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SCOPE

The Advances in Distributed Computing and Artificial Intelligence Journal (ADCAIJ) is an open access journal that publishes articles which contribute new results associated with distributed computing and artificial intelligence, and their application in different areas.

The artificial intelligence is changing our society. Its application in distributed environments, such as the Internet, electronic commerce, mobile communications, wireless devices, distributed computing and so on, is increasing and becoming and element of high added value and economic potential in industry and research. These technologies are changing constantly as a result of the large research and technical effort being undertaken in both universities and businesses. The exchange of ideas between scientists and technicians from both academic and business areas is essential to facilitate the development of systems that meet the demands of today's society.

We would like to thank all the contributing authors for their hard and highly valuable work. Their work has helped to contribute to the success of this special issue. Finally, the Editors wish to thank Scientific Committee of Advances in Distributed Computing and Artificial Intelligence Journal for the collaboration of this special issue, that notably contributes to improve the quality of the journal. We hope the reader will share our joy and find this special issue very useful.

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Segmentation of cDNA Microarray Images using Parallel Spectral Clustering

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Spectral Clustering

Domain Decomposition

Image Segmentation

Microarray Image

ABSTRACT

Microarray technology generates large amounts of expression level of genes to be analyzed simultaneously. This analysis implies microarray image segmentation to extract the quantitative information from spots. Spectral clustering is one of the most relevant unsupervised methods able to gather data without a priori information on shapes or locality. We propose and test on microarray images a parallel strategy for the Spectral Clustering method based on domain decomposition with a criterion to determine the number of clusters.

1 Introduction

Image segmentation in microarray analysis is a crucial step to extract quantitative information from the spots [RUEDA, 2009], [USLAN, 2010], [CHEN, 2011]. Clustering methods are used to separate the pixels that belong to the spot from the pixels of the background and noise. Among these, some methods imply some restrictive assumptions on the shapes of the spots [YANG, 2001], [RUEDA, 2005]. Due to the fact that the most of spots in a microarray image have irregular-shapes, the clustering based-method should be adaptive to arbitrary shape of spots such as fuzzy clustering [GLEZ-PENA, 2009], but it should also not depend on many input parameters. To address these requirements, the spectral methods, and in particular the spectral clustering algorithm introduced by Ng-Jordan-Weiss [NG, 2002], are useful to partition subsets of data with no a priori on the shapes. Spectral clustering exploits eigenvectors of a Gaussian affinity matrix in order to define a low dimensional space in which data points can be easily clustered. But when very large data sets are considered, the extraction of the dominant eigenvectors becomes the most computational task in the algorithm. To address this bottleneck, several approaches about parallel Spectral Clustering [SONG, 2008], [FOWLKES, 2004], were recently suggested, mainly focused on linear algebra techniques to reduce computational costs. In this paper, by exploiting the geometrical structure of microarray images, a parallel strategy based on domain decomposition is investigated. Moreover, we propose solutions to overcome the two main problems from the divide and conquer strategy: the difficulty to choose a Gaussian affinity parameter and the number of clusters k which remains unknown and may drastically vary from one subdomain to the other.

2 Spectral Clustering for cDNA microarray images

Let first introduce some notations and recall the Ng-Jordan-Weiss algorithm [NG, 2002] and then adapt the spectral clustering for image segmentation.

2.1 Spectral clustering

Let consider a microarray image *I* of size *l* x *m*. Assume that the number of targeted clusters *k* is known. The algorithm contains few steps which are described in Algorithm 1:

Algorithm 1. Spectral clustering algorithm

Input : Microarray image *I*, number of clusters *k*.

1. Form the affinity matrix with $n = l \times m$ defined by equation (1).

2. Construct the normalized matrix:

$$L = D^{-1/2} A D^{-1/2} \text{ with } D_{ii} = \sum_{r=1}^{n} A_{ir},$$

3. Assemble the matrix

$X = [X_1 X_2 \dots X_k] \in R^{n \times k}$ by stacking the eigenvectors associated with the *k* largest eigenvalues of *L*,

4. Form the matrix *Y* by normalizing each row in the *n* x *k* matrix *X*,

5. Treat each row of *Y* as a point in R^k , and group them in *k* clusters via the *K-means* method,

6. Assign the original point I_{ij} to cluster *t* when row *i* of matrix *Y* belongs to cluster *t*.

First, the method consists in constructing the affinity matrix based on the Gaussian affinity measure between I_{ij} and I_{rs} the intensities of the pixels of coordinates (i, j) and (r, s) for $i, r \in \{1, \dots, l\}$ and $j, s \in \{1, \dots, m\}$. After a normalization step, the k largest eigenvectors are extracted. So every data point I_{ij} is plotted in a spectral embedding space of R^k and the clustering is made in this space by applying *K-means* method. Finally, thanks to an equivalence relation, the final partition of the data set is directly defined from the clustering in the embedded space.

2.2 Affinity measure

For image segmentation, the microarray image data can be considered as isotropic enough in the sense that there does not exist privileged directions with very different magnitudes in the distances between points along theses directions. The step between pixels and brightness are about the same magnitude. So, we can include both 2D geometrical information and 1D brightness information in the spectral clustering method. We identify the microarray image as a 3-dimensional rectangular set in which both geometrical coordinates and brightness information are normalized. It is equivalent to setting a new distance, noted d , between pixels by equation (2). So by considering the size of the microarray image, the Gaussian affinity A_{ir} is defined as follows:

$$A_{ir} = \begin{cases} \exp\left(- \dfrac{d(I_{ij}, I_{rs})^2}{(\sigma/2)^2} \right) if (i, j) \neq (r, s) \\ 0 \quad otherwise, \end{cases} \quad (1)$$

where σ is the affinity parameter and the distance d between the pixel (i, j) and (r, s) is defined by:

$$d(I_{ij}, I_{rs}) = \sqrt{\left(\frac{i - r}{l} \right)^2 + \left(\frac{j - s}{m} \right)^2 + \left(\frac{I_{ij} - I_{rs}}{256} \right)^2} \quad (2)$$

This definition (2) permits a segmentation which takes into account the geometrical shapes of the spots and the brightness information among them. In the same way, for colored microarray images with Cy3 and Cy5 hybridizations, we can consider 5D data with 2D geometrical coordinates and 3D color levels.

3 Parallel Spectral Clustering: method

The Gaussian affinity matrix A whose components are defined by (1) could be interpreted as a discretization of the Heat kernel [BELKIN, 2002]. And in particular, it is shown in [MOUYSSET, 2010] that this

matrix is a discrete representation of the L^2 Heat operator onto appropriate connected domains in R^k. By combining tools from Heat equations and Finite Elements theory, the main result of [MOUYSSET, 2010] is that for a fixed data set of points, the eigenvectors of A are the representation of functions whose support is included in only one connected component at once. The accuracy of this representation is shown, for a fixed density of points, to depend on the affinity parameter. From this theoretical material, the Spectral Clustering could be formulated as a "connected components" method in the sense that clustering in subdomains is equivalent in restricting the support of these L^2 particular eigenfunctions. So a "divide and conquer" strategy could be formulated to adapt spectral clustering for parallel implementation. As the main drawback of domain decomposition is how to ensure uniform distribution of data per processor, the intrinsic property of microarray image can be exploited in that respect.

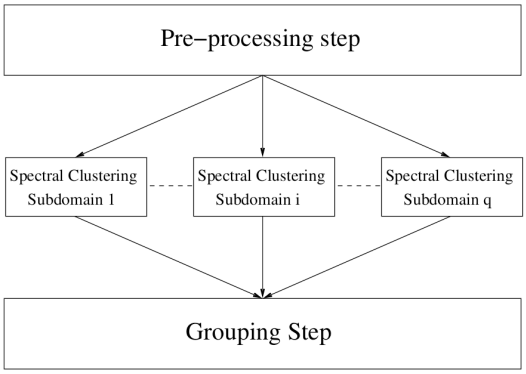

Fig.1 Principle of parallel spectral clustering.

Due to the fact that microarray presents a block structure of cDNA spots, dividing the image in q sub-images is appropriate for a domain decomposition strategy because it ensures a uniform distribution of data per processor. An overlapping interface is investigated to gather the local partitions from the different subdomains.

This interface is characterized by an overlapping subset of points whose geometrical coordinates are close to the boundaries of neighboring subdomains. This partitioning will connect together clusters which belong to different subdomains thanks to the following transitive relation:

$$\begin{aligned} &\forall I_{i_1j_1}, I_{i_2j_2}, I_{i_3j_3} \in I, \\ &if\ I_{i_1j_1}, I_{i_2j_2} \in C^1\ and\ I_{i_2j_2}, I_{i_3j_3} \in C^2 \\ &then\ C^1 \cup C^2 = P\ and\ I_{i_1j_1}, I_{i_2j_2}, I_{i_3j_3} \in P \end{aligned} \quad (3)$$

where I is the microarray image, C^1 and C^2 two distinct clusters and P a larger cluster which includes both C^1 and C^2. We experiment this strategy whose principle is represented in Fig.1 on several microarray images of the Saccharomyces cerevisiae database from the Stanford Microarray database (http://smd.stanford.edu/index.shtml) like the one in Fig.2.

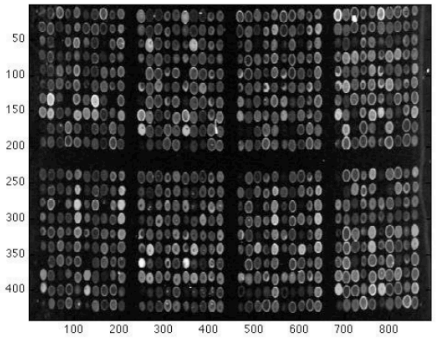

Fig.2 Block structure of microarray image.

It is important to see how the parallel approach can take advantage of the specificities of this particular application. Indeed, when splitting the original image into overlapping sub-pieces of images, the local spectral clustering analysis of each sub-piece involves the creation of many affinity matrices of smaller size. The total amount of memory needs for all these local matrices is much less than the memory needed for the affinity matrix covering the global image.

3.1 Choice of the affinity parameter

The Gaussian affinity matrix is widely used and depends on a free parameter which is the affinity parameter, noted σ, in equation (1). It is known [NG,

2002] that this parameter conditions the separability between clusters in spectral embedding space and affects the results. A global heuristics for this parameter was proposed in [MOUYSSET, 2008] in which both the dimension of the problem as well as the density of points in the given *p*-th dimensional data set are integrated. With an assumption that the data set is isotropic enough, the image data set I is included in a *p*-dimensional box bounded by $D_{\max}$ the largest distance d (defined by (2)) between pairs of points in I :

$$D_{\max} = \max_{\{1\le i,r\le l;1\le j,s\le m\}} d(I_{ij}, I_{rs}) \quad (4)$$

A reference distance which represents the distance in the case of an uniform distribution is defined as follows:

$$\sigma = \frac{D_{\max}}{n^{1/p}} \quad (5)$$

in which $n = l \times m$ is the size of the microarray image and $p=3$ (resp. $p=5$) with 2D geometrical coordinates and 1D brightness (resp. 3D color). From this definition, clusters may exist if there are points that are at a distance no more than a fraction of this reference distance σ . This global parameter is defined with the whole image data set I and gives a threshold for all spectral clustering applied independently on the several subdomains.

3.2 Choice of the number of clusters

The problem of the right choice of the number of clusters k is crucial. We therefore consider in each subdomain a quality measure based on ratios of Frobenius norms, see for instance [MOUYSSET, 2008]. After indexing data points per cluster for a value of k , we define the indexed affinity matrix whose diagonal affinity blocks represent the affinity within a cluster and the off-diagonal ones the affinity between clusters (Fig.3).

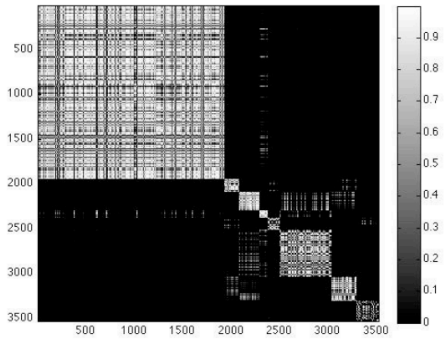

Fig.3 Block structure of the indexed affinity matrix for k=8 clusters.

The ratios, noted r_{ij} , between the Frobenius norm of the off-diagonal blocks (ij) and the norm of the diagonal ones (ii) could be evaluated. Among various values for k , the final number of cluster is defined so that the affinity between clusters is the lowest and the affinity within cluster is the highest:

$$k^* = \arg\min \sum_{i\neq j} r_{ij} \quad (6)$$

Numerically, the corresponding loop to test several values of k until satisfying (6) is not extremely costly but only requires to concatenate eigenvectors, apply *K-means*, and a reordering step on the affinity matrix to compute the ratios. Furthermore, this loop becomes less and less costly when the number of processors increases. This is due to the fact that eigenvectors become much smaller with affinity matrices of smaller size. Also, subdividing the whole data set implicitly reduces the Gaussian affinity to diagonal subblocks (after permutations).

For the *4* x *2* greyscaled spotted microarray image which corresponds to one subdomain of 3500 pixels, the original data set and its clustering result are plotted in Fig.4 for $k=8$.

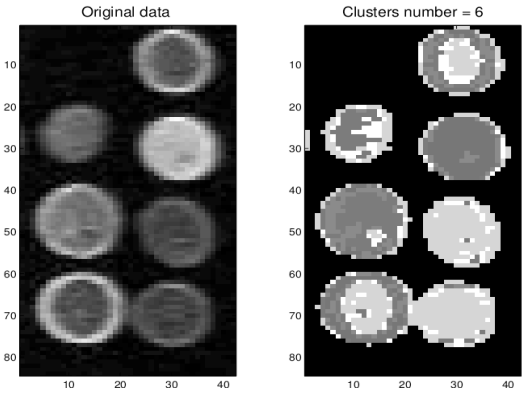

Fig.4 Clustering on one subdomain: 4x2 greyscaled spotted microarray image and its clustering result

3.3 Parallel Implementation of the Spectral Clustering Algorithm

The FORTRAN 90 implementation of the parallel Spectral Clustering Algorithm follows the MasterSlave paradigm with the MPI library to perform the communications between processors (algorithms 2 and 3). Classical routines from LAPACK library [ANDERSON, 1999] are used to compute selected eigenvalues and eigenvectors of the normalized affinity matrix A for each subset of data points.

Algorithm 2. Parallel Algorithm: **Slave**

1: Receive the value and its data subset from the Master processor (MPI CALL)

2: Perform the Spectral Clustering Algorithms on its subset

3: Send the local partition and its number of clusters to the Master processor (MPI CALL)

Algorithm 3. Parallel algorithm: **Master**

1: Pre-processing step

1.1 Read the global data and the parameters.

1.2 Split the data into q subsets regarding the geometry

1.3 Compute the affinity parameter σ with the formula (5). The bandwidth of the overlapping is fixed to $3 \times \sigma$.

2: Send the sigma value and the data subsets to the other processors (MPI SEND)

3: Perform Spectral clustering algorithm on subset

4: Receive the local partitions and the number of clusters from each processor (MPI RECV)

5: Grouping step

5.1 Gather the local partitions in a global partition thanks to the transitive relation (3)

5.2 Give as output a partition of the whole image I and the final number of clusters k are given.

4. Numerical Experiments

The numerical experiments were carried out on the Hyperion supercomputer of the CICT. With its 352 bi-Intel "Nehalem" EP quad-core nodes it can develop a peak of 33TFlops. Each node has 4.5 GB memory dedicated for each of the cores and an overall of 32 GB fully available memory on the node that is shared between the cores.

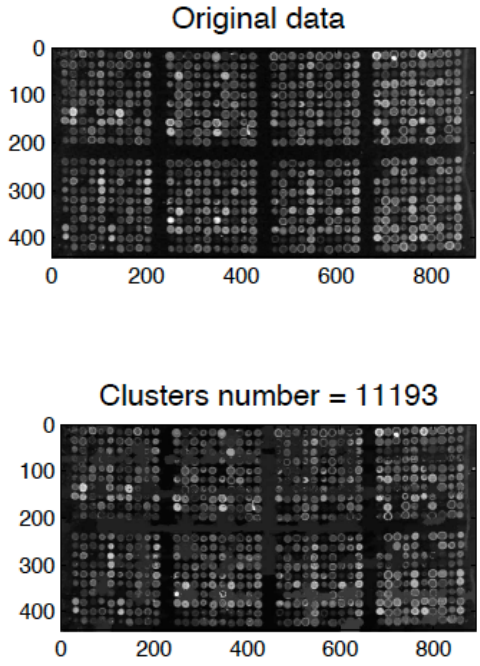

Fig.5 Original microarray image and its clustering result

For our tests, the domain is successively divided in q={18,32,45,60,64} subboxes. The timings for each step of parallel algorithm are measured. We test this Parallel Spectral Clustering on one microarray image from the Stanford Microarray Database. For decomposition in 64 subboxes, the original microarray image of 392931 pixels which represents 8 blocks of 100 spots and the clustering result are plotted in Fig.5. After the grouping step, the parallel spectral clustering result has determined 11193 clusters. Compared to the original data set, the shapes of the various hybridization spots are well described.

We give in Table 1, for each distribution, the number of points on each processor, the time in seconds to compute σ defined by (5), the time in the parallel Spectral Clustering step, the time of the grouping phase and the total time and the memory consumption in GigaOctets. The first remark is that the total time decreases drastically when we increase the number of processors. Logically, this is time of the parallel part of the algorithm (step 3) that decreases while the two other steps (1 and 5), that are sequential, remain practically constant. To study the performance of our parallel algorithm, we compute the speedup. Because we cannot have a result with only one processor in order to have a sequential reference (lack of memory), we take the time with the 18 processors, the minimum number of processors in order to have enough memory by processor. The speedup for q processors will then be defined as T_{18}/T_q .

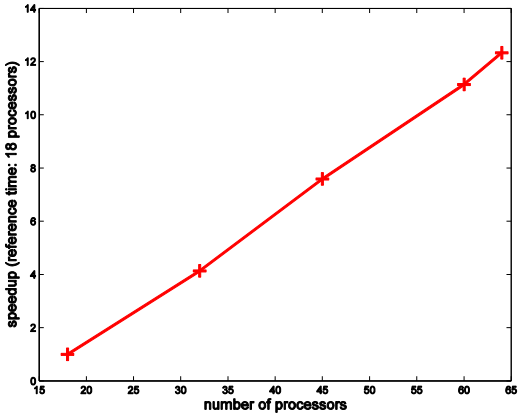

Fig.6: Performances of the parallel part: Speedup with the 18 processors time as reference

We can notice in Fig.6 that the speedups increase faster than the number of processors: for instance, from 18 to 64 processors, the speedup is 12 although the number of processors grows only with a ratio 3.55. This good performance is confirmed if we draw the mean computational costs per point of the image.

Table 1 Microrarray image segmentation results for different splittings.

Number of proc.	Number of points	Time σ	Time parallel SC	Time Grouping	Total Time	Memory Cons.
18	22000	1413	36616	892	38927	7.75
32	12500	1371	7243	794	9415	2.50
45	9000	1357	2808	953	5127	1.30
60	6800	1360	1153	972	3495	0.74
64	6300	1372	1030	744	3157	0.64

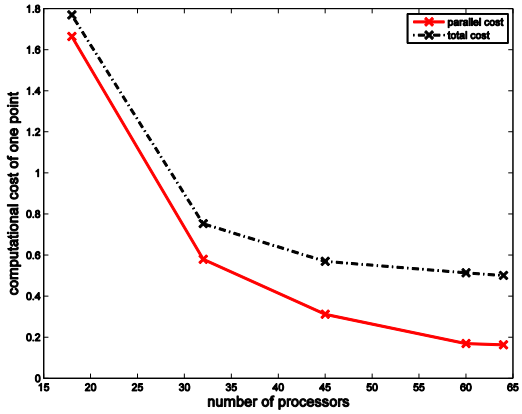

Fig.7 Parallel and total computational costs

We define, for a given number of processors, the parallel computational cost (resp. total computational cost) the time spent in the parallel part (parallel Spectral Clustering part) (resp. total time) divided by the average number of points on each subdomain. We give in Fig.7, these parallel (plain line) and total (dashed line) computational costs.

We can observe from Table 1 that the fewer points we have per subset, the faster we go and the decreasing is better than linear. This can be explained by the non-linearity of our problem which is the computation of eigenvectors from the Gaussian affinity matrix. There are much better gains in general when smaller subsets are considered.

5 Conclusion

With the domain decomposition strategy and heuristics to determine the choice of the Gaussian affinity parameter and the number of clusters, the parallel spectral clustering becomes robust for microarray image segmentation and combines intensity and shape features. The numerical experiments show the good behaviour of our parallel strategy when increasing the number of processors and confirm the suitability of our method to treat microarray images.

However, we find two limitations: the lack of memory when the subset given to a processor is large and the time spent in the sequential parts which stays roughly constant and tends to exceed the parallel time with large number of processors.

To reduce the problem of memory but also to reduce the spectral clustering time, we studied sparsification techniques [MOUYSSET, 2013] in the construction of affinity matrix by dropping some components that correspond to points at a distance larger than a threshold. A threshold based on uniform distance was defined for any kind of data distribution. This distance could be considered as a limit threshold to preserve the clustering results.

We validate this approach in Matlab by showing that the number of non zero of the affinity matrix decreases with still some good results in terms of spectral clustering and even some gains in the time spent to compute the affinity matrix.
These results are confirmed when we use sparsification with our parallel spectral clustering solver. We can show that we are able to reduce significantly the size of the affinity matrix without loosing the quality of the segmentation solution.

With sparse structures to store the matrix, we will also gain a lot of memory. However, we may have to adapt our eigenvalues solver and use for example ARPACK library [LEHOUCQ, 1998]. To reduce the time of the sequential parts, we could also investigate parallelization of the computation of the σ parameter and the ability to separate the spotted microarray image in sub-images.

6 Acknowledgment

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Tweacher: New proposal for Online Social Networks Impact in Secondary Education

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KEYWORD

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Educative Web Tools
Collaborative Systems
User-Centered Design

ABSTRACT

This paper presents and analyzes the potential uses and motivations of online social networks in education, with special emphasis on secondary education. First, we show several previous researches supporting the use of social networking as an educational tool and discuss Edmodo, an educative online social network. The work carried out during two academic years with senior students of primary and secondary schools is also analyzed. After that we present Tweacher an educative social network application and evaluate its use in the classroom to prove its useful use between teachers and students. This research has allowed us to see the reality of social network use among young people and identify the challenges of its application to education environment.

1 Introduction

Social networks have recently been introduced in the lives of many people that were previously far from the Internet phenomenon. And, it is not uncommon to hear talks on the street about Facebook, and not necessarily among young people. The extraordinary ability to communicate and to connect people with networks has caused that a large number of people use them with very different purposes. They are used to find and engage with long ago lost friends, to discuss various subjects, all kinds of support causes, organize meetings of friends, former classmates or to publicize meetings and conferences, through which not only it provides details about the meeting, but people can confirm their attendance or absence of the event.

For that, the educational world cannot remain oblivious to like this social phenomenon, which is changing the way of communication between people. The education system works primarily with information, so there is no sense to use transmission systems and publication of the same based on those used in the early and mid-twentieth century, without incorporating what society already is using as part of their daily lives. Education must train people to what will work in ten years, not to emulate the way that worked for last ten years. Undoubtedly the potential communication of social networks is still to be discovered and should be studied more in depth [Fardoun, H. et al. 2011a]. It is in these moments when they begin to create networks for educational purposes and, without doubt, in the coming months there will be interesting developments in this regard.

Social networks have become a virtual environment where many people converge. The exponential growth of social networks today have turned these sites into an interesting analysis tool to find usages, customs and origin of many users that comprise them. Some of these social networking services like Facebook, among others, are used by many universities in the world to publish their works, videos, resources and projects, to be criticized and evaluated by the

community, and this become of a great support to teachers. Using this tool is increasingly common among humans; hundreds of thousands of users worldwide have experienced the use of Facebook as a tool for the development of social communities. The impact of social networks like Facebook or Twitter is growing stronger worldwide. However, to think about the role of teachers in our time, it would be possible from a contextualization: insert the teacher's role in the context of the knowledge society.

Endless are the number of hours, news, energy that is now being used by the online social networks (hereafter OSN), adolescents being one of the main social groups that depend on these systems to communicate with their peer group and acquaintances. But how can it is possible to work with a tool that has many friends, messages, photos, videos! Which suppose too many distracting to the students, and would be contrary to achieve the objective sought. Some of the research considered in this paper study is Facebook as a tool for college students with positive results. But for teenage students, is responsible enough to use the educational online social networks? Or to use these environments, the student, must be taken out from the OSNs that use commonly, and use others where there are no many elements that make the students lose concentration while they are performing their tasks.

The initial hypothesis to be validated: social networks can serve as an educational tool, acting as a motivator and enabler of social capital in education during adolescence (age range 12 to 18 years, with reference to the Spanish system, named as compulsory secondary education “E.S.O“). The paper is organized in five sections: Social networking in education, the analysis of one of the major educational OSNs, the field work which discusses the use of the OSNs by students, Tweacher application, and it ends with conclusions and future work.

2 Social Networks within Education

This section introduces the basic concepts of the OSN, a series of research on its application in education, and the beginnings of the union of these two fields.

2.1 OnLine Social Networks

According to Danah Boyd [Boyd, D. *et al*. 2007], OSNs are Websites that give users a range of services based on Web technologies that allow individuals to: build a public or semi-public profile with relationships system, to have a list of other users with whom they share a connection, and finally, view and navigate through the list of users' connections with those who share a connection in the system. The shape and nomenclature of the connections listed above vary from one social network to another. What makes the OSNs unique is because they make possible for users to manage and make visible their own social network, not because they allow users to meet others in the network. Normally connections on OSNs are between individuals who have “latent ties”, Haythornthwaite [Haythornthwaite, C. 2002], and that have some offline connection. In many OSN, users are not looking to expand their network of contacts (such as LinkedIn [LinkedIn, 2012]), but they communicate with people they already knew prior to their entry into this OSN.

The most widespread and used features by OSNs users are: uploading and sharing photos and videos, comments on other profiles, friends and private messages between users. Users of these sites also share a number of documents and communicate with each other.

2.2 Computer applications for learning support

Arguably, the first steps of social networks in education correspond to Moodle [Moodle, 2012], at least in terms of the widespread use of the platform. Moodle is a project designed to support a social constructionist framework of education. It is distributed as free software (GNU). Moodle is copyrighted, but user can copy, use and modify Moodle if they agree to distribute the source code to others, without removing the original license and copyrights. The design and development of Moodle is based on an educational philosophy called "social constructionist pedagogy". Moodle can be considered as one of the first OSN focused on education, because it has one of the OSN main features.

Some basic questions that the Web Systems share with education is: Who are the students? What student's intentions and behaviours will be supported by the system? What devices students will use? E-

Learning platforms solve these questions based on five different aspects: purpose, use, content, functionality and presentation. Based on the information taken from [Fardoun, H. 2011], in the following sections, EdModo [EdModo, 2012] is discussed.

Moreover, in [Fardoun, H. 2011], we found comparison of the educational and technical aspects of the main electronic learning platforms: Blackboard Academic Suite 8.0, Claroline 1.8.1, Ecollege, WebStudy Course Management System, Atutor 1.5.4, Moodle 1.9, and JoomlaLMS. They compare various aspects like: productivity, communication, participation of students, administration, content development, licensing, and the required hardware and software. Highlighting after such detailed analysis the communication and motivation as key factors in the student learning process, therefore the student should not be or feel isolated. Finally the authors sort the platforms in two types: Those that are not attractive for most users, but at the same time they are fully developed and have most of the functionality needed by teachers and students. Those that are highly attractive, but do not provide a variety of services.

3 Edmodo Analyses

This section discusses the online social network tool Edmodo [6], an educative social network. The following we describe its implemented functionality, the non-permitted and weaknesses points. Based on the presented aspects in the sub-section 2.2, the purpose of this tool is the informal education, and to be used as an educational system and its contents are usually related to different subjects of the students.

3.1 Edmodo Main Features

In this sub-section we analyse the main features, which are available on the Edmodo platform. It will be discussed some specific functions of communication, organization, file sharing and educational tasks.

The initial interface that the tool offers for teacher and students is very similar, but with some extra functionality in the teacher side, like: The first action offered by the tool for teachers is to create the class groups, as it is required. Each group has a number of options that can be managed, if the user has a teacher role. The teacher can view the group members (students and teachers), he can archive and / or delete a group if it is necessary. From the public view, we may highlight that the teacher can decide the comments to be shared with people who are from outside of a specific group.

In terms of communication that is performed by using a board, the teacher could present it, to an entire group or as a private individual for each student. The teacher has four types of communication: (1) messages, (2) alerts, (3) assignment (or a task which can be rated later) and (4) vote. It is possible to add to each communication element: a file, a link (URL) or an existent item from the digital library. It has a section called "Who?" Where users can send messages in deferent ways to users: individual (private), students group, teachers and parents.

In the student side, the communication options are more limited than those of teacher, where they only have the option message, and they can only communicate in two ways: (1) with the entire class in public way or (2) in private way with the teacher.

Both teachers and students have access to a calendar, depending on the classes they teach, and the students to the classes to which they have joined where also they can view the deliverables or dates set by the teachers. These management features convert the Edmodo tool in a great tool for organizing and planning.

For storing and sharing files, there are two points of view in the Edmodo platform: The teacher view, where he can share folders with material for one or more of his classes, and the student view, with a space of 100 MB, to store his files and/or class assignments.

Finally, from the user profile, other users can see (if they are connected to him): public activity, connections with teachers (if the user has a teacher role) their colleagues, besides seeing there school and classes that they manage or in which they participate.

3.2 Weaknesses and not allowed Features

This section describes the unpermitted or unimplemented functionalities within the platform and its weaknesses. *Studding this information is helping us in the implementation process of our own OSN tool, which we called Tweacher. Tweacher is an OSN for educational purposes whose target audience is very similar to Edmodo*. The weaknesses and the not allowed features we discover in Edmodo are:

- It has no option to send private messages between students, avoid forgetfulness, communication between students occurs globally.
- In the communication part, it has not implemented a chat tool. While, many other social networks (like Facebook, Tuenti, and Myspace) implement a kind of chat area for users.
- It does not work with photo albums and tags like other social networks. It works with generic file type, and do not allow the action of tagging them.
- It does not implement any kind of page in which the user can see the subject structure (index).
- Edmodo structure facilitates informal education; however, the order of the content of the courses and materials is not entirely clear.
- The functionality backpack, where students can save files that cannot be accessed by teachers, can be a weak point, since students could use it to save improper files

4 Fieldwork: Using On-Line Social Networks by Students

This section presents a field study, which reflects the big use of the new technologies and social networks by high school students. Also, it highlights a set of advantages for their application in teaching. The field study is focused on Tuenti [Tuenti, 2012] and Facebook. First, we present the results obtained through an anonymous questionnaire given at three centres of the community *Castilla-La Mancha, Spain* (two secondary and one primary education centres). Next, we will discuss the main findings of this field study conducted during the last two academic years and applied over 425 students (381 secondary education and 64 of primary one).

4.1 Anonymous questionnaires on the use of social networks

We address first the results in secondary education talks (12 to 18 years, questionnaires to students from 1º to 4º of the E.S.O):

In the academic year 2009 / 2010, students carried out 282 questionnaires. The result was that, 88% of students use online social network Tuenti, taking into consideration that according to Spanish law it is illegal for children less than 14 years to use it. Well, the surveys were conducted at the beginning of 2010, so the students were born in 1996 and 1997 (which are 44.7% of respondents). Those are violating the terms of use of this tool, because they are minors, in particular 86.7% are registered on the social network Tuenti.

Given that 88% of the students use the Tuenti social network, from this percentage we extracted other interesting facts like: The average number of "friends" is 198.9 in the profile of each student. The average time spent connected to the Tuenti social network is 1 hour and a half per day. With regard to the social network Facebook, we have: 43.4% of respondents are registered in this social network.

We can highlight 88% of respondents who use the social network Tuenti as 61% of them are connected to the social network for more than one year and 70% have more than 140 "friends".

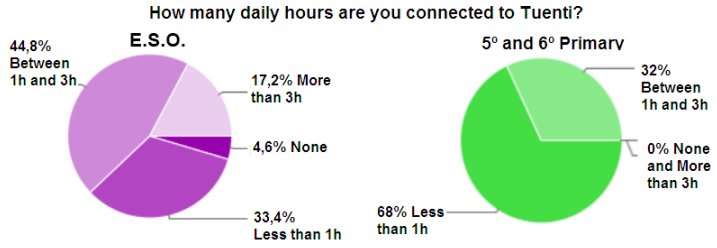

Fig. 1. Hours per Day using Tuenti, course 2010 / 2011

17.2% recognized to consume more than 3 hours use per day (Fig. 1 left.). While when we refer to harassment, the data is not worrisome since 3% have felt bullied at some point. With regard to Facebook, 63% of the students are registered on it, and the average number of friends is smaller to the average number of

friends on Tuenti. The most alarming, and was not taken into consideration in the previous academic year's study, is whether the parents are concerned about what their children are doing using the OSNs (Fig. 2 left.). 55% respond positively to this question. This indicate that 45% of parents who are not interested and do not ask their children about the purpose behind using these new communication environments.

For primary education, the questionnaires were presented to 64 students in various lectures in 5º and 6º of the primary school, during the academic year 2011. We obtained the following results: 43.5% of students use Tuenti which suppose a high number, taking into consideration the prohibition that the Spanish authorities have with respect to this matter. On the other side, 52% of parents worry about what their children do in the OSN (Fig. 2 right), a slightly lower percentage com-pared to E.S.O parents. This slight difference would be probably because some of the children were not yet interested to register in OSNs. Statistics showed that 1.8% of respondents felt harassed using OSNs. And finally, we remark that the number of "friends" and hours of use per day is significantly lower than the results obtained in secondary education. Only 25% have more than 140 "friends" and 68% spend less than an hour online per day (Fig. 1 right).

Fig. 1. Interest of parents for the use of ONSs, course 2.010/11

We can say that, this trend of interaction through online social networks will continue in the future as the new generations make a high use of these networks because of being already an important part of their lives.

4.2 Analysis of the anonymous questionnaires results on social networks

The reason for this analysis is that, in many cases where students do not have online social networks are because of the parents' controls, and the Spanish government that does not allow access to such services for citizens less than 14 years.

After analyzing this data, we can say that it is obvious where adolescents spend their time and what habits they have. Therefore, using this tool, as an educational, by students who know in depth and make use of their free time, can raise the motivation levels with respect to certain subjects. Although the learning curve of using the educational tools will be very quick, it would not reach the common social networks' level.

Could positive academic results be obtained through online social networks? The answer is yes, demonstrated by the results of the research presented next. In [Yan Yu, A. 2010] research the impact of individual use of these online social networks from an educational point of view. This paper takes into consideration two processes of socialization such as: social acceptance and cultural adaptation, showing that an online social network in these processes help positively influence to academic outcomes. Thereby, it demonstrated the positive influence at the university level. So, obtaining positive results at the level of secondary education is one of the objectives of this work, considering that at this age, students need more control (from parents and teachers) than that at the college age.

4.3 Edmodo in a real environment

For this study we have worked with a group of 20 students in the "information technology and communication" subject of 1 bachelor's degree, and 38 students divided into two classes of 4º E.S.O in the "computer" subject during the months of February

and March 2011. With respect to 1 bachelor's degree we highlight the following: We have dedicated and skilled jobs through the platform, there have been an informal communication between student and teacher and student-student. It was also proposed sharing of current information with the rest of the group. The study has been very successful. It was offered to teachers of 1 bachelor's degree the option of working with students using Edmodo. Only 14.3% seemed interested and responded positively (a possible weakness of this type of platform, teachers who feel unprepared or interested).

We conducted a survey with students obtaining the following data: Are OSNs interesting to use for educational purposes? 68.75% answered yes, 25% No and 6.25% indifferent. Would you like to work with Edmodo in other subjects? 66.7% said yes, 33.3% indifferent and 0% No. At the end, we highlight three data: 95% of students have participated in Edmodo, 70% actively and continuously (at least one publication a week), and 50% of students have used the platform in non-lecture hours.

The results obtained during 4º of the E.S.O haven't being as good as 1 bachelor degree, because its use by students was not as expected and their collaboration was proved to be too far below expectations. While bachelor students add news of every kind and discuss with them mates about them in an educate way, E.S.O. students just add contents to the wall of Edmodo when the professor have asked for it. Seeing the data of the sub-section 4.1 of this article the low participation in E.S.O. students was unexpected, ¿Which is the main problem? The difference in age is just one year; E.S.O. is compulsory education while bachelor isn't, differences between social groups and their behaviour as groups ¿could be them some explanations? The unique way to resolve this question is by doing more field-research.

As a consequence of this field-research this year five professors more are using Edmodo at their classes, even with the results of E.S.O. students want new tools during their lessons. In this process we are learning how to teach using these new platforms that the research in e-Learning gives us.

4.4 Others High Schools at a click of distance

In addition to what mentioned in the previous section Edmodo work between two classes of 1 bachelor degree in two different high schools (of Castilla-La Mancha). A new Edmodo group was created and it was supervised by two teachers in charge (one of each high school) established a set of rules of good use, otherwise teachers can use the option "reader" for students with bad behavior. The group was of 41 students in the "information technology and communication" subject of 1 bachelor's degree. They were allowed to name the group to feel unit holders. And the main use was to share news and comment on technology among students of both high schools. The high school students who had been working longer with Edmodo were more active while their counterparts from the other school they were less (with certain exceptions).

Perhaps this extra motivation of being able to interact with peers from another part of his country was what allowed us to obtain better results with bachelor students.

5 Tweacher: A Pilot Online Social Network for Education

This section will present Tweacher, a social application for educational use. It will starts from the concept of micro-blogging and will be added, functions of an Learning Management System (LMS), such as subscriptions to courses or subjects to perform management tasks for students, qualification of these, message board and course material, among others.

With the creation of this tool, we try to exploit the potential shown in the previous section of the article.

Ultimately, Tweacher is a complementary platform that can be used as a tool in the educational process. In which we try to make a different approach to the one made by the creators of Edmodo [Edmodo, 2012].

5.1 Tweacher Architecture: Software and Hardware

The application architecture will have the model client / server, see Fig. 3.

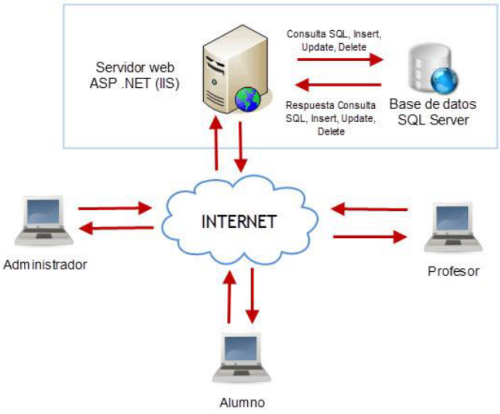

Fig. 3. Tweacher Hardware Architecture

For the function and operation of the present prototype, it was necessary: a Web Server and a Database. In this case, both servers are located on the same machine. The Web Server resolves the made requests, and interpret the code for the generation of Web pages that belongs to the application. The database server has all the tables and the relationships between them, which will be linked with the application to manage the participants, groups, micro-posts and tasks, etc.

We have three types of users involved in the system, which is consistent with the existing application roles: administrator, teacher and student. These may be connected to the system via the Internet, making requests to the server, and this in turn is connected to the database, as needed, to solve some of these requests.

For the implementation of the prototype, an ASP.NET software technology has been used, from Microsoft with C# language, to create dynamic Web sites. The database was created using SQL Server 2010. In Fig. 4 we can see the system that composes the software architecture of the prototype, which in turn is divided into sub-systems.

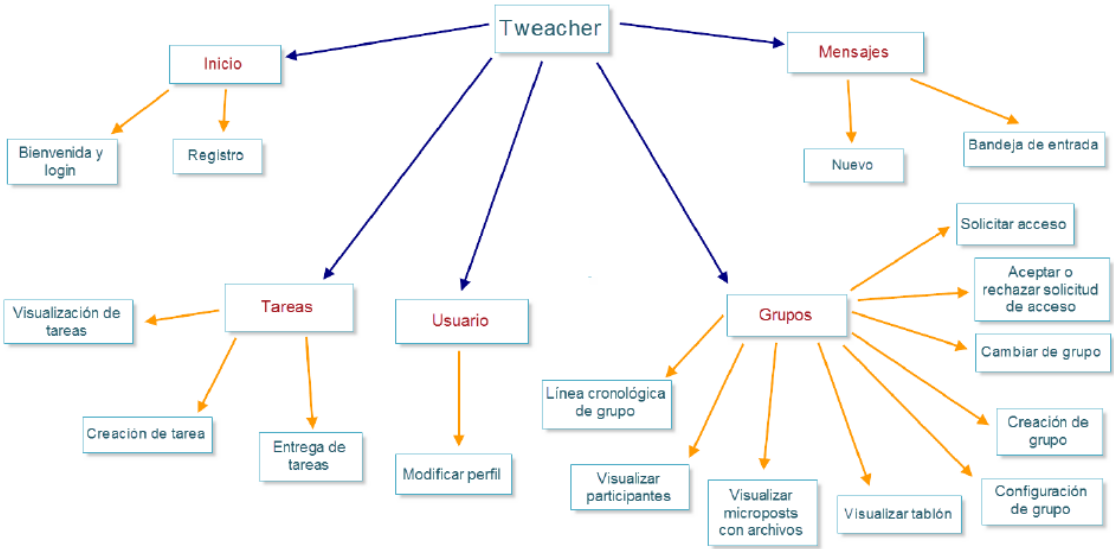

Fig. 4. Tweacher Software Architecture

Tweacher is divided into the following subsystems:

- **Home:** manages the login and user registration. It is a requirement to be registered and logged in, to start using the application.
- **User:** manages the user's personal information, giving this option to modify your profile.
- **Messages**: manages private messages between users. Users have the option to create a new message, or to consult those he has sent in his inbox.
- **Groups:** is the largest subsystem, for being the backbone of Tweacher. For each of the groups the user has a timeline or temporary messages, which he can view. In addition, all users will be able to view the participants, the board and the messages to which the user has attached a file. Another option is to change the current group in which he is belongs to. This subsystem also manages to create a new group by a teacher or administrator, to introduce users to the new group (if they have previously requested access) and configure it.

- **Tasks:** manages the tasks of a group and everything connected with it, starting with its creation, delivery and display.

5.2 Prototype and Key Features

The prototype is designed following an iterative incremental development, focusing on the user interface, according to the initial requirements that were raised, and have been refined in later phases, not only in terms of interface, but also in functionality and User Centered Design [Fardoun, H. *et al*. 2011b] [Fardoun, H. *et al*. 2012]. In the first iteration of the prototype stage, we performed a navigation prototype on paper, which served as a starting point in the design.

In the second iteration we created a low-fidelity prototype, a beta (Tweacher 1.0), which gives us overall information of the application, without going into too much detail. In the prototype shown with GUILayout tool [Blankenhorn K., 2004], a model simulating is done with pencil and paper. It gives us information, in first instance; of the containers that we use and which part will be placed on them in the main screen.

Fig. 5. shows the initial screen after the third and final iteration:

Fig. 5. Tweacher Initial Page

Figure X.3 shows the zone of a student, who is using Tweacher. Next we details each of the main parts:

On the right side of the head we find the user account control area, where it has access to the user profile settings, messages and the end of the session.

In the left part of the Figure their are two different parts:

- First, a top menu, depends of the group to which the user belongs, he can view the participants' list to which he can access: the board, the group of messages with attachments, tasks and configuration of the list (in this case he should be the owner). At this stage of the design, we introduced the "Board and attachment" element in the group.
- On the other hand, the body changing varies depending on what is selected in the top menu. In this case, the user sees the timeline of the group and the message area where he can post his messages, as to attach a file if the user wishes.
- As with any Simple Notification Service (SNS), the application notifies the prompts regarding the recent activity, since the user last access. These alerts include: new messages, new tasks and new access requests.

The "Groups" section indicates the groups to which the user belongs. The user can click one of the groups to change his timeline from the current one, to the one he select. Later, the user can view the participants, the board, and configuration tasks for it (if he is the creator).

The last element common is: "Request access to group", where both the student and the teacher can perform it. The teacher has more options, these are:

- Create a new group and become its manager.
- Check access requests to accept or reject them.
- Create a new task in the groups in which he is the creator

5.3 Tweacher Test

At the beginning of the third iteration, during the design and implementation phases of the prototype, an evaluation process was performed with real users, to ensure the user-centered design of the application.

The evaluation was performed for the first 11 Bachelor students, of a secondary center of Castilla-La Mancha, Spain, who previously have used Edmodo in their classrooms. The evaluation method was chosen through surveys, which reflect the degree of agreement on a scale of 1 to 5, with 1 being "less agree" and 5 represents "most agree". The students performed tasks that included: Making a record in the application, apply for membership in a group, write messages on the timeline of a group, check the remaining tasks, see the private messages and logging.

And some of the results were: Overall, students believe that the difficulty of creating new user is low.

Students found the tool intuitive and easy. 90% of students believe that this application serves as a support tool in learning. Which make us; therefore, conclude that the development of the tests was positive.

6 Conclusions

This work is a study done for the implementation of a tool similar to Edmodo, whose name is Tweacher (Twitter + Teacher). In this study, we try to cover the weaknesses found in the previous tools (sub-section 3.2) and add extra functionality to improve the teaching-learning process through such tools.

With the presented data in section four, we can say that the use of OSNs in educational environment can be positive. And for its implementation as an educational tool, it takes time and especially for its involvement by the faculty.

We can conclude then that Tweacher might be an option as a new educative social network to be used in the classroom, in our case trying to improve tools previously studied and worked as Edmodo.

A possible future improvement could be by establishing the use of counters to warn parents and teachers about the overuse of the tool by students. We did not analyse the parental control features available on Edmodo. It would be interesting to analyse and make a formal proposal on the possible ways of control that parents may have.

7 Acknowledgment

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Crawling PubMed with web agents for literature search and alerting services

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KEYWORD

Crawling PubMed
Web agents
Literature retrieval

ABSTRACT

In this paper we present ASAP - Automated Search with Agents in PubMed, a web-based service aiming to manage and automate scientific literature search in the PubMed database. The system allows the creation and management of web agents, parameterized thematically and functionally, that crawl the PubMed database autonomously and periodically, aiming to search and retrieve relevant results according the requirements provided by the user. The results, containing the publications list retrieved, are emailed to the agent owner on a weekly basis, during the activity period defined for the web agent. The ASAP service is devoted to help researchers, especially from the field of biomedicine and bioinformatics, in order to increase their productivity, and can be accessed at: http://esa.ipb.pt/~agentes.

1 Introduction

In the last two decades the areas of biomedicine and bioinformatics registered an unparalleled growth on research investment, generating an unprecedented amount of new knowledge and its consequent expression in terms of scientific bibliography. PubMed[1] is the largest public database for biomedical literature, currently comprises more than 21 million citations from Medline, life science journals, and online books. This huge volume of literature represents a great progress in knowledge and information accessibility, but also originates difficulties for filtering relevant results, and moreover, increases the time needed to search efficiently a permanently updated database.

Aiming to increase researchers' productivity, it is desirable that scientific literature search incorporate computational help, from crawlers and web agents mainly [KOBAYASHI, M. 2000], to automate routine processes like periodical updates on new publications on specific subjects, generating alerts to the user. Having this automatism, researchers may receive automatically the results from a web agent that performs periodically, based on terms and requirements specifically defined for each agent, an accurate personalized search [BRUSILOVSKY, P. *et al.* 2007] of potentially relevant bibliography, only requiring from the scientists the minimum necessary time to analyze the results.

This reasons motivated us to create and develop a web-based service, named ASAP - Automated Search with Agents in PubMed, which is publically available and allows the creation and management of web agents to automate bibliography searching in the PubMed database.

2 Related work

Recent surveys on literature mining and retrieval solutions [HAKENBERG, J. *et al.* 2013], [MANCONI, A. *et al.* 2012], summarize the innova-

[1] http://www.ncbi.nlm.nih.gov/pubmed/

tions and growing interest on this field of investigation. Focusing the subject of crawling and retrieval in PubMed database, including the subsequent alerting services, the related works available are presented and characterized as follows.

PubCrawler [HOKAMP, K. *et al*. 2004] was developed in 1999, at the Trinity College Dublin, and is a free "alerting" service that scans daily updates to the NCBI Medline (PubMed) and GenBank databases. PubCrawler helps keeping scientists informed of the current contents of Medline and GenBank, by listing new database entries that match their research interests. This service is available at: http://pubcrawler.gen.tcd.ie/

PubCrawler results are presented as an HTML web page, similar to the results of a NCBI PubMed or Entrez query. This web page can be located on the PubCrawler WWW-service, on the user's computer (the stand-alone program), or can be received via e-mail. The web page sorts the results into groups of PubMed/GenBank entries that are zero-days-old, 1-day-old, 2-days-old, etc., up to a user-specified age limit.

@Note [LOURENÇO, A. *et al*. 2009] was developed at the University of Minho and is a platform that aims at the effective translation of the advances between three distinct classes of users: biologists, text miners and software developers. Among other features, can work as an information retrieval module enabling PubMed search and journal crawling. Using the EUtils service provided by Entrez-NCBI, the information retrieval module can retrieve results based on keyword-based queries.

3 Developed work

The ASAP system was developed to assist researchers on the time consuming task of periodical or casual scientific literature search, providing them the automation of this task. ASAP performs focused crawling on the PubMed database to automate publications search and emails the results to the user on a weekly basis.

ASAP is mainly composed by three modules, that are interconnected to perform the fundamental workflow of the system, namely: the web-based services to manage the data that supports the system, the database that organizes and made available the data, and the information retrieval module - this last module also integrates the results communication function. The functional architecture of the ASAP system is presented in Fig.1.

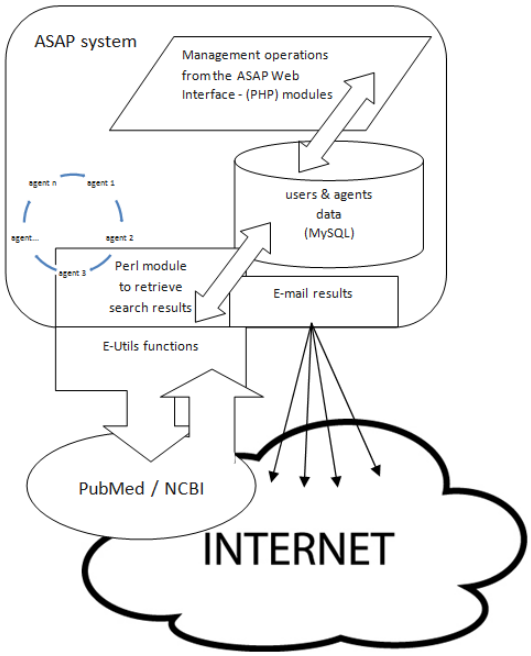

Fig.1 . The ASAP system's functional architecture.

In order to facilitate the adoption of the ASAP service in our community we decided to keep the processes of registering and web agents creation as simple as possible. ASAP is a web-based service and is already available online and translated in several languages. The ASAP homepage, accessible at http://esa.ipb.pt/~agentes, has an easy interface as depicted in Fig.2.

Fig. 2. The ASAP service homepage.

ASAP registered users can create agents to perform, in an automated fashion, scientific literature search based on keywords on the PubMed database, replicating the same search and retrieving the same results as the available ones at the original PubMed's site, since it uses the EUtils functions [BETHESDA, 2010] provided by the Entrez framework [SAYERS, E. W. *et al*. 2011] from NCBI. The EUtils (Entrez Programming Utilities) are used to invoke the crawling processes in the NCBI databases. EUtils comprise a set of seven different methods (eInfo, eGQuery, eSearch, eSummary, ePost, eFetch and eLink) providing an excellent way of access to the NCBI scientific content from external applications.

Each agent can be programmed thematically and functionally. The theme of interest is defined by specifying up to three keywords for each agent. The functional part is modeled by defining the date interval which matches the user interest. A snapshot of the interface used to create agents is presented in Fig. 3.

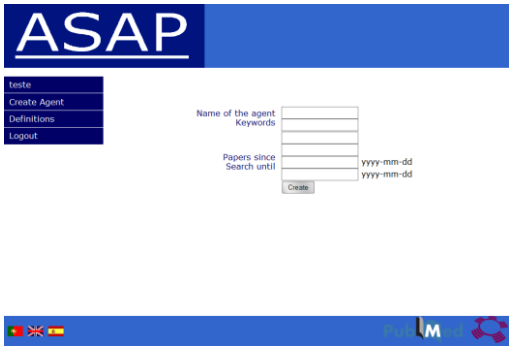

Fig. 3. Agent creation interface.

ASAP modules to manage the users and agents database were written in PHP. The database was created using MySQL.

The information retrieval module, including the notification part, was written in Perl. This module performs a different search for each valid agent and emails the results to the owner, this process is weekly initiated by a daemon.

4 Results and discussion

ASAP results are delivered weekly to the agents' owners, verified the premise of the agent's validity/caducity. The crawler employs the keywords from each agent in the database, building the queries, sent through the EUtils functions, to search the PubMed repository, and returns the retrieved results. From these results it compiles e-mails for each agent, containing the details of the publications list, including the respective abstracts. The newest results appear at the top of the list to facilitate its verification. A link to the original results is also provided for extended view or deeper prospection of the results.

Without effort, the researchers receive in their mailboxes a list of results for each agent and only employ supplementary time on literature searching if novelties are perceived. In this way, a productivity gain is obtained as part of the searching task is automated.

ASAP is actually under tests within the IPB (Polytechnic Institute of Bragança) community and the subjective feedback, as far as it is possible to evaluate by now, is encouraging.

5 Conclusions and future work

We presented ASAP - Automated Search with Agents in PubMed, a web-based service aiming to manage and automate scientific literature search in the PubMed database. The system allows the creation and management of web agents that automatically and periodically crawl the PubMed database to search and retrieve relevant results according the filtering parameters provided by the user, returning him automatic result updating. ASAP is publicly and

freely available, is provided "as is" without warranty of any kind, but we employ our best efforts to protect the confidentiality and security of the users' data.

In future version the parameterization possibilities can be extended to meet the expectations of advanced users, namely to enable enhanced filtering capabilities, but on the other hand, the simplicity and lightness of the service could be compromised. Therefore, we expect to upgrade ASAP but keeping its simplicity as a mandatory requirement, since we believe most users are not interested in web agents if they are difficult to create and maintain.

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Development of Sensor Based Applications for the Android Platform: an Approach Based on Realistic Simulation

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KEYWORD

Context-aware services
Agent based social simulation
Testing
Mobile Devices
Android

ABSTRACT

Smart phones are equipped with a wide range of sensors (such as GPS, light, accelerometer, gyroscope, etc.) and allow users to be connected everywhere. These characteristics offer a rich information source for creating context-aware applications. However, testing these applications in the lab, before their deployment, could become a hard task or impossible because of sensors correlation, too wide testing area or an excessive number of people involved. This work aims to solve these problems carrying out the testing in a simulator, simulating the world in which the application user is immersed into. Tester controls her avatar and the avatar has a simulated smart phone that is connected with the user's smart phone. Applications under test are installed on the real smart phone and are compiled with a library that replaces standard services of the sensors by others that offer data sensor from the simulator (depending on the simulated smart phone context) instead of real world.

1 Introduction

Mobile applications have experimented a new revolution in the last years. And such revolution has been pushed by two related but, in principle, contrary forces. They are two different operating systems, iOS and Android. iOS is a closed operating system which is devoted to the mobile devices manufactured by Apple. Thus, the possibilities for developing in such applications are imposed by the Apple policies for open applications development. Android is the operating system designed by Google. And it follows a radically different philosophy of development: open source and Java based development. Moreover, Android is the second most used operating system for smartphones, it is more popular than BlackBerry and iOS, but it is expected that it will overtake to the number one, the Symbian OS by Nokia [GARTNER, 2010]. So, the mobile software development study is centered on Android mobile applications because the most users are benefited and the group follows an open source philosophy.

Recently, Smart phones are equipped with a set of sensors, such as GPS sensor, accelerometer senor, gyroscope sensor, camera, microphone and etc. All this hardware allows to get context information about the user is involved into, such as date and time, location, activity. This information is used to develop context-aware applications that offer services to users depending on their needs. Despite the promising potential of using mobile phones as context source devices to make context-aware applications, some problems emerge that need to be solved.

One of the central problems on context-aware application development is verification and validation of such applications by testing. Testing software is the process of executing a program in order to find

errors in the code [MEIER, R. 2010]. Such errors must then be debugged. According to the IEEE Standard Glossary of Software Engineering Terminology [IEEE 1990]: "Validation is the process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirement".

The main challenge of testing is to generate a set of values for each sensor, useful and meaningful for each test. The problem increases with the number of sensors and their correlation. For example, suppose a mobile service that offers indoor location information to others based-location applications like in this work [CHON, J. *et al*. 2011]. The service uses the digital compass to get orientation changes and the accelerometer to deduce displacements. To test the service we could generate several sceneries defined by a sequence of values, accelerations for accelerometer and radians for digital compass. Given an initial location and the sensor's values, the service estimates a final location. But it could be easier and more useful if the values are generated indirectly by moving a user and his smart phone in a simulated environment. In this way, the test set could be formed by a list of rooms a user has to visit. Other way could be to define an autonomous user behavior that uses a phone in his natural environment. Anyway, the last two options to define tests are much more natural, comprehensible and realistic than the first one that directly defines a displacement as a sequence of acceleration and radian values.

This work is focused on testing of applications or services for smart phones through a simulator where the environment and interactions are modeled. Considering an Android service or application as the system under test (SUT), some of the errors may be found by using a Unit approach [OSHEROVE, R., 2009]. Concretely, UbikSim [UBIKSIM, 2013] is used as simulator. It has been designed to simulate environments, devices and people interacting with real ubiquitous software [CAMPUZANO, F. *et al*. 2011]. It is already been focused as an ubiquitous computing environments simulator which tries to alleviate the particularities of testing services and applications whose behavior depends on both physical environment and users. Moreover, UbikSim offers a world editor that offers an easy way to create environments and the agents that interact in it.

Using the simulator, not only a sequence of values can be simulated, but it is generated indirectly through defining concrete simulated environments from the reality. It offers two main advantages: (1) software testing is not defined by the component level as a sequence of sensor values, but from stress concrete situations in the virtual world that are more natural and realistic. (2) A graphical representation of the situations means that a set of final users can understand and, therefore, they can validate the application behavior more easily while the testing process is performed simultaneously. So, since the user is getting involved in early stages, we achieve a user centering development philosophy in a natural way.

In this paper the contents are exposed as follows. Section 2 is related with the challenges. At the next section 3, it is exposed a complex example application to test. Section 4 covers SUT testing by simulation. And, finally, the conclusions and future work are treated.

2 Challenges

The most common Android development tools [MEIER, R., 2010] are composed by SDK (Software Development Kit) and ADT plug-in (Android Development Tools), both supported by Google and open source. The SDK includes the Android APIs (Application Program Interface), development tools and the Android Virtual Device Manager and Emulator. ADT plugin extends the SDK functionalities to an IDE (Integrated Development Environment).

The Android software stack is composed by several layers. The Application Framework Layer is the most important. It provides the classes used to create Android applications and a generic abstraction for hardware access and manages the user interface and application resources. The following subsections contain some Android services that are offered by classes of such layer. They can be used as a source of context for developing context-aware applications. Also, it is explained why the existing testing tools are insufficient to test each application based on such services, and even more if we want to simultaneously test an application based on a correlated set of those services.

2.1 Location-based SUT

Mainly on a smart phone, location services are obtained through CellID or GPS. The second one is the

preferred method as it is more precise but it only works outdoor. CellID approximates your location based on the urban cell you are in, and this could employ too many meters, but it works indoor also. Location services on Android are obtained through the *LocationManager* class.

An interesting facility on Android is a hook which allows the programmer to simulate in the emulator, different locations a user passes through, when debugging the application. In this way, the user is not moving, but the emulator virtually does. But the test is not realistic because consists in a file with coordinates and the simulation reproduces constant velocity and straight line displacements. It could be more realistic if the coordinates were given by simulated person displacements in his natural environment. Furthermore, a based-location service including inertial devices could not be tested by this tool.

2.2 Sensor-based SUT

Sensors on Android are managed in a similar way that location, through a *SensorManager* class which is the one giving access to all the sensors of the phone. Exists a wide list of the sensor-types currently available; note that the hardware on the host device determines which of these sensors are available to the SUT.

There are third-party tools which help working with sensors on Android. For example, the Sensor Simulator [SENSIM, 2013] is a stand-alone application of OpenIntents and it lets simulate moving the mobile and the corresponding sensors by only moving the mouse.

Another, Samsung Sensor Simulator [SAMSENSIM, 2013] lets simulate the registers of sensors, obtained by a simulated mobile. It also lets connect to a real device to log real registers from it. But again, those tools are complicated either to manage or to generate the sceneries composed by incompressible sequences of values.

2.3 Audio and Video-based SUT

Audio and video are another source for context sensing. They are interesting by means of their processing, e.g. image processing to detect objects or recognize commands by speech. Android offers this type of services that support data processing through *Camera* and *AudioRecord* classes for video and image processing, respectively.

The emulator allows using a microphone and a webcam to test applications that use those resources. But, it is not considered a tool to feed the SUT with artificial images and sounds that defines scenery for testing.

3 A hard to test SUT example

In this section is studied a type of application which is complex to test. It uses an indoor location-based service (ILBS) to develop an augmented reality (AR). It is conceived to make museum tours more attractive and educational by locating POIs (Point Of Interesting). AR applications need to know the location and orientation of the phone in order to show the POIs on the screen. There are no problems outdoor because the GPS give us the location, but it is not as easy at indoor. In fact, a lot of techniques which try solving this problem are based on different technologies (WiFi, Bluetooth, ultrasound, inertial sensors) or a mix.

There exist different variants of AR, this paper defines it as a term for a live indirect view (through mobile screen) of a physical real-world environment whose elements are augmented by virtual phone-generated POI icons - creating a mixed reality. The augmentation is in real-time and in semantic context with environmental elements.

In order to show the POI icons, each one has a coordinate location and the smart phone gets its own location and orientation from indoor location system. A practical positioning and tracking solution for users in indoor environments relies on both an accelerometer and a digital compass. When a user starts to move, classification data acquired from both sensors are used to approximate the user's location. But the mechanism is needed to get an initial position and to solve accumulated sensor errors. So, several QR (Quick Response) codes, with location information, are distributed in the museum.

The AR application is developed for the Museo Arquelógico de Murcia (MAM) [MAM, 2013]. The museum visitors download it and they can browsing through MAM identifying POI, e.g. archeological pieces, next exhibition hall, toilets, etc. So, a user can identify POIs around him with his smart phone and gets information about them pushing on each POI icon or reaches them physically.

Usually, testing stages are divided in several tasks depending on modular functionality of the SUTs. For this example: (1) friendly graphic user interface (GUI), (2) read QR codes with smart phone camera, (3) the correct QR codes content depending their location, (4) the right location of the POIs and their content, (5) the error of the predictions of the indoor location system based on both an accelerometer and a digital compass and (6) the location of the QR codes depending the error of the predictions. Given these tasks, the fifth is the harder to test. Due to the correlation of sensor values, accelerations and angles. And this type of tests is hard to generate and manage with the actual tools available, as we have seen.

To test indoor AR applications it is used a pilot test that is formed a set test in a real environment, a museum in this case. But it is expensive due to it requires to deploy the infrastructure (QR codes, internet access), probably at least an exhibition hall must be closed, time and money to manage and coordinate people. By its cost, a pilot test is usually performed at the end of the development process. At the same time, it implies more costs because the detected errors are more expensive to resolve in this stage than in early ones.

4 SUT testing by simulation

Context-aware SUTs are harder to test in a lab as the use of sensor values are more correlated. A simulation-based testing is proposed where environment and its elements related (people and devices included) with the SUT are modeled and simulated. So, first a model of the world and the related elements have to be created in order to the SUT could be tested using a smart phone and the simulator.

4.1 Modeling Elements

In this stage, the simulated world, where the SUT of smart phone will be involved, is modeled. It includes: environment, people and devices. The world is modeled using an UbikSim editor. **¡Error! No se encuentra el origen de la referencia.** shows the editor and a model of an exhibition hall of the MAM. This tool offers an easy way to create environments by dragging elements from the catalog (panel located at top-left) to the panel of edition. It already has some elements but we can create new ones quickly. In addition, a 3D view of the model is available on the bottom panel.

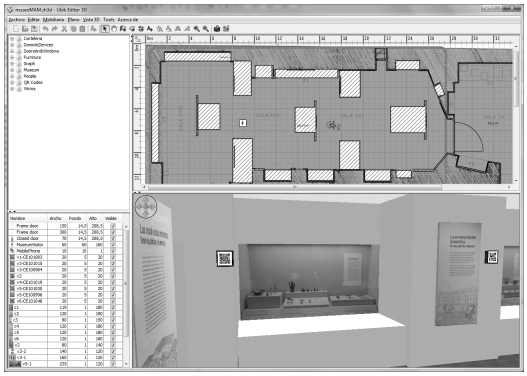

Fig. 1 MAM Exhibition hall modeled with UbikSim.

Each world model represents a test configuration. So, first a basic environment is created (e.g., composed by exhibition hall, furniture and pieces of art) and then, others more complex to test specific functionalities. For instance, to test the indoor location system, it is shown the predicted tracking on screen to check if the error gotten is acceptable. Other sceneries could be composed by different locations of the QR tags.

4.2 Testing process

In this stage, a user or developer tests the SUT installed in a smart phone (or emulator) in a simulated world where the user interacts using a keyboard and a mouse. UbikSim is used as simulator and it has several main features [GARCIA-VALVERDE, T. *et al*. 2009]. UbikSim offers basic models for physical environments (e.g. offices building floors), for humans (e.g. professors in universities) and for sensors (e.g. presence, pressure and open door sensors) that are already developed and validated.

Fig. 2 shows the main schema of the elements and their interactions needed to test the SUT. At left side, it is the simulator and it includes simulated smart phone (SSP) and simulated user (SU). SU carries SSP and it has simulated sensors that register context information from simulated environment (e.g. simulated temperature sensor registers ambient temperature) and SU actions (e.g. simulated accelerometer registers user displacements). At the right side, we find the real elements. A real user (RU) tests the SUT installed in a real smart phone (RSP) that receives sen-

sor values from the simulated environment through SSP like it comes from the real world. RU interacts with the simulated environment with the keyboard and mouse like a computer game such as Counter Strike [COUNTER, 2013].

The example exposed in section 3 will be used in order to illustrate how to test an application. It supposed that the simulator represents the predicted location by RSP and the SUT is completely developed. So, the SUT is installed on the RSP. Also, complete scenery is already created and available to be simulated.

Once the simulator is started with the scenery and the SUT is installed on the RSP, the test can be begun by the RU. To start, RU could to move his SU until a QR tag using the keyboard, then RU activates the QR reader from his RSP to decode the tag. In order to perform this task, the SUT needs to get images from the camera, instead it receives images (containing the QR tag if it is focused) that are displayed on the PC screen by simulator. The tag is identified and processed to get the location information, after this, it is displayed in the simulator. By this way, the user tests easily if the QR tag contains a correct location.

Once the SUT gets its position, the RU can activate the AR from the RSP to identify POIs. RU sees them on RSP screen and can test how the POI icons change by rotating his SU using keyboard. Therefore, RU can check if POI icons are correctly displayed in our RSP screen and also, RU can review the content of a POI pushing its icon.

Finally, by moving SU and consequently its attached SSP that sends simulated acceleration and orientation changes to the RSP. RSP tries to predict the SSP location from those simulated values and, at the same time, RU checks how varies the predictions on the screen. In addition, RU can check if it affects to AR too much depending on if the POIs are located more or less correctly on the RSP screen.

As we have seen, UbikSim contributes to test by means of the displays. The simulation displays are very useful to observe that the application behavior is appropriate. UbikSim works on MASON [MASON, 2013] and can use its features as, for example, inspectors. They are a means to graphically visualize the evolution of variables of interest for the simulation. A large number of inspectors for various simulation variables can be used and monitored dynamically as the simulation evolves. They can be used to check that such variables take always reasonable values, such as estimated locations.

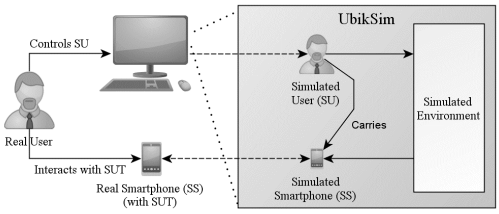

Fig. 2 Proposal of interactions within a mobile applications testing scenario based on simulation.

5 Conclusions

Currently, existing tools are insufficient to test context-aware applications that make extensive use of their sensors whose values have a correlation. This paper proposes an approach to test this kind of applications using simulation. The approach simulates the whole environment where the application will be deployed, such as physical space, people or sensors. In contrast, both the SUT and the smart phone where the SUT is installed are real. Therefore, the user interaction with the SUT is realistic, giving a real experience that is fundamental for validation.

This work is a contribution to the engineering process of smart phone application in general and AmI systems in particular. It has three main advantages. (1) The software testing is not defined by the component level as a sequence of sensor values, but from stress concrete situations in the virtual world that are more natural and realistic. (2) A graphical representation of the situations means that a set of final users can understand and, therefore, they can validate the application behavior more easily while the testing process is performed simultaneously. (3) Some tests can be performed in early stage of software development process because a pilot test is not needed as it was needed before. When an error is detected early, it is easier and cheaper to fix. (4) Developers neither need to learn any new application programming interface (API) nor change source code of the application.

Future works include a deep study about defining a graphical modeling language that allows users to specify how a system (included smart phone) should react against defined situations. The language will be defined for a specific domain, Parkinson Disease. Doctors, caregivers and relatives have to be able to use the notation. Therefore, it will have to be simple

enough. Finally, these models will be translated automatically in a simulation in order to users can validate the model defined themselves.

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Healthier? More Efficient? Fairer? An Overview of the Main Ethical Issues Raised by the Use of Ubicomp in the Workplace

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KEYWORD

Intelligent Working Environment
Ambient Intelligence
Human Resources
Human Resource Management
Ethics

ABSTRACT

The development of Ambient Intelligence (AmI) will radically transform our everyday life and social representations. These transformations will notably impact the working environment. The objective of this paper is to offer a first survey of the main ethical issues raised by the development of intelligent working environments (IWEs). It especially focuses on the capacity of such environments to collect and handle personal medical data. The first two sections of this paper aim to clarify the methodology (2) as well as the object (3) of the research. We then point out some of the main ethical issues raised by IWEs and their capacity to collect and handle medical data. The final section attempts to offer some elements of reflection regarding the ethical principles that should guide the development of IWEs in the future.

1 Introduction[1]

The last decades have witnessed the rapid development of a whole series of researches in the field of "new technologies". This development has not only stirred many discussions in academic circles and the public space, but it has also led to the emergence of new disciplinary fields, particularly in the field of ethics. Alongside the "traditional" bioethics, today we can find a multitude of other ethical applied approaches such as nanoethics, the ethics of genetics, computer ethics, neuroethics, etc.

Technologies which have given rise to these new areas of ethical reflection tend more and more to appear merged. This phenomenon has led to what is often termed the "converging" technologies, or NBIC technologies (in reference to Nanotechnology, Biotechnology, technology Information and Cognitive sciences).

The thus called "intelligent environments"[2] – on which we will focus in this article – are particularly representative of this phenomenon, as well as of the transformations that it implies. They presuppose an omnipresence of computer technology (ubiquitous computing), which is radically transforming our perception of reality and our relation to the world [FLORIDI, 2010].

Indeed, in recent years, several scholars have begun to focus on the ethical and social issues raised by the development of these intelligent environments [FLORIDI, 2010; TAVANI, 2011; BOHN et al., 2004; HILTY et al., 2003; HILTY et al., 2004]. Some of them have looked at the ability of the ambient intelligence to support therapeutic or medical activities

[1] IWE = Intelligent Working Environment; HR = Human Resources; HRM = Human Resource Management

[2] Regarding the terminology see Daniel Ronzani, The Battle of Concepts: Ubiquitous Computing, Pervasive Computing and Ambient Intelligence in Mass Media, UbiCC Journal 4 (2) (2009), pp. 9-19.

towards people with specific health problems (elderly people, diabetics, people with psychiatric disorders, etc.) [SCHUURMANN et al. 2009].

But the development of ubiquitous computing offers other opportunities. It might also be used by companies for managerial purposes. Intelligent environments might be integrated in the workplace to measure and improve working conditions, to check the employees' "state of functioning", to enhance their well-being and performance, and, of course, to optimize corporate productivity. If it is becoming a reality, this kind of use will have a considerable impact on the management and the ethics of HR.

However, we can now observe that the publications dedicated to the emergence of ambient intelligence in the workplace show little interest in these issues.

Most of the existing studies have so far put focus on technical difficulties related to the programming or the design of these new environments [ANISETTI et al., 2006; SOUSA, 2010]. Some address the question of the implications of ubiquitous computing for Information Technology Management in companies [PATTEN et al., 2005]; others have made studies on the acceptance of IWE [RÖCKER, 2009] while other studies have tried to sketch scenarios of the future workplace [BÜHLER, 2009]. The studies dedicated to the examination of the ethical and managerial issues of these developments are scarce. This gap is even more striking when we know that the first applications related to the workplace are making their appearance on the market at a brisk pace[3].

2 Objective, Outline and Method

In this article, I would like to offer a first overview of the main ethical issues related to the development of IWEs and in particular to their capacity to collect and monitor data containing personal medical information such as our heart rate, brain activity or emotional state.

In this perspective, I will first clarify the background of the current developments (3). To do so, I will briefly introduce a *typology* which should help us to categorize the different computing tools that have appeared in recent decades (3.1.). I will then move the focus on the thus called "intelligent environments". I will say a few words about their *origins* and their *features* that can be identified on the basis of an analysis of the existing literature (3.2.), before mentioning a few *examples of applications*, most of them related to working environments (3.3.). In the next section (4.), I will try to point out the main ethical issues raised by the ability of these environments to monitor data containing medical information. Following a consequentialist approach, I will begin to present a quick overview of the potential positive and negative *impacts* involved by this ability (4.1.). Then I will point out some more fundamental socio-ethical challenges raised by the development of these environments (4.2.). Finally, I will offer elements of reflection on ethical principles to the discussion that could help us to frame the potential negative impact of the upcoming development of ambient intelligence in the workplace (5).

3 Theoretical background: what are we talking about?

3.1 Typology of the computing tools

Following the work of authors like Kalle Lyytinen and Youngjin Yoo [LYYTINEN et al., 2002], we can order the developments realized over the last decades in the field of computer sciences on two lines (see Figure 1). The first line indicates the *degree or level of mobility* of the technological tool. The question here is to estimate to what extent and in what proportions the tool we use is mobile or not. The second line assesses its *degree of integration* or *embeddedness* in the workplace or, more specifically, its ability to monitor, record and handle data related to the environment in which it is integrated.

Thus, the first computers that appeared in our workplaces were not mobile – not to say irremovable. Besides they had no ability to measure and handle data related to their environment (1). Gradually, laptops, mobile phones and, more recently, the first smart phones – true small pocket computers that may

[3] See for example the 3D job interviews simulator developed by the Centre de réalité virtuelle de Clermont-Ferrand and the consulting company Athalia (www.aprv.eu) or the intelligent fireman hood developed by the firm Bodysens (www.bodysens.com).

be taken everywhere – have appeared on the market. These first mobile tools presented a relatively restricted, not to say non-existent, level of integration: their functions were essentially limited to word processing, calculation and spreadsheet, as well as to social communication (phone, e-mail) (2).

But, gradually, progresses were also made on the integration line. In recent years, numerous scholars have worked on the development of the computer's capacities to measure and handle ambient data (like the temperature, the luminosity, the tone of a voice, the presence of certain substance in the atmosphere, etc.). We have already used various applications of home automation as for example, blinds that automatically close when the solar radiations become too strong. Having said so, we must acknowledge that the potential integration of today computing tools goes far beyond this type of application. A large number of systems developed by ITC specialists are not following the binary impulse-reaction logic of traditional mechanics any more: they can measure, record and simultaneously analyze a wild range of data related to their environment and treat these in such a way in order to offer an innovative and tailored response to those who are in contact with them. A group of researchers of the Institute of Engineering of Porto, – ISEP [RAMOS et al., 2010], for instance, has imagined a conference room which should be able to take into accounts the emotions and the arguments expressed by the participants of a meeting and use them to play an active role in discussions (3).

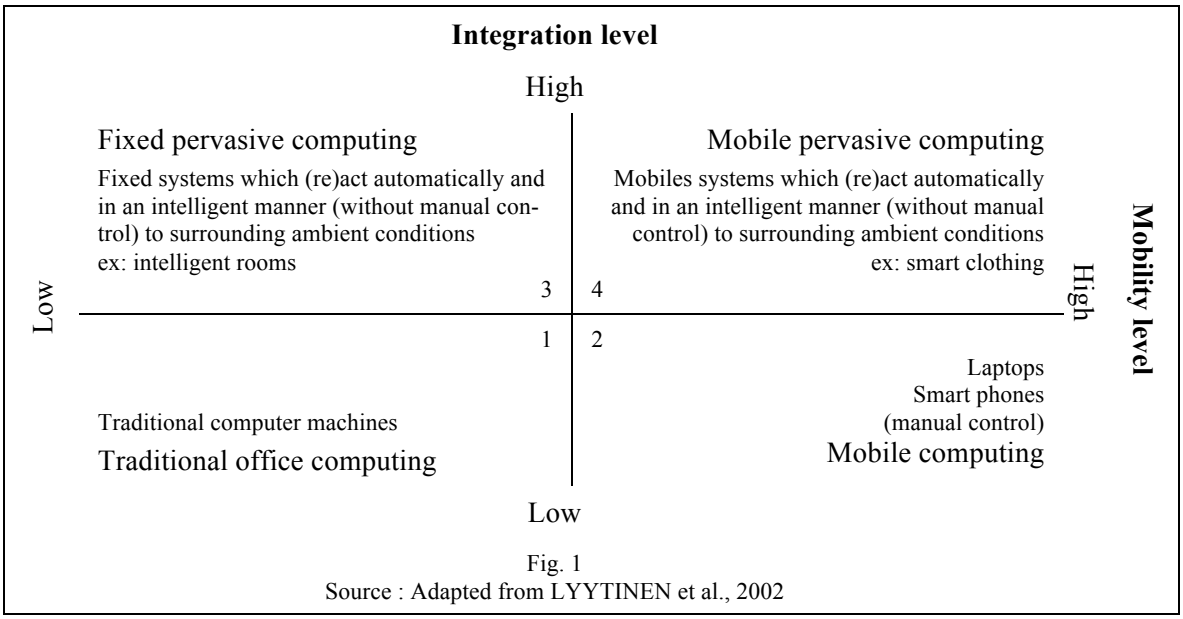

Fig. 1
Source : Adapted from LYYTINEN et al., 2002

While some systems, like the one I have just mentioned, are limited to a given environment (a room, a natural location, etc.), others are much more mobile (4). The Swiss Center for Electronics and Microtechnology (CSEM) in Neuchâtel, for instance, has imagined a firefighter jacket, apparently normal, which can monitor the heart rate and the body temperature of the person who wears it, thanks to sensors integrated in the fabric. Mobile and perfectly embedded in its environment, this jacket should support firemen by allowing them to monitor in real time their level of stress as well as other health risks related to their job.

When we are speaking of ambient intelligence, ubiquitous computing, pervasive computing or intelligent environments[4], we are essentially referring to these two latter types of technology (3 + 4). Before trying to identify more closely the features of these tools, it might be useful to say a few words about their origins.

[4] Regarding the terminology see Daniel Ronzani, The Battle of Concepts: Ubiquitous Computing, Pervasive Computing and Ambient Intelligence in Mass Media, UbiCC Journal 4 (2) (2009), pp. 9-19.

3.2 The Origins of Ambient Intelligence and its Main Features

It is current to attribute the paternity of the ambient intelligence to the American researcher Mark Weiser (1952-1999) who was Head of laboratory and then Chief Technologist at the Xerox Palo Alto Research Center (PARC) between 1987 and 1999 (Bohn et al. 2004; Kinder 2008). The basic idea was apparently to develop "wall-sized, flat panel computer displays [which could also] function as input devices for electronic pens" [WEISER et al., 1999]. Very quickly, a further idea was introduced, namely, that computers should be spread ubiquitously in the environment (floor, walls, etc.) and in the objects of our everyday life (furniture, clothes, accessories, etc.). Allowing computing to become ubiquitous, the researchers at PARC "wanted to put computing back in its place, to reposition it into the environment background, to concentrate on human-to-human interface and less on human-to-computer once. By 1992, when [their] first experimental 'ubi-comp' system was being implemented, [they] came to realize that [they] were, in fact, actually redefining the entire relationship of humans, work, and technology for the post PC-era" [WEISER et al., 1999, 694]

Ubiquity is not the only striking feature of ambient intelligence. Ambient intelligence is also characterized by invisibility or, more exactly, by its *non-perceptibility*. As Nijholt states it, the ambient intelligence does not only remove computers from our field of vision, but also provokes "the mental disappearance of the computing device" [NIJHOLT, 2004, 471].

Sensitivity is another important feature of ambient intelligence. Miniaturized biosensors enable computers to measure and communicate information to their environment. As I have already said, data collected and analyzed might be from various sources: chemical, biological or physiological data, such as the temperature of a room, the presence of a particular substance in the atmosphere, one's electroencephalogram, one's facial expressions or emotional state [ALLANSON et al., 2004]. This capacity made scholars say that ambient intelligence is aware of its context (*context awareness*).

Like most of computing systems, the thus called "intelligent" environments have a *large memory capacity.* The latter are able, for instance, to record an extensive set of data in the long term, and spot on this basis variations which affect the pace and progress of work, as well as the performance, the level of fatigue and stress of workers.

That said, to be fully "intelligent", the computing tool must *be able to adapt to its context* and to the data it collects and analyses. It should have the capacity to react with regards to these data in a targeted and personalized manner, and respond to the particular needs of the persons who are in contact with it [STEFANI et al. 2007].

This adaptation skill combines with an *anticipation skill*. In other words, it is expected from the intelligent environments to meet the user's needs *even before these needs appear*.

Finally, ambient intelligence is often associated to, or even regarded as equivalent to the thus called "persuasive" technologies. Being able to anticipate the user's behaviour and to adapt itself to it, the computer becomes a powerful instrument of persuasion [van den BROEK et al., 2006; HOFKIRCHNER et al., 2007; KAPTEIN et al., 2010].

This assertion leads to the definition of IWEs. I base my own approach on the proposal made by the interdisciplinary research group "Intelligent Working Environments: Socio-ethical and Human Resource Management Challenges" of the School of Business and Engineering Vaud (HEIG-VD, Switzerland).

Working environments fitted with (a) ubiquitous computing system(s), often imperceptible which record(s), integrate(s), correlate(s) and analyze(s) ambient data from diverse sources and is (are) intended to

- *automatically*
- *in due time*
- *in a personalized*
- *and intelligent manner*

... meet the needs of the stakeholders

Fig. 2: Definition of Intelligent Working Environments
Source : Groupe de recherche IWE &HRM 2012

3.3 Application of Ambient Intelligence at work

I would like to add other examples of application to those given in the foot note 3 and point 3.1. In the context of this paper, I will confine myself to a short enumeration of applications related to the workplace in order to allow everyone to obtain a better idea to what tomorrow work could look like. These are just a few examples that we may find in the literature dedicated to ICT:

- a system which dynamically, automatically and in an autonomous manner organizes the planning of a medical team, taking into account the possible emergency health care situations, etc. [CORCHADO et al., 2008];
- a personal digital assistant which can guide employees step by step in the accomplishment of the tasks they have to perform for the maintenance of machines and which offer the possibility of a distance video monitoring systems to deal with particular problems [BÜHLER, 2009];
- a system which is able to detect the temporary memory loss of a worker, to remind him or her of the tasks that have been done and of those that still need being done, and, if necessary, to contact automatically a support person [BÜHLER, 2009];
- a smart computer which is able to assess the fatigue of its user by measuring his/her blink rate and to react by "increasing font size or screen contrast in order to ease" reading [ALLANSON et al., 2004];
- a computational interface which is capable of evaluating the level of frustration of a person by measuring his or her heart rate and blood pressure, and which, on this basis, may adapt itself to the user's needs [ALLANSON et al., 2004];
- etc.

4 Results

No need to say that the development of ambient intelligence raises important ethical issues. The context of this presentation does not allow me to examine these issues in detail. Nevertheless, I would like to point out those that I consider as the most important ones in order to provide an overview of the coming challenges and generate a debate. As stated, I will focus on the use that can be made of the IWEs to measure, record and monitor data containing personal medical information (physical or psychological).

4.1 Risks and Opportunities of the Use of Intelligent Health Monitoring Systems in the Workplace

In the two tables below, I have tried – on the basis of the studies which have been made so far – to briefly list the main advantages and disadvantages that may arise, on the individual, organizational and social levels, because of the use of the IWE's capacity to measure, record and monitor data containing personal medical information.

Table 1: Opportunities and possible advantages for the…	**ind.**	**org.**	**soc.**
Opportunity of a *better adaptation of working places to the physical and mental abilities of workers*, as well as to their specific medical needs [BÜHLER, 2009].	x		
Opportunity of a *better control and prevention of accidents at work* (in case of accidents due to medical disorders, such as for instance attention deficit disorder)[5].	x	x	x
Opportunity of a *better health control and protection for workers* thanks to good anticipation, early detection and personalized treatment of medical disorders (ex: early detection and treatment of cardiac palpitations) [BÜHLER, 2009; Azteca Project][6].	x	x	x

[5] A better prevention of workplace accidents also brings organisational and social benefits since it should go with a reduction of the costs due to employees' failure.

[6] A better health protection for workers also brings organisational and social benefits since it should go with a reduction of the costs due to employees' failure.

Opportunity of a *reduction of the employer's control regarding his/her employees' Health* (since this control may be delegated to the ubiquitous system) [BOOS et al., 2012].		x	
Opportunity of a *better control of epidemic diseases* thanks to early detection, good anticipation and early treatment of contagious diseases.		x	x
Opportunity of *increasing productivity or the economic and managerial performance of the organization* thanks to the improvement in the workers' health (decrease of absenteeism due to illnesses and improvement in some abilities such as concentration, dexterity, etc.).		x	x

Table 2: Risks and potential drawbacks for the…	**ind.**	**org.**	**soc.**
Risk of *invasion of workers' privacy* connected to the recording, handling and possible transmission of data containing personal information about the workers' (physical or psychic) health or habits which may have a medical impact (ex: inappropriate repetitive movements which may cause back pain) [SPIEKERMANN et al., 2009].	x		
Risk of (negative) *discrimination of workers* because of their health status.	x		
Risk of development of *inequalities among employees for the access to the benefits* offered by a health monitoring system due to the implementation and management costs of IWEs.	x		
Risk of *infringement of the worker's right not to know* (communication to the worker of data concerning his/her health that he or she does not want to know, such as for instance a form of cardiac risks [FLORIDI, 2010][7].	x		
Risk of *development or reinforcement of managerial paternalism*, related to the power and authority conferred by the medical knowledge on workers. [KINDER et al., 2008].	x		
Risk of development *of inequalities among the organisations in the access to the economic advantages* offered by the IWEs due to the costs requested for their implementation and management		x	
Risk of *loss of employees' trust in their employer* due to a misuse of data containing personal medical information [HEESEN et al., 2007].	x	x	
Risk of *transmission of false medical data* (to the employee, the employer, etc.) because of programming errors, data forgery or viruses.	x	x	
Risk of *delegating to the ubiquitous system employees' and employers' responsibility* regarding the health in the workplace [BOOS et al., 2012]	x	x	x
Risk of *employees and employers' loss of control over occupational health* (e. g. loss of the human capacity to detect critical health situations) [TAVANI, 2011 ; BOOS et al., 2012]	x	x	x
Risk of an *increase in stress* due to the knowledge of being potentially observed by the ubiquitous system (cf. extension of the Panopticon logic) [Foucault, 1975].	x	x	x

Legend: ind. = individual
org. = organisation
soc. = society

[7] In his article « Ethics after the Information Revolution », Luciano Floridi [FLORIDI, 2010] shortly points out to a similar risk when he speaks of a « substantial erosion of the right to ignore » (7).

These two lists are not exhaustive, but are intended to provide a general overview of the potential (positive and negative) impacts of the development of ambient intelligence in the workplace. Furthermore, the distinction that we make between the individual, organizational and social levels should not be taken literally. Such distinctions remain somehow arbitrary and artificial. Indeed, depending on several circumstances, an increase in productivity or a better economic-managerial performance of a company can provide employees with benefits (for example, perks/bonuses). Nevertheless, it seems to me useful to differentiate at which level lie the advantages/disadvantages brought by the development of IWEs.

4.2 Socio-Anthropological Issues Related to the Underlying Assumptions of IEs

This consequentialist approach offers the advantage to highlight some of the concrete challenges raised by the development of AmI in the workplace, even if confining ourselves to this kind of approach would lead us to miss more fundamental issues. Without going into the details of the meta-ethical discussion [FLORIDI et al., 2002; TAVANI, 2010; WIEGERLING, 2008], it should be noted that the developments of AmI *rely on presuppositions and normative choices that have important socio-anthropological implications*.

The identification of these presuppositions and choices is far from being self-evident. Their implicit or even unconscious character makes the exercise even more complex. However, reviewing the literature devoted to this matter, it can be stated that the research conducted in the field of AmI is generally based on the presuppositions that 1) the limits and boundaries which define the human being as well as the social structures and relations are not "useful", that 2) these limits restrict the range of our possibilities and, finally, 3) removing them would increase our individual and collective well-being. On the normative level, the equivalent of these presuppositions is that we must do everything in our power to support the removal of all socio-anthropological limits and boundaries.

These objective and normative assumptions (or validity claims, to use HABERMAS' words, 1981) appear in the speeches that accompany the development of ubiquitous computing. The analysis of these speeches shows a trend to consider the blur of boundaries as a value: bridging the gap between humans and machines and developing "seamlessness infrastructures" is seen as undoubted progress which offers obvious pragmatic advantages, notably for users [RATTO 2007]. The result is the current blur of all the traditional boundaries which exists between systems, individuals and organizations. Thus, as Luciano Floridi says:

"We are slowly accepting the idea that we are note standalone and unique entities, but rather informationally embodied organisms (inforgs), mutually connected and embedded in informational environment, the infosphere, which we share with both natural and artificial agents similar to us in many respects" [FLORIDI, 2010, 11].

"ICTs are as much re-ontologizing our world as creating new realities. The threshold between *here* (*analogue*, *carbon-based*, *offline*) and *there* (*digitial*, *silicon-based*, *online*) is fast becoming blurred, but this is as much for the advantage of the later as it is to the former. The digital is spilling over into the analogue and merging with it […]. As a consequence of such re-ontologizing of our ordinary environment, we shall be living in an infosphere that will become increasingly *synchronized* (time), delocalized (space) and correlate (interactions)" [FLORIDI, 2010, 8-9].

The potential impacts of these evolutions are significant.

1. *On the anthropological level* first. With the development of ubiquitous computing machines are becoming more and more humanized. In other words, the technological tool gradually acquires the capacity to think and to act like any individual in the social body. As a consequence, it seriously raises the question of its moral status and legal personality. Can we/should we regard a smart system as a being who is potentially responsible (accountable/liable) for its "actions" and "decisions"? [FLORIDI, 2008; HILDEBRANDT, 2008].

At the same time, the human beings are becoming more and more technologically driven: our actions and decisions are increasingly dependent on computers, at the *risk of weakening, or even losing*, *our own competences* [SWIFT, 2007]. In other words – and

getting back to the question at hand –, it may be that by putting the capacity to assess and manage our health status into the hands of the ambient intelligence we are gradually led to call in question or neglect our own capacities in this field. Indeed, as Adam Swift points it out:

"The surrender of a certain degree of agency to ubiquitous computing systems is a trade that should not be taken lightly or without deeper inquiry […]. When McLuhan argues that every technological 'extension' of human faculties corresponds with an 'amputation', he is suggesting that while our reliance on new technological systems may relieve some of the burdens of everyday life, our organic faculties are likely to – 'atrophy to a corresponding degree'" [SWIFT, 2007, 37].

(2) But that is not all. The developments of AmI also imply *a complete reconfiguration of the social functions and spaces*. A working environment capable of measuring the employees' physiological data and to meet their needs changes the role and the power of the employer. As briefly mentioned the latter may in the world of ambient intelligence, be authorized – through the knowledge and skills conferred upon it by the machine – to take on a resolutely active role in maintaining the health of his/her employees, in the same way as a doctor or a therapist would. Similarly, we can expect that the role of physicians will also evolve and that they will be requested to contribute to the improvement of the company's performance because of their (medical) knowledge.

Such interferences regarding functions and roles will surely have repercussions on the borders of social spheres. As the firm becomes an area capable of controlling and operating synchronically its coworkers' health, the definition of the area itself is being transformed, and potentially becomes a therapeutic (or para-therapeutic) care center.

How can or should this new field be seen with regard to the care centers that already exist? Furthermore, what will become medical centers and hospitals when AmI's medical skills will be developed and running in our working places?

5 Discussion

As the latter section shows it, it becomes clear that social, anthropological, and ethical – both complex and fundamental – matters come into play, and that the answers cannot be let neither to the responsibility of a certain group (IT, HR managers, lawyers, etc.) nor exclusively taken individually.

The stakes related to AmI's development (at work) call upon a shared responsibility. They must thereby be the object of public and wide-ranging discussions (HABERMAS, 1991) designed to validate shared moral values that we want to pursue, and ethical or legal norms that we consider essential regarding the possible perspectives that AmI could offer.

In this perspective, it is urgent not only to spread such researches on the development of AmI technology to a wide public, but also to encourage the debate within companies and in the whole society.

This debate must first be on the merits of the AmI's development. In other words, we should communicate now, publically and with transparency, the underlying assumptions and axiological choices (objective and normative validity claims) of the research, and we should validate or invalidate them in a concerted manner.

We must question ourselves about the boundaries that define our conception of the human being, and social relationships. Are these boundaries still useful or relevant? Should we move them, go past them, reassert them, strengthen them? And in that case, why and for what purpose?

In the meantime, and without any prejudice about the results of this discussion, we have to make sure to anticipate AmI's development, especially in the field of work, and this must be done without any delay. Ubiquitous computing – as almost any other technology – has an important power of attraction and fascination. As seen, it vehicles a lot of promises and offers opportunities we cannot deny: a better professional integration for disabled people, a better safety at work, a better health protection, etc. These elements make us think that there is a fair chance that AmI will continue growing even if we doubt – partially or totally – about the underlying assumptions and axiological choices.

Thereby it is essential that we pursue together the discussion about the possible consequences of AmI's development, and that we continue questioning ourselves about the normative framework that should be built in order to counteract the potential negative effects.

In order to shape the latter subject I would like to

finish with some ethical principles that I believe could help thwarting these potential negative effects.

As I see it, some conditions must be respected so that the gathering and management of medical information by AmI can be accepted.

I. Protection of privacy

Medical data measured in the workplace are properties of employees. The employer (or any other person) may have access to them only if a preponderant good requires it. I am not entitled to tell, on my own, what this preponderant good might exactly be. It must be defined democratically through an open and public discussion. Nevertheless, it seems obvious to me that if a good brings advantages to a restricted part of the population it cannot be considered as preponderant [RAWLS 1971].

1. Protection of privacy over productivity

It seems to me that the productivity of a firm promotes in theory only a certain group of people (mainly managers or shareholders) without creating equality. Thereby productivity cannot be *a priori* defined as a preponderant good, and does not justify the recording and handling of workers' medical data.

2. Balance between privacy's protection and protection against impoverishment

The case is slightly different if the existence of the company is threatened. From the employee's point of view we may understand that he or she may be willing to renounce to his or her privacy in order to secure his or her existence and the existence of his or her family. But from a political ethical perspective, the infringement of the workers' privacy for the sake of the company survival, or even, for the sake of economical interests is hard to defend. As a society we have the power to set a legal framework which may prevent companies from being economically dependent on the medical information delivered through IWEs. To say it in other words, nowadays companies can survive without these kinds of environments and without storing any special information on their employees' health. Possessing such environments and such information does not constitute a competitive advantage. Yet, this aspect can change in future. If we want to protect privacy, we must assume our political responsibility and prohibit the collection of workers' medical data in order to gain a competitive advantage.

3. *Balance between privacy and population's health*

A major epidemiologic risk could justify the gathering and handling of a worker's medical data through IWEs. In this case, it will be necessary to take into account the probability as well as the gravity of the risk (degree and speed of contagion, degree of morbidity and mortality, gravity of the disease, existence of preventive and therapeutic means, etc.).

II. Health protection

The medical data collected through IWEs should not be harmful to the workers' health. Only some preponderant good may justify health damage.

1. Primacy of the best possible sanitary situation

A major epidemiologic risk could justify the use of IWEs causing health damage. However, in this case, it will be necessary to take into account the probability as well as the gravity of the risk (see above)

2. Primacy of the worker's health over productivity

The improvement in the company's productivity may not be considered as a preponderant good. It does not permit to justify any damage to the workers' health (see above).

III. Free and informed consent

Workers must receive complete, comprehensive and transparent information about the data that will be collected at their place of work (nature and extent of the data collected, way they will be used, etc.) before the activation of the AmI system. They must also have the possibility to give their free consent to the collection and the handling of such data (item mentioned in the employment contract for instance).

IV. Control of the employer's data handling
The way in which data are used by the company must be submitted to regular control by an external institution. Disregard of the legal and ethical rules must be submitted to sanctions.

V. Protection of the weakest co-workers
The medical data collected through IWEs must not be used in order to justify managerial measures causing a negative discrimination among workers. Yet, we may accept as legitimate the use of such data in order to improve the working conditions of a person experiencing a physical or psychic deficiency, if this deficiency affects his or her well-being in the company, provided that explicit consent is given by those concerned.

VI. Protection against false data
Everything must be done in order to guarantee the validity of the (medical) data collected at the workplace, and its protection against forgery and viruses.

6 Conclusion

I have tried to show that IWEs and their ability to collect and handle medical data raise fundamental ethical issues. It is important that these stakes can be debated and discussed, not only amongst academics, but also within companies, publicly and politically. Indeed the first applications of AmI are coming onto the market very rapidly. These applications will have considerable implications on our everyday organization and our conception of human beings and social relations. If we want to take an active and constructive part in these changes it is urgent to begin the discussion now.

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Designing Intelligent Tutoring Systems: A Personalization Strategy using Case-Based Reasoning and Multi-Agent Systems

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KEYWORD

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ABSTRACT

Intelligent Tutoring Systems (ITSs) are educational systems that use artificial intelligence techniques for representing the knowledge. ITSs design is often criticized for being a complex and challenging process. In this article, we propose a framework for the ITSs design using Case Based Reasoning (CBR) and Multi-agent systems (MAS). The major advantage of using CBR is to allow the intelligent system to propose smart and quick solutions to problems, even in complex domains, avoiding the time necessary to derive those solutions from scratch. The use of intelligent agents and MAS architectures supports the retrieval of similar students models and the adaptation of teaching strategies according to the student profile. We describe deeply how the combination of both technologies helps to simplify the design of new ITSs and personalize the e-learning process for each student.

1 Introduction

Intelligent Tutoring Systems (ITSs) constitute a type of Intelligent Educational Systems (IESs). ITSs contain adequate knowledge domain and its purpose is to transmit that knowledge to the students by means of an individualized iterative process, trying to emulate the way a human tutor guides the student in his/her learning path. Developing and implementing an ITS is a difficult task, since the required technology often implies most of the areas of Artificial Intelligence (AI): knowledge representation, diagnosis, cognitive modeling, qualitative processing and causal modeling process. Besides, it is necessary to have a good knowledge on the domain or topic selected to be taught. The ITS intelligence is constituted by the diagnosis process and the tutoring process adaptation, according to the student profile. In this sense, a challenging research goal is the development of ITSs with adaptive characteristics. Adaptive ITSs can be obtained at several levels: (a) at the level in which the material or the help is presented, (b) considering the difficulty of the problems proposed, or (c) during the selection of the suitable instructional strategy according to its capacities, abilities and learning styles preferred.

In response to this challenge, in this article we propose a Case-Based Reasoning (CBR) approach to design Intelligent Tutoring Systems able to personalize the teaching process in different domains. This approach has three important advantages: (1) it provides a learning method, which uses knowledge adquired from past experiences, (2) it allows the retrieval of similar student models from multi-

organizational distributed datasets and the adaptation of teaching strategies according to the student characteristics and (3) it preserves all the major pedagogical features associated with cognitive tutoring systems, a highly effective subtype of ITS. The reusable problem-solving method permits scalability, ease acquisition and maintenance of knowledge.

We also present a highly modular multi-agent architecture to create two interlacing components. One component produces the expert model as a dynamic and advancing representation of the solution and the other produces an instructional layer tailored to the specific student. The instructional layer is therefore independent of the expert model and it is able to provide feedback inspecting students progress across the entire solution.

The paper is organized as follows. Section 2 introduces the methods and technologies used in our approach. Section 3 explains the framework for designing ITS. Section 4 describes a case study of the implemented prototype. Finally, section 5 is devoted to present the conclusions.

2 Material and methods

Our approach incorporates aspects of cognitive tutoring and knowledge-based systems design within the framework of the INGENIAS methodology [18]. In the problem solving process, the Case-Based Reasoning paradigm is used. The system can effectively infer the students knowledge through the cases generated when the student solves a problem.

2.1 Intelligent Tutoring Systems (ITSs)

Intelligent tutoring systems started to be developed in the 80s, they were designed with the idea of providing knowledge based on some form of intelligence in order to guide the student in the process of learning [9]. An intelligent tutor is a software system that uses Artificial Intelligence techniques to represent the knowledge and interacts with the students in order to teach them [24]. In [8] the authors add the consideration of different cognitive styles of the students who use the system according to [2]. In the 90s, with the advances of cognitive psychology and the new programming paradigms, ITS have evolved from a mere instructional proposal to the design of environments of new knowledge discovery application [21].

2.2 Case-Based Reasoning

CBR is an approach to problem solving that emphasizes the role of prior experience (i.e. new problems are solved by reusing and, if necessary, adapting the solutions to similar problems that were solved in the past). Solving a problem by CBR involves obtaining a problem description, measuring the similarity of the current problem with previous problems stored in a case base (or memory) with their known solutions, retrieving one or more similar cases and attempting to reuse the solution of one of the retrieved cases, possibly after adapting it to account for differences in problem descriptions. The solution proposed by the system is then evaluated (e.g., by being applied to the initial problem or assessed by a domain expert). Following the revision of the proposed solution, the problem description and its new solution can then be retained as a new case. Thus the system has learned how to solve a new problem. Figure 1 shows the CBR cycle, adapted from (Aamodt & Plaza, 1994) [1]. It works as follows:

1) Retrieve previously experienced cases related to the current problem.
2) Reuse these cases in one way or another.
3) Revise the solution based on re-using previous cases.
4) Retain the new solution (as a new case) by adding it into the existing case-based database. Then, a CBR system will gradually grow larger and become a valuable resource.

The use of CBR has been considered in the past to enhance Intelligent Tutoring Systems with learning abilities. In [10] the authors propose the use of CBR as a technology for student modeling in ITSs. That approach follows the steps of the CBR cycle and it can build concrete student models by combining rule-based reasoning. But such approximation only supports the retrieval and reusing phases of the cycle. Other approaches recommend the use of CBR for instructional and route planning [16]. In [11] an Intelligent Tutoring System based on the CBR methodology was developed. This system is able to produce novel courseware arrangements for new students, based on a process of case adaptation. Elorriaga [6] proposes an approach for producing case-based in-

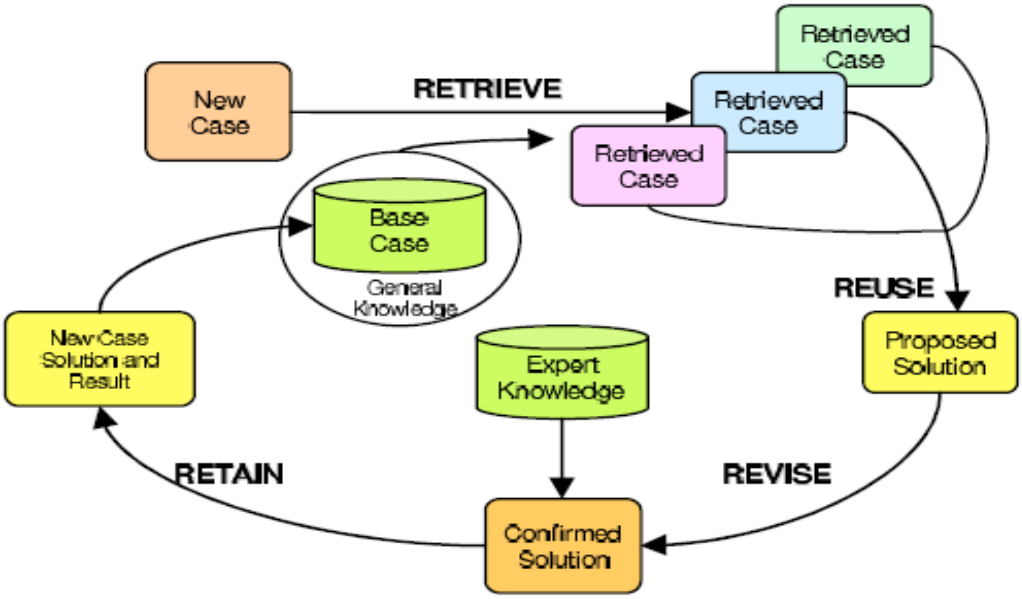


Fig. 1. The CBR cycle. Adapted from (Aamodt & Plaza, 1994)

structional planners that are integrated in ITS to enhance the pedagogical model.

The works mentioned above only use CBR as a technology for building isolated ITS modules but they do not consider CBR as a methodology that integrates all the components of the ITS architecture.

The use of CBR presents the following advantages in our approach:

- It provides a better prediction accuracy to model the student than other techniques (p.e. Bayesian Networks) [9], [23].
- It reflects the same method as a human tutor uses when making students estimations by applying analogical reasoning.
- It can handle both quantitative and qualitative data (i.e. prescore/motivation).
- It can use an existing solution to adapt it to the new students.
- It allows fast prototyping.
- It simplifies the acquisition and knowledge management.
- It can effectively support all the steps in the ITS design by storing past cases, retrieving similar cases and adapting them to new problem.
- It takes advantages of expert prior knowledge.

2.3 Multi-agent Systems (MAS)

Agents can be defined as autonomous, problem-solving computational entities capable of effectively performing operations in dynamic unpredictable environments. Such environments are known as multi-agent systems [25]. Agents interact and maybe cooperate with other agents. They are capable of exercising control over their actions and interactions.

The integration of agent technology and CBR has been proposed in mobile [13], adaptive agents [17] and active CBR [14]. These approaches are focused on the retrieval mechanisms and the associated case representation and indexing. However, a major problem for these systems is the difficulty to adapt and evaluate the proposed solution.

The main benefits of using intelligent agents within CBR environment are:

- Autonomy: the ability of agents to make an independent decision.
- Ability to learn from experience autonomously.
- Goal-driven: the provision of detailed knowledge so that goals can be achieved.
- Reactivity: capability to react to changes in the environment.

- Ability to cooperate: a group of agents work together to achieve a common goal.
- Ability to communicate: the agents must be able to communicate with other agents and/or users.

Our ITS-CBR framework is composed of intelligent agents working to find the most similar cases. Agents access local case bases to retrieve the best matching cases, which, when assembled, may not result in the best overall case in terms of global measures. But cooperation among them may lead to the achievement of the overall goal. Which means that the teaching strategy selected does not just rely on a few cases stored locally, instead of this it is affected by larger and distributed datasets).

2.4 The INGENIAS Methodology

INGENIAS [18] is an agent based methodology which has evolved from an object oriented approach [19]. The role of agent oriented methodologies is to assist in all the phases of the agent life cycle and its management.

The elements that an agent oriented methodology must provide could be grouped into four main categories [10]: (1) concepts and properties are basic notions about the domain area where the methodology will be applied; for example, notions of agent and its characteristics, (2) notations and modelling techniques are related to the specific symbols used in the methodology for representing the concepts and properties (the modelling language), (3) the process indicates which stages of the software development cycle are covered by the methodology and finally, (4) pragmatics considers aspects related to the management and the use of the methodology for example, facility and costs of adopting it, expertise required, support tools for the application of the methodology, etc.

INGENIAS covers these four basic categories, but it also provides a process to guide the software development; a language based on the main concepts of agent theory (for example the notions of agent, role, mental state, goals, believes, tasks, etc.); different models for describing different views of the system at different abstraction levels and a modelling tool.

The ITS Multi-agent system presented in this article has been designed by using INGENIAS.

3 Adaptation of CBR and MAS for designing ITSs: The framework

The relationship between CBR systems and ITSs is established by representing student models as cases. The advantage of this approach is that a problem can be easily conceptualized in terms of agents and be implemented as a CBR system afterwards. ITS-CBR updates its base of cases continually and consequently it adapts itself to changes in the environment. Moreover, each stage of the CBR cycle is automated by the system.

The framework proposed consists of an integrated set of components which are distributed and divided into smaller parts called agents. The complementary properties of CBR and agents technology can be advantageously combined to solve the ITS design, where any single technique fails to provide a satisfactory solution. Within this approach, the ITS-CBR functional architecture consists of the following components: (1) the student model generation layer, (2) the multi-agent case base reasoning layer and (3) the knowledge module and the delivery layer, which can all be seen in Figure 2.

3.1 Student Model Generation Layer

The student module models the knowledge that the student has about the domain he/she is trying to learn and how it evolves. The student module is composed of the student model and the diagnostic process. On the one hand, the student model describes the knowledge that the student has adquired in the domain to be learnt. Different types of techniques can be used: vectors, semantic networks, Bayesian networks, affirmation repositories, etc. On the other hand, the diagnostic process is in charge of updating the student model based on the current student model and the student performance during the learning process, according to diverse variables previously defined (problem evaluation, answers to questions, time spent in studying each explanation, etc.).

The student model has as many instances as students using the ITS. Each of these instances tracks the student during his/her use of the system. The student model can spread over several courses and cur-

ricula. It is initialized when the student takes his/her first course within the ITS. The most important attributes to be considered in the student model are:

- Knowledge Level: tutorial, topic and concept.
- Capacities: problems solved with right answers.
- Limitations: exercises where the student had problems.
- Attitudes: exercises solved using some kind of help.
- Learning path: The route through topics and concepts that the student follows in the learning process.

portant topics about the domain of interest that should be previously known are included. According to the students' performance on the preliminary test, the system assigns the student to a stereotype category concerning her/his knowledge level. At the end of the process, an initial student model (ISM) is obtained. In this model, each new student is regarded as a case and the students knowledge level is inferred taking into account his/her performance on the preliminary test.

In the ***Formal Case Representation Process*** the representation scheme is dependent on the case size and the complexity of the attributes which describe the case (Stage II in Figure 2). These attributes are

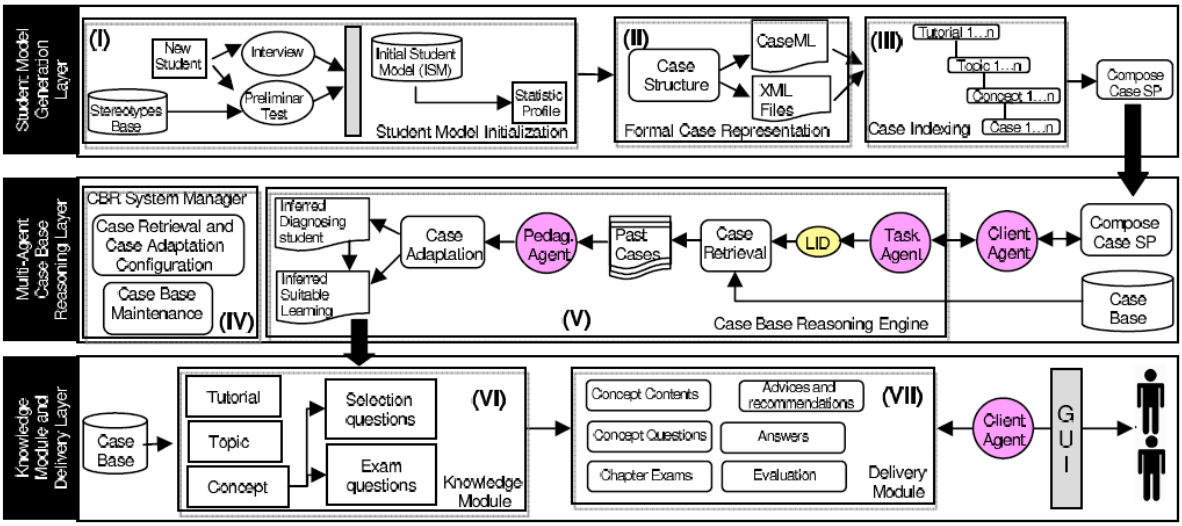


Fig. 2. Multi-agent CBR architecture

In ***Student Model Initialization Process*** the information about a new student is acquired by means of an interview and preliminary test (Stage I in Figure 2). At first, the student is interviewed about some personal data required to set an initial student model. The interview takes place the first time that a student interacts with the system. It contains questions related to personal and domain independent data, such as the student's name, age, etc. as well as several indirectly domain dependent characteristics. In order to assess the prior knowledge level of the student concerning the domain being taught and/or certain important prerequisite topics, the system uses a preliminary test. This test contains representative questions that cover the whole domain previously taught. In addition, im-

used as a basis for finding similar past teaching strategies of known cases. A case of the ITSCBR platform consists mainly of three parts: (1) the problem description, (2) the solution and (3) the relationship. The description part contains the values of the attribute describing the behaviors of the case, while the solution part contains the solutions. The relationship part describes the links among cases. Multiple cases can be use to represent a single problem.

Traditionally, there were several types of methods for representing cases: (a) textual approach, (b) attribute-value and, (c) structured representation. However, the textual approach needs a human interpreter. The attribute-value representation has no structural or relational information and fails to describe complex

objects. The structured representation as an objected oriented case requires approaches for similarity assessment that allow to compare two differently structured objects, which is quite difficult. Thus, we decided to use the Case Markup Language (CaseML) [3] a standard vocabulary for case description, which improves the issues above described and ensure the success of case interchange and distributed case-based reasoning. CaseML is conceptually built around an existing activity description framework: IMS Learning Design (which was in turn adapted from Educational Modeling Language developed by the Open University of the Netherlands) [12], [5]. The main elements of IMS Learning Design are essentially the same for CaseML and they appear in Figure 3. The related concepts are:

- Objectives: The intended outcomes of the case.
- Prerequisites: The starting conditions required to start the case.
- Triggers: The events or conditions that start and stop the activity.
- Actors: The individuals involved in the case (roles in IMSLD).
- Primary activities: The activities directly part of the case activity (such as diagnosis, or teaching strategy selection).
- Support activities: The activities that support the case activity.
- Environment/scenario: The context in which the case is conducted.
- Services: The tools required to conduct the case.

The classes in CaseML are: CaseBase, Case, Problem, Feature, Solution and SimilarityAssessment. The properties in CaseML are: hasProblem, hasSolution, hasDescription, hasSimilarityAssesment and hasAdaptation. Figure 4. depicts the classes and the properties mentioned. Details about them can be found in [3].

In *Hierarchical Case Indexing Process* the cases are divided into groups. In the highest level, there is a tutorial. In the second level, there are different topics that compose the course. In the next level, there are concepts, which are knowledge units of each topic. Finally, we find the cases themselves, grouped according to the concepts. Other elements included are: selection and exams questions. These elements are used to obtain information about level of knowledge acquired by the student in some parts of the tutorial. The hierarchical organization reduces the space of cases to be analyzed, as a result the system can focus on potential cases to be reused (Stage III in Figure 2).

Finally, the Compose Case Student Profile (SP) is obtained. It corresponds to the set of cases structured adequately for being matched in the next phase.

3.2 Multi-agent Case-Based Reasoning Layer

The MAS-CBR component provides the featured CBR techniques employed within ITS. The CBR System Manager (Stage IV in Figure 2) allows users to

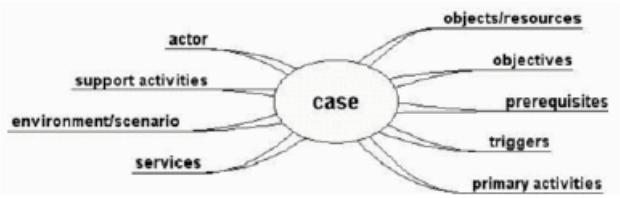


Fig. 3. CaseML Root Elements

configure the various case-retrieval and case-adaptation parameters incorporated in the *CBR engine* (Stage V in Figure 2): field-level weights, case-retrieval and thresholds.

The MAS-CBR has the steps of the case-based reasoning methodology. This is to say that the system goes in 4 cycles that are: Retrieval, Reuse, Revise and Retain.

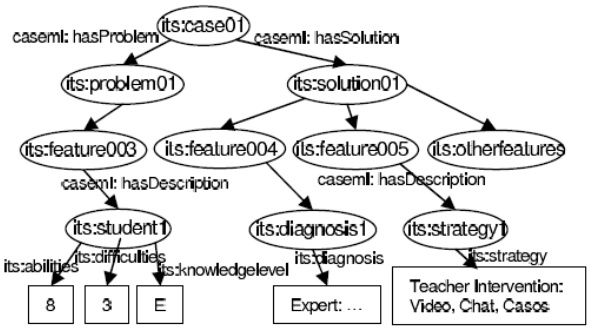


Fig. 4. CaseML Scheme

- *Retrieval Phase*: In this phase, the system searches for a similar solved case by comparing new cases with the existing case base. Once the Initial Student Model is obtained, the first task is the specification of the characteristics that will formulate the input space of the retrieval algorithm. The involvement of domain experts and human teachers is very important in this process, since they are the most appropiate source for providing such information. In this sense, we had selected attributes such capacities and students limitations. During the assessment,

the capacities attribute corresponds to a list of exercises that the student has solved correctly and the limitations attribute corresponds to a list of exercises that the student was not able to solve correctly. Figure 5 illustrates how an assessment is proposed.

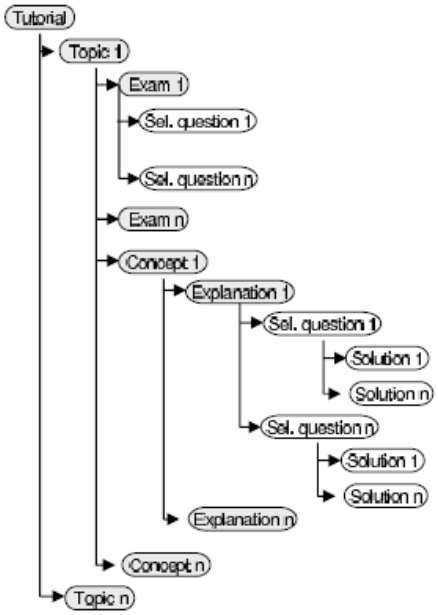
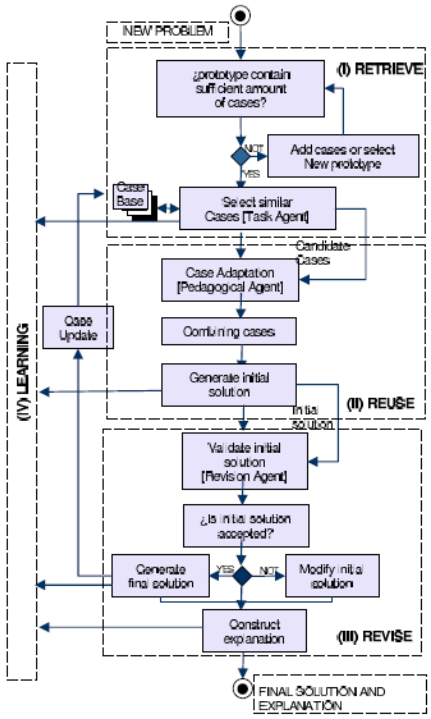


Fig. 5. Assesment Process

An assessment is composed of exam questions and selection questions. The exam questions are the questions contained within the topic exams. They consist of ”written” exercises that the student must solve and they will be evaluated and corrected by a teacher or an expert outside the system. The selection questions are contained among the textual contents of each concept. Their objective is to evaluate the knowledge obtained by a student on the concept as s/he examines the explanations. This type of question consists of a heading and a series of answers to choose from, of which one/s could be correct. The task agent performs the case retrieval process (Stage I in Figure 6.).

This agent executes the following tasks: (a) to receive candidate cases from case base, (b) to merge candidate cases and (c) to choose the best case(s). In the students' classification based on the initial student model, the ”Lazy Induction Descriptions (LID)” algorithm is used.

The main aim of LID is to determine which the more relevant features of the problem are and to search for cases sharing these relevant features



in the case base. The problem is classified when LID finds a set of relevant features shared by a subset of cases belonging all of them to the same solution class. Then, the problem is classified into that solution class. LID follows a top-down strategy to build a description D containing the most relevant features of the problem p so that all features in D are satisfied by a subset of cases in the case base CB. In general, cases in this subset belong to different solution classes. LID adds relevant features to D until the subset of cases satisfying D belong to one unique solution class. LID takes this class as the solution for the current student. In this phase the main attributes considered are the Learning Path and the Knowledge Level. The LID algorithm is described in Figure 7.

```
D := 0; C := {c1...cn}
Function LID (CB, p, D)
S_D := Discriminatory-set (D, CB)
 if ∀ c ∈ S_D ⇒ c_i ∈ C_i then return C
    else f_d := selected-feature (p, CB, C')
         D' := add-feature (f_d, D)
         LID (S_D, p, D')
 end-if
end-function
```

Fig. 6. The procedure of Case-based ITS Modeling

Fig. 7. LID Algorithm

The set of cases SD that are subsumed by the description D is called discriminatory set. A case C is subsumed by a description D when all the information contained in D is also contained in C. Initially, D is an empty description so it subsumes all the cases in CB (SD= CB). Consequently D has to be specialized.

The specialization of a description D is achieved by adding features to it. In particular, LID adds a feature f with the value v that this feature has in the current problem p. After that, the new description D' = D + (f=v) has a smaller discriminatory set SD0 formed by those cases subsumed by D'. Thus, specialization reduces the discriminatory set SD at each step. LID uses a heuristic measure based on the López de Mántaras distance (RLM) [15] to determine the feature to be added. LID specializes D by selecting one feature f from all the features used in p in the following way: each feature fi in p induces a partition Pi = Si1... Sing in the set SD so each Sik that belongs to Pi contains those students in SD having the same value vk in the feature fi. Intuitively, the RLM distance assesses how similar a partition is with regard to a referent partition in the sense that the fewer the distance the more similar they are.

- *Reuse of Adaptation Phase*: Once the similar cases are identified through the case retrieval phase; their corresponding solutions need to be adapted so that, a fine grained personalized solution is derived and expose to the active student. Generally speaking, the retrieved solutions require adaptations in order to be applied to the new problem. The adaptation process may be either as simple as the substitution of a component from the retrieved solution or as complex as a complete change of the solution structure. In MAS-CBR pedagogical agents use compositional adaptation [20] to reuse the solutions of the retrieved case(s) and to propose suitable solutions to the active student (Stage II in Figure 6.). The procedure for the adaptation is described as follows:
  1) Compute the similarity between a retrieved case and a new problem (np - new student). The similarity value was obtained using the LID algorithm described in the Retrieval Phase.
  2) For each similar case *Ci*, compute the normalized similarity (NS) between a retrieved case *Ci* and the new student over the set of retrieved cases (RC) as follows: For every student *np*:

$$Temp = \sum_{i=1}^{RC} 1 / Sim(np, C_i) \qquad (1)$$

$$NS(np, C_i) = 1 - (1/(Sim(np, C_i) * Temp)) \qquad (2)$$

  3) Determine the appropriateness degree of available solution components. Let *SolCi* be a component of a solution from a past case *Ci* and

$$AD_{np}^{SolC_i} \qquad (3)$$

be the appropriateness degree for *SolCi*, then, for every student np:
For i=1 to RC
If *SolCi* exists in the solution of the similar case *Ci* then:

$$AD_{np}^{SolC_i} = AD_{np}^{SolC_i} + NS(np, C_i) \qquad (4)$$

The appropriateness degree is calculated at a component level. If *SolCi* is greater that some predefined threshold value, then the component would appear in the final solution.
  4) After combining the components from multiple cases to form the final solution, the resulting new case is added to the case base.

With this adaptation method, global and attribute-level similarity are taking into account. This means that the new solution obtained is specific according to the student profile.

- *Revision Phase:* This phase has traditionally been one of the most difficult to automate in a CBR system [7]. In our work a ***revision agent*** (Stage III in Figure 6.) uses an evaluation system to perform this task. When a case solution generated by the adaptation phase is wrong, the revision agent is responsible of modifying the solution taken into account the available knowledge about the problem. This agent performs two tasks:
  1) It revises each step that the student follows in the learning process: this task is supported by a set of ***concept agents***. These agents evaluate the degree of knowledge attained by the student at the time of learning a concept. Besides, (a) it provides the student with the necessary explanations to learn the concepts, (b) it monitors the time devoted by the student to study the textual explanations of the concept; (c) it informs the student if the chosen answer or answers to a question are correct or not and supplies the correct answers if needed and (d) it finally provides the pedagogical agent with the value of the degree of knowledge ob-

tained by the student in the concept when it is requested.

2) *Repair the case solution using domain-specific knowledge:* This task involves detecting mistakes in the initial solution and retrieving or generating explanations for them. The agent uses the failure explanations to modify the solution in such a way that these faults do not occur again.

- *Retain Phase:* Once the ***revision agent*** ensures the correctness of the solution, the new case can be retained (Stage IV in Figure 6). Otherwise, if the agent detects irregular conditions, the case is not stored and a report is generated.

Finally, the ***Client Agent*** is responsible for the interaction with the user. It is able to understand the students requests and translate them to the other agents. This agent is the unique communication interface of the student and it has different tasks that are crucial for the correct operation of the whole system: (a) assisting the student on performing requests and compiling his profile, (b) deducing the students information needs by both communicating with him and observing his behavior, (c) translating the users request and selecting the agent(s) able to solve his problem(s) and (d) presenting and storing the retrieved data.

3.3 Knowledge Module and Delivery Layer

In the Intelligent Tutoring Systems field, the elements that represent the knowledge of the domain are included in this part, known as the expert module (Stage VI and VII in Figure 2). These elements are organized in a structure called ***curriculum structure.*** The elements that represent all the knowledge to be adquired by a student in a determined tutorial are stored in the system knowledge database. These elements are introduced into the system by an expert in the tutorial domain. Based on concepts of the domain knowledge for each tutorial, a division has been chosen to represent the curriculum structure, as efficiently as in systems like BITS [4] or SMODEL [26]. Thus, the student adquires knowledge of the domain at the same time as s/he adquires knowledge in each of the tutorial concepts. Hence, in the curriculum structure of the system the following elements can be distinguished:

- **Tutorial:** The tutorial element includes all the knowledge about a specific tutorial that can be found on a superior level.
- **Topics:** On the upper level, each tutorial is divided into a number of topics. Each topic contains several concepts associated with the information that is going to be taught and an exam that must be passed by the student.
- **Concepts:** The concepts correspond to knowledge units that must be learnt by the student throughout the tutorial. Each concept is made up of a series of textual contents that explain the information, which corresponds to the concept.
- **Selection questions:** Among the textual contents of each concept, a series of selection questions are inserted. Their objective is to evaluate the knowledge adquired by a student on the concept. This type of question consists of a heading and a series of answers to choose from. From them, one or more questions could be correct.
- **Exam questions:** These are the questions contained within the exam topics. They are exercises that the student must solve, which will be evaluated and corrected by a teacher or expert.

4 Designing the CBR Multi-agent System

The system application domain is Health Education, which includes medical training for different participants: medical doctors, nurses and the community in general. The system has been designed to provide rich learning environments to help in the improvement of the decision making process in Health Education. In order to do this, we have identified the main roles played by the system users, the sources of information they consult and the kinds of knowledge they have or require to perform their tasks.

4.1 Using INGENIAS to design the Multi-agent System

As was mention above, INGENIAS proposes a process in which the analysis starts focusing on the main structure of the system, the main agents, the roles they play and how they are organized. Then, the main goals and tasks of the agents are defined. The process continues with the identification of workflows and agents interactions and it goes on until the use cases of special situations are modelled. In this section, we have focused on the system architecture, the agents goals and tasks and how they interact with other agents in their environment (such as the user, resources or other applications).

1) Modeling System Architecture: The architecture of the system is based on the main elements involved in the learning process. From the analysis of these elements, five main agents were defined: client, task,

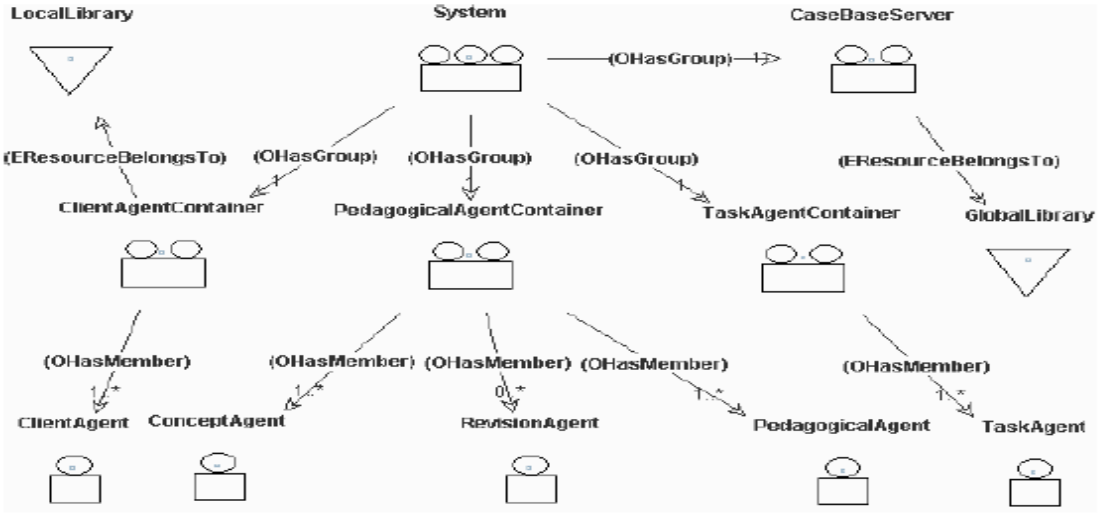
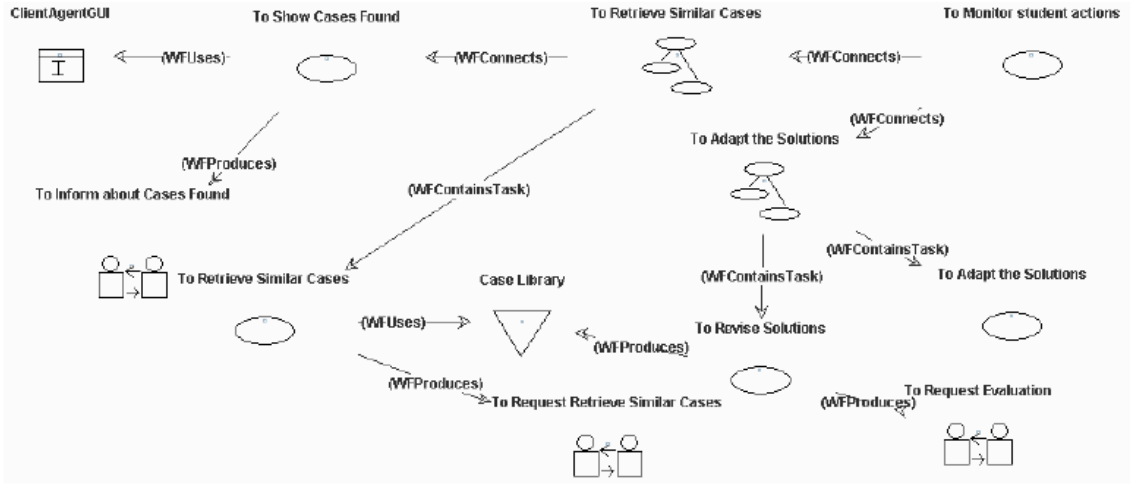


Fig. 8. Organizational Model that illustrates the system architecture



pedagogical, concept and revision agents. Figure 8 illustrates the organizational model that describes the system architecture. As can be seen, the agents are organized in three containers, client, pedagogical and task agent. This happens because the containers can be each one in a different machine. In the architecture there is also a case base server with a global library, where the knowledge base will reside and a local case library for each client agent container. The system uses this local library to store information about a student (profile and learning path) in its local machine that can be afterwards relevant to update its student model.

Fig. 9. Workflow diagram that illustrates the main activities and interactions in the system

2) Modeling Workflows and Agents Interactions: If a student starts a new session, the information in the local case library is extracted by the *client agent*. If the student selects a tutorial, an event is triggered and captured by the *client agent* and a new case is sent to the *task agent*. This agent obtains the students information as cases and starts the retrieval process in order to find cases similar to the new one. When the

search has finished, the *task agent* sends a message to the *pedagogical agent* informing it about the cases found. The *pedagogical agent* receives the information about similar cases and adapts the solution for the new case. That is, the *pedagogical agent* infers the state of knowledge of the student and selects among a set of teaching strategies, the most adequate according to the student profile. Figure 9 shows a workflow model of the systems interactions.

3) Modeling Agents Task and Goals: A very important step in multi-agent systems design is the identification of the goals that agents will follow and the tasks they must perform in order to complete those goals. In our system the main goal is to help the student in the accomplishment of his/her learning process. This goal is composed of other two; the first is to identify the students need and profile and the second is to provide the student with a personalized learning that can help to solve those needs. In order to fulfill these goals, four main tasks are defined: (a) to generate the student model, (b) to monitor the student activities, (c) to retrieve similar cases and (d) to adapt the solutions.

4.2 Implementation of the System

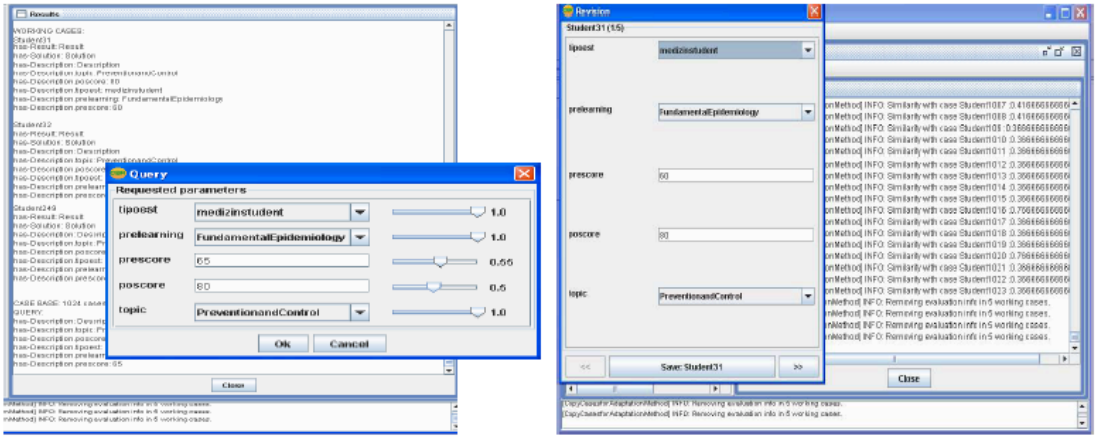
In order to evaluate the feasibility to implement the STIMTutor architecture, we have developed a prototype for training in Tuberculosis Infectious Diseases. The JColibri CBR framework [22] has been used to create our own CBR components. Figure 10(a) shows how the prototype presents information about similar cases found by the task agent during the retrieval process. In this example, the student decides to carry out a learning process in ”Prevention and Control” of Tuberculosis like Communicable Disease. When the student selects the tutorial, an event is triggered and captured by the client agent. This agent obtains information about the student. Then, the client agent communicates with the task agent in order to retrieve the most similar cases to the new student. Finally, the results obtained are revised and adapted in order to obtain new case suited to the student. Figure 10(b) shows revision and retain processes. The results obtained using CBR and MAS were important in STIM-Tutor in the following ways: (a) the evaluation of the student performance helped to decide when to give hints or answers if the student could not answer a question, (b) the student reply history allows the tutor to finish a dialogue and return to the original plan when the student could not continue along a causal link, (c) the category student answer, a part of the student reply history, is effective in helping to decide on different retry strategies. It recognizes near misses and other categories of answers that could be previously treated as totally incorrect, (d) the tutoring history prevented the tutor from giving the same hint repeatedly and (e) the teaching strategy was adequate according to the performance and the students profile. In this sense, an ITS developed under this approach incorporates a better understanding of the learning process and provides richer and more effective instructional experience to the students.

5 Conclusions

Intelligent tutoring systems have significant advantages over existing training methods. ITSs offer constant feedback and help aimed at efficiently bringing students to mastery. By constantly monitoring and maintaining a representation of how the student is progressing, the system can adapt to provide personalized training. Considering that the ITS design is a complex process, we have developed a framework which uses CBR and MAS technologies. The framework presented here was used to create STIM-Tutor, an ITS for training in Communicable Diseases in the Health Education domain.

The approach presented reconstructs the essential characteristics of cognitive tutoring systems and utilizes CBR as an approach to diagnosis the students knowledge, the adaptive generation of problems and the acquisition of new knowledge.

With CBR the designer can construct the desired



(a) Case Retrieval in STIM-Tutor (b) Case Revision and Retain in STIM-Tutor

Fig. 10. CBR Stages in STIM-Tutor

solution through solved cases and previous experience with students.

The use of agents to automate the CBR stages is also considered significant. In our approach, the multi-agent system distributes the case base and the CBR cycle among several agents. These agents support the formulation and the breakdown of problems and they help in the identification and retrieval of reusable cases. The modular architecture enables to reuse components and the efficient management of the case base.

Therefore, the main contributions of this article are: first a framework which use CBR for the ITS design, adapting learning contents and teaching methodologies to the student profile. Second, the use of multi-agent systems to automate the CBR cycle enabling modularity and component reuse. We also have adapted the algorithms used in the phases of the CBR cycle to be used by agents.

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Platform image processing to study the structural properties of retinal vessel

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KEYWORD

arterial stiffness;
cardiovascular disease;
AI algorithms;
pattern recognition,
image analysis;

ABSTRACT

This paper presents a technological platform specialized in assessing retinal vessel caliber and describing the relationship of the results obtained to cardiovascular risk. Retinal circulation is an area of active research by numerous groups, and there is general experimental agreement on the analysis of the patterns of the retinal blood vessels in the normal human retina. The development of automated tools designed to improve performance and decrease interobserver variability, therefore, appears necessary.

1 Introduction

The vascular system in the human retina is easily observed in its natural living state in the human retina by the use of a retinal camera. The retina is the only human location where blood vessels can be directly visualized non-invasively. The identification of landmark features such as the optic disc, fovea and the retinal vessels as reference co-ordinates is a prerequisite to systems being able to achieve more complex tasks that identify pathological entities. Reliable techniques exist for identifying these structures in retinal photographs. The most studied areas in this field can be classified into three groups [17]: (i) The detection of the fovea, usually chosen as the position of maximum correlation between a model template and the intensity image [15]. (ii) The location of the optic disc, which is important in retinal image analysis for vessel tracking, as a reference length for measuring distances in retinal images, and for identifying changes within the optic disc region due to disease. Techniques such as analysis of intensity pixels with a high grey-scale value [14][6] or principal component analysis (PCA) [15] are used for locating the disk. Other authors [13] use the Hough transform (a general technique for identifying the locations and orientations of certain types of shapes within a digital image [13]) to locate the optic disc. A ‘‘fuzzy convergence’’ algorithm is another technique used for this goal [7]. (iii) The segmentation of the vasculature form retinal images, that is, the representation of the blood vessels and their connections by segments or similar structures [2] [10] [16] [11] [7].

In this work is proposed a novel platform image processing to study the structural properties of vessels, arteries and veins that are observed with a red-free fundus camera in the normal human eye, and the fractal analysis of the branching trees of the vascular system. The platform, called Altair "Automatic image analyzer to assess retinal vessel caliber", employs analytical methods and AI (Artificial Intelligence) algorithms to detect retinal parameters of interest. The sequence of algorithms represents a new methodology to determine the properties of retinal veins and arteries. The platform uses the latest computer techniques both statistical and medical.

The next section presents the platform. Section 2 presents the most important characteristics of the platform, showing some of the relevant techniques and results. Finally, some conclusions and future work are presented in section 3.

2 Platform image processing

The platform facilitates the study of structural properties of vessels, arteries and veins that are observed with a red-free fundus camera in the normal human eye, and the fractal analysis of the branching trees of the vascular system. The main goal is to relate the level of cardiovascular risk in patients to everything that can be observed in the retinas. In this work we are interested in obtaining as much information as possible from the images obtained (Index Artery / Vein, Branching, Area occupied by the veins and arteries, Distribution of the capillary). Figure 1 shows an example of images taken directly from the fundus. The retinal vessels appear in a different color, with the optic disc and fovea.

Fig. 1. Retinograph image

The original image passes through each one of the modules (preprocessing, detection, segmentation and extraction of knowledge), which use different techniques and algorithms to obtain the desired image information.

Firstly, a phase called "digitization of the retina", in which the different parts of the eye image are identified. Here a data structure is created, which makes it possible to represent and process the retina without requiring the original image. This phase includes steps of preprocessing, detection and segmentation. Secondly, a phase of "measurements" in which we work with retinas that have been previously identified. This phase includes extraction of knowledge and manual correction, or expert knowledge, if necessary.

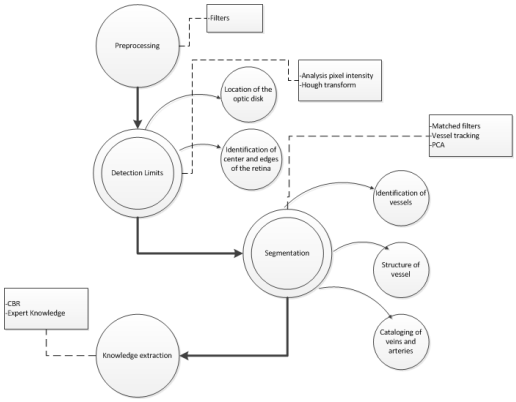

Fig. 2: Outline of the platform

The *preprocessing* step reduces noise, improves contrast, sharpens edges or corrects blurriness. Some of these actions can be carried out at the hardware level, which is to say with the features included with the camera. During the testing, retinography was performed using a Topcon TRC NW 200 nonmydriatic retinal camera (Topcon Europe B.C., Capelle a/d Ijssel, The Netherlands), obtaining nasal and temporal images centered on the disk (Figure 1). The nasal image with the centered disk is loaded into the platform software through the preprocessing module.

The *identification of the papilla* is important since it serves as the starting point for the detection and identification of the different blood vessels. This phase identifies the boundaries and the retinal papilla from a RGB image of the retina. The following values are returned: Cr is the center of the retina, which identifies the vector with coordinates x, y of the center of the retina. Cp is the center of the disc, which identifies the vector with the coordinates x, y of the center of the papilla. Rr, is the radius of the retina. Rp, is the radius of the papilla.

Fig. 3: Identification result in the detection phase.

C_r	C_p	R_r	R_p
1012,44 ; 774,13	**1035,98 ; 734,11** 1104,87 ; 562,52 915,38 ; 736,77 900,27 ; 658,74	**692,68**	**111,76** 108,92 122,15 101,95

Table 1. Sequence of output values in detection modules (pixel)

To carry out the identification of the limits, and in particular to the identification of the circumferences, it became necessary to carry out a process of image segmentation. Segmentation is the process that divides an image into regions or objects whose pixels have similar attributes. Each segmented region typically has a physical significance within the image. It is one of the most important processes in an automated vision system because allows to extract the objects from the image for subsequent description and recognition. Segmentation techniques can be grouped in three main groups: techniques based on the detection of edges or borders **¡Error! No se encuentra el origen de la referencia.**, thresholding techniques **¡Error! No se encuentra el origen de la referencia.** and techniques based on clustering of pixels **¡Error! No se encuentra el origen de la referencia.**. After analyzing the possibilities we chose one of the techniques of the first group that provided the best results. In this case using an optimization of the Hough transform **¡Error! No se encuentra el origen de la referencia.**. This technique is very robust against noise and the existence of gaps in the border of the object. It is used to detect different shapes in digital images. When applying the Hough transform to an image must first obtain a binary image of the pixels that form part of the limits of the object (applying edge detection). The aim of the Hough transform is found aligned points that may exist in the image to form a desired shape. For example, to identify a line points that satisfy the equation of the line: ($\varrho = x \cdot cos\ \theta + sen\ \theta$, in polar coordinate). In our case, we look for points that verify the equation of the circle:

- In polar coordinate system: $r^2 - 2sr \cdot cos(\theta - \alpha) + s^2 = c^2$, where (s, α) is the center and c the radius.
- In cartesian coordinate system: $(x-a)^2 + (y-b)^2=r^2$, where (a,b) is the center and r the radius.

For the algorithm is not computationally heavy, does not check all radios, or all possible centers, only the candidate values. The candidates centers are those defined in a near portion of the retina and the radius are in approximately one sixth the radius of the retina. To measure the approximate diameter of the retina, the algorithm calculates the average color of the image column: diameter of the retina is the length that has non-zero value (black).

Having identified the papilla (Figure 3) is a necessary step because it provides a starting point for other stages of segmentation and reference point for some typical measurements. Typically the correct result is the circumference of the higher value in the accumulator (over 70% of cases). In almost 100% of the cases, the correct identification is between the first 3 greatest accumulator values having.

The ultimate s in this step is to identify each blood vessel as a series of points that define the path of the vessel. Each of these points will be assigned a certain thickness. Moreover, it will be necessary to distinguish whether a particular blood vessel is a vein or an artery. AI algorithms responsible for identifying veins and arteries must perform a series of sweeps in search of "key points". Algorithms based on matched filters[2] [10] [16] [11], vessel tracking [19] and PCA [15], among others, are used for obtaining the proximity points between objects (veins, arteries, capillaries), the structures retinal structures or assemblies, branching patterns, etc. These algorithms work with transformations of the original image of the retina obtained from the previous step. Three steps are necessary within this module: (i) identification of vessels; (ii) definition of the structure of vessel; (iii) cataloging of veins and arteries.

2.1 Vessel identification

In this step the blood vessels are identified in the image by thresholding techniques. Its purpose is to remove pixels where no enters the structuring element, in this case the blood vessels. The image on the retina is blurred to keep an image similar to the background. This image is used as a threshold so that the pixels of the original image will be treated as vessels if its intensity reaches 90% of the background intensity. The image below represents the application of the-

se techniques in a row. The blue line represents the values of the pixels in the image; the red line, the background values; and the green line the point where there is a vessel:

Fig. 4. Thresholding techniques for the identification of vessels

In the figure it is possible to observe that on the left there is a very small vessel artery from below. In the middle is a fat vein and right three tiny vessels. Furthermore the edge of the retina is marked as a vessel although obviously not is. To decide where there is a vessel and where, it applies the following algorithm (Figure 7a). Where Original(x,y) is the pixel (x,y) of the original image and Background(x,y) is the pixel (x,y) of the background image.

2.2 Vessel Structure

This phase defines the tree forming blood vessels. Various techniques are used in conjunction with the following steps:

Step 1: Identification of connected components

- Dilate the binary image of the vessels (horizontally and vertically) to join possible discontinuities.
- Identify the connected component of the papilla. The remainder are discarded, will mostly noise points. Labeling.

Step 2: Morphological image processing.

- Choose corona of 10 pixels thick around the disc.
- Search regions in the corona. The center of gravity of each region found is taken as the starting point of a vessel.
- Choose another corona of 10 pixels around the former so that they overlap slightly.
- Search regions in the new corona. The center of gravity of each region corresponds to a found point of a vessel skeleton. If a region of this corona shares some pixel with the previous corona, join both points (nodes) with an edge.
- Repeat the above two points to cover the entire surface of the retina.

```
Step 3: Resolution of conflicts such as
vessel bifurcations or crossovers.
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Fig. 5: Pseudocode of the identification algorithm of the structure of the vessels

The following image shows the output of this phase. At the end of this stage the whole arterio-venous tree is stored in a structured way that not only allows to know if a vessel passes for a point or not, but it also is known through which passes each vessel, which is its parent, etc.

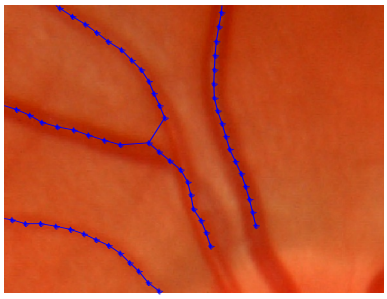

Fig. 6: Structure of the vessels

2.2 Veins and arteries catalogue

To detect whether a vessel is vein or artery, main branch is taken of the vessel. For every point (x, y) of the branch:

```
If (Original (x,y) < Background (x,y) *
threshold)
     Probable vein
If not
     Not vein
Threshold ~0.7
```

Figure 10: a) Pseudocode of the identification algorithm of veins.

In general, if most of the points of the main branch of the vessel (from 60%) are points classified as "probable vein", we conclude that this vessel is a vein, otherwise an artery. Currently, there are no publicly available databases that can be used to assess the performance of automatic detection algorithms on retinal images. In this work, we assessed the performance of our platform using retinal images acquired from Primary Care Research Unit La Alamedilla, SACYL, IBSAL, Salamanca, Spain . The images were obtained using a TopCon TRC-NW6S Non-Mydriatic Retinal Camera. Figure 7 show the testing performed using 10 retinal images. No difference was found between values in terms of age, sex, cardiovascular risk factors, or drug use. The first row of values is shown in the examples retina and previous figures in this paper. The figure shows:

- Area veins and arteries.
- Diameter of veins and arteries (D).
- Veins P (VP) = number of veins around the papilla.
- Veins A (VA)= number of veins that cross the corona outlined with radius=2*Rp. Rp is the radio of the papilla.
- Veins B (VB)= number of veins that cross the corona outlined with radius=3*Rp.
- Same values for arteries. And the ratios leaving the region around the papilla and out of the disc (which could serve as a reference of bifurcations that has been, though not in the manner in which they branch).

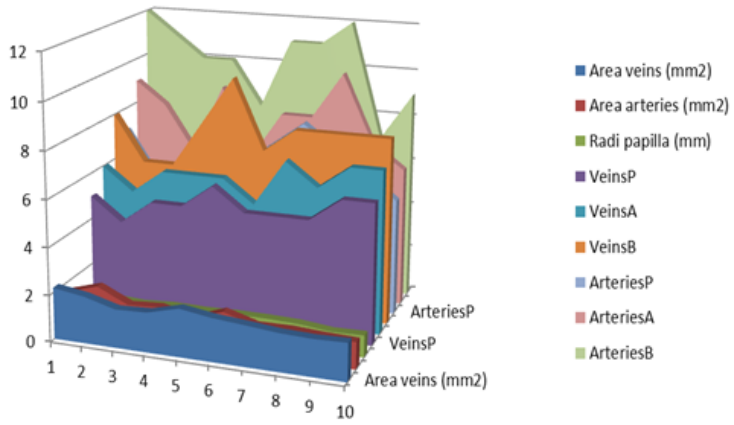

Fig. 7. Relations between the parameters obtained by the platform

It is possible to observe the measurement values of veins and arteries (thickness, area) are similar between different retinas (in this case not introduced any sick patient retinal image). Parameters like the veins in the papilla and AV index are the most fluctuating. Due to the lack of a common database and a reliable way to measure performance, it is difficult to compare our platform to those previously reported in the literature. Although some authors report algorithms and methods **¡Error! No se encuentra el origen de la referencia. ¡Error! No se encuentra el origen de la referencia. ¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.** with similar performance than our platform, these results may not be comparable, since these methods are testing separately and were assessed using different databases.

3 Conclusions and Future work

This platform will show a high intra-observer and inter-observer reliability with the possibility of expert corrections if necessary. Results of its validity analysis must be consistent with the findings from large studies conducted with regards to both cardiovascular risk estimation and evaluation of target organ damage. The results obtained during the use of the platform will be connected and used to extract additional information by using reasoning models such as case-based reasoning (CBR) [4][18]. Platforms such as Altair offer the potential to examine a large number of images with time and cost savings and offer more objective measurements than current observer-driven techniques. Advantages in a clinical context include the potential to perform large numbers of automated screening for conditions such as risk of hypertension, left ventricular hypertrophy, metabolic syndrome, stroke, and coronary artery disease, which in turn reduces the workload required from medical staff. As a future line of study in this point, the next step would be to analyze the significance of the measurements obtained with regard to their meaning in a medical context. That is, to describe the relationship of the results obtained to the risk of cardiovascular disease estimated with the Framingham or similar scale and markers of cardiovascular target organ damage. The platform is intended as a unified tool to link all the methods needed to automate all processes of measurement on the retinas. It uses the latest computer techniques both statistical and medical.

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