



# International Journal of Interactive Multimedia and **Artificial Intelligence**

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*I don't need to waste my time with  
a computer just because I am a computer scientist.*  
Edsger W. Dijkstra

**Special Issue on Experimental Simulations**

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## Challenges In Cloud Computing

### Automation

- How long to deploy an application?
- What version do I use?
- How do I upgrade applications?

### Portability

- How do I change providers?
- What is being used?
- How much does it cost?

### Auto-Scaling

- Can my application auto-scale?
- How do I configure auto-scaling?

### Disaster Recovery Planning

- Can my application tolerate faults?
- How do I recover my system?

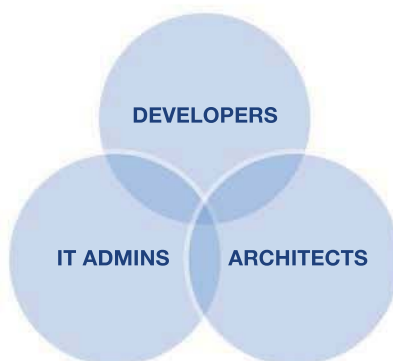
## ElasticBox Solution

### Automation

- ✓ Automatic Deployments
- ✓ Automatic Configuration
- ✓ Disaster Recovery

### Runtime Environment

- ✓ Application Scaling
- ✓ Fault Tolerance
- ✓ Resource Clean-up
- ✓ Replication



### Framework Design

- ✓ Architecture Policies
- ✓ Versioning
- ✓ Platform Management

### Infrastructure Control

- ✓ Cost Analysis
- ✓ Policy Management
- ✓ Traceability



# EDITOR'S NOTE

Editors Note, Jesús Soto Carrión and Elisa García Gordo

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## I. A NEW WAY TO SHARE PRACTICAL ARTIFICIAL INTELLIGENCE AND INTERACTIVE MULTIMEDIA KNOWLEDGE

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**T**HIS publication contains all research activities performed by students during 2007/2008 academical year. The editor's council has been reviewing and selecting several outstanding research contributions related with the following knowledge areas:

- **Medical diagnosis:** currently interactive multimedia and artificial intelligence techniques suggest the possibility to offer new approaches focused to discover and obtain high precision diagnosis, merging technical and medical knowledge. The experimental research works show the high-potential provided by software prototypes based on visual perception, fuzzy logic and bayesian theories.
- **Semantic metadata:** semantic web theories and formal languages has been growing during last years due to effort made by a high number of researchers. Besides, it is important to point out an special area “Semantic Metadata” with the main aim of provides several benefits on metadata management. Geographical Information Systems, Documental management systems among others can be better off by the use of ontologies (instead of natural language) as structural metadata formal knowledge. This section includes the most important contributions.
- **Nature conservancy:** we can help protect the world's most beautiful and diverse places developing technology that preserve threatened habitats around the world. Artificial intelligence, robotics and real-time monitors are essential tools used into our laboratory to build prototypes which seek how we can design and deploy real projects on demarcated environments.
- **Intelligence perception:** this section includes two big areas, intelligence indoor positioning systems and intelligence visual identify systems. Learning algorithms has been used to create adaptive positioning and identify systems.

This journal has been created with the aim of publish, share and bring together our experiences and work performed during one academical year. However we hope receive more contributions from IA and multimedia researchers, in order to open and extend future next issues of the journal. Finally, we would like to thank all unselfish contributions made by the members of editor's council:

Dr. Oscar San Juan (Oviedo University).  
 Ing. Gloria García (Pontifical University of Salamanca).  
 Dr. Juan Luis Chulilla.  
 Lca. Pilar Azagra Albericio.  
 Lca. Raquel Ureña Joyanes.

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## II. OPENLAB PROJECT

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OpenLab is an open laboratory of ideas and projects related to application development and research using artificial intelligence and interactive multimedia techniques. It has been created from new practical laboratory approach applied on artificial intelligent courseware.

The legacy education model focused on a teacher changes around the nature's education in the world of computer science. Research produces new theories that make it necessary adapting teaching to some more modern and useful concepts. The student doesn't learning the theory properly, specially in our night-shifts groups (worker-students). It isn't enough to go into the classroom and teaching about equations, reasoning and proofs in the last years of a degree. The student needs practical applications that allows solving in a more efficient way the real-life problems.

In certain cases it is not possible propose a set of practices with direct application on coursework, since it is necessary too much previous knowledge. However in artificial intelligence and cognitive sciences it is possible, given the wide range of existing tools and the student knowledge level.

The OpenLab project inspired by bologna process guidelines, attempts to launch a set of artificial intelligence projects every year. Each project is developed by a small team (3-5 members) with an specific technique: bayesian networks, fuzzy logic, neural networks. decision trees, among others. Due to time constraints, each team is specialized in a concrete field and exposes the results at the end of the year.

After three successful years we conclude, that group working combined with good personal tutor sessions allows obtain high-quality projects that can be reused each year. Thus if an student wishes to develop a game using XNA technology and some artificial intelligence technique (heuristic search, planning, etcetera) in following years another student will be able to use the project finished. We hope to continue improving our interactive multimedia and artificial intelligence laboratory in order that students can discover the practical application of artificial intelligence techniques.



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# Social maturity of WWW and AI feedback: opportunities for an additional human revolution

Dr. Juan Luis Chulilla and Lic. Pilar Azagra Albericio

In these days, Internet Adoption Curve in developed countries belongs to an interval between early majority and late majority. There is already a significant population profile which can be defined as 'digital natives', more or less isolated from their 'digital immigrants' thanks to the abyss defined by the decisive integration of Internet in digital natives' daily lives. This situation is actually significant if one takes in mind that digital persona of digital natives is much more than a mirror of, let's say, actual persona and both belongs to a new, multifaced entity still not well understood.

As Adoption Curve has progressed, the complete range of social software has been under a harsh darwinist pressure. The most important selection factor has been the social success of each social software via personal, colective and professional impact. Some social software has not resisted 'Net pace (i.e., gopher or archie); other types have achieved and maintained the status of killer application; finally, new types of social software has emerged in the last fifteen years. From blogs and their metareality (blogosphere/The Conversation), wikis and other collaborative spaces, to the last big social network, multidimensional products (Facebook, MySpace, etc.). Second life and another previous attempts (like VRML, X3D, etc.) have shown clearly that main ingredient of success is not cutting edge technologies (beyond the bare minimums for make things work, very close to commodities in these days), but uses and images that the users produces about each technology: what they can do with each kind of social software by themselves alone or in company of other peers. Twitter, del.icio.us or digg are just three examples choosen from a huge pool which proof that simple and clear interfaces are not obstacles toward success at all.

Social evolution of Internet, its way to its maturity after teen crisis (web 1.0), has carried with it specific successes utterly unforeseeables both because of their magnitude and potential. One of the most clear examples would be Wikipedia. A reference space generated freely (discharging maintenance costs), feeded by huge numbers of amateurs/microexperts and totally usable by any individual with connection to Internet. Beyond casuistics in Web 2.0, true essence of social impact of a social mature Internet would be the unending amount of ways in which knowledge, communication and activism can be shared and builded: all that can be done with and for other people. Digital citizen, both native or immigrant, can make use of possibilities of personal, professional and collective development that just weren't foreseen, beyond the direst dream of Science Fiction, wider and deeper than River World or Foundation. It is possible that, in fact, this circumstance has take part of science-fiction decadence.

A priori, there is no clear signs of a deceleration of the change pace. Indeed, since web 2.0 has gained popularity as a concept (more or less, half a year after O'Reilly conferences when term was conceived), there has been no interruption of announcement of new and then quickly popular new social software, with a significant public and media impact. However, there is a fact which is determining clearly the evolution of all the social software: information overload.

This net of human for humans, this eclectic set of services and documents has reached a point in its path in which Internet power users adapt themselves as good as they can to a quantity of information received at a pace without precedents at all. There are clearer and clearer signs of that there is no intelectual and even no biological tools for copying with that magnitudes of information. Search engines are just too good and efficient, and social software types are just too atractives for some population profiles.

The worst fact is not the human impossibility of overcome information overload, but the effects of that situation. The abused term of multitasking (applied to human beings) is coming with a serious price, the difficulty of maintain deep thought. Some of the benefits of social software are quickly evolving into created necessities, and this new condition contributes to explain the problem mentioned just before.

There is no way to assure if definition and transition to some web 3.0 compromise is an urgent needing or not. If finally Internet obtains a framework in which software tools (agents) can operate with information at its level, this would mean a decissive step forward.

This scenario could evolve into a state of continuous positive feedback. Until now, interaction between different social software has permitted an evolution which pace is only surpassed by its consequences. As I affirmed lines above, unavoidably out of control growth of possibilities of access to information has reach a state of use of Internet with clearly negative consequences in differents aspects of daily life and proffessional activity. If finally emerges a way of improve user's capability of cope with The Problem of information overload, it will have consequences both unforeseeable and deep: if the user can cope adequately with information overload and gains the possibility of access and operate with quantities of information even bigger, it would produce decissive effects both to individuals and communities.

If some part of natural intelligence is based in the capatibility of capture and work with information and produce new results as new information, an improved access to Internet information would improve the intellectual

capabilities of the population. If some of the ways than AI can offer for overcome information overload obtain certain success, abyss between digital native, digital immigrant and digital refugee would be a tiny step compared with the (nasty) future that waits for those who cannot obtain benefits from this developments.

This possible future is needing urgently solid analysis in order of potentiate the possitive benefits and minimize the negative ones. Social disadjustments can dwarf every other previous generational shock. Intellectual impact can reach an state of dystopia clearly comparable with "Logan's run" but without the imaginery of Carroussel: all those people that wouldn't be able to adapt and obtain the new condition of "augmented human being" would be too much close to be considered as living fossiles, parts of a past that still hasn't learned that future is here right now and for stay.

As a conclusion, interaction between AI technologies and the Web is close to be in a critical moment: every time is clearer that AI is needed for overcome web 2.0 information overload. However, if this combination obtain a remarkable success, it can produce deeper social effects (positives and negatives) by far compared with any other previous technologies, keeping in mind that they would affect the core of cognitive capabilities of human being. As digital divide of today can be just a tiny step compared with the abysm derived from AI success, I do believe that reflection and analysis of it is an urgent necessity, specially if it reach the sphere of public debate. Maybe this time we will be able of maintain Pandora's box closed.

# ADT-3D Tumor Detection Assistant in 3D

Jaime García Castellot, and Jaime Lazcano Bello

**Abstract** — The present document describes ADT-3D (Three-Dimensional Tumor Detector Assistant), a prototype application developed to assist doctors diagnose, detect and locate tumors in the brain by using CT scan. The reader may find on this document an introduction to tumor detection; ADT-3D main goals; development details; description of the product; motivation for its development; result's study; and areas of applicability.

**Key Words** — ADT-3D, Brain tumor, CT Scan, image processing, Jaimes' algorithm, Kmeans, Matlab, segmentation, tumor, Visual Intelligence.

## I. INTRODUCTION

### A. A piece of history on Computerized Tomography

According to *Tomografia Computerizada* [1] on October 1<sup>st</sup>, 1971 the first brain scan was performed in a London hospital. From then on, there has been a quick development on the field. In 1973, the EMI Scanners, developed by Electrical Musical Instruments Co. headed by Hounsfield, expanded rapidly to the US and Europe. After which the brain scan adopted different names such as CT Scanner (Computerized Tomography) by Anglo-Saxons, TDM (Tomodensitometry) or CAT Scan (Computerized axial tomography); all of which were also known as X-ray scanners.

Since Hounsfield begun the investigations, there have been many changes on the discipline. The improvements try to shorten the swap time and refine the image quality. Xavier Vila [2], on its website, explains quickly, easily, and visually the evolution of those changes. X. Vila states that there are four different machinery ages.

At the early stages on tomography there was only one detector, which rotated opposite to the X-ray tube, which is how tomography was reached. Then, these machines were upgraded to decrease rotation times and maximize the angle of rotation from 180 degrees up to 360 degree.

### B. Computerized Tomography

The CT technology was developed in order to carry out head studies, but previous advances made possible the study of the whole body. Nowadays, the CT can be used for any region of the body.

The CT core are X-rays<sup>1</sup>. The main difference is how they are used. For CT Scans the X-rays are applied over small body slices. Therefore, instead of a body projection, CT obtains a full resolution slice. Many manufactures have

developed different CT machines, building up the different generations, from the first to the very last fourth scanner generation. Generations differ from each others on the tube-detector system. The most use CT scan generation is the 3<sup>rd</sup> which is illustrated on the following picture.

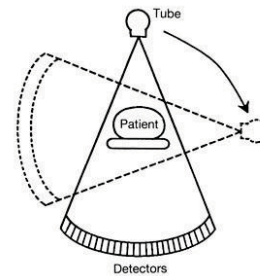


Fig 1. "Schematic drawing of tube-detector system of 3rd generation CT scanner. The X-ray tube emits a sharply collimated fan beam of X-rays which passes the patient and reaches an array of detectors. Tube and detector array rotate together around the patient; one exposure often comprises 360° rotation." [3]

The X-rays are emitted from the scanner as thin telescopic fan shaped beam, making a regular angle with the patient long side. The distance between the patient and the tube must match with the fan projection. The thickness of the fan could be selected creating thicker or thinner slices, from one to ten mm.

Each slice is divided into a constant number of volumes, so-called voxels (Figure 2). Each single voxel value is obtained by combining the values of several projections. Each projection is done rotating the tube around the patient, for each rotation the values are received by the array of detectors which are on the opposite side the tube (Figure 1). When the voxel is represented as a two-dimensional image, it becomes a pixel. The pixel value, position, and size represent the whole voxel data. As an image, the value will be a represented in the grey scale, depending on the selected brightness. The higher the attenuating voxel the less quantity of rays have crossed through it, e.g. bone, which are brighter in the grey scale, closer to white. On the other hand, the less dense tissue, which more amount of X-rays cross through, the darker the voxel representation is.

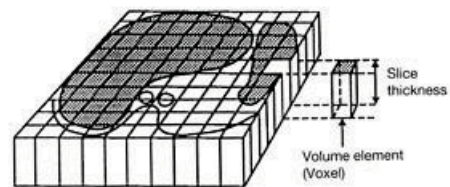


Fig 2. "The imaged slice of tissue divided into volume elements, voxels. The attenuation in each voxel determines the brightness (shade of grey) of the corresponding pixel in the final two-dimensional image." [3]

The relationship of bones as white and air as black voxels is obtained from the Hounsfield Scale. The Scale links each voxel value with a grey shade scale. The default numbers are -1,000 to represent air, 0 for water, and +3,000 for dense

<sup>1</sup> X-rays: The oldest and best known of the medical imaging techniques. X-rays, discovered by Röntgen more than 100 years ago, are high energy radiation produced in a special type of lamp called an X-ray tube. X-rays are also a form of electromagnetic radiation, but with a much shorter wavelength and a higher frequency than visible light. [4]

elements, such as bones. The brain tissues average is between 60 and 120. The unit uses is called HU, Hounsfield Unit. In fact, each manufacturer use its own scale but always referred to Hounsfield Scale, see the picture below.

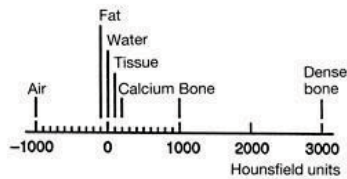


Fig 3. "Scale of Hounsfield units (HU). The approximate scale locations of different substances are indicated. (By "tissue" is meant most fat-deficient soft tissues and parenchymal organs.) Reference points: -1,000 HU for air, 0 HU for water." [3]

CT scan resolution is far greater than older radiography techniques, but moreover, the spatial resolution is lower. The voxels thickness is as large as the slice. If the scanning set-up asks for a normal study of the patient, the number of slices to determinate the patient's head will be lower than forty. If the head is represented using computer programs there will be many gaps between slices. The empty gaps are fill by using the average value among the surrounding voxels. The process is called interpolation, the added gaps are in fact not real data. This is called the spatial loss of CT scannig. This spatial loss could be resolved using thinner and more slices. Consequently, longer CT examinations will be needed.

A thin slice resolves the spatial loss, but also requires higher amount of radiation to obtain a usable slice. The process of thinner slices will multiply the radiation levels.

In CT scanning is crucial the relationship between quality, time, radiation, and area covered.

### C. Technological approach

Nowadays, the contribution of technology to any field is fundamental but especially indispensable on medicine. It is clear the close relationship between medicine and technology since the manipulation of high complex medical equipments is part of the technological progress made up to date.

A vertiginous advance on science has characterized last fifty years, causing all technologies to advance rapidly. For those whose professions involve the utilization of the technologies, it's being difficult to stay on top of the rapid changes. Technological developments have positively altered medicine, since it has enabled the better comprehension of the multiple processes, which explain the symptoms of several illnesses. Therefore, it has help on the understanding of many symptoms and repercussions on the human body.

A classic classification of medical technologies could be: diagnosis, preventive, therapy, rehabilitation, and management.

### D. Medical approach

A brain tumor is "a benign or malignant growth in the brain. Primary brain tumors arise in brain tissue. Secondary brain tumors are cancers that have spread to the brain tissue (metastasized) from elsewhere in the body. Brain tumors can and do occur at any age" [5].

A brain tumor is still very difficult to diagnose. According to the University of California, San Francisco [6], the doctor would first ask about family medical history and perform a complete physical examination. Then, depending on the results obtained, it may be possible that the doctor request a CT scan, MRI, Brain Scan or other test. Unfortunately, neither CT Scan nor MRI provides complete accurate data about the presence of a tumor.

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## II. MAIN GOAL

---

By utilizing the group of slices obtained from a CT Scan of the head, the ADT-3D is able to recognize a brain tumor. To perform this task it will be necessary to generate a 3D representation of the sections or slices. Once the three-dimensional image has been generated the ADT-3D will proceed to study the different regions using Artificial Intelligence Vision methods and algorithms such as Kmeans and Jaimes' segmentation algorithms.

The result of all these processes should help to differentiate visually the tumor from the rest of the brain mass. The visual differentiation would make it easier to study the properties of tumors.

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## III. DEVELOPMENT DETAILS

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### A. Functionality

The main goal of ADT-3D is to assist doctors during the brain tumor detection and the possible diagnosis on patients who undergo the CT Scan. ADT-3D fulfils the 3D analysis of the possible tumors. The utilization of these three-dimensional images enables tumor location on XYZ axis for their later examination.

### B. Development tools

#### 1) MATLAB R2007b

MATLAB is a development environment based on MATLAB language. "MATLAB® is a high-level language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++, and Fortran." [7]. This language can be used in many different fields such as signal or image processing; communications; test and measurement, as well as other scientific fields of investigation.

On this development environment it is possible to manage code, files, and data. It includes many functions for statistics, optimization, and numeric data integration and filtering. There are also great amounts of functions that facilitate the manipulation of bi-dimensional, and three-dimensional images.

#### 2) MATLAB Newsgroup [8]

Software developers may have to face problems to which are not able to find a solution. The *MATLAB Newsgroups* is a website tool offered by Mathworks. It allows software developers to have a common point of contact to solve programming problems. The *Newsgroup* has an extensive database with hundreds of conversations, about the programming language, concerning troubleshooting.



### C.Data Manipulation

ADT-3D data input consist on a variable number of DICOM images, which represent the brain mass in consecutive slices. An example of this is shown on Figure 4. The utilization of such technique on CT Scans allows first, to store data about the patient's head. Secondly, to manage a 3D body in a group of slices.

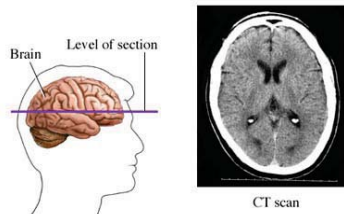


Fig 4. The figure represents one of the DICOM images that form the data input of ADT-3D.

Then, each single image on the group of input images is transform into a bi-dimensional matrix. The next step is to create a three-dimensional matrix out of the group of 2D matrixes. The created volume matrix is used for holding the patient's data, which is used as the numeric input to ADT-3D.

The process of transformation from image into numeric values is done through `dicomread()`, a function provided by MATLAB environment. As long as the input argument of the function is a DICOM image, then the output argument will be an square matrix containing the voxel values. An example of this transformation is seen on Figure 5.

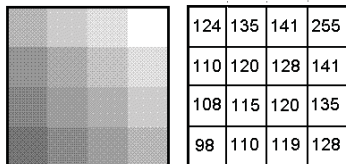


Fig 5. It shows the numeric values corresponding to the given image when MATLAB's `dicomread()` is used.

During the process of converting images into figures, each bi-dimensional matrix is added to a three-dimensional matrix. The size of its third dimension will be equal to the number of images conforming the brain scan. The outcome it's a 3D matrix, containing all data acquired during the CT Scan, becoming the initial unit of work.

### D.Segmentation

The segmentation is a computer technique “*in computer vision in which an image is divided into regions*” [9]. Also defined as: “*the act of dividing or partitioning; separation by the creation of a boundary that divides or keeps apart*” [10]. What about image segmentation? If the term segmentation is applied to the word image, tImage Segmentation is the act of dividing or partinioning an image into regions defined by the creation of a threshold.

There are many different segmentation algorithms, each one uses different characteristics from the studied object. There are four common approaches used with intensity images (e.g. Dicom images which use voxel values). The

four approaches are: threshold techniques, edge-based methods, region-based techniques, and connectivity-preserving relaxation methods.

ADT-3D uses Jaimes' algorithm for segmentation. The algorithm is explain in more detail below. Jaimes' algorithm uses Kmeans algorithm as part of the process, but since Kmeans does not divide the data with the needed accuracy, it applies other filters.

### E.Jaimes' Algorithm

#### 1)Differentiate a tumor from brain mass

The main goal of ADT-3D is the identification of brain tumors. How could it be done? The answer is on the segmentation of the image. Image segmentation, as part of Visual Intelligence, is responsible for discrimination on different pictures. DICOM's protocols differentiate tumors from other brain masses by using the Hounsfield Unit Scale. Based on Hounsfield Unit Scale, tumors score diverse values than the rest of brain mass.

#### 2)Kmeans

Kmeans algorithm divides any image into k number of different classes. The k value can be determinate by using other algorithms such as Chain-Map or Max-Min over the image. Kmeans algorithm, applied to a DICOM data collection, allows a maximum k value of five. It denotes that Kmeans will give five different centroids, and each pixel matrix will be related to one of these centroids. Unfortunately, a classification using only five types of classes is not enough to differentiate tumors from other brain masses.

#### 3)Variables

**Mdata:** It is a three-dimensional matrix that contains the input data for both Kmeans segmentations.

**Mclasses:** Is the result of the application of Kmeans to Mdata.

**Mresult:** The output data of the application of Jaimes' algorithm is stored in this 3-D matrix.

#### 4)Iteration 1

Mdata is the input information to Jaimes' algorithm, a matrix containing the original numbers. Kmeans allows us to classify raw data contained in Mdata based on a scale from 1 to k elements. As it was stated above k value is equal to 5.

The following figure is an example of this step:

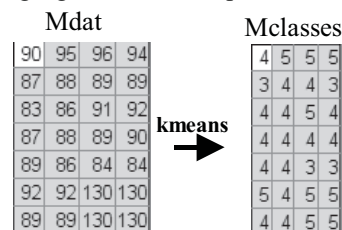


Fig 6. The first table represents the data input values, where the four bottom-right hand corner values represent a simulated brain tumor. Unfortunately, the estimated outcome should be such that only those four values should have a value of five. Moreover, there are other extra 5's not related to a brain tumor. Thus, the idea is to improve this first segmentation.

The application of Kmeans is executed using the following code.

```

For nc=1:60
X = Mdata(:, :, nc);
k = 5;
[idx, partialClasses] = kmeans(X,k);
Mclasses(:, :, nc)= partialClasses;
End

```

Fig 7. Kmeans brings forward two values: idx and PartialClasses. The former contains centroid values and the latter saves the data related to each element's classification.

### 5)The Adjustment

The previous step has achieved a decent approximation. Nevertheless, it has confused certain brain masses also as tumors. How could be possible to isolate the tumor? The exponential function solves this problem by applying the  $f(x) = x^2$  function for each matrix pixel:

$\forall x_1 \in R$  Example:  
 $\forall x_2 \in R$   $x_1 = 92$   
 $f(x) = x^2$   $x_2 = 130$   
 $\Delta(x_1, x_2) \in \Delta(f(x_1), f(x_2))$   $\Delta_1(92, 130) = 38$   
 $\Delta_2(f(92), f(130)) = \Delta(8464, 16900) = 8436$

Fig 8. Two different numbers from the same class could be distanced by using the exponential function  $f$

The distance between numbers will be increase if the  $f$  function is applied. It does not matter if the element belongs to the same class. Once the function is applied, it is also multiplied by the Mclasses number k. In this way, a hypothetical second iteration will distinguish tumors from brain mass values. The following function represents how the adjustment is done for a selected group of data.

Mdata	Mclasses	Mresult
90 95 96 94	4 5 5 5	32400 45125 46080 44180
87 88 89 89	3 4 4 3	22707 30976 31684 23763
83 86 91 92	4 4 5 4	27556 29584 41405 33856
87 88 89 90	4 4 4 4	30276 30976 31684 32400
89 86 84 84	4 4 3 3	31684 29584 21168 21168
92 92 130 130	5 4 5 5	42320 33856 65535 65535
89 89 130 130	4 4 5 5	31684 31684 65535 65535

$$Mclass = kmeans(Mdata) \quad Mresult = (Mdata.)^2 \circ Mclass.$$

Fig 9. The Adjustment function is applied to Mdata after the First Iteration. Is easy to appreciate how the tumor pixels have grown more than the brain mass data pixels.

The Adjustment process is done by using the following MATLAB code.

```

Mresult=Mclasses;
dim = size(Mclasses)
for i=1:dim(3)
    for j=1: dim(2)
        for k=1: dim(1)
            Mresult(k,j,i)=
                Mdata(k,j,i)*Mclasses(k,j,i)*Mdata(k,j,i);
        end
    end
end
end

```

Fig 10. The Mresult matrix is the weighting output. Mresult will be used on the second Iteration.

### 6)Iteration II

Once the adjustment is done, the second Kmeans Iteration may proceed. As well as on the first Iteration, the number of

centroids and classes will be five. The difference between iterations is that class five is reserved for high tumor probability pixels. The picture below shows how the second Iteration leads the tumor to the fifth class.

Mresult	Mclasses
32400 45125 46080 44180	3 4 4 4
22707 30976 31684 23763	2 3 3 3
27556 29584 41405 33856	2 2 4 3
30276 30976 31684 32400	3 3 3 3
31684 29584 21168 21168	3 2 2 2
42320 33856 65535 65535	4 3 5 5
31684 31684 65535 65535	3 3 5 5

$Mclass = kmeans(Mresult)$

Fig 11. As well as the First Iteration, the Second Iteration returns a new Mclasses matrix. Now the accuracy is higher. Anyway, it is needed the last step to assure a precise result.

### 7)Smooth

The last algorithm's step has a crucial effect on the final results. Sometimes, depending on the working slice, other non-tumor related five class pixels could be detected. For sure, a tumor is a non-stoppable growing amount of cells. When smooth is applied to a group of pixels the result is that those isolated pixels loose importance. The smooth process is done over the Mclasses matrix. The objective is to penalize the spread pixels. It is done by giving more importance to the grouped fifth class pixels. Thus, the final matrix solution will increase the five class pixel groups using float numbers from 1 to 10. The smooth comparing data will be five. The higher concentration of fives that are closer to each other, the higher possibility for that value to reach 10. The process will produce a final matrix like the following one.

Mclasses	Mresult
3 4 4 4	4.3450 4.7870 4.5670 4.4210
2 3 3 3	3.8760 4.2980 4.2310 3.0120
2 2 4 3	4.0789 4.0530 4.6740 4.1230
3 3 3 3	4.0023 4.0789 4.2980 4.7300
3 2 2 2	4.2300 4.6000 3.5676 3.7680
4 3 5 5	5.4300 5.2000 7.4530 8.5650
3 3 5 5	5.7823 5.8670 8.3400 9

Fig 12. The final matrix is finally obtained. It could be appreciated how the tumor has been finally found out. The tumor related pixels values are clearly distant from the brain mass pixels.

The following matlab code represents how the smooth is implemented:

```

%Create the Mresult matrix
Mresult = Mclasses;
%patch smoothing factor
rfactor = 0.125;
%isosurface size adjustment
level = .8;
%useful string constants
c2 = 'facecolor';
c1 = 'edgecolor';
p=patch(isosurface(smooth3(Mresult ==5), level));
reducepatch(p, rfactor)
set(p, c2, 0.8*[1,0.5,0.5], c1, 'none');

```

Fig 13. The smooth is applied for the pixel value of 5. The reducepatch function with a rfactor lower than one perseveres the shape of the smoothed zone. The set line configures the output representation. The result is shown on Figure 3.

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#### IV.ADT-3D COURSE OF ACTIONS

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Thanks to the user interface, it is possible to monitorize each step on the process of tumor detection, recognition and isolation. The first step is *Image load*, which reads dicom images from the hard drive and transforms them into a three-dimensional image. The second step is *brain mass isolation* consisting on two subprocesses such as noise reduction and bone exclusion. Third, it is *Tumor simulation*, due to the difficulty of finding head CT scans with tumors on them. The simulation, as explained later on, consists on the generation of a head tumor. The following step, *Segmentation*, is the most important since it divides the studied data (or head) into different classes for later envision and study. The next step is *Class Visualization* allowing the 3D visualization of the different classes obtained from the segmentation. Later on is *Class Plotting*; this step is used to display on a bi-dimensional image all the different classes resulting of the segmentation. Finally, it is *Tumor Visualization*, which is used to visualize the detected tumors isolated from the rest of brain mass. Two possible visualizations are offered to the user: a group of bi-dimensional images that represents the diverse slices of the detected tumors; and a three-dimensional representation of those tumors.

##### A.Constant Functions

Here can be found the different functions, which are present during the running time of the program. They can be executed at any given time to obtain the desired result. These results are display graphically, so the user of the system can acquire a better knowledge of them. The quantity of feedback given to users is vital. It simplifies the diagnosis process.

##### 1)3D Visualization

The function's name is self-explanatory. Provided that the user of the system has executed correctly the step in which this function is attached; then, the outcome will be a three-dimensional representation of the results obtained. Nevertheless, this process takes more time than users might expect, due to the fact that the process of transformation from a three-dimensional matrix into a 3-D representation requires reading each single item on the matrix. Moreover, since usually the dimensions of a matrix are 256x256x60, it results on a composition of almost four million elements.

MATLAB handles the representation of any volumetric data, but in order to perform a proper representation it requires the programmer to establish certain information related to color map, axis aspect, and other elements.

Once the user has the 3D illustration of the results, the view can easily be rotated; amplified or reduce its scale; and even change the color map. Automatically all these functionalities are included by MATLAB. An example of this type of representation can be seen on Figure 14.

##### 2)Video Visualization

Is a function that makes possible a dynamic bi-dimensional visualization of three-dimensional matrixes. The process is simple and requires fewer time compared to the 3D visualization function. In order to decide how the data is going to be sliced, the function's data input has to be

a three-dimensional matrix. The decision is done by sizing the matrix and by selecting the smallest dimension. The next step is to show the first 2D slices on the stack, then a counter is set up to count a number of milliseconds. Once this is done then the second 2D slice is shown and so on. The final output is a dynamic movie simulation, which exhibits correlating images.

Since this functionality is directly perform by `implay()`, a MATLAB function. It is not strange to assume that color map, velocity, and other aspects of the movie could be easily changed.

##### 3)Image Closure

The main purpose of this function is to close all other open images but the interface, which is also considered a figure. Some processes, such as 2D visualization of tumors, can generate too many figures. Deleting the images one-by-one could be boring and time-consuming for the user. Thus, *Image closure* is provided to close all open images except the user interface, making it fast and easy.

On the one hand, some users might find this function unnecessary and useless. On the other hand, its users would surely benefit from its features.

##### B.Image Load

If *Image Load* is not the first procedure ever to be executed on the system, then any other action would have no reaction. The reason for this is that this process is in charge of reading the data input images. As stated above, Dicom images have to be store in the computer or in a server and they have to be reachable by this procedure.

It is not required that the input images enclose a common string name including an identification number (e.g "ImageName"+num+".FileExtention"). However, the use of a common string name would facilitate loading images into the system, at least to the programmer. In any case this would affect on response times from this process, but it would help, on one hand, the organization of images belonging to the same patient, and on the other hand, the programming code used to read and load the images. This way, it could be a more autometized and simpler process.

##### C.Brain Mass Isolation

The intention of this process is to isolate brain mass from the rest. Now that images have been loaded into a matrix, it is possible to get rid of all those parts that are not needed to detect a brain tumor. The process is done in two steps: first, *Noise Reduction* and second *Bone Exclusion*. Both procedures will be explained below with plenty details.

##### 1)Noise Reduction

The apparition of noise on images is usually unwanted and random, causing a variation of values in the image's pixels. It can be originated, for example, on electronic devices such as radios, sensor devices (e.g. cameras). Unfortunately, CT Scans are not an exception to the apparition of noise. The problem of noise reduction was deeply studied by Hanson [11]. He differentiates three different types of noises: random, artifactual and structural. He also classifies random noise into statical, electronic and roundoff noise.

In relation, noise reduction was applied in two different



steps. First, the voxel values lower than twenty are assigned a zero. A study of voxel values were done to check that those values under twenty could be easily erase without the loss of information. The second step is to delimitate brain mass boundaries meaning that those values over the skull and under the patients' jaw are equalize to zero. This would prevent those values to interfere on the system.

#### 2) Bone Exclusion

The second step on *Brain Mass Isolation* is in charge of minimizing bone tissue. The brain's surrounding bone complicates the process of tumor detection, recognition, and isolation; therefore, it has to be minimized as much as possible.

An extensive bone tissue values should be completed to perform appropriately the bone exclusion. Such study includes bone original Voxel values and the calculation of the bone mass average. Then, the average bone values are used to check that no other brain mass might be also affected.

In the end, bone tissue is excluded from the CT Scan three-dimensional matrix. If the matrix is now delineated either onto two or three dimensions, the representation would show the brain.

#### D. Tumor Simulation

As hard as it is to find a digital CT Scan example, getting one with a tumor is even more difficult. For this reason, tumors on ADT-3D have to be simulated. Simulating brain tumors is not an easy task owing to the fact that they are supposed to seem real, at least to the system. ADT-3D is tested based on its capability to recognize brain tumors, meaning that the most desirable features are accuracy and effectiveness.

The tumors are simulated based on voxel density values. Brain tissues were found to be between 60 and 120, raising the question of which value had to be used. Various alternatives such as above, below, and inside the stated limits. The final decision was to simulate three different brain tumors. The main characteristics for all three is dissimilarity from each other. It can be accomplish by using dispare voxel values, location, and size. Such specifications intend to test the system to its maximum capacity.

#### E. Segmentation

The segmentation algorithm used on ADT-3D is called *Jaimes*. This algorithm is explained on further details on section *Jaimes' Algorithm*, included on *Development Details*. This algorithm provides a better differentiation of the original input data and thus a better segmentation is achieved. Based on Kmeans segmentation algorithm classifies the input data into five different classes. On the fifth class is where detected tumors can be found.

*Segmentation* is the most time-consuming process due to the fact that almost twelve million digits are used (three element's iteration for each item on a three dimensional matrix of 256x256x60). It supplies information to *Class K Visualization*, *Class Plotting*, and *Tumor Visualization*.

#### F. Class K Visualization

There is a simple but tedious requisite demanded by this function. The requisite is the correct execution of *Segmentation*. By using this function it is possible to represent, in a three dimensional environment, the specified K class given as an input value.

The data input is *Segmentation's* data output, thus only a matrix is given. In order to represent one of the classes contained on the matrix all values different to K are equalized to zero for the representation, but then the values are restored. Otherwise, it could only be possible to delineate the first class.

#### G. Class Plotting

*Segmentation's* output matrix is used as input data, thus *Class Plotting* uses the same matrix than *Class K Visualization*. In this case the intention is to visualize a determined matrix slice on a two dimensional draft. The difference with Class K Visualization relays on the fact that now all the different classes are shown on a 2D picture.

Class Plotting introduces the idea of individual segment visualization. Such technique increases the feedback given to the user of the system. As said before, is better to have an informed user than an ignorant one.

#### H. Tumor Visualization

*Segmentation* supplies *Tumor Visualization* the necessary information to envision tumors. Recalling Jaimes' algorithm outcome is a three-dimensional matrix containing the belonging of each element to a K class, on a range of 1 to 5. It is possible to say that tumors are localized on the fifth class. Tumor detection, diagnosis, and recognition are done on *Segmentation*. It is time to picture the result to the user, usually a doctor, who would have the last word on this matter. ADT-3D assist the process of detection, and under that circumstance, offers the detailed information achieved.

##### 1) Tumor's 3D Visualization

*Tumor's 3D Visualization* function is only in charge for the 3D representation of the detected tumors. The only difference with *3D Visualization* is the data input.

##### 2) Tumor's 2D Visualization

*Tumor's 2D Visualization* is in charge for generating a bi-dimensional image of tumors location in a similar way to *Video Visualization*. The idea is to display a variable number of 2D images, not in video, each one of them containing different parts of the tumors.

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#### V. REASONS

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ADT-3D (Three-dimensional Tumor Detection Assistant) came up as a scientific proposal for tumor detection. The main purpose was to offer information related to the possible infected areas. In this matter it facilitates, complements, reduces time, lowers cost, and sets up an entry point to other further advanced systems.

#### A. Facilitates

Nowadays, CT Scans display for doctors the gained data



from patients. The data can be presented in different formats, chosen by the doctors depending on the situation. Adding the ADT-3D inside CT Scans would facilitate and greatly improve the detection and diagnosis of tumor because it is specifically designed for this mission.

#### B.Adds functionality

Doctors around the world would agree, "Medicine is not an exact science". During the diagnosis process, most doctors will contact colleges to discuss a series of events that point towards a final judgment. The insertion of ADT-3D in a CT Scan may lead to a greater efficiency detection tumors and diagnosing each single patient. The improvement in efficiency would utilize better the time doctors' work diagnosing the patient. Therefore, there would be more time to expend curing the tumor.

#### C.Economizes

As a result of the implementation of ADT-3D system into CT Scan there is a smaller delay for the results, but on the other hand, since the data was processed and studied by the ADT-3D, it saves time. The economization of time and money is always seen as a positive asset. In any case, the implementation of the ADT-3D would only improve and advance the process. The addition of the new system would never become a disadvantage. The possible high cost of the new ADT-3D would be cover by the time savings on doctors and patients' time, and ever greatly it would be more than justified by the lives that it would save.

#### D.Clarifies

For image diagnosis the most common method used by doctors is the ocular identification of unknown shapes and forms. Unfortunately, in few cases, this type of identification cannot be used because the affected areas are particularly small. If we take tumors as an example, it is expected that first stages of the illness cannot be detected because of the difficult location and the small size of the tumor. ADT-3D assist doctors with the detection and diagnosis phase, which includes early stages since it's a computerized system that can access all the data from the patient, even the smallest piece. The figure 3 represents how easily a tumor could be shown with ADT-3D.

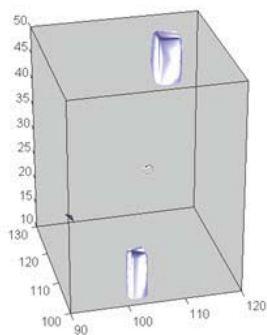


Fig 14. The figure represents the tumors detected in a brain example. There are two cubes that represent two experimental tumors.

#### E.Sets up an entry point

At the moment there is no other product similar to ADT-3D in the market. Its broadcasting could be inspirational for people with especial interest, attracting better facilities or more time and money. The utilization of this system can, positively improve the quality of life for many people. Present CT Scan or MRI's do not include any kind of Artificial Intelligence algorithms. The expansion of Artificial Intelligence to other fields has improved their main features and client satisfaction; therefore, the inclusion of AI methods and algorithm in Medicine would also help any patient

## VI.RESULTS

### 1)Introduction

First of all, it should be said that ADT-3D is a prototype. As a prototype, the goal is achieved; the brain tumor is found, located, and shaped.

ADT-3D objective is to find a brain tumor, excluding any other CT scan elements such as bone, face, neck or skin. ADT-3D works only with the brain mass.

There is a limitation in ADT-3D results because it has only tested with data source in which the experiments were done. As said before, in the experiment the tumors were simulated through data.

The following test were run after the matrix was obtained, delimited, and the tumors were added. Unfortunately, it was impossible to find any CT scan examples which had tumors. Neither on the net, nor at any Madrid's hospital tried.

### 2)Tumor density equal to brain average.

Once known the source protocol, it depends on the CT manufacturer; the non-meaningful value is selected. The test consists on adding a simulated tumor value similar to the brain tissue. If ADT-3D works properly, this kind of tumor cannot be detected by the system. The following picture shows where the simulated tumor was added..

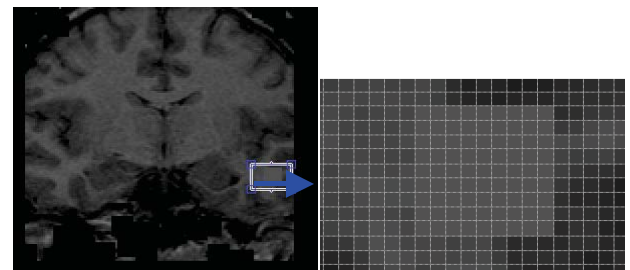


Fig 15. The simulated tumor has a value of 90, which is really close to brain tissue. It is not simple to distinguish where the tumor begins.

The simulated tumor could only be distinguished because of the shape, but never by comparing it to the voxel density levels. In order to recognize the tumor, another kind of

artificial intelligence algorithm could be use to target shape oriented recognition.

An example of the detected tumors can be seen on Fig 14. In the sample (Fig 14), the 33rd slice does not show the tumor with value 90 because the density difference is almost equal to the surrounding brain tissue.

The following picture represents how the tumor is segmented by Jaimes' Algorithm.

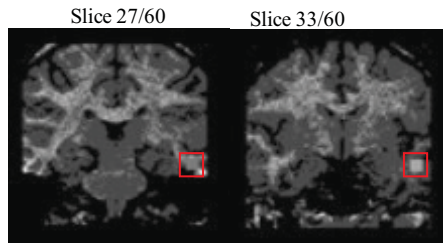


Fig 16. The tumor values are exactly the same, but due to the low value, for each slice the tumor is classified by the segmentation algorithm on different classes, instead of the same class.

Figure 16 shows how the Jaimes' Algorithm perceives the simulated tumor. For each slice the Kmeans class changes. In this way, it is impossible to join all the squares into a 3D image or a five class section for 2D recognition.

### 3)Intermediate Tumor Value

The Intermediate Tumor Value runs a simulation slightly above the average brain tissue density values. The tumors with density values above 90, the average, are easily recognized by ADT-3D. Tumors will be distinguished but the smoothen step is crucial here. Without image smoothing many spread pixels would be perceive as tumors.

The next picture represents how is a 110 value tumor is represented.

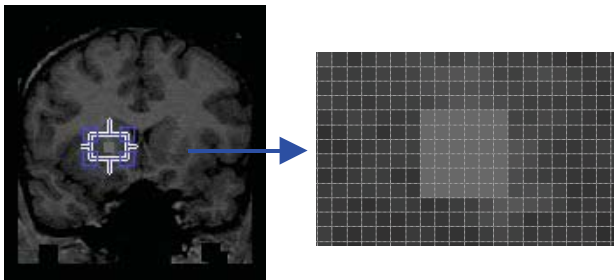


Fig 17. The tumor is seen better now because there is more distance comparing to the brain average value.

Once our Algorithm is applied the tumor is automatically detected. On Figure 14 the top part of the cube shows a tumor. The 2D result is shown below.

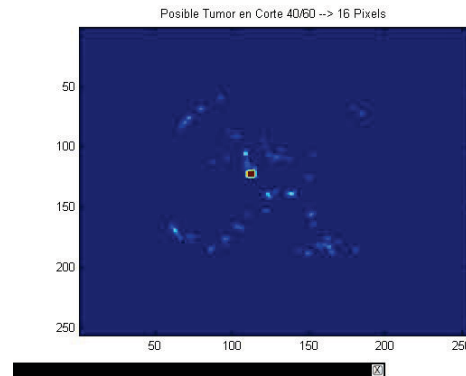


Fig 18. The 2D solution represents with garnet color the possible tumors and the number of pixels that satisfied the tumor condition.

Therefore, the case illustrates the ADT-3D objective, to automatically find tumors otherwise undetected by conventional CT Scans.

### 4)High Tumor Value

The last test is done to ensure the recognition of high-density tumor values. The voxel density selected is 130, which is hardly ever found merged into brain tissue. It could be said that any other value higher than 130 will be surely recognized, because the algorithm performs better in voxel density values above and beyond 130.

It is important to emphasized how the simulated tumor is contrasted differently to the brain mass. The following images demonstrate the difference in contrast.

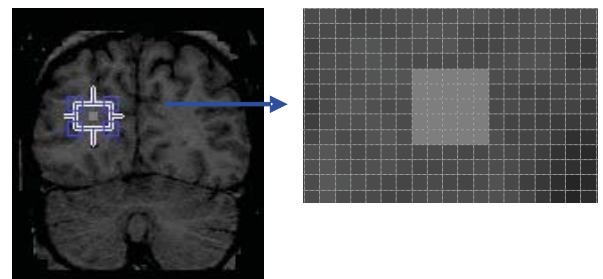


Fig 19. The tumor value is so high that comparing to the brain mass it is closer to white values, such as bone.

The 3D result obtained is shown on the Figure number 13. There are two cubes. This tumor is represented as the lower cube. The 2D recognition representation for one slice is on figure .

When comparing figures 18 and 20 is easily perceive that the higher the tumor density the less number of elements will be represented in a 2D picture. Figure 18 has more noise, more irrelevant information, while Figure 20 has only the tumor and two small data zones.

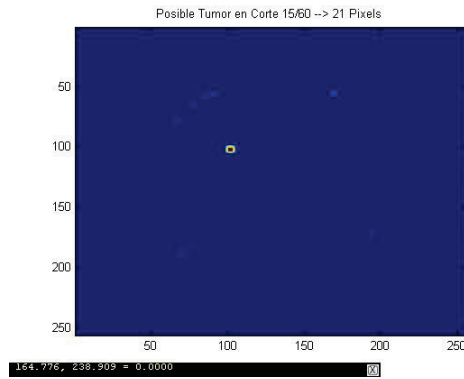


Fig 20. The tumor on slice 15 is shown as a gamet square with 21 high chance tumor pixels.

### 5) Results Analysis

These three simulated tumors were used to check ADT-3D performance. The first test verified ADT-3D detection capabilities for tumors with voxel density values equal to brain tissue. The second test tested ADT-3D capacity to find tumors with density voxel values slightly above brain tissue average. Finally, ADT-3D was tested for tumors with voxel density levels above 130.

The three tests reinforced the usage of Jaimes' algorithm on ADT-3D for brain tumor detection. Anyways, the prototype has to be further tested and CT scan voxel density values have to be collected to better understand and improve the process.

## VII. PRODUCT LIMITATIONS

Unfortunately, any prototype has its drawbacks and limitations. The positive aspect is that it is possible to learn from them so that future updates can overtake them. Once ADT-3D was finalized, it was studied and tested in further detail to analyze its outcome. The negative side carries some limitations that could be divided into two independent categories: Physical and Software limitations.

### A. Physical Limitations

Physical limitations concern the hardware devices in which ADT-3D is launched. Ram memory, processor speed, and similar features affect directly to the velocity of execution but never to the effectiveness. As a matter of fact ADT-3D is a very demanding project in terms of hardware requirements. It needs at least 1 Gb of RAM, and a processor equal or higher to 2,5GHz to work properly. The results of investing in hardware would mean better response times, which is always desirable.

### B. Software Limitations

Software limitations are related to the effectiveness of the program. ADT-3D uses density values to discriminate classes during the segmentation process. There could be tumor areas which densities are too similar to densities on the surrounding areas, this would make impossible to detect that tumor. This is an important software limitation of ADT-3D but doctors already face this problem. Doctors

many times detect tumors using their visual perception on a CT Scan, which also shows density values.

### C. Area of Applicability

ADT-3D is a remarkably peculiar product which requires specific data from a CT Scan. Its main goal is to assist with tumor detection. For this reason the only possible application in the field could be Medicine. It is in radiology where the product is more feasible because its implemented into CT scans. Computer applications have revolutionized every area of Medicine, but they have to be updated.

## VIII. CONCLUSION

Although additional studies are necessary to provide ADT3D more capabilities, it is clear that this project represents the very start of computing software applied to medical area.

Nowadays it is known that there are many applications dealing with medical stuff recognition using Artificial Intelligence. Each IT company focused on TC develops not only in the hardware, but also in software to deal with the achieved data. ADT3D tries to be cross-platform software able to work with any kind of raw data acquired by a CT machine, no matter its firm.

The current ADT3D is a prototype, an introduction of what could be done. The whole project could be improved, from the GUI to the core. The Jaimes' Algorithm, or the core as it was said, is a mathematical approximation to the tumor recognition which must be studied and improved. The present algorithm only works for simple cases where the whole tumor has a constant value.

Visual Intelligence Computing branch is getting more and more significant, acquiring new people day by day. The applicability of this computing area is enormous because it could be used easily as a human tool, not only for medical stuff, but also, for car identification numbers, people identification, optical character recognition ...

Developing ADT3D has been a great challenge during the last eight months. During the development of this project, MATLAB has been our third coworker. Matlab is a great prototype oriented application with a clear advantage: find much information on the Internet. Internet research has been also important to achieve the goal of recognition, so, as well as people provide their free code on the internet, ADT3D will be for free for all on the Internet.

Upgrades are an important part on each project or prototype. ADT-3D particularly could improve the user interface. The GUI was developed to perform the desired task but user interaction with it was not taken into account. User experience is key to many applications, upgrading the actual interface could make easier and simpler the understanding of the process.

New functionality could be added so that ADT-3D performs new tasks as acquiring data from the computer or servers to treat it as input data. Many additional functions could improve the productivity and capabilities of the system.

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# Computer-aided diagnosis of pancreatic and lung cancer

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**Abstract** — when we talk about cancer diagnosis the most important thing is early diagnosis to prevent cancer cells from spreading. We may also consider the high cost of diagnostic tests. Our approach seeks to address both problems. It uses a software based on Bayesian networks that simulates the cause-effect relationships and gets the chance of suffering a pancreatic cancer or lung cancer. This software would support doctors and save a lot of time and resources

**Keywords**— Bayesian networks, pancreatic cancer, lung cancer and computer-aided diagnosis

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## I. INTRODUCTION

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**P**ancreatic cancer is the cancer with a higher mortality. Is the fourth leading cause of death in the United States of America. In 2006 were predicted 33,700 cases of which 32,300 were fatal [1]. In Spain (year 2004) the situation is as follows [2]: 2,438 deaths (4% of all cancer deaths in men) and 2098 (5.8% of all cancer deaths in women).

Lung cancer is the most widespread cancer (27.4% in Spain). In USA accounted for more deaths than breast cancer, prostate cancer, and colon cancer combined. In year 2004, 108,355 men and 87,897 women were diagnosed with lung cancer (89,575 men and 68,431 women died).

Both lung cancer and pancreatic cancer persist as a challenge to medicine, because despite advances in diagnostic techniques and therapeutic resources, the statistics reflect the few dressings in relation to the number of patients cared for. This is due largely to the fact that in recent years there have been no meaningful responses to attempts to reduce exposure to carcinogens, in the case of lung cancer, and also that did not improve the detection of the tumour at an early stage, which would have been able to increase the possibility of healing, but especially not yet have an appropriate solution for these pathologies.

In an organization as the Spanish health, oncology institutes are not designed so far to leave in search of any persons concerned. Patients who received are overwhelmingly referrals with confirmed or presumptive diagnosis and usually at a relatively advanced stage of evolution.

Hence the need arises to create a web application that calculates instantly and reliably the likelihood of suffering from cancer. This reliability will ultimately depend on the human factor, since it will be the oncologists who through his experience and statistical data to determine the values of

probability tables that use the system to infer the likelihood of final diagnosis. The medical knowledge is stored in a bayesian network (see Fig. 6) that models the relationships between symptoms, risk factors, etc.

The project aims to provide an early warning system and determine the likelihood of developing now or in the future some of the, previously mentioned, types of cancer, according to risk factors, symptoms and other diseases.

Given the seriousness of these types of cancer and the known fact that a large percentage of cases are discovered in advanced stages of the disease, a tool aimed to inform and to alert the population is a great help. This type of tool can be further enhanced in the current social context, where a growing sector of the population has access to the Internet, from where access to this software can be easy and instantaneous, increasing considerably the potential utility of the application for physicians and patients.

Besides the usefulness purely informative, this project would have a preventive character because:

- If the application concludes that a person is at risk of cancer due to certain risk factors, this person could increase their awareness of the problem and how to avoid them.
- A sufficient risk of suffering from cancer could push the individual to carry out periodic reviews, which could lead to earlier detection of the disease.

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## II. CANCER DIAGNOSIS

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### A. Pancreatic cancer

Pancreatic cancer is presented with an incidence of 8 to 10 cases per 100,000 inhabitants per year in many industrialized countries of Europe [1]. This incidence is higher than that recorded a few years ago [2]. In Spain, the incidence of pancreatic cancer has risen dramatically in the second half of the twentieth century, with an increase in the same close to 200% [3]. Pancreatic cancer is the fourth leading cause of cancer deaths in the United States, both men and women [1,4,5]. Until the last evolutionary stages, when the majority of diagnoses are introduced, pancreatic cancer is a disease of evolution silent and insidious. Since the disease is usually diagnosed when it is no longer confined to the pancreas, has a survival rate at 1 year of

15-20%, and when survival is valued at 5 years, that figure drops to 2-4% [1,6]. Only when the pancreatic cancer is small (less than 2 cm.) sits at the head of the organ, and there are no lymph node metastases and invasion of neighbouring organs, can be expected survival rates of 20% to 5 years.

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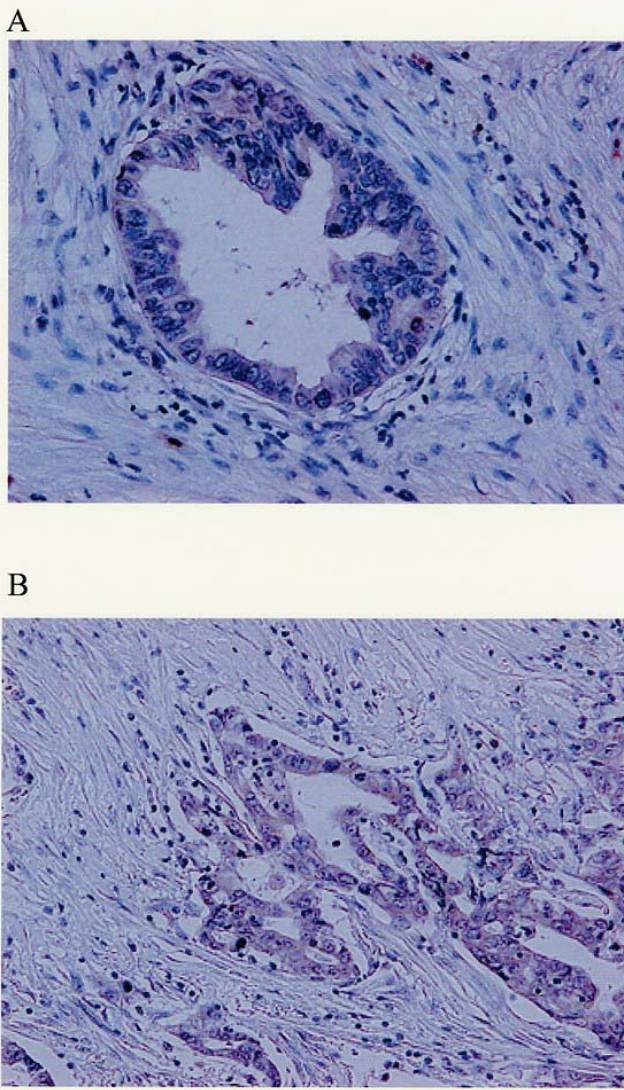
*B.Lung cancer*

Fig. 1 Immunohistochemical detection of KIT and SCF expression in pancreatic cancer. (A) KIT-positive pancreatic cancer cells ( $\times 200$ ). (B) SCF-positive pancreatic cancer cells ( $\times 200$ ).

[Credit: Yasuda et al. Molecular Cancer 2006 5:46 doi:10.1186/1476-4598-5-46]

It is a very aggressive and deadly cancer, most patients die before the first year after diagnosis. It is the most common cancer in men over 35 countries, especially developed or industrialized countries [22], including Spain, being the leading cause of cancer death in both men and women. More people die of lung cancer than of colon cancer, breast and prostate combined. It represents 12.5% of all malignant tumors in Spain. [23]

The number of cases has increased since the beginning of the century, doubling every 15 years. The incidence has increased nearly 20 times between 1940 and 1970. At the beginning of the century, it was considered that most were metastatic lung tumors, and that cancer was rare primitive.

### III.SYMPTOMS, RISK FACTORS AND PATHOLOGIES

A risk factor is anything that affects the likelihood of developing a disease. Having a risk factor, or even several factors, does not mean that a person can contract the disease. In addition, many people who develop the disease may have no known risk factor [9].

#### A.Pancreatic cancer

Over the years it has investigated the possible existence of risk factors that influence the emergence of pancreatic cancer. In this sense, risk factors have been invoked since demographic factors to personal terms with a greater or lesser risk could be related to pancreatic cancer [10].

It is unknown the cause of emergence of pancreatic cancer; it is more common in smokers and in the obese people and almost 1/3 of cases is due to cigarette smoking. There is controversy over whether diabetes type 2 is a risk factor. In addition, it is known that a small number of cases are related to symptoms that are transmitted through families [11].

Now we are going to show a list of symptoms, risk factors and pathologies related with pancreatic cancer. After, we will develop the most significant facts and will put the range of values used in the bayesian network. We have chosen the range of values depending on the relevancy of the fact in relation with the diagnosis.

#### Symptoms [11,15,16,17]:

- Weight Loss (Fig. 2)
- Loss of appetite (Fig. 2)
- Abdominal distention (Fig. 3)
- Edema in lower extremities (Fig. 3)
- Backache (Fig. 3)
- Mass palpable abdominal (Fig. 3)
- Abdominal pain (Fig. 3)
- Clots or fatty tissue abnormalities (Fig. 3)
- Uneven texture of fat tissue (Fig. 3)
- Relaxation of the gallbladder (Fig. 3)
- Nausea or vomiting (Fig. 3)
- Diarrhea (Fig. 3)
- Indigestion (Fig. 3)
- Eyes and skin yellowish (Fig. 3)
- Urine of dark colour (Fig. 3)
- Faeces of clear colour (Fig. 3)

#### Risk factors [11,13,14,19,20,21]:

- Sex (Fig. 4)
- Age (Fig. 4)
- Smoking (Fig. 4)
- Food (Fig. 4)
- Consumption of coffee (Fig. 4)
- Consumption of alcohol (Fig. 4)
- Race (Fig. 4)
- Obesity and physical inactivity (Fig. 4)
- Exposure to asbestos, pesticides, dyes, petroleum (Fig. 4)

#### Pathologies [10,17,18]:

- Pernicious anemia (Fig. 5)

- Endocrine tumours (Fig. 5)
- Estimatorrea (Fig. 5)
- Anorexia (Fig. 5)
- Ascites (Fig. 5)
- Cystic fibrosis (Fig. 5)
- Chronic pancreatitis (Fig. 5)
- Tonsillectomy (Fig. 5)
- Peptic ulcer surgery (Fig. 5)
- Cholecystectomy (Fig. 5)
- Allergies (Fig. 5)
- Thrombophlebitis (Fig. 5)
- Long-term diabetes (Fig. 5)
- Diabetes mellitus of recent beginning (Fig. 5)

#### a) Age

The risk of pancreatic cancer increases with age. Almost all patients are older than 45 years. More than 90% are over 55 and almost 70% are over 65. The average age at the time of diagnosis is 72 years. (see Fig. 4)

In the bayesian network we used the following range of values: *children, young or adult*

#### b) Sex

Men are slightly more likely to develop pancreatic cancer than women. This difference was most pronounced in the past, but has declined in recent years. Perhaps that difference, at least partly, is due to higher consumption of tobacco. (see Fig. 4)

Range of values: *male or female*

#### c) Race

Black people and Orientals in this order are more likely to develop pancreatic cancer compared to white people. The cause is unknown, but may be due to higher rates of smoking and diabetes among men, and overweight in women of those races. (see Fig. 4)

Range of values: *white, black or oriental*

#### d) Tobacco

Smokers have a risk of two to three times greater of suffering pancreatic cancer. Scientifics consider that this may be due to chemical agents that exist in cigarette smoke. The chemical agents enter in the blood causing damage to the pancreas. It is thought that between 20 and 30 percent of all pancreatic cancer cases are smoking cigarettes. (see Fig. 4)

Range of values: *former smoker, non-smoking, moderate or high*

#### e) Diet

Some studies have found a relationship between pancreatic cancer and a diet high in fats, or that includes the consumption of lots of red meat, pork and processed meats (such as sausage and bacon). Others have discovered that a high consumption of fruits and vegetables can help reduce the risk of pancreatic cancer. But not all studies have made these associations, and the true value of the food is still under study. (see Fig. 4)

Range of values: *good or poor*

#### f) Obesity and physical inactivity

People with overweight are much more likely to develop pancreatic cancer, like those with little physical activity. (see Fig. 4)

Range of values: *mild, moderate or serious*

#### g) Diabetes

The pancreatic cancer is most common in people who suffer from diabetes mellitus. The reason for this relationship is unknown. Most risk is detected in people with diabetes type 2, which usually starts in adulthood and is often linked to overweight and obesity. There is no certainty if there is an increased risk in people with diabetes type 1 (in younger people). (see Fig. 5)

Range of values: *negative or positive*

#### h) Chronic pancreatitis

The chronic pancreatitis is a long-term inflammation of the pancreas. This condition is associated with an increased risk of pancreatic cancer, but most patients with pancreatitis never develop this cancer. Perhaps the main reason for this association is that patients with pancreatitis also are more likely to have other risk factors such as smoking. Very few cases of chronic pancreatitis are caused by inherited gene mutation (see family history). People with this hereditary form of chronic pancreatitis seem to have a high risk for a lifetime of suffering pancreatic cancer (approximately 40 to 75 percent). (see Fig. 5)

Range of values: *negative or positive*

#### i) Exposure to working conditions

The intense exposure at work to certain pesticides, dyes and chemicals used in metal refinery could increase the risk of pancreatic cancer. (see Fig. 4)

Range of values: *negative or positive*

#### j) Family history

It seems that the pancreatic cancer occurs more frequently in some families. Perhaps up to 10% of pancreatic cancers are related to changes inherited DNA (mutations). These changes often increase the risk for other cancers as well. Some examples include:

*Mutations in the BRCA2 gene:* this mutation also increases the risk of ovarian cancer and breast cancer

*Mutations in the p16 gene:* it also increases the risk of melanoma.

*Mutations of the gene PRSS1:* cause severe pancreatitis during an early stage.

*Hereditary non polyposis colorectal cancer (HNPCC or Lynch syndrome):* also increases the risk of colorectal cancer and endometrial cancer.

*Peutz-Heghers Syndrome:* also has partnered with polyps in the digestive tract and other cancers.

Scientists have found some of these changes in DNA and can be identified through genetic testing. (see Fig. 4)

Range of values: *negative or positive.*

#### k) Stomach Problems.

The stomach infection with the bacterium called *Helicobacter pylori*, which causes ulcers, could increase the risk of pancreatic cancer. Some researchers believe that excessive stomach acid could also increase the risk. (see Fig. 3). Range of values: *mild, moderate or serious*



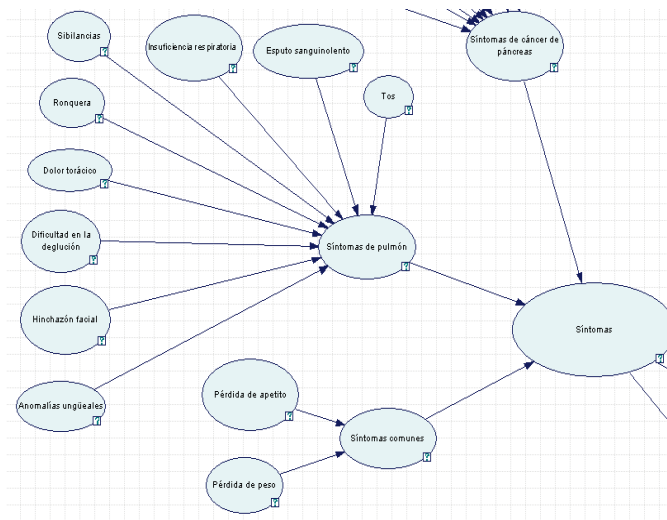


Fig. 2 Detail of the bottom left corner of the bayesian net modeling the patient's symptoms. Both common symptoms and the specific symptoms of lung cancer are included.

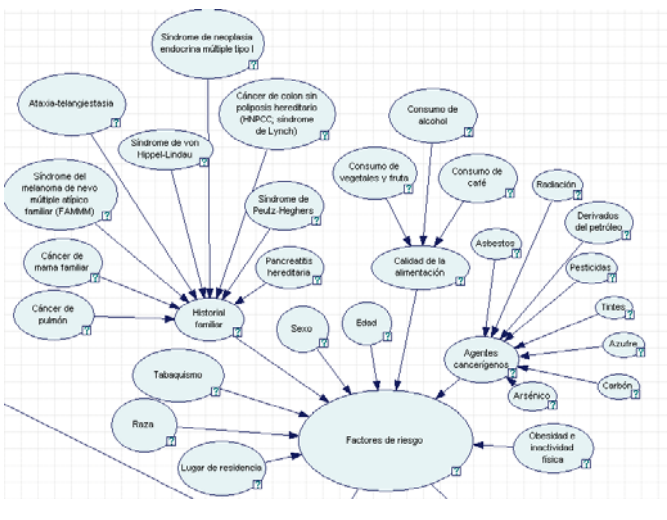


Fig. 4 Detail of the center of the bayesian net. We can observe risk factors grouped in four categories: diseases in the family history, quality of food, exposure to carcinogens and general risk factors. In the last category we have sex, smoking, etc.

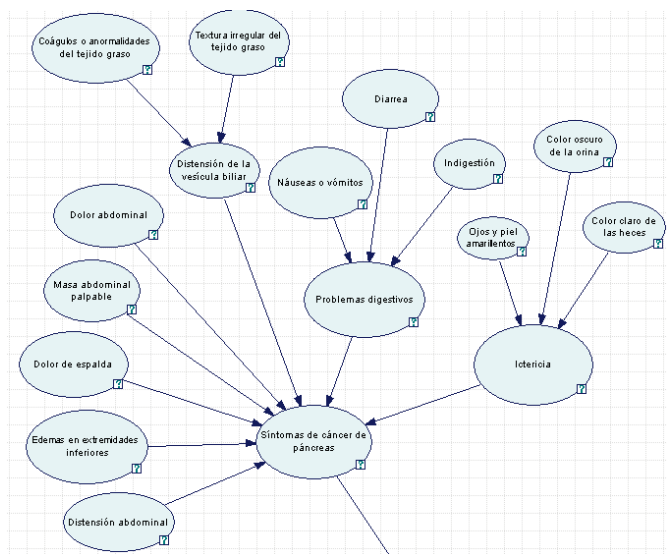


Fig. 3 Detail of the specific symptoms of pancreatic cancer. They are divided in: symptoms related with distension of the gallbladder, symptoms related with digestive problems, symptoms related with jaundice and general symptoms of pancreatic cancer.

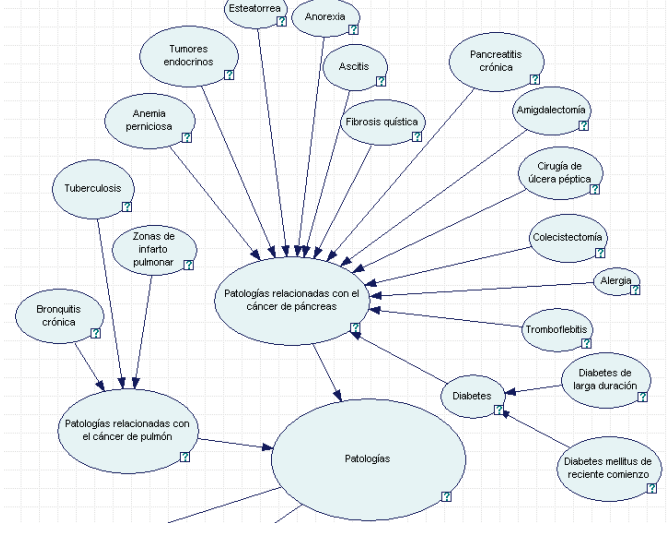


Fig. 5. Detail in the upper right corner. Now we have pathologies. They are divided in two big groups: pathologies related with pancreatic cancer and pathologies related with lung cancer. It is remarkable the two types of diabetes.



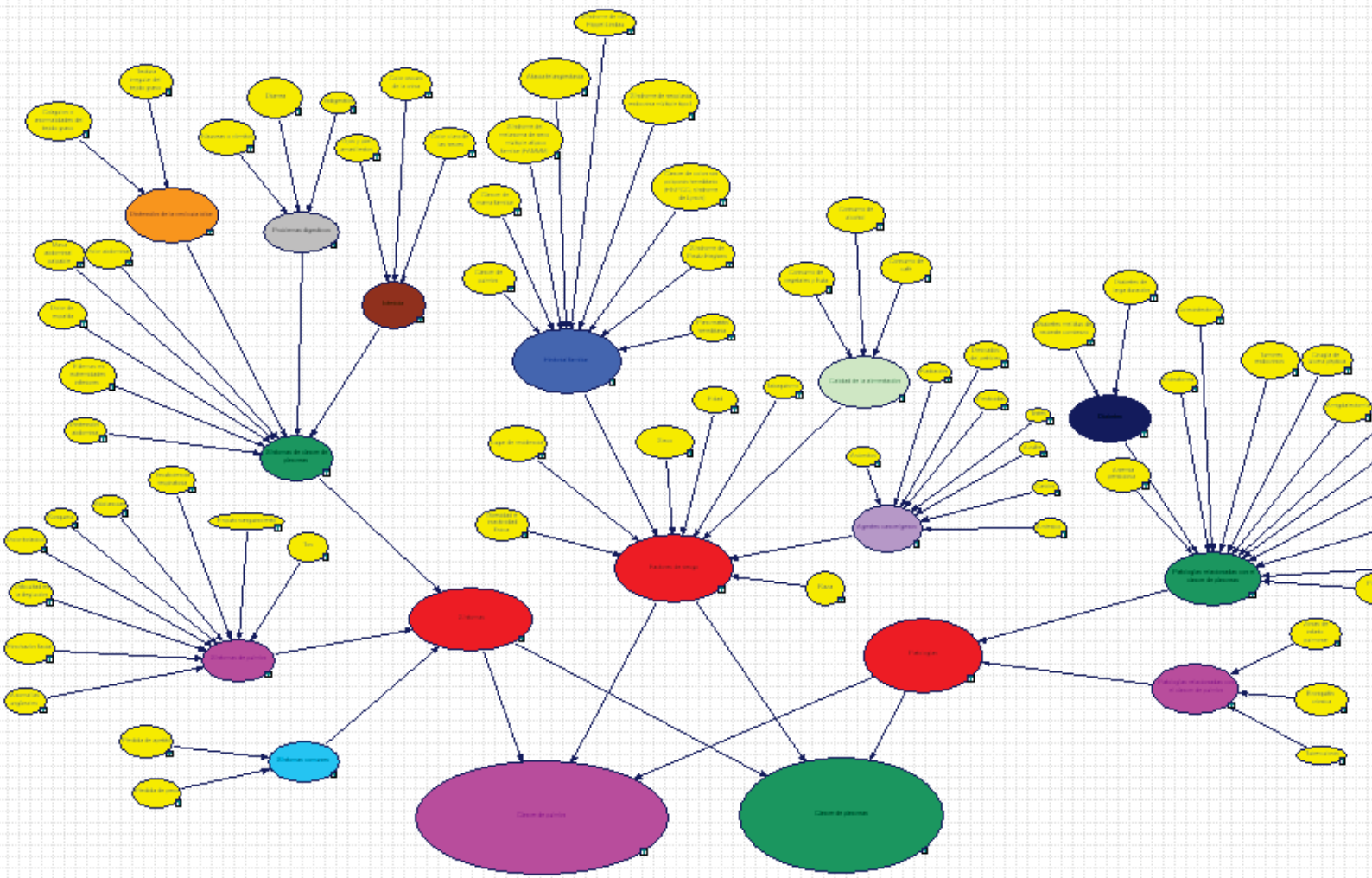


Fig. 6. Overview of the bayesian network that models the system's medical knowledge. The color code of the nodes is:

- Yellow**: it expresses the input (risk factors, symptoms and diseases). These nodes have an associated probability value. Depending on the response of the patient (or defaults in case of unknown response) will be established the evidences of the network.
- Pink**: from left to right, symptoms and pathologies related with lung cancer. Top down, the node of lung cancer that determines the final positive/negative probability (the output)
- Light green**: from left to right, symptoms and pathologies related with pancreatic cancer. Top down, the node of pancreatic cancer that determines the final positive/negative probability (the output)
- Purple**: from left to right, the general nodes that determine symptoms, risk factors and pathologies
- Pink**: node that determines the quality of food knowing consume of alcohol, café, vegetables and fruit
- Lavender**: node that represents exposure to carcinogens. The node depends on: asbestos, radiation, pesticides, dyes, petroleum, sulphur, coal and arsenic
- Dark blue**: node that represents the incidence of diabetes in the final diagnostic. It depends of two types of diabetes: long-term diabetes and diabetes mellitus of recent beginning
- Brown**: jaundice. It depends on three symptoms: eyes and skin yellowish, urine of dark colour and faeces of clear colour
- Grey**: digestive problems. This node depends on three symptoms: nausea or vomiting, diarrhea and indigestion
- Orange**: distension of the gallbladder. Depends on two symptoms: clots or fatty tissue abnormalities and uneven texture of fat tissue

**l) Consumption of coffee**

Some previous studies indicated that coffee consumption might be a risk factor; more recent studies have been unable to confirm this. (see Fig. 4)

Range of values: *little or much*

**m) Consumption of alcohol**

Most studies have found no relationship between alcohol consumption and pancreatic cancer. However, consumption of alcohol in large quantities may increase the risk of developing diabetes and chronic pancreatitis. (see Fig. 4)

Range of values: *little or much*

**B. Lung cancer**

Lung cancer is so far the deadliest in the developed world. One of the reasons that make it so deadly is that lung cancer is often not detected until it is in advanced stages.

However, some lung cancers are diagnosed in its early stages as they are detected by tests like bronchoscopy (visualization of the interior of the bronchi through a flexible lighted tube), or sputum cytology (microscopic examination of the cells contained in phlegm that is ejected with cough).

**Symptoms:**

- Nail anomalies (Fig. 2)
- Weight Loss (Fig. 2)
- Loss of appetite (Fig. 2)
- Facial swelling (Fig. 2)
- Swallowing difficulties (Fig. 2)
- Chest pain (Fig. 2)
- Hoarseness (Fig. 2)
- Wheeze (Fig. 2)
- Shortness of breath (Fig. 2)
- Bloody sputum (Fig. 2)
- Cough (Fig. 2)

**Risk factors:**

- Sex (Fig. 4)
- Age (Fig. 4)
- Smoking (Fig. 4)
- Food (Fig. 4)
- Consumption of coffee (Fig. 4)
- Consumption of alcohol (Fig. 4)
- Race (Fig. 4)
- Obesity and physical inactivity (Fig. 4)
- Exposure to asbests, pesticides, dyes, petroleum (Fig. 4)

**Pathologies:**

- Chronic bronchitis (Fig. 5)
- Tuberculosis (Fig. 5)
- Pulmonary infarction zones (Fig. 5)

**a) Tobacco**

The tobacco reaches the alveoli and water-soluble components are absorbed by the mucous, not being absorbed the fat-soluble ones (tar or pitch) that contain carcinogenic polycyclic aromatic hydrocarbons. The pitch is phagocytes by alveolar macrophages and eliminated in the sputum, but not all alveolar macrophages will be eliminated in the sputum, many of them break in their journey towards the glottis leaving the pitch. This will be deposited in the carina

(confluence of the bronchi), especially in the more upper and peripheral ones, producing its irritation. The pitch irritates the mucous membrane and destroys the surface of the respiratory epithelium forcing the basement membrane to increase their proliferative capacity. The basement membrane increases both his "turn over" (basal cell hyperplasia, stratification of the epithelium), ending producing squamous cell metaplasia, which will evolve to dysplasia (carcinoma in situ) and finally to anaplasia as carcinoma in situ and invasive carcinoma. [24] . (see Fig. 4)

Range of values: *former smoker, non-smoking, moderate or high*

**b) Sex**

Lung cancer is the most common malignancy in men. The relationship between the sexes nowadays is 4 men for every woman: (4:1). The woman continues to have a lower incidence, but has already been located in some countries in second place after breast cancer, or even in the first place.

Several studies have found that the lung cells of women have a higher chance of contracting cancer when exposed to tobacco. (see Fig. 4)

Range of values: *male or female*

**c) Family history**

If you've suffered a lung cancer, there is an increased risk of having another lung cancer. Brothers and sons of people who have had lung cancer may have a slightly higher risk. If the father and grandfather of a person died from lung cancer, and this person smokes, the most likely cause of his death will be a lung cancer. . (see Fig. 4)

Range of values: *negative or positive*

**d) Exposure to work conditions**

**Asbests:** This is another risk factor for lung cancer. People who work with asbests have a higher risk of suffering from lung cancer and, if also smoke, the risk increases greatly. Although asbests has been used for many years, Western governments have almost eliminated its use at work and in household products. The rate of lung cancer linked to asbests, mesothelioma, often begins in the pleura.

**Radon:** Radon is a radioactive gas that is produced by the natural decay of uranium. Radon is invisible and has no taste or smell. This gas can concentrate inside houses and become a potential risk of cancer.

Some workers industry-related to asbests, arsenic, sulfur, (the three Aes) vinyl chloride, hamatita, radioactive materials, nickel chromates, coal products, mustard gas, chloromethyl ethers, gasoline and diesel derivatives, iron, beryllium, etc., whereas the non-smoker has a probability of 1 suffering from lung cancer, the smoker has 30 or 40, employees of these industries have up to 70 times more at risk. All types of radiation are carcinogenic. The uranium is weakly radioactive, but lung cancer is four times more prevalent among non-smoker miners of uranium mines than in the general population and ten times more prevalent among smoker miners. [25, 26] (see Fig. 4)

Range of values: *negative or positive*

#### e) **Pollution (place of residence)**

It is conceivable that pollutants from the atmosphere (especially urban) play a role in increasing the incidence of bronchogenic carcinoma today. Lung cancer is most common in the city than in rural areas (1,3-2,3 times higher among men with similar smoking costumes) because:

- Engine gases (cars and motor vehicles in general) and heating systems. The sulfur dioxide is one of the most important carcinogenic substances.
- Particles of pitch pavement of the streets.
- Radioactive Particles.
- The radon gas and natural radioactivity are very abundant in certain geographical areas.

These four factors have an action mechanism like the tobacco. While most authors acknowledge the existence of a small urban factor in the incidence of lung cancer, the main culprit, with overwhelming numerical difference is the tobacco. (see Fig. 4)

Range of values: *field or city*

#### f) **Diet**

Some studies conclude that diets with little vegetables could increase the risk of lung cancer in people who are exposed to tobacco. It is possible that apples, onions and other vegetables contain substances that offer some protection against lung cancer. It is believed that certain vitamins, especially vitamins A and C, are protective of the bronchial walls, by their ability to inactivate free radicals, carcinogens, or their ability to precisely regulate certain cell functions, across different mechanisms. But it has been shown that  $\beta$ -carotene was ineffective as chemoprevention of lung cancer and also two large studies like the Carotene and Efficacy Trial (caret) and Alpha-Tocopherol, Beta-Carotene (ATBC) Lung Cancer Prevention Study, 18000 and 29000 participants, respectively, showed that consumption of beta-carotene increased (rather than reducing) the risk of contracting lung cancer (18% on average), and particularly for smokers of 40 or more cigarettes daily, Who experienced an increase in the incidence of 42%. (see Fig. 4)

Range of values: *good or poor*

#### g) **Prior bronchial pathologies**

Chronic bronchitis: It is accepted that can cause lung cancer.

*TB*: It is a chronic irritation on the lungs parenchyma that leaves a scar that favors the emergence of lung cancer (carcinoma or scar scar on cancer, especially adenocarcinoma).

*Areas of pulmonary infarction*, inclusions of foreign bodies, idiopathic pulmonary fibrosis (10% dying from cancer bronchogenic), scleroderma and other kinds of scars. (see Fig. 5) Range of values: *negative or positive*

#### h) **Viruses**

The relation of viruses with lung cancer has two different bases:

In the experimental field, the incidence of bronchial epithelial metaplasia is caused by paramyxovirus.

As for the human pathology, there is a link with bronchus-alveolus carcinoma.

#### i) **Age**

Mainly this cancer affects people between 55 and 65 years. 80% of cases occur in patients over 50 years of age. Lung cancer is very uncommon in people younger than 40 years. The average age of the patients is 60 years but more cases are being diagnosed in young subjects. (see Fig. 4)

Range of values: *children, young or adult*

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## IV. THE APPLICATION

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### B. Description of the system

The main engine of the system is artificial intelligence. Medical knowledge is built through Bayesian networks that simulate disease diagnosis. The system uses the following software: Genie & Smile. (Decision Systems Laboratory, Department of Information Science and Telecommunications and the Intelligent Systems Program, University of Pittsburgh, USA). The project has been developed in the C# language under the platform .NET using the library *smilenet.dll* to access network capacities of the Bayesian networks software previously mentioned.

The network nodes are distributed in three general categories: symptoms, risk factors and diseases. Each one of this general nodes is influenced by several, which are grouped depending on the type of cancer they are related to (pancreatic, lung or both), except in the case of risk factor, which are all considered as global.

Each node contains tables of probability, which reflects the importance of the evidences that each node describes. This probability values must be defined by experts and/or using statistical information. In the case of this prototype, the values have been established according to statistical information found in previous studies. With some reference values, we created a numerical progression from the lower-probability-cases to the higher ones, but this is only an approximation of which it should be. In order to obtain consistent diagnostic values, these tables must be reviewed by an expert who can, according to his knowledge, set more detailed and reliable values for these tables.



Fig. 7. Colour-enhanced image of a lung cancer cell dividing. [Credit: Anne Weston]



When application is being run, the doctor will ask the patient about the evidences (above nodes of the network) and will insert the appropriate value in each field of the form (each field has as much predetermined answers as rows in its bayesian network's node. The doctor must select one depending on the patient's answer).

If some evidence is unknown, the system will take values of equally likelihood (for example, abdominal distention: <mild, serious> will produce an evidence value of 0.5) in order not to distort the outcome.

Once the form has been completed, the diagnostic can be started. The system will return the likelihood of suffering from lung cancer and pancreatic cancer.

This system has been developed as a web application (which allows easy updates) in order to be adaptable to the complex structure of the modern medical organizations or research groups. Many of these organizations have a distributed architecture which does not allow isolated elements to work properly. The web application allows an expert to modify the bayesian network in the application server (due to new discoveries), either the structure of the bayesian network or the values of the tables, and users will have the latest version available immediately via web (Medical Center Intranet, Internet with VPN, LAN ...).

### C. Structure of the application

Each functional element of the object oriented application is implemented by two files: the .aspx file, that shows the interface with the user and the .aspx.cs file, that will control the actions of the functional element. Following this schema we can divide the structure of the application in three parts:

#### 1. Input:

a) *AgenteDeInterfaz.aspx*: this file shows a form with fields that should be filled in by the user. The fields are drop down lists with several options depending on the content. For easy understanding, the fields are organized in: symptoms, risk factors, family history, exposure to agents and pathologies. At the end of the form there is a button to make the diagnosis.

b) *AgenteDeInterfaz.aspx.cs*: this file recovers the values of the fields selected by the user and stores them in a web session (a web session is a technical resource for keeping information between different web pages). Then the control flow of the program redirects to the next functional element (the Filter).

#### 2. Filter:

a) *AgenteDeFiltrado.aspx*: this file does not show anything. It is needed due to structure of the application.

b) *AgenteDeFiltrado.aspx.cs*: this file creates a new object for managing the bayesian network. At this point we can comment that the bayesian network (see Fig. 6) is a file called 'diagnosticoCancer.xdsl' (this file is created previously with the Genie's software and represents the medical knowledge of the system) and stored in the root directory of the application. After creating the bayesian network management object we read the network and now we have access to its values. Then we recover the values stored in the web session and we check if the fields have been filled in. If

a field is void we set neutral values of likelihood depending on the type of field. We have three types: with two options (0.5), with three options (0.3333) and with four options (0.25). When all checks are finished we write the new values of the network and the control flow of the program redirects to the next functional element (the Output).

#### 3. Output:

a) *AgenteRedBayesiana.aspx*: this file shows the final results of the diagnostics. It points out through labels: the positive/negative probability of pancreatic cancer and the positive/negative probability of lung cancer.

b) *AgenteRedBayesiana.aspx.cs*: this file is responsible for the calculations of probability that express the diagnosis. First of all it makes the same work as '*AgenteDeFiltrado.cs*'. But, instead of doing the checks, it sets the values of evidence of the network (for a better understanding see the reference [27]). If a value has not been selected we set some default one. Then we update the beliefs of the bayesian network. And now we make up the calculations of probability with the two final nodes (pancreatic cancer and lung cancer, see Fig. 6) and show the results to the user.

### D. Efficiency analysis

In computational complexity theory, big O notation is often used to describe how the size of the input data affects an algorithm's usage of computational resources (usually running time or memory).

The application uses simple instructions and merely carries out checks on the entry of information. As already commented, application filters those data that are not introduced and provides default values. The complexity of these actions is minimal:  $O(1)$ .

However, the most complex actions are the two 'for' loops that estimate the probability of suffering pancreatic or lung cancer. Each loop has a complexity of  $O(n)$ .

So, the complexity of the application is  $O(n)$ , technically it is said linear complexity. Hence we can say that the application is quite efficient.

Of course this analysis only covers our application. For a complete estimate, calculations of Genie's software on the network should be considered.

For more information read information related to the Bayesian networks, inference, the Bayes theorem ... We suggest as an introduction the following article in the reference [27].

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## V. CONCLUSION AND FURTHER WORK

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Information and communications technologies are an essential tool in the field of health sciences both in research and management. The health system will work better if we introduce them gradually.

This project would produce benefits to pancreatic cancer research (the project is useful as a basis of a Bayesian network more realistic) as well as in a more agile working of medical consultations.

For future developments it would be a chance to add to the Bayesian network results of diagnostic tests (images,



analysis,...), thereby obtaining a complete diagnosis based on symptoms, risk factors, disease and diagnostic tests. The system could, for example, communicate with other medical image processing systems or implement a subsystem of image recognition (using neural networks).

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# EvoWild: a demo-simulator about wild life

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**Abstract** — During the last years we can see how AI (Artificial Intelligence) is reappearing because of technological improvements. These improvements make possible the management of large groups of information with acceptable reply times.

On the other hand, cost reductions in technology make possible that an investigation field like AI becomes to an inversion field closer to scale economies, that's why it'll be economically profitable to invert in this type of applications.

One of the fastest consequences is the AI implantation in a big amount of devices of our environment, cell telephones, palms and of course, in the video game industry.

This is the reason that took us to develop EvoWild, a simulation about wild life that has video game format and tools but at the same time implements AI algorithms like genetic algorithms and reasoning based in cases.

**Keywords**— AI (Artificial Intelligence), EvoWild, Genetic Algorithms (GAs), Reasoning Based in Cases (RBC).

## I. INTRODUCTION

In the middle of the 70's the first video games appeared, even thought they never were in the market until almost the 80's. The first machines that were sold were very simple, they used to present black and white graphics and little details, all its states were based in rules. Soon, this new way of entertainment became popular[1][2]; being such a great success years after when the first consoles came out, they showed an easier manner to play compared to the other machines.

In each generation, video games got better in spectacular graphics and in the artificial intelligence of the enemies, so much that at present they reach great heights of realism in both fields. Moreover, during these years of evolution, we could see a clear division between these two markets: Personal computers and Consoles. Curiously nowadays it seems like both worlds come together again since there are coming up very many video games for them.

Because of today we have access to machines with very acceptable performance to face AI oriented programming tasks and this fact increases the possibility of developing demonstrations cases of real life through graphic simulations, this project will focus on these points and also in developing and applying AI algorithms to simulate life in a wild environment.

EvoWild product is the result of this project.

## II. WORK STUDY

One of the first challenges of this project was to make contact with knowledge already forgotten that at the same time don't belong to the activities of a Computer, but as always in this profession, we must learn from other disciplines to do our work. In this case there is a clear sample as we'll see based on parallel studies conduct.

We must be clear: the classification, behaviour, forms of communication and learning of living creatures. We also should study how the natural selection intervenes in evolution and the effects that it produces, as well as the role of mutations in the way they evolve from animals in the real world.

The selected tool among all those studied is XNA and we are going to work on C# as programming language.

XNA is an API devised by Microsoft to develop games, both PC and Xbox360. Technically it is a work environment based on .Net Framework 2.0.

XNA, with freeware versions for non-profit developers, was born with the intention of simplifying the process of creating games and bringing it to all those programmers who always had been overwhelmed by the complexity of existing tools.

From these work studies we will draw conclusions that will help us to develop EvoWild with a reasonable approximation to reality.

## III. EVOWILD

EvoWild is based on a series of studies to establish a firm basis of the principles of the game.

Among these studies[3][4][5][6][7], we highlight the following:

### A. Animal Classification

In this game, it's very important that all the relations and all the species resemble as closely as possible to reality. As we'll see, this will allow us to have a solid base of entities and classes of animals that will take part in the game (see Figure 1).

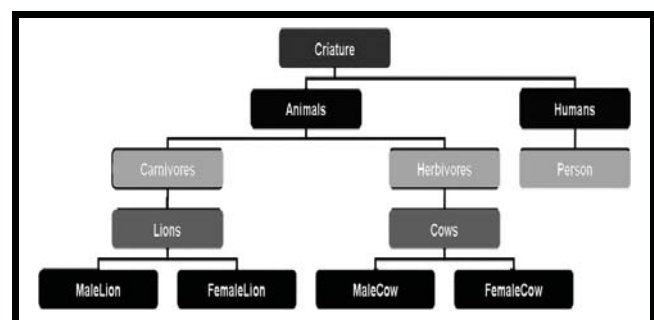


Figure 1 Animals Tree from EvoWild

### B. Behaviour

Establish the individuals and families behaviours will make us easier to understand and extend their conducts since they are classified and categorized.

As a conclusion, the animals from EvoWild can have three different states of conduct: aggressive, mild and scared. From our work study we draw the following conclusions for EvoWild:

- Carnivorous:
  - The carnivorous pursues only when hungry and when it gets closer to the victim, then, it attacks.
- Herbivorous:
  - If an herbivorous see a carnivorous that pursues it (running), then, it flees.
  - If an herbivorous see a carnivorous that attacks it, then, it fights trying to defend itself.

#### C.Communication

One of the most important facets of every living being is communication with their same species and with the environment. The main communication systems to bear in mind are: visual, chemical, hearing, electric and touch.

In this version of the game, we'll only have one communication system and we've chosen the visual one since it's the most representative of all the senses. Our animals will have a certain range of vision that will use to discover the world at the time they walk.

#### D.Apprenticeship

This is other of the goals that we want EvoWild to have in this version, this way animals that take part in the game will be able to learn in order to provide solutions to their needs.

In EvoWild, animals have a limited ability to remember the world where they are as well as to learn from actions previously performed and its consequences, for example, they can remember if they have drunk certain water from a certain lake and what they have got in return.

To give a learning system of these characteristics to the animals we'll use Reasoning Based in Cases (RBC) described in .

### IV.THE GAME

Is focusing on the actions undertaken by animals that are on the board game, that's why it's a game demo format that allows the player to interact with animals selecting and receiving information from the actions and decisions that are taken during the game.

One of the features that make EvoWild to be a game and not a simple demo or a simulation is that it satisfies the requirements of the loop game (see Figure 2)[8]. The characteristic of this loop is that it's thought for the player to interact in real time with the game so the loop is oriented to reading the entry that provides the player, while the simulation programs or demonstration are geared to the process be as perfect as possible. EvoWild tries to align the two features in order to offer a game that reflects a certain degree of accuracy about the process of real life.

EvoWild contains the following elements typical of a game:

- Board game: Where all the action takes place in the game, it's composed of the following elements[8]:
  - Map game: It defines the space for the development of action.

- Map Objects: It contains all the objects that interact with the creatures during the game; it contains the inanimate objects of the game.

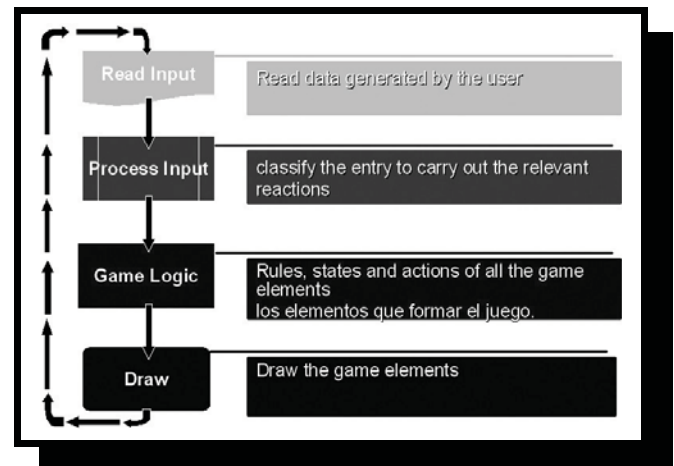


Figure 2 Loop Game

- Map not-pass areas: It delimits areas of the map that may or may not be circumvented by the creatures in the game, as well as the edges of objects such as lakes, rocks, etc...
- Information to the player area: Zone where the player can consult requesting information by using the mouse.

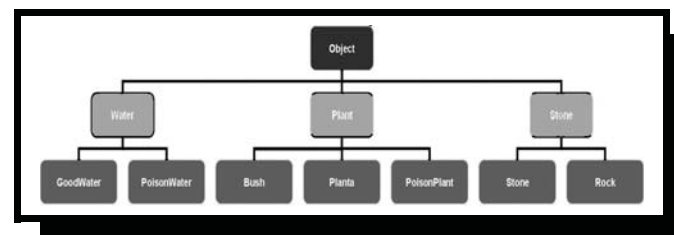


Figure 3 Objects

- Inanimate objects: In this category there are all the objects that belong to EvoWild and do not have the ability to move so they have no graphic animation but they may be alive, like plants for example.

**Creatures:** They are the main class of EvoWild and they develop all the activity of the game. Under this class we can find all the animals that have been considered in the animal classification (see Figure 1).

### V.CREATURES FROM EVOWILD

Without doubt, from the whole game creatures are the elements that have received all the attention during the development and on which we've done the most complex studies because they are the centre on which all the action revolves.

As a result of the studies mentioned in paragraph , creatures have a learning module based on experiences (see ), a module that allows their reproduction and creates offspring with common characteristics to the parents (see ) like the possibility of moving. All this is present at the "Creature

Loop" that represents how the creatures have to behave and act accordingly (see Figure 4).

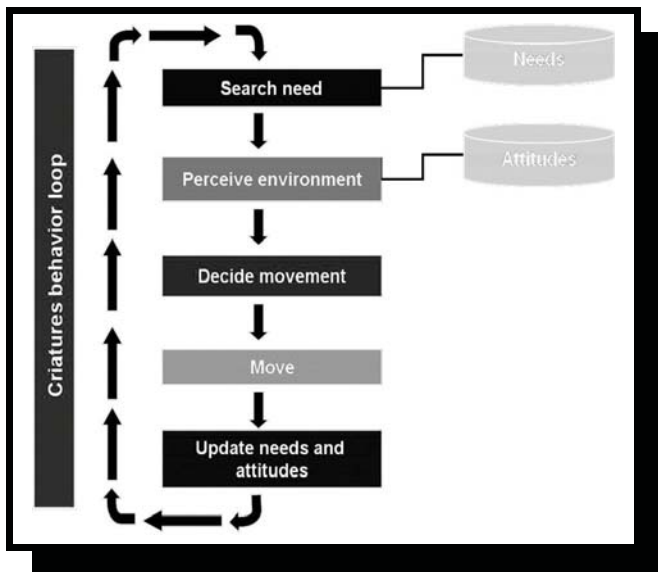


Figure 4 Creature Loop

The "Creature Loop" is divided into five very different functions and, on the other hand, builds and maintains information on the needs and attitudes of the creatures.

We say that the creatures are led by the need since, as we can see in the loop, it is the first function they do and once a creature detects which is its most important need, it'll be trying to find somewhere in its memory that meets this need. We will call this point the final destination point. The creature will address this point walking from the point where it is, but it won't do it in a "robotic" way, it will be able to take new solutions and even change the final destination point if on its way it discovers that it can meet the need with a closer object than the one it had chosen previously.

This way the creature will be choosing among different options that perceived using the function of charging the environment, which gives it more benefit. If during the perception of the environment detects a predator or prey, depending on the case and on its status needs, it may take a decision to flee, pursue or continue to its destination without bearing in mind animals in the environment according to detect the attitude of the creatures that surrounded it.

Once explored the environment and with all the information about its attitudes and the needs that it can satisfy, the creature takes a decision that may be any of both: to change its attitude or to satisfy some of its needs, for which it sets the direction where to go calling "moverse()".

The function "moverse()" gives the creature toward the direction which should turn, we must remember that the creature moves searching to satisfy the need with highest priority. This is the direction that it should take, but on its way, it can recalculate its address short-term (that is the one that its field of perception marks) going to meet needs, trying to escape or attacking, depending on the case.

Once it has walked a certain space (calculated in steps), its needs and its state have got to be recalculated, because depending on how far or near objects that satisfy it needs are, these may change completely. An example of this is that

every 50 steps thirst increases, so that if its main need was eating and walking enough without finding what to drink, its priority can change from eating to drinking, and therefore it could require remembering the closest point where sometime earlier it drank.

The idea that the creatures are led by necessity is interesting because very rarely they will be entirely satisfied and therefore downtime will be small.

#### VI.AI IN EVOWILD

EvoWild is inspired by the original Game of Life[9] designed by the British mathematician John Horton Conway in 1970.

This game represents a cellular automaton formed by a board of infinite cells or grilles where there are cells surrounded by eight other cells that evolves according to the laws mentioned above until it detects the total extinction of the cells, stabilization total of the cells among a finite set of well-located states or a constant occupation of cells that is not foreseeable but that continues to shape constant.

This game really does not require players during its execution, the actions of the player are limited to select some initial conditions, like the configuration of cells, to start the game. From this moment, the game evolves according to the laws mentioned above until it detects the total extinction of the cells, stabilization total of the cells among a finite set of well-located states or a constant occupation of cells that is not foreseeable but that continues to shape constant.

EvoWild goes one step further and aims to represent the interactions among a finite set of populations of individuals based on the laws of natural selection postulated by Darwin.

#### A. Genetic Algorithms

Genetic Algorithms (GAs)[10][11] are selection algorithms based on methods adaptive.

The basic principles of Genetic Algorithms were established by Holland (1975) and are well described in various texts: Goldberg (1989), Davis (1991), Michalewicz (1992) and Reeves (1993).

They are usually used to find optimal solutions of searching problems. As its name suggests they are based on selecting the best among the possible solutions that exist in a certain moment during the development of finding a solution to the problem, which is very similar to the theory of evolution, Darwin (1859), based on the idea of selection of the most powerful.

This way in the genetic algorithm model we can identify the same words that Darwin used for his model. We have, on one hand, a population of individuals who are interrelated in a given environment. The interrelationships within the population are a way to select or discriminate from the solution the individuals who don't bring significant improvements to this solution against those who do it.

There are different types of interactions among populations of these individuals; moreover they interact with an environment that has a certain set of qualities which conditions the evolution of a particular kind of individuals. Broadly speaking we could have these sets of populations:

- A population of predators who are responsible for eating a population of prey.



- Another population of preys that require a certain quantity of food provided by the environment in which they live.

The quantity of food is a very important variable in the evolution since the lack leads directly to extinction unless the species in question adapts themselves to another kind of food.

The relationships that will occur in these conditions are often competing for resources in several ways.

- Within a population of individuals, each one is competing for the limited resources, such as food and water that finds within its environment.
- Also within the population, the individuals see the others, to some extent, as finite resources to struggle for, since to mix themselves they look for the best animals, which often form a small group.

This repeated mixture generation after generation and the fact that weaker individuals are prey to predators is what makes to improve the species more and more tending to a solution of individuals becoming more perfect and therefore much closer to the final solution.

For the development we are talking about, we have taken into account the simply genetic algorithm because it is ideally suited to the needs of our game and it's the closest to the actual genetic transfer in living things.

### B. Simple Genetic Algorithm

It is an algorithm that simulates very convincingly any phase from the creation of an individual from two parents. Individuals newly created are part of the new generation.

This algorithm explicitly incorporates the theory of the animal selection, developed by Darwin, since during the combination of both parents they choose themselves from the set of the best, as it's shown in Figure 5.

The first action is to select the pair of parents with greater capacity for adaptation to the environment and therefore with more chance of success in their survival. This is a very important factor in the game since it is designed to simulate the adaptation and coexistence in an environment of different animals and see their relations and chances of survival.

#### 1) The code

The genetic algorithms are mainly based on the existence of intrinsic information of an individual's population, this information is the genome.

A genome is a set of grouped values known as chromosomes; this set of heats contains all information of what the individual is and, so far, it doesn't change from his birth to his death.

Within the nomenclature used by biologists, they refer to the genome in two terms: one is the phenotype or genome that is used to combine at the stage of reproduction and the other is the genome that has a mature individual. Generally they should match but because of the interaction with the environment they can cause alterations in the genotype or phenotype that make the individual to show altered characteristics compared to the rest of their kind. These alterations were tested in 1901 by Hugo de Vries in a study work about the offspring of a plant called *Oenothera*

*Lamarckiana* when he realized that there were giant individuals. These alterations are known as mutations and represent a sudden change in a part of the genome.

```
BEGIN /* Simple Genetic Algorithm */
  Generate initial population.
  Compute the individual's evaluation function.
  WHILE NOT Finished DO
    BEGIN /* Produce new generation */
      FOR Population size/2 DO
        BEGIN /* Reproductive cycle */
          Select two individuals from the previous
          generation, for crossing (probability of selection
          proportional to the evaluation function of the
          individual).
          Muto two descendants with some probability.
          Compute the evaluation function of the two
          mutated descendants. Insert the two mutated
          descendants in the new generation.
        END
      END
    IF population has converged THEN
      Finished:= TRUE
    END
  END
```

Figure 5 Simple Genetic Algorithm

The changes that occur by mutations in the genome are transmitted only if they are in the phenotype since it is the one that the parents combine.

A change in the genome by a mutation is a change that will be manifested throughout generations and generally they won't be shown from one generation to another.

A genome is represented by a chromosome that the standard model of Simply Genetic Algorithm shows as series of ones and zeros but for us it will be a set of real values from 0 to 100, these values are consistent with the values that animals have and also measures their level of alignment with the current environment.

As we see the Simple Genetic Algorithm is based on series of functions (see Figure 5) that have been adapted to create *EvoWild* as follows.

In *EvoWild*, we have isolated the functions of the reproductive cycle and we have implemented them at the stage of the animal reproduction, this way these animals will have a conduct as close as possible to conventional animals.

When an animal decides to reproduce, it looks for a couple in its environment and in the case that there are more than one it chooses the best suited one. It knows this information because when you create new animals you give them a score in the "evaluacionCriatura" attribute.

Once the couple is selected, we call "reproducirse()", this function uses the genome of the couple to call "parir()" where all functions of Simple Genetic Algorithm are performed.

In *EvoWild* "parir()" (see Figure 6) is the main function of the genetic algorithm because it creates two new genomes for the two offspring (in this version only two offspring are created), the genome of the mother and the genome of the father are mixed, later with little likelihood the genomes of

the offspring mutate and finally, it's left to chance the election of the sex and the genome of each animal during the creation of new animals that are inserted into the game.

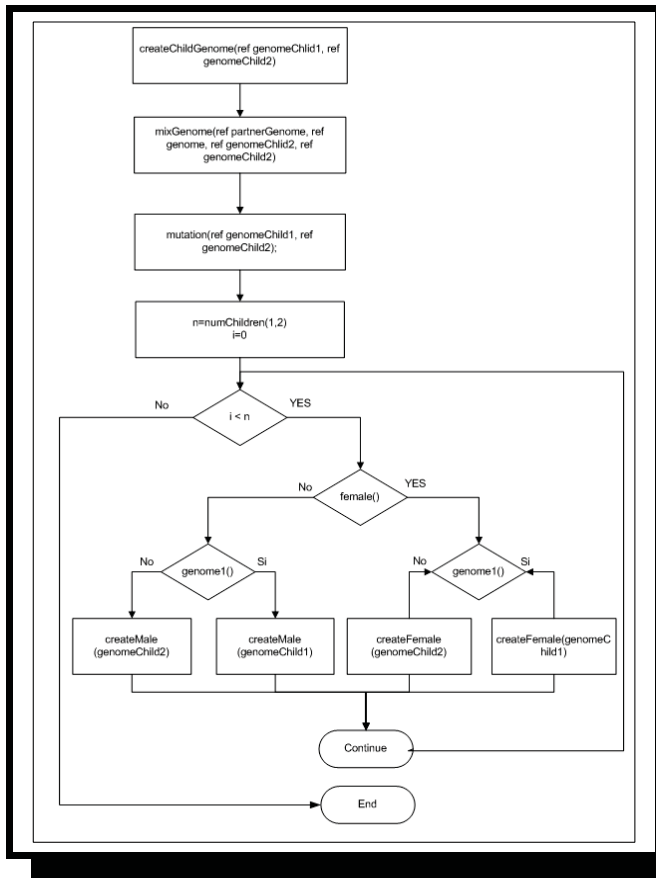


Figure 6 giveBirth() function

In this function, “parir()”, as we have mentioned before the genomes mix. In order to get that, it follows the procedure below.

- The genome is a list of numbers that a parent brings.
- To mix them we choose a position of that list at random, this position divides the list into two sub-lists. One of them will be the head of the genome of one of the sons and the other will be the tail of the list of the genome of the other.
- With the same position, the genome from the other parent is divided into two sub-lists, first and second. The first list will form the top of the list of the genome of a child who earlier got the tail and the second one will be the tail of the child that got the head on the step before.

We already have two strings of genomes that combine the characteristics of their parents. Now, for features to change a little bit and only occasionally, we apply a mutation to the genomes of the two children. This mutation will be applied for each item in the list, but only when they draw a probability over 95%.

### C.Reasoning Based on Cases (RBC)

It represents the way of thinking and reasoning that animals have against different problems throughout their

lives. RBC systems are based on solving problems using experiences from the past; the overall process of a RBC system is represented in Figure 7. The key concepts of any RBC system are:

- Problem: An adverse situation for which we must give a solution.
- Context: It's the set of circumstances in which the problem takes part.
- Case: It's a problem including its context.

The process that RBC uses to find the solution is:

1. It describes the problem and its context.
2. It recovers from memory a similar problem using the context to select it.
3. If there is a similar case, its solution is proposed as a solution to the problem.
4. If there is no similar case, it tries to give a new solution.
5. In either case, the solution is reviewed in order to see if it was the expected one.
6. Whether it is or it is not the solution, it is stored to be used as a case for subsequent experiences, it becomes a case learned.

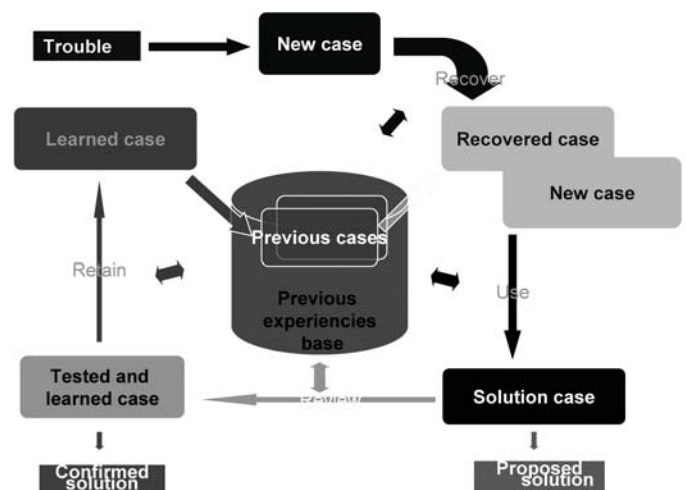


Figure 7 RBC

As we can see, the most important point about RBC algorithms is to identify a case and its context because the context is what helps us to apply the algorithm in similar situations. Since EvoWild has very well-defined the RBC contexts it's an easy way to give the creatures an apparent form of thinking and reasoning.

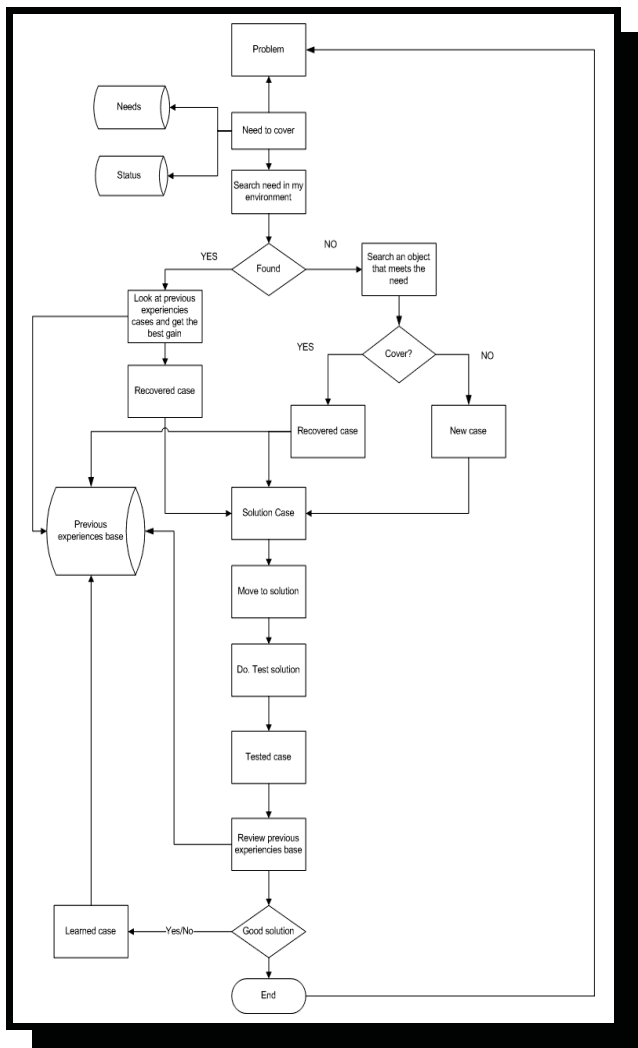
The creatures that live in EvoWild have the peculiarity of being able to remember and somehow to think their next action, leaving little room for decision-making by chance.

Creatures of the game move according to a motivation. In the case of EvoWild the main motivation is the need, either to meet shortfalls as thirst or hunger or to flee looking forward to survive when they receive attacks from other creatures, in both cases they use learned behaviours from their past.

To prevent the movement of the creatures by the board are the product of chance or random as we have implemented RBC algorithm reasoning and making some decisions of the creatures, such as when a creature detected several objects in

their field of vision RBC used to identify who they are and make a decision that gives you more benefit, as seen in the algorithm decision see title .

The proposed solution for the CBS in EvoWild is the next:



**Figure 8 RBC in EvoWild**

## VII.CONCLUSION

In EvoWild we have done an approaching task from real-world to computer-simulated-world with a good grade of accuracy; this has been possible because we have used two of the most typical algorithms in AI, even though we have implemented simplified versions of both.

The main conclusion we can draw is the power that this programming technology is able to provide for resolving everyday selection problems and everyday searches with a reasonable cost.

Taking a look at the long history of AI and potholes that

have been mainly due to lack of technological resources, another conclusion is that, it seems that nowadays and not long ago, it is the right moment to begin a profitable deployment and development in most of the fields in which it can be used any type of resource related to new technologies.

## VIII.FUTHER WORK

Perhaps one of the most interesting areas for development in the future would be to try to have a set of models of ecosystem and to be able to test each of the developments under same conditions.

Another pending point would be to study different types of solutions after making some changes in the model. It could be used as a preventive system of what can happen IF.

It also could be very interesting to make creatures able to adapt themselves to local conditions, changes in eating habits, temperature, radiation...

## IX.THANKS

We would like to thank Jesus Soto, Professor of the subject of AI in the Computer Science Faculty at the Pontifical University of Salamanca in Madrid, the help and advices he gave us, with whom it has been possible the adventure of to creating a game that incorporates AI.

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# Intelligent Garbage Classifier

Alvaro Salmador, Javier Pérez Cid, Ignacio Rodríguez Novelle

**Summary** — IGC (Intelligent Garbage Classifier) is a system for visual classification and separation of solid waste products. Currently, an important part of the separation effort is based on manual work, from household separation to industrial waste management. Taking advantage of the technologies currently available, a system has been built that can analyze images from a camera and control a robot arm and conveyor belt to automatically separate different kinds of waste.

**Keywords**— Waste management, computer vision, object detection, object classification, robot control, robotics, recycling, garbage classification.

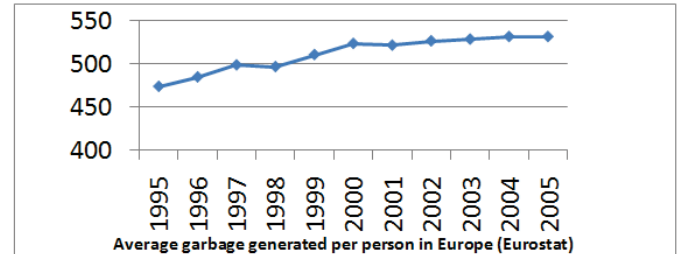
## I. INTRODUCTION

The environmental problems and its treatment go back to the 15th century. Till then the rural society had not exceeded the capacity of the nature to be regenerated. It was necessary to wait until the 60s and 70s in order that the world began to arouse seriously on the real scope of the problem. The conference of Stockholm of the United Nations supposed a historical milestone, since it demonstrated for the first time the world worry for a problem related to the ecology. From then on, they did not stop repeating similar national and international manifestations. But it was in the 80s when the world realized the real problem: the migration of the field to the cities.

To work correctly a hectare of city needs hundreds of Ht of sea, rivers, forests and fields. In the last two centuries the world population has increased unstoppably, passing from 1 billion inhabitants in 1800 to more than 6 billion today. This situation has gone, undoubtedly, accompanied of a growth of the energetic consumption of 6,000 %.

At present, many countries and organizations carry out and support measures to correct the long-term situation. Is necessary to stand out the European model, which uses its power and representation to impose environmental obligations both to the member states and to the companies that act inside the area of the European Union. Among these obligations it emphasizes taking responsibility of the generated residues, being based on the principle: “the one who contaminates pays”

In spite of these efforts the problem of the accumulation of residues is still present. The average European generates 517 kilos of garbage a year. The immense majority of these residues will end up by being deposited in dumps or being incinerated. Only a small percentage will be destined for the recycling.



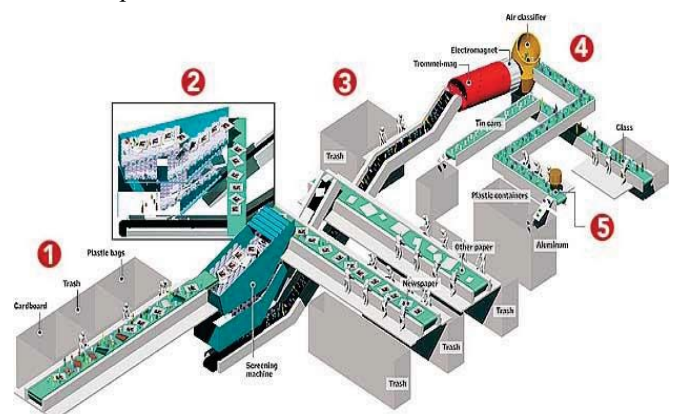
Meanwhile, 100 million tons of residues accumulate in the pacific forming a real soup of waste that doubles the surface of the USA.



## II. STATE OF THE ART

The first step in the separation cycle is at home, the people should separate the garbage in different bags. The following step is to collect all the waste to a big recycling plant, that will complete the process of separation. And last the treatment and return of the materials.

On the image below we can appreciate the methodology of current separation.



Both automated sections are in the top right. The first one consists of a red pipe which is a big magnet, its function consists of separating the metals. The yellow pipe it is a blower, it is in charge of separating the papers. The rest of the

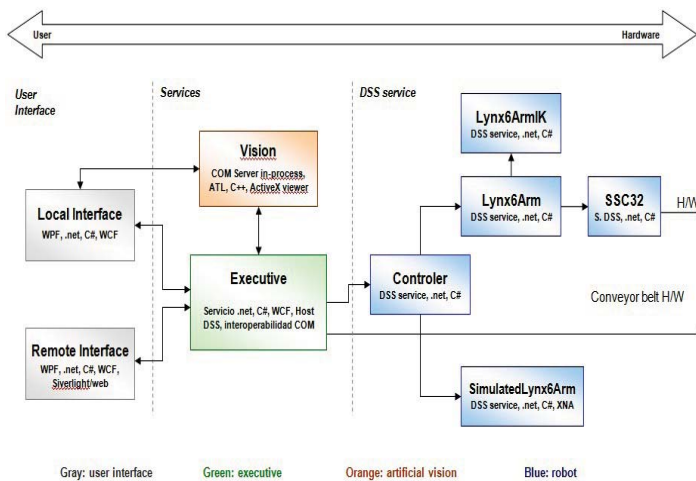


process, as we can see, it is workmen who perform manual classification.

### III.SYSTEM DESCRIPTION

The system separates inorganic elements using four different components: webcam vision, robotic arm, user interface and conveyor belt.

The elements are placed on the conveyor belt that moves them up to where the webcam is, the webcam is in charge of telling the conveyor belt when to start and stop. Once the object is right under the camera, the system will analyze the image and determine which kind of object it is, and its shape to tell the robotic arm the coordinates for picking it up and placing it in the appropriate container. All this can be monitored and controlled from a very friendly user interface.



### IV.CONVEYOR BELT

#### A.Mechanics.

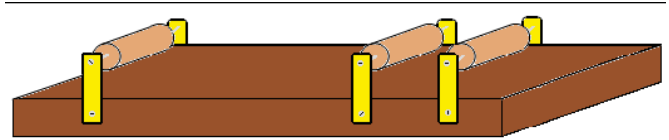
It is a conveyor belt witch speed is going to be controlled from the PC, across the port series connection.

First the belt was cut by 200cm x 17cm. The ends joined sticking them with glue, leaving a total length of 97cm of usable surface. Later on we applied a hand of black painting.

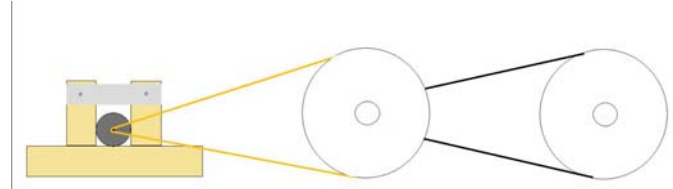
Three strips of wood of cylindrical form and fluted for a better grasp are the managers of doing of axes. Every strip measures 38cm approximately.



Later with a few metallic sheets the strips joined the table



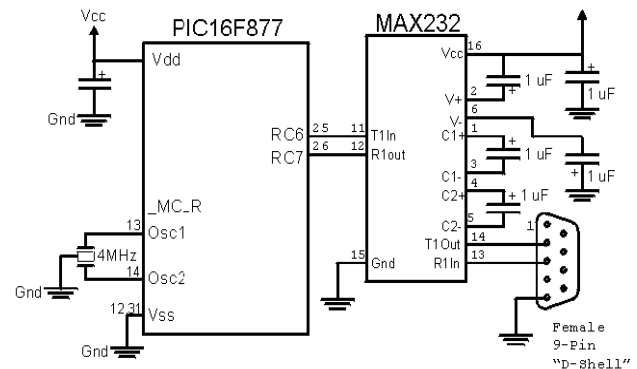
The following step in the assembly is connecting the engine and building a system of wheels of rubber smoothed by the center to create a rail to be able to insert the strap.



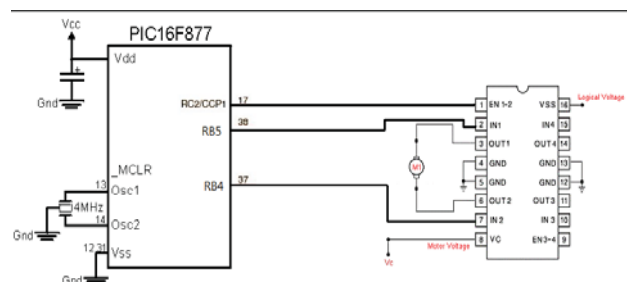
In the left part of the image we can see the engine attached to a structure of wood that was build to hold the engine and avoid any movement.

#### B.Electronics

The electronics consists of two modules, the first one is the connection between the PIC 16f877 and the CI MAX232, which will be the module entrusted for the serial connection and the second module that connects 16f877 with the Driver L293b who will take charge of handling the direct-current motor.



This is the scheme to obtain a correct connection with the PC. The ports of the PIC 16f877 numbers 25 and 26 are in charge of the transmission and receipt of information, in addition these ports are special since they allow the use of the USART to be able to do synchronous or asynchronous transmission of information.



This is the scheme to make the engine work. To control the

speed it uses the port 17 of the PIC. To control the direction of the engine it uses ports 37 and 38. The driver L293b will be the manager of transforming the possible combinations into movements for the engine.

#### V.ROBOTIC ARM

The robotic arm divides in two clearly differentiated dimensions:

We have the physical dimension, with rigid pieces that simulate the human bones, and servo engines that realized the function of muscles and joints.

We also have the logic, or what a nervous system would be, which will give the orders to all the engines to shape a certain position and to behave as a human arm. This nervous system has been programmed by Microsoft Robotics Studio.

##### A. Microsoft Robotics Studio

Robotics Studio is an environment to create robotic applications in a simple way. It's designed to work with the majority of robots and devices on the market. A robotic application in Robotics Studio it's a group of coordinated and independent services that work and communicate with each other.

Let's imagine the example of an application for the control of airbags. We might have a service in the bumper that was detects impacts and sends messages to report about them. The bumper sends this info to the switchboard which only takes care of deciding the right airbag for that signal and the transmission of it, finally the airbag's functionality will only be to inflate whenever it receives a signal. Each one is and independent and relatively simple service but the coordination of all produces the wished effect.



It is necessary to emphasize some of Robotics Studio's principal components:

The Concurrency and Coordination Runtime (CCR). This allows the services to work simultaneously without creating conflicts. If the services were the traffic of a city, CCR would be the system of traffic lights and signals.

The Decentralized Software Services, which entrusts the proper communication between the different services. In regard to the previous car/traffic analogy, DSS would be the regulation and legislation of driving.

There are other components of minor relevancy but equally useful like AGEIA's physical simulation, which allows us to test with virtual models (great to avoid crashing electronics), and the visual environment (VPL) that allows the construction of applications without a big knowledge of programming through a very friendly user interface.

##### B. Robotic Arm services

To make the robotic arm move in the desired direction we need five services:

Controller is the service that handles the other services. It

will receive the orders of the executive, and transform them in signals for the other services.

Lynx6Arm is the service for controlling the arm; it contains the logical structure and architecture of the arm with all its components and capacity of functioning, it will take care of the limits on all the variables and orders the service SSC32 to execute them. This service is directly connected to the Control service Lynx6ArmIK is a service that contains functions of utility for Cartesian three-dimensional coordinates in angles of the joints transformation, is a support service to Lynx6Arm. SimulatedLynx6Arm is a service for simulation, is analogous to Lynx6Arm and is signed to the messages sent to this one, so that it imitates all its movements. The simulation provided by Robotics Studio is based on XNA. SSC32 is the service that deals with the communication with the control hardware of the robot, it's the one entrusts to construct the necessary orders and to transmit them to the circuitry of the robot.

#### VI.USER INTERFACE

Thanks to the use of the new technologies as WPF (Windows Presentation Foundation) there can be created among other things rich and really interactive User's interfaces. In IGC the user has an interface developed with WPF that follows the lines of design of Microsoft Office and Visual Studio. The interface divides in 2 clearly differentiated sections:

- Area of menus: where the user has all the options that as well as all the actions that he can realize with IGC. Organized strategically with the aim, that the user always has to scope all of his options.

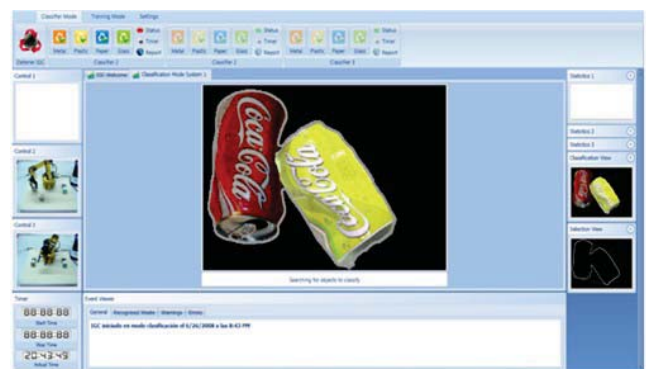
- Area of work: where the user arranges all the information that he needs on the task that is being realized.

From the point of view of the functionality of the system, it offers 3 manners of functioning:

- Way of Classification: where the user sees the system work and classification it shows the images directly from the camera..

- Way of Training: where the user can train the system to add new objects that he wants to classify, in an easy and simple way. The interface puts to his disposition in the central panel, a window that shows him not recognized objects, in order that the user with a simple click could typify.

- Way of configuration: where the user can prepare the system.



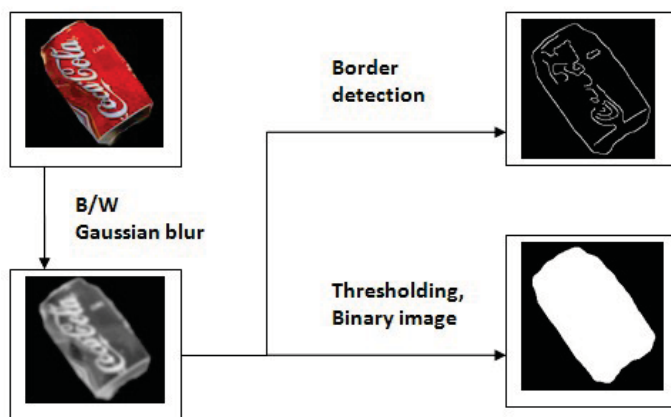
## VII.COMPUTER VISION

IGC's aim is to analyze images captured by a camera in order to identify and classify different kinds of objects. We use a combined approach that utilizes several algorithms in various stages, in what constitutes a demonstration of the maturity of the technologies and methods we leverage for a particular application: classifying objects for recycling. The objects we classify are of four different kind of food and beverage containers, depending on material – metal, glass, plastic and paper. We thereby demonstrate the effectiveness of the system in a particularly relevant practical situation, as most garbage classifying facilities still use human labor to classify some kinds of residues. In order to properly classify the objects, we need to isolate them from the background and somehow characterize them. The most relevant characteristic we have considered and have decided to use is the objects' shape, so the system can recognize objects by their shapes in a similar way as humans do. After this training, we can characterize an arbitrary object and compare it to known objects in order to determine what type of object it is.

### A.Segmentation

The first processing step (segmentation) involves distinguishing objects from the background and from other objects. In this step, quite generic image processing methods are used, namely:

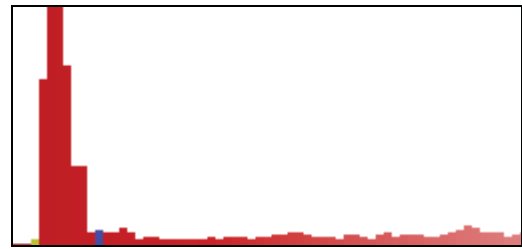
- Border detection (Canny algorithm)
- Thresholding to isolate from the background and eliminate noise
- Gaussian blur to soften details and filter noise
- Conversion from color to black and White and binary image, use of the saturation channel to help find borders
- Contour detection in binary images to analyze objects separately



#### 1)Thresholding

There are several alternatives for thresholding:

- Analysing the histogram
- Using fixed values
- Otsu algorithm



Histogram example: pixels with low values (left) have been detected as the background distribution. Details (right) vary much more their value/intensity.

Otsu's algorithm consists on dividing the pixels in two classes or clusters, using a threshold value calculated as the one that provides the highest variance intra-class, defined as the weighted sum of the variances of each cluster:

$$\delta_{\text{intra}}^2(T) = n_B(T) \cdot \delta_B^2(T) + n_O(T) \cdot \delta_O^2(T) \quad [1]$$

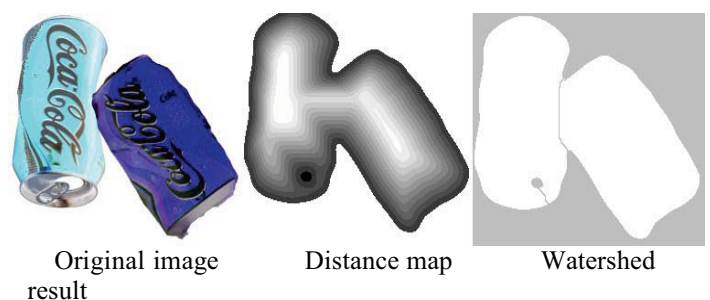
Where  $n_B$  y  $n_O$  are the number of pixels below and above the threshold, and  $\delta_B$  y  $\delta_O$  their variances, respectively.  $T$  is the threshold value chosen.

An interesting variation we use, consists on considering only the pixels near the borders (detected with another algorithm), so the thresholding thus applied tends to maintain the separations on that borders.

#### 2)Watershed segmentation

Even if the objects to be analysed have been separated from the background, it's still possible that some of them are in contact, so it is necessary to separate them. In order to do this we use watershed segmentation.

Watershed algorithms [1], [7], [5], consist on processing the binary image to build a distance map to the object borders (that is, the value each pixel whose value was one becomes its distance to the nearest zero pixel), and then progressively filling each level from chosen seeds so that when different seeds finally meet, a barrier is established to create a separation. As the name watershed indicates, it's like filling lakes with water and putting a fence when two masses of water touch.



### B.Characterization

In order to classify objects by shape, which is our objective, it will be first necessary to characterize and abstract that shape in some form we can mathematically operate and compare [5], [8]. We use two such shape descriptors: Hu moments and Fourier descriptor.

### 1) Moments

Moments of an image are magnitudes of the form:

$$m_{p,q} = \int \int x^p y^q f(x,y) dx dy \quad [2]$$

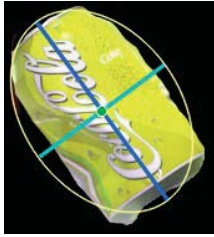
Where  $p$  and  $q$  indicate the order of the moment and  $f(x,y)$  is the pixel value at coordinates  $(x, y)$  in the image [4], [6]. The name moments comes from its similarity to inertia moments of solids.

Cetral moments (referred to the center of the object), can also be calculated:

$$\mu_{p,q} = \int \int (x - x_c)^p (y - y_c)^q f(x,y) dx dy$$

As well as normalized central moments,  $\eta_{p,q}$ , which are normalized using the area of the object.

The values thus obtained are particularly useful to characterize and reconstruct certain features of the analysed image, such as its center, semiaxis, area, orientation, etc. This will be very useful for us to determine the objects orientation and position in order to move it by mechanical means.



In addition, several of these moments can be transformed into seven values which are invariant to rotation, translation and scaling, which are Hu invariants [4]. We use them to characterize the object's shape from its binary image:

$$\begin{aligned} I_1 &= \eta_{20} + \eta_{02} \\ I_2 &= (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2 \\ I_3 &= (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2 \\ I_4 &= (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \\ I_5 &= (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \\ I_6 &= (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}) \\ I_7 &= (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \end{aligned}$$

As we are also interested in the object's size, we can add an eighth value representing its size –be it area or elongation –

in order to achieve the final characterization that is an 8-dimensional vector.

### 2) Fourier descriptor

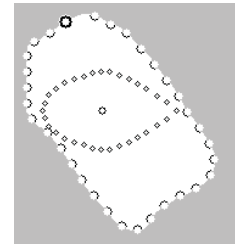
For this characterization, the contour of the object is transformed into a Fourier function whose parameters will characterize the object as an  $n$ -dimensional vector (the number of dimensions depends on the detail chosen) [3], [10].

There are several ways of doing the transformation and point sampling from the contour (polar coordinates, Cartesian coordinates, first derivative, etc.). In our case, based on favorable results obtained [3], we use complex numbers to represent Cartesian coordinates of shapes and transform them with a discrete Fourier transform (DFT).

The sequence of  $N$  complex numbers,  $x_0, \dots, x_{N-1}$ , is transformed in the sequence  $X_0, \dots, X_{N-1}$  according to the formula:

$$X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} kn} \quad k = 0, \dots, N-1$$

In order to make the  $X_k$  coefficients invariant to rotation and translation transformations,  $X_0$  is eliminated and all other coefficients are normalized by  $X_1$ . In this manner, the vector that finally characterizes the shape is of dimension  $N-2$ . We have chosen the minimum value of  $N$  that allows for an effective characterization of the object.



### C. Learning and classification

In order to classify the characterized objects, it's necessary to compare them to previously known objects. We do so by searching points in the  $n$ -dimensional space corresponding to a certain image descriptor which are close to the image descriptor of the object we want to classify.

The simplest and probably most effective classifier for this problem would be a  $k$ -nearest neighbours classifier ( $k$ -NN). This algorithm finds the  $k$  nearest points to the one we want to classify and thus determines that it belongs to the same class most of those  $k$  points belong. Taking into account our classes can be quite heterogeneous (overlap, samples quite far apart and so on), partitioning algorithms like SVM are probably not a good option, so we have chosen an improvement on  $k$ -nn.

After both classifiers (Fourier descriptor and Hu moments) provide the distances to known classes, a set of fuzzy rules decide in which class to classify the object.

### 1) HKNN algorithm

Even though the  $k$ NN algorithm can be effective enough, we use an improvement of that algorithm, *K-local*



*hyperplane nearest neighbours* (HKNN) [9], which generates a local hyperplane for the  $K$  nearest neighbours of each class and then compares the distances to each one of the hyperplanes in order to determine which class is closest.

The advantage of this algorithm is that it “fills” the gaps in space that are not covered by sufficient samples gathered for a particular class. Nevertheless, in some cases it can happen that the point is very far from the sample points of the class but very close to the hyperplane. Because of this another parameter apart from  $K$  is introduced,  $\lambda$ , in order to penalize moving away from the centroid.

Formally, the local hyperplane of a class can be defined as:

$$LH_c^K(x) = \left\{ p \mid p = \sum_{k=1}^K \alpha_k N_k, \alpha \in \mathbb{R}^K, \sum_{k=1}^K \alpha_k = 1 \right\}$$

where  $c$  refers to the class,  $K$  is the number of points and  $N_k$  is the vector for each local point.

## 2) Mahalanobis distance

This method to find out the distance between two points is particularly useful for our Hu moments descriptor, as this method adjusts each vector component based on the statistical variation of the samples. Classes can be better separated in this fashion [2]

Given the matrices  $\mathbf{X}$  and  $\mathbf{Y}$  as the column matrices corresponding to the vectors of two different points and having a co-variance matrix  $\mathbf{C}$  for the samples' distribution, then the Mahalanobis distance  $d$  between  $\mathbf{X}$  and  $\mathbf{Y}$  is:

$$d = ((\mathbf{X}-\mathbf{Y})^t \cdot \mathbf{C}^{-1} \cdot (\mathbf{X}-\mathbf{Y}))^{1/2}$$

This method seems much less useful, on the other hand, for our Fourier classifier, as the covariance matrix in that case is huge and almost degenerate in most cases, which can cause problems with the numerical methods used (namely, Cholesky and LU factorization), besides it makes no sense to apply it to the Fourier descriptors, as the importance of each dimension decreases as the order increases (low-frequency versus high-frequency –small details- wave components).

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## VIII. CONCLUSION

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Recycling is paramount for the preservation of the environment. Leveraging the latest technologies in computer vision, robot control and other fields and taking advantage of their maturity, a system has been built that makes it possible to visually classify and separate different types of waste effectively, a task that would normally require manual work.

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# Software fires detection and extinction for forest

Nuria Utande González de la Higuera and Juan Carlos García Seco

**Resume - This article shows the most usual fire detection and forest extinction application technologies at present. We will see all different methods used by these applications that can be found in the Market and some examples. Also, some basic questions about the most influent parameters when a fire must be extinct are shown. Finally, after having shown all the technologies, we will build a model about an intelligent system which not only detects, but also extinguish wildfires.**

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## I. INTRODUCTION

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Nowadays, Wildfires are one of the most important environmental problems in Mediterranean countries. Yearly, thousand of yards are affected by this problem. In the last few years many projects related to wildfires have been carried out with the same goal: reduce the effects that a forest fire causes. And the trend continues, these projects are becoming more sophisticated and are integrating the latest technology that exists in the market.

Most of the projects are dedicated to wildfire detection through image processing and neural nets systems so it allows that forest fires can be monitored, with several predictive models of fire behaviour.

Secondly we will show different methods which are the most used to detect forest fires actually and also examples of projects that use these methods.

Thirdly, how main factors can determinate the extinction of a forest fire and how those data can be treated automatically to integrate them in a software.

Finally we describe the prototype that we want to develop, trying to give details of the technology used and answering why it has been chosen.

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## II. WILDFIRE DETECTION

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It is important to monitor mountains and forest using an efficient, quick and precise system of detection at the beginning of a forest fire and its location. An expensive system to extinct a forest fire depends on how quickly detects the fire and set up the initial action or soon-attack. In this way we can be surprised if before they grow out of control, if it is not so, it is very difficult and dangerous to extinct it.

*They spend lot of time determining the exact point, so that the system can provide any information necessary for the operation of automatic choice, in order to get an immediate action or soon-attack*

The objective is to detect a possible outbreak of fire and to determine its extension as quickly as possible, as well as determining the exact location thereof.

Currently there are different types of technologies being used for this purpose. They include the use of infrared cameras and satellite imagery and the use of a geographic information system (GIS).

### III.A. Detection using infrared and optical cameras:

[12] The objective is to monitorize the forest area and the

automatic detection of fires as well as the exact location of the fire, using infrared and optical cameras. These systems usually consist of a central oversight monitor, a unit for images processing and surveillance towers distributed by the ground. Each surveillance tower usually has the vision of the infrared camera and another television located on a device capable of moving horizontally and vertically, so that it provides the cameras a 360 degrees vision over the monitored area.

The cameras send recorded images to the image processing unit and from this one; a possible fire can be detected using the images that had been sent.

When a fire alarm is detected, automatically the camera detects the fire and stops in its position. Then the alarm will appear on the screen, warning the people that manage the control point. When the person in charge of the central alarm verify that it is a real wildfire, we will launch the established action protocols.

### System Forest 99:

[9] The software that uses this type of cameras is the "System Forest 99" developed by the local company Baeza and implemented in Andalusia. It became operational in the "Infocid 2000" campaign.

This system is based in the use of infrared cameras to detect forest fires and it is activated when an alarm is set in motion a plan of attack. In order to get a quick detection and to obtain the maximum effectiveness of the system, this system consists in a complex monitoring stations network and a good communication network, from which are controlled the high potential risk fire areas. Those are the ones with more trees and that ensure both a correct vision of a large area, as an optimum link of communications.

To sum Forrest System 99 provides the following improvements:

- Exact location of the source of heat.
- Avoid false alarms.
- Improve night vision compared with that made by a person.
- Produce a deterrent effect.
- Contribute to decision-making in extinction.

### System for early detection of forest fires:

[11] Developed by the company INVAP for the Prevention System and combat forest fires in Mexico.

This is another example of a forest fire detection system based on optical and infrared cameras. It would allow the immediate detection of fires outbreaks, because the scheme will be implemented in a systematic sweep with the possibility of halting the movement and amplifying the image so it can locate any potential fire hazard.

This system provides interesting developments because it has installed a system that collects meteorological data (atmospheric pressure, relative humidity, temperature, wind

speed and direction, rainfall and dew point) that is very important to determinate a good plan of attack against the detected fire.

In addition, another technology developed is a safety device against vandalism. Its function is to detect the presence of people in an area near the remote station. Because of this, it is equipped with motion sensors and fixed black and white cameras. The signs and pictures of the device will be forwarded to the board of command and control.

#### *Service fire detection Orange:*

[6] Orange is developing a system to detect fires using the mobile phone network. This is again the same idea, detection based in infrared detecting outbreaks heat, but transmitting in the mobile networks.

They have developed some specific devices for natural environments for this project. They have temperature, infrared and ultraviolet sensor, which are interconnected by Wi-Fi or GPRS. These devices will be placed some distance and transmit data over the GSM / GPRS network to a server. The information can be viewed on a website that generates alerts, reports and graphs.

#### *IV.B. Detection from satellite images:*

[10] Forest fires are clearly seen from the heights of Earth orbit. In addition to the columns of smoke, sensors installed on satellites, which are used for this kind of projects, can "see" the infrared heat emitted by themselves.

The detection systems of wildfires through images collected by satellites are the most novel. Both NASA and the European Space Agency are using this technology in their detection projects.



Figure 1. -- Envisat satellite --

Figure 1 taken by Envisat satellite. The image corresponds to a forest fire occurred in California.



Figure 2.-- Envisat satellite --

Figure 2 captured by the satellite Envisat, corresponds to the fires in Galicia and Portugal in 2006.

The satellites measure the infrared radiation emitted by the Earth to detect the temperature at the earth's surface and produce maps with "hot spots". When the satellite detects a temperature above the 38'85 ° C interprets that there is a fire. In Spain remote sensing is used for fire prevention for several years

#### *FireRisk Project:*

[2] [4] This project is developed by the Alcalá de Henares University (Madrid, Spain).

The project aims is to develop an operational methodology to evaluate the risk of wildfire as well as its integration into valid documents for the work of forest management. To get this, along with more traditional methods of spatial analysis, is suggested the use of new technologies such as remote sensing and GIS. It uses the information that different space observation satellites give, but it needs other sources of information that will be mixed within a GIS.

#### *V.C. Detection from other methods:*

[14] A company of Vila-real (Castellon, Spain) has created a detection system based on laser methods assets. This system has two fundamental characteristics: the response time that elapses from when the fire is originated until the system is able to detect it (it is "very fast") and the ability to indicate the "real location of the fire along with its intensity or virulence". The main difference with infrared-based systems is that this system detects smoke columns, what makes a faster detection, while what the infrared detect is the heat.

#### *VI.D. GIS:*

A geographic information system is an assembly of hardware, software, geographic data and people, which is designed to collect and manage geographically referenced information in order to solve complex problems.

The functionalities are:

- *Location*: ask about the characteristics of a particular place.
- *Status*: compliance or not conditions imposed on the system.
- *Change*: comparison between temporal or spatial situations other than some feature.
- *Routes*: calculate best routes between two or more points.
- *Guidelines*: detection of spatial patterns.
- *Models*: generation of models from simulated events or actions.

In the field of forest fires are often working with satellites. Experiences show that this way of working has great potential in terms of prevention, monitoring, assessment and restoration.

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#### VII. EXTINCTION OF WILDFIRES:

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When it is necessary to make decisions during the design of the plan, must be also beared in mind a large amount of information about the characteristics of fire (weather conditions, topography of the land, fuel types), the available to the media, the coordination and communication with others units and centers, etc.

When designing the plan attack it should be taken into account factors affecting the spread of fire, and also the available ways to carry out its extinction, and with the entire information act in accordance with the needs of each case.

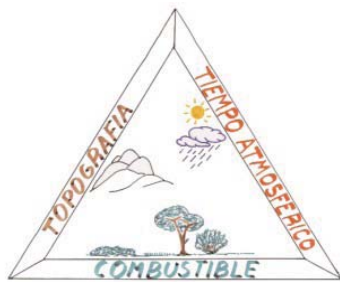


Figure 3 - Triangle of fire –

In Figure 3 are shown the factors that determinate the development of a forest fire, which are topography, fuels and weather. Each exerts influence over the other. For example, in the upper parts of ridges have more precipitation than lower and temperatures go down as it rises along the slopes.

Getting the environmental characteristics at the time of the fire, the fuel that is in the area and the terrain features that is affected by soil can help to "predict" the behavior of the fire and thereby maintain a more effective attack.

With the obtained data we must decide, which are the basic actions that need to be made first and the most appropriate method of extinguishing the fire, so it will be extinguished as quickly as possible.

##### VIII.A. Fuel:

It is necessary to characterize the combustibility of a zone, because the greater the accumulation of fuel in an area, the more heat may release and the more intense the fire could be.

Fuels should be classified depending on the type of fuel, the horizontal provision of fuel and depending on the vertical provision of fuel.

##### IX.B. Weather atmospheric:

The meteorological variables that influence forest fires can be classified into two groups: those affecting the start of the fire and those that affect the spread.

At the time of the fire extinction we must look the variables that affect the spread of fire. The wind is the decisive factor. Wind is a crucial element in the behavior of fire, often being responsible of the fire that overcomes the barriers of defense and the formation of crown fires that are manifested in virulent form.

##### X.C. Topographic factors:

Topography is the most consistent of the three factors and has great influence on the other two. There are three factors that affect in a very important way to the behaviour of fire:

-- *Setup*: it has a great influence on the wind, and it will affect at the direction and speed of the spread of fire.

-- *Exhibition or hillside position*: it has an important effect on temperature and relative humidity, in the development of vegetation that covers and in the humidity state of vegetables fuels.

-- *Pending*: topographic is the most important factor in the behaviour of fire. It influences the modes of transmission of energy doing that upstream, phenomena convention of radiation are more efficient. The more inclined the slopes are, the greater speed the fire spreads.

##### XI.D. Extinction Methods:

###### Direct Method:

If the fire is at its initial stage or has some features that allow act in the proximity of the flames, or water is available and ways to launch it, the fire can be attacked directly on to quell the blaze. With this method we can act mainly on two elements of the triangle of fire, heat and oxygen.

###### Indirect method:

It consists in isolating fuel the flames, establishing lines of defence in a right distance from the front lines, in order to circumscribe one or more perimeters to complete the stage of control.

This method acts primarily over fuel, removing it by strips or pouring chemicals that permeate the fuel and prevent or retard burning.

##### XII.E. Software:

###### SIDAEX:

[1] [15] It is a system developed by the Granada University (Granada, Spain).

They have created a computer model that reproduces the extinction of forest fires. It is capable of generate independently plans for extinguishing forest fires from existing data on land (the place where the fire was generated, environment, resources, etc.).

This system comprises a series of computer programs, including two: BACAREX, a data base which reflects the experience of the Plan INFOCA, and SIADDEX, a program capable of use data from previous plans to establish performance.

The extinction technician may access the system via Internet, using a desktop computer, a laptop or a PDA (a small digital device).

---

#### XIII. PROTOTYPE TO DEVELOP:

---

We want to develop a prototype of an intelligent system which is able to detect quickly a potential wildfire, and suggest the more effective attacks for its extinction.

This application must detect early a forest fire, activate the alarm, show an attack plan, and present the basic characteristics of the affected area.



For the early detection of a fire, the system will use webcams that will be located in the watchtowers. These images are transmitted to a server through an image recognition algorithm that will detect the smoke caused by a possible fire. So it should differentiate between smoke from a fire and smoke of an engine, dust, etc.

When a fire is detected, it can be known where it has led since each image comes from a camera that is uniquely identified. This is essential in order to set the exactly location with no errors.

To detect wildfires after exposing the most common methods that are used, we have opted for the web and infrared cameras, and not by satellite images. The first outbreak can detect fires in real time, while satellite images spend more time until is possible to detect a fire. We think that the use of satellite images is more appropriate for tasks of monitoring and tracking of a forest fire than for detection.

Also in each watchtower there will be installed anemometers (which will measure wind speed), electronic weathervanes (which will detect the wind direction) and thermometers (which will measure the outside temperature). When it detects a possible fire, the computer will require data from speed and direction of wind, and the outside temperature from the sensors. Those sensors will only transmit the information collected when the computer required the information.

The first-attack plan will be based on the application of bayesian networks to this problem, forest fires.

We need to know exactly all the circumstances of the land where the fire has been detected, such as topographical features of the terrain or weather conditions, or the fuel of the

area where the outbreak has been detected.

The exact location of the focus is clear from the location of the camera that has detected a possible fire. Each camera has an IP address associated. In addition to the exact location of each camera, it has certain parameters associated that characterize the terrain and vegetation that monitors. This way, when the server recognize a possible fire from an image sent by a camera, it gets the IP address of the camera that has commanded it, and we will know the location, topographical features and fuel is in the area.

We get the environmental characteristics from the sensors placed on the outside.

All this information feeds the Bayesian network, which must be able to decide the best attack based on the data provided.

Bayesian networks or probabilities are a graphical representation of units for probabilistic reasoning in expert systems.

When we talk about showing an attack, we mean that the application must show the available resources more adequate to quell the fire, such as water pumps, seaplanes, and so on. It should also suggest the best technique that can be used against that fire, and the exact location of where the fire must be attacked.

It should also show the characteristics of the terrain, such as the type of fuel, land topography, and meteorological factors as much detail as possible to minimize the time of recognition, and to organize the team as quickly as possible.

We think that it is need a smart system that detects the fire very quickly, but also can determine quickly which are the possible attacks to quell it. Thus immediately after detecting a

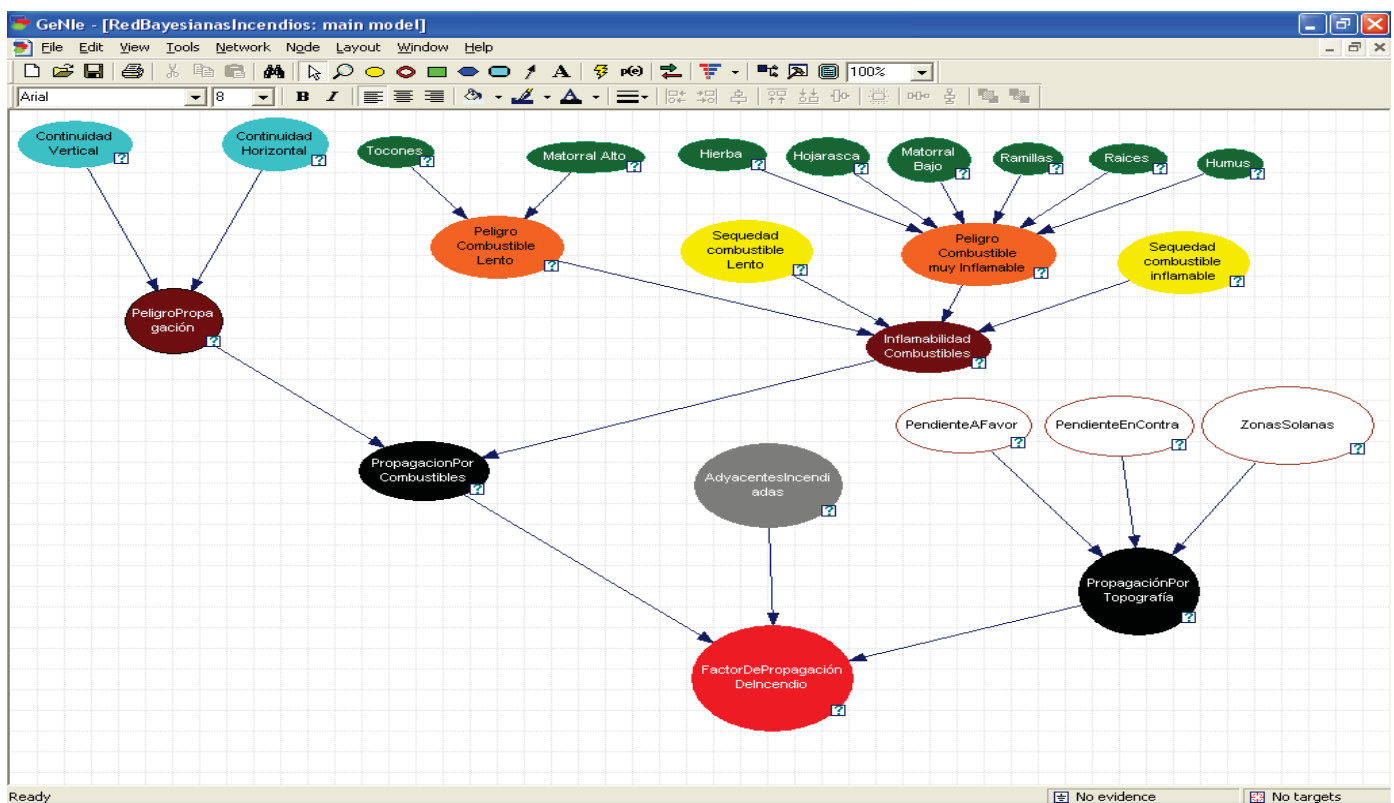


Figure 4 – Bayesian network

fire provide to forest officials all the features and facilities and the best plans suited to it extinction.

#### A. Bayesian Network:

A Bayesian network is a directed acyclic graph representing the cause-effect relationships between nodes.

Because of this, it is a good response to our demands. We can introduce as much nodes as we need, because the field characteristics and the effect will show us the danger degree that exists to spread a particular area of the watched land. To create our network we have used the Decision Systems Laboratory program from Pittsburg's University, which provides a better intuitive interface than other programs with the same technology.

As mentioned previously, our fire behavior model is as real as possible and there should be taken into account many terrain factors. Therefore in our network can be seen that we have included not changing the factors (topology and fuel) and how much detail as possible.

As it is shown in the figure 4, we have created a large network in which is introduced information about the amount of fuel, their dryness level and other topographical features of the terrain. Also it has been taken into account whether there was any area adjacent to submit fire on it, since this affects a very crucial at a more rapid spread of fire.

A green node are input nodes, and corresponds with one of the three factors of the triangle of fire we have seen previously (Figure 3). They enter the grade of fuel, quantity of the kind referred to in terno there. The fuels introduced into the network are:

- "Matorral Alto" (scrublands high)
- "Matorral Bajo" (Under scrublands)
- "Tocones" (Stumps)
- "Hojarasca" (Fallen Leaves)
- "Hierba" (Herb)
- "Ramillas" (Little Branches)
- "Raíces" (roots)
- Humus

The values that can take these nodes are:

- "MuyPocos" (Very few)
- "Pocos" (Few)
- "Medios" (Means)
- "Bastantes" (Enough)
- "Muchos" (Many)

Blue nodes represents the continuous fuel degree in two different aspects, one represents the continuous horizontal degree and the other continuous vertical one. They can take null, low, medium and high as input values.

Yellow nodes symbolize the dryness degree that exist both in slow fuel type as highly flammable ones. They are entry nodes, and their values can be little means or much. Gray nodes corresponds to other node cause, and indicates whether there are adjacent burned areas or not, and their input values can be yes or no.

White nodes correspond to topographic characteristics of the area. These nodes can be:

- Favourable slope: in the direction of fire.
- Against slope: against the direction of fire.

-- Sunny Area.

They can take null, very little, little, medium, high and very high values as input.

Orange nodes symbolize dangerousness fuel degree depending on the type of fuel in question. We have differentiated on the one hand the slow rate of fuel (which takes longer to begin to burn), and in the other hand the highly flammable fuel (with little amount of heat turned very easily). These nodes are nodes effects of green nodes, as output can take very little, little, medium, high and very high.

Brown nodes represent the spreading fuel danger, one effect of continuous and the other by dryness degree and quantity of fuel. These ones are effect nodes of blue and green ones respectively. Depending on the impact of each node can take effect on them as output values: very low, low, medium, and quite a lot. As an example of the effect it has on the nodes we see that figure 5 shows the table of values to be based on the input values. Discuss such that when the fuel danger, highly flammable fuels danger are very high and dry slow fuels and very much flammable, has a 100% chance the danger is very high for fuel.

Peligro Combustibles	Poco			Medio			Mucho			Muy Alto		
	Poco	Medio	Mucho	Poco	Medio	Mucho	Poco	Medio	Mucho	Poco	Medio	Mucho
Poco	0	0	0	0	0	0	0	0	0	0	0	0
Medio	0	0	0	0	0	0	0	0	0	0	0	0
Mucho	0	0	0	0	0	0	0	0	0	0	0	0
Muy Alto	0.1	0	0	0	0	0	0	0	0	0	0	0
Alto	0.2	0.2	0	0.4	0.3	0	0.2	0.1	0.1	0.01	0.01	0
Muy Alto	0.7	0.8	1	0.6	0.7	1	0.8	0.9	0.9	0.99	0.99	1

Figure 5 – Table of "InflamabilidadCombustibles"

Black nodes symbolize the two types of dangers that exist, on the one hand the fuel danger and other danger by continuity. The "PropagaciónPorCombustibles" node is the cause of the nodes effect "PeligroPropagacion" and "InflamabilidadCombustibles". "PropagaciónPorTopografia" node is the cause of "PendienteAFavor", "PendienteEnContra" and "ZonasSolana" effect nodes. Depending on the influence they may have their nodes effects on them; it may take as output null, low, medium, high and very high.

The last node remains to be taking is the red one. Red node represents the ultimate factor for the spread on the area that we are calculating the prediction. This node will determine the degree of danger of spreading to the area, whose output values may be invalid, very little, little, medium, high and very high. This node is the one that takes us back the final answer, which determines the degree of danger of spreading plowed this area and its probability.

#### B. Process simulation of fire behavior:

We divided the ground to monitor different areas that will form our territory on which we are simulating. To start the fire behavior simulation process you need to indicate the area where the fire began (in the final design would be given this post by the fire detection system, which would provide the

exact location of the fire) and indicate wind direction and speed (and collect the same data from a weather station located on the outside).

Once the fire has started, we begin the simulation process. The first thing we have done for each area of field is estimating its spread factor, and we transform the information for each area into understandable data for our Bayesian network. Once we have done this, we input the values into the net and it gives us the back spread factor of each area. When we finished making this process, we determine the areas that will be affected by the fire.

When we know the spread factor of each area, we must determine if the air is going to fire or not. At the moment influences the outcome of the Bayesian network, and the information captured from weather station.

For each area, the system checks the wind direction regarding the origin node, and it also checks the spread factor obtained as a result of the process that has generated the bayesian network. Depending on the type of spreading factor we must consult the speed wind, because when the spreading factor is medium, low or null and the wind speed is very high, it makes that this area sooner or later catch fire (we have reached this conclusion after conducting an investigation on the matter). On the other hand, depending on the length of the field and the wind speed, the system decides how long it will take to reach the fire to some or other areas.

When the process finishes and the system has obtained as simulation conclusion that this area is going to burn, the system adds the area to a list of areas on fire.

This process is repeated as many times as necessary, so that in the first pass, there is only one area origin of a fire, but as it repeats the process and are added to the list of AREAS burned areas, these are origin in the following areas past.

#### XIV.CONCLUSIONS:

With the above, we think that new applications that will be developed in the future in the wildfires area, not only should focus on early detection of fires, as well as they should add features such as the design of an automatic attack plan.

Furthermore we believe that with the diverse technology that we are provided of, it could be developed a very good application for early fire detection using different types of technology, and relying on each other. In order not having to decide if the application must be based on satellite images or based on web and infrared cameras, we think that it can be based on both, giving each its benefits.

We also consider important to study the possibility of providing a strategy to attack the fire so effective that will be unique to each fire detection, and to provide just in the moment when the fire is detected.

With an implementation of these characteristics combined with an effective prevention plan by the competent authorities, it could pose a significant improvement in combating forest fires trying to reduce the consequences thereof.

But we must not ever forget that there is no better strategy for fire fighting than prevention, and that is something in our hands.

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# Iris recognition using the JAVAVis Library

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**Abstract** --This project has been created to develop a biometric identification system through a man's iris using a computer to perform the processing of the pictures. To develop this application, and to differentiate the project from others who have already implemented, we have used the image processing library JAVAVis and JAVA as a programming language.

**Keywords** - - biometric, image, iris, wavelet

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## I.INTRODUCTION

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Biometrics is based on the premise that each individual is unique and has distinctive physical traits or behaviours, which can be used to identify or validate him/her. The Iris human structure is only one per person and it forms a very complex system unchanged during any person's life.

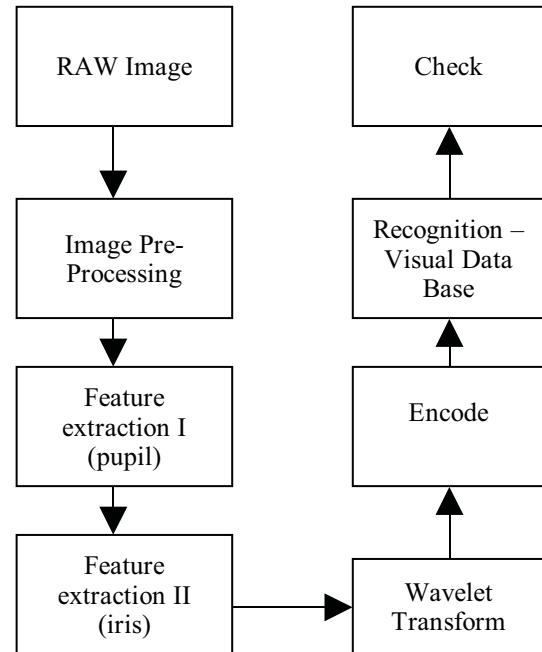
For several years the human iris has been using for user authentication. To this, an image capture is necessary. It must be transform into black-white ones, in an environment properly lighted, using a high-resolution camera.

Usually this is done by looking through the a fixed camera lens, a person simply positioned in front of the camera and the system captures the iris image, this image is processed to extract Biometry optical iris patterns, which in turn are subject to mathematical algorithms to produce a sufficient amount of data to identify ambiguously of the individual concerned. That is compared with another sample taken earlier and stored in the database system, so that if both match the user is considered authenticated successfully, the probability of a false acceptance is the lowest of all biometric models.

We start from the idea that in a future the application could be used by capturing images through a webcam, but now and ought to technical limitations, images prosecuted are .JPG files previously entered into the computer, which must have a high resolution to achieve a smooth running of the program. The image, of which we are referring to, is digitally processed to obtain a code that characterized it. They are used in the treatment pre- processing algorithms to enhance image quality and thus, extract higher quality information and therefore more accurate.

The code that characterizes an iris image is obtained by applying Haar wavelet transform type. The iris code is composed of 366 bits and thus obtained 1.5031x10110 different codes. Evidence of encryption algorithms have been conducted on internet images.

Phases for the recognition of the image:




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## II.PHASES OF THE IMAGE PROCESSING

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1. Capture the image.
2. Pre-processing image with the help of JAVAVis library.
3. Removing the area of interest.
4. Haar wavelet application.
5. Compare with codes from the database.

### I. Capturing the image.

At the beginning of the project and facing to a future that might be applicable and useful in a real way, there was talk of obtaining images with pictures taken directly to a person's iris with a webcam in real time, but the technical features that were necessary, and those that we did not have, what prevented. The final solution was to derived images from previously saved files on the computer with the extension .jpg





Fig 1. Photo of an eye in JPG format

## II. Pre-processing image with the help of JAVAVis library.

Once we have the eye image in a format in which we can work, we begin the most important phases in the processing of the image.

The first one is to give the image, obtained in color, in a 256 gray scale. This process is made in order to, in further phases, be able to stand out the most characteristic features of the image. For that, we use the function given by the java library in which the project is based on, FColorToGray. This function takes as input parameters the image that is going to be processed and the type of gray image, that is, if the image is byte, bit o real type. For our case, the image is in bytes. As output parameter, we will obtain the image converted in a gray scale.



Fig 2. Picture of the eye in JIP format

We do this with the help of a simple conversion:

```
JIPImage jipImage = jipToolKit.getColorImage(imagen.JPG)
```

Next, it will be necessary to apply a new filter called Median Filter. This filter is used to reduce the noise existing in the digital images, naming noise to any pixel value of an image that does not concern exactly with the reality. This happens most of the time when acquiring an image using an electronic capturing set, so noise acquired at the transmission stretch, due to interferences or errors in the bit information transmission, is needed to be added to that type of noise.



Fig 3. Photo of the eye converted to gray.

```
JIPImage imageGray = fColorToGray.processImg(jipImage)
```

Therefore, it is necessary the use of the FSmoothMedian function, returning the image with the edges of the two most prominent areas, even more emphasized, for them to be easier to be distinguished.

Now is when the first of the two binarizations made in the image is executed. The aim of the binarization is first, to distinguish the edges of the pupil so the values applied at the binarization exist exactly to emphasize in obtaining it, and second. To obtain the candidate circles that will be the pupil.

Binarization consist in delimiting through two values, the pixels that will have to be transformed in 0 (white) or 1 (black). These values have to be among 0 and 256, and are not inserted randomly because they are different for each image. To get those values it will be necessary to make the image histogram which is a function that represents graphically the intensity of the image pixel (gray intensity).

The obtained values are recuperated by means of the "observation" of the limit points where the values of the image are launched. When introducing these values in the binarization function, the image will get transformed into a black and white image.

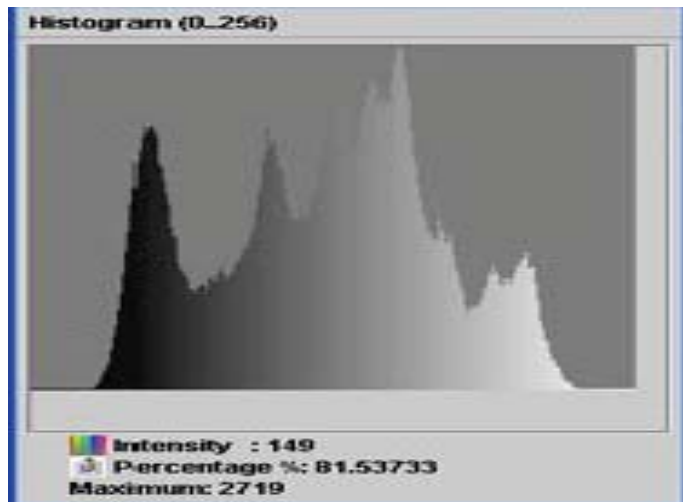


Fig 4. Histogram of the eye



Fig 5. Eye with the medium filter

```
FSmoothMedian fsmoothMedian = new FSmoothMedian()
JIPImage imgFiltroMediana =
fsmoothMedian.processImg(imageGray)
```

Now we can obtain the limits of the pupil well defined, because they are the ones that have been emphasized at the binarization. The eye pupil that is being processed will get totally white at the end.

To execute the binarization, the java library implements the FBinarize function, that gets a byte image and it is converted in a binary one (with 1 and 0 type values). The pixels which gray tones are among the given values, will get the value of "1", and the others, the value of "0".

Focusing again in the object of this first binarization, that is to find the limits under the pupil is positioned, we have to keep in mind that this binarization, having launched the function, will have obtained a "0" in each pixel of the pupil. Because this can occur in some deformed characteristic of the iris, we will understand that the pupil will be determined because, between the possible candidate circles, it will be the one with more radius, made entirely of white distinctives (100% white).

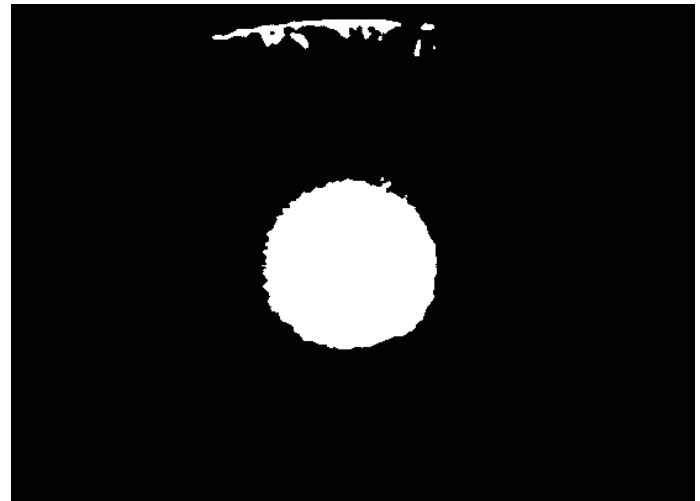


Fig 6. Binarization of the image to get the pupil.

```
FBinarize fBinarize = new FBinarize();
fBinarize.setParamValue("u1", min);
fBinarize.setParamValue("u2", max);
```

Also, we have talked about "candidate circles". Candidate circles are obtained from the image through the FHoughCirc function. This function obtains the number of circumferences of a bit type of the image using the Hough Transform for circumferences. It returns a Poly image with the "draw" of the image and two output parameters. In first place ncir, that is the number of circumferences found, and in second place, the circumstances, that are just a circumference type objects vector which contains their centres and their radius.

The input parameters are the minimum and the maximum possible radius of the circumference and the necessary number of votes to carry out the condition of being circumference. In our case, this number of votes is 32, which coincides with the number that the function takes by defect.

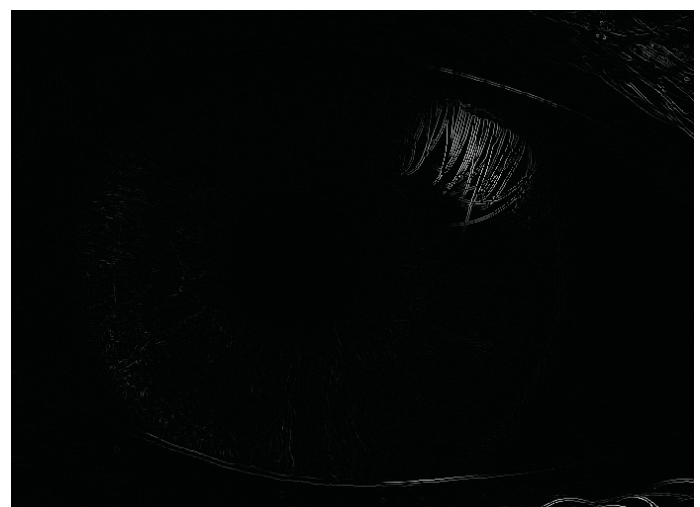


Fig 7. Image Canny of the iris.

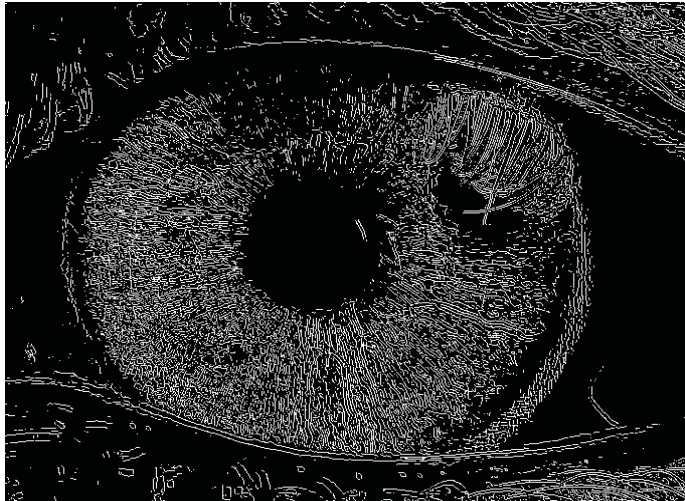


Fig 8. Final Image, where we will only take the iris part.

Considering that once made all these filters we will have the limits of the pupil, it is important to say that in an human eye, the "x" coordinate of the pupil centre coincides with the "x" coordinate of the iris centre, but doesn't occurs the same with the "y" coordinates.

It seems clear that the next step is to be able to distinguish the iris limits. For that, we make a new binarization to the initial image (once have made the colour to gray change filters and the median) with the difference that now we previously apply a new filter, the Canny filter.

Canny is a filter made to detect edges, which maintains vital criteria for the case that concern us. The first of them is the reliability in detecting points of outline.

Therefore, the image that will process in the binarization will have even more emphasized edges. As having said previously, binarization is a process that is made after obtaining the threshold values limited by the hestogram, but this time we will focus on values that stand out exactly in the opposite way that we wanted in the last binarization, in other words, we want the pupil becomes totally black, and enhance the important points, therefore characteristics of the iris.

Once made the image transformation to a bite image, we will use again the FHoughCirc function, in order to obtain the candidate circles, now, keeping in mind the data thatwe already know about the "x" coordinate of the iris' central point of the circle.

As well as with the pupil, with the iris the criteria is the same. It will be chosen the candidate circle which follows the condition of having the same "x" central coordinate as the pupil and the larger radius.

Once the two circles in which we are interested are localized and delimited, we take out the important circle that identifies a person, the one which corresponds to the iris, and the one whose top area limits with the obtained data in the last round, and the bottom area limit with the data obtained from the circle that belongs to the pupil.

### III. Removing the area of interest

It is here where, we obtain "the donuts", namely, the iris.

At this point there the rest of the picture is not necessary for anything.

To obtain the information that it is wanted, namely, the characteristics that make each individual can be identified ambiguously through him/hers iris, it is necessary that the image will be process. Now there is a function that will allow us to stretch the iris.

```
FRectifyOmnidir fRectifyOmnidir = new FRectifyOmnidir();  
JIPImage imgRec = fRectifyOmnidir.processImg(image);
```

Finally it is obtained as a result, an image that represents the context of the iris.

```
FRectifyOmnidir fRectifyOmnidir = new FRectifyOmnidir();  
JIPImage imgRec = fRectifyOmnidir.processImg(image);
```



Fig 9. Stretching of the Iris.

Finally it is obtained as a result, an image that represents the context of the iris.

### IV. Haar wavelet transform

With the image properly treated, it is just need to get that information in the form of securities registered values, in some way.

This is point where it is necessary to apply a Haar wavelet transform. These transformations performed consecutive iterations to achieve the level of detail required in each case. To obtain accurate information from the iris, there are needed five iterations performed as shown in the figure below:







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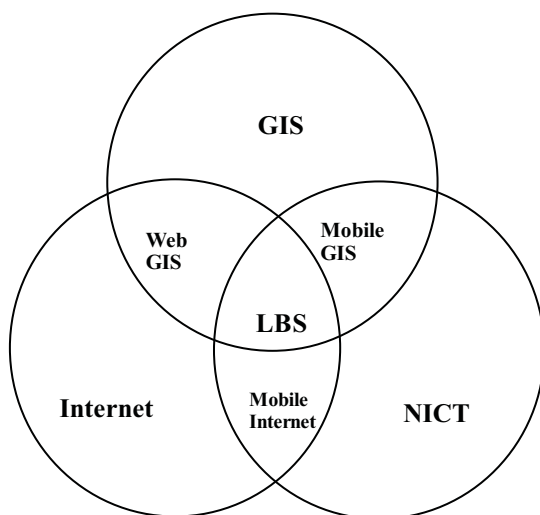
# Fuzzy Logic Indoor Positioning System

Gómez Bey, Bernardo; García Sanz, Roberto

**Abstract — The GPS system is not valid for positioning indoors, thus positioning systems are designed using Wi-Fi technology that allows location of a device inside buildings. The use of fuzzy logic is argued by the failure to find positioning systems based on this technology, which seeks to observe how their use in this field.**

## V. INTRODUCTION

The LBSs are location services accessible from mobile devices across mobile networks. These services are used from wide variety of customers, ranging from laptop computers to mobile devices. Any request to these kind of services return the position of a mobile terminal. From these definitions, LBS relies on the use of three Technologies



**Figura 1.** LBS as an intersection of Technologies.

Among the most outstanding characteristics of LBS are:

**High performance:** It should respond in thousandths of seconds.

**Scalable architecture:** Support for hundreds of concurrent users and terabytes of information.

**Reliable:** It must be able to respond the 99,999% of the time.

**Fluent:** Support for real-time and dynamic information.

**Movil:** it must be available from any device and it must be accessible from anywhere.

**Open:** It must to support the usual standard and usual protocols.

**Insurance** It must safely manage the database and services.

**Interoperable:** It must be integrated with e-business applications.

## VI. TECHNIQUES TO CALCULATE POSITIONS

These techniques are often used in combination with each other:

### A. Cell origin (COO).

The identifier of the cell normally is the identifier of the nearest base station. This is known that the position is defined at the perimeter of the base station, which is known his position.

### B. Time of arrival (TOA).

If we know the transmission speed of the signal, and the time between sending and receiving the signal, we can calculate the distance. We can know the position on a reference with these data. In this case we require high-precision clocks to calculate signal delay, because this is transmitted at very high-speeds.

### C. Difference time of arrival (TDOA) or (E-OTD).

These techniques calculated the distance measuring the time, but it is based on the difference of signals from three base stations, allowing triangularize the position. In the case of TDOA, task “calculating the position” is carried out by the network provider, in the case of E-ODT it is executed by the mobile device.

### D. Angle of Arrival (AOA), direction of arrival (DOA):

The use of directional antennas allows mobile devices to detect the angle of arrival of the signal. Because the mobile devices move that is not very accurate. Another possibility is that many base stations have segmented antennae, which divide the circumference of reach of the station at 90, 120 or 180 degrees, depending on the number of segments.

## VII. GNSS

The GNSS technology or Global Navigation Satellite System. The breakthrough of this technology is due to the emergence of global positioning remote systems, at an affordable price for the common user.

As reference of this technology is GPS (Global Positioning System) developed by the United States. Although we find other systems such as GLONASS (Global Navigation Satellite System) developed by the Russian Federation and Galileo, developed by the European Union, although it not operational today.

The intention is that all three systems work together to provide better service, taking greater availability and accuracy.

The GPS (global position system or global positioning system) or-Navstar GPS is a GNSS, which determines the position (altitude, latitude and longitude) of an object anywhere in the world by triangulation.

To determine the position of an object are used at least four satellites, those receive the position and a clock signal. The use of more satellites only brings greater precision to the system.

The delay of the signal is calculate by the data obtained, we need the time has been taken to travel from the satellite to the target device, and if we know where the satellite was, we can calculate the position of the device by triangulation.

The two-dimensional triangulation is based in the angle with respect to some points known. In three dimensions to calculate the position we determine the distance from each satellite to the receiver, and once we known the distance to each satellite we can determine the relative position with respect to each satellite, and also we know the position of each of satellites, we can calculate the actual position of the receiver.

The clock of the GPS system has an extreme precision, very similar to the atomic clocks that are in each of the satellite system.

With the information gathered by the GPS receiver calculates the distance that separates the satellites, by the time that takes to the signal to reach the receiver and knowing the speed of transmission of the signal.

The GPS system raises some drawbacks in terms of positioning, but includes:

*A. Selective Availability:*

The U.S. defence department keeps the possibility of including some degree of error in calculating the position, which can range from 10-100 meters. At present they are not using this feature, although there is nothing that will forbid.

*B. Topology-satellite receiver:*

Recipients must consider the geometry receptor-visible satellites used in the calculation of distances, since a certain spatial configuration can increase or decrease the accuracy of the measures.

*C. Aspects atmospheric disturbance and Ionospheric meteorological phenomena:*

Both affect the dissemination and propagation of electromagnetic signals between satellites and devices (receivers).

But without a doubt, the biggest drawback of the GPS system is that it doesn't works like a internal system, because it needs to have direct visibility between the receiver and each of the satellites used, so you have to find alternative techniques positioning.

## VIII.WIFI

The mobile wireless networks using electromagnetic waves to send information from one place to another. Although this type of technology takes several decades used for specific applications, has recently experienced a boom due to technological improvements already existing lower prices.

A breakdown of these networks is: Wireless Wide Area Networks (WMAN) ej. GSM and UMTS, Wireless Local Area Networks (WLAN) ej. IEEE 802.11, and Wireless Personal Area Networks (WPAN) - ie. Bluetooth

	Technology	Long.Max	Speed (Mbps)	Frequency
WMAN	GSM		0.009 – 0.014	
	GPRS	100m – 35Kn	0.160	~900 MHz,
	UTMS (G3)		2.0	
WLAN	Ultra-Wideband	10m	100	
	IEEE 802.11a	50m	54	~2.4 y 5 GHz
	IEEE 802.11b	100m	11	
WPAN	Bluetooth	10m	1	~2.4 GHz
	Homero	50m	10	
	IrDA	1 – 1.5m	1 - 16	

## IX.INDOOR POSITIONING SYSTEM (WLAN)

A WLAN is a data communications system that transmits and receives data using electromagnetic waves (although it is also possible with infrared light), instead of twisted pair, coaxial or fiber optics used in conventional LANs, and provides wireless connectivity within an area of coverage.

There are three types of typical configurations

*A. Peer to peer or ad-hoc networks:*

It consists of a network of two or more mobile handsets equipped with the corresponding wireless network card, so that communication is established between the nodes, communicating directly with each other.

*B. Infrastructure Mode:*

They have more scope than the ad-hoc networks, but its implementation is necessary for the installation of an access point.

*C. MultiNetwork:*

Allow link various networks (WLAN and / or WMAN) among themselves, for them relies on the use of directional antennas, which give visibility outside closed environments.

Co.	Standard	Frec.	Physic Level	V. Max.	Date
IEEE	802.11b	2,4 GHz	DSSS	11 Mbit/s	2001
IEEE	802.11a	5 GHz	OFDM	54 Mbit/s	2002
IEEE	802.11g	2,4 GHz	OFDM/ DSSS	54 Mbit/s	Fin 2002
ETSI	HiperLAN2	5 GHz	OFDM	54 Mbit/s	2003
ETSI / IEEE	5GHz Unified Protocol (5- UP)	5 GHz	OFDM	108 Mbit/ s	2003
Bluetooth SIG	Bluetooth	2,4 GHz	DSSS/ FHSS	0,721 Mbit/s	2002

#### X. CALCULATION OF THE POSITION THROUGH THE RSS

The location through Wireless networks can be carried out in different ways:

##### A. Vector Power

The signal information of the access points as laid down in the training of the devices is stored in a database (vector where each cell contains the power that comes from each user to access point).

##### B. Triangulation of Power

The customer receives the signal of three access points and provided an estimated current position through a system of equations .

##### C. Heuristic

It is not only whether a system by itself, but is more a complement to two previous ones. There are several possibilities for its implementation: Near, close neighbours (K-times Proximidad), theory of Bayes or neural networks.

#### XI. STATEMENT OF THE PROBLEM

As mentioned, the GPS system is not valid for positioning indoors, thus positioning systems are designed Wi-Fi that allows location of any device inside a building.

The use of fuzzy logic is argued by the failure to find positioning systems based on this technology, which seeks to observe how their use in this field.

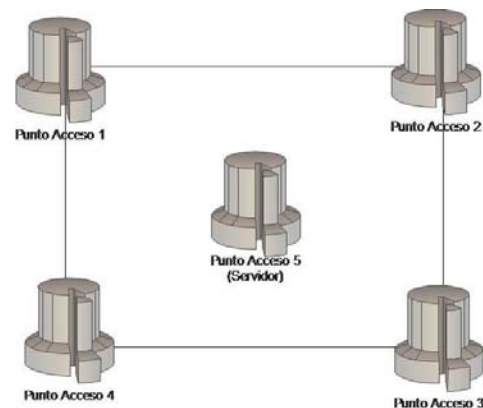
In addition one of the advantages we found in the use of

this technology is simplicity, the whole system focusing on the design of the driver and diffuse the rules governing it. The solution therefore is about our way of thinking and reasoning.

Let's build on systems DOT, which is responsible for calculating the position of the device is the provider, in our case one of the access points at their disposal. In addition the system will make use of a fuzzy controller for calculating the region where the device was found. One characteristic of our system is that positioning by region, bounded by the number of access points used, and not one based on positioning coordinates.

Our physical environment of development will be an enclosed area with square or rectangular shape with 5 access points, located one on each corner and one in the center of campus. The latter is considered as central server with the aim to be responsible for calculating the position.

The graphic location would be as follows:



In the event that compound is too big, will require an expansion of the system, which will be incorporated into another server and so many access points as necessary, bearing in mind that all access points can be reused for the new server .

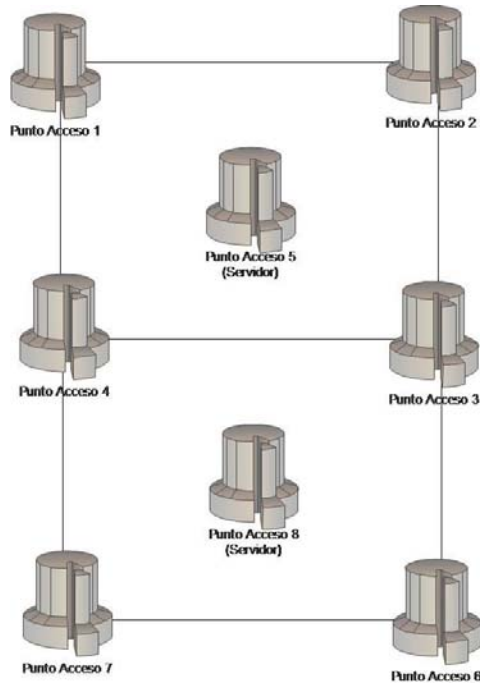
Although such systems can incorporate a training system, which is to undertake measures prior to the signal received from a few known points, indicating that when the system receives the signal level of each access point, the device is found in that particular position. But our goal is to eliminate this phase of training, through the ability of different access points to be among them.

As position of access points is fixed and known, each access point system to inform the signal strength from each other access points. The system can estimate the position of the client device within the square using this information and processing signal delays existing on each access point located anywhere on the plant.

This simplification, implies that the system will not be as



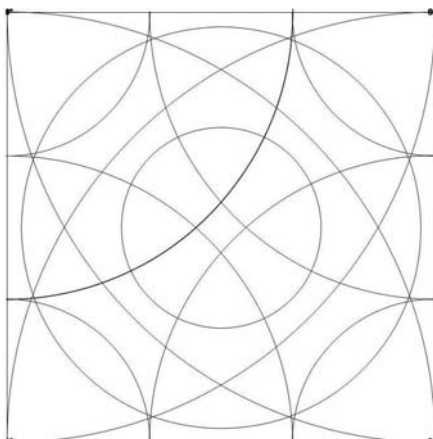
precise as if you use the training system, but on the other hand the system will be more adaptable to changes in the environment.



The position of the client device is calculated by a “central server”, thus it is possible releases client device resources thereby the server perform this type of tasks.

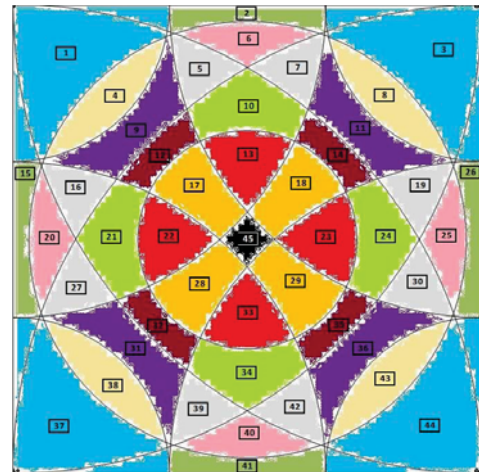
For this functionality you can ask the server at any time if a particular device is located inside the enclosure.

The definition of regions is set from the regions defined by the ranges of each access point, this range has been divided into three, for each access point, giving a map like this:

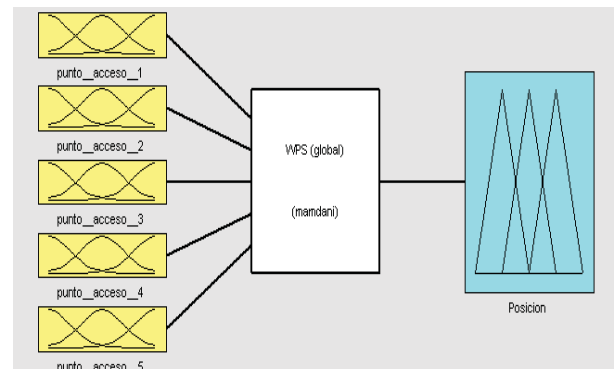


Since the number of regions obtained is very high, we will group the regions depending on the ability to define different regions depending on the divisions established.

Thus we have the following map of regions:



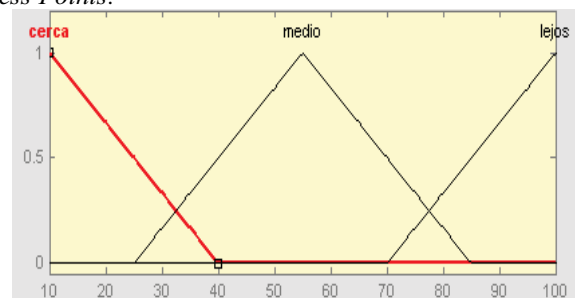
Our system is fundamented in the implementation of a fuzzy controller that is structured as follows:



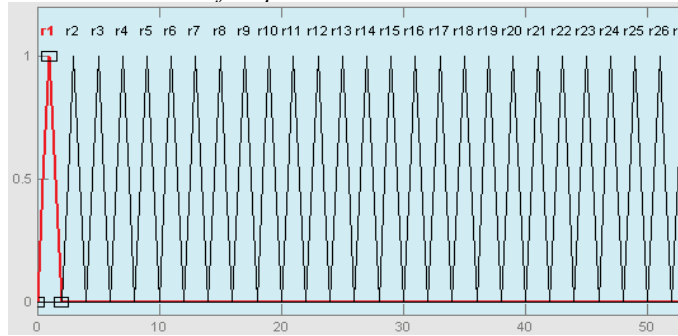
Each of access points will have three variables: Near, Middle and Far. To correspond with the degree of closeness of the device to access point.

Access points are structured as follows:

*Access Points:*



And the structure of Departure:



The output will become one of the possible areas where we can find our device, which will be defined by a fuzzy logic dependent on the input variables.

*Functions.*

We have four functions to control the system:

- 1) *Evaluar*. This feature is the entry values signal received from each access point and takes us back the position of the receiver.

```
function out=evaluar(params)
x=readfis('WPS.fis');
out=evalfis(params,x);
```

- 2) *ModificarPA*. This feature applies to each variable inlet fuzzy controller, representing each of the access points, and adjusts the concepts near, medium and far as signal strength between access points.

```
function modificarPA(imf,params)
x=readfis('WPS.fis');
x.input(1).mf(imf).params=params;
x.input(2).mf(imf).params=params;
x.input(3).mf(imf).params=params;
x.input(4).mf(imf).params=params;
writefis(x,'WPS.fis');
```

- 1) *ModificarS*. This function is applied to the variable inlet diffuse controller who represents the server, and adjusts the concepts near, medium and away from this, according to Intesa signal received from access points.

```
function modificarS(imf,params)
x=readfis('WPS.fis');
x.input(5).mf(imf).params=params;
writefis(x,'WPS.fis');
```

- 1) *Modify\_range*. This feature allows you to specify the range of each variable inlet controller diffuse.

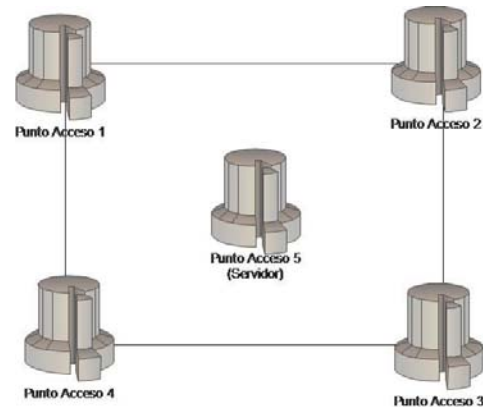
```
function modify_range(ivar,range)
x=readfis('WPS.fis');
x.input(var).range=range;
writefis(x,'WPS.fis');
```

## XII.CASES TEST

Two scenarios were simulated to verify the results of our system.

*Test 1.*

Scenario unhindered.



Where the values of signal strength are as follows:

	PA-1	PA-2	PA-3	PA-4	PA-5
PA-1	-	-45	-51	-42	-24
PA-2	-45	-	-40	-49	-27
PA-3	-51	-40	-	-47	-26
PA-4	-42	-49	-47	-	-27
PA-5	-24	-27	-26	-27	-

We apply the role of approximation () for adjusting regions.

aproximación (45,42,40,47,24,27,26,27)

After making adjustments in the system, both the range of variables and the variables:

```
modificarRangos ('1',[10,47])
modificarRangos ('2',[10,47])
modificarRangos ('3',[10,47])
modificarRangos ('4',[10,47])
modificarRangos ('5',[10,27])
```

```
modificarPA ('1',[9,10,19])
modificarPA ('2',[19,28,38])
modificarPA ('3',[38,47,48])
```

```
modificarS ('1',[9,10,14])
modificarS ('2',[14,18,23])
modificarS ('3',[23,27,28])
```

It calculates the position:

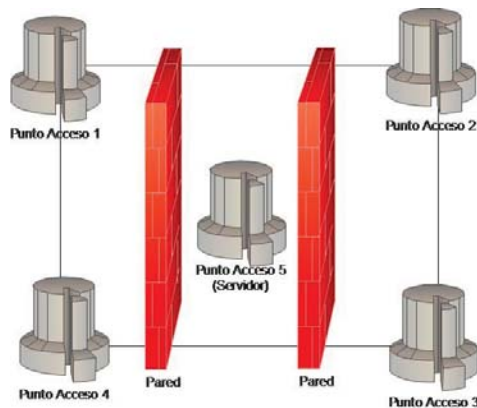
```
evaluar ([ , , , , , ])
```

The results are:

Signal Get					Actual Position	Get Position
PA1	PA2	PA3	PA4	PA5		
27	22	41	50	19	R7	R7
26	39	40	28	18	R21	R21

Test 2.

Scenario unhindered.



Where the values of signal strength are as follows:

	PA-1	PA-2	PA-3	PA-4	PA-5
PA-1	-	-61	-75	-41	-30
PA-2	-61	-	-38	-70	-31
PA-3	-75	-38	-	-57	-30
PA-4	-41	-70	-57	-	-28
PA-5	-30	-31	-30	-28	-

We apply the role of approximation () for adjusting regions.  
aproximación (61,41,38,57,30,31,30,28)

After making adjustments in the system, both the range of variables and the variables:

```
modificarRangos ('1',[10,61])
modificarRangos ('2',[10,61])
modificarRangos ('3',[10,61])
modificarRangos ('4',[10,61])
modificarRangos ('5',[10,31])
```

```
modificarPA ('1',[9,10,22])
modificarPA ('2',[22,35,49])
modificarPA ('3',[49,61,62])
```

```
modificarS ('1',[9,10,15])
modificarS ('2',[15,20,26])
modificarS ('3',[26,31,32])
```

It calculates the position:

```
evaluar ([ , , , , ])
```

The results are:

Signal Get					Actual Position	Get Position
PA1	PA2	PA3	PA4	PA5		
35	33	57	62	23	R10	R10
37	56	60	35	20	R21	R21

### XIII. CONCLUSION

Among the possibilities for indoor positioning, we found that the positioning based on fuzzy logic takes us back the position of a non-precise, because it is necessary in regions determined beforehand, rather than coordinates or absolute positioning.

The system can be complicated, as much as we want, installing a larger number of access points, which would generate a greater number of regions and smaller area, which we increased the accuracy of our positioning. Once assumed this loss of precision, we note that the system design is simpler and more adaptable that if you use other technologies, since it uses fuzzy logic, similar to human logic, and as a major advantage is that it does not require a training system, making the system itself is adjusted automatically each an interval of time.

As we have found problems that gives us the possibility to use a single controller diffuse to define the regions is very limited, as these must be defined by concentric circles for each access point, not in line with real values obtained. Should you find different intensity values in an access point to various access points, the system will choose the lesser intensity in order to cover all access points involved. Besides this restriction affects the logic of the system, because if a calculation differs slightly from what is established, the result may be a region which is out near the actual position of the object. Therefore, we have achieved a valid positioning system for detecting presence, because if properly defined regions or increasing the number of access points the location of the receiver can be sufficiently accurate for this type of application.

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# DSMUS 1.0

Sergio Redondo, Héctor Sainz, Arucas Chacón.

**Abstract – This paper shows how we have developed a video game for Nintendo DS in order to play “Mus”, one of the most popular Spanish card games, thereby we considered designing a video game would be an interesting way of applying our acquired knowledge about artificial intelligence.**

**Key Words – Artificial Intelligent, Case-Based Reasoning, Mus.**

## I. INTRODUCTION

**O**UR intelligent system will be built through **Case-based reasoning**, i.e, firstly, our video game will only know how to play without experience. Every game will be stored and used as previous experience for next games. So, the video game, little by little, will be able to use its previous experience, which has been acquired by playing, in order to play better [2].

Although our first option was Bayesian Networks, Nintendo DS features did not allow to import an external library to interact with Nintendo DS devices. As we could not use a bayesian network henceforth CBR was our best option. Now it only needs a simple text file where the cases are saved [1].

PALIB (PA9.h), which is a C++ library, has been used to handle NDS's features [4]. There are more libraries, such as Libnds, but Palib is the best for beginners [3].

According to the relevance of CBR, our project could be an example of how useful and easy it is.

As there are many parameters to be taken into account while a player is playing “Mus” we decided *Nearest neighbour technique* would be the best option to implement our strategy video-game [2].

A typical algorithm for calculating nearest neighbour is:

$$\frac{\sum_{i=1}^n w_i \times \text{sim}(f_i^I, f_i^R)}{\sum_{i=1}^n w_i} \quad (1)$$

Where  $w$  is the importance weighting of a feature,  $\text{sim}$  is the similarity function, and  $f^I$  and  $f^R$  are the values for feature  $i$  in the input and retrieved cases respectively.

## II. CASES

We use cases in order to decide which is the best move to win a round (“Grande”, “Chica”, “Pares” and “Juego”).

Our algorithm produces a result by employing the formula :

$$x + \sum_{i=1}^{i=4} \text{parameter}_i * \text{weight}_i \quad (2)$$

X: card index according to the cards value and round.

The parameters or features and its weights, that will be taken into account to calculate the case, are detailed below (order by priority):

- My hand → player's current hand.
- IamFirstOverMyOpponent → I have priority over my opponent.
- Near30Opponent → My opponent is closer to 30 than me.
- Near30Me → I am closer to 30 than my opponent.

The algorithm result will be a case index, which will be used to find the best suitable case.

Weights:

- 1 -> value= position in 332 possibilities for “Grande” and “Chica”  
There are 332 different combinations of cards.
- 0.9 -> BeingMano (positive value(yes)=1\*0.9, negative value(no)=0)
- 0.8 -> Near30Opponent (value=Opponent's points\*0.8)
- 0.7 -> Near30Me (value=My points\*0.6)

Cases are stored in simple text files. In **DSMUS 1.0** there is one file per round (“Grande”, “Chica”, “Pares” and “Juego”) and per player, that means sixteen files. In future versions a player will be able to play against Nintendo DS.



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### III. ARCHITECTURE FILES

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In this chapter it is described how a case file is structured.

**File Name:** “casesXY.dat ” :

X: player (0,1,2,3)  
Y: round (0=“Grande”, 1=“Chica”, 2=“Pares”, 3=“Juego”)

For instance:

*cases00.dat, cases01.dat, cases02.dat, cases03.dat, cases10.dat, ... cases33.dat.*

At the beginning of the game, every file is dumped into a list ( that will be contained in a matrix of lists ) in order to speed up access.

At the end of the game the case matrix will be dump into its corresponding file.

As it was said before, a case is a set of fields or paramaters: index ,won ,lost and used times.

```
struct caso{
    float index;
    int used;
    int won;
    int lost;
    struct case *next;
}* CaseMatrix[4][4];
```

An example of a case file content could be:

```
#332.4$1$1$0$##330.4$1$0$1$##220.6$1$0$1$##214.6$1$0$1$##0$1$0$1$#
```

- ‘#’ is used as a case divider and ‘\$’ is used as a divider between fields.

For instance:

```
Caso1: #332.4$1$1$0$#
Index: 332.4
Times used: 1
Times won: 1
Times lost: 0
Caso2: #330.4$1$0$1$#
Index: 330.4
Times used: 1
Times won: 0
Times lost: 1
Caso 3: #220.6$1$0$1$#
Index: 220.6
Times used: 1
Times won: 0
Times lost: 1
```

Where the index is the first field, the second one means how many times this case has been used, the next one specifies how many times this case has won, and the last one shows how many times this case has lost.

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### IV. HOW TO CHOSE THE CASE – SIMILARITY FUNCTION (QUEHACES)

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The cases are indexed by a float number, which is the result of an algorithm based on the nearest neighbour.

Firstly, once the index case is calculated by the formula explained before, the system will search in the corresponding file for the correct index. If the index is in the case file, it will be used. If it has not been found, another new one will be created.(check the chapter “**how it is created**”).

Secondly, in order to design a game as real as possible, it has been used a likelihood of doubt in order to bet or not according to a random value.

In this way, players will know the possibilities of winning and losing with the case but they will be free to decide their next move (simulated by a random value).

For instance:

*Cards: ‘r’r’r’s’p’ (king,king,knave and card whose number is two or one)  
Round: “Grande”  
Player: Number 3*

1. The case index is calculated by the formula.

- Card index: cards value in this round:

‘r’r’r’r’r’ is the best card combination for “Grande” round, whose value is 332.

As there are 332 cards combinations for “Grande” round.

‘p’p’p’p’p’ is the worst card combination for “Grande” round, whose value is 1.

*Example ‘r’r’r’s’p’ index: 280*

- IamManoOverMyOpponent whose value could be 1 or 0.

*IamManoOverMyOpponent=1*

- Near30Opponent and Near30Me whose values could be 1 or 0.

*Near30Opponent = 0*

*Near30Me = 1*

*Case index = 280+1\*0.9+0\*0.8+1\*0.7 = 281,6*

2. The case index is searched in the corresponding file considering player and round.

*File: cases30.dat*

#332.4\$1\$1\$0\$##330.4\$1\$0\$1\$##281.6\$6\$4\$0\$##214.6\$1\$0\$1\$##0\$1\$0\$1\$#

290 8,15 5,5 1

*Wanted index : 281,6 → It is in the case file.*

*Times used:6*

*Times won:4*

*Times lost:0*

*Times skipped: 2= (6-(4+0))*

3. Calculating percentage of victory.  
percentage=(won\*100)/used;

*percentage=(4\*100)/6 = 66,66*

Now, player knows his percentage of victory, but wining still depends on his behaviour and a random value.

4. Calculating random value.

*Random value = 80*

If the random value is lower than the percentage of wining, player will bet. otherwise he will pass that round.

*He will pass this round because 80 > 66,66*

When a case is reused, the used, won or lost times fields will be increased by one.

#### V. HOW IS IT CREATED A NEW CASE?

If the case is not in the file of cases, a new case is created in order to decide what a player is going to do in this round by averaging between the border indexes

It is worth highlighting that this operation is only useful in order to decide what a player is going to do in this round. However this case is not stored in a case matrix.

The stored one will be:

Case Index = whatever it is

Times used:1

Times won:0 or 1 (it depends on the winner)

Times lost:1 or 0 (it depends on the winner)

According to decision making, an example of case could be:

For instance:

*The index 290 is looked for but it is not in the file but there are the indexes:*

Index	Number of times	used	won	lost
300	12,3	10	0	
280	4	1	2	

*So, it is calculated the average between 300 and 280's parameters.*

*New case:*

This way of managing doubt has also been taken into account to decide if a player wants his cards or not. (**quieroMus function**)

#### HOW TO DECIDE IF A PLAYER WANTS HIS CARDS?

It is calculated for every index (importance of the cards) of every round.

The highest value is 277 according to the best cards (four kings), so it is calculated a rule of three between the index and 277.

Once the player knows his cards's "importance", he will make the decision, which is simulated by a random value, about drawing or not other cards.

#### VI. HOW TO DECIDE WHICH CARDS IS A PLAYER GOING TO PLAY WITH? – ("DESCARTE")

In **DSMUS 1.0** players only keep king cards, i.e, starting on the basis that players do not want their cards ("querer Mus"), they count how many kings they have.

According to the number of kings the best combination of cards that a player could have if he keep one, two or three cards it's calculated.

For instance:

Cards : 'r''r''4''p'.

1. Calculating best possible combinations in order to have better cards:

- one card left:

best possible combinations: RRR4, RR44, RR74; RRRP, RRPP

-two cards left:

best possible combinations: RRRR

2. Taking every combination into account, it calculates the best one.

According to the group of the best combination belongs, i.e. one card left or two cards left, that will be the best decision.

Best option: RRRR

So, player will decide to leave two cards.

Best option: RRRR (the best cards)

VII. INTERACTION OF PLAYERS

Firstly, there are two points of view according to players' role: game partner and opponent.

PARTNERS

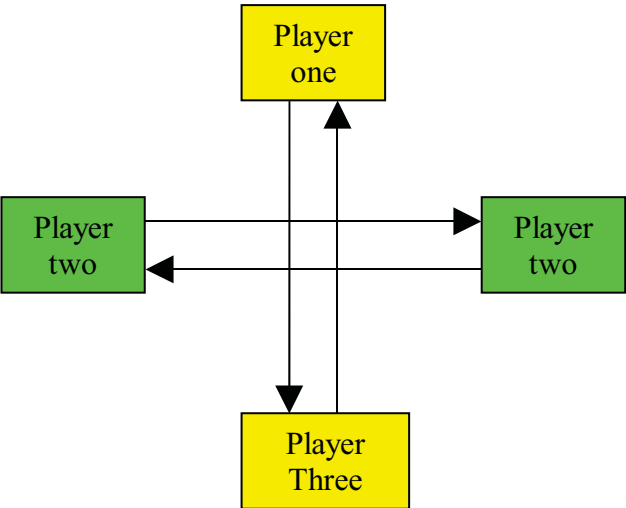


Fig 1.Partners Diagram

OPONENTS

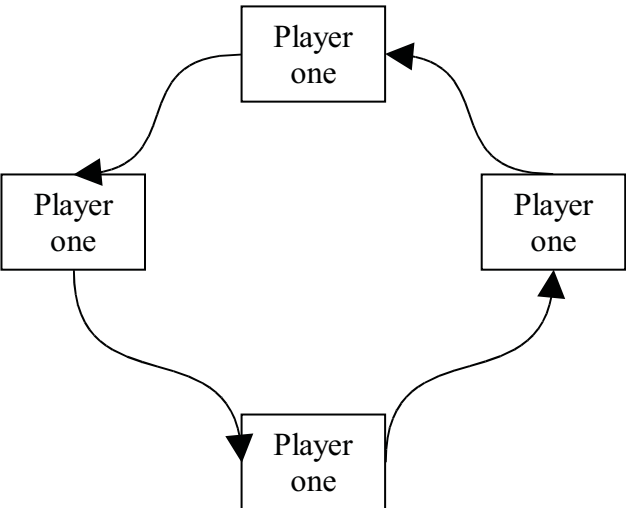


Fig 2. Opponent Diagram

This is a recursive function (jugar) which is going to be explained by an example.

ACTION: ALL OF THEM PASS

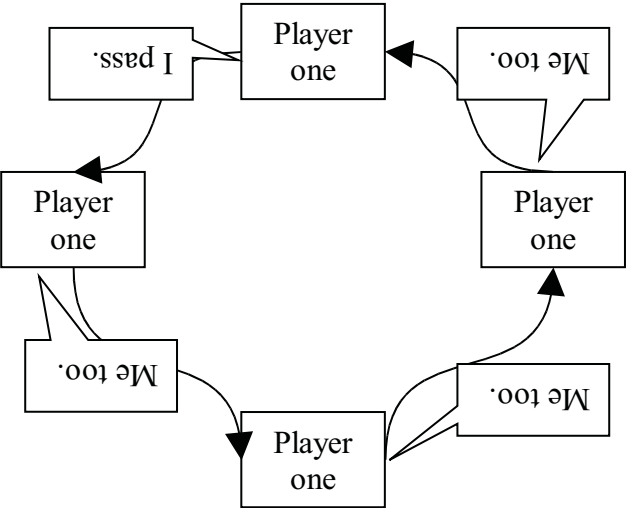


Fig 3. Game function Diagram I

So, if a player makes the decision of passing, the control will be given to his opponent.

ACTION: Player Three bets (“envida”)

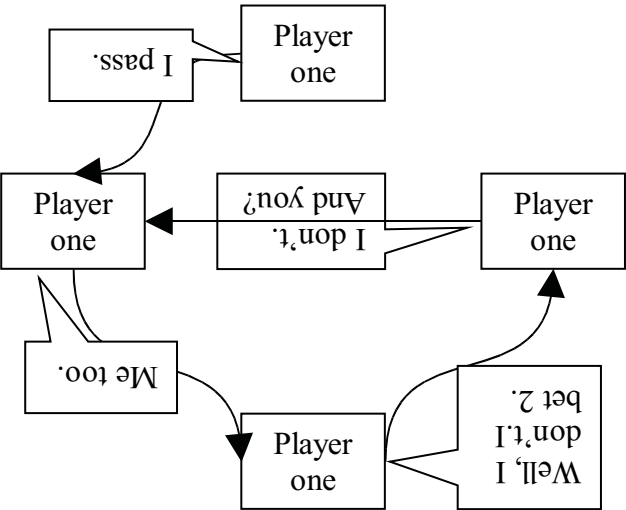


Fig 4. Game function Diagram II

So, if a player has to answer back a bet, assuming he does not want to bet, he will have to ask to his partner.

ACTION: Player Two bets ("envida")

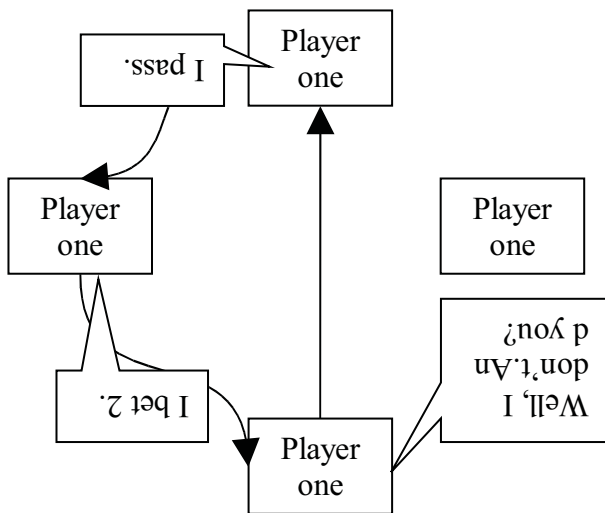


Fig 5. Game function Diagram III

This function finishes if :

- all of the plays pass this round
- one of the player agree with a bet which an opponent made.
- "ORDAGO" → a bet which is higher than 30 points

#### VIII. TOOLS

As it was said before, it has been used Palib library in order to handle NDS features, but there are more choices, such as, DSLua, which is a SDK , whose programs have to be written in Lua programming language , an important disadvantage[8].

##### A. Card game "Mús"

Mus is a popular Spanish card game originating from the Navarre and Basque regions in Spain. From there it spread all over the country, where it is now the most played card game, spawning countless Mus clubs or *peñas* and becoming a staple game among college students. It is highly regarded, being considered by many as one of the finest card games.

It is played (normally in two pairs) with the Spanish deck which is a deck of 40 cards (without eights or nines). The game has four rounds:

- **Grande** (*Biggest*): playing for the highest combination of cards.
- **Pequeña** or **Chica** (*Smallest*): playing for the lowest combination of cards.
- **Pares** (*Pairs*): playing for the best matching card combination.
- **Juego** (*Game*): playing for cards total values of 31 or more. Sometimes replaced by a **Punto** (*Point*) special round.

It has a distinctive feature in that signals (*señas*) between players are an accepted as part of the game.[7]

##### B. CBR

Case-based reasoning is a problem solving paradigm that in many respects is fundamentally different from other major AI approaches. Instead of relying solely on general knowledge of a problem domain, or making associations along generalized relationships between problem descriptors and conclusions, CBR is able to utilize the *specific* knowledge of previously experienced, concrete problem situations (cases). A new problem is solved by finding a similar past case, and reusing it in the new problem situation. A second important difference is that CBR also is an approach to incremental, sustained learning, since a new experience is retained each time a problem has been solved, making it immediately available for future problems.[2]

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# AI Sport Forecast Software

Kiyomi Cerezo Takahashi

**Summary** —this article aims to explain the development of an application whose function is to predict the results of different sporting encounters. To do this an analysis of the influential factors, algorithms and technology implemented, will be carried out.

**Key words** — Bayesian Network, data mining, model of tasks and model of agents.

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## VI. INTRODUCTION

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This research shows an early prototype based on Beliefs Networks, designed to provide the keys to be able to carry out a prediction of results for different sporting encounters, in our case a football match. For that purpose, we must analyse the different factors that form part of the information that determines the prediction:

- Climatic factors
- Ambient factors
- Human factors

Later on, the importance of variables such as humidity or temperature at the time the match is played and that of the stadium in which it is played, will be detailed. Besides this, how the state of the players, number of injured players etc will also be studied.

It is equally important to know the tools which will be used in the development of this prediction such as the probabilistic model (bayesian network and networks of Markov), the data minig or the different sources of data information to be analysed.

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## VII. BAYESIAN NETWORKS

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Everything related to bayesian networks can be found in references [1], [2] and [3].

### A. Definition

A bayesian network is a structure which captures the existing dependency between the attributes of the observed data. The bayesian network describes the distribution of probability that governs the bringing together of the variables specifying suppositions of conditional independence along with conditional odds. Therefore the bayesian networks allow the specification of independent relations between the joining variables. Therefore, the network allows specific independent relationships between joining variables.

Between the characteristics of the bayesian network you can notice that they allow learning about dependant and casual relationships, to combine knowledge with data and can manage incomplete databases.

A bayesian network is a graph without cycle directed and

noted that describes the distribution of joint probability that governs an assembly of random variables.

So, a bayesian network B defines a unique distribution of joint probability:

$$P_B(X_1, X_2, \dots, X_n) = \prod_{i=1}^n P_B(X_i | \Pi_{X_i})$$

It is important to observe the topology or structure of the network as it not only provides information about the probabilistics dependences between the variables, but also about the conditional dependencies of a variable or the joining those given or other variables. Each variable is independent of the variables that aren't its descendants in the graph, given the state of their variable father.

The inclusion of the relationships of independence in the graphs's structure makes the bayesian network a good tool for representing knowledge in a compact form (it reduces the number of parameters necessary). Besides this, it provides flexible methods or reasoning based on the propagation of the possibilities covering the network in agreement with the theory of probability laws.

Figure 1 represents a specific example of a bayesian network which represents some knowledge about medicine. In this case the nodes represent illnesses, symptoms and factors that cause some illnesses. As mentioned previously, the variable which the arrow is pointing to depends on that which is in the origin. For example, fever depends on typhoid and flu.

It can be observed that the suppositions of wise independence can be observed by the network, for example, reactions depend on food, flu, fever and pain (nodes not descendant of reactions) given typhoid (it's only node father). Therefore the following can be observed in the network:

$$P(R | C, T, G, F, D) = P(R | T)$$

Where R is reactions, C is food, T is typhoid, G is flu, F is fever and D is pain.

Also represented are the parameters of conditional probability associated with some of the network nodes. The table P(C) shows the values of probability previous to food consumption, P(T | C) the probability of typhoid given food consumed; and P(F | T, G) the probability of fever given typhoid and flu. In this case to record the parameters it isn't necessary to maintain complete tables, given that the studied variables are binaries. As for each one it would only be necessary to record the values in a column. Taking into account that the size of the parameter tables grows exponentially with the number of fathers of a node, it is worthwhile recognising different techniques to reduce the number of necessary parameters.

### B. Inference

Using the constructed network, and given the set values of some of the variables of an instance, it is possible to estimate the values of the other variables using probabilistics

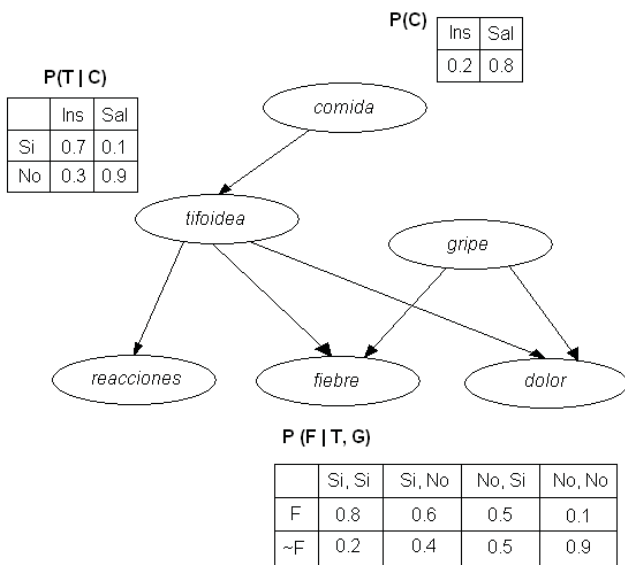


Fig. 1. Example of a Bayesian network with some parameters

reasoning.

The probabilistic reasoning through the Bayesian network consists of spreading the effects of the evidences (known variables) through the network to learn of the probabilities after the unknown variables. This way, an estimated value for these variables as a function of the probability values already obtained can be determined.

When the observed values are known for all the network variables except one, obtaining estimation for this is immediate from it formulates the distribution of joint probability of the network.

In a more general case it would be interesting to obtain value estimation for a variable given the values observed for the subjoining of the remaining.

Different types of algorithms proposed exist, which are applied depending on the topology graph and obtain the probability of a single objective variable or of the entire unknown. It is not this project's intention to enter into details about different algorithms.

### C. Learning about Bayesian networks

The problem faced with Bayesian learning can be described informally as: given the joining of training  $D = \{u_1, u_2, \dots, u_N\}$  of instances of  $U$ , is found the network  $B$  which is better fitted to  $D$ . Typically, this problem can be divided into 2 parts:

- Structural learning: to obtain the network structure
- Parameter learning: knowing the graph structure, to obtain the probabilities corresponding to each node.

### D. Parameter learning

#### Complete data

Learning about the parameters is simple when all of the variables are completely observed together with the training. The most common method is the call estimator of maximum verisimilitude, which simply consists in estimating the

desired probabilities using the frequency of the training data values.

The quality of these estimations will depend on whether a sufficient number of samples. When this isn't possible the existing uncertainty can be quantified representing it by means of a distribution of probability, thereby consider it explicitly in the definition of the odds. Habitually Beta distributions are employed in the case of binary variables, and distributions Dirichlet distributions for multi-value variables. This approximation is useful when counting on the support of the application experts to concrete the values of the distribution parameters.

#### Incomplete data

More difficulties surface when the training data is incomplete. 2 types of incomplete data are possible:

- Missing values: some missing values from one or various values in some examples
- Hidden Node: all of the variable values are missing

The first case is easier and various different alternatives exist:

- Eliminate the examples with missing values
- Consider a new additional value for the unknown variable
- Consider the most probable value using data from other examples
- Consider the most probable value based on the other variables.

The 2 first options are common with learning problems and always valid and there is a high number of incomplete data. The third option ignores the possible dependences of the variable, when the structure already counts the described graph, this doesn't usually provide the best results.

The fourth technique serves for an already known network to infer the unknown values. Firstly, to complete the parameter tables using the all the complete examples. Then, for each incomplete instance, known values are assigned to the corresponding variables in the network and spreads its effect to retrospectively of those not observed. Afterwards, it is taken as the most probable observed value and all the probabilities of the model are updated before the following instance is processed.

The apparition of hidden nodes requires more complex treatment. In this case different techniques exist to estimate the missing values. One of the most common is the application of EM (Expectación Maximization). Its application for the learning of parameters can be translated as the following:

- Assign random values (or values based on expert knowledge if available) to the unknown probabilities of the network.
- Use the known data to estimate unknown inferring them over the model with current probabilities.
- Complete a joining of data with the estimated values and then return to calculate the network probabilities.
- Repeat the two previous steps until there are no significant changes in the probabilities.

A certain similarity exists between the bayesian network learning when hidden nodes exist and the learning of weights in the hidden layers of a perceptron multilayered in which the values of entrance and exit for each sample are known, but no value for the elements of intermediate process. Based on this idea a graduating technique similar to that used in the algorithm of backpropagation. The technique intends to maximise the probability of the training data known the hypothesis  $P(D|h)$ , considering the hypothesis joins all the possible combinations of the values for the odds that even customize curl the network. For this, follow the gradient in  $\ln P(D|h)$  with respect to the network possibilities, updating every parameter  $w_{ijk}$  unknown in an interactive way with the increase:

$$w_{ijk} \leftarrow w_{ijk} + k \cdot \sum_{d \in D} \frac{P(x_{ij}, \pi_{ik} | d)}{w_{ijk}}$$

Where  $w_{ijk}$  is the corresponding unknown parameter to the conditional probability of which the variable  $X_i$  takes the value  $X_{ij}$  when it's parents  $\Pi_i$  take the values  $\Pi_{ik}$ , and  $k$  is a rate of learning. In each interaction the  $X$  probabilities restabilise after the increase.

The algorithm EM as well as the ascending gradient finds solutions which are only optimum locally, for which in both cases the quality of the result will depend on the initial assignation of the unknown probabilities.

#### Structural learning

Structural learning involves exploring a space of graphs. This task is very complex. When the number of variables (nodes) increases by a small amount the number of possible graphs constructed by them changes dramatically. Because of this on many occasions the search area for graphs is restricted by concrete characteristics. Many algorithms exist specifically for network learning where  $G$  is limited to a graph, or a multiple graph or to other less general structures.

Nevertheless, techniques exist to learn about networks with general structures. Working without restrictions should allow a construction of networks which fit better to the joining of the training, for complexes that be the dependences among the attributes.

There are two approximations habitual for network learning when carrying out a guided search for an average global quality. The general operation consists of generating different graphs using a search algorithm and applying to each one of those a quality measuring function to decide which graph to save in every step.

Exist many algorithms that follow this technique, defined using by combining two elements:

- Search algorithm
- Global measure of adjustment

It is common to apply heuristics search algorithms. To try an exhaustive search over the graph space is simply intractable. Some of the possibilities are the assention techniques (hill climbing), genetic algorithms, bidireccionals, etc ...another options is to apply a voracious search. It starts with an empty network to which successive local operations are applied improving by a maximal form the measurement of adjustment until an optimum local is found. The applied

operations included the addition, deletion and inversion of arrows.

Also there are many measurements of adjustment. Two common ones are the B measurements and the description of the beginning of the minimum longitude.

The bayesian measurement intends to maximise the probability of the structure given the training data  $P(Bs|D)$ . As the objective of the measurement is to compare the value obtained for different structures  $i$  and  $j$ , it is common the following quotient:

$$P(BSi|D) / P(BSj|D) = P(BSi, D) / P(BSj, D)$$

Considering discrete variables and independent data, the joining probability of the second quotient can be estimated using the made predictions for each structure before the training data.

On the other hand, the main MDL characterises the learning in terms of understanding the data. The objective of the learning is to find a model that aids the obtaining of the original data in the quickest way possible. Take into account the longitude of this description:

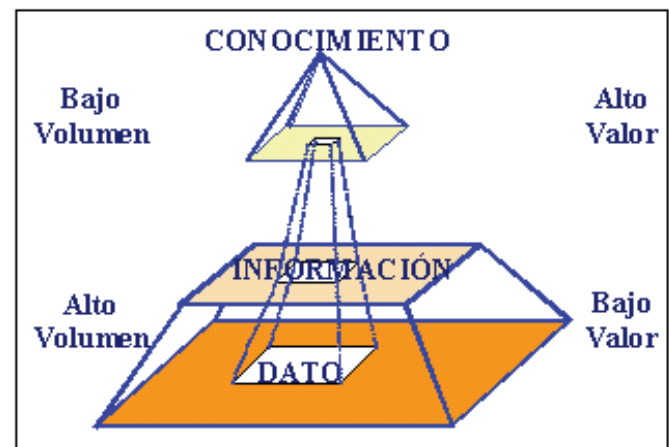


Fig. 2. Relation between data, information and knowledge

- The description of the model, penalising the complexity.
- The description of the data that the model used, encouraging their plausibility.

In the context of the bayesian network, the model is the network. Each bayesian network describes the conditional probability of PB above the instances that appear in the data. Using this distribution, a plan can be built and be codified that assign shorter words of code to the most probable instances. In agreement with the main MDL, a network B should be chosen such that the length combined of the description of the network and the data codified (with regard to PB) be low.

As from this point, different authors define different ways of measuring each element in the description using the general plan:

$$MDL(B|D) = \text{complexity}(B) - \text{plausibility}(D)$$

The bayesian as well as the MDL are both well known and well studied. Both function are asymptotic equivalents when the size of the sample is increased, and besides this the correct asymptotic: With probability equal to one the distribution learned converges to the underlying distribution

to the extent that the number of sample enlarges.

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#### VIII. MARKOV NETWORKS

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According to [1] A network of Markov is a pair  $(G, \Psi)$  where  $G$  is a graph done not direct  $\Psi = \{\psi_1(c_1), \dots, \psi_m(c_m)\}$  Is an assembly of potential functions you defined in the conglomerates  $C_1, \dots, C_m$  of  $G$  that define a function of probability  $p(x)$  by middle of

$$p(x) = \prod_{i=1}^n \psi_i(c_i).$$

If the graph done is not direct  $G$  is triangulated, then  $p(x)$  can also be factorized, utilizing the functions of probability conditioned  $P = \{p(r_1|s_1), \dots, p(r_m|s_m)\}$ , of the following form

$$p(x_1, \dots, x_n) = \prod_{i=1}^m p(r_i|s_i),$$

Where  $R_i$  and  $I_i$  are the residues and separators of the conglomerates. In this case, the network of Markov comes given by  $(G, P)$ . The graph  $G$  is an I-MAP done not direct of  $p(x)$ .

Therefore, a network of Markov can be utilized to define the qualitative structure of a model by means of the factorization of the function of corresponding probability through potential functions or functions of probability conditioned. The quantitative structure of the model will correspond to the concrete numeric values assigned to the functions that appear in the factorization. All of this is reflected in [4].

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#### IX. DATA MINING

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Leaving from the article [5], data mining came about as a technology which would try to aid the comprehension of the contents of a database. In a general way, the data is the prime material. In the moment the user attributes an especial significance it become information. When the specialists elaborate or find model. Doing the joined interpretation between information and this model represents an aggregate value, and then we refer to knowledge. Figure 2 shows the hierarchy that exists in a database between data, information and knowledge. Also observed is the volume present in every level and the value that those responsible for the decisions give to this hierarchy. The area inside the triangle represents the proposed objectives. The separation of the triangle represents the long union between data and information, but not between the information and knowledge. The data mining works in the superior level looking for XX, behaviour, grouping, sequences, trends or a associations that can generate a model that allows us to understand better the dominium to help in possible decision making.

Reflecting on the previous text we can say that Datamining is the process of discovering patterns of interesting and potenciales useful information, immersed in a big database which is constantly interacted with. Datamining is a combination of processes such as:

- Extraction of data

- Data cleaning
- Characteristic selection
- Algorithms
- Analysis result

The usefulness of data mining can be given inside the following aspects:

The usefulness of data mining can be given inside the following aspects.

- Systems partially unknown, if the system model that produces the data is well known, then we don't need the data mining as all of the variables are predictable. This is not the case in commercial electronic, due to the effects of human behaviour and climate. In these cases there will be a part of the system which is known and there will be a part altered by nature. Under these circumstances, starting from a large amount of data associated with the system, the possibility exists to find new aspects previously unknown to the model.
- Large amounts of data: to find a lot of information in some databases is important for a company to find the form of analysing "mountain" of information (which for a human is impossible) and that is prove some type of result.
- Potent hardware and software: Many of the present tools in the mining industry of data are based on the intensive use of the computation, consequently, a convenient team and an efficient software, with which count a company, will enlarge the performance of the process to seek and to analyze information, which at times should turn them with productions of data on the order of the Gbytes/Hour The use of the dates mining can be beneficial Possessing data on its productive processes, clients monitoring data, etc.

The general phases for the creation of a data mining industry project independently of the technique specifics of extraction of know-how used:

- It Filtered of data: The format of the contained data in the source of data never is the suitable one, and the majority of the times is possible to utilize no algorithm of mining industry. By means of the preprocessing, the data are filtered (are eliminated unknown, invalid, incorrect values, etc.), samples of the same are obtained (greater velocity of answer of the process), or they are reduced the number of possible values (by means of I round, grouping, etc.).
- Selection of variables: Even after it to have been preprocessing, continues having a huge quantity of data. The selection of characteristics reduces the size of the data, choosing the most influential variables in the problem, without barely sacrifice the quality of the model of knowledge obtained of the process of mining industry. The methods for the selection of characteristics are two: Them they based on the election of the better attributes of the problem and the ones that seek independent variables by means of tests of sensibility,



heuristics algorithms.

- Extraction of know-how: By means of a technique is obtained a model of knowledge, that represents bosses of behavior observed in the values of the variables of the problem or relations of association

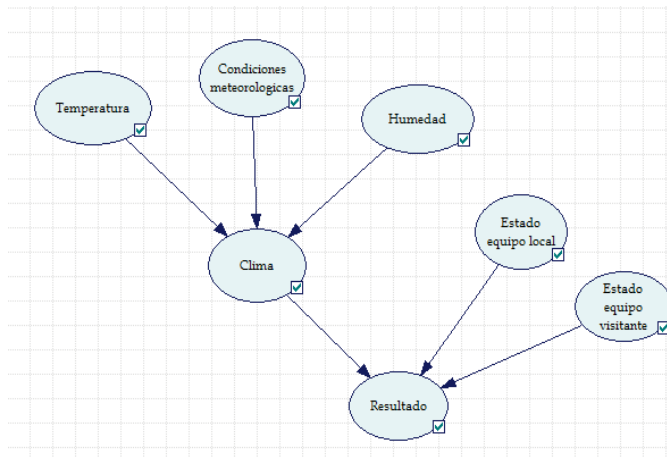


Fig. 4. Bayesian Network

among variable happinesses. Also they can be used several techniques at the same time to generate different models.

- Interpretation and evaluation: Finally it proceeds to their validation, verifying that the conclusions are valid and satisfactory. In the case of to have obtained various models by means of the use of different techniques, the models in search should be compared of that that be adjusted better to the problem. If none of the models reaches the results expected, some of the previous processes in search of new models will be altered.

## X.FACTORS THAT INFLUENCE THE ANALYSIS

### A. Climatic factors

To all lights we can affirm that the importance of the climatic situation during the celebration of a sports event that is disputed outdoors is determinant in the analysis of the possible results.

There it will be that to be keep in mind factors as the rain, snow, if this cloudy or sunny in the same way that the temperature and the humidity that there is at the moment to dispute the party. All these variables should be quantified at the moment of to do the calculations of the odds that were used to do the prediction.

### B. Human factors

In whichever sport the most influential factor is the human factor and because of it one must treat to quantify variables as the so much state of mind like the physicist since both are influential at the moment of to carry out a sport. Besides it is necessary to know the state of the team as important assembly being to know the possible drops that has a team, quantifying the shrinkages that produces in the possibilities of winning a match.

## XI.APPLICATION DESIGN

According to the following plan:

The operation of the application itself B utilizing an agent of natural language that is reached by Internet, to them you paginate sports, where by means of a web semantics and a meticulous one ontology would be obtained and storing the necessary key information for our prediction.

On the other hand another agent, the meteorologic access to the National Institute of Meteorology by means of the same mechanism that the agent of natural language to collect and to store the referring information to the cities where the sporting events were celebrated.

Once they executed these two agents should act the filter agent, which takes charge of filtering and store information that is not prominent and also has been stored for the agent of natural language.

After this moment the application executes the agent of inference responsible that utilizes all information filtered and the climatic data to apply them a series of rules based on the networks B, to foretell with accuracy and truthful.

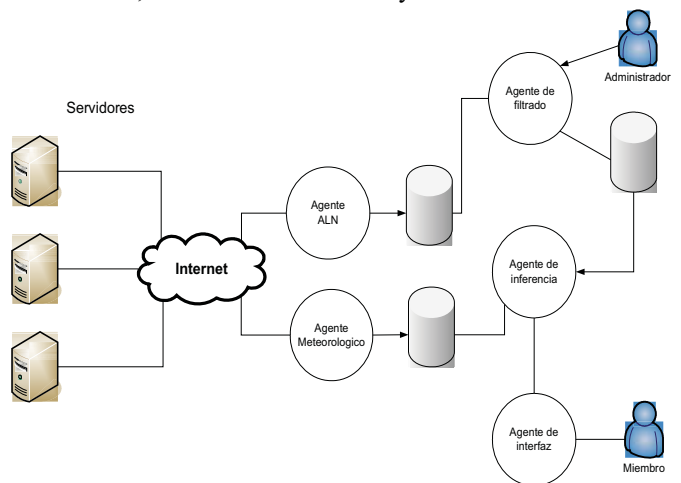


Fig. 3. Agents diagram

One intelligent agent finalizes the execution of all inference task, the interface agent takes charge of showing this information to the user whether computer or any mobile device.

To develop the application a tool is used for Bayesian Network creation that determines this work, Genie 2.0, diagram below shows it's construction

Once the bayesian network is designed we should use an API to be able to use it in the implementation of the program code Java in which we have done the application. The API is jSmile, a wrapper that should be added to the project as a bookstore.

Following we must use a database; in our case we will use Access since we do not need the boards to be very complicated. We will have a board with the parties of the day, another with the meteorological information, on each team of the day and to finish one with all fields that are defined within bayesian network structure.

How the application works?

The program is based on an application web in which we will be able to agree as administrator or client.

If login as client, the user can see a listing with all matches

that are disputed in that day. The user should select the match that desire to visualize the prognostic so the application carry out the inference of the database with the information stored previously.

In the case that it be agreed as the administrator itself will have access to several options, such as access to meteorological information, which has been collected by the National Institute of Meteorology or to the referring information to all teams of football that has been collected from main sports pages of the network by natural language agents

In this section the administrator should filter some information collected since not all the information is relevant. This procedure avoids redundancies.

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## XII. CONCLUSIONS

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After execution of a complete battery of tests, we have been verified that there are not sufficient variables. The ones that have kept in mind themselves are the human aspects, (difficult to measure of an objective form) and climatic factors (do not affect equally to all the teams). Because of that, our prototype should be worked using real-time data (climate, people) as statistics (historic) to improve our inference process. Web Service technology and SOA world provides new scenarios that suggest the possibility to improve our early Bayesian inference process.

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# IMusic: a Bluetooth music application

Angel Aguilera Manglano, Borja Sierra Espín

**Abstract** — nowadays, we can see a huge amount of customized services in lots of applications. A more customized experience get a real full satisfaction to the customers.

The project was born with the aim of providing this kind of service. Thus a client takes part in the decision- making of the local songs, creating a playlist with songs ordered as the customer's data preferences.

The way is easy: a customer who enters the premises, install the software that local provides and then he has to indicate their customer likes and get it transmitted via Bluetooth. This information is received by the customer attention server and it generates a playlist with personalized songs.

**Keywords**— *AI system, Bluetooth connection, customized music application, mobile interface.*

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## XIII. INTRODUCTION

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MUSIC IS FOUND IN EVERY KNOWN CULTURE SINCE ANCIENT TIMES. THE "OLDEST KNOWN SONG" WAS DATED 4,000 YEARS AGO. THE MUSIC HAS BEEN VARYING WILDLY BETWEEN TIMES AND PLACES AND IT CAN BE DIVIDED INTO GENRES IN MANY DIFFERENT WAYS. THE GOAL OF THE APPLICATION WE WANT TO DEVELOP IS TO SERVE CUSTOMIZED MUSIC TO PLACES SUCH AS PUBS, RESTAURANTS, HOTELS TO HELP THESE PLACES TO OFFER A BETTER SERVICE FOR THEIR CUSTOMERS. TO MAKE THIS POSSIBLE WE ARE GOING TO USE: TECHNOLOGIES AS BLUETOOTH TO SET UP THE CONNECTION BETWEEN CUSTOMERS AND THE MUSIC SERVER, GENIE AND SMILE LIBRARY TO PAIR EACH CUSTOMER WITH THE MUSICS GENRE HE FITS BETTER, AND A .NET APPLICATION TO RECEIVE ALL THE INFORMATION FOR THE CREATION OF THE PLAYLIST

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## XIV. FIRST STEP: HOW TO RECEIVE THE CUSTOMER'S LIKES?

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The first problem we face is how to get the application closer to the customers. All of us are living in the communication era so there are lots of ways to make the connection between the application and clients:

The first idea was to set up a point of connection at the local -a few computers linked to the main server for example- so clients go and fill in a simple form with their musical likes.

Another possibility was to allow a WI-FI access point which makes possible links of customers with their laptops.

Once connected, they could be redirected at the local main page, and all they have to do is fill in the form provided.

But those ideas are quite hardworking or uncomfortable to the clients, in one hand have to stay in line -on the case there is no free computers on the local- to get the likes transmitted in the other hand with the second idea they have to carry with the computer on and it's a nonsense to go party with all of these gadgets.

So if we want the application was successful we need to find the technology that fits those problems, and we found it on Bluetooth technology.

The most of the cell phones nowadays works with Bluetooth, and if we can use this mobile devices, to get an access to the local main server we could solve the connection problem.

Due to the fact that Bluetooth technology is a standardized wireless technology and it is designed to be compatible across a range of very different operating systems and devices, makes us to choice this alternative.

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## XV. SECOND STEP: HOW TO DO AN APPLICATION FROM CUSTOMERS?

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### A. Initial decisions

We want a customer's application that allows sending their musical likes and getting it received by the customers dedicated server.

At first we choose to create a .NET technology server for attending all the Bluetooth connections from the customers. All Bluetooth libraries that we found on .Net are under subscription, and those libraries such "IntheHand.Net.Personal" free of charge doesn't work properly because their implementation and options are very limited and do not provide many possible cases of communication in Bluetooth.

Because of that we decided to develop a server with Java technology. The functionality of this server is basically listen Bluetooth connections and to store the content of these connections (saving them into a database).

This java library is in the API JSR-82 and defines two packages that depend on the CLDC javax.microedition.io package:

- javax.bluetooth: core Bluetooth API
- javax.obex: APIs for the Object Exchange (OBEX) protocol

These two packages are totally independent:

- The first one defines classes and basic interfaces for the discovery of devices, service discovery, connection and communication. The communication through javax.bluetooth is at low level: through data streams or by providing arrays of bytes.
- The second one handles the high-level OBEX protocol, this protocol is very similar to HTTP and is mainly used for exchanging files. The OBEX protocol is a standard developed by IrDA and is also used on other wireless technologies than Bluetooth.

The main development platform for the API JSR-82 is J2ME. The API is designed to rely on the CLDC configuration,

however there are implementations to use this API in J2SE. Regarding the client side we did not have any problem at all as most of the mobile work perfectly with MIDlets.

“A MIDlet is a Java program for embedded devices (dedicated to a single activity), more specifically for the Java Virtual Machine MicroEdition (JavaME). Generally MIDlets are games and applications that runs on a mobile phone.).”

But regarding the customers dedicated server side we found the following problems:

- In the detection phase, our own Bluetooth device which we will send and receive it doesn't be detected by the javax.bluetooth library. After several days of searching we discovered the problem, it was because our Bluetooth device is using a Bluetooth stack protocol that is not included in the library we are working with. The USB Bluetooth device that we had was running with the Microsoft protocol stack and it wasn't compatible with the library we used. Thus we had to remove the J2ME library and replace it with “bluecove-2.0.2.jar” which accepted the Microsoft protocol stack. This library contains all the protocols the other library has and many others protocols, so the coding was the same but this time it works.
- In the discovery phase we don't find any problems because both server and client java use the same Bluetooth technology for communication so the bluetooth profiles are the same, if there is no correlation between these profiles could not be exchanging information with another device. It is worth to comment that we had to alternatives for the communication due to the API javax.bluetooth makes possible two different ways of connection: SPP and L2CAP:
  - With SPP we get an InputStream and an OutputStream.
  - with L2CAP we get an array of object that we could send or receive
 We choose SPP.

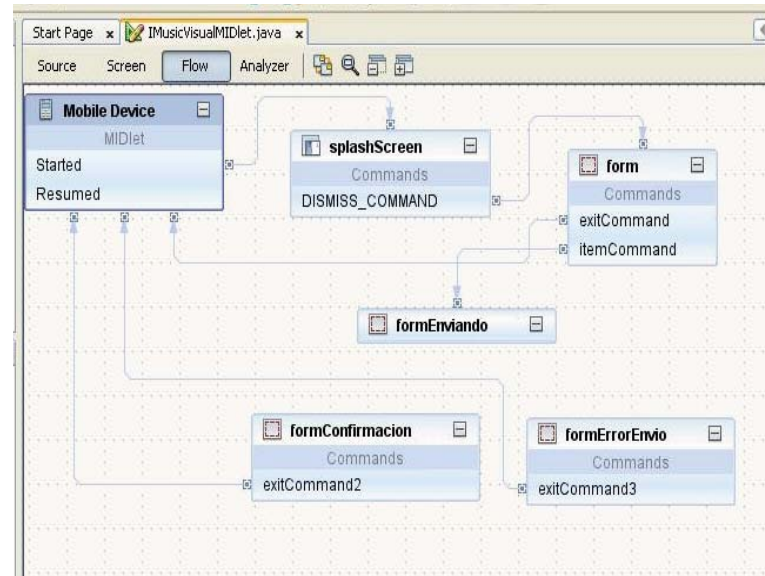
Once these 2 problems were solved, everything related to Bluetooth was swimmingly.

### B. Developing the customer application

Programming on J2ME, and using the Bluetooth API (JSR 82), which provides a standardized API for using Bluetooth networking, we made the customer application possible.

After the implementation the result was that we have a functionally interface which allows clients to connect their own phones with a java application that performs the task of storing the client's form.

The basic navigation structure of the mobile application is:



It is just a simple form with 3 lists of radio Buttons on which the customer has to select his preferences of songs

“Genero”: Genre

“Duracion”: Length (short, medium, long)

“Procedencia”: Origin (national, foreign)

Once selected by pushing the send button the form is sent to the customers dedicated server, and it's stored properly.

The interface looks as follows:



And finally the structure we want to build is:





### Third Step: Build the Bayesian Network

At the point of view of the local, in order to set the best playlist, the application needs to access the customer's data forms to help the application choose the songs that fits the best. All we have to do is perform an application that arranges the songs on the right position of the playlist. This is possible with the help of Genie (Artificial Intelligence) application that compares all songs on the database with the statistics music likes of all the customers at the local. The result is a preference ordered playlist which begins to play.

### C.Genie Application

The GeNIe (Graphical Network Interface) software package can be used to create decision theoretic models intuitively using the graphical click-and-drop interface. GeNIe is the graphical interface to SMILE, a fully portable Bayesian inference engine developed by the Decision Systems Laboratory and thoroughly tested in the field since 1998. GeNIe 2.0 is the latest version of GeNIe. GeNIe 1.0, released to the community in 1998, has received a wide acceptance within both academia and industry. Users of the programs have shared with us their experiences and their suggestions have led to the development of GeNIe 2.0. GeNIe 2.0 has a refreshingly new modern interface, and is even more intuitive and easier to use than GeNIe 1.0. In addition to aesthetics, GeNIe 2.0 has many more new features to offer.

#### Primary Features:

- Graphical editor to create and modify network models
- Uses the SMILE Engine. You may develop models in GeNIe and create a custom interface for them using SMILE
- Supports chance nodes with General, Noisy OR/MAX and Noisy AND distribution
- Open multiple networks and cut and paste sections of models between them
- Complete integration with MS. Excel, cut and paste data into internal spreadsheet view of GeNIe
- Cross compatibility with other software. Supports all major file types (e.g. Hugin, Netica, Ergo)
- Support for handling observation costs of nodes
- Support for diagnostic case management

### D.SMILE LIBRARY

SMILE (Structural Modeling, Inference, and Learning Engine) is a fully platform independent library of C++ classes implementing graphical probabilistic and decision-theoretic models, such as Bayesian networks, influence diagrams, and structural equation models. Their individual class, defined in SMILE API (Application Programming Interface), allows you to create, edit, save, and load graphical models, and use them for probabilistic reasoning and decision making under uncertainty. SMILE supports directly object-oriented methodology. SMILE is implemented in C++ in a platform independent fashion. Individual classes of SMILE are accessible from C++ or (as functions) from C programming languages. As most implementations of programming languages define a C interface, this makes SMILE accessible from practically any language on any system. SMILE can be embedded in programs that use graphical probabilistic models as their reasoning engines. Models developed in GeNIe can be equipped with a user interface which utilizes SMILE as the backend engine. SMILE is released as a dynamic link library (DLL). There are also several SMILE wrappers, such as SMILE.NET (.NET interface), SMILEX (Active X), jSMILE (Java interface), etc.

#### Primary Features:

- Graphical editor to create and modify network models.
- Platform independent, versions available for Windows, Unix (Solaris), Linux, Mac, Pocket PC, etc.
- SMILE.NET available for use with .NET framework. Compatible with all .NET languages, including C# and VB.NET. May be used to create web-based applications of Bayesian networks.
- Thorough and complete documentation.
- Robust and running successfully in the field since 1997.
- Responsive development team support, we will compile SMILE for your platform on demand.

### E.Let's build it!

We've got 12 nodes on which we make the comparison between the received statistics likes of customer and the current songs stored on the database of the local

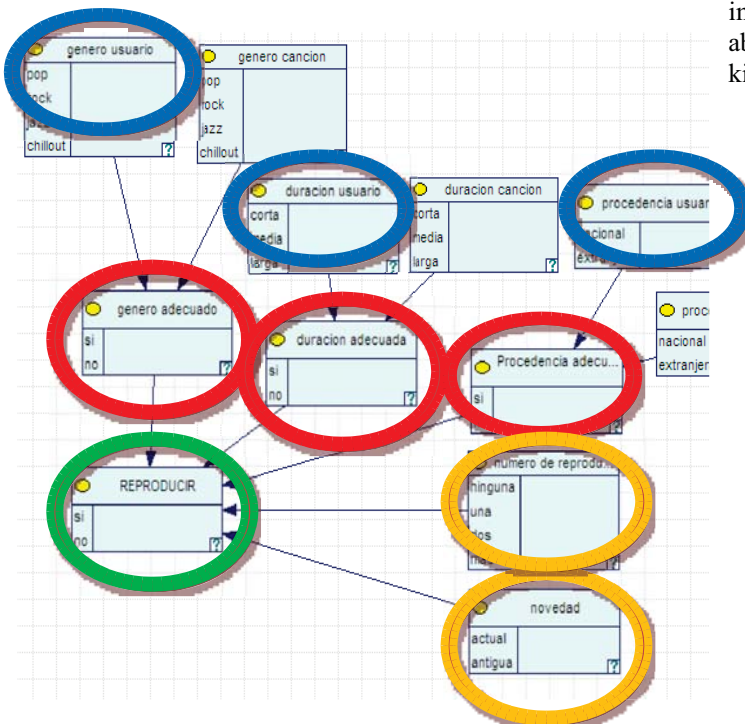
We are going to explain the meaning of this tree structure:

- The nodes with no circle surrounded means the attributes of the songs, such attributes as genre ("genero de cancion"), length ("duracion de cancion") and origin ("procedencia de cancion"). This information is set on the nodes by "setEvidence" method, a method of the library that SMILE provides us. All the songs of the database have to get this attributes.
- The nodes surrounded with blue circles mean the statistic information of all the customers who send the form with the Bluetooth customer application.

The joint of these nodes ends on nodes surrounded with red circles called: appropriate genre ("genero apropiado"),

appropriate length (“duracion apropiada”) and appropriate origin (“procedencia apropiada”) which includes the value of the result of evaluate the previous nodes.

- The nodes surrounded with orange circles mean the information about number of reproductions the song has and if the song is recent. The first one penalized the songs with more number of reproductions; the second one generates more value to the song with this attribute.
- All of those nodes ends on the node with the green circle; it has a value for each song on the database taking into consideration all the previous nodes.



Once we get evaluated all the songs finally, it only remains to arrange the songs into a list and began the reproduction of this playlist.

#### XVI.FORTH STEP: HOW TO CREATE THE COMPARISON?

We are going to explain where we find our conclusion about decision rates selected on the different styles of music, this site is a metadata database of music called:

“<http://www.allmusic.com/>”.

The database consists of:

- Basic Metadata: names, genres, credits, copyright info, product numbers, etc.
- Descriptive Content: styles, tones, moods, themes, nationalities, etc.
- Relational Content: similar artists and albums, influences, etc.
- Editorial Content: biographies, reviews, rankings, etc.

Allmusic also claims to have the world's largest digital archive of music, including approximately six million songs fully digitized.

The Allmusic database is also used by several generations of Windows Media Player and Musicmatch Jukebox to identify and organize music collections. Windows Media Player 11 and the integrated MTV Urge music store have expanded the use of Allmusic data to include related artists, biographies, reviews, playlists and other metadata.

#### A.Related researches

Since IMUSIC is a customer likes oriented application it's important to know what studies have been taken on this topic about criteria, needs, likes in order to set the decision of what kind of music they want:

- Young Spaniards between 15-35 years old, lives surrounded of technologies since all of them have a mobile phone, about a 95% have personal computer, 84% have digital camera, 73% mp3 player and a 62% have a videogame-consol under a first trends research by Nokia.

The first conclusion is that differences between men and women are quite few on use of technologies and the big group on use of new technologies is the young people. Nowadays young people want a comprehensive mobile phone with Bluetooth, USB connection, digital camera, mp3 player, external memory. And talking about design the preferred format for mobile is the opening slide, which is preferred by 31 per cent of young people, followed by monoblock with 26 percent.

The research highlights the importance of music among young people who listen to an average of 23 hours per week and consider it to be more important than the sport, leaving march, politics or religion and that lie behind family and friends.

- Another study on the people musical likes conducted by Renaud Lambiotte and Marcel Ausloos Statistical Physics experts contend that the musical likes of people are more diverse from what we know.

These physicists have analyzed a website for exchanging music files and have found that people likes a wide variety of music for a mix of several predefined categories. The results could give a new way of classifying musical genres and be useful for analyzing market trends music. The study is based on the Audioscrobbler site, where users can upload their favorite music to a personal library on a central server. The site is designed to encourage their users to discover new types of music through the suggestions that other people do in their personal libraries.

Using data from January 2005 researchers were able to examine the music heard by a total of 35,916 people together "possess" 617900 musical groups in their personal libraries. At the top of the list were

Radiohead, Nirvana, Coldplay, Metallica and the Beatles. To analyze the list of users and music listeners used methods of the theory of complex networks in which people and music are two kinds of nodes in a network. Physicists began with a network "absolutely connected" in which two people are "connected" if at least share a song from the same artist.

After applying an adjustable filter to the result network which took into account the correlations between entire collections of music rather than among individual musical groups it could see that as increasing the value of the filter structures found disconnected or "branches" formed along the overall structure of the original network, thus revealing trends and patterns in the form of a map of different music genres.

This method of analysis allows study how music and new trends appears and it quantifies the musical signatures of a large number of individuals and visualizes their collective behavior that eventually leads to the emergence of new sociological communities.

- An investigation of Injuve has done a study about musical preferences, which indicates the percentage of young people who say they like "Fairly" or "much" each of the following musical genres:

	TOTAL (%)
Pop, pop-rock	50.1
Dance	40.2
Latina, salsa	36.4
Cantautores	30.7
Electrónica	29.6
Baladistas, canción melódica	29.5
Rumba	21.9
Flamenco	21.2
Rock'n'roll, rock clásico	20.0
Hip-hop, rap	18.0
Rock alternativo, grunge, indie-rock	17.6
Indie-pop, power-pop, pop alternativo	16.7
Popular o típica de su región o comunidad autónoma	16.3
Reggae, ska	16.2
Musicas del mundo, étnicas	15.3
Rhythm&blues, soul, funk	14.9
Heavy, hard rock, metal	14.9
Clásica	13.7
Rock progresivo, psicodelia	11.7
Punk, hardcore	11.6
New age	10.3
Jazz	9.5
Folk, country, blues	7.3
Total	1.900
NS: p>.05.	

Thus, among the styles like "fairly" or "a lot", highlights the pop-rock or pop (likes to half of those interviewed), dance music (40%), Latin music and salsa (36 %), Songwriters (31%), electronic music (30%) and the trivial and melodic song (30%). The rest of styles presented acceptances below (all less than 22%).

The classification is usually done in musical genres along the following criteria:

1. Features melodic, harmonic and rhythmic.
2. Instrumentation
3. Geographic place where it's developed mainly.
4. Historical sources.
5. Structure of works (songs, movements, etc.).
6. Standards and techniques of composition and interpretation.
7. Ways and methods of broadcasting

#### B.Decisions making

Conclusions on previous researches:

- Referring to the first research we could deduce that it could be better to take the advantages of the current mobile technology for connect our application with the customers likes. Instead of use terminal input devices and all that it entails as the problem of setting up in each local, this solution is cheaper and better. But even so using mobile technology there are many options you can use instead, those options are: WiFi, infrared...

- The second research gives us information on all genres that exist today in order to catalog all the music likes of customers.

Through this research we find that we may be expanding and improving the Bayesian network that it will help us to decide what music is appropriate and what not as the likes of customers.

Because there are so many musical genres, in our first version we will introduce only a few genres.

In the future versions we will expand the application to get a better align with the likes of customers. Then we could establish the musical genre as an essential attribute to decide what kind of music we want.

- With the third research we figure out what is the music likes globally. One of the objectives of our application is that any customer can find a way to express their musical tendency and to make it possible we have to develop an easy and friendly user interface that allows each user whatever likes he has can become an important build-part of the songs decision making of the local.

Because the interface developed has to be simple we couldn't include so many musical genres, so for a first version we have chosen the following genres:

- Pop
- Rock
- Jazz



○ Chillout

After getting information about several researches we found we have reached the following conclusion about their influence on each other genres:

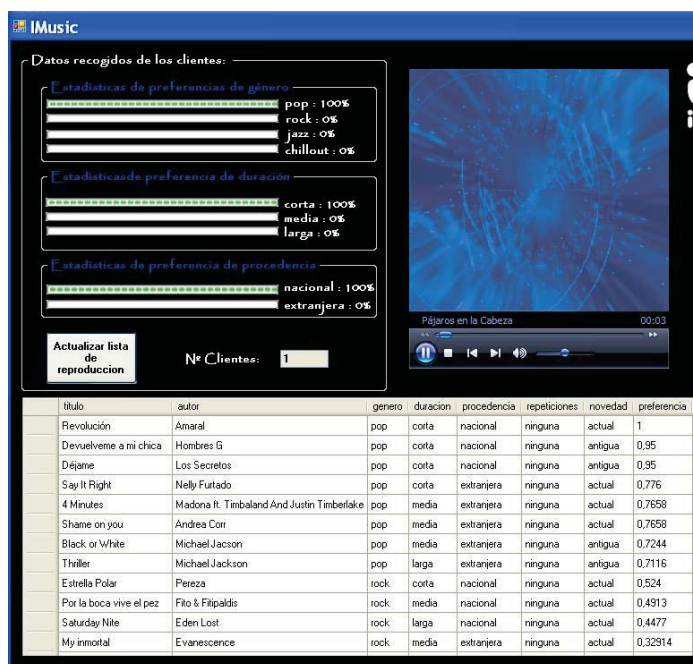
Influence of	over	%
Pop	Rock	30%
	Jazz	10%
	Chillout	5%
Rock	Pop	50%
	Jazz	20%
	Chillout	10%
Jazz	Pop	10%
	Rock	36%
	Chillout	60%
Chillout	Pop	15%
	Rock	20%
	Jazz	50%

We also found information about different styles and trends of music so the next step was quite easy: pair each musical genre at the Genie application with the others genres to make a intelligence decision making based on the origin of this style, trends, music speed ( bits per second).

Once make this step, we have to make decision of the results given for the customers as well, this decision consist on the form they had filled in. The fields with the relevant decision making weight was:

- Genre
- Nationality
- Length

This process is done for each song of our Database so at the end we have a “CUSTOMIZED PLAYLIST” ready to use into our local music application designed to play songs:



## XVII. CONCLUSIONS

In the last few weeks we have spend a lot of time working on development of iMusic prototype, thinking if this project could get ahead. Sometimes we have the feeling that we can't do this, but eventually, the reward of all this hard work is worth it.

Technology talking, we have to learn a lot of packages and libraries to make possible the communication between a simple mobile phone, with a computer, which it comes to mind that there is a lot of applications that could make the daily life better. We even learnt, how to make a free chat using the phones with Bluetooth, and many others applications, that could fit well with our own interest (a little help on test evaluations, for instance). Talking about the iMUSIC application, we found very interesting the idea of being able to send, the kind of music you wants more, and this idea of business can be tempting for those locals that want to experiment a new idea of service for offering the customers. The next step that the application could overtake is to learn about new music tendencies and include them in our application. These procedures probably require a huge change on the application intelligence actions, but it is quite interesting to be developed in the future.

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# General purpose MDE tools

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**Abstract**—MDE paradigm promises to release developers from writing code. The basis of this paradigm consists in working at such a level of abstraction that will make it easier for analysts to detail the project to be undertaken. Using the model described by analysts, software tools will do the rest of the task, generating software that will comply with customer's defined requirements. The purpose of this study is to compare general purpose tools available right now that enable to put in practice the principles of this paradigm and aimed at generating a wide variety of applications composed by interactive multimedia and artificial intelligence components.

**Keywords**—MDA, MDD, MDE, Software Factories

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## XVIII. INTRODUCTION

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**M**ODEL Driven Engineering (MDE) is a new paradigm which opens new expectations in software development. The aim of this idea is to release the developer of the boring routine of writing in a specific programming language the software that complies with the requirements specified by the customer. If needs are correctly in a language that machines can interpret, what would happen if we let them translate it to a programming language?

Although its an emerging technology, in the last few years its popularity has caused the creation of a considerable number of tools based on it. The purpose of this study is to compare the general purpose tools that are available right now.

The remaining part of this paper is organized as follows: In section 2, we present a brief review of the main concepts of this paradigm, to understand the technical terms that will be used afterwards. In section 3 we review related researches and set the tools and features to be evaluated. In section 4 we show a comparative study. In section 5 we discuss the results and in section 6 we show our conclusions.

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## XIX. BACKGROUND

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In the mid 60's "The Software Crisis" [14] came apart. Software development had got to a point where mostly all resources were spent in its maintenance instead of its creation.

The origin of the problem was the fact that software production was intended to create code as fast as possible to deliver it to customers. The result was a poor quality software, which carried out the basic needs of the customer, with many errors and not very reliable. Its exploitation in most cases meant a long process of debugging and change. This process degraded even more code quality, and made very difficult to maintain by other developers.

Then, Software Engineering appears [17], consolidating methodologies and increasingly sophisticated tools designed

to help engineers to work with a high-level overview of systems which development they have to organize and run.

Software engineers design high-level documents supported by graphics languages such as UML [11]. However, in most cases, this initial documentation is not maintained anymore when it comes to the later stages of development in which we must codify and deadlines beset. The result is a rift between high-level documentation and the real state of the project.

All these problems are compounded by the size and complexity of the projects, emphasizing that the solution does not seem likely to be focused on the code despite advances as significant as the object oriented software and design patterns.

Finally, in recent years a new paradigm has appeared which tries to find a solution focusing on models: Model Driven Engineering (MDE). Concerning this concept, several proposals to implement appear, but the most important are: Model Driven Architecture (MDA) and Software Factories, one opposite to another.

### A. Model Driven Engineering

The Model Driven Engineering (MDE), proposes to focus software development on models, rather than on code. In this context a good definition of a model is provided by the Object Management Group (OMG) [8]: "A model of a system is a description or specification of that system and its environment for some certain purpose. A model is often presented as a combination of drawings and text. The text may be in a modeling language or in a natural language."

From these models, combining two basic aspects [16]: **Domain-Specific Modeling Languages (DSML)** to formalize the application structure, behavior, and requirements within particular domain, and **transformation engines and generators**, to analyze certain aspects of models and then synthesize various types of artifacts, which can range from source code to alternative model representations.

The aim is to provide developers with the definition and construction of a high level system module, and from then on, create successive models with a lower level of abstraction each time, reaching at last, a model directly executable on a physical machine.

### B. Model Driven Architecture

Model Driven Architecture (MDA), is an OMG proposal [8] which seeks to standardize an implementation of MDE. The three primary goals of MDA are portability, interoperability and reusability through architectural separation of concerns.

MDA defines three types of models, each with a higher level of abstraction than the next:

The **Computation Independent Model (CIM)** shows the system but does not show details of its structure. It is used to answer the following question: What makes the system?

The **Platform Independent Model (PIM)** shows the systems logic and its interactions with other systems but without detailing what kind of technology it will use or if it adapts itself to a particular platform. It is used to answer the following question: How does the system do what was defined in CIM?

The **Platform Specific Model (PSM)** which combines PIM specifications with the details that specify how to use the system with a particular type of platform.

To define these models, the technology proposed by OMG is MOF [10]. Each of the Domain-Specific Modeling Languages that are used to describe it (UML, SPEM, etc...), will be defined by their corresponding metamodels which in turn will be instances of MOF.

Transformation of models is the key to the process, which consists of converting a model in another model of the same system. The MDA tool must generate one or more PSMs from a PIM along with a set of transformation rules. The same tool or a different one will generate an executable model (source code) of the application from PSM together with additional information.

The standard language that proposes for the definition of OMG transformation models is the Query / View / Transformation (QVT) [10], which in turn is based, on the restrictions language Object Constraint Language (OCL) [12].

### C. Software Factories

Software Factories are an alternative to MDA led by Microsoft. Both are opposite proposals, but an objective analysis of these [9] leads to the conclusion that both are not as antagonist as the confrontation of OMG vs. Microsoft could make us suppose.

A Software Factory, is defined as [3] "A software product line that provides a production facility for the product family by configuring extensible tools using a software template based on a software schema."

Software Factories focus on the development of similar systems by promoting reuse of architectures, software components and knowledge. In this case the role of the model is to define the design of the parts of the system that extend the functionality of the patterns already developed.

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## XX.MDE TOOLS

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To compare the tools, it is necessary to choose which are the appropriate and which are the characteristics that are going to assess for each of them. We have reviewed the related work in recent years and we have selected a battery of features to implement this study.

### A. Related Work

There have been various studies characterizing and/or comparing development tools oriented models. Most of these are focused toward MDA tools that are without discussion, the most popular.

Stuart Kent's work [5] provides a first classification on the basis of the aid that each tool provides the developer.

The study of King's College [6], is interesting but is dedicated to a single tool, OptimalJ. The evaluated features are drawn from the specification of MDA [8].

The work of Czarnecki and Helsen [2] is geared to establish a classification approach of transformation models which use the tools.

Molina et al. [7] conducted a comparison between OptimalJ and ArcStyler based on the characteristics assessed in the study of King's College [6] that added three additional features

Tariq and Akhter in [18] establish a set of characteristics that they understand are essential for a MDA tool. This study was applied to 10 commercial tools.

Wang, W. compared to the extensive work [19], 6 tools focused on the UML models transformation.

The work done by Herrera et al. [4] is a compilation of the characterizations made in most of the earlier work and brings some new. However, the comparison focuses exclusively on open-source tools.

Quintero and Anaya in [15] do a categorization of the tools based on the usefulness for the end user. They conducted a compendium and the selection of evaluation criteria used in previous studies. Finally apply the comparative to 10 tools, 2 for each of the categories.

Bollat et al. in [1] conducted a comparison using features drawn from previous work and the specification of MDA [8]. These features are studied in three tools in order to assess whether any of these can be adapted to a particular architecture.

Finally, in other work [13] we had an extensive review of tools and collected many features defined in the other works previously detailed.

### B. Reviewed tools

Of all the tools seen in previous work, we have chosen for our study those that meet a series of requirements that we believe are suitable for automating and supporting the entire MDE development process.

The required features were as follows:

- 2) **Models level:** The tool can handle CIM, PIM and PSM models.
- 3) **M2M:** Tool performs transformations between models.
- 4) **Applications type:** It must be generalist, being oriented to implement the widest possible coverage.
- 5) **Graphical editor:** Integrates a graphical editor of models (typically UML), or a module that allows it.

We have decided to collect two sets of features of the selected tools. The first group of characteristics identified the tool and give idea about its origin and agility in its development and maintenance. They are as follows:

- **Name:** Name of the tool.
- **License:** Type of license under which it is distributed.
- **Release:** Release now available.
- **Updated:** Date has been released the current version. This indicates whether the tool has been recently updated or on the other hand takes time stalled its development.

- **Last year releases:** Number of versions that have been released in the last 12 months (September 2007-September 2008). This indicates whether the tool has been frequently updated or on the other hand takes time stalled its development.
- **URL:** Internet address where people can get more information and eventually download the tool.

The second group is purely technical features and we considered important in deciding whether to choose one or the other. They are as follows:

- **Models language:** Languages used to represent models, both textual and graphical.
- **Platform use:** Platform on which the tool can be used.
- **Platform purpose:** Platform for which the tool is capable of generating code.
- **Language purpose:** Programming languages that is capable of generating.
- **Other features:** Other features that may be considered relevant to the tool.

## XXI.COMPARISON

The tools selected from among those available today [20], [21], [22] and that meet the requirements are ArcStyler,

and maintenance.

## B.Technical features

This is the group of features (Table II) that are considered important in deciding whether to choose one or another tool.

## XXII.DISCUSSION

Now we will comment each of these tools, emphasizing its strong and weak points.

AndroMDA is a powerful and versatile tool with a consolidated cartridges system that allows generate code for different architectures. Although it doesn't have a graphical editor, it supports UML 2.0 and Eclipse EMF based tools. One possible drawback derived from its own versatility and complexity is an abrupt learning curve.

Their development also seems somewhat stalled. After the release of version 3.2 in November 2006, a beta version was released of the expected 4.0 in May 2007. Almost a year later, in April 2008 revision 3.3 was released with some minor changes and corrections. Yet there has been no stable release of version 4.0.

ArcStyler supports multiple platforms and a very friendly interface. Stresses for its ease of use, but it seems that their development is stalled, with its latest version of April 2006.

Borland bet with force by MDE with its tool Together, for

TABLE I  
IDENTIFY FEATURES

Name	License	Release	Updated	Last year release	URL
AndroMDA	BSD	3.3	21/04/2008	1	<a href="http://www.andromda.org">http://www.andromda.org</a>
ArcStyler	Commercial	5.5	11/04/2006	0	<a href="http://www.interactive-objects.com/products/arcstyler/arcstyler-overview.html">http://www.interactive-objects.com/products/arcstyler/arcstyler-overview.html</a>
Borland Together	Commercial	2008	08/06/2008	2 (2007 and 2008)	<a href="http://www.borland.com/us/products/together/index.html">http://www.borland.com/us/products/together/index.html</a>
Eclipse Modelling					<a href="http://www.eclipse.org/modeling/">http://www.eclipse.org/modeling/</a>

Borland Together, AndroMDA and Eclipse Modelling. OptimalJ, although it meets the requirements has been dismissed for having been discontinued.

## A.Identify features

This set of features (Table I), identify the tool. Also give ideas on the origin of the tool and agility in its development

which has released two versions in the last year. It presents an excellent support for PIM using BPMN and a user-friendly interface based on Eclipse.

We also take in notice its implementation of OCL 2.0 and the use of QVT for model-to-model transformations.

Eclipse modelling is not exactly a tool, but a framework which includes many of these tools. But being a very active

TABLE II  
TECHNICAL FEATURES

Name	Metamodels	Platform Use	Platform purpose	Language Purpose
AndroMDA	UML 1.4 (XMI); All EMF-based	JVM	J2EE; .NET; Other	Java; C#; etc..
ArcStyler	UML 1.4	Windows; Linux; IBM RSM	J2EE; .NET	Java; C#
Borland Together	UML 2.0 (XMI 2.0)	JVM	J2EE; .NET; Other	Java, C++, and C#
Eclipse Modelling		JVM		

project, with a large amount of free and advanced tools, has moved us to include it in this work. To use this toolkit, we must have a good knowledge of the technologies being employed and dedicate a large amount of time in collecting and preparing the proper plug-ins.

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### XXIII.CONCLUSIONS

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From our point of view, the most advanced generalist tool, easy to use and which meets the requirements, is now Borland Together 2008. It specially emphasizes for its support for PIM and implementation of standard MDA.

If you want to use free software, AndroMDA and Eclipse Modelling tools are very nice options, although they need more knowledge and dedication.

Anyway we should be alert for the of a stable version of AndroMDA 4.0 with better support of PIM.

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