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Trends in Practical Applications of Heterogeneous Multi-agent Systems. The PAAMS Collection

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Contents

Multi-agent System for Occupational Therapy

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Abstract. This paper presents a new solution for improving evaluation and intervention processes carried out by therapist. The proposed solution is based on a multiagent system especially designed for occupational therapy. The proposed solution aims at improving the traditional system to fulfill valuation scales, generation of therapy reports and extraction of statistics. Besides, the system proposes new techniques to improve the interaction with the user, by means of interactive cards that can be used for rehabilitation when working with intellectual handicapped patients. The paper shows the proposed application, as well as some preliminary results.

Keywords: Occupational therapy, evaluation, intervention, multi-agent systems.

1 Introduction

Occupational therapy evaluates the ability of a person to perform activities of daily living and intervenes if such capacity is at risk or threatened for any reason. Occupational therapists are the professionals responsible for carrying out, by hand, the essential processes of assessment and involvement of users in occupational centers [16, 10]. The current methodology has some problems in both processes: the difficulty of managing the vast amount of information generated on paper, the availability of this information, the lack of safety data, and some little update audiovisual media, etc. [16, 10]. Multi-agent systems and intelligent mobile devices architectures are suitable to handle complex and highly dynamic problems [2]. Agents and multi-agent systems have been successfully implemented in areas such as e-commerce, medicine, oceanography, robotics, etc. [3. 5, 7, 8, 9, 11, 13, 14, 15, 16, 18, 20, 21]. They have been recently explored as supervision systems, with the flexibility to be implemented in a wide diversity of scenarios, including health care environments. The current application of multi-agent systems in social environments is an area of increasing interest [11, 22, 23, 25, 28]. In general, the multi-agent system represents an appropriate

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approach for solving inherently distributed problems, whereby clearly different and independent processes can be distinguished.

This paper aims to improve and computerize the processes of assessment and intervention carried out by therapists, obtaining a mobile application that can help the medical staff to carry out their duties. This improves the traditional process, allowing the completion of rating scales, the generation of reports of therapy and extraction of statistics. It also improves the interaction between professionals and users using interactive maps that allow rehabilitation of mental disabilities and / or intellectual. Thus, we improve the evaluation process using scales implemented in the application and allowing better management and assessment of records and facilitating the completion of the scales and the measurement of users. We assist the intervention process by using flashcards, which improves user interaction and therapist, providing access to different types of issues and improving the user experience. We also facilitate the mobility of the therapist using a single mobile device to make the whole process of occupational therapy anywhere and by providing access to all information without depending on the location of the user or therapist.

The reminder of the paper is organized as follows: Section 2 reviews the state of the art, Section 3 introduces the proposed system and Section 4 presents the results and conclusions obtained.

2 Background

The Spanish Association of Professional Occupational Therapists (APETO) defines occupational therapy as: a socio-health profession that through the assessment of capacities and physical, mental, sensorial and social problems of the individual that aims, through proper treatment, to enable patients to achieve the greatest degree of independence as possible in their daily life, contributing to the recovery from illness or facilitating adaptation to disability [1]. The goals of occupational therapy on the users defined by ENOTHE (European Network of Occupational Therapy in Higher Education) [16] are: to maximize functional abilities, develop residual capacities, supply sunk functional deficits and achieve reintegration in society, living with a disability, but with the greatest degree of independence possible.

The occupational therapy process has different phases involving three types of actions: assessment, intervention, and analysis of results. So far, all occupational therapists adhere to a methodology in the process of assessment and intervention carried out in the centers they work [16]. These processes are virtually identical in all cases and determine the actions to be taken on each of the users and processes to be followed in their evaluation and subsequent rehabilitation. In the following paragraph, we are going to describe the process in a general manner:

(1) Initial intervention. It is a process guided by a semi-structured interview with the patient. During the interview be completed entirely manually and paper the following rating scales: Barthel Index, Lawton and Brody Scale, Scale Kels, Rating Scale Hobbies and Leisure (EVOTL), Leisure Interest List (LOII), Pfeiffer Questionnaire, Mini-Mental.

(2) Due to the complexity of the processes of initial assessment and reassessments, sometimes, it is carried out in different sessions, since they require a long period and the involvement of the person being evaluated.
(3) Evaluation report. The results of the assessments are compiled in a report, which is used as a basis for a treatment planning. After the intervention, a re-evaluation can be required if necessary.

Regarding applications for mobile devices used for evaluation and intervention in occupational therapy, there are currently no applications specifically designed for occupational therapy, although it is possible to find applications of sanitary type (used by people of various professional categories such as:. Doctors, physiotherapists, psychologists, nurses, etc.) that can be useful in tasks performed by the occupational therapist. We can classify these applications into two groups, depending on the device on which they run: wired devices and mobile devices. For wired devices, it is possible to find applications as PROIEC [19] that provides a structured intervention in the non-pharmacological field, intended for the person with dementia and rehabilitation of cognitive deficits particular material. For mobile devices, such as tablets or smartphones, some applications used in occupational therapy are: Baluh [4] that provides a communication solution for people who have difficulty speaking. It offers natural sounds, reading text, and is available in 14 languages and uses ARASAAC pictograms distributed under Creative Commons license. Baluh is used for intervention with children and adults with PDD (Pervasive Developmental Disorder). Picaa [11] is a support tool in the educational environment for users with special needs that facilitates and stimulates activities related to education. NeuroScores is a mobile application containing neurological scales, to evaluate stroke severity, progression, prognosis and outcome. It includes the rules for conducting a proper systematic neurological examination in the "Stroke Code". It calculates the score on the different scales of assessment, making a summary of the exploration and giving us a prognosis and treatment recommendations. Nerve Whiz is an application for medical professionals which shows the anatomy of the nerves. It studies the muscle innervation and areas of sensitivity loss making use of diagrams and charts. It is available for iOS devices. Glasgow scale is a mobile application that determines the level of consciousness using the Glasgow scale. It allows different user profiles depending on patient assessment. It is available for devices with Android.

To design the proposed approach, we evaluated different technologies. There are currently several operating systems for mobile devices that can be classified based on market share (data according to a study by International Data Corporation): Android (59%), iOS (23%), Symbian (6,8%), BlackBerry OS (6,4%), Bada (3,6%), Windows Phone. As can be seen, more than 80% of the sector is coped by the to the two leading mobile OS: Android and iOS. This prominence is due not only to the market data, but also the number of applications available, the maturity of the OS, the number of devices that possess, revenues, etc. One of the advantages of multiagent systems is the independence of operating system. To test the system we have developed a personal agent for the therapists that can be run on a iOS tablet.

3 MAS for Occupational Therapy

PANGEA is an agent platform to develop open multiagent systems [28], specifically those including organizational aspects such as virtual agent organizations. The platform allows the integral management of organizations and offers tools to the end user. Additionally, it includes a communication protocol based on the IRC standard, which facilitates implementation and remains robust even with a large number of connections. A general overview of the architecture is presented in Figure 1. The platform examines two modes of operation. In the first mode, the agents reside in the machine itself, while in the second mode the platform allows for the possibility of initiating all agents in different machines. The latter case has the disadvantage of allowing only minimal human intervention since it is necessary to previously specify the address of the machine where each of the agents are to reside; however it has the advantage of greater system distribution.

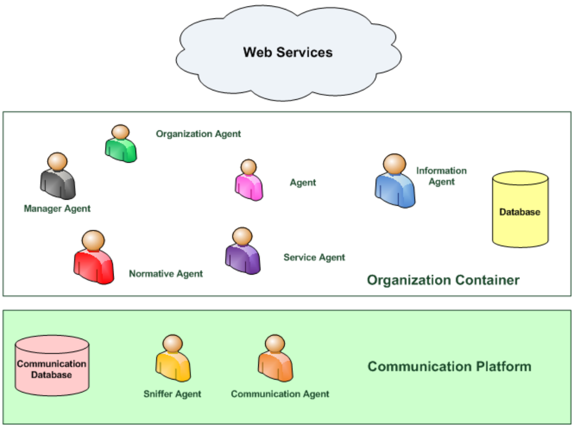

Fig. 1. PANGEA architecture

PANGEA has been used to develop a MAS for occupational therapy, where interface agents are installed on a iOS-based device and interact with the organization of agents. The use of PANGEA allow us to design the system in terms of organization, taking into account the human social infrastructures that participate in the occupational therapy problem. Thus, in the proposed solution we have defined a series of specialized agents:

- Therapist agent. This agent is installed in the mobile device (tablet) used by the therapist. The agent contains the valuation scales and the color cards that can be updated when connecting to the rest of the agents in the platform. The agent allows the therapist to write reports and to plan interventions.
- Store agent. This agent stores the information provided by the therapist agents related to patients' evaluation and intervention. Besides, this agent stores information about the different actors in the system (therapists and patients).

- Scales agent. This agent manages the different valuation scales that can be used by the therapist.
- Evaluator agent. This agent is specialized on analyzing the Information provided in the reports and obtain statistics about evaluations and interventions. The agent incorporates a case-based reasoning [11, 8, 9] system and defines rules to represent the knowledge obtained from the evaluations and interventions. In the future work this agent will incorporate a decision support system for the therapists to make recommendations based on past experiences.

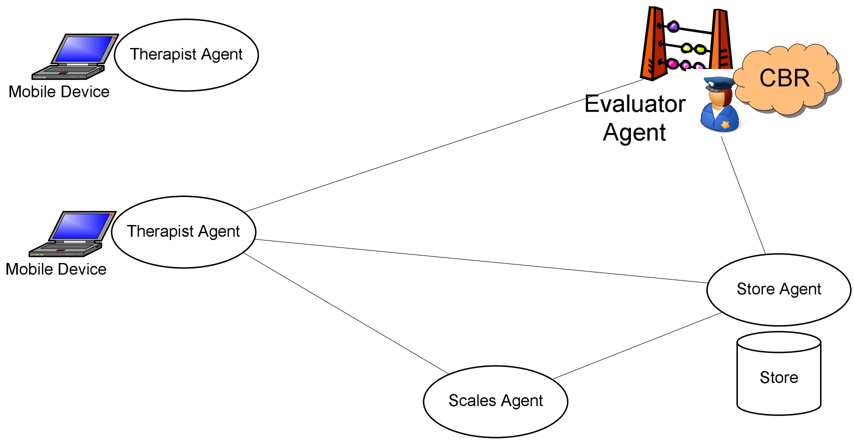

Fig. 2. Multi-agent architecture for occupational therapy

The proposed multi-agent system can be easily connected to similar MASs that would be installed in different health care scenarios [24, 26, 27], allowing interconnection and reuse of the resources available for occupational therapy. Besides, the use of the PANGEA architecture allow us to define organizational structures similar to those used in human societies. In this paper, we will focus on a particular multi-agent system without taking into account organizational aspects, and more specifically on the Therapist agent, which is installed on a mobile device and provides a tool to the therapist interact with the patient and to carry out the evaluations and interventions. The organizational aspects will be studied in further work.

4 Preliminary Results and Conclusions

After reviewing the state of the art, it has been found that the current therapeutic approach is mostly manual, and generates a lot of information that sometimes it is difficult to manage. Besides the use of a physical medium such as paper makes it difficult to find information, data mobility, and access to records. Moreover, in the intervention process, the use of color cards is repetitive and monotonous for the patient. Most of the times the cards are not up to date and the patient can only interact with them. In relation to the methodology followed by the occupational therapist, a new opportunity arises to improve the evaluation and intervention process. The process can be automated using a multi-agent system that can notably improve aspects such as computation and communication. In this sense, the use of agents installed in mobile devices facilitate the patient evaluation in a ubiquitous manner and an efficient storage and access to the required information. Furthermore, the use of the proposed multi-agent system provides a high flexibility for the management and monitoring of all the patients and therapeutic history. It also allows all therapists of a medical center (or even from different medical centers) to follow a common methodology, and access all the information in a ubiquitous manner. Regarding the patient, the use of an interactive device, enhances the experience in the intervention process, motivating them to perform therapeutic activities and facilitating access therapy processes. Figure 3 shows an example of a therapist agent. Figure 3.a shows a screenshot of the intervention phase, and more specifically some items used as color cards. Figure 3.b shows a screenshot of the evaluation phase. As can be seen in Figure 3.b, the therapist can choose different valuable scales and write a final report for each of the patients.

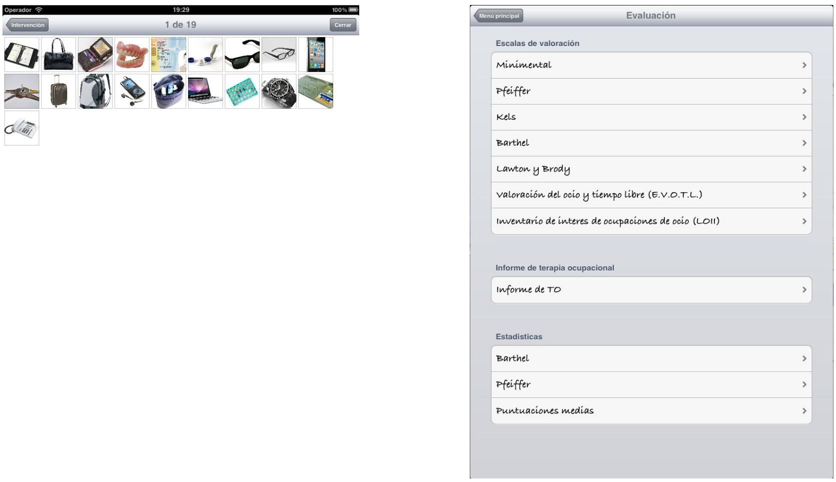

Fig. 3. Screenshot of the therapist agent. a) Flash cards. b) valuation scales

The proposed approach requires a mobile medium size, given the characteristics of the contents thereof. It must be portable but of an appropriate size to display forms and images to a readable size for patients and therapists. It must allow access to the internet and be friendly to both the application for single-strength SSOO own interface. In this case we opt for a tablet type device to install the therapist agent. The use of the PANGEA platform allows an easy remote connection of the therapist agent.

The proposed approach was evaluated in a medical center in the north of Spain with 10 users and the initial results were promising. In particular, the system was tested with 10 patients attending a pre-laborer workshop for people with mental and intellectual disabilities. The sessions consisted on conducting an initial evaluation, recognition of numbers and letters, colors, coins and banknotes, the same way the traditional material was used to support the acquisition of skills and abilities. From the point of view of a professional of neural rehabilitation, this application provides a substantial improvement in both the occupational therapist and the patients attending the medical center. One of the advantage mentioned by the medical staff is the mobility and independence of local resources. Besides, the therapist highly valuated the statistical analysis provided by the system, which notably improves the previous manual processes. Another important point for the therapist is the quality of the cards (images).

Our future work will focus on the evaluation of the multi-agent system and inclusion of organizational aspects. We will also focus on a more general group of individuals to evaluate the proposed approach.

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References

1. APETO (last accessed 2014), http://www.apeto.com
2. Bajo, J., Corchado, J.M.: Evaluation and monitoring of the air-sea interaction using a CBR-agents approach. In: Muñoz-Ávila, H., Ricci, F. (eds.) ICCBR 2005. LNCS (LNAI), vol. 3620, pp. 50–62. Springer, Heidelberg (2005)
3. Bajo, J., De Paz, J.F., Rodríguez, S., González, A.: Multi-agent system to monitor oceanic environments. Integrated Computer-Aided Engineering 17(2), 131–144 (2010)
4. Baluh (last accessed 2014), http://blog.baluh.org/
5. Borrajo, M.L., Baruque, B., Corchado, E., Bajo, J., Corchado, J.: Hybrid neural intelligent system to predict business failure in small-to-medium-size enterprises. International Journal of Neural Systems 21(04), 277–296 (2011)
6. Carneiro, D., Castillo, J.C., Novais, P., Fernández-Caballero, A., Neves, J.: Multimodal Behavioural Analysis for Non-invasive Stress Detection. In: Expert Systems With Applications, vol. 39(18), pp. 13376–13389. Elsevier (2012) ISSN: 0957-4174
7. Corchado, J.M., Aiken, J.: Hybrid artificial intelligence methods in oceanographic forecast models. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews 32(4), 307–313 (2002)
8. Corchado, J.M., De Paz, J.F., Rodríguez, S., Bajo, J.: Model of experts for decision support in the diagnosis of leukemia patients. Artificial Intelligence in Medicine 46(3), 179–200 (2009)
9. Corchado, J.M., Bajo, J., De Paz, J.F., Rodríguez, S.: An execution time neural-CBR guidance assistant. Neurocomputing 72(13), 2743–2753 (2009); De Paz, J.F., Rodríguez, S., Bajo, J., Corchado, J.M.: Case-based reasoning as a decision support system for cancer diagnosis: A case study. International Journal of Hybrid Intelligent Systems 6(2), 97–110 (2009)
10. Creek, J., Lougher, L.: Occupational Therapy and Mental Health. Churcill Livingston - Elsevier (2008)
11. Fernández López, A., Rodríguez Fórtiz, M.J.: Dispositivos móviles iPod touch y iPad para Aprendizaje en Educación Especia. In: Arnaiz, P., Hurtado, M.D., Soto, F.J. (Coords.) 25 Años de Integración Escolar en España: Tecnología e Inclusión en el ámbito educativo, laboral y comunitario, Consejería de Educación, Formación y Empleo, Murcia (2010)

12. Fdez-Riverola, F., Corchado, J. C.: based system for forecasting red tides. Knowledge-Based Systems 16(5), 321–328 (2003)
13. Fraile, J.A., Bajo, J., Corchado, J.M., Abraham, A.: Applying wearable solutions in dependent environments. IEEE Transactions on Information Technology in Biomedicine 14(6), 1459–1467 (2011)
14. Garijo, F., Gómez-Sanz, J.J., Pavón, J., Massonet, P.: Multi-agent system organization: An engineering perspective. In: Pre-Proceeding of the 10th European Workshop on Modeling Autonomous Agents in a Multi-Agent World, MAAMAW 2001 (2001)
15. Griol, D., García-Herrero, J., Molina, J.M.: Combining heterogeneous inputs for the development of adaptive and multimodal interaction systems, Advances in Distributed Computing And Artificial Intelligence Journal
16. Hagedorn, R.: Occupational Therapy Perspective and processes. Churchill Livingstone - Elsevier (1995)
17. Pavon, J., Sansores, C., Gomez-Sanz, J.J.: Modelling and simulation of social systems with INGENIAS. International Journal of Agent-Oriented Software Engineering 2(2), 196–221 (2008)
18. Pinzón, C.I., Bajo, J., De Paz, J.F., Corchado, J. S.-M.: An adaptive hierarchical distributed multi-agent architecture for blocking malicious SOAP messages within Web Services environments. Expert Systems with Applications 38(5), 5486–5499
19. PROIEC (last accessed 2014), `http://www.terapia-ocupacional.com/ayudas-tecnicas/IVE/proiec.shtml`
20. Rodríguez, S., Pérez-Lancho, B., De Paz, J.F., Bajo, J., Corchado, J.M.: Ovamah: Multiagent-based adaptive virtual organizations. In: 12th International Conference on Information Fusion, FUSION 2009, pp. 990–997 (2009)
21. Rodríguez, S., de Paz, Y., Bajo, J., Corchado, J.: Social-based planning model for multiagent systems. Expert Systems with Applications 38(10), 13005–13023 (2011)
22. Schuler, D.: Social computing. Communications of the ACM 37(1), 28–29 (1994)
23. Sánchez-Pi, N., Carbó, J., Molina, J.M.: A Knowledge-Based System Approach for a Context-Aware System. Knowledge-Based Systems 27, 1–17 (2012)
24. Tapia, D.I., Alonso, R.S., De Paz, J.F., Corchado, J.: Introducing a distributed architecture for heterogeneous wireless sensor networks. In: Omatu, S., Rocha, M.P., Bravo, J., Fernández, F., Corchado, E., Bustillo, A., Corchado, J.M. (eds.) IWANN 2009, Part II. LNCS, vol. 5518, pp. 116–123. Springer, Heidelberg (2009)
25. Tapia, D.I., Abraham, A., Corchado, J.M., Alonso, R.: Agents and ambient intelligence: case studies. Journal of Ambient Intelligence and Humanized Computing 1(2), 85–93 (2010)
26. Tapia, D.I., Rodríguez, S., Bajo, J., Corchado, J.M.: FUSION@, a SOA-based multi-agent architecture. In: International Symposium on Distributed Computing and Artificial Intelligence (DCAI 2008), pp. 99–107 (2008)
27. Tapia, D.I., Alonso, R.S., García, Ó., de la Prieta, F., Pérez-Lancho, B.: Cloud-IO: Cloud Computing Platform for the Fast Deployment of Services over Wireless Sensor Networks. In: 7th International Conference on Knowledge Management in Organizations: Service and Cloud Computing, pp. 493–504 (2013)
28. Zato, C., Villarrubia, G., Sánchez, A.: PANGEA - Platform for Automatic Construction of Organizations of Intelligent Agents. In: Distributed 9th International Conference Computing and Artificial Intelligence (2012)

Indoor Location System for Security Guards in Subway Stations

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Abstract. Indoor locating systems (RTLS), have notably advanced during recent years, becoming one of the main challenges for several research teams. The main objective of indoor locating systems is to obtain functional systems able to locate different elements in those environment where GPS (Global Positioning System) is limited. The growing use of mobile devices in the information society provides a powerful mechanism to obtain geographical data and has led to new algorithms aimed at facilitating object positioning with easonable power consumption. In this paper we propose an innovative indoor location architecture that makes use of the data provided by mobile devices to locate objects. The architecture is applied to a case study in a real environment focused on obtaining the location of security staff in the subway network in a city in the north of Spain.

Keywords: indoor locating system, Wi-Fi, MQTT.

1 Introduction

Indoor locating systems have significantly evolved during recent years [10] [13] [15] [3]. The main challenge of current research in indoor locating systems is to provide a system that can calculate the position of different resources in indoor systems with a reduced cost [1][2]. Estimating the location of a given resource constitutes the basis of the design of advanced services such as resource identification, security,

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recommendation systems, human behaviour analyzers, etc. [28][30]. The majority of these services are deployed in indoor environments such as hospitals, subway stations, shopping malls and so on, characterized by a weak or inexistent GPS signal. Thus, taking into account the importance of location-based services[11][14], it is necessary to design new and effective indoor locating systems.

Nowadays, the use of Wi-Fi technology allows the development of real time indoor locating systems with a low-cost infrastructure[16][17] compared to alternative technologies such as (*Radio Frequency iDentification*) [5] or ZigBee[6]. The technological infrastructure required to provide indoor location use Wi-Fi communication, which is based on the deployment of Access Points in the environment to be controlled. These access points can be used as readers. One of the advantages of this kind of solution is that Wi-Fi systems are very common and it is usual to find Wi-Fi[20][22] access points installed in a broad variety of public places, hospitals or environments dedicated to leisure activity. The existing technology[18] can be reused to implement indoor location solutions without additional costs. Furthermore, the use of wireless technologies makes it possible to locate people by means of their smartphones or another electronic low-cost devices.

In this paper we propose an indoor location architecture based on Wi-Fi technology that provides the location of the subway security guards and determines the station where the security guard is located at any given moment. The systems calculates the position of the security guard based on his or her personal smartphone[23][12][27], which presents several limitations including connectivity problems and battery consumption. The smartphone is not only used as a tag to be located, but also as a way to comminicate with other security guards. The architecture defines a new algorithm to estimate the real positon of the users using GSM (Global System for Mobile) signals and resource-constrained devices. The algorithm uses reduced data frames and the infrastructure uses a low-latency setting, which facilitates effective communications with an external server.

The rest of the paper is organized as follows: Section 2 revises the state of the art of the situation that has motivated this research, Section 3 presents the architecture and its application to a case study. Finally Section 4 present the results obtained.

2 Background

Nowadays it is possible to find differnt algorithms and commercial systems aimed at facilitating the indoor location of a user. Table 1 presents a comparative study between the main existing systems, identifying their strengths and weaknesses.

Existing systems [19] [21] present business models with several restrictions, based on pay-per-use systems and hardware renting systems.

Table 1. Comparison Between Commercial Systems

DEVICE	THECNOLOGY	TYPE	SIZE (CM)	ACCURACY (M)	ADVANTAGES	DISADVANTAGES
HELICOMM (EZ-TRACER)	ZigBee	Beacons	6.8x4x1.7	3	Development Kit	Very Expensive
EKAHAU	WiFi	Tag	4.5x5.5x1.9	5	Through wall	Calibration Process
AEROSCOUT	WiFi-RFID-UWB	Beacons	7.4x5x1	15	Movement sensor	Calibration Process
UBISENSE	UWB 7Ghz-TDOA-AOA	Beacons	8.3x4.2x1.1	0.3	-	Without Warranty
SAPHIRE MULTISPECTRAL	TDOA 5.94Ghz	Tag	2.8x2.8x2.54	1	Only USA	-
AWARE POINT	ZigBee	Tag	1.6x2.7x0.5	10	ZigBee Alliance	Very Expensive
TIMEDOMAIN	UWB	Tag	1.9x2.3x0.9	15	Health Enviro-ment	Poor Informa-tion
PLACELAB	WiFi	Beacons	1.9x2.8x1.9	13	Open Source	Microsoft

The common feature of all the systems evaluated [25] [29] (and main disadvantage) is the introduction of proprietary hardware, which does not make is possible to use a conventional smartphone to identify location. Furthermore, many existing systems require [24] [26] the use of a tag component. This item type is invasive for users and lacks functionality if a similar service can be offered by using a mobile terminal.

3 Location Architecture for Subway Environments

This section presents an arquitecture especially designed to locate human resources in indoor environments, more specifically in subway stations. The special characteristics of this environment require the design of an innovative solution. The main objective of the proposed architecture is to locate security staff in subway stations. Different alternatives have been evaluated to design the architecture. The proposed system uses GSM signals and smartphones, due to the execessive cost that the use of wi-fi tags can cause. The system infrastructure, which is shown in Figure 1, is composed of two different sub-systems: central server and mobile devices. From the software point of view the architecture proposes two elements: the location engine and the location system, both of which are explained in the following sub-sections.

3.1 Communication System

This system interconnects the mobile devices with a central server, which is in charge of calculating positions from the information acquired by the mobile devices.

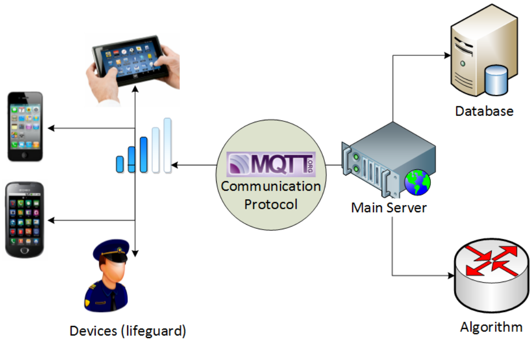

Fig. 1. Proposed architecture

***Mobile Devices*:** An Android application is installed in each of the mobile devices executed as a service. The application periodically scans the wireless networks detected in the surroundings and sends the information collected to the central server. The data frame format contains the information of the detected networks, the time of the scan, the mobile device identifier and the percentage of battery of the device.

The Wi-Fi networks detected by the mobile devices correspond to the access points installed in the subway stations. The Wi-Fi infrastructure for each of the subway stations consists of two Access points, model UBN PICOSTATION M2H, on either side of the platform. The stations have a length of 100m while the Access points can cover 150 m.


```
{
    "battery": "98.57143",
    "datimeTime": "26/11/2013 13:14:37:871",
    "identificador": "641d4cfce40cbf67",
    "listadoAp": [
        {
            "BSSID": "fc:0a:81:1e:d4:20",
            "SSID": "eduroam",
            "frequency": "2437",
            "level": "-85"
        },
        {
            "BSSID": "28:5f:db:05:d2:5f",
            "SSID": "roble",
            "frequency": "2437",
            "level": "-67"
        }
    ]
}
```


Fig. 2. Mobile Datagram Example. Example of Beacon

Central Server: The mobile devices capture the data which are sent to a central server using an innovative communication system called MQTT (MQ Telemetry Transport). The use of a communication protocol as Machine-to-Machine (M2M) allows data transmission in high latency networks with certain constraints [31]. It is a lightweight protocol that allows a publication-subscription mechanism, which is very useful for a low consumption bandwidth. In the architecture presented in this paper, the subway stations are not equipped with a high speed bandwidth and the communication between the mobile devices and the central server is implemented by means of GPRS (General Packet Radio Service).

One of the most innovative aspects of the proposed architecture [32] is the integration within a MQTT protocol for Information exchange. This provides high efficiency compared to the existing commercial systems that use SOA (Service Oriented Architecture). The comparison shown in Table 2 shows underscores the advantages of using a MQTT protocol instead of a traditional client/server architecture in terms of battery consumption. Table 2 presents a comparison between MQTT and HTTPS messages for a total of 1024 communications [7].

Table 2. Comparative Battery saving

	3G		WiFi	
	HTTPS	MQTT	HTTPS	MQTT
% Battery / Hour	18.43%	16.13%	3.45%	4.23%
Messages / Hour	1708	160278	3628	263314
% Battery / Message	0.01709	0.00010	0.00095	0.00002
Messages Received	240 / 1024	1024 / 1024	524 / 1024	1024 / 1024

As can be seen in Table 2, the use of MQTT can be justified in terms of battery savings alone.

3.2 Location System

The location algorithm presented in this paper uses a signpost technique to calculate the station where a security guard is located [4]. Signpost is characterized by its simplicity and a low computational cost [8]. The location of each of the security guards is estimated detecting the more powerful signal as shown in Figure 4.

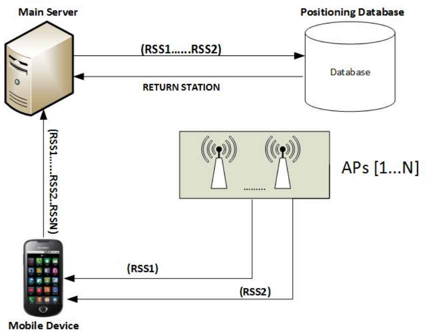

Fig. 3. Wifi Architecture

As seen in Figure 5, the 12 subway stations in the case study used to evaluate the architecture in this paper are separated by a considerable distance. As a result, the routers do not interfere with each other, and can estimate the station where there is a guard with a rate of 100%.

Station	1	2	3	4	5	6	7	8	9	10	11	12
1	0	250	296	312	314	288	287	295	293	300	311	299
2		0	298	288	302	287	298	296	287	301	280	291
3			0	289	308	319	317	285	317	286	320	302
4				0	297	298	297	292	285	315	308	320
5					0	297	298	285	296	289	302	294
6						0	296	305	317	299	306	316
7							0	268	286	316	298	310
8								0	269	281	293	296
9									0	280	312	316
10										0	254	295
11											0	281
12												0

Fig. 4. Distances between stations in meters

To make the location process work correctly, it is necessary to link the metro stations with the Wi-Fi beacons that have been deployed in the case study. This relationship is implemented using a relational database, and the MAC addresses of the associated access points are stored for each station, as shown in Figure 6.

STATION	LATITUDE	LONGITUDE	XPOS	YPOS	ID	XLABEL	YLABEL	TIPE
STATION 1	43.401.959	-2.946.509	780	55	PLT	-60	-15	2

Station	MAC
STATION 1	dc:9f:db:9a:9f:27
STATION 2	dc:9f:db:9a:9f:c8

Fig. 5. Relationship between stations and routers

The central server stores the location data of the security guards in a database. These data are used to generate analysis and extract knowledge.

4 Results and Conclusions

The architecture presented in Section 3 has been installed in a subway network in the city of Bilbao in the north of Spain. The system infrastructure included 42 access points in 21 stations, and the security guards were equipped with 12 mobile devices, model GT-i9502 MTK6589, with an Android 4.2 operating system. The system was tested during one month and no anomalies were detected during the evaluation.

The central server was used by a supervisor to control the location of the security guards. To facilitate this task we developed a visualization tool that presents the location of the security guards in a very intuitive way. The central server implements monitoring services that are used by the supervisor to define alarms that are triggered when a security guard deviates from his or her usual route.

Figure 7 shows a screenshot of the central server application which is installed in the central server and allows monitoring the security guards.

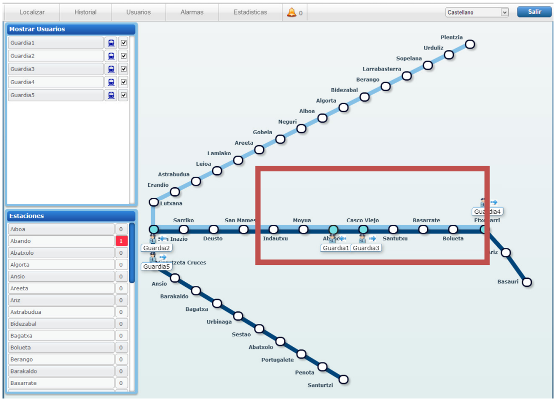

Fig. 6. Utility to view the positions

The users' location is updated in the visualization tool using Node.js technologie [9], an asynchronous platform that allows the development of scalable networks in a very quick way. The location of each security guard is asynchronously and immediately updated when a frame from a mobile device is received, without any refresh or request message required.

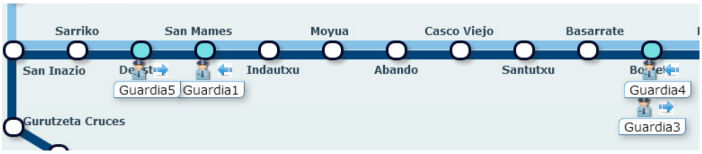

Fig. 7. Detailed View of lifeguard movements

System users have highlighted the ease of use and accuracy of the architecture. One of the most appreciated aspects among supervisors was the ability to generate multiple reports from the location data of the security guards stored in the database. For the supervisor it was of special interest to know the time spent by a security guard in a particular station, as shown in Figure 8.

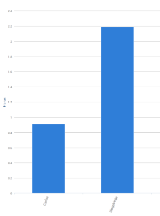

Fig. 8. Report Example

Different tests were conducted to evaluate the battery consumption by comparing the proposed system with commercial systems. The use of a protocol with low latency and the avoidance of using conventional web services, yielded an average of 27% in terms of optimizing the battery life of mobile devices.

The results presented in this paper show that it is possible to implement a functional indoor locating system in an environment as complicated as subway stations, using wireless networks and with a reduced cost of deployment. It has been shown that the use of a M2M protocol provides quantitative battery savings in mobile terminals.

Finally, we believe that it is of interest to evaluate the system in a more complex environment and check whether there is any functional limitation on the number of users that can be supported by the application. This is our next challenge.

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References

1. Anand, P., Siva Prasad, B.V., Venkateswarlu, C.: Modeling and optimization of a pharmaceutical formulation system using radial basis function network. International Journal of Neural Systems 19(2), 127–136 (2009)
2. Carnicer, J.M.C., García-Esnaola, M.: Lagrange interpolation on conics and cubics. Comput. Aided Geom. Design. 19, 313–326 (2002)
3. Chen, Y.-C., Chiang, J.-R., Chu, H.-H., Huang, P., Tsuid, A.W.: Sensor-Assisted Wi-Fi Indoor Location System for Adapting to Environmental Dynamics (2011)
4. Huang, C.N., Chan, C.T.: ligBee-based indoor location system by k-nearest neighbor algorithm with weighted RSSI. Procedia Computer Science 5, 58–65 (2011)
5. Tesoriero, R., Tebar, R., Gallud, J.A., Lozano, M.D., Penichet, V.M.R.: Improving location awareness in indoor spaces using RFID technology. Expert Systems with Applications 37(1), 894–898 (2010)
6. Hui, L., Darabi, H., Banerjee, P., Liu, J.: Survey of Wireless Indoor Positioning Techniques and Systems. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews 37(6), 1067–1080 (2007)
7. Web, `http://stephendnicholas.com/archives/1217` (last visited January 14, 2014)
8. Tapia, D., Bajo, J., De Paz, J.F., Alonso, R.S.: Using Multi-Layer Perceptrons to Enhance the Performance of Indoor RTLS (2011)
9. Web, `http://nodejs.org` (last visited January 14, 2014)
10. Corchado, J.M., Fyfe, C.: Unsupervised neural method for temperature forecasting. Artificial Intelligence in Engineering 13(4), 351–357 (1999)
11. Fdez-Riverola, F., Corchado, J.M.: CBR based system for forecasting red tides. Knowledge-Based Systems 16(5), 321–328 (2003)
12. Tapia, D.I., Abraham, A., Corchado, J.M., Alonso, R.S.: Agents and ambient intelligence: case studies. Journal of Ambient Intelligence and Humanized Computing 1(2), 85–93 (2010)
13. Corchado, J.M., Lees, B.: Adaptation of cases for case based forecasting with neural network support. In: Soft Computing in Case Based Reasoning, pp. 293–319 (2001)
14. Corchado Rodríguez, J.M.: Redes Neuronales Artificiales: un enfoque práctico. Servicio de Publicacións da Universidade de Vigo, Vigo (2000)

15. Bajo, J., Corchado, J.M.: Evaluation and monitoring of the air-sea interaction using a CBR-Agents approach. In: Muñoz-Ávila, H., Ricci, F. (eds.) ICCBR 2005. LNCS (LNAI), vol. 3620, pp. 50–62. Springer, Heidelberg (2005)
16. Fraile, J.A., Bajo, J., Corchado, J.M., Abraham, A.: Applying wearable solutions in dependent environments. IEEE Transactions on Information Technology in Biomedicine 14(6), 1459–1467 (2011)
17. Corchado, J.M., De Paz, J.F., Rodríguez, S., Bajo, J.: Model of experts for decision support in the diagnosis of leukemia patients. Artificial Intelligence in Medicine 46(3), 179–200 (2009)
18. De Paz, J.F., Rodríguez, S., Bajo, J., Corchado, J.M.: Case-based reasoning as a decision support system for cancer diagnosis: A case study. International Journal of Hybrid Intelligent Systems 6(2), 97–110 (2009)
19. Tapia, D.I., Rodríguez, S., Bajo, J., Corchado, J.M.: FUSION@, a SOA-based multi-agent architecture. In: International Symposium on Distributed Computing and Artificial Intelligence 2008 (DCAI 2008), pp. 99–107 (2008)
20. Corchado, J.M., Aiken, J.: Hybrid artificial intelligence methods in oceanographic forecast models. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews 32(4), 307–313 (2002)
21. Corchado, J.M., Aiken, J., Rees, N.: Artificial intelligence models for oceanographic forecasting. Plymouth Marine Laboratory (2001)
22. Rodríguez, S., Pérez-Lancho, B., De Paz, J.F., Bajo, J., Corchado, J.M.: Ovamah: Multiagent-based adaptive virtual organizations. In: 12th International Conference on Information Fusion, FUSION 2009, pp. 990–997 (2009)
23. Tapia, D.I., De Paz, J.F., Rodríguez, S., Bajo, J., Corchado, J.M.: Multi-agent system for security control on industrial environments. International Transactions on System Science and Applications Journal 4(3), 222–226 (2008)
24. Borrajo, M.L., Baruque, B., Corchado, E., Bajo, J., Corchado, J.M.: Hybrid neural intelligent system to predict business failure in small-to-medium-size enterprises. International Journal of Neural Systems 21(04), 277–296 (2011)
25. De Paz, J.F., Rodríguez, S., Bajo, J., Corchado, J.M.: Mathematical model for dynamic case-based planning. International Journal of Computer Mathematics 86(10-11), 1719–1730 (2009)
26. Bajo, J., De Paz, J.F., Rodríguez, S., González, A.: Multi-agent system to monitor oceanic environments. Integrated Computer-Aided Engineering 17(2), 131–144 (2010)
27. Tapia, D.I., Alonso, R.S., De Paz, J.F., Corchado, J.M.: Introducing a distributed architecture for heterogeneous wireless sensor networks. In: Omatu, S., Rocha, M.P., Bravo, J., Fernández, F., Corchado, E., Bustillo, A., Corchado, J.M. (eds.) IWANN 2009, Part II. LNCS, vol. 5518, pp. 116–123. Springer, Heidelberg (2009)
28. Rodríguez, S., de Paz, Y., Bajo, J., Corchado, J.M.: Social-based planning model for multiagent systems. Expert Systems with Applications 38(10), 13005–13023 (2011)
29. Pinzón, C.I., Bajo, J., De Paz, J.F., Corchado, J.M.: S-MAS: An adaptive hierarchical distributed multi-agent architecture for blocking malicious SOAP messages within Web Services environments. Expert Systems with Applications 38(5), 5486–5499
30. Corchado, J.M., Bajo, J., De Paz, J.F., Rodríguez, S.: An execution time neural-CBR guidance assistant. Neurocomputing 72(13), 2743–2753 (2009)
31. Gómez, J., Patricio, M.A., García, J., Molina, J.M.: Communication in distributed tracking systems: an ontology-based approach to improve cooperation. Expert Systems 28(4), 288–305 (2011)
32. Pavon, J., Sansores, C., Gomez-Sanz, J.J.: Modelling and simulation of social systems with INGENIAS. International Journal of Agent-Oriented Software Engineering 2(2), 196–221 (2008)