 1263-1268.

[Edwards, 1982] Edwards, W.: „Conservatism in human information processing"; in B. Kleinmuntz (Ed). Formal representation of human judgment, John Wiley & sons / New York, NY (1982)

[Ennett, 2003] Ennett, C.: „Imputation of missing values by integrating artificial neural networks and case-based reasoning"; Unpublished PhD Thesis, Carleton University (2003)

[Fischhoff, Beyth-Marom, 1983] Fischhoff, B. & Beyth-Marom, R.: „Hypothesis evaluation from a Bayesian analysis"; Psychological review, 90, 3, (1983), 239-260.

[Graber, 2007] Graber, M.L.: „Diagnostic errors in medicine: What do doctors and umpires have in common?"; Morbidity & mortality, 1-6, (2007).

[Hayward, Hofer, 2001] Hayward, R.A., Hofer, T.P.: „Estimating hospital deaths due to medical errors: Preventability is in the eye of the reviewer"; Journal of the American Medical Association, 286, (2001), 415-420.

[Hughes et al., 2000] Hughes, C.M., Phillips, J., Woodcock, J.: "How Many Deaths Are Due to Medical Errors?"; Journal of the American Medical Association, 284, (2000), 2187-2189.

[Kahneman, Tversky, 1982] Kahneman, D. & Tversky, A.: „The simulation heuristic"; in D. Kahneman, P. Slovic & A. Tversky (eds)," Judgment under uncertainty: Heuristics and biases"; Cambridge university press / Boston, MA (1982)

[Kahneman, Tversky, 1972] Kahneman, D. & Tversky, A.: „Subjective probability: A judgment of representativeness"; Cognitive psychology, 3, (1972), 430-454.

[Klayman, Ha, 1987] Klayman, J. & Ha, Y-W.:„Confirmation, disconfirmation, and information in hypothesis testing, Psychological Review, (1987) 94 (2), 211-228.

[Koehler, 1996] Koehler, J.J.: „The base rate fallacy reconsidered: Descriptive, normative, and methodological challenges"; Behavioral and brain sciences, 19, 1, (1996), 1-53.

[Lopes, 1983] Lopes, L.L.: „Toward a procedural theory of judgment"; Psychological documents, 13, 2, (1983), MS no. 2590.

[McDonald et al., 2000] McDonald, C.J., Weiner, M., Hui, S.L.: „Deaths Due to Medical Errors Are Exaggerated in Institute of Medicine Report"; Journal of the American Medical Association 284, (2000), 93-95.

[Miller et al., 2003] Miller R.M., Elixhauser A., Zhan C.: ”Patient safety events during pediatric hospitalizations“; Pediatrics, 111, (2003) 1358–1366.
[Peterson, Beach, 1967] Peterson, C.R., Beach, L.R.: „Man as an intuitive statistician“; Psychological bulletin, 68, 1, (1967), 29-46.
[Phillips, Edwards, 1966] Phillips, L.D., Edwards, W.: „Conservatism in a simple probability inference task“; Journal of experimental psychology, 72, 3, (1966), 346-354.
[Ramnarayan, 2005] Ramnarayan, P.: „Decision support systems: A how-to guide to their evaluation“, Sage Publications electronic resources, http://c.sagepub.com (2005)
[Ramnarayan, Cronje, 2005] Ramnarayan, P., Cronje, N.: „Report on Isabel adult medical validation study“; Isabel Healthcare report, London, UK (2005)
[Roth, Fonagy, 2004] Roth, A., Fonagy, P.: „What Work for Whom? Second Edition: A Critical Review of Psychotherapy.“ Guildford Press/ New York (2004)
[Schiff et al., 2006] Schiff, G.D., Kim, S., Abrams, R., Cosby, K., Lambert, B., Elstein, A.S., Hasler, S., Krosnjar, N., Odwazny, R., Wisniewski, M.A., & McNutt, R.A. Advances in patient safety, 2, (2006), 255-278.
[Wason, 1968] Wason, P.C.: „Reasoning about a rule“; Quarterly journal of experimental psychology, 12, (1968), 129-140.
[Wason, 1960] Wason, P.C.: „On the failure to eliminate hypotheses in a conceptual task“; Quarterly journal of experimental psychology, 20, (1960) 273-281.
[Wells, Lindsay, 1980] Wells, G.L., Lindsay, R.C. L.: „On estimating the diagnosticity of eyewitness nonidentification“; Psychological bulletin, 88, 3, (1980), 776-784.
[Winzelberg et al., 2000] Winzelberg, A.J., Eppstein, D., Eldredge, K.L., Wifley, D., Dasmahapatra, R., Taylor, C.B. & Parvati, D.: „Effectiveness of an Internet-based program for reducing risk factors for eating disorders“; Journal of consulting and clinical psychology, 68, 2, (2000), 346-350.

Development of Accessible Web Applications: Highlights and Trends

Myriam Arrue
University of the Basque Country-Euskal Herriko Unibertsitatea
Laboratory of HCI for Special Needs
Manuel Lardizabal 1, 20018 Donostia, Spain
myriam@si.ehu.es

Markel Vigo
University of the Basque Country-Euskal Herriko Unibertsitatea
Laboratory of HCI for Special Needs
Manuel Lardizabal 1, 20018 Donostia, Spain
acbvietm@sc.ehu.es

Julio Abascal
University of the Basque Country-Euskal Herriko Unibertsitatea
Laboratory of HCI for Special Needs
Manuel Lardizabal 1, 20018 Donostia, Spain
Julio.abascal@ehu.es

Abstract: The aim of this paper is to review the most well-known methodologies for web applications development as well as the existing supporting tools and techniques with an accessibility-centric perspective. In this sense, many development methodologies with different characteristics are described: models based methodologies, user-centered processes, usability engineering methodologies and accessibility engineering methodologies. Some of these methodologies have specific supporting tools which facilitate the accomplishment of several tasks. However, there are other methodologies which are not concretely related to any supporting tool. Therefore, web developers must deal with diverse tools in order to perform some activities. In these cases, the development of accessible web applications is more difficult. The paper concludes that there is not any development framework which is useful throughout the development process and describes the tools we have implemented. These tools are useful for performing several activities of different phases of the process and can be easily integrated in a comprehensive framework in order to facilitate the development of accessible web applications.

Keywords: Web accessibility, Web engineering, Web applications, development process, development supporting tools.

1 Introduction

Web applications play an increasingly important role when carrying out usual activities in our life. The amount of information and services provided by web applications is rising vertiginously. However, many people with physical, sensorial or cognitive disabilities can not access to most of these services. Even if they may be the users who will benefit more from the use of these applications, as the offered services frequently facilitate carrying out diverse activities in areas such as business, leisure, learning, etc. Therefore, applying Universal Design principles in the development of web applications is essential in order to ensure access for all types of users.

In recent years, the development process of web applications has changed considerably. Initially, web applications consisted of a limited number of web pages, most of them static, with an informative or advertising aim. They were often developed by people with minimum experience in software development and the development process was not led by any appropriate methodology. As a result, low quality web applications have been developed [Murugesan, 02]. In recent years, web applications have become more complex and nowadays they integrate different technologies. Currently, they cover diverse activities and can be classified in different categories based on their functionality: informational, interactive, transactional, workflow oriented, collaborative work environments, online communities, portal-oriented, ubiquitous and semantic web applications [Murugesan, 05] [Kappel, 06]. The following table, Table 1, shows examples of each type of web application.

Functionality/Category	**Examples**
Informational	Online newspapers, product catalogues, newsletters, manuals, reports, online books, etc.
Interactive	Registration forms, online games, etc.
Transactional	Online shops, online banking, travel agencies, etc.
Workflow oriented	Online planning and scheduling, inventory management, status monitoring, etc.
Collaborative work environments	Distributed authoring tools, collaborative design tools, etc.
Online communities	Discussion groups, online auctions, etc.
Portal-oriented applications	Community portals, online shopping malls, business portals, etc.
Ubiquitous applications	Customized services, location-aware services, Multi-platform delivery, etc.
Semantic Web applications	Recommendation systems, Syndication, knowledge management systems, etc.

Table 1: Examples of each type of web applications.

Figure 1 [Kappel, 06], shows the different types of web applications according to their degree of complexity and their development history. In this figure, it can be appreciated that although there are some exceptions, in general there is a correlation between the chronology of development and the complexity degree. One exception are portal-oriented applications as they are of less complexity level than collaborative work environments even if the former type of applications appeared more recently. In addition, it has to be noted that a web application may evolve to different types throughout its lifecycle as new functionalities are added. Commonly, in the initial stages of the development process a simple web application is implemented which is refined in next stages by accommodating more functionalities until a more complex web application is developed.

Therefore, even if the WWW was initially designed as an information media, it has been transformed into an application media in the last few years [Ginige, 01]. Companies show also a growing tendency to introduce web applications in their management processes [Hoffman, 05]. In this sense, previous business standalone applications are evolving into light web applications which have proven to be more manageable and easier to distribute.

Consequently, web applications development has changed from merely being a hypertext based interface design process to a much more complex task which involves different activities such as planning, system architecture design, evaluation, quality assurance, system performance evaluation, maintenance, updates management and so on. Applying methodical, systematic development processes in order to guarantee the development of reliable, efficient, maintainable and secure web applications is of paramount importance. However, the development methodologies defined in the area of software engineering are not directly applicable to web applications due to their specific characteristics [Mendes, 06]. In this context arose the Web Engineering discipline. Its objective is to define appropriate techniques and methodologies to satisfy the needs of web applications development process [Ginige, 01].

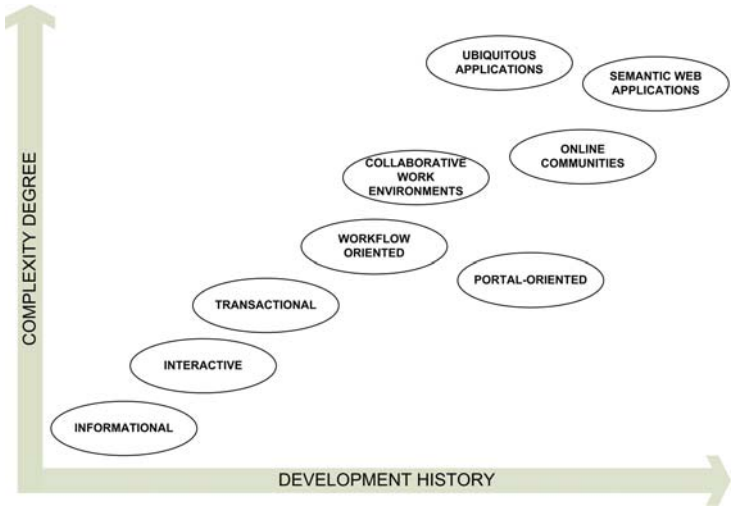


Figure 1: Classification of web application types according to their development history and complexity degree.

The aim of this paper is to highlight the most significant methodologies created for the development of accessible web applications as well as the existing techniques and tools for supporting the developers throughout the process. In addition, it presents specific tools and methods we have developed in order to support developers in performing some accessibility regarded tasks. These tools and methods can be included in a development framework for facilitating the implementation of accessible web applications.

2 Universal Accessibility

According to Brajnik [Brajnik, 00], web applications are interactive software systems which interact at least with two types of user: the end-users and developers. The objective of end-users when accessing to these applications is to perform concrete tasks in a satisfactory way. The developers access the web applications in order to perform updates and maintenance tasks.
Therefore the users of web applications can be classified according to different factors:

- Their objectives and the tasks they try to perform. For example, searching for information, buying a product, etc.
- Users' context. The users' behaviour is highly dependant to different aspects such as their cultural level, interaction language, experience accessing the Web, etc.
- Used technology. Users interact with web applications through a technology layer unknown for web developers. They may use different tools and devices for this interaction such as different browsers, protocols, plug-ins, operating systems, connections of different characteristics, assistive technology, etc.

Several laws have been enacted all around the world [http://www.w3.org/WAI/Policy/] so that agencies supported by public funding would make their sites accessible for people with disabilities and the elderly. However, the rest of websites are not required to meet Universal Access principles and because of that the WWW remains not accessible. Some facts may encourage companies to develop accessible sites:

- In some developed countries people with disabilities reaches %20 of the population. Thus, making a website accessible might considerably increase its potential users and therefore raise the profits of a company.
- Accessible sites get a higher ranking in search engines [Pemberton, 03].
- It will positively affect company image.

These are some of the reasons why "Universal Access" concept is turning into something extremely significant for the current Information Society. If the main objective is the methodical development and maintenance of accessible web applications accessibility issues should be included in the methodologies defined in the area of Web Engineering.

Besides governmental efforts other initiatives have also fostered web accessibility awareness. One of the most proactive initiatives is the Web Accessibility Initiative (WAI) [http://www.w3.org/WAI/] that was set up by the World Wide Web Consortium. This initiative published the well-known Web Content Accessibility Guidelines (WCAG) [http://www.w3.org/WAI/intro/wcag.php] which is the most universally accepted and established set of guidelines for developing and evaluating web content accessibility. In addition, several accessibility evaluation and reparation tools have been developed.

Even though all these efforts are extremely useful for producing accessible web applications, they have proven not to be sufficient in order to achieve the Universal Access objective. Unfortunately, many websites required to be accessible by law are still not accessible. In 2004, Lazar et al. [Lazar, 04] carried out a survey in order to gather web developers' perceptions about web accessibility. According to this study, web developers request methodologies which incorporate web accessibility issues throughout all the development process. In the same study, confusing accessibility guidelines and lack of adequate software tools are two of the reasons given by web developers for the current low accessibility level of web applications.

In fact, a large amount of web accessibility guidelines have been developed recently. Nowadays, in addition to general purpose guidelines such as WCAG or Section 508, other sets of guidelines related to specific application type (informational, transactional, etc.), specific users' characteristics (elderly, teenage people, deaf, etc.) and accessing devices (mobile devices, etc.) can be found. Web developers may be confused when trying to deal with all this information defined in a heterogeneous format. We can conclude that even if laws, guidelines and tools have successfully spread web accessibility awareness, they are not enough to achieve accessible websites.

3 Web Applications Development Process

According to Sommerville [Sommerville, 92] a software application based on a correct development methodology should satisfy four key properties: easy maintenance, reliability, efficiency and an appropriate user interface. The last property refers to the design of the interface according to the abilities of future application users. Diverse development methodologies have been defined in order to facilitate the development of software applications which satisfy these basic properties. They give guidance for planning, organizing, coordinating and managing software development activities.

The characteristics of the software application to be developed such as size, complexity and specific features as well as the temporal restrictions should be taken into account when selecting a concrete process model for the current development.

As mentioned previously, web applications initially consisted in a limited number of web pages, most of them static, with an informative or advertising aim. They were often developed by people with minimum experience in software development. Therefore, the development process was not based on any appropriate methodology. This has lead to the development of poor quality web applications which are difficult to maintain [Murugesan, 02].

Therefore, the need for methodical, systematic development processes is obvious in order to guarantee the development of reliable, efficient, easy to maintain and secure web applications. However, the development methodologies defined in the area of software engineering are not directly applicable to web applications due to their specific characteristics [Mendes, 06] [Kappel, 06]. Some of these specific characteristics of web applications are the following:

- Web applications developers are not always experts in the area.
- Technologies integrated in web applications are in constant evolution.
- There is a need for integrating different technologies and systems.
- End-users' characteristics are often unknown.
- Use of different devices to access the web applications.
- Complex maintenance process due to frequent updates.
- Difficult to estimate the number of end-users.
- Abilities, knowledge and preferences of end-users are heterogeneous.
- Internationalization of web applications in terms of cultural and linguistic differences has to be considered due to global access of the Web.
- Stability of the system is crucial as it is supposed to be permanently operable.

The following sections describe different development methods proposed in Web Engineering discipline.

3.1 Development Methodologies Based on Models

According to Fraternali [Fraternali, 99], a web application is defined by three major design dimensions:

- Structure, describes the pieces of content that conform the web application and their semantic relationships.
- Navigation, composed by the facilities for accessing the content and browsing in the application.
- Presentation, describes the way content and navigation mechanisms are presented to the user.

The development methodologies based on models provide the necessary primitives and mechanisms for specifying structural, navigational and presentational high-level views by abstracting from any architectural issue. Therefore, these methodologies are based on the specification of structural, navigational and presentational models.

The traditional hypermedia development methodologies are model based. The most referenced methodologies by Web Engineering community are Hypermedia Design Model (HDM) [Garzotto, 93], Relationship Management Methodology (RMM) [Isakowitz, 95], Object Oriented HDM (OOHDM) [Schwabe, 95], WebML [Ceri, 00] and Autoweb [Fraternali, 00]. However, none of the previously mentioned web engineering methodologies integrate the necessary web accessibility regarded activities. In Montero et al. [Montero, 03] a framework for the analysis and comparison between the hypermedia development methodologies is proposed. This framework states several requirements which have to be conformed by the methodologies. In addition, it analyses the most well-known methodologies according to these requirements. The requirements related to the development of usable and accessible systems are the following:

- R1: Provide the designer with artifacts to specify system requirements.
- R2: Count on software support tools to help in systems development process.
- R3: Model the different types of users.
- R4: Allow to describe the interactive behaviour of hypermedia systems.
- R5: Make possible the evaluation of the system utility.

The results of this analysis are shown in the following table, Table 2.

Requirements	HDM	RMM	OOHDM	Autoweb	WebML
R1	P	P	P	P	P
R2	C	P	P	C	C
R3	N	N	C	N	C
R4	C	N	C	N	C
R5	C	C	N	N	N

Table 2: Results of the analysis carried out in order to determine the fulfilling of the requirements R1-R5. Notation: P stands for Partially fulfilled requirement, C stands for Completely fulfilled requirement and N stands for Not fulfilled requirement.

According to the analysis carried out none of the methodologies provide the necessary mechanisms for specifying the non-functional requirements such as accessibility, usability, efficiency, etc. Most of the analyzed methodologies are supported by software tools and three of them HDM, Autoweb and WebML completely fulfilled this requirement. However, the tools implemented in order to support these methodologies do not provide the necessary functionalities for the maintenance phase. The majority of tools provide functionalities that may be applied from conceptualization to implementation phase. OOHDM and WebML are the only methodologies which provide mechanisms for user modeling. RMM and Autoweb do not provide any support for describing the interactive behaviour of the system. Finally, this study analyses the possibility of performing system evaluations. HDM and RMM are the only methodologies that support this task. However, the criteria of the evaluations are based on design features [Garzotto, 95].

3.2 User-Centered Development Methodologies

The objective of User-Centered Development (UCD) methodologies is to develop user interfaces which can be used by all types of users regardless of their abilities. Therefore, these methodologies should consider the users characteristics, context of use, tasks to perform, etc.

Initially, the UCD methodologies were based on the use of specific usability methods and techniques in an isolated way. Currently, several frameworks for integrating these methods and techniques have been developed [Stephanidis, 01].

The most well-known framework is proposed in the ISO 13407: *Human-centred design processes for interactive systems* [ISO/IEC, 99] standard developed in 1999. The objective of this standard is to provide a guide for the development of usable interactive systems by incorporating the user-centered design into their lifecycle. The following figure, Figure 2, shows the development process proposed in this standard.

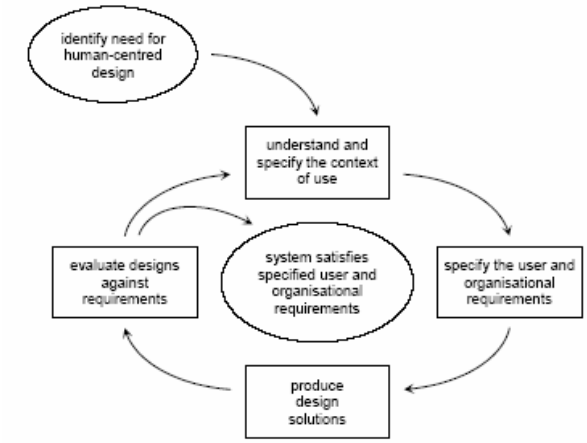


Figure 2: Web Applications development process proposed in ISO 13407 standard.

According to Jokela et al. [Jokela, 03] this standard can not be considered as a comprehensive methodology as it does not provide details about the methods and techniques to apply in order to determine the effectiveness, efficiency and satisfaction of the end-user when using the developed system. In this sense, a comprehensive study about the methods and techniques available can be found in [Maguire, 01].
Web Site Design Method (WSDM) [De Troyer, 98] [De Troyer, 05] is a user-centered development methodology based on models, In this sense, a user analysis is initially performed in order to gather the characteristics of different groups of users. Afterwards,, the information is modeled according to the characteristics of different groups of users. Therefore, the developed systems will be more usable as they will contain functionalities for personalizing the interface.

3.3 Usability Engineering

The principal objective of Usability Engineering is to define development processes which incorporate and order usability regarded activities. According to Nielsen, the objective of Usability Engineering is to build bridges, provide links and create connections between the users' abilities and the possibilities of computers.
One of the first defined development process in Usability Engineering area is the Nielsen's model [Nielsen, 93]. It enumerates the necessary activities that a comprehensive development methodology of Usability Engineering should incorporate. In addition, it specifies several usability evaluation techniques and methods.
The Usability Engineering Lifecycle was proposed in 1999 [Mayhew, 99]. This methodology defines three basic phases for the development process: requirements analysis, design/testing/development and installation. The user interface design the most significant step in this methodology. The prototyping techniques and usability evaluation are integrated in the Usability Engineering Lifecycle.
The two methodologies described above are the most referenced ones though there are other ones such as MPIu+a [Granollers, 04]. This methodology attempts to

integrate aspects from software engineering, human-computer interaction and usability engineering. The principal components of the process model proposed are the following: software engineering development process, prototyping technique and evaluation.

3.4 Accessibility Engineering

The Unified Web Evaluation Methodology (UWEM) [Velleman, 06] is a methodology specifically defined for accessible web applications evaluation proposed by the Web Accessibility Benchmarking Cluster (WAB Cluster) [http://www.wabcluster.org/] conformed by the collaboration of several European research projects: BenToWeb, EIAO and Support-EAM.
The objective of UWEM is to facilitate the compatibility and coherence of automatic accessibility evaluation and monitoring tools. This methodology focuses on the evaluation phase. It is consisted of several principles and best practices which support both manual evaluations by experts and automatic evaluations. It is based on WCAG 1.0 set of guidelines. Therefore, this methodology unifies the interpretations given to each guideline.
Other methodologies have been defined in Accessibility Engineering area. Some of them attempts to incorporate accessibility into user-centered development. The one presented in [Henry, 04] is a methodology which considers accessibility as a subset of usability. Therefore, accessible development techniques are integrated into each phase of the development process. In [Stephanidis, 98] another methodology for integrating accessibility into user-centered development is presented. This study proposes a conceptual framework independent from any particular technology for incorporating accessibility to the user interface lifecycle. For this purpose, it determines some process-oriented accessibility guidelines which extend the user-centered user interface development.
A methodology integrating accessibility in model based development is presented in [Plessers, 05]. The objective of this methodology is to incorporate semantic knowledge about the objects in web pages so screen readers could detect the meaning of the objects. Therefore, this methodology includes the semantic of the objects composing a web page by an ontology specifically developed, Web Authoring for Accessibility (WAfA) [Yesilada, 04]. This process will be automatic and extends the previously mentioned WSDM model based methodology.
Another model based methodology for the integration of accessibility aspects into the development process is described in [Jeschke, 06]. In this case, the objective is to analyse the way accessibility aspects could be integrated in the development of e-learning platforms.
Nevertheless, these methodologies do not consider web accessibility as a whole. Many of them focus on specific stages of the lifecycle (such as the evaluation phase) whereas others focus on users' specific disabilities (such as visually impaired users).

4 Tools for Supporting the Development Process

The methodologies described in the previous section are difficultly applied by developers without the help of supporting tools or techniques. This section is dedicated to analyse the existing tools for web application development.
An exhaustive study about the existing tools for supporting web applications development can be found in [Fraternali, 99]. According to to this study these tools may be classified in six different types according to their functionalities:

1. Visual editors and site managers
2. Web-enabled hypermedia authoring tools
3. Web-DBPL (Data Base Programming Language) integrators
4. Web form editors, report writers, and database publishing wizards
5. Multiparadigm tools
6. Model-driven application generators

None of these tools cover totally the development process of web applications. Each one has useful functionalities for one or more phases of the process. In Table 3, the functionalities supported by each type of tools are specified.

	1	2	3	4	5	6
A						Models generating facilities
D	Presentation design	Navegation design	Structural design		Presentation design	Structural, navegational, presentational model
I	Code generation	Code generation, Data Base (DB) connectivity	DB queries & web pages integrating facilities	Code generation	Code generation, DB content publishing	Code generation, DB generation, connectivity
E				Code debugging		
M	Web site management facilities		Content maintenance	Versions control, configurations management	Web site management facilities Content maintenance	

Table 3: Functionalities implemented in each type of tools for performing activities of specific development process phases. Notation: A stands for Analysis Phase, D stands for Design Phase, I stands for Implementation Phase, E stands for Evaluation Phase and M stands for Maintenance Phase.

4.1 Tools and Techniques to Support Web Accessibility

Some of the above mentioned tools have functionalities related to accessibility. However, specific tools and techniques for facilitating the development of accessible web applications have been developed in recent years.

One complex aspect that developers have to deal with is the management of accessibility guidelines throughout the development process. In fact, the extensive amount of information about web accessibility in terms of best practices, techniques and sets of guidelines developed recently makes difficult to perform activities such as:

- Search for the sets of guidelines which are significant for the current development.
- Select the most adequate sets of guidelines.
- Remove guideline overlaps and solve conflicts.
- Verify the coherence of the selected sets of guidelines.
- Analyse the applicability of the selected guidelines in the current development.
- Develop directly applicable design rules from the selected guidelines.
- Plan and perform frequent accessibility evaluations based on the selected sets of guidelines during the development process.

Several Guidelines Management Tools have been developed in order to facilitate the development process of accessible web applications. SIERRA [Vanderdonckt, 95] is one of the first approaches for managing usability knowledge by a software tool. However, this tool does not support any evaluation process. Sherlock [Grammenos, 00] manages usability guidelines by a client-server system and evaluates automatically only some of the defined guidelines. Another system, called GUIDE, for managing usability guidelines and storing the guidelines applied for a particular application development is presented in [Henninger, 00]. Nevertheless, none of this approaches support completely the development process.

More recent approaches, such as Mariage et al. [Mariage, 04] and Leporini et al. [Leporini, 06] are useful throughout the development process of web applications including the evaluation stage. Both aim at abstracting the interaction with accessibility guidelines with graphical interfaces. Unfortunately, both are standalone applications which have some drawbacks compared with a web application. Moreover, the guideline formats used by these applications are not proven to have been developed based on the results obtained from an analysis of the different types of sets of guidelines. Therefore, some guidelines may not be adequately evaluated or either specified.

In addition, many automatic web accessibility evaluation tools have been developed [http://www.w3.org/WAI/ER/tools/] [Ivory, 03]. Most of them evaluate predefined sets of general purpose accessibility guidelines such as WCAG 1.0, Section 508, etc. In addition, there are few tools which also allow evaluating other sets of guidelines more specific to the type of web application or users' characteristics [Vanderdonckt, 05] [Leporini, 06].

Another important activity when developing web applications is their quality assurance. It is essential to develop high quality web applications. This implies the necessity of applying metrics, methods and quality models in their development process. Web accessibility has to be also integrated in this activity in order to develop accessible web applications.

Some quality models have been defined due to the specific characteristics of web applications such as the 2QCV3Q [Mich, 03] and the WebQEM [Olsina, 02] quality models. The characteristics of web applications and the necessary metrics for their evaluation are included in these models. However, none of these models consider

accessibility as an essential property of web applications since it is included as an attribute of other properties.
Therefore, methods for evaluating and metrics for measuring the accessibility property of web applications are necessary for quality assessment and analysing the evolution of their accessibility level. In the last few years, several quantitative metrics for measuring web accessibility have been defined. Sullivan & Matson [Sullivan, 00] evaluate only eight checkpoints from WCAG 1.0. The so-called "failure-rate" is a proportion between potential errors and real errors. Hackett et al. [Hackett, 04] proposed the WAB formula (Web Accessibility Barrier). This formula uses as input parameters the total pages of a website, total accessibility errors as well as potential errors in a web page and error priority. Bühler et al. [Bühler, 06] propose a novel approach in order to adapt measurement to different disabilities groups. However, these metrics are still in a developing stage until better results are obtained. Fukuda et al. [Fukuda, 05] defined accessibility metrics for blind people such as navigavility and listenability.

5 Framework for Accessible Web Applications Development

The previously presented tools and methodologies for accessible web applications development do not cover all the development process since they just focus on specific phases of the lifecycle. Most of the existing tools focus on evaluation procedures and therefore their integration in a development environment gives a partial, incomplete solution. Web developers are not provided with any unified interface to easily integrate accessibility regarded activities in development environments. Therefore, they are forced to deal with several interfaces and interpret several output formats which might not be interoperable. These constraints lead web developers to forget accessibility issues throughout the development process and consider them only when the web application is in the last implementation stages. Thus, repairing accessibility errors in late iterations requires major changes.
We have implemented several tools and techniques which cover different activities in the lifecycle of web applications. These tools can be easily integrated with other development tools to conform a comprehensive framework for accessible web applications development.
In the following sections, we highlight the activities which have to be carried out regarding web accessibility. Tools, techniques, methods and models which will be useful in each stage of the lifecycle are also included. In addition, we meet some of these requirements by means of developed prototypes, and techniques to implement sound methods.

5.1 Analysis Phase

In this stage a user-centered approach concerning the analysis of end-users' specific characteristics is the main activity to be carried out regarding accessibility. In some cases, these features are known, for example, when developing a web application for a intranet. However, there are other situations where the objective will be to develop a web application which can be accessed by all groups of users independently of their abilities and characteristics. In these cases, it is essential to elaborate user profiles

which contain the necessary characteristics so as many as possible different groups of users are included. However, as stated by Abascal and Nicolle [Abascal, 05] the broad diversity of users and disabilities makes it difficult the inclusion of all potential users. "Universal Design" guidelines and techniques have to be considered in order to create user profiles which do not exclude any group of users. Therefore, it is essential to perform an exhaustive analysis of the existing sets of guidelines in order to select the most appropriated according to the type of web application to develop and end-users' characteristics. Activities regarding accessibility are the following:

- Analysis of end-users' features and characteristics of application.
- Bear in mind "Design for All" paradigm to avoid creating excluding user profiles.
- Analysis and selection of guideline-sets to be applied in the development.

The process of seeking for adequate guidelines is of great significance as the selected sets will be considered during all the development process. Since the sets of guidelines could be published in diverse formats, their automatic manipulation is a challenging task. In this sense, we have designed an XML-based uniform language for the representation of guidelines. Further information can be obtained in [http://sipt07.si.ehu.es/evalaccess3/gxml.xsd] [Arrue, 07a]. In addition, we have developed a framework for guidelines management [Arrue, 07b]. One of its main features consists of a guidelines search tool which makes possible performing queries depending on end-user features or application type. Therefore, it can be used as an online guidelines repository so that knowledge about web accessibility can be easily retrieved, and shared among developers. Afterwards, these guidelines sets will be useful in design stage and for evaluation purposes. Figures 3 and 4 are screenshots of the accessibility guidelines search interfaces.

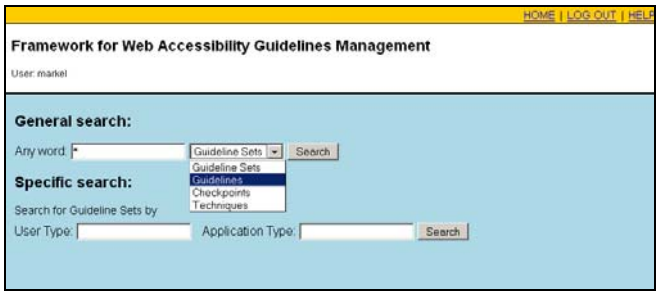


Figure 3: Guidelines, checkpoints and techniques search.

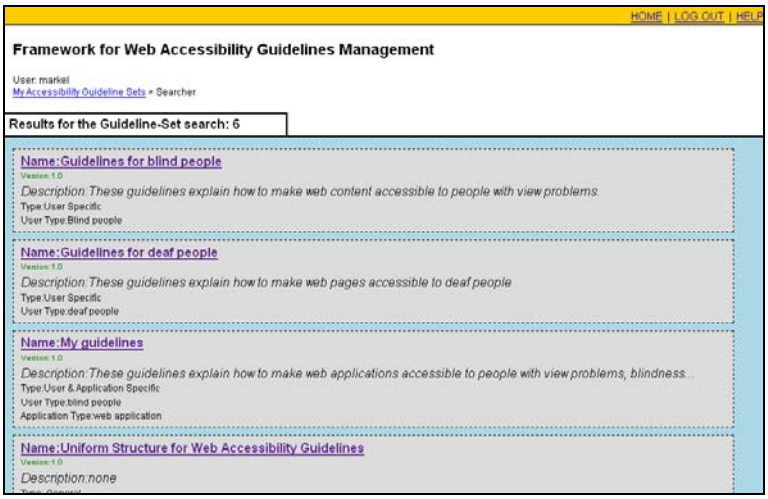


Figure 4: Guidelines search result.

5.2 Design Phase

It is essential to use adequate tools in order to model user tasks defined in the analysis phase as well as the specific features of the web application and characteristics of end-users. The navigation mechanism and transitions among the different web pages are defined in this stage. For this purpose, it is necessary to deal with the different cognitive models of the considered groups of users. In early iterations the interface is a vague approximation to what is intended to be developed, and tends to be a preliminary sketch usually drawn in sheets. Afterwards, these first drafts evolve into real web scenarios where the design is carried out using design authoring tools.

In some cases, the selected guidelines have to be interpreted by means of techniques in order to be applied. These techniques have to be identified, for example the TWCAG techniques [http://www.w3.org/TR/WCAG10-TECHS/] which implement the WCAG set of guidelines. We have developed a web application for techniques definition, Figure 5 shows a screenshot. Developers will be able to include their own interpretations of guidelines and store them for evaluation or sharing purposes. Since many web developers find guidelines definitions ambiguous and confusing, this tool allows sharing the interpretations of guidelines among developers' community and facilitates the communication between those with more expertise and novel developers. Activities regarding accessibility are the following:

- Interpretation of selected guidelines.
- Identification of techniques to apply guidelines in a correct way.
- Design and development of appropriate navigation schemas based on selected cognitive models.

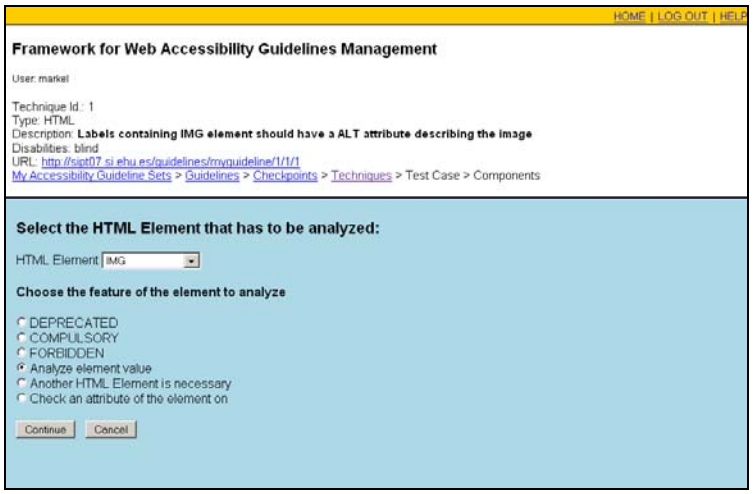


Figure 5: Including design techniques for later evaluation purposes.

5.3 Implementation Phase

The user interface should be developed in order to efficiently satisfy the needs of different groups of end-users. In this sense, it is essential to consider all the alternative content that should be included. This would guarantee that all users will be able to access most of the content. Activities regarding accessibility are the following:

- Application development according to the selected guidelines.
- Usage of adequate authoring tools.
- Implementation of a unique flexible user interface.
- Incorporation of all the necessary alternative content.

The architecture of the implemented tools facilitates their integration and the interoperability with other applications such as authoring tools. The knowledge stored in the repositories of guidelines and the results obtained by these tools is based on XML.

5.4 Evaluation Phase

The fulfillment of all the specifications defined in the analysis stage and the quality level of the final product are verified in this stage. As far as web accessibility is concerned, the evaluations performed in this stage will determine whether the web application fulfils the accessibility level specified. Therefore, diverse accessibility evaluations have to be performed in this stage in order to detect any possible barrier and fix them. Performing a comprehensive evaluation implies combining diverse kind of evaluations:

- Automatic evaluation with tools: this is a preliminary test stage aiming to remove the first and most "evident" obstacles. "Evident" means those errors automatically testable with the help of tools. According to Lang [Lang, 03], this evaluation method presents diverse advantages in terms of costs and efficiency as automatic evaluation tools yield error reports in a short period of time. The aim of this

evaluation is to clear up the content so that forthcoming evaluations with experts and users take less time and they could focus on other complex issues. An effective evaluation tool should be able to validate the fulfilment of most of the guidelines. Yet, nowadays it is a far objective since there is not enough research done to evaluate some checkpoints such as WCAG 1.0 14.1 checkpoint: "Use the clearest and simplest language appropriate for a site's content".

- Expert driven manual evaluations: as mentioned above, the evaluation of some guidelines requires human judgment. Web accessibility experts perform evaluations based on heuristics in order to evaluate this kind of guidelines. Performing main tasks in web application and carrying out walkthroughs with different browsers, assistive technologies, devices, etc., is another way of testing. These evaluation methods allow detecting accessibility barriers under different conditions of use [Brajnik, 06].
- Evaluations with users: this evaluation type is essential since it allows detecting real accessibility barriers for users with specific characteristics. Selected users should cover the broader range of disabilities if a comprehensive evaluation is required. The evaluations coincide with tasks carried out with users with the main functionalities of the web application. These evaluations take place in controlled environments such as specific laboratories where the experts can observe the actions of the users and gather information about the interaction following accepted usability evaluation techniques such as the ones described in Nielsen and Mack [Nielsen, 94] and Rubin [Rubin, 94]. However, results obtained from remote evaluations carried out in users' common browsing environment can be also useful as mentioned in [Petrie, 06]. All the problems detected should be analysed and fixed.

All these evaluations are complementary and necessary. If only automatic evaluation is carried out the fulfilment of several guidelines will not be checked and the required minimum accessibility level is seldom reached. On the other hand, evaluations with users also help finding out usability barriers which accessibility guidelines and therefore automatic accessibility evaluation tools do not consider. Activities regarding accessibility are the following:

- Accessibility evaluation with automatic tools, experts and disabled users.
- Evaluation of the quality of the web application.
- Documentation of all the detected errors.
- Repair detected errors.

Guidelines sets and techniques defined and obtained in the previous stages have to be incorporated in flexible evaluation tools. We have developed an evaluation tool that can be easily integrated into other application. Therefore, it can interact with the previously presented guidelines management tool in order to evaluate the guidelines retrieved from its repository [Abascal, 04].

5.5 Maintenance Phase

Due to the dynamic nature of the WWW, updates are frequent in web applications and the accessibility level and then the quality tends to decrease. Nowadays, these updates are commonly managed by Content Management Systems (CMS). To our best knowledge, none of the existing commercial CMS considers web accessibility issues.

Therefore, it is essential to monitor the accessibility level of the web application. This stage could be understood as the accessibility monitoring stage since the evolution/involution of accessibility should be measured. Determining whether an update has increased or decreased the accessibility level of a web application is a complex task which has to be carried out in order to fix errors and keep always its accessibility and quality level. Activities regarding accessibility are the following:

- Monitoring of the accessibility level of the web application.

We have defined web accessibility quantitative metrics [Arrue, 05] [Vigo, 07] which accurately measure the accessibility level of a web application in order to monitor its accessibility evolution. Due to the mentioned flexibility and interoperability, these metrics can be automatically calculated by a tool which has been developed with this aim. Currently, we are integrating this feature into a monitoring tool which accurately computes the evolution of the accessibility level in web applications during their lifecycle.

6 Conclusions

In the last few years, many initiatives have been launched in order to foster web accessibility. These initiatives have promulgated the elaboration of a large amount of information related to web accessibility. However, web developers find difficult to deal with all this information. Therefore, specific methodologies which guide designers developing accessible web applications are necessary. These methodologies should define the necessary accessibility regarded activities and establish an ordered process for the development tasks.

In this sense, many development methodologies have been defined with different characteristics: some of them are based on models, others are user-centered, etc. However, the defined methodologies can hardly be implemented if adequate supporting tools are not available.

This paper revises the most well-known methodologies for web applications development with an accessibility-centric perspective. In addition, it investigates the existing supporting tools. Some of the methodologies specify the techniques and tools adequate for carrying out the necessary tasks. However, there is not any adequate framework which supports all the process of accessible web application development. Consequently, developers are forced to use diverse tools with different interfaces and information formats.

This paper proposes several tools we have implemented to facilitate the development process. They are useful to perform specific accessibility regarded activities and can be easily integrated to generate a more comprehensive development framework.

References

[Abascal, 04] Abascal, J., Arrue, M., Fajardo, I., Garay, N. and Tomas, J. (2004). Use of Guidelines to automatically verify web accessibility. International Journal on Universal Access in the Information Society (UAIS), Vol. 3, No. 1, pp. 71-79.

[Abascal, 05]Abascal, J., Nicolle, C. (2005). Moving towards inclusive design guidelines for socially and ethically aware HCI. Interacting with Computers. Vol. 17, No. 5, pp. 484-505

[Arrue, 05] Arrue, M., Vigo, M. and Abascal, J. (2005). Quantitative Metrics for Web Accessibility Evaluation. Proceedings of the ICWE 2005 Workshop on Web Metrics and Measurement. University of Wollongong School of IT and Computer Science.

[Arrue, 07a] Arrue, M, Vigo, M, Abascal, J. (2007). Including heterogeneous web accessibility guidelines in the development process. In Proceedings of Engineering Interactive Systems 2007. (In press).

[Arrue, 07b] Arrue, M, Vigo, M, Aizurua, A, Abascal, J. (2007). Accessibility Guidelines Management Framework. In Proceedings of International Human-Computer Interaction 2007. (In press).

[Brajnik, 00] Giorgio Brajnik. Automatic web usability evaluation: what needs to be done? In Proc. Of 6th Human Factors and the Web Conference, June 2000, Austin, Texas.

[Brajnik, 06] Brajnik, G. (2006). Web Accessibility Testing: When the Method Is the Culprit. Computers Helping People with Special Needs. Lecture Notes in Computer Science 4061. pp 234-241

[Bühler, 06] Bühler, C., Heck, H., Perlick, O., Nietzio, A., and Ullveit-Moe, N. Interpreting Results from Large Scale Automatic Evaluation of Web Accessibility. In K. Miesenberger et. al (Eds.). Computers Helping People with Special Needs 2006. Lecture Notes in Computer Science 4061. Springer, 184-191.

[Ceri, 00] S. Ceri, P. Fraternali, A. Bongio. Web modeling language (WebML): a modeling language for designing web sites. Computer Networks, Vol. 33 No. 1-6, pp. 137-157, 2000.

[De Troyer, 05] De Troyer, O., Casteleyn, S., Plessers, P.: "Using ORM to Model Web Systems", In On the Move to Meaningful Internet Systems 2005: OTM 2005 Workshops, International Workshop on Object-Role Modeling (ORM'05), pp. 700-709, Publ. Lecture Notes in Computer Science 3762 Springer 2005.

[De Troyer, 98] O. M. F. De Troyer , C. J. Leune, WSDM: a user centered design method for Web sites, Computer Networks and ISDN Systems, v.30 n.1-7, p.85-94, April 1, 1998

[Fraternali, 00] Piero Fraternali and Paolo Paolini. Model-driven Development of Web Applications: The Autoweb System. ACM Transactions on Information Systems (TOIS), Vol. 18, No. 4, pp. 323-382 (2000).

[Fraternali, 99] Piero Fraternali. Tools and Approaches for Developing Data-Intensive Web Applications: A Survey. ACM Computing Surveys, Vol. 31, No. 3, pp. 227-263, 1999.

[Fukuda, 05]Fukuda, K., Saito, S., Takagi, H., Asakawa, C. (2005). Proposing new metrics to evaluate web usability for the blind. Extended Abstracts Proceedings of the 2005 Conference on Human Factors in Computing Systems, CHI 2005, pp. 1387-1390

[Garzotto, 93] Garzotto, F., Paolini, P., and Schwabe, D. HDM: A model-based approach to hypertext application design. ACM Transactions on Information Systems (TOIS), Vol. 11, No. 1, pp. 1-26. 1993.

[Garzotto, 95] Franca Garzotto, Luca Mainetti and Paolo Paolini. Hypermedia Design, Analysis, and Evaluation Issues. Communications of the ACM, Vol. 38, No. 8, pp. 74-86. 1995.

[Ginige, 01] Ginige, A., Murugesan, S. (2001). Web engineering: A methodology for developing scalable, maintainable web applications. Cutter IT Journal. Vol. 14, No. 7, pp. 24-35

[Ginige, 01]Ginige, A. and Murugesan, S. (2001). Web Engineering – An introduction, Special Issue on Web Engineering, IEEE Multimedia. Vol. 8 No.1, pp. 14-18

[Grammenos, 00] Dimitris Grammenos, Demosthenes Akoumianakis, Constantine Stephanidis. (2000). Integrated support for working with guidelines: the Sherlock guideline management system. Interacting with Computers. Elsevier. Vol. 12, No. 3, pp. 281-311.

[Granollers, 04] Toni Granollers. MPIu+a. Una Metodología que Integra la Ingeniería del Software, la Interacción Persona-Ordenador y la Accesibilidad en el Contexto de Equipos de Desarrollo Multidisciplinares. PhD dissertation. Universidad de Lleida. 2004.

[Hackett, 04] Hackett, S., Parmanto, B., Zeng, X. (2004). Accessibility of Internet websites through time. In Proceedings of 6th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 32-39

[Henninger, 00] Scott Henninger. (2000). A methodology and tools for applying context-specific usability guidelines to interface design. Interacting with Computers. Elsevier. Vol. 12, No. 3, pp. 225-243.

[Henry, 04] S.L. Henry, M. Grossnickle, Accessibility in the User - Centered Design Process, Georgia Tech Research Corporation, 2004, Available at http://www.uiaccess.com/accessucd/

[Hoffman, 05] Hoffman, D., Grivel, E., Battle, L. (2005). Designing software architectures to facilitate accessible Web applications. IBM Systems Journal. Vol. 44, No.3, pp. 467-483

[Isakowitz, 95] T. Isakowitz, E. A. Stohr, P. Balasubramanian, RMM: a methodology for structured hypermedia design. Communications of the ACM, Vol 38, No. 8. pp. 34-44. 1995.

[ISO/IEC, 99] ISO/IEC. 13407 Human-Centred Design Processes for Interactive Systems, ISO/IEC 13407:1999 (E), 1999.

[Ivory, 03] Ivory, M.Y. (2003). Automated Web Site Evaluation: Researchers' and Practitioners' Perspectives. Kluwer Academic Publishers. Dordrecht, The Netherlands.

[Jeschke, 06] Sabina Jeschke, Helmut Vieritz. Accessibility and Model-Based Web Application Development for eLearning-Environments. In Proceedings m-ICTE 2006. Current Developments in Technology-Assisted Education, pp. 1161-1165. FORMATEX, 2006.

[Jokela, 03] Timo Jokela, Netta Iivari, Juha Matero, Minna Karukka. The standard of user-centered design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. In Proceedings of the Latin American conference on Human-computer interaction, pp.:53 – 60. 2003.

[Kappel, 06]Kappel, G., Pröll, B., Reich, S., Retschitzegger, W. (2006). An Introduction to Web Engineering. Web Engineering The Discipline of Systematic Development of Web Applications. John Wiley & Sons. pp. 1-21

[Lang, 03]Lang, T. (2003). Comparing website accessibility evaluation methods and learnings from usability evaluation methods. Available at http://www.peakusability.com.au/pdf/website_accessibility.pdf

[Lazar, 04] Lazar, J., Dudley-Sponaugle, A., Greenidge, K. (2004). Improving Web Accessibility: A Study of Webmaster Perceptions. Computers and Human Behavior. Vol. 20 No. 2, pp. 269-288

[Leporini, 06] Leporini B., Paternò F., and Scorcia, A. (2006). An Environment for Defining and Handling Guidelines for the Web. In K. Miesenberger et al. (Eds.). Computers Helping People with Special Needs. LNCS 4061. Springer, pp. 176-183.

[Leporini, 06]Leporini, B., Paternò, F., Scorcia, A. (2006). Flexible tool support for accessibility evaluation. Interacting with Computers. Vol. 18, No.5, pp. 869-890

[Maguire, 01] Martin Maguire. Methods to Support Human-Centred Design. International Journal of Human-Computer Studies, 2001. Vol. 55, No. 4, pp. 587-634.

[Mariage, 04] Mariage, C. and Vanderdonckt .(2004). Creating Contextualised Usability Guides for Web Sites Design and Evaluation. In R. Jacob et al. (Eds). Proceedings of the 5th International Conference on Computer-Aided Design of User Interfaces, CADUI 2004, pp. 147-158.

[Mayhew, 99] Mayhew, D.J. The Usability Engineering Lifecycle: A Practitioner's Handbook for User Interface Design. Morgan Kaufman. 1999.

[Mendes, 06] Mendes, E., Mosley, N., Counsel, S. (2006). The need for Web Engineering: An Introduction. Web Engineering. Springer, pp. 1-27

[Mich, 03] Mich, L., Franch, M. Gaio, L. (2003). Evaluating and Designing the Quality of Web Sites. IEEE MultiMedia. Vol. 10, No. 1, pp. 34-43

[Montero, 03] Susana Montero, Paloma Díaz, Ignacio Aedo. A Framework for the Analysis and Comparison of Hypermedia Design Methods. In Proceedings of The 21st IASTED International Multi-Conference on Applied Informatics (AI 2003), M. H. Hamza (Ed.), pp. 1053-1058, February 10-13, 2003, Innsbruck, Austria.

[Murugesan, 02] Murugesan, S., Deshpande, Y. (2002). Meeting the challenges of web application development: the web engineering approach. Proceedings of the 24th International Conference on Software Engineering, ICSE 2002. pp. 687-688

[Murugesan, 05]Murugesan, S. and Ginige, A. (2005). Web Engineering: Introduction and Perspectives. Web Engineering: Perspectives and Techniques. Idea Group, pp. 1-30

[Nielsen, 93] Nielsen, J. Usability Engineering. Academic Press Professional, Boston, MA. 1993.

[Nielsen, 94] Nielsen, J., Mack, R. (1994). Usability Inspection Methods. John Wiley & Sons, NY.

[Olsina, 02]Olsina, L. and Rossi, G. (2002). Measuring Web Application Quality with WebQEM. IEEE Multimedia. Vol. 9, No. 4, pp. 20-29

[Pemberton, 03] Pemberton, S. The Kiss of the Spiderbot. ACM Interactions, Vol. 10, No. 1. 2003, pp. 44

[Petrie, 06] Petrie, H., Hamilton, F., King, N. and Pavan, P. (2006). Remote usability evaluations with disabled people. Proceedings of the SIGCHI conference on Human Factors in computing systems, CHI 2006, pp. 1133-1141

[Plessers, 05] P. Plessers, S. Casteleyn, Y. Yesilada, O. De Troyer, R. Stevens, S. Harper, C. Goble, Accessibility: A Web Engineering Approach, In Proceedings of the 14th International World Wide Web Conference (2005) 353-362.

[Rubin, 94] Rubin, J. (1994). Handbook of Usability Testing. John Wiley & Sons, NY.

[Schwabe, 95] Daniel Schwabe and Gustavo Rossi. The Object-Oriented Hypermedia Design Model. Communications of the ACM, Vol. 38, No. 8, pp. 45-46. 1995.

[Sommerville, 92] Sommerville, I. (1992). Software engineering. Addison-Wesley, Reading , MA

[Stephanidis, 01] Stephanidis, C. (2001) The concept of Unified User Interfaces. In: C. Stephanidis (ed.) User Interfaces for All - Concepts, Methods, and Tools, 371-388. Lawrence ErlbaumAssociates.

[Stephanidis, 98] Stephanidis, C., Akoumianakis, D., Sfyrakis, M., & Paramythis, A. (1998). Universal accessibility in HCI: Process-oriented design guidelines and tool requirements. In C. Stephanidis & A. Waern (Eds.), Proceedings of the 4th ERCIM Workshop on User Interfaces for All, pp.

[Sullivan, 00] Sullivan, T., Matson, R. (2000). Barriers to use: usability and content accessibility on the Web's most popular sites. ACM Conference on Universal Usability. Proceedings of the 2000 conference on Universal Usability, pp. 139-144

[Vanderdonckt, 05]Vanderdonckt, J. and Bereikdar, A. (2005). Automated Web Evaluation by Guideline Review. Journal of Web Engineering. Rinton Press. Vol. 4, No. 2, pp. 102-117

[Vanderdonckt, 95] Jean Vanderdonckt. (1995). Accessing guidelines information with Sierra. In K. Nordby, P. H. Helmersen, D. J. Gilmore, S. A. Arnesen (Eds.). Proceedings of IFIP TC13 International Conference on Human-Computer Interaction. INTERACT '95, pp. 311-316.

[Velleman, 06] E. Velleman, C. Velasco, M. Snaprud, D. Burger (Eds.), Unified Web Evaluation Methodology (UWEM 1.0), 2006, Available at http://www.wabcluster.org/uwem1/UWEM_1_0.pdf

[Vigo, 07] Vigo, M. , Arrue, M., Brajnik, G., Lomuscio, R., Abascal, J. (2007). Quantitative Metrics for Measuring Web Accessibility. International Cross-Disciplinary Conference on Web Accessibility 2007. (Accepted for publication)

[Yesilada, 04] Yesilada, Y., Harper, S., Goble, C., Stevens, R. Screen Readers Cannot See (Ontology Based Semantic Annotation for Visually Impaired Web Travelers). In Proceedings of the International Conference of Web Engineering ICWE 2004, pp. 445-458.

Learner Course recommendation in e—learning based in Swarm Intelligence

Ana-Belén Gil, Francisco J. García
Department of Computer Science, Sciences Faculty
University of Salamanca
Plaza de la Merced s/n. 37008 Salamanca (Spain)
abg@usal.es , fgarcia@usal.es

Abstract: This paper analyse aspects about recommendation process in distributed information systems. It extracts similarities and differences between recommendation in e-stores and the recommendation applied to an e-learning environment. Also explain the phenomena of self-organization and emergence cooperative in complex systems coupled with bio-inspired algorithms to improve knowledge discovery and association rules. Finally, present recommendation applied to e-learning by proposing recommendation by emergence in Multi-Agent System architecture.

Keywords: Recommendation, E-learning, Multi-agent System, Emergence, Swarm Intelligence

Categories: E.4., H.3., H.4., I.2., J.7.

1 Introduction

The continued growth and increasing complexity of Web-based applications, from traditional e-commerce, to Web services, to all kind of dynamic content providers; has led to a proliferation of searching tools. Personalized services, such as recommender systems, help engage visitors, turn casual browsers into customer, or help visitor to more effectively locate pertinent information. The goal of any recommendation in any ground is to make a selection between all the possible items by using some attributes predefined by the context. Customers' preferences toward particular features of products (from books to learning objects) are analyzed by different techniques and then rules of customer interest profiles added with context are derived in order to do the recommendation [Berlanga et al, 2005]. Thus, in general, recommendation processes are defined as result of several small parameters all together in continuous interaction.

As we go into complex systems, we detect important characteristics that we identify in recommender systems. Emergent behaviour in complex systems can be seen in recommendation systems also. User behaviour in the decision process is determined not by a global control but instead by the interactions with the

environment. The user has to deal with spread amount of partial information. Both are then distributed, large, open, and heterogeneous.

Recommendation process in e-commerce is the task to select and organize the services relevant to the user is interested in. Our approach uses ontological domain knowledge's to do this task. Domain ontologies are valuable in the explicit knowledge services representation and in extracting relevant domain semantics to the user profile. The services are semantically defined (OWL-S [5], provides all the information Web Services need to interact) and then could be turned into agents semantically noted with their characteristics. Complex dynamic processes in recommendation turn into simple agent interactions in the environment.

The purpose of this paper is to present relations between recommenders and complex systems a new architecture to support recommendation in e-learning working with Learning Objects (LOs). The paper that began with this introduction is organized as follows: Section 2 explains a recommendation perspective summarizing technologies and grounds as e-commerce and e-learning. Section 3 presents the complex systems characteristics and how to accomplish with multi-agent systems implementation due collective behaviour that emerges by a bio-inspired approach. Section 4 introduces the proposed agent-based e-learning architecture. Finally, Section 5 closes the paper, presenting our conclusions and some ideas on further work.

2 The Recommendation Perspective

Before the appearance of Service Oriented Architecture [WSA, 2004], all information was residing in static pages on Internet. Then, search engines commonly find thousands of potentially relevant sites. Throw some applications, a user is required to specify his goals in terms of a query which was then compared (typically at a simple keyword level) with documents in a collection and those likely to be most related to the query and thus potentially relevant to the user. The Artificial Intelligence (AI) community, there has been a great deal of work on how AI can help to solve this problem. Notions of personalized search engines, intelligent software agents, and recommender systems gained large acceptance among users for the task of assisting them in searching, sorting, classifying, filtering and sharing the vast amount of information available on the Web. The combination of the modelling of preferences of particular users, building content models, and the modelling of social patterns in intelligent agents provides users with means for managing information in a rational way, and, thus, helping to overcome the information overload.

Nowadays with the Semantic Web develop we will be called to provide access not just to *static documents* that collects useful information, but also *services* that provides new ways to offer information while new process model to afford it. Service retrieval technology has emerged, but the information retrieval community has focused on the retrieval of documents, not exactly services, and has as a result emphasized keyword-based approach. As the number of such services increase it will become increasingly important to provide tools that allow people (and software) to quickly find the services they need attending personalized selection.

2.1 Recommenders in E-commerce

These tools in the EC environment act as a specialized seller for the customer, then usually added with personalization abilities for each user, based on the analysis of their preferences and interests. The recommenders mainly relied on user interfaces, techniques of marketing and large amounts of information about others customers and products for offering the right item to the right customer [Gil and García, 06]. The recommenders are the fundamental elements in sustaining the usability and site confidence [Egger, 01] that confers them an important role in the designing of any market place [Spiekermann and Paraschiv, 02]. EC recommenders are gradually becoming powerful tools for EC business [Gil and García, 03] covering complex mechanism mainly in order to supporting user's decision process by allowing the analogical reasoning by the human being. Recommenders in e-commerce need then for developments in several grounds as HCI, Data-mining, cognitive sciences or marketing. EC Sites have made a big effort to supply the customer with tools for making easier the shopping on the Net. The need for facilitate user in EC goes along understanding consumer's behavior in order to facilitate and personalized access to the big amount of information needed to search and assimilate before make any purchase.

There are a large number of recommenders with personalization aspects over Internet. A comprehensive overview of recommenders on e-commerce is found in ([Sarwar et al, 2000], [Shafer et al, 2001], [Montaner et al, 2003]). A rough classification can be made based on the kind of information and the way the recommendation system handles this information to operate. If we consider the purchase system, the consumer's communities or a hybrid of the two as the primary element for building the recommendation, we outline three categories.

1. **Collaborative-Social-filtering systems** build the recommendation by the aggregation of consumer preferences. These kinds of systems make matching to other users based on similarity in behavioural or social patterns. The statistical analysis of data extraction or data mining and knowledge discovery in databases (KDD) techniques (monitoring the behaviour of user over the system, ratings over the services, purchase historical, etc.) build the recommendation by analogies with many other users. Similarities between users are computed using the user-to-user correlation. This technique finds a set of "nearest neighbours" for each user in order to identify similar liking. Some collaborative filtering systems are Ringo [Shardanand and Maes, 1995] or GroupLens [Konstant et al, 1997]. The above technique suffers mainly from problem of sparsity due to the need for a large volume of users in relation to the volume of items offered (critical mass) for providing appropriate suggestions. Also is impossible the offer for new services because as never had been purchased before they no enter in the dynamic till they are choose for a large amount of people before.

2. **Content-based-filtering systems** extract the information for the suggestions based on the items the user has purchased in the past. These kinds of systems use supervised machine learning to induce a classifier to discriminate between interesting or uninteresting services for the user due to her

purchases' history. Classifiers may be implemented using many different techniques from artificial intelligent as neural networks, Bayesian networks, inducted rules, decision tree, etc. The user model is represented by the classifier that allows the system to weight the like or dislike for the item. This information identifies the more weighted items that will be recommended to the user. Some content-based systems also use item-to-item correlation in order to identify association rules between items, implementing the co-purchase item. Some example are [Mooney and Roy, 2000], or Syskill & Webert [Pazzani et al, 1996], where a decision tree is used for classifying web documents attending some content domain on a binary scale or the well-known recommendation mechanism for the second or third item in Amazon. The above technique suffers mainly from the problem of over-specialization because the consumer is driven to purchase the same kinds of items that they have already purchased. This is a problem also for recommending new articles in the store (no consumer have brought this item before).

3. **Knowledge-based systems** can be understood as a hybrid between collaborative-filtering and content based systems but also extended. It builds the knowledge about users linked also with the services knowledge. This information is used to reason what meets the user's requirements with the item. The relation between services and clients leads to inferences that build the knowledge in the EC engine. Several papers ([Balabanovic et al, 1997], [Shafer et al, 2001], [Hayes et al, 2002]) show the benefits of these systems. Some of these systems provide new solutions for the information filtering based on trust.

2.2 Technologies in Recommendation

As the problem of recommendation is very spread, attending different aspects to solve we can identify mainly two technological way to abroad it. The Web mining and the agent based technologies. Both are further working into additional computer science fields, such a as AI.

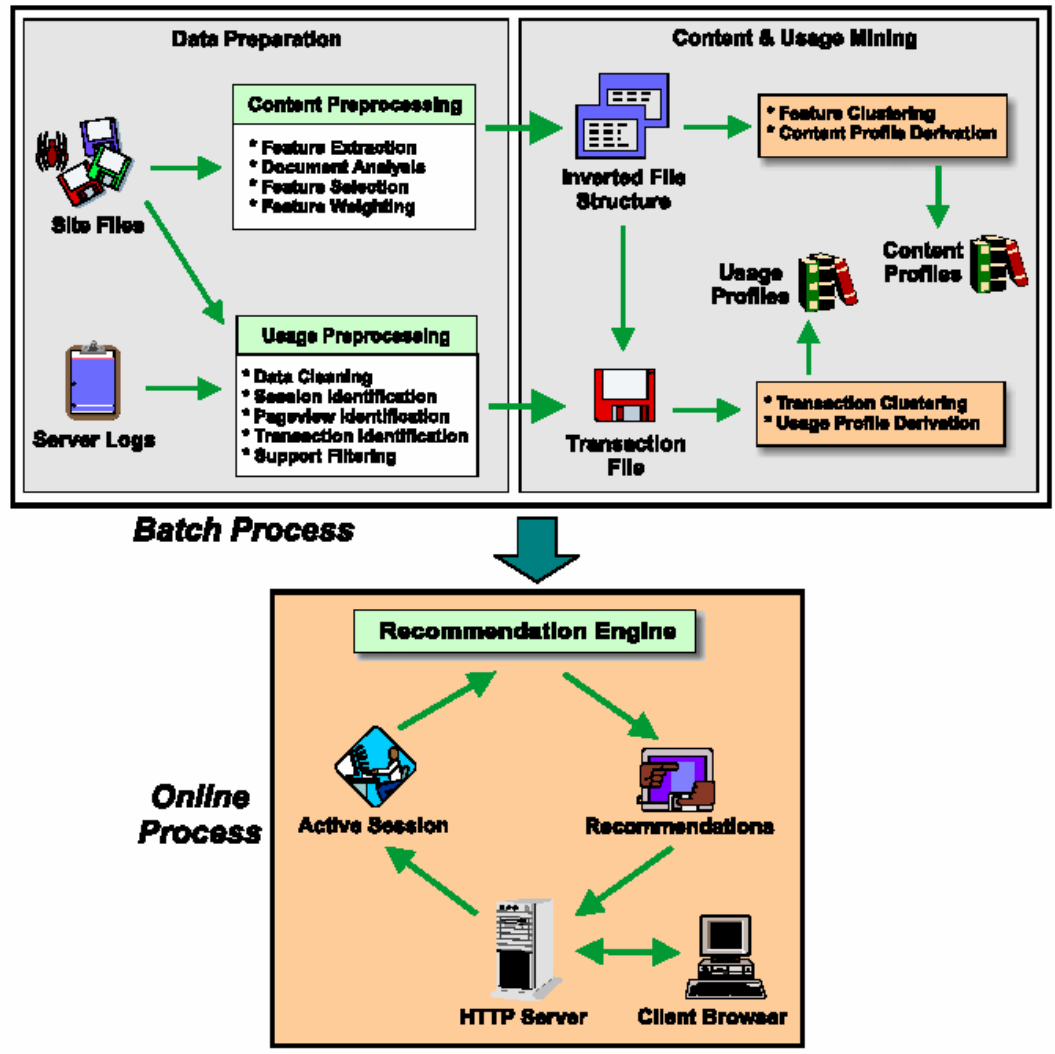


Figure 1: A general framework for automatic personalization based on Web Mining [Mobasher et al, 2000]

Web mining is the extraction of interesting and useful knowledge and implicit information form artifacts or activity related to the Web. Web servers record and accumulate data about user interactions whenever requests for resources are received. Analyzing the Web access logs can help understand the user behaviour. User profiles are built by combining user's navigation paths with other data features, such a page viewing time, hyperlink structure, and page content. A comprehensive overview of Web usage mining research (using access logs and mined logs by associating rules

and clusters) is found in [Cooley, 2000], [Mobahed et al, 2000] and [Srivastava et al, 2000].

Another way to information retrieval is agent based applications to filter and present relevant information for user we want to give relevance, due our work, to these applications based on *ecosystems of adaptive multiagent systems*. A classical view of the agent system mediated architecture is presented in next figure.

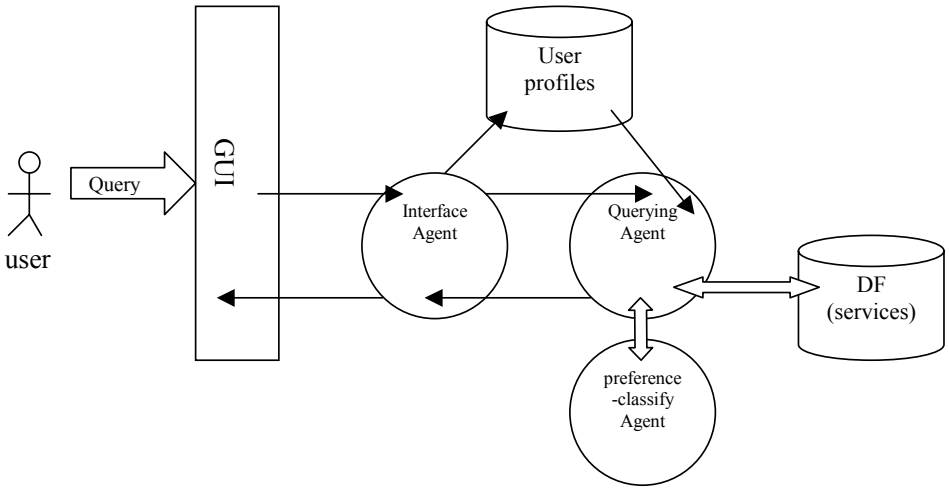


Figure 2: Architecture Agent based for the recommender system

Sheth and Maes, [Sheth and Maes, 1993] implemented an ecosystem architecture of agents to filter Internet News in a system called Newt. A genetic algorithm uses algorithmic analogues to the genetic crossover and mutation operations to generate candidate profiles that inherit useful features from their ancestors, and uses competition to identify and retain the best ones. The crossover operator was periodically applied to combine segments of two candidate profiles which were among those that had produced the highest ranks (using a cosine similarity measure) for articles that the user later identified as desirable. A mutation operator was sometimes applied to the newsgroup name to explore whether existing candidate profiles would perform well on newsgroups with similar names. All of the candidate profiles contributed to the ranking of the documents shown to the user, although those, which consistently performed well, contributed more strongly to the ranking. Hence, the profile itself was determined by the population of candidate profiles, rather than by any individual candidate.

A similar approach was implemented in Amalthaea [Moukas, 1997] by creating an artificial ecosystem of evolving agents that cooperate and compete in a bounded resource environment. New agents are created by crossover or mutation (or both). Both operators are applied to the evolvable part of the agents, the genotype. The other part of the agents, the phenotype contains information that should not be evolved, usually instructions on how to handle the evolvable part. The two point crossover

operator works as follows: given two agents returns two new agents that inherit a part of the keyword vectors of the parents. The operator randomly selects two points in the keyword vector and exchanges all the fields of the two parents that lie between these points, creating two new agents. Mutation is another method for creating offspring agents. The mutation operator takes the genotype of an agent as argument and creates a new agent that is a randomly modified version of its parent. The weights of the mutated keywords are modified randomly while the new mutated keyword is a randomly selected keyword from an agent that belongs to another cluster. The Fab [Balabanovic and Shoham, 1997] and PSUN [Sorensen and McElligot, 1995] systems also implemented this architecture.

However the size and complexity of data increases with the syntactical level in recent web advanced. Among the most important Web resources are those that provide services. By 'service' we mean Web sites that do not merely provide static information but allow one to effect some action or change in the world, such as the sale of a product or the control of a physical device. The Semantic Web should enable users to locate, select, employ, compose, and monitor Web-based services automatically.

The generalized term Web Service actually, does not describe a coherent or necessarily consistent concept. More than this appears a new paradigm for the Web by covering the set of technologies, architectures, aspects at different levels of the e-Market or any kind of vision in which software entities become offered and consumers of information. It is often used loosely to denote a collection of related technologies, which include: SOAP (Simple Object Access Protocol), Web Services Description Language (WSDL), OWL-S (Ontology Web Language Service), Universal Description, Discovery and Integration (UDDI), etc. The term Web Service determines any perspective in which entity software offers information to other one [Gil, 2004].

That means to model and stored the user model and the content attributes metadata information using standard specifications with metadata structures based on XML. New analysis tools may prove inadequate and more intelligent techniques coupled with metadata treatment appearing recommendation process applied to Web Semantic Services recommendation resumed in next figure.

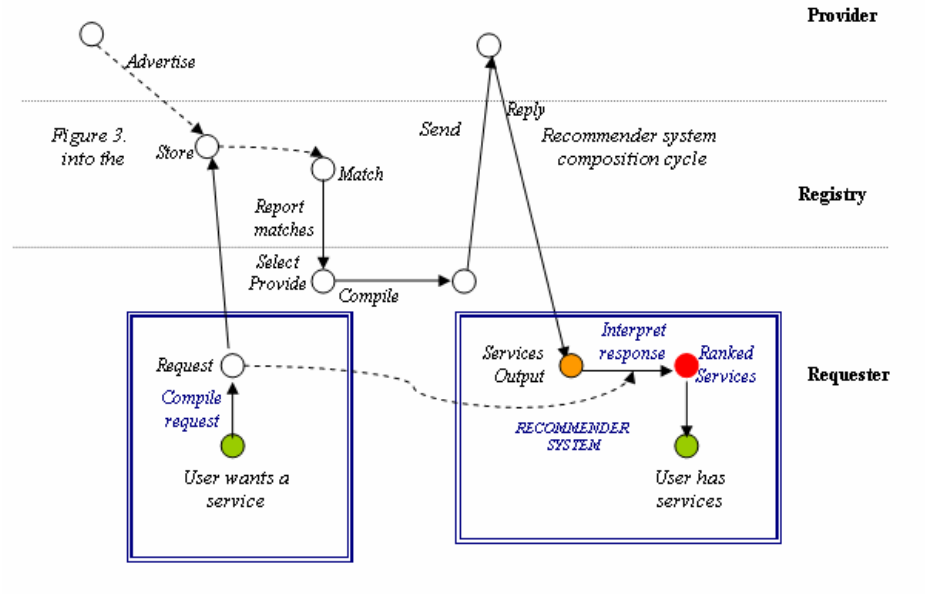


Figure 3. Recommender system into the composition cycle

2.3 Recommenders in E-learning

The encreasing number of e-learning resources implies that a dynamic educational on-line infrastructures would be needed to manage efficiently all the educational services and elements. E-learning recommendation system that would recommend a learning element to a learner based on the tasks already done by the learner and their successes, and based on tasks made by other ”similar” learners.
The similarity of the learners could be established using user profiles, or could be based on common previous access patterns as we explain in e-commerce but now the context is quite different, because the appearance of a new role, the tutor. The aim of any learning process is to acquire some contents and the path is stronger that just to by a book.

Metadata Categories	Metadata Elements
1.General	1.2 Title 1.4 Description, 1.5 Keywords, 1.6 Coverage,
5.Educational	5.1 Interactivity Type, 5.2Learning Resource Type, 5.3 Interactivity Level,

	5.4 Semantic Density, 5.6 Context, 5.7 Typical Age Range, 5.8 Difficulty, 5.9 Typical Learning Time, 5.10 Description, 5.11 Language
7.Relation	7.1 Type, 7.2 Resource,
8.Annotation	8.3 Description,
9.Classification	9.1 Purpose, 9.2 Taxon Path 9.2.1 Source 9.2.2 Taxon 9.2.2.1 Id 9.2.2.2 Entry 9.3 Description 9.4 Keyword

Table 1. Metadata categories and elements suggested for LOs management

As consequence of Semantic Web, an important contribution from computer science to knowledge management and e-learning systems is the learning object (LO) concept. This element has characteristics of independent units, which are able to be reused for other educational situations and platforms. Each one of LOs has metadata (data about data) for their description and administration. In this way it is possible to know what kind of LO we are trying. LOs are characterized by the separation of their content and presentation, for this reason an important issue to consider evaluating and filter them extracting a recommedation based in their metadata information. Metadata based on IMS specifications, IMS LOM [IMS LOM, 2006], provide LOs information to their description and managing, in this way it is possible to know if their characteristics are suitable for other educational situations. The specification includes conformance statements for how meta-data documents must be organized and how applications must behave in order to be considered LOM-conforming.

According to this, knowledge management for e-learning based on reusable units of learning means the possibility to access specific content according to the learners' needs [Morales et al, 2006]. This stage is possible due to standards, which were established as an attempt to avoid interoperability platform problems. To meet these requirements these elements should satisfy a diverse range of requirements including personalization and adaptation. All these caracteristics are well-known in e-commerce recommenders.

To support the teaching and learning process through e-learning systems there are a lot of KMS possibilities, such as delivering and evaluating courses, etc. ([Rosenberg, 2001]; [Avgeriou, 2003]). However, according to LOs and standards capabilities, it is necessary to consider how to manage quality LOs, taking into account their characteristics (See Table 1).

We outline the big importance of the recommenders in E-Learning, while we augur a big growth of these tools through the expansion of the Semantic Web

3 Multi-Agent System in Complex Systems Implementation

Complex system consists of a large number of interacting units, which when studied in a global perspective could be seen to possess important redundant features and analogies. Further, a complex system is inherently stochastical in its extensive spatiotemporal universe and hence, some of its features could manifest as patterns occurring more frequently than others. These occurrences brings into patterns specifying the repeated aspects of the complex system appearing the emergence phenomenon. In order to describe the relation between individual dynamic for each unit that becomes into a collective dynamic when interacting, appears the term self-organization ([Biebricher et al., 95] , [Bonabeau et al., 99]). The Self-organization phenomenon arises as spontaneous formation by evolution and differentiation of complex order structures forming in non-linear dynamic systems by way of feedback mechanisms involving the elements of the systems. But by far, more crucial is that interacting components in complex systems bring the global structure using only local information, without reference to the global pattern is forming.

In order to build and study these kinds of complex systems, the multi-agent systems (MAS) deal with aspects of cooperation, coalition formation and some others characteristics that fit with the complex systems description. Each agent has incomplete information or capabilities, no global system control, decentralized data, asynchronous computation and social ability.

In a very general sense, the elements of the system are treated as multi-agents, relatively autonomous entities which have a set of different rules to interact with each other. The interaction rules may also be associated with local variables, reducing direct communication among agents which in turn must be hardly influenced by the environment changes with the flexibility and needed permeability. By changing the rules of interaction or the influence of the environment during the simulation, one might be able to observe different kinds of collective dynamics and the emergence of new system properties not readily predicted from the basic equations.

Different variations of multi-agent models are applied to simulate socio-economic processes, ecological dynamics, human structure formation, transportation and industrial dynamics, etc. ranging models from ecology to engineering and to artificial life. In order to endow the agents in the complex systems with a communication mechanism (this supply the self-organization) the system is recognized with some assets due to physical properties ([Parunak et al., 01] , [Shehory et al., 99]) by adapting physics to DAI (Distributed Artificial Intelligence) or by applying organization models extracted for the biology [Bonabeau et al., 99].

3.1 Biologic Oriented Agentification

The Numerous sorts of social insects and the most known example, the ant colonies are the inspiration of the organizational models for complex systems [Dorigo and Stützle, 04]. In general the swarm has to achieved a collective task, each insect deposits a small quantity of chemical substances, called pheromones, allowing to

mark her passage (adding memory) while indicating to its congeners some information about the environment and information about its own state (communication). Two individuals interact indirectly through the environment. In fact, pheromones lead directly a specific behaviour in the individual who perceives them, this is called stigmergy. As defined Ramos [[Ramos and Ajith, 04]], stigmergy could be defined as a typical case of environmental synergy of learning via the environment. Pheromones act as the chemical transmitters endowing ants communicate between them on a short distance. Ants are capable of external storage of information in the environment, achieving memory.

In order to understand the collective behaviour, computer simulations are used to examine the parameters and their interactions. In general, these insects' colonies in real world provide three operations on chemical pheromones that support purposive actions into agents' models. It aggregates deposits from individual agents, evaporates them over time (with the effect of avoiding overloading and forgetting obsolete information), and diffuses them to nearby locations (with the effect of providing a gradient that agents can follow). In such ecosystem we identify the following agent properties:

- *Autonomous entity*. Each agent acts independently and asynchronously to satisfy its goal. It implies distribution into separated smaller functions.
- *Able to act in its environment*. The basic interaction between the agent and the environment can be considered as indirect chemical communication mediated by an external storage.
- *Know its environment partially.* This knowledge is based on the interaction of the agent on local or at microscopic level. Each agent works within a bounded rationality. It adapts constantly.
- *Works towards individual goals*.
- *Able to interact with others agents*. The agent has social interactions.
- During the evolution of the system, due to the interaction between agents in the environment, a *collective behaviour emerges by adaptation*. This behaviour is observed in the macroscopical level. It appears thus some multi-agent characteristics:
- *Aggregation* of numerous agents due to *common characteristics* discovered along the evolution in the tasks.
- The multi agent as a system has a goal to achieve.
- No agent controls the global task. Ants perform impressive feats of coordination without direct inter-agent control.
- The environment is dynamic or/and incompletely described.

In a more general view, ecosystems are complex biological systems in which an essential characteristic is adaptation. Some mathematical models of ecosystems simulate models of heterogeneous agents that evolve in a system, according to their fitness to some aspect of the ecosystem. Normally these agents compete for resources or work together for a common goal.

4 Recommender Systems Proposal for E-learning Environment

Swarm intelligence use emergent computing. Dorigo ([Dorigo and Di Caro, 99] , [Dorigo and Stützle, 04]) define this paradigm with the bio-inspired computational algorithm ACO (Ant Colony Optimization). This algorithm applied that social ants build networks of paths that connect their nests with available food sources. Mathematically, these networks form minimum spanning trees. Thus, they minimize the energy they spend to bring food to the nest. However, general research using artificial ants tends to resolve more difficult issues by adding complexity to the ant's behavior to solve specific problem domains.

Important are the efforts to extract and study user patterns on Internet, where Ramos [Ramos and Ajith, 04] proposes an ACLUSTER (Ant Colony Cluster) application to cluster Web usage patterns for predicting the Web traffic volume.

We propose that recommendation problem can be solved by designing agents covering aspects about learner and LO. These agents interacting at microscopic level will emerge in a final structure by self-organization from a bottom-top MAS architecture, describing the solution. The management of the elements in recommendation problem has self-organization aspects that could be well thought-out as an ecosystem model due to some related aspects:

- LO's information similar or related trends to create groups.
- The most needed information related to user educational needs of learners grows and evolves while the others it forgets and disappears.
- The dissemination of all the information in its environment occurs by a short-range interaction processes and attends to diffusion phenomenon by decreasing in time.

Based on the natural selection in the MAS model each service is represented by an ant while all the ants cooperate and compete for satisfy the personal requirements of the user emplaced in the environment also as food sources. Both ants and food sources are agents. Just only these ants that describe services sufficiently similar ([Paolucci et al., 02], [Paolucci et al., 03]) to the service requested matches the request in the degree in that they agree with the profile of the user. These elements are the ground in the architecture proposed in next section.

4.1 Architecture proposal

The system architecture proposed (See Figure 3) is distributed in three layers.

The first layer contains the graphical user interface (GUI). The first layer canalizes the communication data: user makes its requests, browsers and selections and received the recommendations. The interaction with user has strong domain-dependent aspects (described semantically).

The *second layer* contain the main application layer where it is located the recommendation strategies. It is conceived as an agents' ecosystem. The ecosystem is generator of a dynamical representation of the environment through their space evolution in the time. The ecosystem defined in this 2nd layer is composed by a discrete environment where agents pregnant with user domain characteristics. These agents receive and emit information through the environment.

Finally, the *third layer*, related as repositories, contains the services knowledge base domain (ontology knowledge) and several extensions to the World Wide Web containing data facilitators. At this level is stored also a repository of information for the system.

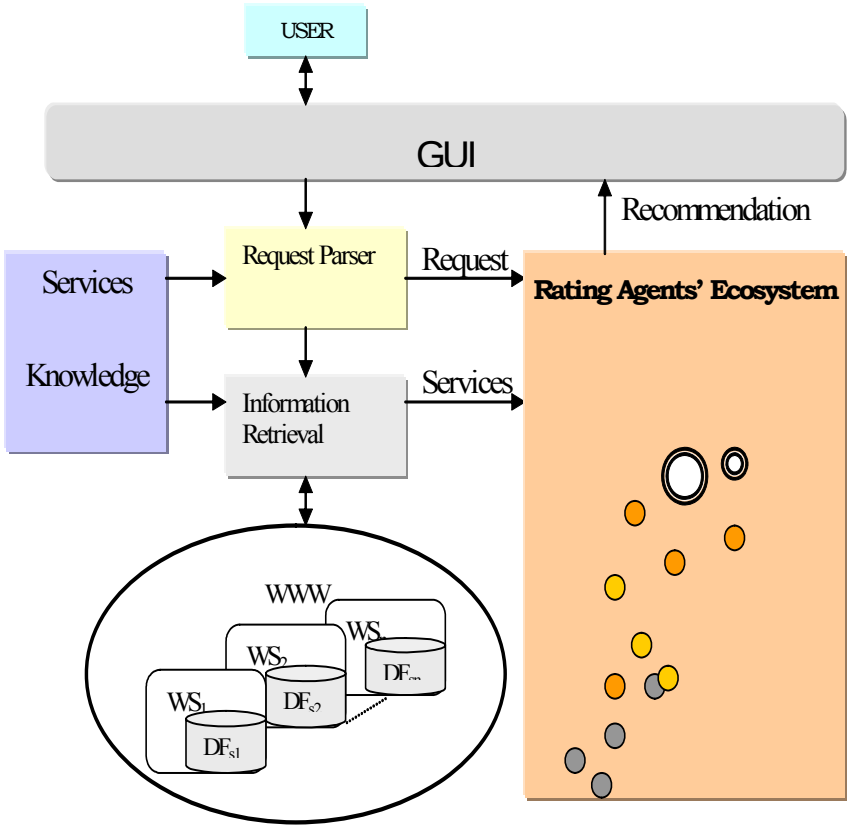


Figure 4: The recommender system architecture

4.2 The Clustering and Sorting Ant Algorithm

Some kind of ants, *Pheidole pallidula* [Deneubourg et al, 1991], *Laius niger*[Chretien, 1996] and *Messor sancta* form piles of items such as dead bodies (corpses), larvae, or grains of sand. There ants deposit items at initially random locations. When other ants perceive deposited items, they are stimulated to deposit items next to them, being this type of cemetery clustering organization and brood sorting a type of self-organization and adaptive behaviour. The clustering and sorting behaviour of ants has stimulated researches to design new algorithms for data analysis. Objects placed next to each other by the sorting algorithm have similar attributes.

Deneubourg et al. [Deneubourg et al, 1991] have propose a first model (called BM, for basic model) where a population of ant-like agents randomly moving onto a 2D grid are allowed to move basic objets apiling there with same type and build clusters. This algorithm was aimed to a robotic implementation. The probability p_p for a randomly moving, unladen agent (representing an ant in the model) to pick up an item is given by Equation, where f is the perceived fraction of items in the neighbourhood of the agent, and k_1 is constant. In the same way the probability p_d, Equation 2, for a randomly moving loaded agent to deposit an item is given by where k_2 is constant.

$$p_p = \left(\frac{k_1}{k_1 + f} \right)^2 \text{ Where } \begin{matrix} if\ f << k_1 & p_p \to 1 \\ if\ f >> k_1 & p_p \to 0 \end{matrix}$$

Equation 1: BM probability to pick up an item

$$p_d = \left(\frac{f}{k_2 + f} \right)^2$$

Equation 2: BM probability to deposit an item

This method was then further generalized by Lumer and Faieta (hereafter LF algorithm) [Lumer and Faieta, 1995], applying it to exploratory data analysis. They showed that their model provides a way of exploring complex information spaces, such as document or relational databases. LF defines a distance or dissimilarity between objects in the space of object attributes. The objects can be described by a finite number of related-valued attributes by allowing information access and compared from a n-dimensional space, hence belong to obtain different clusters according. The LF algorithm works as follows. Let $d(o_i, o_j)$ be the distance between two objects in the space of attributes. Let assume than an agent is located at site r at time t and finds an object o_i at that site. The local density $f(o_i)$ with respect to object o_i at a site r is given by:

$$f(o_i) = \begin{cases} \frac{1}{s^2} \sum_{o_j \in Neigh_{(SXS)}(r)} \left[1 - \frac{d(o_i, o_j)}{\alpha} \right] & if\ f > 0 \\ 0 & otherwhise \end{cases}$$

Equation 3: LF Local density with respect to objetc oi at site r

$f(o_i)$ is a measure of the average similarity of object o_i with the other objects o_j present in the neighbourhood of o_i. α is a factor that defines the scale for dissimilarity. This factor acts as regulator of the similarity allowed between different items to form same cluster or not. Where Lumen and Faeita define picking up and dropping probabilities (Equation 4, Equation 5) where k_1 and k_2 are two constants similar to the ones in the BM.

$$p_p(o_i) = \left(\frac{k_1}{k_1 + f(o_i)} \right)^2$$

Equation 4: LF picking up probability

$$p_d(o_i) = \begin{cases} 2f(o_i), & if\ f(o_i) < k_2 \\ 1, & if\ f(o_i) \geq k_2 s \end{cases}$$

Equation 5: LF Dropping probability

They applied the algorithm to a database containing the profile of 1650 bank customers. Attributes of the profiles included marital status, gender, residential status, age, a list of banking services used by the customer, etc. Given the variety of attributes, some of them qualitative, quantitative another ones, they have to define several dissimilarity measure and to combine them into a global dissimilarity measure. Lumer and Faieta evolve the model [Lumer and Faieta, 1994] with some features in order to correct the tendency to create more clusters to desire. This new three features endow the agents with different moving speeds, adds with short-term memory (then agents can remember the last m items they have dropped) and system are equipped with behavioural switchers that actives some actions or possibility to destroy clusters. Despite interesting results, it is not obvious that this algorithm has a future in terms to efficiency in computation time.

Recently, Ramos et al, along different papers [Ramos et al., 2002] [Ramos and Merelo, 2002] Ramos and Ajith [Ramos and Ajith, 2004], have extended the yet explained Deneubourg, Lumen and Faieta's model. This algorithm, called Ant Clustering Algorithm (ACLUSTER), avoids the additional complexity on predecessor algorithms (short-term memory, multiple ant types that move at different speeds) by introducing pheromone trails to achieve unsupervised clustering.

Ramos and Merelo used a redefined Chialvo and Millonas [Chialvo and Millonas, 1995] model wherein an individual ant can be described by its position and direction. The probabilities of an ant moving between any particular pair of position and direction to any other pair are determined by their pheromone weighting function.

$$W(\sigma) = \left(1 + \frac{\sigma}{1 + \delta\sigma}\right)^{\beta}$$

Equation 6: Probability of moving to a location with pheromone density σ(r)

Where the value β determines the randomness with which an ant follows a pheromone trail, $1/\delta$ is the ant's sensory capacity, which describes the fact that each ant's ability to sense pheromone decreases somewhat at high concentration. The normalised probability of going from location i to location k is given by:

$$P_{ik} = \frac{w(\sigma_i)w(\Delta_i)}{\sum_{j/k} w(\sigma_j)w(\Delta_j)}$$

Equation 7: probability to go from cell i to cell k

Where Δ_j measures the magnitude of the difference in orientation from the previous direction at time t-1. Each individual leaves a constant amount η of pheromone at the cell in which is located at every step t, and also this pheromone decays at each time step at a rate k.

The two major factors that influence any local ant action are the number of objects in their neighbourhood and their similarity. Ramos and Ajith [Ramos and Ajith, 2004], defined the probability function for picking up or dropping as function of different stimulus intensities (number of items and their similarity), at site r:

$$P_p = (1 - \chi) \cdot \varepsilon \qquad P_d = \chi \cdot \delta$$

Equation 8: Probability functions for picking up or dropping

Where χ is defining as the response threshold associated to the number of items, n, present in a 3x3 region around **r** and d is the similarity between objects as Euclidean normalized distance computed within all the pair objects present in tant 3xe region around r.

$$\chi = \frac{n^2}{n^2 + 5^2}$$

Equation 9: Response threshold associated with number of items in neighborhood

Where δ and ε are defined as the response threshold functions associated to the similarity of objects in case of dropping first one and picking it up the later:

$$\delta = \left(\frac{k_1}{k_1 + d} \right)^2 \qquad \varepsilon = \left(\frac{d}{d + k_2} \right)^2$$

Equation 10: response threshold functions

ACLUSTER has been applied to clustering textual documents [Ramos and Merelo, 2002] and by introducing [Ramos and Ajith, 2004] a new type of Data-Mining based on Stigmergic paradigms by hybridizing bio-inspired Swarm Intelligence with Evolutionary computation. This work provides encouraging results.

5 Conclusions

This paper has shown a brief look into self-organization and emergence while we examined some aspects connecting with recommender systems. It explains the basis where we have rested to propose a recommendation mechanism in e-learning based on complex systems over a bio-inspired algorithm. The environment contents the knowledge of the whole phenomenon, the real facts due to the domain, the user preferences representations and also the characteristics in the LOs, modelled and epecified using the IMS Learning Information specification. These elements by interaction bring up the final representation at macro-level that customized a dynamical and personalized representation for the recommendation.

The goal is to have a structural and immediate connection between the set of elements from OL that user needs, relied in the semantic content and qualities evaluation and the landscape of agents that represent the recommendation. We are working in the ACLUSTER algorithm to introduce new metrics that allows identifying the similarity between LOs in the environment. The possibility of this proposal is at simulation phase.

The work try to build a solutions for real-life applications, based on swarm intelligence that will bring a great promise for the further advancement in this ground.

Acknowledgements

We want to thank to the group GRIAL (Research Group in Interaction and eLearning) of the University of Salamanca for their contributions and ideas for the development of this work.

This work was partly financed by Ministry of Education and Science as well as FEDER Keops project (TSI2005-00960).

References

[Avgeriou et al, 2003] Avgeriou, P., Retails, S., & Skordalakis, M. (2003). An architecture for open learning management systems, En Y. Manolopoulos, S. Evripidou, A.C. Kakas (Eds.) Advances in Informatics. 8th Panhellenis Conference on Informatics. Lectures Notes in Computer Science. LNCS 2563. Berlin: Springer Verlag, pp.183-200.

[Berlanga et al, 2005] Berlanga, A., García, F., Gil, A. "Adaptive Hypermedia Systems: Personalized Education in E-Learning". Educational Virtual Spaces in Practice, The Odiseame Approach, F.J. García, J. García, M. López, R. López and E. Verdú (Eds.), pp. 133-146, Editorial Ariel. ISBN: 84-344-2659-5, 2005.

[Biebricher et al., 95] Biebricher, C.K., Nicolis, G., Schuster, P., 1995: Self-Organization in the Physico- Chemical and Life Sciences, EU Report 16546.

[Bonabeau et al., 99] Bonabeau E., M. Dorigo & T. Theraulaz, 1999. From Natural to Artificial Swarm Intelligence. New York: Oxford University Press.

[Chialvo and Millonas, 1995] Chialvo, D.R. and Millonas M.M. How Swarms Build Cognitive Maps. The Biology of Intelligent Autonomous Agents, 144, NATO ASI Series, pp. 439-450. 1995

[Chrétien, 1996] Chrétien, L. Organisation Spatiale du Matériel Provenant de l'excavation du nid chez Messor Barbarus et des Cadavres d'ouvrières chez Lasius niger (Hymenopterae: Formicidae) .PhD thesis, Université Libre de Bruxelles, 1996.

[Deneubourg et al, 1991] Denebourg J.-L., S. Goss, N. Franks, A. Sendova-Franks, C. Detrain, and L. Chretien. The Dynamic of Collective Sorting Robot-like Ants and Ant-like Robots. Procs. of 1st Conf. on Simulation of Adaptive Behavior: From Animal to Animats, edited by J.A. Meyer and S.W. Wilson, pp. 356-365. Cambridge, MA: MIT Press. 1991

[Dorigo and Di Caro, 99] Dorigo M. and G. Di Caro, 1999. The Ant Colony Optimization Meta-Heuristic. In D. Corne, M. Dorigo and F. Glover, editors, New Ideas in Optimization, McGraw-Hill, 11-32.

[Dorigo and Stützle, 04] Dorigo, M., Stützle, T. (2004) Ant Colony Optimization. MIT Press.

[Egger, 01] Egger F. N. (2001). Affective Design of E-Commerce User Interfaces: How to Maximise Percived Trustworthiness. In Proceedings of The International Conference on Affective Human Factors Design. Asean Academic Press, London.

[Gil and García, 03] Gil, A. and F. Garcia (2003). "E-commerce Recommenders: Powerful Tools for E-business." Crossroads - The ACM Student Magazine 10(2): 24-28.

[Gil and García, 06] Gil A.B., García, F.J. (2006) "Recommender Systems in E-Commerce". En Encyclopedia of Human Computer Interaction.Idea Group Publishers. Claude Ghaoui Editor. ISBN:1-59140-562-9, 2006.

[Gil, 2004] Gil, A.B. "E-Commerce y Web-Services: Un Paso Adelante en la Interoperabilidad". En Tendencias en el Desarrollo de Aplicaciones Web. F. García Peñalvo y Mª Moreno García (Eds.), Departamento de Informática y Automática de la Universidad de Salamanca, pp. 73-84, 2004.

[IMS LOM, 2006] IMS LOM. (2006). Learning Resource Metadata Specification. http://www.imsglobal.org/metadata/index.html#version1.3

[Konstant et al, 1997] Konstant, J.; Miller, B.; Maltz, D.; Herlocker, J.; Gordon, L.; Riedl, J. Grouplens: applying collaborative filtering to Usenet news. Communications of the ACM, 40(3): 77-87, 1997

[Lumer and Faieta, 1994] Lumer, E. and B. Faieta. Lumer E.D. and Faieta B. Diversity and Adaptation in Populations of Clustering Ants. Procs. of SAB´94 – 3rd Conf. on Simulation of Adaptive Behavior: From Animal to Animats, The MIT Press/Bradford Books, Cambridge, MA. 1994

[Lumer and Faieta, 1995] Lumer, E. and B. Faieta. Exploratory Database Analysis via Self-Organization. Unpublished manuscript, 1995. Refered in [Bonabeau et al, 1999]

[Montaner et al, 2003] Montaner, M., López, B., de la Rosa, J. Ll., "A Taxonomy of Recommender Agents on the Internet", Artificial Intelligence Review, Kluwer Academic Publishers. Volume 19, Issue 4, pp. 285-330. June, 2003

[Mooney and Roy, 2000] Mooney, R. J.; Roy, L., Content-Based Book Recommending Using Learning for Text Categorization, Proceedings of the V ACM Conference on Digital Libraries, San Antonio, USA, pp.195-204, 2000

[Morales et al, 2006] Morales, E., García, F., & Barrón, Á. (2006). "Quality Learning Objects Management: A proposal for e-learning Systems" 8th International Conference on Enterprise Information Systems (ICEIS'06). Paphos, Cyprus, 23 al 27 de Mayo del 2006.

[Paolucci et al., 02] Paolucci, M., Kawmura, T., Payne, T., and Sycara, K., 2002. Semantic matching of web services capabilities. In First International Semantic Web Conference.

[Paolucci et al., 03] Paolucci, M., Sycara, K., and Kawmura, T. Delivering Semantic Web Services, 2003. Tech. report CMU-RI-TR-02-32, Robotics Institute, Carnegie Mellon University.

[Parunak et al., 01] Parunak, H. Van Dyke, Brueckner, Sven, 2001. Entropy and Self-Organization in Multi-Agent Systems. Proceedings of the International Conference on Autonomous Agents (Agents 2001), 124-130.

[Ramos and Ajith, 04] Ramos, V., Ajith Abraham, 2004. Evolving a Stigmergic Self-Organized Data-Mining. In ISDA-04, 4th Int. Conf. on Intelligent Systems, Design and Applications, Budapest, Hungary, ISBN 963-7154-30-2, pp. 725-730, August 26-28.

[Ramos and Ajith, 2004] Ramos, V., Ajith Abraham. Evolving a Stigmergic Self-Organized Data-Mining. In ISDA-04, 4th Int. Conf. on Intelligent Systems, Design and Applications, Budapest, Hungary, ISBN 963-7154-30-2, pp. 725-730. 2004.

[Ramos and Merelo, 2002] Ramos, V., Merelo J. Self-Organized Stigmergic Document Maps: Environment as a Mechanism for Context Learning. Procs. Of AEB'02- 1er Spanish Conference on Evolutionary and Bio-inspired Algorithms, Mérida., pp. 284-293. 2002.

[Rosenberg, 2001] Rosenberg, M.J. (2001). E-learning. Strategies for delivering knowledge in the digital age, Mc Graw Hill.

[Sarwar et al, 2000] Sarwar, B.; Karypis, G.; Konstan, J.; Riedl, J. Analysis of Recommendation Algorithms for E-Commerce. ACM Conference on Electronic Commerce, pp.158-167, 2000

[Shafer et al, 2001] Shafer, J.; Konstan, J. A.; Riedl, J. E-Commerce Recommendation Applications. Data Mining and Knowledge Discovery, 5 (1/2), pp. 115-153, 2001

[Shardanand and Maes, 1995] Shardanand, U.; Maes, P. Social Information Filtering: Algorithm for Automating "Word of Mouth". Proceedings of ACM CHI'95 Conference on Human Factors in Computing Systems, pp. 210-217, 1995

[Shehory et al., 99] Shehory, O, Kraus, S. Yadgar, O., 1999. Emergent cooperative goal-satisfaction in large scale automated-agent system. Artificial Intelligence Journal Vol 110(1).

[Spiekermann and Paraschiv, 02] Spiekermann, S.; Paraschiv, C. (2002). Motivating Human–Agent Interaction: Transferring Insights from Behavioral Marketing to Interface Design. Electronic Commerce Research, Vol. 2, pp. 255–285.

[WSA, 2004] Web Service Architecture. W3C Working Draft 11 February 2004. http://www.w3.org/TR/ws-arch/

.

Evaluation of a collaborative annotation system

Invited talk at the second international ICDL conference, December 5-8, 2006, New Delhi, India

Annelise Mark Pejtersen, Center of Cognitive Systems Engineering, Denmark
Submitted to TC13 January 30th 2007

Abstract

This talk presents an expert evaluation of a collaborative annotation system named Digital Library Annotation Service, DiLAS. It can be accessed globally by individual users as well as by different user communities, and knowledge can be created and shared globally within English speaking communities. It contains a collection of textual documents on Information Science and Software Science and it gives access to all kinds of related material such as authors' home pages, photos, articles etc.

An analytical evaluation was conducted as a *Participatory Group Evaluation*, which involved presentation beyond the written papers of the objectives and rationale behind the development of the prototype. The empirical evaluation of DiLAS consisted of two experiments. The first evaluation experiment was a bottom up evaluation that began at the elementary level with an evaluation of the usability of the interface. A *Cognitive Walkthrough* approach was chosen using a qualitative approach. The next evaluation moved towards the broader work context with a *User and Work Centred Evaluation* involving an entire, collaborative task situation, which required knowledge sharing on a common real life work task.

It describes a first evaluation stage in an iterative evaluation process, and the results are a set of user requirements, short term as well as long term requirements to redesign of the interface of DiLAS and to missing collaborative functions. Some of these requirements should be considered as a first part that will be concluded by a future end-user evaluation in real life work will inform the next stage of the DiLAS development. Some requirements have already been implemented in the development of the next DiLAS prototype 2.

Reference:

Pejtersen, A.M.; Hansen, P. and H. Albrechtsen (2006). A Work Centred Approach to the Evaluation of a DL Annotation System for Knowledge Sharing in Collaborative Work. In: *Proceedings of the International Conference on Digital Libraries (ICDL), held 5-8 December 2006, New Delhi, India*. Vol. I., p.78-90. Published by TERI, New Delhi, 2006.

Developing Collaborative and Ubiquitous Applications using CIAM

Maximiliano Paredes, Ana I. Molina, Miguel A. Redondo and Manuel Ortega.
Department of Information Technologies and Systems, School of Computer Engineering
University of Castilla - La Mancha
Paseo de la Universidad 4. 13071 Ciudad Real (Spain)
Manuel.Ortega@uclm.es

Abstract: In this article we explain how we apply the CIAM methodology based on the CIAN notation in order to generate user interfaces in collaborative applications. CIAM has been applied successfully in the development of desktop applications, such as Domosim-TPC, demonstrating its effectiveness in the definition of user interfaces for collaborative applications where a shared context is required. We present the AULA system modeled by means of CIAM. The results in the application of this Methodology show the necessity to include those aspects closely related with context modeling and the synchronization of contents; that is why we make an outline of the way to take into account these characteristics as a future work.

Keywords: CSCW, Human – Computer Interaction, User Interfaces, Ubiquitous Computing, Mobile Computing

Categories: H.5.2, H.5.3, K.3.1

1 Introduction

In the last years a great amount of collaborative applications have been developed. On the other hand only a few applications have been developed according to the paradigms of ubiquitous or mobile computing. Most of them were carried out in the same manner as other applications were developed, without taking into account the special characteristics of these paradigms. Therefore, the requirements that characterize these paradigms may not be considered in the most appropriate way; in special, we have to mention the aspects of user interface development and the perception of the context of the application.

From our point of view we need appropriate frameworks and tools (Methodologies, CASE tools, etc.) to help in the analysis and design processes of these complex applications in the same way as we already have them for the development of applications without these characteristics. In addition, we need to follow a process that considers the methods belonging to the Software Engineering methodologies but also we have to take into account the experience learnt from the Computer – Human Interaction approaches.

AULA is a collaborative and ubiquitous application intended to be an aid in language learning by means of a methodology called MECA. AULA has been

developed to be used with PDAs inside and outside a language classroom. For this reason the synchronization of contents is required when the PDAs are online.

The learning process begins as follows: the students create a document structured in aspects and ideas. They use an editor with facilities for collaborative edition in an argumentative discussion process. The system has also different collaborative tools, such as a chat or an electronic mail, structured in *aspects* and *ideas*, and a set of linguistic tools to help in the edition of the texts.

In this article we explain how we apply the CIAM methodology based on the CIAN notation in order to generate user interfaces in collaborative applications. We apply this framework to a particular case: a foreign language learning system called AULA. For this, the paper is organized in the following way: section 2 introduces the CIAM methodological approach for designing interactive groupwork applications, presenting a brief explanation of its stages and the issues that can be specified in each. Section 3 explains the individual and collaborative writing model for foreign language learning. In section 4 a methodology called MECA, used for modelling collaborative writing learning, is presented. Section 5 explains the application of CIAN for modeling the system AULA (that implements the methodology MECA). Finally the conclusions extracted from this work are presented, and the future works we plan to follow are described.

2 CIAM Methodology

In this section the CIAM (*Collaborative Interactive Applications Methodology*) proposal is presented. CIAM is a methodological approach for the development of CSCW (*Computer Supported Cooperative Work*) applications that takes into account the modeling of work in-group and interaction issues. Unlike other existing proposals in the fields of conceptual modelling of CSCW systems and modeling of issues related with the Computer Human Interaction, CIAM considers the joint modeling of both issues, as well as the differentiation between the concepts cooperation and collaboration [Dillenbourg, 95].

This approach consists of three main elements:

- A *conceptual framework* that clearly defines the concepts studied and modeled in each one of the phases in the methodological proposal [Molina, 06].
- A *methodological framework* that defines the set of phases that compose the proposal, as well as the set of specification techniques to use in each of them [Molina, 07].
- A *notation*, called CIAN (*Collaborative Interactive Applications Notation*), that allows expressing the peculiarities of the interactive groupware systems.

In the figure 1 we can see the stages of the CIAM proposal. In each of them several collaborative and interactive systems issues are specified. The *Sociogram Development* stage allows to specify the social context in which the work in-group will be developed (roles, actors, work teams,…). The following two stages allow the specification of the tasks of greater level of abstraction to be performed by the group (*Responsibilities Modeling*) and the temporal and data dependencies that exist among

them (*Inter-Action Modeling*). In the *Work in-Group Tasks Modeling* the collaborative and cooperative tasks identified in previous stages are specified in a differentiated way and with a greater level of detail. The collaborative tasks specification is based on the *shared context* definition [Ellis, 91]. In the *Interaction Modeling* stage the interactive tasks to be supported by the Application User Interface to develop are specified. For this we use the CTT notation [Paternò, 04]. An interactive task tree will be created for each individual task or individual responsibility and for each work in-group task. In the case of collaborative tasks the interaction model is obtained from the shared context definition.

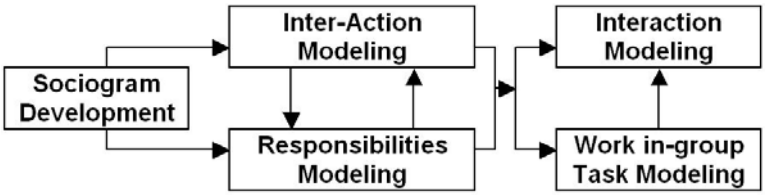


Figure 1. Stages in the CIAM methodological proposal

The models created in each of the stages of the proposal are specified using a set of graphical elements that are summarized in figure 2. On the top left (2.a) of the figure we can see the icons that represent the organization members (roles, actors, software agents, etc). On the bottom left (2.a) and the top centre (2.b) areas we can see the icons for representing the nodes that forms the Inter-Action Model and for indicating the several tasks and interdependences types. On the right area (2.c) we can see the icons used for representing an interaction task model in CTT notation. We have enriched this notation by means of the use of three new icons to express visualization features and blockade of the objects that compose the shared context in a collaborative task. A more detailed description of the notation CIAN can be found in [Molina, 06].

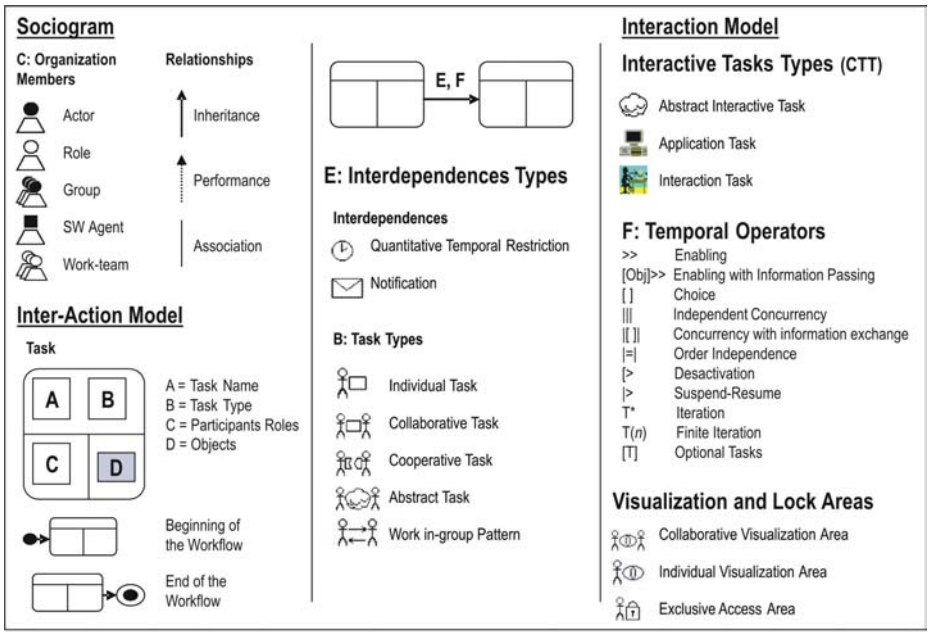


Figure 2. CIAN Notation

3 Individual and Collaborative Writing Model for Foreign Languages Learning

Writing individual process is composed of three sub-processes [Hayes, 80]:

- Planning. Author knows the writing subject and the context (writing tools, expression techniques, etc.). The author set goals and plans and define a w*riting project.* This *writing project* will direct the process.
- Coding. Author produces the text. This generation of text is based on the writing project and on the author's knowledge.
- Reviewing. Author reads the encoded text and improves the quality of the text produced.

This process is difficult in a collaborative writing environment. The collaborative writing is a task where a group of authors (co-authors) produce written documents. The co-authors share and discuss different ideas and have the same objective: creating a text. Sharples et al. [Sharples, 93] emphasize the collaborative writing complexity and identify some important issues, summarized in:

- Division of tasks and the work coordination strategy. The division of work and the coordination strategy are very important. There are three strategy types: Sequential, Reciprocal and Parallel.

- Work groups and communication. The members of the group can have different views. This discrepancy generates conflicts. We need to manage these conflicts adequately.
- External representation issues. We need structured representation of context. This structure represents the writing task status: generated text, objects, ideas, scheduling, etc. Therefore, aspects related with performance and control of versions are important.

Finally, the collaborative writing is composed of two stages: pre-process of writing (creation of group, planning, etc.) and process of writing (generation of text and discussion).

Collaborative writing is a pedagogical tool. In this approach, the students should write a text composition. In the classical scenario the students have a notebook and a pen and there is a blackboard in the classroom. The teacher writes the composition's title on the blackboard. Besides, the teacher specifies related information, for example the deadline to complete the task. Then, a text generation process is begun. The students individually write text on their notebooks. Therefore, each student generates composition fragments. Later, a discussion process is made. At this point, the students propose their fragments of composition. They write their text on the blackboard and the group discusses about acceptance or rejection of this text. At this point, the students have new ideas and they propose improvements or alternatives, fine-tuning the original proposal. Sometimes the group can decide to eliminate the proposal. Other times, the author of the proposal modifies his/her fragment of text and later the author proposes this change. The students know their mates' comments. They do all this work using the blackboard.

In this process, the student develops active and passive abilities [García, 04]. The students accept an active role in this process. The teacher observes the discussion and argumentation process. Sometimes, the teacher can participate along the process, clarifying and explaining some questions or issues. Therefore the teacher is a mentor in the discussion process. This process finishes when the students get to an agreement. In the last step of the composition, the teacher plays an active role. The teacher discusses the written solution (it is written on the blackboard) and highlights mistakes, improvements, extensions, etc. and the students write down. In this process, the student develops active and passive abilities. In particular, the students develop active abilities when they prepare their contributions and develop passive abilities when they read other contributions.

4 Applying MECA to design a learning model

MECA is a methodology for modelling the learning of collaborative writing [Paredes, 06]. The main aim of MECA is to help to efficiently structure the collaborative writing learning. The methodology identifies stages, agents and components generated by the agents. The MECA proposes six stages organized in three main categories:

- Pre-process. The learning activity is defined.
- Writing. The composition is performed.

- Analysis. Assessment of the activities performed by the students.

Next we are going to describe our learning scenario (a collaborative composition) guided by MECA. We need to consider some aspects of ubiquitous computing. We are going to emphasize the requirements of this scenario. The students use a PDA, which can be used anywhere at any time, while the teacher uses a PC. The students and the teacher use an electronic whiteboard and a PDA in the classroom. Therefore, some constraints are considered in this computer environment: time, space, multi-devices, and multi-user restrictions. MECA structures the lesson in the following main stages:

A) In the first stage the teacher should do the pre-process activity. This activity is accomplished before the beginning of the lesson and consists in defining the title and the type of composition (letter, report, request, etc.). Besides, the teacher should define the working group. MECA proposes small working groups (from 2 to 6 students). Later, the teacher should schedule the work session. This scheduling involves determining the date and length of the session. Finally, the teacher sends this information to the group of students (using electronic mail or face to face).

B) In the second stage, the students begin to work when they receive the information (the title and the type of composition). This process is individual and this process happens before beginning the session. The student has a PDA which has software tools in off-line mode. The student writes text on his PDA using text edition tools (sections and paragraphs of the composition). MECA proposes organizing this text in two types of information: aspects (they are titles of sections of the composition) and ideas (the paragraphs integrating an aspect). This task is usually performed outside the classroom and the PDA facilitates these actions.

C) In the third stage a session begins inside the classroom. The students propose their fragments of text to the classmates (beginning of the session) and the proposals are visualized on the whiteboard. These proposals are aspects and ideas written by the students (described in the above item). At this point, we need to start an information synchronization of the PDAs. Next, the discussion process begins. At this point the students discuss, propose, modify and argue their contributions. Now the students use on-line tools by means of their PDAs (for example, they use text edition utilities). The students agree or refuse proposals and the discussion process finishes. Later, the students should order the accepted proposals and the teacher assign the students' roles.

D) In the last stage the teacher reviews the composition generated by the students. MECA proposes quantitative and qualitative analysis methods. This analysis evidences work done by each student and shows collaborative process' conclusions, indicating work done inside and outside the classroom. The teacher assesses work and explains errors, improvements, etc. At this point, the composition activity finishes.

In conclusions, we identified context-awareness information (time, space and devices). We have to define synchronization strategies. Besides, we found context-sensitive actions, for example text edition. This can be collaborative (inside-the-classroom edition) or individual (outside-the-classroom edition).

We have applied MECA to language learning courses, in particular English as a Foreign Language (EFL), and we have implemented the AULA platform for this purpose. A detailed description of the system can be found in [Paredes, 03].

5 AULA Modeling using the CIAN notation

In this section the application of the CIAM methodological proposal and the use of CIAN notation, for the modeling of the AULA system are presented.

5.1 Social Structure in AULA

In the first stage of the CIAM methodology the social structure of the organization in which the groupware system to be designed will be implanted is modeled (the so-called *sociogram* of the organization is created). For this the different actors and roles of the system as well as their grouping (in groups and work teams) are identified. Figure 3 shows the sociogram of the AULA system. Two roles are identified: *student* and *teacher*. Both are specializations of a generic *user*, who interacts with the application. The Teacher role is in charge of defining the composition topic and making the planning of the work session. Also he/she will be the one in charge of facilitating and guiding the composition process. The *teacher* and *student* roles can form a work team in the context of some of the tasks supported by AULA (for example, in the process of discussion of the proposals). The work teams are formed by a set of *students* (minimum 2 and maximum 6) and a *teacher*. By means of the use of cardinalities these restrictions can be expressed. CIAN allows specifying the number of actors who can carry out a certain role. In this case an indefinite number of *students* and *teachers* is admitted, but at least an actor must exist for each role.

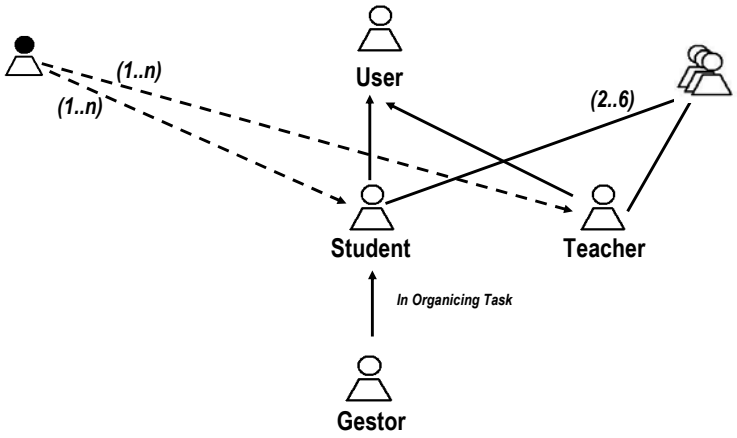


Figure 3. Sociogram of AULA

The notation also allows specifying role specializations in the context of certain tasks. In the diagram we can see as the *Student* role is specialized in the *Manager* role in the context of the *Organizing Task*. When the discussion process has finished a

student assumes the Manager role. This student is the one in charge of readjusting the composition. The system must activate this role when the student accesses the content organization tool.

5.2 Responsibilities Modeling

In this phase of the methodology the tasks of a greater level of abstraction to be supported by the system are identified. In AULA we identify the tasks shown in Table 1. This specification technique, which we have called *Participation Table*, allows the user to relate tasks and roles, as well as to specify the task type (individual, collaborative and cooperative).

Roles / Tasks	Student	Teacher	Type
Defining Topic		**X**	
Creating Activity		**X**	
Composing Personal Work	**X**		
Discussing Contents	**X**	**X**	
Organizing Contents	**X**		
Analyzing Solution	**X**	**X**	

Table 1. Participation Table

The tasks supported by AULA are the following ones:

- *Defining Topic*. (corresponding with the first stage of MECA; see paragraph A of section 4). The teacher role is the one in charge of performing this task. This task consists of defining the composition subject. This is an individual task. The teacher must define the following items: the *title* of the composition, the *composition type* (informal, administrative request, letter to a friend, etc), the *temporality* (duration of the work session) and some extra information or *observations*.
- *Creating Activity*. The work session is planned. In this task the teacher must specify certain information. Thus, for example, the teacher will indicate the date of beginning and end of the work session in the classroom. Also in this task the students group is defined and the decision policy of the group is chosen. When a proposal exceeds a certain number of *ok* votes (% of votes), the proposal is accepted. In this task this percentage of votes is specified. In the context of this task additional information related to the session can be

specified (classroom identifier, recommendations, date and hour of the chat sessions, etc.). This task is of an individual nature.

- *Composing Personal Work*. This task corresponds with the second stage of MECA; see paragraph B, section 4. The task called Composing Personal Work is performed by the student. The students, individually, write text fragments in their PDA. These text fragments will be proposed by the student in the classroom (in the work session). The student can do this task anywhere because the student has a mobile device.
- *Discussing Content*. This task is of a collaborative nature. This task is performed by the student and the teacher in the classroom (at the beginning of the session). The student proposes his/her text fragments (third stage of MECA; see section 4, paragraph C). At this point a discussion process begins: the students discuss and propose changes, alternatives, improvements, etc. The group will accept some proposals and will reject others. The teacher is the one in charge of facilitating this process.
- *Organizing Content*. This task is performed by a student. It is a task of an individual character. The student orders the text fragments accepted by the group. This task is taken over by the Manager role (see Figure 3).
- *Analyzing Solution*. (corresponding with the fourth stage of MECA; see paragraph D, section 4). This task is performed by the teacher and the students, in a collaborative way. First, the teacher reviews the text of the composition proposed by the students. Then, the teacher evaluates the knowledge of the students. Finally the students and the teacher review the composition and the teacher identifies errors, proposes improvements, etc.

Next, the responsibilities models of AULA are shown. Tables 2 and 3 show the *Responsibilities Models* of the teacher and student roles, respectively. Table 2 indicates the tasks assumed in an individual way by the teacher, as well as the tasks of work in-group in which he/she participates. The Responsibilities Model shows, for each task, its type, the manipulated objects (as well as the access modifiers to such) and the task pre-requirements (of execution and information). For example (Table 2), in the *Discussing Content* task the teacher must access the object *Proposal*. This task begins when the *Composing Personal Work* task finishes (this condition is expressed in the *Pre-requirements* column - *Task*). This task needs the object *Proposal* (we indicate this in the *Pre-requirements* column – Data) (Table 2). The *Defining Topic* task is the first task to be executed in the work-in group flow specified (it is indicated by means of the pre-requirement *INI*). By means of the information specified in the table we can see, for example, as the teacher role is the person in charge of creating the *Topic*, *Group*, *Activity* and *Experience* objects. The teacher also consults the *Proposal* and *Solution* objects, which are objects created by the students. The student is the one in charge of creating, in addition to these two objects, the *Feasible Solution* object.

Responsibility	Task Type	Object in Domain Model	Pre-requirements	
			Task	Data
Defining Topic		C: Topic	INI: Initial Task	
Creating Activity		L: Topic C: Group C: Activity	Defining Topic	Topic
Discussing Contents		L: Proposal	Composing Personal Work	Proposal
Analyzing Contents		L: Proposal L: Solution C/L: Experience	Organizing Contents	Solution

Table 2. Responsibilities Model of the Teacher role

Responsibility	Task Type	Object in Domain Model	Pre-requirements	
			Task	Data
Composing Personal Work		L: Topic C: Proposal	Crating Activity	Topic
Discussing Contents		L: Proposal C: Feasible Solution	Composing Personal Work	Proposal
Organizing Contents		L: Feasible Solution C: Solution	Discussing Contents	Feasible Solution
Analyzing Contents		L: Proposal L: Solution	Organizing Contents	Solution

Table 3. Responsibilities Model of the Student role

5.3 Inter-Action Modeling

The *Inter-Action Model* shows the order of accomplishment of the tasks. This model shows the roles, accessed and generated objects, and the main tools used for supporting the work in-group (for example, decision making tools, conversation, etc). Figure 4 shows the inter-action model supported by the AULA system. The three states shown in this model correspond with the three main stages in MECA (Process, Writing and Analysis). We use abstract tasks to handle the complexity of the created model. The learning activity begins in the *Definition* task (first node of the inter-action model). In this task the teacher creates the objects *Topic*, *Group* and *Activity*. The *Definition* task is an abstract task, formed by the tasks of a smaller level of abstraction, *Defining Topic* and *Creating Activity*. Next, the *Composition* task (second node) begins. This task begins when the *Definition* task has finalized and the *Topic* object has been created. The students read the title of the composition (the *Topic* object) and create the composition (the *Solution* object). The students use two types of

auxiliary tools: tools related to the objective of the task (*Book, e-Dictionary* and *Composition Editor*) and social tools (*Chat, email, Decision making*, etc.). This task ends when the students reach a consensus by majority (? *MajorityAgreement >= Topic.Consensus*). The teacher also takes part in the *Composition* task, facilitating its accomplishment. We have defined this task as an abstract task, since later its operation will be in detail. The last task is the *Analysis* task (third node). The students and the teacher study the proposals and the created solution (objects *Proposal* and *Solution* respectively). In addition, the teacher evaluates the work performed (he/she creates the *Experience* object). The learning activity ends at this point.

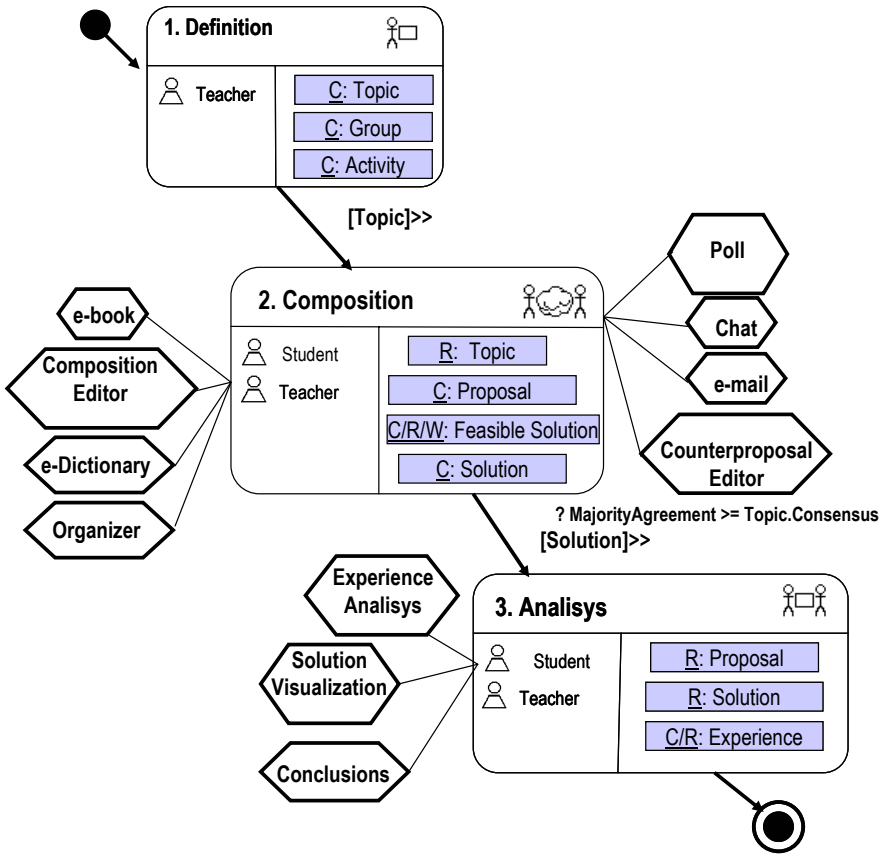


Figure 4. AULA Inter-Action Model (abstract level)

As we have previously mentioned, the abstract *Composition* task is the most complex task. Figure 5 shows this task in detail. The abstract *Composition* task is formed by two individual tasks and a collaborative task. The process begins when the students write their text fragments (the *Composing Personal Work* task). The students

read the composition title (the *Topic* object) and write text (creating the new *Proposal* object). Later, a session begins in the classroom (*Discussing Content* task). This session must begin on a specific date and at a specified time (this is indicated by means of the expression *t=Topic.date & Topic.hour* in the input flow of the task). The students create a final draft (the *Feasible Solution* object). This task finishes when most of the students decide what solution will be considered as the solution of the group (*MajorityAgreement >= Topic.Consensus*). Later, the task *Organizing Content* begins. A student (*Manager* role) organizes the text of the draft (*Feasible Solution*) and creates the final composition (*Solution*). Figure 6 shows the abstract *Discussing Content* task in detail. The three subtasks shown in the figure model the activities corresponding with the third stage of MECA (section 4, subsection C).The first subtask is the *Proposals Reading* task. The group reads the proposals and creates a first version of the draft (*Feasible Solution*). Then, the students and the teacher review and discuss this draft (by means of a discussion process) and the students create a new version (*Contributions Discussion* task). Next, the *Agreement* task begins. In this task the students must vote the draft. If the students reach an agreement the process finishes. On the contrary, if the students disagree, the draft must be modified, returning the execution to the *Contributions Discussion* task.

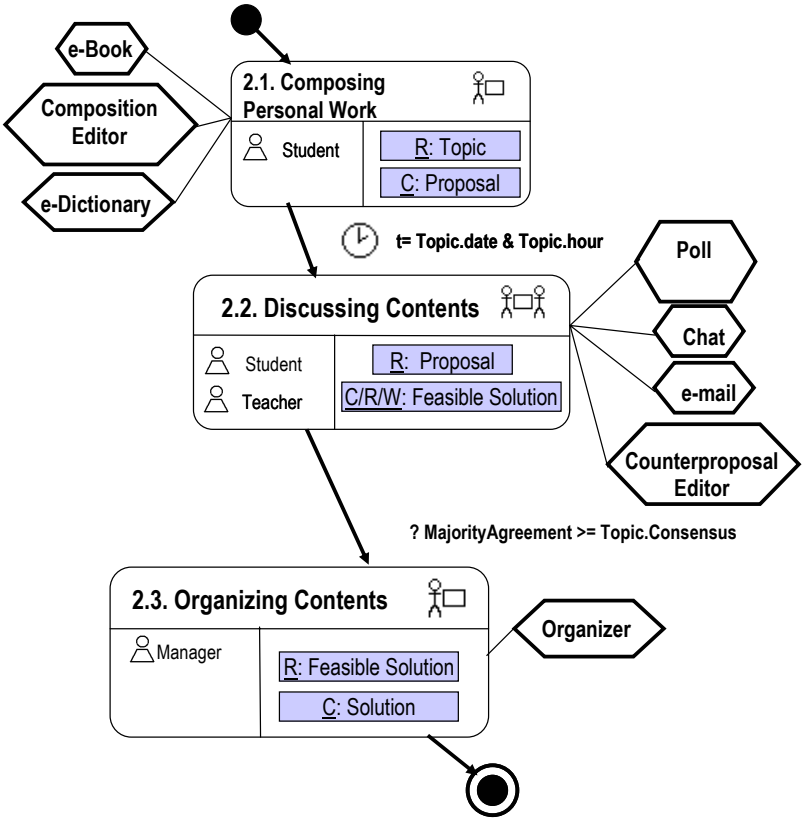


Figure 5. Detailed model of the abstract Composition task

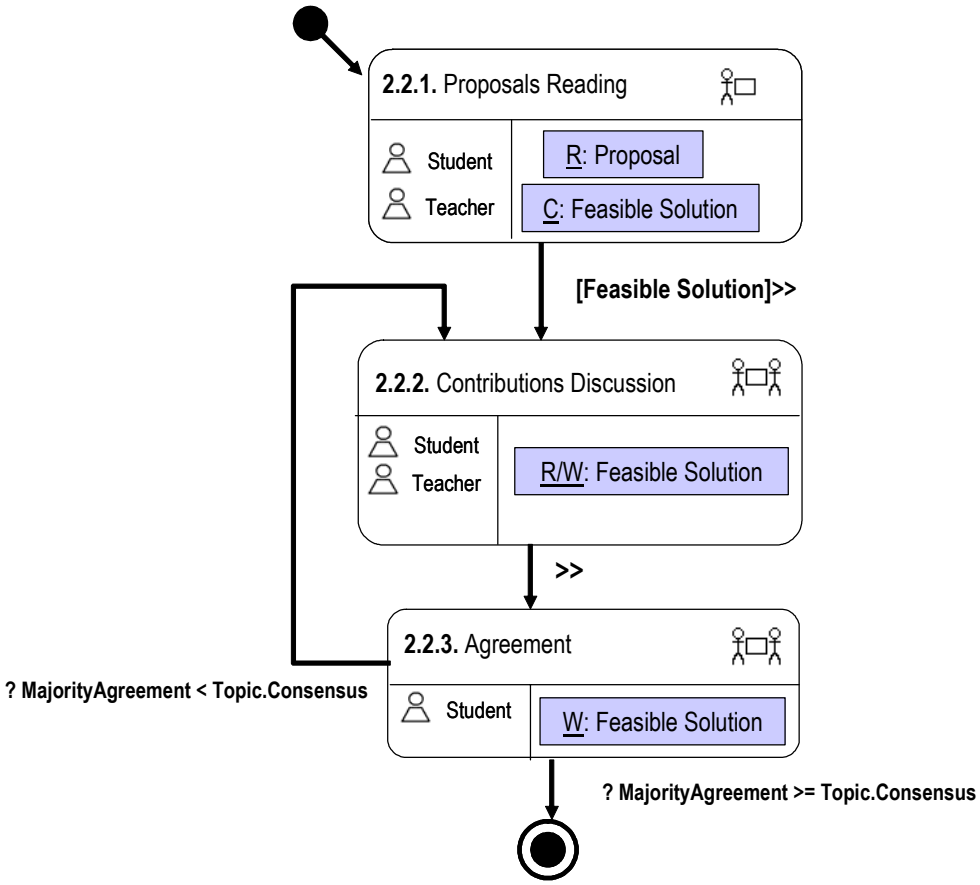


Figure 6. Discussing Contents Inter-Action

Figure 7 shows the appearance of the specification of the collaborative task called *Contributions Discussion*. Modeling collaborative tasks implies to know the roles involved in their execution and the objects of the data model that are manipulated in a shared way. The area on the left of the figure shows the roles involved in the task (student and teacher), the objects manipulated (*Feasible Solution*) and the access mode to these objects (reading and/or writing). The central area shows the objects of the data model manipulated that constitute the shared context. For specifying the shared context we use UML notation to which we add some icons to express visualization features and blockade of the objects that compose the shared context (see figure 2.c). In the shared context specification area we have the *Topic, Aspect, Idea* and *Arguments* objects. One *Topic* is composed of several *Aspects* and an *Aspect* is composed of several *Ideas*. The aspects and ideas can have arguments. These objects are acceded in an exclusive mode.

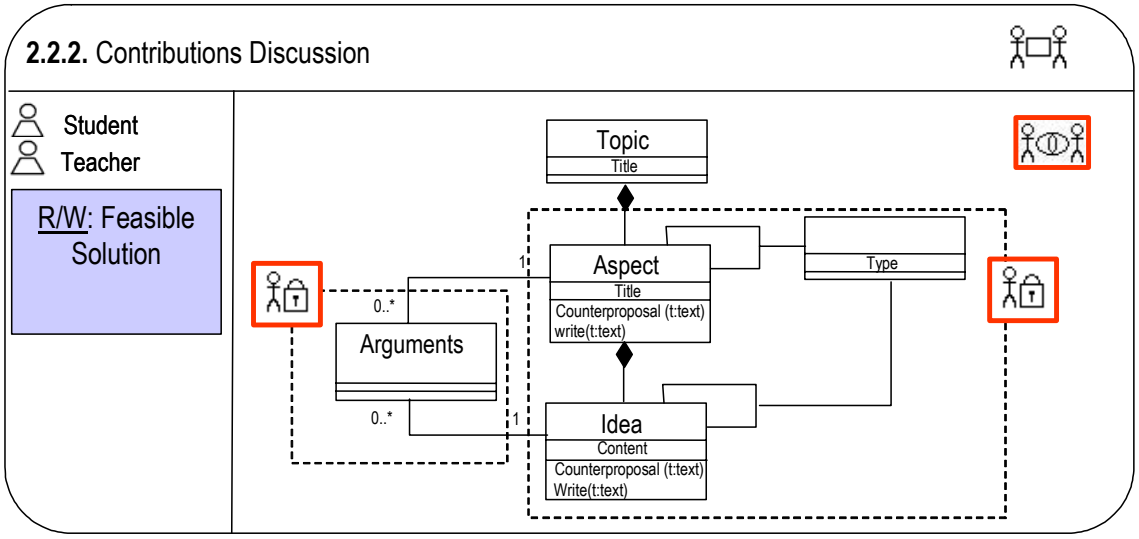


Figure 7. Contributions Discussion

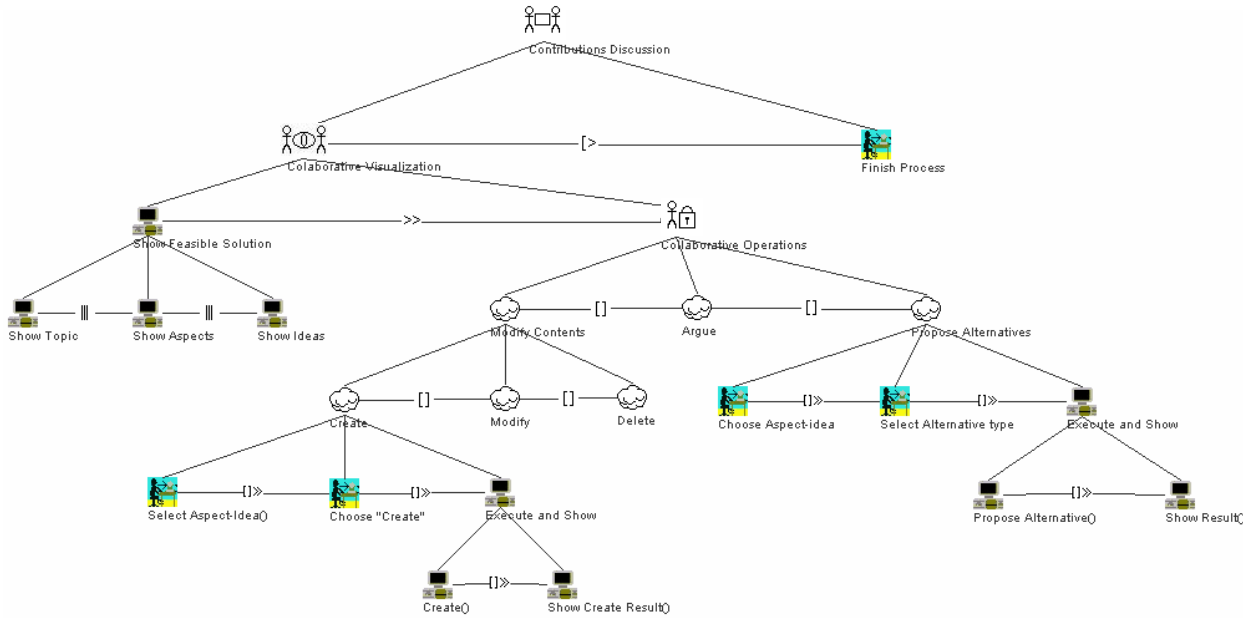


Figure 8. Modeling the Contributions Discussion task with an enhanced CTT Tree.

6 Discussion

Analyzing the models built we can observe that CIAM and CIAN allow the representation and modeling of the composition scenario created with AULA (see Figure 3). This model shows the tasks to do, the roles involved and the main and most significant objects handled and the way to do this. A precise definition of the roles and responsibilities for each task is also shown. Although not demonstrated as computable, this model is based on a conceptual framework described by means of ontologies, which facilitates its interpretation [Molina, 06].

The application of CIAM to the modeling of tasks supported by the AULA system has been demonstrated, dealing in depth with the modeling of a collaborative task. In particular, the Composition task presents a greater wealth of requirements relative to work-in-group/learning-in-group situations. The modeling of the collaboration starts with the previous description of tasks, roles and responsibilities and then describes how to share the context and how to access the objects of the shared context (see Figure 7). Thus, areas of individual visualization, of collaborative visualization and of exclusive edition are defined.

It is remarkable how CIAN systematically guides the extraction of the interaction model from the model of the shared context. This model of interaction is expressed in CTT (figure 8) and works as an entry point to use it with development tools of user interfaces based on models as is the case of TERESA [Berti, 2004] or the Dygimes framework [Luyten, 04]. This process is described in depth in [Molina, 2007]. Thus, a user interface is obtained starting from an interaction model that gathers the requirements to support collaborative tasks.

In the specification of requirements for the AULA functionality there are other aspects related to the mobile computing paradigm. CIAM does not offer mechanisms involving these requirements. For example, there are objects data of the system created in different contexts (online and offline). These objects need tasks synchronization. CIAM does not model these aspects at the data level or at the task level. There are specific tasks for different devices. For example: tasks of argumentation on the interactive whiteboard (teacher and students), text editing tasks on PDAs (students) and tasks of planning of the composition on a PC (teacher). CIAN does not allow the user to associate tasks to devices nor can it describe and characterize tasks that are made with PDA devices in contexts of mobile computing. The use of these devices with this approach has had important implications: tasks that can be made with or without a connection to a network, the need to have synchronization tasks of information generated offline, physical proximity of the students, tasks that are done face-to-face in the classroom or which can be done at a distance, etc. In summary, we focus on the modeling of aspects related to contexts such as computation, user and physical, time and device contexts. The last one, in particular, can indeed be included modifying the model of interaction directly expressed in CTT. Nevertheless, this is not done in a guided and systematic way as the rest of the steps that CIAM proposes.

7 Conclusions

In this article we have presented how to apply a methodological approach (CIAM) for the development of user interfaces to support collaborative and interactive activities that can be developed in a context of mobile computing. CIAM guides the designer following different phases from modeling to reaching an interaction model that can directly be used by a MBUID tool [Myers, 1995] to get implementations of end user interfaces. CIAM is based on the CIAN notation that allows users to accurately describe the features of a collaboration process (roles, responsibilities, tasks, shared context, etc). Nevertheless, it does not use semantics to describe the features of mobile computing, specially required for the modeling of the context. This has arisen from its application in the design and development process of the user interface that supports one of the tasks of collaborative learning in the language learning system called AULA. This system is thought to support collaborative tasks with PDA mobile devices. Therefore, this has been a case of study really appropriate to discover the CIAM potential in helping to the development of collaborative user interfaces. Also it has been useful to show the necessities of extension of CIAM in order to add certain features of the mobile computing paradigm and specially some parameters that allow modeling the context.

References

[Berti, 04] Berti, S., Mori, G., Paternò, F., Santoro, C. (2004). TERESA: A Transformation-Based Environment for Designing Multi-Device Interactive Applications. Demo Paper in Proceedings of CHI 2004, CHI '04 extended abstracts on Human factors in Computing Systems, ACM Press, pp.793-794, 24-29 April 2004, Wien, Austria.

[Dillenbourg, 95] Dillenbourg, P., Baker, M., Blaye, A., O'Malley, C. (1995). The Evolution of Research on Collaborative Learning. London.

[Ellis, 91] Ellis, C., Gibbs, S. & Rein, G. (1991) Groupware: Some Issues and Experiences. Communications of the ACM. Vol. 34, no. 1, pp. 39-58, January 1991.

[García, 04] García, L., & Novella, M. A. (2004). Preparación de Materiales Didácticos Auditivos. Ponencias Seminarios de Diagnóstico Locales de la CECU. In http://www.congreso.unam.mx/ponsemloc/ponencias/873.html 22/12/04.

[Hayes, 80] Hayes, J.R., & Flower, L.S. (1980). Identifying the organization of writing process. In Gregg y Steinberg (Eds.), Cognitive Processes in Writing. LEA.

[Luyten, 04] Luyten, K. (2004). Dynamic User Interface Generation for Mobile and Embedded Systems with Model-Based User Interface Development, PhD. thesis, Universiteit Limburg.

[Molina, 06] Molina, A.I., Redondo, M.A., Ortega, M., (2006) A Conceptual and Methodological Framework for Modeling Interactive Groupware Applications. The 12th International Workshop on Groupware (CRIWG 2006). Y.A. Dimitriadis et al. (Eds.) Groupware: Design, Implementation, and Use: CRIWG 2006, LNCS 4154, pp. 413 – 420, 2006.

[Molina, 07] Molina, A.I., Redondo, M.A., Ortega, M. (2007) CIAM: A methodology for groupware user interface development. Journal of Universal Computer Science. Know-Center. Acepted for publication.

[Myers, 95] Myers, B. A. (1995). "User Interface Software Tools." ACM Transactions on Computer-Human Interaction 2 1: 64-103.

[Paredes, 03] Paredes, M., Sánchez-Villalón, P.P., Ortega, M., Redondo M.A., Bravo, C., & Bravo, J. (2003). Semi-automatic Assessment Process in a Ubiquitous environment for Language Learning. In J.M. Cueva, B.M. González, L. Joyanes, J.E. Labra y M.P. Paule (Eds), Web Engineering. LNCS 2722, 255-258. Springer Verlag.

[Paredes, 06] Paredes, M. (2006). AULA: un Sistema Ubicuo de Enseñanza-Aprendizaje Colaborativo. PhD. Departamento de Tecnologías y Sistemas de Información. Universidad de Castilla – La Mancha.

[Paternò, 04] Paternò, F. (2004). ConcurTaskTrees: An Engineered Notation for Task Models. The Handbook Of Task Analysis For HCI. D. Diaper and N. A. Stanton. LEA, Mahwah, NJ.,: 483-501.

[Sharples, 93] Sharples, M., Goodlet, J.S., Beck, E.E., Wood, C.C., Easterbrook, S.M., & Plowman, L. (1993). Research Issues in the Study of Computer Supported collaborative writing. En M. Sharples (ed.), Computer Supported Collaborative Writing (pp. 9-28). Springer-Verlag.