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Juan M. Corchado
Javier Bajo Pérez
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Trends in Practical Applications of Agents and Multiagent Systems

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Prof. Janusz Kacprzyk
Systems Research Institute
Polish Academy of Sciences
ul. Newelska 6
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Poland
E-mail: kacprzyk@ibspan.waw.pl

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Trends in Practical Applications of Agents and Multiagent Systems

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Editors

Prof. Juan M. Corchado
Universidad de Salamanca
Departamento de Informática y Automática
Facultad de Ciencias
Plaza de la Merced S/N
37008 Salamanca
Spain
E-mail: corchado@usal.es

Prof. Javier Bajo Pérez
Universidad Pontificia de Salamanca
Escuela Universitaria de Informática
Compañía 5
37002 Salamanca
Spain

Prof. Kasper Hallenborg
University of Southern Denmark
The Maersk Mc-Kinney Moller Institute
Campusvej 55
DK-5230 Odense M
Denmark

Prof. Paulina Golinska
Poznan University of Technology
Insitute of Manangement Engineering
Strzelecka 11
60-965 Poznan
Poland
E-mail: paulina.golinska@put

Prof. Rafael Corchuelo
ETSI Informática
Avda. Reina Mercedes, s/n
Sevilla, 41012
Spain
E-mail: corchu@us.es

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Preface

PAAMS'11 Workshops complement the regular program and the special sessions with new or emerging trends of particular interest connected to multi-agent systems.

PAAMS, the International Conference on Practical Applications of Agents and Multi-Agent Systems is an evolution of the International Workshop on Practical Applications of Agents and Multi-Agent Systems. PAAMS is an international yearly tribune to present, to discuss, and to disseminate the latest developments and the most important outcomes related to real-world applications. It provides a unique opportunity to bring multi-disciplinary experts, academics and practitioners together to exchange their experience in the development of Agents and Multi-Agent Systems.

This volume presents the papers that have been accepted for the 2011 in the workshops: Workshop on Agents for Ambient Assisted Living, Workshop on Agent-Based Solutions for Manufacturing and Supply Chain, Workshop on Agents and Multi-agent systems for Enterprise Integration.

We would like to thank all the contributing authors, as well as the members of the Program Committees of the workshops and the Organizing Committee for their hard and highly valuable work. Their work has helped to contribute to the success of the PAAMS'11 event. Thanks for your help, PAAMS'11 wouldn't exist without your contribution.

Juan Manuel Corchado
Javier Bajo
PAAMS'11 Organizing Co-chairs

Acknowledgements: This conference has been supported by Junta de Castilla y León (Spain).

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The series "Advances in Intelligent and Soft Computing" contains publications on various areas within the so-called soft computing, which include fuzzy sets, rough sets, neural networks, evolutionary computations, probabilistic and evidential reasoning, multi-valued logic, and related fields. The publications within "Advances in Intelligent and Soft Computing" are primarily textbooks and proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both theoretical and applied. An important feature of the series is the short publication time and world-wide distribution, allowing a rapid and broad dissemination of research results.

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Trends in Practical Applications of Agents and Multiagent Systems

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A New Adaptive Algorithm for Detecting Falls through Mobile Devices

Miguel Sánchez, Patricia Martín, Laura Álvarez, Vidal Alonso,
Carolina Zato, Alberto Pedrero, and Javier Bajo

Abstract. Most of elderly people suffer physical degeneration that makes them particularly vulnerable to falls. Falls cause injuries, time of hospitalization, rehabilitation which is particularly difficult for the elderly and disabled. This paper presents a new system with advanced capacities for learning and adaptation specifically designed to detect falls through mobile devices. The systems proposes a new adaptive algorithm able to learn, classify and identify falls from data obtained by mobile devices and user profile. The system is based on machine learning and data classification using decision trees. The main contribution of the proposed system is the use of posturographic data and medical patterns as a knowledge base, which notably improves the classification process.

Keywords: Context-Aware, Adaptive Algorithms, Machine Learning, Fall detection, Decision trees.

1 Introduction

Falls are one of the most serious problems in the geriatric care because they are one of the fundamental causes of injury and even death in elderly people. According to the World Health Organization (WHO), between 28% and 34% of people 65 and older experience at least one fall per year [14]. In Spain the data are also alarming. Various authors consider that falls are due to a combination of multiple factors, and can be grouped into two main groups: intrinsic and extrinsic factors, and consequences of they are not only physical but also psychological, social and economic [4, 6, 7].

Miguel Sánchez · Patricia Martín · Laura Álvarez · Vidal Alonso · Carolina Zato · Alberto Pedrero · Javier Bajo
Universidad Pontificia de Salamanca, c/ Compañía 5, 37002 Salamanca, Spain
e-mail: patrimrodilla@usal.es, miguel@chocosoft.net, lalvarezba@gmail.com, carol_zato@usal.es, {valonsose,apedreroes,jbajope}@upsa.es

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Medical studies to identify a patient as an individual propense to suffer falls are based primarily on subjective methods which are difficult to automate or computerize: PCD (Computerized Dynamic posturography) [16, 15], Tinetti test [12, 11] that is based on observable criteria, such as rolling gait, patient's response to an imbalance etc. These methods preset a clear challenge for the computational technologies, not only due to the subjective characters of the indicators, but also because these indicators do not have a standardized treatments. This situation makes necessary to investigate in new solutions aimed at fall's detection in an effective an non-intrusive manner. This paper proposes an innovative adaptive algorithm specifically designed to detect falls. The algorithm obtains data from a detection mechanism built into a mobile phone. The paper proposes an improvement on the traditional methods, incorporating machine learning techniques.

The paper is structured as follows: First we review the state of the art of the technologies involved in the work. Section 3 presents the proposed mechanism to detect falls. Finally, Section 4 presents the results and conclusions obtained.

2 Related Work

Most of the algorithms used for fall detection are based on matrix of data collected by hardware devices, either through specialized sensors or by analysis of images captured by cameras in real time. The data processing is performed in accordance with the type of data being analyzed, but it lacks an intermediate layer able to add metadata to these data. For example, the approach proposed by Y. Zigel [17] is aimed at detecting ground vibration and sound produced by a fall. Another clear alternative is the use of video resources. Rougier and Meunier propose the use of 3D extrapolation of the human head in a video image to recognize a fall [13]. Nowadays, motion recognition using video cameras [8] is widespread, and privacy issues had been resolved by treating images as shapes represented by sets of data [1]. These systems require a complex technological investment to control the environment, and are sensitive to delays in data analysis and false positives. To avoid such problems there are alternative research lines based on data collection through accelerometers and gyroscopes ([2], [3]) that can be integrated in a single device. The data collected corresponds to the parameters of the human movement, different in each individual. In general, with these methods is possible to detect the fall, but not to model correctly the activity and movement associated with it. Chien et al. [5] tried to solve this problem using a k-nearest neighbor classifier that provided good results, but requires complex processing capacities, which are currently very difficult to introduce a standard Smartphone.

Systems based on the study of the relevant data and the noise (which varies depending on the subject and its movement) carry us to the fields of medicine and posturography. The tendency to fall out of elderly people based on their movement had been quantified using computable values in the so-called of Tinetti test, and other papers arising afterwards [9, 10]. Thanks to the work of Raiche et al. [11] and Roqueta [12], we propose to add an intermediate layer based on ambient intelligence in the algorithm. This intermediate layer takes into account the parameters of the patient movement and risk of fall, quantifies a series of patterns and filters the data, separating the valid data from noise. Finally, work on motion analysis according to changes in human posture ([15], [16]) allow us to add more complexity to the proposed algorithm, and to model the human activity of patients with acceptable accuracy. In this sense, the use of input data based on real human motion combined with data obtained from accelerometers and other hardware devices, provides the presented algorithm with advances robustness and efficiency.

3 Proposed Mechanism

This study proposes a new classification method that minimizes the false negatives (those cases in which a fall has occurred and the system does not detects it), and improve the response time. Moreover, the system is integrated within a mobile device, which notably reduces the consequences of falls in patients, reducing the response time to alerts and providing advances information about the patient location. The user wears the mobile device in a waist belt. The mobile device execute a background real time algorithm, which analyzes the data about the user's position and identifies the following situations: standing, sitting, moving or falling, either forward or backward. The proposed algorithm manages two data sources: user profile and data obtained from the mobile device. The following sub-sections explain the data sources and the adaptive algorithm proposed in this study.

3.1 User Profile

The proposed system requires a initial training phase to detect those patient's parameters that influence the Tinetti test [11, 12] and the PCD analysis [15, 16]. A user profile is defined for each patient which contains patterns of his movements as well as information about his disabilities and the risk of falls.

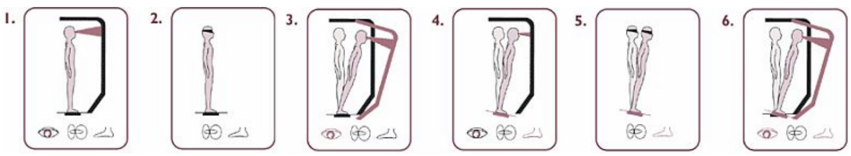


Fig. 1 Sensorial tests proposed in the PCD

As shown in Figure 1, the PCD is based on the assessment of the postural control by studying the movements of the center of pressure (projection of the body center of gravity) under different circumstances in a dynamometric platform. This kind of platform is used to diagnose disorders of the body's balance. This allows the evaluation of the mechanisms that control body stability. That is, it explores the SV sensorial component, vision and proprioceptive receptors, and motor component. The PCD help us to define a series of indicators that are taken into account in the proposed algorithm to quantify the balance and other metrics of the user:

- Degree of stability (Equilibrium score). This parameter defines the stability as a non-dimensional percentage, comparing the maximum amplitude of anterior-posterior swing to the theoretical limits of stability in the anterior-posterior direction. Values close to 100% indicate a minimum swing, while values close to 0% indicates a movement of the center of gravity close to the theoretical maximum of 12.5º. The sensorial analysis can help to detect normal and abnormal patterns. There are four ratios that allow us to detect differences between Condition 1 and the mean score on altered individual conditions.
- Visual ratio (VIS) refers to the ability of the patient to use the visual information. Low values are characteristics of patients who become unstable with uneven support.
- Vestibular ratio (VEST) indicates the ability to use vestibular information. Values close to 0 are obtained for patients which are unstable under conditions with uneven support and without visual system.
- Visual preference ratio (PREF) provides information about the degree of swing with visual reference support. Anomalous values indicative that the patient becomes unstable in visual moving environments.
- Gravity center alignment. Quantifies the location of the patient's gravity center related to the patterns obtained during the training phase. Values out of the central zone determine the limits of the stability.

The PCD and the Tinetti test [11, 12] allow us to provide the proposed algorithm with solid information, to classify falls. Our user profile takes into account three possible groups of users: High, Moderate and Low risk to suffer falls or swing disorders.

3.2 Data Obtained from the Mobile Device

The mobile device must be equipped with a three-axis accelerometer (X, Y, Z) on a single silicon chip. The chip includes all the electronic capacities to process the signals. The accelerometers are now integrated in most mid-range mobile devices on the market. The data taken into consideration are the (x, y, z) coordinates of the patient's movement, the pitch of the terminal, the roll (rotation of the terminal) and the shake typical for a fall. The final algorithm processes these six parameter, together with the user profile and provides classifications, as shown in the following sub-section.

3.3 Proposed Adaptive Algorithm

The proposed algorithm, based on J48 decision trees, is presented in Figure 2.

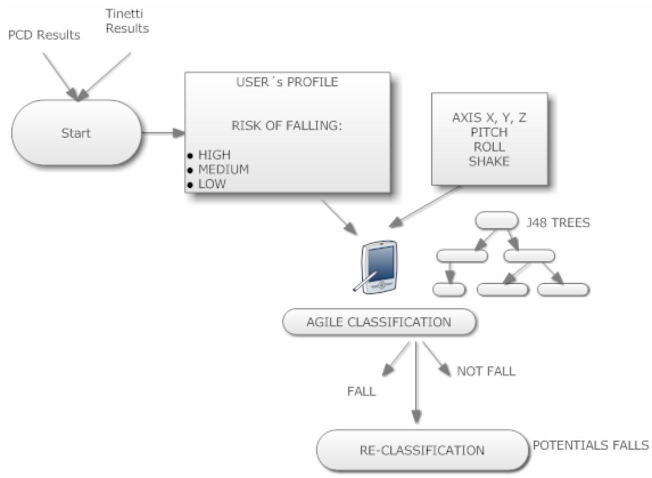
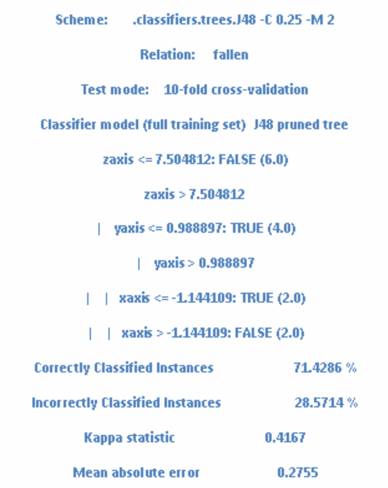


Fig. 2 Algorithm based on J48 decision trees to detect falls via mobile device

As can be seen in Figure 2, in a pre-processing step, non-relevant parameter are filtered. Then, an algorithm based on the J48 decision tree is applied and the situations are classified as FALL, NOT FALL and POSSIBLE FALL. The system provides a real-time response, and the possible falls can be classified using more complex techniques that require extra time. The system is adaptive, since as new data about the patient profile and possible postures, it can learns and adjust the classification parameters that characterize each of the possible status for the patient. In this way, the algorithm allows personalization to the patient profile, adjusting the classification parameters to his particular movements. The choice of classification and learning method was primarily due to the response times and low computational complexity of the decision trees, which are critical when working with resource constrained devices, and to the possibility of removing attributes which are not particularly relevant for the classification or incorporate noisy data. Moreover, decision trees implements a strategy based on the use of the gain ratio criteria, defined as I (Xi, C) / H (Xi). Thus it is possible to avoid potential benefits to the selection of those variables with the greatest number of possible values.

4 Results and Conclusions

The system was tested under simulation conditions. The test's parameters were setted up using previous postural studies related to elderly people. Over three months of testing 500 files were obtained using data from real falls. Initially, the parameters were personalized for the users. Then, the system was tested simulating different fall situations. As shown in Figure 3, the results of classification with three possible outputs in the tree were as follows: 72% of the situations were classified by the decision tree as Fall or Not Tall, and 28% of the situations were


Scheme: .classifiers.trees.J48 -C 0.25 -M 2

Relation: fallen

Test mode: 10-fold cross-validation

Classifier model (full training set) J48 pruned tree

zaxis <= 7.504812: FALSE (6.0)

zaxis > 7.504812

| yaxis <= 0.988897: TRUE (4.0)

| yaxis > 0.988897

| | xaxis <= -1.144109: TRUE (2.0)

| | xaxis > -1.144109: FALSE (2.0)

Correctly Classified Instances 71.4286 %

Incorrectly Classified Instances 28.5714 %

Kappa statistic 0.4167

Mean absolute error 0.2755

Fig. 3 Percentages of classification Fall/Not Fall obtained by the proposed approach. The unclassified instances are assigned to the Possible Falls group.

classified Possible Fall (incorrectly classified instances that will be evaluated using a more complex strategy).

The system has a very good response time for those cases that can be identified as Fall and Not Fall. Moreover, as can be seen in Figure 4, it is possible to calculate the cost curve for the misclassification error, providing the system with the ability to detect situations were a fall was detected by error. the system prioritizes the detection of false positives, trying to avoid undetected fall situations.

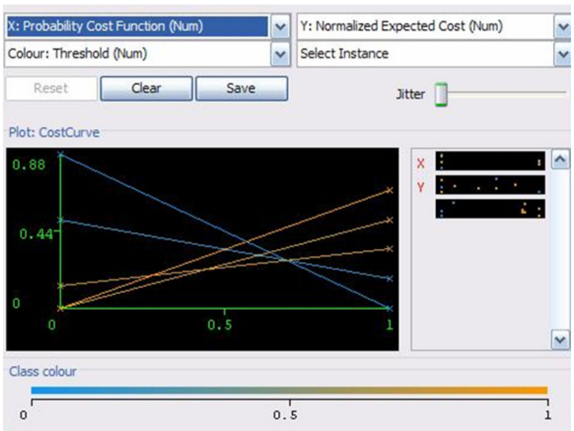


Fig. 4 Cost curve for the misclassification error

The system presented in this study proposes a novel algorithm, that incorporates medical criteria for detecting falls. Current strategies do not incorporate this kind of criteria. The system provides a good response time, since it is able to successfully classify 72% of the cases as Fall or Not Fall using a decision tree-based strategy. The rest of the cases can be identified as suspicious and evaluated using a more computational complex strategy. In adition, the system can be easy integrated in modern distributed architectures, as multi-agent systems, and provides functionalities as alarm systems (using SMS and phone call facilities of mobile devices). The system is able to recalculate the parameters of the user in real-time. The error rate decreases as the system learns from the new input data, and the minimum mean quadratic error obtained in the experiments was 0,16. Our future work focuses on improving the classification algorithm in different ways:

- To improve the accuracy in terms of computerization of PCD and Tinetti indicators in the overall algorithm, reaching even more autonomous and personalized patterns.
- Improve the mechanism to detect the initial position, to facilitate the situation of the device in different parts of the body.
- Improve the sensibility of the parameters of the mobile devices. Effects as shake, can affect the sensibility of the system, and it is possible to automatically tune the parameter and refine the decision boundaries in the decision tree.

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