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Editorial

This volume of the journal "Research in Computing Science" contains selected papers on the modern interdisciplinary research areas: computational linguistics, when the computer model the linguistic abilities of humans, and artificial intelligence, when computers model another human activities like vision, reasoning, decision making, etc.

The papers were carefully chosen by the editorial board on the basis of the at least two reviews by the members of the reviewing committee or additional reviewers. The reviewers took into account the originality, scientific contribution to the field, soundness and technical quality of the papers. It is worth noting that various papers for this special issue were rejected.

The papers of this volume are related both to computational linguistics and artificial intelligence. In case of computational linguistics, a linguistic task is formulated and formal (implemented in software) methods are applied for its solving. For example, these tasks are development of emotional lexicon for Mexican slang or representation of ontologies. On the other hand, the formal methods of artificial intelligence can be applied also to very wide variety of tasks related to intellectual activities, like classification of barking or psychological profiles, business management or crime data mining, among others.

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Grigori Sidorov
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Development of Affective Lexicon for Spanish with Mexican Slang Expressions

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Abstract. Nowadays exists a growing interest in the automatic extraction of subjective expressions (opinions, emotions and feelings) in texts. To identify the semantic orientation of a text, it is assumed that the occurrence of expressions that belong to some emotional category can be regarded as evidence that there is an affective state. Based on this assumption, we create an affective lexicon, consisting in the translation from English to Spanish of various lexical resources, including works based on psychological theories to identify words associated with emotions. The lexicon was manually enriched through semantic relationships as inclusion and synonymy using explanatory dictionaries. Expressions used in Mexican slang were also included in the lexicon. Every word in the lexicon was labeled with its semantic orientation; these are: "very positive", "very negative", "positive" or "negative", for the translated words and "positive" or "negative" for the Mexican slang. The lexicon currently consists of 3550 words and 255 slang expressions.

Keywords: Affective lexicon, emotions, semantic orientation, Mexican slang

1 Introduction

Recently, emotions play an important role in intelligent behavior researching in Artificial Intelligence. The rapidly growing field of affective computing aims at developing systems and resources for predict, understand, and process emotions [1]. Defining what an emotion is, is a very difficult problem. Emotions are not linguistic things; however the most convenient access we have to them is through language, thus one reasonable way to separate emotions from non-emotions is to consider referents of emotion or opinion words [2, 3]. Opinion words are the most important indicators of sentiments; these words are commonly used to express positive or negative sentiments. A list of such words and phrases is called a *sentiment lexicon*, *opinion lexicon* or *affective lexicon*. This kind of lexicon is instrumental to sentiment analysis in the

lexicon-based method, which uses a dictionary of sentiment words and phrases with their associated orientations and strength, and incorporates intensification and negation to compute a sentiment score [4].

The purpose of this work is to present the development of a resource for sentiment analysis. This resource is an Affective lexicon composed by the translation from English to Spanish of sentiment words and also by Mexican slang expressions. The paper is organized as follows: Section 2 presents related works with the creation of affective and emotional lexicons. Section 3 describes the method followed for the creation of the affective lexicon. Section 4 details the results and lessons learned. Finally the Section 5 exposes the main conclusions and ideas for further works.

2 State of the Art

In this section we describe some works from both theoretical and computational approaches. These approaches are mainly useful for categorizing and classifying emotions, and also for identifying the intensity and the valence or semantic orientation of the emotions. From the psychological point of view we described some examples like the work presented in [2], where an Affective Lexicon was developed with a taxonomy of affective conditions using a list of 500 words used by other psychologists in their studies of emotion, including words from the work described in [5]. Also, in [5] a geometric representation was built, this representation consists of the relations among the 28 emotion words by placing them in a Euclidean space, where the 28 terms are definable in a two dimensional bipolar space pleasure-displeasure and degree of arousal.

Another work is the one referred in [6] where a corpus was built by collecting a representative sample of words denoting emotions by inspecting some lexical resources like [7], this corpus is composed by emotional words according to a communicative theory in which there should be a set of terms that refers to basic emotions, the theory implies that any emotional term should devolve upon one of the basic emotion modes, or some subset of them.

Now, we described some examples of the methods followed in the computational approach, like the work described in [8] where an affective resource called WordNet-Affect was created from WordNet, through the manually selection of a subset of words and by the labeling of every word of the subset with its affective category. Another example is the proposed method in [9] where a Spanish lexicon was built by the combination and translation from English to Spanish of resources like OpinionFinder, WordNet and SentiWordNet.

Also, in [10] a method for a dictionary creation was presented, in the dictionary created the words are labeled by multiple annotators with the six basic emotions, and the dictionary was evaluated with Kappa and PFA (Probability Factor of Affective Use). Finally in [11] an emotional lexicon called SentiSense was created, the creation of this lexicon is based in psychological theories with the purpose of obtain not only the semantic orientation but also the intensity of the emotion, and in this work it is also used WordNet as a reference.

3 Methodology

In this section we described the method for the creation of the affective lexicon for Spanish with Mexican slang expressions. According to the state of the art, we decided to start a translation with words already classified in emotional categories. Fig. 1 shows our solution methodology for developing the affective lexicon, which consists of three phases: (i) Translation of resources from English to Spanish, (ii) manual enrichment using semantic relationships and (iii) manual enrichment of Mexican slang.

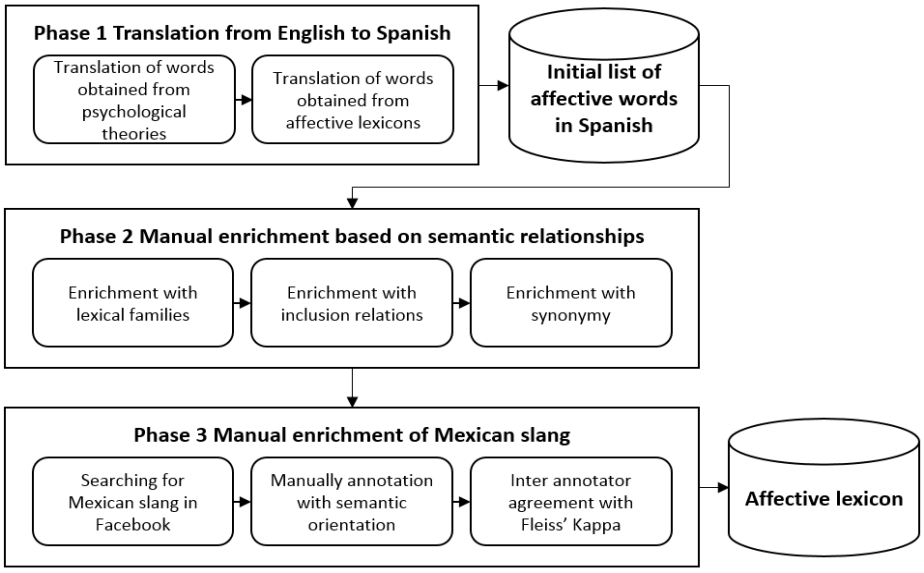

Fig. 1. Solution Methodology for developing Affective Lexicon

3.1 Phase 1: Translation of Lexical Resources from English into Spanish

In this phase words obtained from psychological theories listed below were translated from English to Spanish. The translation is a problem in this kind of research, since many terms have somewhat different denotation and connotation meaning in different languages [12]. Thus, the meaning of the words is analyzed into its context where it can be used.

Translation of words obtained from psychological theories

1. A Circumplex Model of Affect [5].
2. Geneva Emotion Wheel Rating Study [12].
3. The GRID meets the Wheel: Assessing emotional feeling via self-report [13].
4. What are emotions? And how can they be measured? [14].
5. Structure of emotions [15].

Translation of affective lexicons

1. WordNetAffect [8]
2. General Inquirer [16].
3. Opinion Finder [17].

Translation process

1. A word was taken from one of the lexical resources.
2. The word was translated using *Google*[1] and *Linguee*[2].
3. The context of the word was verified by searching their meaning in both English and Spanish. We used the *Oxford Dictionary* for English and *The Dictionary of Spanish Language of the Royal Spanish Academy* for Spanish.
4. Based on the meanings of the word, we choose the best translation.
5. The translated word was added to the Affective Lexicon and we labeled it with the semantic orientation specified in the lexical resources. This semantic orientation can be "very positive", "positive", "very negative" and "negative".
6. The resource where the word comes from is also specified.

Fig. 2 shows a brief content of the Affective lexicon. The first column corresponds to word translated, the second column is the polarity of the word, and in this case: "+" for *positive*, "++" for *very positive*, "-" for *negative* and "--" for *very negative*. The third column is the emotion associated to the translated word; the emotions were obtained from the psychological theories. From fourth column to nine are the lexical resources, where "GI" means General Inquirer, "WNA" means WordNetAffect and "OF" means Opinion Finder. In the final column appears the word in its original language (i. e., English). Columns from fourth to nine can contain one of the symbols "+", "++", "-" or "--" which means that the word was found in the lexical resource specified in the column header with the polarity represented by the symbol.

Spanish	Polarity	Emotion	Morgan-Heise	Russell	Scherer	GI	WNA	OF	English
Regocijo	+	Joy				+			Rejoice
Angustiado	--	Anxiety	--						Anguish
Tranquilo	+	Serenity		+					Calm
Deplorable	-	Sadness					-		Deplorable
Despojado	-	Sadness					-		Bereft
Abatido	--	Sadness			--				Dejected
Furioso	--	Anger	--						Furious
Furiosamente	--	Anger							Fiercely
Colérico	--	Anger							Choleric
Solidaridad	+	None						+	Solidarity
Placentero	++	Hapiness	++	++	++				Delighted

Fig. 2. Brief example of the content of the Affective lexicon

[1] Free online Translation service provided by Google.
[2] Both an editorial dictionary and a search engine for translations from the bilingual web.

3.2 Phase 2: Manual Enrichment based on Semantic Relationships

In this phase, the initial list (the one generated in the previous phase) was enriched with semantic relationships that are explained below. The types of enrichment were obtained from *The Dictionary of Spanish Language of the Royal Spanish Academy, The Reverse Dictionary, A printed Dictionary of Synonyms* and *WordReference*[3].

Enrichment with lexical families

A lexical family consists of a base word and all its derived and inflected forms. So, for the word "*pervertir"* (pervert), the words "*perverso"* (perverse), "*pervertido"* (perverted), "*perversidad"* (perversity), "*perversión"* (perversion), "*pervertidor"* (perverter), may be all members of the same lexical family [18]. So, for each translated word, members of its lexical family were also included keeping the same polarity.

Enrichment with inclusion relationships

The inclusion relationships describe situations where one entity type comprises or contains other entity types. Class inclusion is the standard subtype/super type relationship that frequently appears in data modeling. Examples include: "*coche"* (car) is a type of "*vehículo"* (vehicle), "*rosa"* (rose) is a type of "*flor*" (flower), and "*robo*" (robbery) is a kind of "*crimen"* (crime) [19].

Enrichment with synonymy

Synonyms are words that have the same or nearly the same meaning. For example, the word "*aprehender*" (apprehend) and "*detener*" (detain) are synonyms [19]. Dictionary of Synonyms were used for obtaining synonyms of the translated words.

3.3 Phase 3: Manual Enrichment of Mexican slang

In this phase, the lexicon was enriched with Mexican slang and other expressions like emoticons and interjections commonly used. Firstly, the vocabulary was obtained; then the expressions were annotated with the semantic orientation; and secondly, the annotator agreement was evaluated.

Searching for Mexican slang in Facebook

A Software System for automatic extraction of comments obtained from Facebook was developed in order to identify common expressions used in the Mexican slang. According to the context in which the word was used, the meaning of the expression was also added. Table 1 presents some Mexican Slang Expressions. First column shows the Mexican Slang Expressions. Second column describes the meaning of the expressions according to its context. Finally, third column presents an example, where the word is used.

[3] Online Lenguage Dictionaries.

Table 1. Mexican Slang Expressions with meanings and context examples.

#	Mexican Slang Expression	Meaning	Context example
1	*Qué pedo!* – What the fuck!	*Enojo* (Angry)	*Qué pedo contigo!! Te estas pasando de ojete!!* (What the fuck with you!! You're doing wrong!!)
2	*Qué pedo!* – What's up	*Saludo* (Salute)	*Qué pedo wey, ya saliste de la uni, vamos por una frías!* (What's up buddy, are you out of school?, Do you wanna go for a beer?)
3	*Madreado*	*Golpeado* (Beaten)	*Lo dejaron bien madreado por andar en donde no debe.* (He was very beaten because he made something wrong)
4	*Madreado*	*Cansado* (Tired)	*Tuve un chingo de trabajo hoy, terminé bien madreado.* (I had a lot of work, and I'm so tired)
5	*Chingar*	*Robar* (Steal)	*Estoy que me lleva la... fui al centro y me chingaron mi celular.* (I can't believe it... I went to the downtown and someone stole my cell phone)
6	*Chingar*	*Molestar* (Annoy)	*Esos del banco siempre están chingando por teléfono.* (The bank cashiers always annoy me by phone)

Manual annotation

Every word in the list previously generated was labeled by five people as "positive" or "negative" and also if they agree with the meaning of the word. The purpose of this manual annotation is to validate the quality of the semantic orientation and the meaning of the Mexican slang expressions that we previously found in the Facebook comments. With the annotations of the five people we generated a table as shown in Table 2.

Table 2. Example of manual annotations of the Mexican slang.

#	Person 1				Person 2				Person 3				Person 4				Person 5			
	P	N	A	D	P	N	A	D	P	N	A	D	P	N	A	D	P	N	A	D
1		X	X			X	X			X		X		X	X			X	X	
2	X			X	X		X		X		X		X		X		X		X	
3		X	X			X	X			X	X			X	X			X	X	
4		X		X		X	X			X	X			X	X			X	X	
5		X	X			X	X			X		X		X	X			X	X	
6		X	X			X	X			X	X			X	X			X	X	

The first column makes reference with Table 1, the next columns are the annotations of the five people, where the letters used mean: P = Positive, N = Negative, A = Agree and D = Disagree.

Other expressions

Some interjections, abbreviations and emoticons frequently used in the Facebook comments were also added. Table 3 shows some examples of these expressions.

Table 3. Examples of interjections, abbreviations and emoticons.

#	Exp.	Meaning	Context example
1	ash	*Desagrado* (Displeasure)	*Ash, no lo puede hacer alguien mas??? Porqué siempre yo???* (Ash, can someone else do this??? Why always me???)
2	nhp	*No hay pedo* (No problem)	*nhp!!! Yo pongo mi casa para la party!!!!!* (nhp!!! We can celebrate the party in my home!!!!!)
3	npi	*Ni puta idea* (No fucking idea)	*npi de cuando se publiquen los resultados.* (npi when the results will be published)
4	mms	*Mamadas* (Foolishness)	*Qué mms son esas de postear feliz viernes!!* (What a mms are those of post happy Friday)
5	chin	*Frustración* (Frustration)	*No llegué a tiempo chin!! No hice el examen.* (I'd not in time chin!!! I didn't resolved the exam)
6	mta	*Enojo* (Anger)	*Mta!!!! llevo mil horas esperando la ruta!!!* (Mta!!!! I've been waiting a thousand hours for the microbus arrive)
7	T_T	*Triste* (Sad)	*Alguien puede ayudarme!!! T_T No sé que hacer!!! :(* (Can anybody help me!!! T_T I don't know what to do!!!)
8	>.<	*Molesto* (Annoying)	*No es posible que existan personas así!!!!* >.< (How is possible that people like that could exist!!!!)
9	:D	*Feliz* (Happy)	*Wiiii El día tan esperado llegó, por fin de vacaciones!!! :D* (Wiiii The long awaited day is here, vacation!!!)
10	^.^	*Feliz* (Happy)	*Que tu novio te regale chocolates, no tiene precio!* ^.^ (If your boyfriend gives you chocolates, is priceless!)

Inter annotator agreement with Fleiss' Kappa

Fleiss' Kappa metric [20, 21] was applied in order to evaluate the agreement between the annotators. We conducted two assessments, the first one for the polarity annotation, and the second one for the annotation of the meaning. The results were the following: for polarity annotation a value of 0.82 was obtained and for the annotation

of the meaning a value of 0.79 was obtained. According to the Fleiss' Kappa metric the firs result means "very good" agreement and the second one means "good" agreement [21]. In both cases, the subjectivity involved in the interpretation and annotation of the affective words has an impact into the results.

4 Results and Lessons Learned

In this section the size of the Affective lexicon and some lessons learned in the creation of the Affective lexicon are presented.

4.1 Size of the Affective Lexicon

Table 4 shows some examples of the elements of the categories that are part of the Affective Lexicon and the total number of expressions included in every category. In the last category, the emotion associated to the affective word was obtained from the lexical resources translated. First column presents the Affective Lexicon categories; Second column shows the total number of expressions in every category. Finally, last column details some examples of the expressions contained in the categories. In the Affective Words category, the emotion associated to the affective word is also presented.

Table 4. Number of elements of the Affective lexicon

Category	Total expressions	Expressions	
		Semantic Orientation	Example
Emoticons	131	***Positive***	:D :-) n.n ^.^
		Negative	:-(T.T u.u </3
Interjections and abbreviations	60	***Negative***	snif, ogt, ash
		Positive	wi, aw, yeah
Mexican slang expressions	255	***Negative***	*Desmadrar* (Break)
			Chingar (Bothersome)
			Cagetiza (Scolding)
		Positive	*Poca madre* (Spectacular)
			Chingón (Able)
			Chulo (Nice-looking)
Affective words	3550	***Very Negative Emotion***	*Asesinar* (kill) *Ira* (rage)
		Negative Emotion	*Llorar* (cry) *Tristeza* (sadness)
		Very positive Emotion	*Entusiasta* (enthusiastic) *Alegría* (hapiness)
		Positive Emotion	*Plácido* (placid) *Serenidad* (serenity)

4.2 Lessons Learned

The translation took a lot of time because we analyzed the meaning and the context of every word, and the final translation is based on what we considered as the best option. We found some words and phrases that can be used in both positive and negative way, and also words with more than one meaning. In the lexicon we kept both positive and negative context and also all the possible meanings of the words. But, in the practice it is necessary to implement an algorithm to identify the context in which the word is used.

5 Conclusions and Future Works

The main motivation for the development of this research arises from the need to generate lexical resources for Sentiment Analysis in Spanish. In the literature we observed that lexical resources for Spanish are limited, hence we developed an Affective Lexicon.

A common expressions used in Mexican slang were included. These expressions cannot be obtained from other resources because they are designed for Castilian or English. Thus we can say that this project is pioneer in including Mexican slang expressions in an affective lexicon.

As future work we propose:

- The manual enrichment of the Affective lexicon takes a lot of time and it is susceptible to mistakes. So, the best option is to develop a tool for the automatic enrichment through semantic relationships.
- It is necessary to carry out a deeper analysis of comments posted in Social Networks for identifying more Mexican slang expressions to enrich the Affective lexicon with this kind of expressions.
- It would be interesting to identify and classify affective expressions by domain, for example to identify the most common of them used in football, politics, tourism, etc.

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Learning Styles Analysis based on Pattern Recognition Techniques

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Abstract. This paper presents an analysis of different learning styles observed in a group of college freshmen. Recognizing relevant aspects of each style provides aid in the planning of actions that could reduce dropouts and increase the academic performance of first-year students in colleges. To accomplish this study an assessment tool was devised and implemented applying techniques of clustering and measurement of the attributess informational weight. The results showed distinctive attributes that allow them to be classified within five groups (learning styles) that were labeled according to the Felder-Silverman model, and from said groups the visual as well as the active style appear dominant in the case study.

Keywords: Clustering, informational weight, learning styles

1 Introduction

The Pattern Recognition Techniques (PR) allows us to acquire valuable knowledge from data sets that store some information of some specific context. They can be used to automate the speech recognition, fingerprint identification, social problems analysis, or in the prediction of new outcomes in almost any environment, weather it is related to banking, educational, financial, chemical, among others [5]. This discipline can emulate the human ability to describe the behavior of data using automated methods.

There are several PR tasks that can be applied to solve a problem, especially those that solve prediction problems (classification) and description (clustering). The first ones refer to the allocation of a new object to a known class, i.e. the set of training data is divided into a finite number of classes, which can be identified by patterns of behavior, and through these patterns define the class which a new object belongs to. On the other hand, the descriptive problems include mainly those without an a priori classification, in this case the goal is to find a partition

that allows to characterize the objects in the data set into groups with similar behavior [12].

As a result, the PR has been successfully applied to several areas, including agriculture, astronomy, biology, economics, geology, medicine, among others. In this paper, the addressed issue is applying these intelligent techniques to education. One of the highlights of this environment is to provide knowledge to students in a way they understand all concepts and tools teached in class. In order to achieve this goal it is necessary that teachers know the learning styles of their students [9], since some absorb knowledge through traditional learning strategies (readings, concept maps, etc.), but others need different strategies to get what is transmitted by teachers.

There have been several instruments and conducted studies to understand and classify the different learning styles of students, which allows to know and use different methodologies to suit their characteristics, such as the one made at the Universidad Tecnológica de Perú [2] where they found through a statistical analysis that the divergent style is prevalent among students of that institution. Furthermore, the Peruvian University [10], used as an instrument The Honey - Alonso Learning Styles Questionnaire (CHAEA) and Roman JM, Learning Strategies Questionnaire (ACRA), moreover a relationship between learning styles and strategies of their students was found by applying a statistical analysis, considering their academic performance as a fundamental part.

Meanwhile, Mara del Carmen Aguilar Rivera [1] indicates that the relationship between styles and learning strategies in students entering the university explains theories and concepts with regard to measuring instruments used, as the obtained results are analyzed and the related statistical application of the questionnaires used. To find this relationship the Cronbach's Alpha estimate was used, which is interpreted as a weighted average calculated from the variances or correlations of the study variables. The results focus only present correlations between different learning styles and strategies.

It is noteworthy that building a model of learning styles, it allows the classification of students according to the way on how they receive and process information, as shown in "Minería de datos para descubrir estilos de aprendizaje" Elena Durán and Rosanna Costaguta [6], in which they also indicate three stages to develop this work: pre-processing, data mining and post-processing. The aim of this study was to identify the prevalent learning style in a group of college students, but not to find their behavior patterns.

The recognition of various styles in the way of learning indicates the existence of different individual, social and cultural factors in the ways in which the student interacts with the acquisition of knowledge [13], [4]. Hence the interest of this research is, performing it with the help of professionals in education, to organize and characterize groups that result after completing the corresponding surveys.

The application of pattern recognition techniques serves as a tool for identifying learning styles in students of first semester of the Computer and Electronics Academic Area (AACyE) of the Hidalgo State Autonomous University (Universidad Autónoma del Estado de Hidalgo) (UAEH). Its data was obtained from a

questionnaire designed to identify the factors that may influence the academic performance, in order to obtaining information to improve decision making and, from it, develop strategies to improve the school performance.

2 Study Case and Employed Methodology

This section introduces the process that was conducted to collect data allowing the characterization of students in groups according to different learning styles. As well as, the description of data, and the used pattern recognition procedure, are shown.

2.1 Preparation of Data

In order to recognize what learning styles are predominant in college freshmen, we chose to apply a questionnaire that serves as an assessment instrument of their study habits and preferences in their learning process, so we can pass on this knowledge on to teachers allowing the use of specific learning strategies.

The questionnaire was developed in conjunction with an expert of the Academic Area of Educational Sciences (Área Académica de Ciencias de la Educacin) UAEH, based on three different evaluation tools:

1. Questionnaire to university students by Martha Artunduaga Murillo [3]
2. Learning Styles Test by David Kolb [8]
3. Abbreviated ACRA scale to university students by Jesús de la Fuente Arias et. al [7]

The overall purpose of these questionnaire is to evaluate the academic performance in order to identify strategies to improve performance and reduce dropout rates at universities.

Abbreviated ACRA is a self-instrument, which is inspired by the principles of cognitive information processing, allowing quantitatively evaluate various learning strategies used by students. In the study phases it handles the acquisition, encoding, retrieval and information support.

The other Artunduaga's measurement scale, focuses primarily on academic performance and dropouts, emphasizing on basic skills and students abilities to organize their time, to manage and implement a study method to receive and organize information. It also considers the degree of motivation and satisfaction provided by their studies, their capacity of future planning, academic and self-concept as well as their skills.

The final questionnaire is composed by 37 questions (considered as attributes) and was applied to 165 students in the first semester of the Bachelor in Computer Science (94 students), Electronic Engineering (28 students) and Telecommunications Engineering (43 students) of AACyE at the Institute of Basic Sciences and Engineering UAEH (Instituto de Ciencias Básicas e Ingeniería UAEH).

From these 165 students, 37 were women and 128 men between 17 and 25 years old. Once the surveys were applied, the results were captured in a database

that would build the minable view for processing. Since it is possible to choose more than one answer for each question a set of keys was made to identify the possible answers of the students

2.2 Aplicacition of Pattern Recognition Process

To carry out the processing of the data, obtained in the previous section, the modeling process shown in [11] which involves the participation of specialists in the area of application and pattern recognition specialists, was applied. This process is shown in Figure 1, where it can be observed how a real situation is modeled up to the solution of the problem, including a pattern recognition model which allows us to find hidden knowledge in the data. In this particular case, it is a characterization of the students according to learning styles they use in their training.

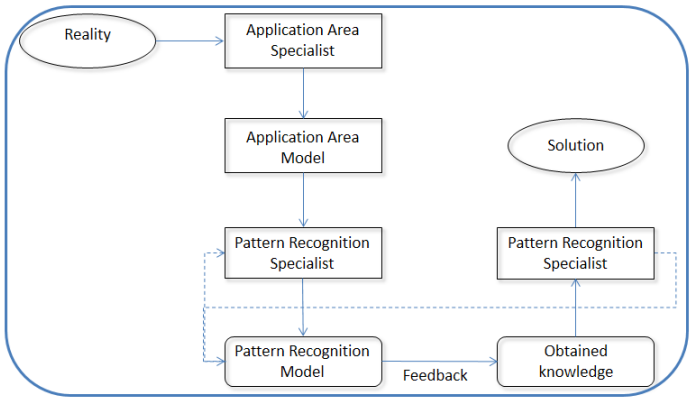

Fig. 1. Pattern Recognition Process

The role every specialist must follow in the pattern recognition and application areas were identified, so that each one contributes effectively to the solution of the problem. With the help of the expert in education, the model was found in the application area as a set of pre-selected, integrated and prepared data (using the data described in Section 2.1). This model allows access to information using pattern recognition techniques. The chosen techniques are in the family of unsupervised classification, since the aim is to find the partition on which the data is grouped making it possible to characterize the obtained groups. Finally, this characterization will help to recognize learning styles employed by the surveyed students. Figure 2 presents the specific model of pattern recognition for this case study.

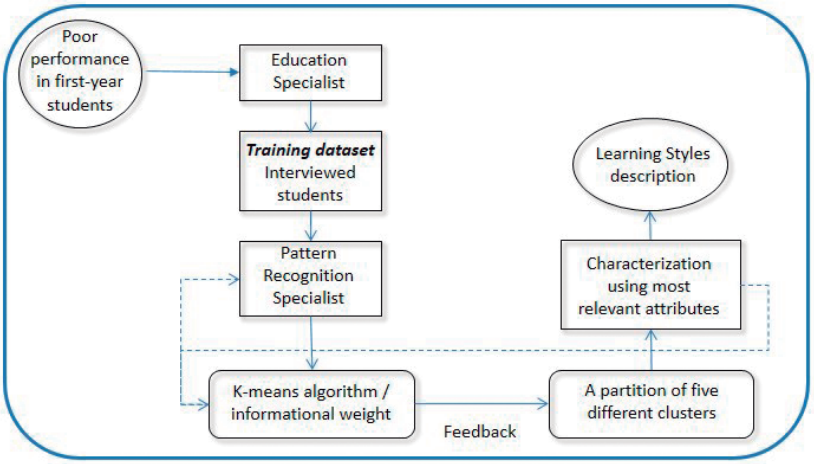

Fig. 2. Pattern Recognition Process applied to the analysis of learning styles

3 Experimental Results

The following experiments were performed using the Weka software version 3.6.12. The first step was applying the Simple K-Means algorithm to generate the groups that represent the freshmen learning styles. The parameter k was set to five, given Felder and Silverman's [6] model, where the learning styles recognized are sensory, visual, active, sequential and inductive.

The distribution of samples attained by the 165 students surveyed into the five groups, is shown in Table 1; where it can be noticed the two learning styles that are predominant in this sample.

Table 1. K-Means results

Cluster	**0**	**1**	**2**	**3**	**4**
Number of instances	28	**55**	18	13	**51**
Percentage	17	**33**	11	8	**31**

Subsequently, in order to determine which are the most influential variables in this study, the information of the variables that describe the behavior of the surveyed students was measure. This measure helped choose the most representative variables to build the characterization of each group, applying Weka's Information Gain Ranking Filter method, the attained results are shown in Table 2.

The first ten variables that charted value greater than 0.45 were used as reference and from the most common findings, the characterization of each group

Table 2. Information Gain Ranking Filter results

Position	Attribute	Ranking	Position	Attribute	Ranking
1	21	0.6365	20	32	0.2305
2	18	0.5621	21	8	0.2240
3	34	0.5619	22	6	0.2111
4	20	0.5375	23	7	0.1974
5	22	0.5128	24	10	0.1745
6	24	0.5033	25	37	0.1705
7	33	0.4978	26	31	0.1670
8	19	0.4884	27	15	0.1309
9	27	0.4560	28	5	0.1177
10	30	0.4544	29	1	0.1100
11	26	0.4383	30	2	0.0428
12	28	0.4344	31	16	0.0395
13	11	0.3832	32	29	0.0287
14	25	0.3824	33	4	0.0124
15	23	0.3174	34	3	0.0000
16	17	0.3133	35	13	0.0000
17	9	0.2851	36	14	0.0000
18	36	0.2614	37	35	0.0000
19	12	0.2342			

was built. Table 3 shows these descriptions, alongside the general description given by Felder and Silverman of each learning style.

Based in the comparison between the description obtained and the description given by these authors, and with the help of an expert in the subject, it was possible to label each group as one of the learning styles aiding in the identification of the different types of college freshmen. Making use of these descriptions teachers could develop strategies to improve the students academic performance.

4 Conclusions

The application of PR techniques in different areas has been relevant to solving real problems. In particular, in the area of education, to find knowledge on information provided by students, faculty and staff, it allows to develop different strategies for an efficient decision making.

The development of this work allowed to determine patterns of behavior that recognize learning styles (sensory, visual, active, sequential and inductive) among freshmen in a particular study case, whether the students are from the area of Computing and Electronics of the University of the State of Hidalgo (Computación y Electrónica de la Universidad Autónoma del Estado de Hidalgo). A survey was conducted among the newly admitted freshmen and once this data was prepared, a partition was obtained from it through the K-Means

Table 3. Description of the different learning styles

Learning style	**Definition (Felder and Silverman)**	**Obtained cluster**	**Characterization obtained from the experiments results**
Sequential	Sequential learners follow linear reasoning processes when solving problems. Global learners make intuitive leaps and may be unable to explain how they came up with solutions	0	Are observant people who reason and mentally prepare what to say or write. Best learn through practice. In order to memorize makes use of visual tools such as concept maps
Visual	Remember what they see: pictures, diagrams, flow charts, time lines, films, demonstrations. Rather attain information by listening	1	They are reserved and quiet, learn best when they observe carefully. When faced with a problem they generate approximate answers by inferring from the knowledge they possess. Their study habits mainly include the use of processing strategies such as drawings, graphics and images, to establish relationships between the content of their subjects
Inductive	Induction is the natural human learning style observe the world around them and draw inferences. State the governing principles and work down to the application	2	They are rational and reserved, who work hard to get things done. Analyze by dividing things into parts and generate an approximate answer by inferring from the knowledge they possess. Learn best through observation
Sensory	Learn and memorize facts, they are practical and careful. Prefer principles and theories, like innovation and dislike repetition	3	They are open people and responsible that learn best when they rely on their logical thinking, who make use of rational theories and learning strategies to memorize by repetition, mnemonics, pictures, summaries and mind maps. When faced with a problem they generate approximate answers by inferring from the knowledge they possess
Active	Active experimentation involves doing something in the external world with the information. Reflective observation involves examining and manipulating the information introspectively	4	They are rational and open minded people who mentally prepare what to say or write. They learn through reasoning and practice. Repetition, mnemonics and summaries are common learning strategies

algorithm. These results were used to analyze the set of variables that describe these students, which allowed us to identify the characteristics that best define each learning style.

From the characterizations found in this sample it was observed that the visual and active ones are dominant learning styles. These results will generate proposals to adapt different teaching styles of teachers in this area, in regards to the dominant learning styles of the student population, without neglecting the others.

As future work it intends to apply other clustering algorithms and automatically choose the best among them, in order to find the relationship between the

model of Felder-Silverman and others. Besides, we consider to apply association rules methods to compare the obtained characterization in this work and the set of rules that describe the obtained clusters.

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A Petri Net-based Approach to OWL Ontology Representation

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Abstract. *Ontologies* are an essential component to construct the *Semantic Web*. Therefore, their accuracy and quality must be assured. From the point of view of several fields of study, *models* (or *representations*) are useful to achieve that goal. *Petri Nets* are a graphical and mathematical modeling tool whose capabilities to express important systems characteristics makes them valuable for ontology representation, verification and reasoning. However, given that their application has been reduced to depict taxonomies, the verification and reasoning process are partially achieved. So, there is a need to have a comprehensive ontology representation. In this paper, we introduce the *Ontology Conditional Coloured Petri Net (OCCPN)* model, a Petri Net extension to represent ontologies. Unlike existing proposals, OCCPN not only gives details of the taxonomy but, by evaluating conditions, also provides modeling primitives to create complex classes and describe properties as well as additional restrictions.

Keywords: Ontology, modeling, Petri net

1 Introduction

Ontologies as an essential component of the *Semantic Web* [1]. This puts stringent demands on their accuracy and quality [11].

Different areas, e.g. knowledge representation, ontology engineering, and model–based engineering, highlight the fact that *"models are useful to ensure quality and discover errors in conceptual design"* [4]. In this sense, the first activity to develop high–quality ontologies should be to create an expressive enough and well–founded model that serves as their surrogate, and, then use it in the evaluation process.

By following this methodology, some works apply *model–theoretic notions* to the design and analysis of ontologies, so that, ontology representation and examination are performed by using the principles of a given mathematical

theory [6, 5]. Although promising, this procedure requires high understanding of formal tools. Other approaches use *Petri Nets (PNs)* to ontology representation and verification [8, 13]. Liu et al. [8] introduce the State Controlled Coloured Petri Net (SCCPN), which includes both structures to depict ontology concepts and their associated relationships and dynamic knowledge inference by means coloured tokens. The same authors, but in a posterior work [13], claim that standard ontologies are not sufficient to handle imprecise or fuzzy information and, as a result, extend SCCPN to model and verify fuzzy ontologies. Nevertheless, this work does not provide class constructors nor property characterization, which limits the scope of the verification and, in consequence, falls short to account for the rich scenario described in [11]. This begs what is the research question of this paper: *to what extend can Petri Nets capture the expressiveness required for modeling ontologies*. Up to date, PNs has been used for ontology modeling, only at a taxonomic level, given their capacity to describe concurrent, asynchronous, distributed, parallel, non–deterministic and/or stochastic systems [9]. Therefore, in this paper, we address the question based on previous experience on PNs, specifically, we tap into the *Conditional Coloured Petri Net (CCPN)* [7, 3], a PN extension designed for active rules [10]. We expand CCPN to represent ontologies and develop the *Ontology CCPN (OCCPN)*. By evaluating conditions, OCCPN not only depicts a taxonomy but also provides the means to create complex classes, describe properties and additional restrictions. This makes our model more comprehensive. As a PN extension, the OCCPN has both a graphical and mathematical model [9]. In this paper, only the former is presented.

The rest of the paper is organized as follows. Section 2 explains the set of OWL language constructs. Then, CCPN foundation is presented. Section 3 illustrates an example of the ontology representation using OCCPN. Section 4 and 5 gives details about classes and properties, respectively. Section 6 shows a complete OCCPN model. Finally, Section 7 formulates conclusions and future work.

2 Background

This section outlines two important notions: the *Web Ontology Language*, a means for authoring ontologies, and *Petri Nets*, particularly, the *Conditional Coloured Petri Net*, a useful modeling tool.

2.1 The Web Ontology Language

The *Web Ontology Language (OWL)* is a language designed to represent ontologies through the definition of their parts, namely: *classes (concepts)*, *individuals (instances)*, and *properties (relations)* [14, 12, 2]. A *class* assembles objects with similar characteristics. An *individual*, or *class instance*, is a particular element that satisfies the class description, the set of all class individuals constitute the *class extension*. *Properties* define relations, either between individuals or between individuals and data values. Next subsections give more details about these parts.

Classes OWL has two *predefined classes*: `owl:Thing`, whose extension comprises all individuals, and `owl:Nothing`, which does not have any element. Every new class is a subclass of `owl:Thing`, and `owl:Nothing` is a subclass of any class [2]. There are several forms to declare new classes: the easiest one is creating a *named class*, i.e., a named instance of `owl:Class`; other ways, known as *class constructors*, are those that establish constraints on the elements of their extension. However, this last method produces *anonymous classes*.

Class constructors cover enumeration, set operators, and property restrictions.

Enumeration, `owl:oneOf` clause, fabricates a class by the exhaustive listing of its instances. Set operators, involving `owl:intersectionOf`, `owl:unionOf`, and `owl:complementOf` instructions, describe classes by acting like their traditional set operator counterparts. Property restrictions include *value* and *cardinality* constraints. The former, regulate the *type* of the class extension, and, the latter, the *number*. In this way, `owl:someValuesFrom`, verifies an *existential* quantification, `owl:allValuesFrom`, validates a *universal* one, and `owl:hasValue`, examines a *particular value*. `owl:minCardinality` and `owl:maxCardinality` check the *minimum* and *maximum* quantity of instances in the property, respectively.

When a class is a subclass, by means of the `owl:subClassOf` clause, of another one, the extension of the former is a subset of the extension of the latter. If two classes, using the `owl:equivalentClass` assertion, are equivalent, their extensions are the same. On the contrary, if they are disjoint classes, using the `owl:disjointWith` declaration, the intersection of their extension is the empty set [14, 12].

Individuals Individuals are, either named or anonymous, class members [2]. Therefore, they contain data for each part of the class template: attributes and properties. Additionally, individuals specify facts regarding their identity by means of the sentences `owl:sameAs`, `owl:differentFrom`, and `owl:AllDifferent`, which establishes that two individuals are the same, two individuals are different, and all the individuals in a list are all different, respectively.

Properties *Properties* have *name*, *domain*, and *range*. The property links elements from the domain to those from the range. If components from both domain and range are individuals, then the type of the property is `owl:ObjectProperty`. But, if they are individuals and data types, then the kind is `owl:DatatypeProperty` [2]. A property can have additional features, which imposes new constraints on it. For example, *logical characteristics*, namely: `owl:TransitiveProperty`, and `owl:SymmetricProperty`, as their names suggest, verify if a property fulfills the conditions to be transitive and symmetric, respectively. *Functional features* include the statements `owl:FunctionalProperty` and `owl:InverseFunctionalProperty`. The former describes a condition in which there is, at most, one unique value from the range for each domain instance. The latter checks the functional constraint and its contrary, i.e., there is, at most, one unique value from the domain for each range instance.

Finally, properties are closely interrelated by means the `rdfs:subPropertyOf` statement, which indicates that if $\mathcal{P}_1$ is a sub-property of $\mathcal{P}_2$, then the pairs satisfying the former are a subset of those accomplishing the latter, and the `owl:inverseOf` clause, that defines $\mathcal{P}_2$ as the opposite of $\mathcal{P}_1$ [14, 12].

2.2 Petri Nets

A *Petri Net (PN)* is both a graphical and mathematical modeling tool. It is a directed, weighted, bipartite graph consisting of two types of nodes, namely: *places* and *transitions*, which graphically are represented as circles and bars (or boxes), respectively [9]. Arcs are from a place to a transition or vice versa. In the former case, places are known as input places, and, in the latter, as output places. A marking, or state, assigns a non–negative number of tokens, represented as black dots, to each place of the PN. A transition is enabled if in each one of its input places there is, at least, $w(p, t)$ tokens, where $w(p, t)$ is the weight of the arc from p to t. If the transition fires, the tokens are removed from each one of its input places and are added to each one of its output places [9].

Conditional Coloured Petri Nets (CCPNs) are a PN extension originally developed to model both structure and dynamics of active rules [10]. One of its main advantages is the ability to evaluate complex conditions in transitions. Fig. 1 shows its graphical part, for further details refer to [7].

A *primitive place* represents an indivisible event. A *copy place*, as its name alludes, reproduces its original one. A *virtual place* acts as an information warehouse. A *composite place* delineates complex events, for example, conjunction.

CCPN has the following types of transitions: *rule*, *composite*, and *copy*, which evaluates the condition of an active rule, creates complex events, and duplicates events, respectively. There are two types of *arcs*: *normal* and *inhibitor*. The *token* element defines CCPN dynamics since *a transition fires if it is enabled and*, for rule and composite typed ones, *its condition*, using the data contained in the token, *is evaluated to true*. The inhibitor arc exhibits the contrary behavior, i.e., its transition is enabled if there is no token in its input place.

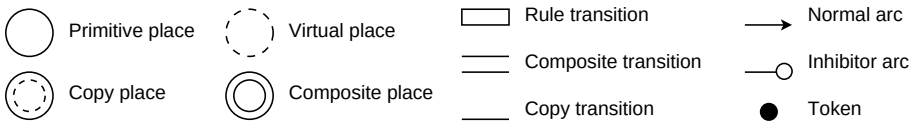

Fig. 1. CCPN basic elements.

3 Ontology Modeling through OCCPN

This section introduces *Ontology CCPN (OCCPN)*, a CCPN augmentation to represent OWL ontologies. The aim is to benefit from the ability of CCPNs to evaluate conditions in transitions and provides modeling primitives to depict the

features described in Section 2.1. In consequence, OCCPN is a richer ontology representation. This part specifically looks into how classes, individuals and properties can be modeled through OCCPN. The intention is to give an intuitive presentation. Section 4 and 5 will later provide a more formal account.

3.1 Classes and Individuals

In OCCPN, a *primitive place* represents a *named class* (see Fig. 2(a)). *Place color* includes the elements: 1) name, 2) axioms, indicating relationships among classes, 3) attributes, attached to class with datatype properties, and 4) operations, depicting object properties. When *defining a new named class*, both name and axioms take a constant value, the rest of the attributes acquire data with *each new class instance*. *Class instantiation* is represented by *depositing tokens* into a primitive place. Such as Fig. 2(b) shows, each token has a name, a type, data for place color, and identity facts.

3.2 Properties

A *property* is represented by the set of ordered pairs, (x, y), $x \in$ *domain*, $y \in$ *range*, for which the property is evaluated to true. Since *rule transitions* appraise conditions, they are useful to stand for properties.

Fig. 2(c) shows the OCCPN structure to model *object properties*: given a rule typed transition, T_0, its input places, C_0 and C_1, symbolize domain and range, respectively, and its output spot, C_2, depicts the set of ordered pairs that satisfy the condition attached to transition. C_2's color has the following elements: 1) name, corresponding to property's name, 2) logical characteristics, 3) property interaction, and 4) functional features.

Since *datatype properties* link individuals to data values, they do not need a rule typed transition, they are captured by *class attributes*. For a given datatype property, its *domain* matches with the *class name*, its *name* corresponds to the *attribute name*, and its *range* constraints the *attribute's datatype*.

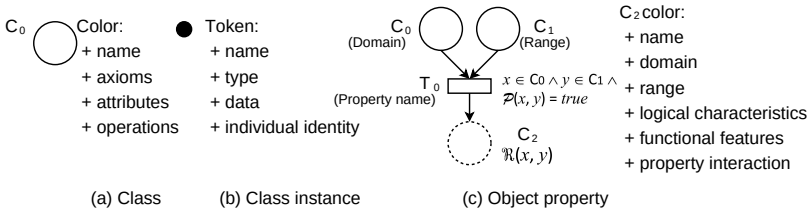

Fig. 2. OCCPN structures for basic ontology elements.

3.3 Example

This section shows an excerpt of a camera ontology which describes a little issue in the field of photography. The complete specification is in reference [14].

Fig. 3 demonstrates, on the left side, the OWL statements to describe two classes, namely: `Lens` and `ValueRange`, and some properties, both datatype and object. Its corresponding OCCPN structure is on the right side.

Classes, defined in lines 1–2 and 8–9, correspond to primitive places labeled as `ValueRange`, and `Lens`, respectively. Lines 3–7, which connect the datatype property named *minValue* to `ValueRange` class, match to attribute definition in the color of `ValueRange` place. A similar situation emerges around lines 10–14 which characterize a datatype property for `Lens` class.

Object property, declared in lines 15–18, ties, through `aperture` relation, individuals from `Lens` class to those coming from `ValueRange` category. In OCCPN, this behavior is achieved by using a rule typed transition having as input places those representing `Lens` and `ValueRange` classes. Its output place acts as a warehouse of those pairs that overcome condition evaluation.

Finally, lines 19–20 creates an individual of `Lens` class, which, in turn, is reflected in OCCPN by the marking in the `Lens` place. This token comprises the name and type for the focalLength attribute.

```
1. <owl:Class rdf:about="&myCamera;ValueRange">
2. </owl:Class>
3. <owl:DatatypeProperty rdf:about="&myCamera;minValue">
4.   <rdfs:domain rdf:resource="&myCamera;ValueRange"/>
5.   <rdfs:range rdf:resource="&xsd;float"/>
6. </owl:DatatypeProperty>
7. <rdfs:Datatype rdf:about="&xsd;float"/>
8. <owl:Class rdf:about="&myCamera;Lens">
9. </owl:Class>
10. <owl:DatatypeProperty rdf:about="&myCamera;focalLength">
11.  <rdfs:domain rdf:resource="&myCamera;Lens"/>
12.  <rdfs:range rdf:resource="&xsd;string"/>
13. </owl:DatatypeProperty>
14. <rdfs:Datatype rdf:about="&xsd;string"/>
15. <owl:ObjectProperty rdf:about="&myCamera;aperture">
16.  <rdfs:domain rdf:resource="&myCamera;Lens"/>
17.  <rdfs:range rdf:resource="&myCamera;ValueRange"/>
18. </owl:ObjectProperty>
19. <myCamera:Lens rdf:ID = "lens_instance">
20. </myCamera:Lens>
```

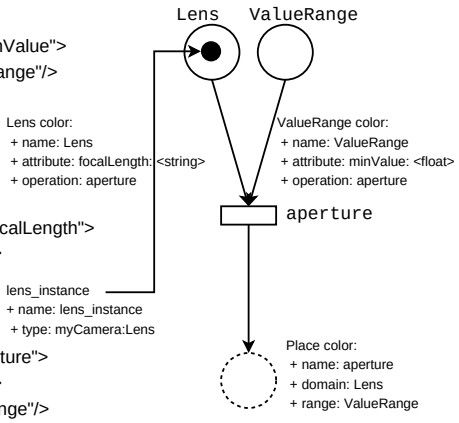

Fig. 3. An ontology part described by OCCPN.

4 Class Descriptions in OCCPN

OCCPN provides modeling primitives for the OWL statements to describe classes in detail, namely: predefined classes, class constructors, and class interrelation.

Fig. 4 shows the OCCPN structures for the OWL predefined classes: `owl:Thing` and `owl:Nothing`. A *source place* is a multicolor one since it represents the set

Fig. 4. OCCPN structures for predefined classes.

of all individuals. It is very similar to a CCPN virtual place in the sense that both act like token depot regardless of token's type; however, a source locality is unique and can have instances. A *sink transition* exemplifies `owl:Nothing` class extension: the *empty set*, since it consumes tokens, but does not produce any. In light of `owl:Nothing` is a subclass of every class, and, to be consistent with the notation follows next, in OCCPN, a sink transition ends with a half-round. A *virtual place* (see Fig. 1) only aids to consummate a class extension; hence, it either has no name nor instances. For this reason, it portrays *anonymous classes.*

4.1 Constructors

The easiest way to create a class in OCCPN is assigning a class name to a primitive place. However, OCCPN also provides arrangements to build more elaborated (anonymous) classes.

Enumeration. In OCCPN, a class defined by enumeration corresponds to a *constant virtual place*, i.e., that containing particular elements, only those specified in its color. Elements outside the color specification are not allowed.

Set operators. Fig. 5 shows the composition for `owl:intersectionOf`, `owl:unionOf`, and `owl:complementOf`. The performance of each structure is analogous to its corresponding logical operator. Place C_{n+1} in Fig. 5(a) stores those individuals that are members of each input place of composite typed transition T_0. T_0 is responsible to verify class membership. Place C_{n+1} in Fig. 5(b) allocates elements which are in C_1, C_2, ..., C_n or in all of them. Finally, Fig. 5(c) uses an inhibitor arc to check complement of a place C_1, i.e., those individuals not in C_1.

Property restriction. Fig. 6 describes the general form of a *restriction on an object property*. Both *cardinality* and *value* constraints are verified by adjusting the condition of transition T_1, which represents the property limitation.

If any cardinality constraint proceeds, the arc (C_1, T_1) modifies its weight with a new value, either w or the interval (w_1, w_2). Then, the transition T_1 verifies that the number of tokens in its input places is enough to fire it according to this new restriction.

Depending on the type of *value constraints*, the condition in transition T_1 verifies either *existential quantification*, *universal quantification*, or *a precise value*.

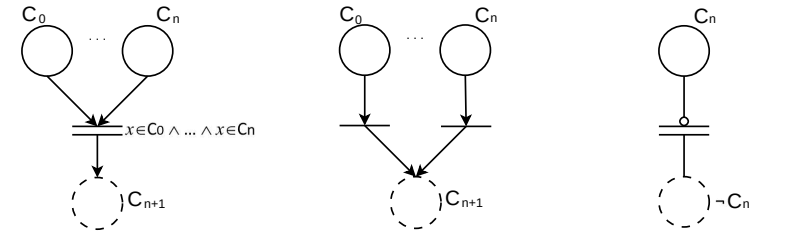

Fig. 5. OCCPN structures for set operators.

Restrictions on a datatype property add new constraints on the attribute that represents it, which, in turn, is in the place color. *Value constraints* delimits *attribute's domain*. On the other hand, *cardinality restrictions* limit the number of values that an attribute can take. Therefore, an attribute can be *not null*, if `owl:minCardinality` has a number, different from zero, as its argument; *mono-valuated*, when its cardinality is exactly one; or *multi-valuated*.

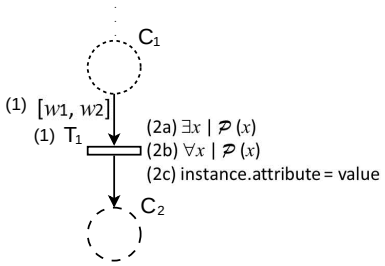

Fig. 6. General form of a restriction on an object property: (1) for `owl:cardinality` constrains, and (2a), (2b), (2c) for `owl:someValuesFrom`, `owl:allValuesFrom`, and `owl:hasValue` constraints, respectively.

4.2 Relation to other Classes

Subclass. In OCCPN, subclasses are pictured as the structure showed in Fig. 7(a). The color of a subclass place comprises its own description and, by extension, the specification of its superclass. Fig. 7(b) presents the case of disjoint subclasses, and, Fig. 7(c), the situation of overlapping ones. Notice that rule typed transitions can replace the copy ones to represent subclassed defined by a predicate.

Disjoint. The OCCPN structure for the disjoint statement is in Fig. 8. The composition encircled in dashed lines acts like a permanently disabled switch, so

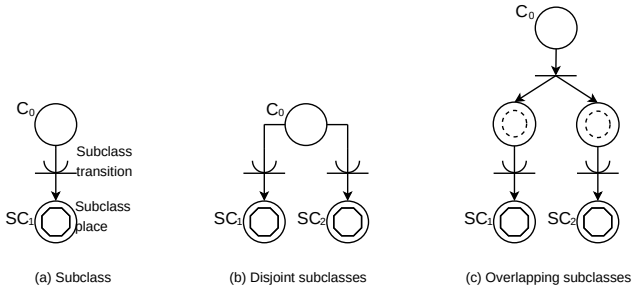

Fig. 7. OCCPN structures for subclasses.

that, place C_1 is never reachable from place C_0 and vice versa, which guarantees that they do not have individuals in common.

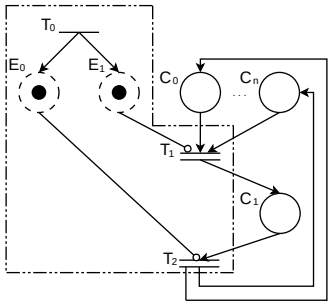

Fig. 8. OCCPN structure for the `owl:disjointWith` clause.

Equivalent. OCCPN does not have any special structure to represent the `owl:equivalentClass` sentence because it is useless to include two different places to describe the same class extension. The section *"class axioms"*, in the place color, describes the equality among classes.

5 Property Definition in OCCPN

In the OCCPN model, most of the property features described in Section 2.1 are either declared as implicit conditions on the attributes in the place color or considered as additional constraints in the rule typed transition. In this last case, property characteristics are also declared in the sections "logical characteristics", "functional properties", or "property interaction" of the place color, as appropriate.

5.1 Logical Characteristics

In OCCPN, logical characteristics of an object property describe new subclass structures, see, for example, Fig. 9(a) that shows the `owl:TransitiveProperty` statement. However, for the sake of the model, the rule typed transition that represents the object property also verifies the condition that describes each one the logical relations, such as Fig. 9(b) shows. By so doing, place C_3 stores all the individuals satisfying the original condition and all the individuals that overcome the second restriction. The color of the place C_3 also indicates the type of the relation.

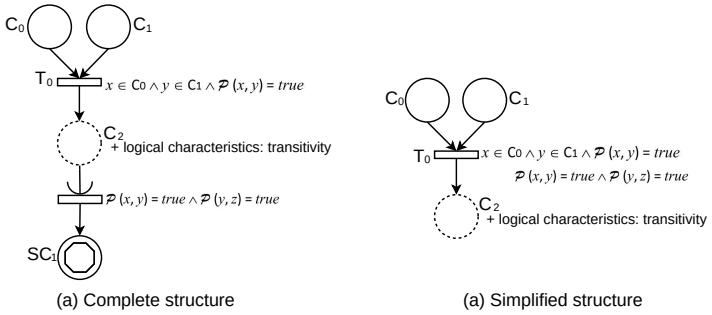

Fig. 9. OCCPN structure for `owl:TransitiveProperty`

5.2 Functional Features

In OCCPN, `owl:InverseFunctionalProperty` and `owl:FunctionalProperty` features on object properties are similar to logical characteristics, i.e., there is a nested condition attached to the rule typed transition.

When the `owl:InverseFunctionalProperty` applies on datatype properties, it defines a *not null*, *mono-valuated*, and *key* attribute. There is a *not null* and *mono-valuated* attribute if the `owl:FunctionalProperty` is declared.

5.3 Relation to other Properties

Inverse. The clause `owl:inverseOf` does not have any special construction in OCCPN. The color of the output place of the rule typed transitions that symbolize the object property captures this information.

Subproperty. The OCCPN structure for the `rdfs:subPropertyOf` clause is similar to that showed in Fig. 9(a), but T_1 evaluates the condition of the sub-property instead of the logical/functional restriction. As it can be observed, individuals in place C_4 fulfill the conditions of both property and sub-property.

6 Running Example

Fig. 10 presents the complete OCCPN model for the camera ontology described in reference [14]. Section 3 covers the basic transformation from ontology to OCCPN, therefore, we only focus on the `ExpensiveDSLR` complex class creation. As OWL statements in Fig. 10 shows, this class (place E0) is the conjunction (transition T0) of two subclasses (places E1 and E2): one of them comes from `DSLR` class (place E3), and, the other one, is the result of a property restriction (place E4) which establishes that, at least, one camera owner must be a professional (transition T1). This corroborates that OCCPN is able to represent the OWL expressiveness.

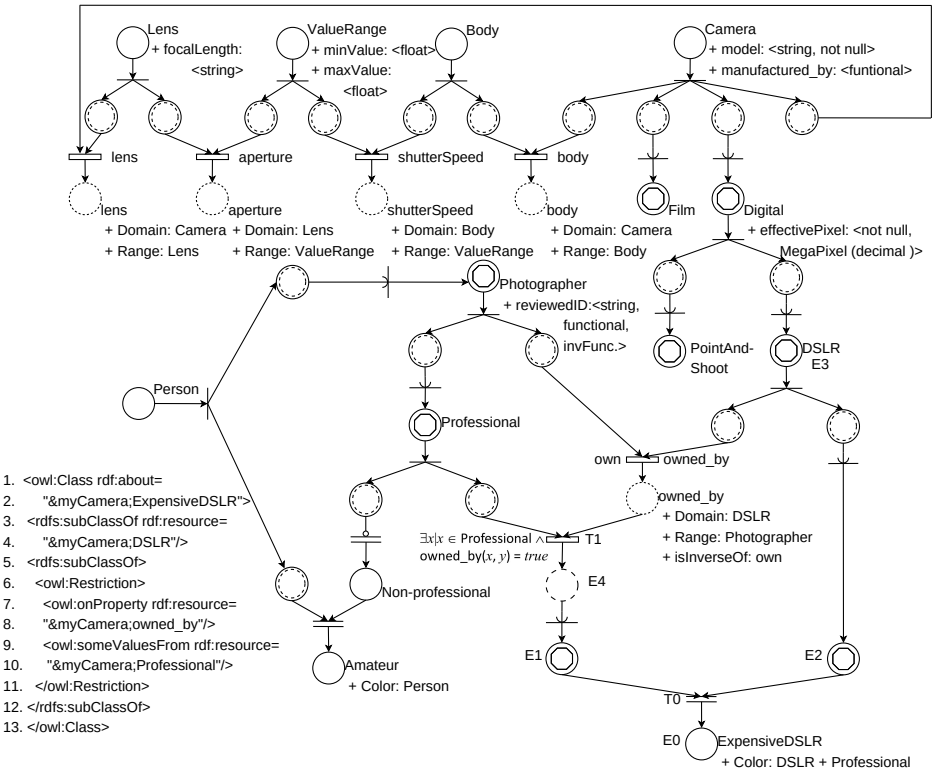

Fig. 10. The camera ontology [14] described by OCCPN.

7 Conclusions

This paper introduces OCCPN, a model to represent OWL ontologies. Previous approaches focus on the creation of classes through assigning them an identifier,

and relations of specialization, exclusion, and instantiation. By contrast, OCCPN provides modeling primitives for the whole set of OWL language constructs, and in so doing accounts for a comprehensive approach. Future work includes the development of the formal reasoning process on OCCPN. Additionally, we plan to address the usefulness of OCCPN to detect not only structural errors, such as redundancy, circularity, and contradiction, but also those involving semantics.

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A Comparison between the Macro and Micro Mechanical Model using Values of the Human Cochlea vs. Fluid Mechanical Model for Automatic Speech Recognition

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Abstract. This paper shows a comparison between the macro and micro mechanical model, proposed by Neely and Kim, and extended by Elliot and Ku vs. mechanical fluid model proposed by Lesser and Berkeley both used in ASR tasks. These models are used to set the central frequencies of a bank filter to obtain parameters from the speech in a similar form as MFCC (Mel Frequency Cepstrum Coefficients) has been constructed. Also we show an equation that show the relation distance vs. frequency extracted from the solution of the mechanical fluid model mentioned above. Neely's model was used with a set of different parameters of the cochlea, used by Nelly, Elliot and Ku in their works, such as mass, damping and stiffness; among others. The performance obtained was of the 98 to 100% using this model while a 98.5% performance was reached using the second propose; for a task that uses isolated digits pronounced by 5 different speakers in the Spanish language. Finally corpus SUSAS with neutral sound records with some advantages in comparison with MFCC was used.

Keywords: Speech recognition, cochlea, place theory, bank filter

1 Introduction

For a long time Automatic Speech Recognition Systems (ASRs) have used parameters related with Cepstrum and Homomorphic Analysis of Speech [1], Linear Prediction Coefficient (LPC) [2], Mel Frequency Cepstrum Coefficients (MFCC) [3], and Perceptual Linear Prediction (PLP) [4], these last two being the most important. In each of these representations, the principal objective is to have a representation to compress speech data without irrelevant information not pertinent to the phonetic analysis of the data and to enhance aspects of the signal that contribute significantly to the detection of phonetic differences. MFCC and PLP coefficients employ Mel and Bark scales respectively. These consider perceptual aspects to obtain a set of coefficients that represent the speech signal.

On the other hand, the most important organ in human hearing is the cochlea and various physiological models have been proposed [5] and [6]. Recently works related

with the application of the cochlea behavior in ASR systems can be found, that is because in recent years the researchers have emphasized "human engineering", that is, to adopt the processing strategies of the human auditory perception. The application of such a human perceptual feature may improve ASR performance which has been established in literature [7, 8, 9, 10, 11, 12].

In [12] an extraordinarily precise auditory model was used extracting the excitation dependent shapes of the delay trajectories and then a set of features were used without any other spectral information to carry out speech recognition task under different noise conditions on the TIMIT database.

However, average recognition rates do not reach that of the MFCC features (except for very low noise SNRs), but the system behaves very stable under different noise conditions. In [11] they proposed a feature extraction method for ASR based on the differential processing strategy of the AVCN, PVCN and the DCN of the nucleus cochlear. The method utilized a zero-crossing with peak amplitudes (ZCPA) auditory model as synchrony detector to discriminate the low frequency formants. They used HMM recognition using isolated digits that showed better recognition rates in clean and non- stationary noise conditions than the existing auditory model.

In [10] they employed a counterpart of the next physiological processing step in comparison with frequency decomposition and compression of amplitudes concepts. A simplified model of short-term adaptation was incorporated into MFCC feature extraction. They compared the proposal mentioned above with that structurally related to RASTA, CMS and Wiener filtering which performs well in combination with Wiener filtering. Compared with the structurally related RASTA, the adaptation model provides superior performance on AURORA 2, and, if Wiener filtering is used prior to both approaches, on AURORA 3 as well.

2 Characteristics and Generalities

The cochlea is a long, narrow, fluid-filled tunnel which spirals through the temporal bone. This tunnel is divided along its length by a cochlear partition into an upper compartment called scala vestibuli (SV) and lower compartment called scala timpani (ST). At the apex of the cochlea, SV and ST are connected to each other by the helicotrema [13]. A set of models to represent the operation of the cochlea has been proposed [14, 15, 16, 17] among others. In mammals, vibrations of the stapes set up a wave with a particular shape on the basilar membrane. The amplitude envelope of the wave is first increasing and then decreasing, and the position at the peak of the envelope is dependent on the frequency of the stimulus [18]. The amplitude of the envelope is a two-dimensional function of distance from the stapes and frequency of stimulation.

Helmholtz based his description of the function of the cochlea largely on the observations of Hensen, who had shown that the width of the basilar membrane varied along the length of the cochlea. Combining this result with Ohm's description of sound as a combination of tones of different frequencies, led Helmholtz to the view that the cochlea performed a sort of Fourier analysis of the incoming sound waves. The physical process by which this Fourier analysis operated was the resonance of BM fibers (across

the membrane width) with different resonance frequencies (varying with the lengths of the fibers). A sound wave would set all the fibers of the BM in motion, but the ones which had resonance frequencies closest to the frequencies present in the sound signal would respond maximally. This would create a pattern over the length of the cochlea describing the frequency content of the signal: the frequency map, or place coding.

The frequency-to-place map is often characterized as a Place Theory. The specific interpretation by Helmholtz is one of the subset of Resonance Theories, which contained tuned elements, membrane resonance, or tube resonance. There was also a number of Nonresonance or Wave Theories in the Place Theory category.

The opposing category—at the time—was the group of Frequency Theories either with a nonanalytic (telephone) or analytic further specification. Or schematically:

Frequency-to-Place Map Theories around 1950

I. Resonance Theories:
   a) tuned elements,
   b) membrane resonance,
   c) tube resonance.

II. Frequency Theories:
   a) analytic,
   b) nonanalytic (e.g., telephone theory).

This paper proposes an equation extracted from the fluid mechanical model to find a relationship between these frequencies and the place of the excitation into the cochlea. This expression is then compared with the macro and micro mechanical model proposed by Nelly&Kim in 1986, with the objective to analyze the performance in a Automatic Speech Recognition task for two databases. First of them we use Spanish digits and the second using neutral SUSAS Corpus.

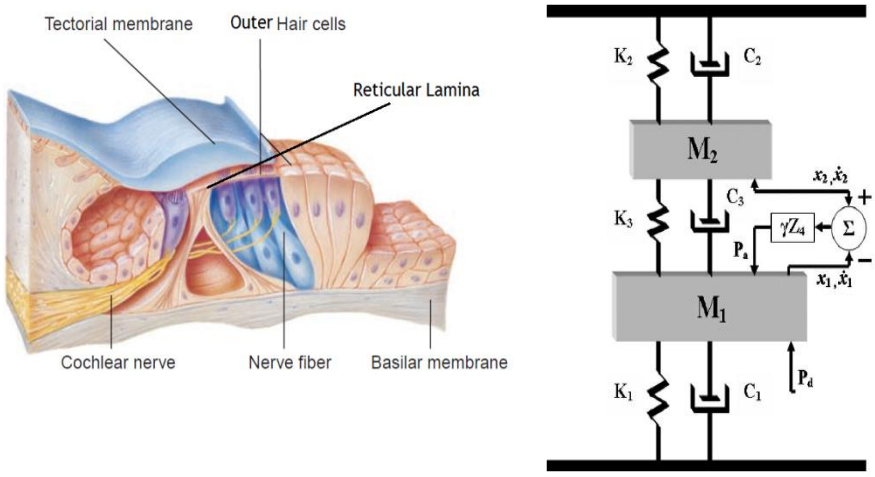
In the micromechanical the anatomical structure of a radial cross-section (RCS) of the cochlear partition (CP) is illustrated in the following figure 1. In the model, the basilar membrane (BM) and tectorial membrane (TM) are each represented as a lumped mass with both stiffness and damping in their attachment to the surrounding bone. When the cochlea determines the frequency of the incoming signal from the place on the basilar membrane of maximum amplitude, the organ of Corti is excited, in conjunction with the movement of tectorial membrane; the inner and outer hair cells are excited obtaining an electrical pulse that travels by auditory nerve.

Now the modeling cochlear will be divided in two ways of study. The first is the hydrodynamic movement that produced a movement on the basilar membrane and the second is the movement of the outer hair cells. This is named as the model of Macro and Micro Mechanical Cochlear [17]. The equations that describe the Macro Mechanical Cochlear are [17]:

$$\frac{d^2}{dx^2} P_d(x) = \frac{2\rho}{H} \ddot{\varepsilon}(x) \tag{1}$$

$$\frac{d^2}{dx^2} P_d(0) = 2\rho \ddot{\varepsilon}_s \tag{2}$$

$$\frac{d^2}{dx^2} P_d(0) = 2\rho \ddot{\varepsilon}_s \tag{3}$$



(a) (b)

Fig. 1. Anatomical structure of the cochlear partition (a). The outer hair cells, micro mechanical representation (b).

The equations (1), (2) and (3) were solved by finite difference, using central differences for (1), forward differences for the (2) and backward difference for (3), generating a tri-diagonal Matrix system[16] which we solved using the Thomas algorithm. It represents the Micro mechanical, because it uses the organ of Corti values.

The solution for P_d obtains the maximum amplitude on the basilar membrane. For these experiments the cochlear distance pattern is obtained manually. As can be seen, to solve equation 3 a set of variables related with the physiology of the cochlea is needed and some of these variables are described in [17]. These values are immersed into Z_p and Z_m; for example in [17].

For another side, we have a model proposed by Lesser and Berkley in 1972 that employs mechanical fluids to solve the same problem. Let $u = (u_1, u_2, u_3)$ be the fluid velocity, p the pressure, and ρ the constant density of the fluid. The mass of fluid in a fixed volume V can change only in response to fluid flux across the boundary of the volume. Thus [23],

$$\frac{d}{dt}\int_V \rho dV = -\int_S \rho(u \bullet n)dS = 0 \tag{4}$$

where S is the surface of V, and $n = (n_1, n_2, n_3)$ is the outward unit normal to V.

After considering that the momentum of the fluid in a fixed domain V can change only in response to applied forces or to the momentum flux across the domain boundary, and using the divergence theorem to convert surface integrals to volume integrals, 2 is obtained:

$$\int_V \left(\rho \frac{\partial u_i}{\partial t} + \rho \nabla \bullet (u_i u) + \frac{\partial p}{\partial x_i} \right) dV = 0 \tag{5}$$

After considering that V is arbitrary, fluid motions are of small amplitude and there is an irrotational flow, the following equations are shown:

$$\rho \frac{\partial \phi}{\partial t} + p = 0, \qquad \nabla^2 \phi = 0 \tag{6}$$

Lesser and Berkley developed a model that combines these last two equations with the equation of a damped, forced harmonic oscillator and is considered one of the simplest of the cochlea models. They propose that each point of the basilar membrane is modeled as a simple damped harmonic oscillator with mass, damping, and stiffness that vary along the length of the membrane.

Thus, the movement of any part of the membrane is assumed to be independent of the movement of neighboring parts of the membrane, as there is no direct lateral coupling. The deflection of the basilar membrane, $_{\eta}$(x, t), is specified by a model of a forced harmonic oscillator defined as

$$m(x)\frac{\partial^2 \eta}{\partial t^2} + r(x)\frac{\partial \eta}{\partial t} + k(x)\eta = p_2(x, \eta(x,t), t) - p_1(x, \eta(x,t), t) \tag{7}$$

where $m(x) = 0.1,\ \ r(x) = 300\ e^{-\alpha x},\ \ k(x) = 10^9 e^{-2\alpha x}$. An analytical solution of this problem can be found using standard Fourier series [23]. Solutions of this form are looked for:

$$\phi = x\left(1 - \frac{x}{2}\right) - \sigma y\left(1 - \frac{y}{2\sigma}\right) + \sum_{n=0}^{\infty} A_n \cosh[\ n\pi(\sigma - y)]\cos(n\pi x) \tag{8}$$

This paper proposes solving the Lesser and Berckley equation using the solution proposed in [20]. This solution is related with the place theory of hearing, initially proposed by Von Békésy. To perform the analysis each section of the membrane is considered as a forced harmonic isolated oscillator, which is excited by an external force $Fe^{j\omega t}$ that represents the driving force on each section of the basilar membrane and this force is produced by vibrations transmitted into the cochlea by the oval window. Two solutions are proposed related with the before mentioned equation. Firstly, the forced harmonic oscillator is represented by the following equation

$$m(x)\frac{d^2\eta}{dt^2} + R_m(x)\frac{d\eta}{dt} + k(x)\eta = Fe^{j\omega t} \tag{9}$$

where m is the mass, R_m mechanical resistance and k is the damping constant.

Considering that $\eta = Ae^{j\omega t}$, then amplitude of the wave sound into the cochlea is represented by [20]. Secondly, a damped harmonic oscillator with the following equation is considered:

$$m(x)\frac{d^2\eta}{dt^2} + R_m(x)\frac{d\eta}{dt} + k(x)\eta = 0 \tag{10}$$

Then, a solution is given by

$$\eta = Ae^{-\beta t}\cos(\omega_0 t + \phi) \tag{11}$$

Equation 12 shows that the amplitude for each section of the membrane depends of the frequency ω in the applied force. The amplitude has a maximum when the denominator has its minimum value and this occurs at a specific frequency excitation

called resonance frequency. This is defined by the values of mass and stiffness, when the frequency ω of the applied force is equal to $k(x)/m(x)$ it is said that the system is resonant in amplitude and obtains the maximum value of the basilar membrane displacement. This last equation can be expressed as a function of frequency and distance, if considering that $\omega = 2\pi f$ thus, this is possible using our purpose literature does not find an equal relationship [20]:

$$A = \frac{F / m(x)}{\sqrt{\left(4\pi^2 f^2 - \frac{k(x)}{m(x)}\right)^2 + 4\pi^2 f^2 \frac{R_m(x)^2}{m(x)^2}}} \tag{12}$$

Figures 2 and 3 show the behavior of the basilar membrane with the values obtained when we calculate the equation obtained. As is seen, before 300 Hz the behavior of the micro and macro mechanical model is not adequate, independently of the parameters used. This result is a consequence of the characteristics of the model proposed by [17]. Proposing our analysis from this frequency to 4.5 KHz was decided. Also, the response obtained has a behavior logarithmic. This is an important indication because the Mel function is related with a similar mathematical function. We don´t use an analytical expression to obtain the response of Neely model.

As mentioned above, the Neely model and later works have considered putting a number of these micro-mechanisms along the cochlea at the same distance between them.

For that, this principle to establish the following relation between a minimal and maximal distance was used.

$$d(n) = d_{max} + \sum_{n=0}^{n\,\text{int}} n \frac{d_{min} - d_{max}}{n\,\text{int} + 1} \tag{13}$$

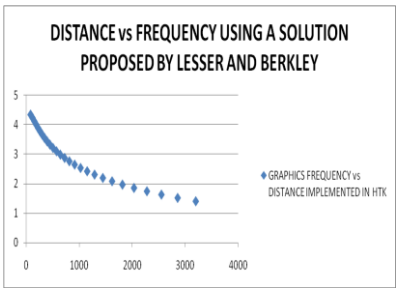


Fig 2. Distance vs Frequency using model Lesser&Berckley's

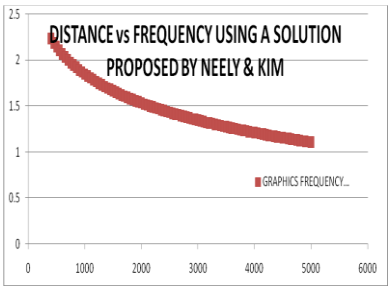


Fig 3. Distance vs Frequency using model Neely's

In [5] d_{min} and d_{max} are obtained from Figure 3 and 4, considering that $F_{min}=300$ Hz and $F_{max}=4.5$ KHz. This paper proposed a space equidistant between different points to analyze the cochlea. After that, for each distance one specifically frequency of excitation to the Basilar Membrane was obtained.

3 Experiments and Results

From the last analysis a computational model to obtain the distance where the maximum displacement of the basilar membrane occurs to a specific excitation frequency of the system was developed, which depends of the physical characteristics of the basilar membrane. The following procedure describes the computational model of the cochlea using the proposal in [20]. It is important to mention that the maximum response of the pressure curve used in [19] was obtained.

1. Obtain speech signal, realize preprocessing (It includes pre-emphasis, segmentation, windowing and feature extraction), for each sentence.
2. In the feature extraction, the same procedure as MFCC was used but the filter bank is constructed following the next steps.
   - 2.1 Take the minimal and maximal frequency where filter bank are going to be constructed.
   - 2.2 Calculate maximal and minimal distance from the stapes of the cochlea, nearer to start implies high frequencies, farthest implies low frequencies.
   - 2.3 Determine a set of distances equally spaced
   - 2.4 Determine the frequency related with these distances, this represents the center of the filter bank.
   - 2.5 Construct filter bank with frequency center obtained from the analysis of the Neely model using values in table
3. Follow the same steps to obtain MFCC, multiply spectral representation from Fourier Transform with filter bank, calculate energy by bands using logarithm, and finally, apply discrete cosine transform.
4. Obtain a new set of coefficients for each speech signal.
5. Train the ASR and proceed with recognition task using the new parameters.

A database with 5 speakers that pronounced Spanish isolated digits, from 0 to 9 was applied as workbench that is "cero, uno, dos, tres, cuatro, cinco, seis, siete, ocho and nueve". LPC, MFCC, CLPC were used and our coefficients named EPCC (Earing Perception Cepstrum Coefficients) obtaining better percent correct recognition in some tasks using them in comparison with others representations mentioned above. HTK Hidden Markov Model Toolkit was used as training and recognition software; our new parameters were added into HSigp.c file, contained inside HTK http://htk.eng.cam.ac.uk, and were used in tasks of ASR employing HTK.

This first experimental used a database that contains only digits in the Spanish language and the characteristics of the samples were frequency sample 11025, 8 bits per sample, PCM coding, mono-stereo. The evaluation of the experiment proposed involved 5 people (3 men and 2 women) with 300 speech sentences to recognize for each one (100 for training task and 200 for recognition task). 1500 speech sentences extracted from 5 speakers individually were taken, and the Automatic Speech Recognition trained using Hidden Markov Models with 6 states (4 states with information and 2 dummies to connection with another chain). Also, 3 Gaussian Mixture for each state in the Markov chain were employed. The parameters extracted from the speech signal were 39 (13 MFCC, 13 delta and 13 energy coefficients) when using MFCC or our proposal, and used to train the Hidden Markov Model.

Table 1 contains results obtained in percentages when using LPC, CLPC, MFCC and our parametric representation to train as parameters.

Table 2 shows results using Delta and Acceleration coefficients. It is important to mention that HTK give us results in two forms: by sentence and by words http://htk.eng.cam.ac.uk. We show both for reasons of consistency.

Table 3 contains results obtained in percentage when using LPC, CLPC and MFCC, DELTA, ACCELERATION AND THIRD DIFFERENTIAL.

Table 1. LPC, CLPC and MFCC coefficients

SENTENCES				WORDS			
PARAMETERS/# STATES	*4*	*5*	*6*	PARAMETERS/# STATES	*4*	*5*	*6*
LPC	87.5	94	94	LPC	87.94	94.47	94.47
CLPC	90	97.5	98.5	CLPC	90.45	97.99	98.99
MFCC	97.5	97	99	MFCC	97.99	97.49	99.5
EPCC KU	98	99	99.5	EPCC KU	98.45	99.5	99.8
EPCC ELLIOT	98.5	98.5	99	EPCC ELLIOT	98.75	98.75	99.5
EPCC NEELY	98.7	99	99.5	EPCC NEELY	98.5	99.5	99.75
EPCC RESONANCE ANALYSIS	99.25	99.35	99.6	EPCC RESONANCE ANALYSIS	99.35	99.45	99.75

Table 2. LPC, CLPC, MFCC, DELTA and ACCELERATION coefficients

SENTENCES				WORDS			
PARAMETERS/# STATES	*4*	*5*	*6*	PARAMETERS/# STATES	*4*	*5*	*6*
LPC	79	90.5	91.5	LPC	79.4	99.4	91.96
CLPC	93	99	99	CLPC	93.47	99.5	99.5
MFCC	99	99	99	MFCC	99.5	99.5	99.5
EPCC KU	100	100	100	EPCC KU	100	100	100
EPCC ELLIOT	100	100	100	EPCC ELLIOT	100	100	100
EPCC NEELY	100	100	100	EPCC NEELY	100	100	100
EPCC RESONANCE ANALYSIS	99.30	99.6	99.7	EPCC RESONANCE ANALYSIS	99.45	99.75	99.8

Table 3. LPC, CLPC, MFCC AND DELTA, ACCELERATION, DELTA, and THIRD DIFFERENTIAL coefficients

SENTENCES				WORDS			
PARAMETERS/# STATES	*4*	*5*	*6*	PARAMETERS/# STATES	*4*	*5*	*6*
LPC	77	89.5	89	LPC	77.39	89.95	89.45
CLPC	89.5	99	99	CLPC	89.95	99.5	99.5
MFCC	98.5	99	99	MFCC	98.99	99.5	99.5
EPCC KU	100	100	100	EPCC KU	100	100	100
EPCC ELLIOT	100	100	100	EPCC ELLIOT	100	100	100
EPCC NEELY	100	100	100	EPCC NEELY	100	100	100
EPCC RESONANCE ANALYSIS	99.4	99.6	99.8	EPCC RESONANCE ANALYSIS	99.6	99.8	99.8

In the second experiment, a corpus elaborated by J. Hansen at the University of Colorado Boulder was used. He has constructed database SUSAS (Speech Under Simulated and Actual Stress) http://catalog.ldc.upenn.edu/LDC99S78. Only 9 speakers with ages ranging from 22 to 76 were used and we applied normal corpus not under Stress sentences contained into corpus. The words were “brake, change, degree, destination, east, eight, eighty, enter, fifty, fix, freeze, gain, go, hello, help, histogram,

hot, mark, nav, no, oh, on, out, point, six, south, stand, steer, strafe, ten, thirty, three, white, wide, & zero".

A total of 4,410 files of speech were processed. Finally, Tables 4 shows results when using our proposal (Earing Perceptual Cepstrum Coefficients, EPCC) the best representations used in the state of the art and in the last experiment versus MFCC in SUSAS corpus.

Table 4. Results obtained using HTK, SUSAS Corpus and manual labeling

	MFCC		**EPCC Using Neely values**		**EPCC Using Ku values**		**EPCC Using Elliot values**		**EPCC Using resonance analysis**	
	sent.	**word**	**sent.**	**word**	**sent.**	**word**	**sent.**	**word**	**sent.**	**word**
boston1	91.84	92.06	90.61	90.87	90.2	90.48	89.39	89.68	90.2	90.84
boston2	95.51	95.63	93.47	93.65	93.47	93.65	93.06	93.25	93.88	94.05
boston3	96.73	96.83	93.88	94.05	95.92	96.03	96.33	96.43	92.65	92.86
general1	96.73	96.83	92.24	92.46	93.88	94.05	93.88	94.05	95.51	95.24
general2	94.29	94.44	90.61	90.87	90.61	90.87	89.39	89.68	93.06	93.25
general3	93.47	93.65	88.16	88.49	93.47	93.65	93.06	93.25	94.69	94.84
nyc1	91.84	92.06	91.84	91.67	87.35	87.3	96.33	96.43	93.06	92.86
nyc2	91.02	91.27	91.84	92.06	86.53	86.9	93.88	94.05	89.8	90.08
nyc3	95.92	96.03	92.65	92.86	90.61	90.87	89.39	89.68	90.2	90.48

4 Conclusions and Future Works

This paper describes new parameters for ASRs tasks. They employ the functionality of the cochlea, the most important hearing organ of humans and mammalians. At this moment, the parameters used for the MFCC analysis have been demonstrated to be the most important parameters and the most used for this task. The interest of this paper is show the implementation of the cochlear models in Automatic Speech Recognition tasks. We show that the theory of these models can be used to obtain parameters from the speech signal and used as input to the Hidden Markov Model Toolkit.

Also, the paper show an analytic solution to the Lesser & Berkley model (this model was proposed in 1972 and is based in the mechanical fluid and its solution used the Fourier series), that is based in the resonance analysis proposed by Helmholtz. Then we show a mathematical expression can be compared with another used in the State of the Art, for example the equation of Greenwood. This article demonstrated that our propose is very interesting because the performance reached was adequate and can be used to obtain speech signal parameters for Automatic Speech Recognition. In conclusion, the cochlea behavior can be used to obtain these parameters and the results are adequate.

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Model of Knowledge Base for Supporting the Classification of a Psychological Profile in the Context of Social Engineering

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Abstract. Companies are looking for protecting their information implementing security policies and security tool kits in order to save the information, regardless that most thefts or unauthorized access are mainly committed by Human. The social engineer (perpetrator) finds vulnerabilities in employees (victims) who manage the information within Companies. To prevent this issue, is important to identify the profile of the social engineer using a psychometric tests such as 16PF. This psychometric test can identify characteristic on the personality of Social Engineer profile. The profile identified from this psychometric test allows detailing personality variables. Design a knowledge base KB will be a support to prevent and controlling the access to information from social engineering. The purpose of this Knowledge Base is characterize the Social Engineer profile to be applied for evaluate profiles in employees and candidates to job post in various Companies.

Keywords: Model knowledge base, social engineering, information security, psychological test 16PF, human hacking

1 Introduction

Most Companies invest on physical infrastructure, firewalls and software to ensure the transmission and confidentiality of information in order to protect their information. Several security policies, tool kits and hardware are implemented to save the information. However, inside the architecture of information systems, there are security holes where its functionality depends on the surveillance and control from human. The Social Engineering combines psychological techniques and pentesting tool kits to exploit these vulnerabilities on the system.

Social Engineer (perpetrator) uses psychological techniques to manipulate people (victims) in order to perform actions that may be convenient or inconvenient, achieving his goal. Goal can be getting access to confidential information in Companies [1]. Personality test 16PF (Personality Factor Questionnaire) is useful for factor analysis to

identify the basic dimensions of personality in humans. The first publication was in 1949 by Cattell, since 1949 others version are created such as 16PF: A, B, C, D, E and 16PF V -5, all versions measure the same factors, and factors are evaluated using the same methodology to obtain the same information . To characterize the profile of Social Engineer the 16PF Fifth Edition was used.

Social Engineer has patterns behavior characterized by the theft of confidential information using persuasion, deception and shrewdness to manipulate the actions on the targets. Interpret these kind of behavioral factors several physiological tools are proposed from theories of personality factors.

The knowledge base KB is a data repository, where knowledge of a specific domain is stored. Knowledge base is characterized by the ability to upgrade on the time, new knowledge providing from an expert. This knowledge is named as tacit knowledge. When tacit knowledge is transferred it becomes to explicit knowledge. Knowledge is carried on the discovery of valid data indicated objectivity. This discovery is generated by events or actions generating new experiences forward a specific domain [2].

2 State of the Art

Analyzing types of behavioral patterns and predict when a person has characteristics of a Social Engineer, different tools and hypothesis are proposed from the psychological theories to find personality factors. In [3] it is proposed a model to categorize the information in social networks, and then protect it from attacks using social engineering.

In [4] it is proposed a penetration testing methodology within a Company using social engineering. During the test a group of employees were evaluated. This test determines the vulnerabilities found on the targets and the methods to obtain the confidential information. This information is collected in a final report, describing the failed and successful attempts.

In [5] it is designed and implemented specialized expert systems to support decision-making for particular areas. One such system is called Copernicus focused on classification of perceptual skills. This is a tool for computer-aided diagnosis in mental disorders based on Minnesota Multiphasic Personality Inventory test (MMPI).

In [6] it is exposed an analytical study on the predictive power, the locus control and the risk propensity over five personality factors in predicting dishonest decisions in organizational contexts. These factors were measured as: neuroticism, extraversion, openness to experience, agreeableness and responsibility. Neuroticism refers to the tendency to feel nervous, anxious, self-conscious, hostile, vulnerable and impulsive. Extraversion is the tendency to be talkative, gregarious, outgoing, assertive and positive emotions. Openness to experience refers to the receptivity of new ideas, perspectives and experiences, involving tendency to fantasize and being sensitive to the arts. Affability is the propensity to be nice with others, empathy and humility. These features reflect the individual's personality. The analysis defines this profile as the basic component of personality, for measuring it, the 16PF was used to identify, analyze and explain this kind of personality [7].

In [8] authors propose a knowledge-based system (KBS) applied to the analysis of application security system. The knowledge base contains information on regulations, standards and current best practices, and related reports vulnerabilities to take public knowledge in the computing community.

In [9] it is proposed a knowledge-based system (KBS) applied to analysis the security on a system management application. The model is based on a knowledge-based system (KBS) which has a cognitive component that allows incorporate knowledge to the system. The constant threats and cyber-attacks this KBS through dynamic learning will keep updated it-self and is helpful for Information Security Officers in order to preparing requirements specification.

2.1 Concepts

Psychological Test 16PF.

The 16PF test consists of a questionnaire to measure normal personality dimensions [10] and is the only one that is built from a point of view not pathologic [11] (See Table 1).

Table 1. Global Personality Dimensions 16 PF

Dimensions		High and Low Meaning
Extraversion	EXT -	Introverted, Inhibited
	EXT +	Extraverted, Participating
Anxiety	ANS -	Hardy, Stress-resilient.
	ANS +	Stress Prone, Emotionally Unstable
Tough-Mind-edness	DUR -	Receptive, Open-minded
	DUR +	Tough- Minded, Resolute
Independence	IND -	Accommodating, Agreeable
	IND +	Independent, Persuasive, Willful.
Self-Control	AUC -	Unrestrained, Follows Urges
	AUC +	Self- Controlled, Reliable

In Colombia the 16PF V-5 is a valid and reliable test for recruitment, accompanying clinical psychologic processes, vocationally orient and perform legal evidences [12]. Additionally, propose 16PF as a valid instrument for psychological profiles on cyber-criminals [13]. This psychological test supports a set of variables, called primary 16PF scales (see Table 2).

To measure of personality has been proposed multiple instruments. However, the 16PF is the most used nowadays. Due to the acceptability of this instrument (16PF V - 5) in the Colombian context and because studies argue that other psychological test

such as BFQ not measure the total variance of personality [14], for purpose of this case, We opted to use the 16PF.

Table 2. 16PF primary factors

Factors	High and Low Meaning	
Warmth	A -	Reserved, Impersonal, Distant
	A +	Warm, Outgoing, attentive to others
Reasoning	B -	Concrete
	B +	Abstract
Emotional Stability	C -	Reactive, Emotionally Changeable
	C +	Emotionally stable, Adaptive, Mature
Dominance	E -	Differential, Cooperative, Avoids conflicts
	E +	Dominate, Forceful, Assertive
Liveliness	F -	Serious, Restrained, Careful
	F +	Lively, Animated, Spontaneous
Rule- Consciousness	G -	Expedient, Nonconforming
	G +	Rule-Conscious, Dutiful
Social Boldness	H -	Shy, Threat-Sensitive, Timid
	H +	Socially Bold, Venturesome, Tick-Skinned
Sensitivity	I -	Utilitarian, Objective, unsentimental
	I +	Sensitive, Aesthetic, Sentimental
Vigilance	L -	Trusting, Unsuspecting, Accepting
	L +	Vigilant, Suspicious, Skeptical, Wary
Abstractedness	M -	Grounded, Practical, Solution-Oriented
	M +	Abstracted, Imaginative, Idea-Oriented
Privateness	N -	Forthright, Genuine
	N +	Private, Discreet, Non-Disclosing
Apprehension	O -	Self-Assured, Unworried, Complacent
	O +	Apprehensive, Self-Doubting, Worried
Openness to Change	Q1 -	Traditional, Attached to familiar
	Q1 +	Open to change, Experimenting
Self-Reliance	Q2 -	Group-Oriented, Affiliative
	Q2 +	Self-Reliant, Solitary, Individualistic
Perfectionism	Q3 -	Tolerates Disorder, Unexacting, Flexible
	Q3 +	Perfectionistic, Organized, Self-Disciplined
Tension	Q4 -	Relaxed, Placid, Patient
	Q4 +	Tense, High Energy, Driven

Knowledge Management.

The headers in Companies are conscious of the strategic role of knowledge is recognized like generator of added value.

The success background in Companies is recognized by the ability to change according to knowledge evolution. The importance of the study of knowledge is caused by changes in the economy which are represented by the development of strategies to improve competitiveness and achieve sustainable development of actors in the markets [CEDV-1] [15]. Because this discussion, defining that knowledge management like a

dynamic process of pro- creation, storage, transfer, application and use of knowledge , for purposes of improving the performance in Companies [CEDV -2] [16]. Knowledge is a significant resource attached to importance of generate, dissemination and use of information. There are two types of knowledge: explicit and tacit. Explicit knowledge is formal and systematic, easy to communicate and share through products, formulas or software. The knowledge tacit is personal, hard to formalize and communicate it. This is related to the action and function [CEDV -3] [17].

Knowledge management is an organizational systematic and specific process, its purpose is to acquire, organize and communicate tacit and explicit knowledge of employees to be transferred to other employees of the organization in order to improve productivity and efficiency in their work [CEDV -4] [18]. Because universality of knowledge is important to generate knowledge bases. A knowledge base integrates data mining and new knowledge. All of this is based on known knowledge (tacit or explicit). A knowledge base seeks to establish the characteristics and quality of information [CEDV -5] [19].

An expert according to the Royal Spanish Academy (RAE) is "A person who is very skilled and he has great experience in a job or activity" other meaning is "A person with many knowledge of a subject".

3 16 PF Test Results

The psychological test 16PF was applied to 10 people. The profile found is according to people with harder knowledge in computing and exploit security vulnerabilities on the systems, they were referred as social engineer profile. The result was analyzed by an expert (psychologist) and result is shown in table 3.

Table 3. 16PF Test Result Profile

PRIMARY SCALE	FACTOR VALUE	PRIMARY SCALE	FACTOR VALUE
RESERVED	5	OPEN MINDED	3
CONCRET	6	ABSTRACT	9
EMOTIONALLY CHANGEABLE	8	EMOTIONALLY STABLE	2
DIFFERENTIAL	9	DOMINATE	3
SERIOUS	4	LIVELY	7
NONCONFORMING	2	DUTIFUL	7
SHY	2	SOCIALLY BOLD	7
UNSENTIMENTAL	4	SENTIMENTAL	8
TRUSTING	7	SUSPICIOUS	7
SOLUTION-ORIENTED	4	IDEA-ORIENTED	8
GENUINE	8	DISCREET	4
SELF-ASSURED	4	SELF-DOUBTING	7
TRADITIONAL	7	EXPERIMENTING	3
GROUP-ORIENTED	3	SELF-RELIANT	8
FLEXIBLE	8	PERFECTIONISTIC	3
PATIENT	8	TENSE	3
GLOBAL DIMENSION			
STRESS-RESILIENT	8	STRESS PRONE	3,2

PRIMARY SCALE	FACTOR VALUE	PRIMARY SCALE	FACTOR VALUE
INTROVERTED	5	EXTRAVERTED	7
UNRESTRAINED	7	SELF- CONTROLLED	4
ACCOMMODATING	7,8	INDEPENDENT	3
RECEPTIVE	7	TOUGH- MINDED	4

4 System Architecture

Seven components integrated the system functionality. Each employee answers the 16PF test applied by a psychologist. The results are obtained in terms of numerical values are stored in an Excel database, the format allows to specify the primary scales, and global dimensions. These data are taken by the psychologist and is transferred to the system through a graphical interface. This data is compared with values stored previously in the knowledge base, which contains the basic parameters obtained in the laboratory from the 16PF test. It will determine the primary scales and global dimensions for establishing whether an individual evaluated has the profile of social engineer.

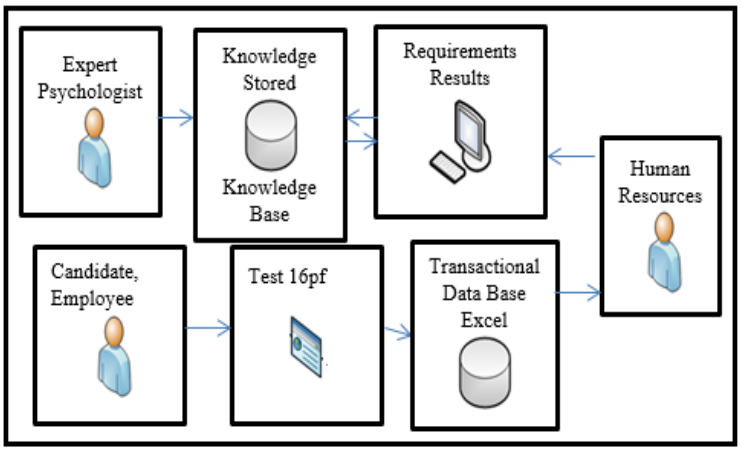

Fig. 1. *Test 16pf* result values are inserted manually into a *transactional data base* built in Excel by the *Human Resource*. System compares the values from *transaction data base* Excel with the data stored in the *Knowledge Base* and the feedback is shown by a graphical user interface.

4.1 Components

Candidate or Employee.
The test 16PF is applied by psychologists to employees or candidates to get a job in Companies. The results are analyzed and stored in a transactional database (Excel).

Psychologist or Expert.
He analyzes the results obtained from the test 16PF. He is in charged to feeds the knowledge base with specific information and general information.

Human Resources.
Use the system to check if the results obtained by applying the test 16PF on employees or candidates, are according to the parameters of primary scales and global dimensions found in the knowledge data base.

Knowledge Database.
In order to obtain the psychometric characteristics that determine whether a candidate or employee has the profile of social engineer. In this case a sample of 20 people have been evaluated by the 16PF test. The results were analyzed in detail by an expert psychologists. With the analysis of results it was possible to obtain quantitative data for each set of variables (primary scales and global dimensions), which are the general items to identify the profile evaluated will meet the characteristics to be a social engineer. Interaction with Knowledge Base is performed by an expert psychologist, who is the actor responsible for maintaining the current information stored in the system. The update consist to feed the knowledge base with the data for the primary scales and global dimensions.

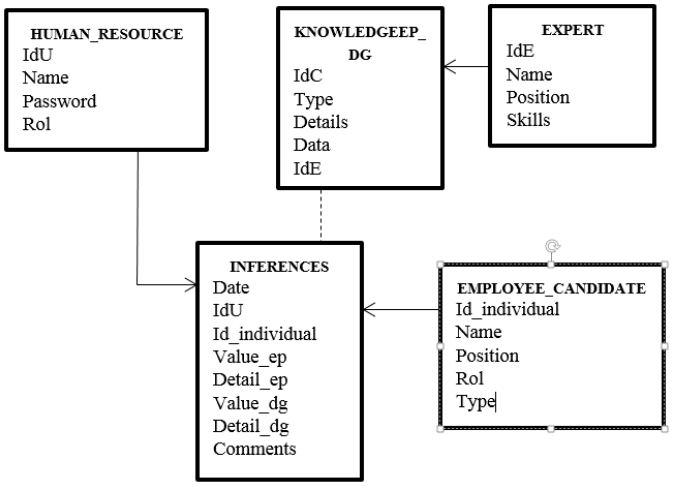

Fig. 2. Knowledge Model for the system

Data Model.
PS: Primary Scales
GD: Global Dimensions

- Human resource area has stored the knowledge with the actors who are responsible for interacting with the system, searching for determine whether an evaluated has a profile of Social Engineer.
- Expert stores data related experts in charged to update the knowledge data base.
- Employee is the data structure that stores information related to 16PF result applied to candidates or employees in the Company. This results determined from the inferences in the system and will determine the profile.

- Inferences saves the results obtained from the application of16PF test. There the results are saved by date, relating the values of primary scales and global dimensions.
- The stored knowledge serves as support for the inferences in the system, added to the results for each candidate or employee evaluated by the 16PF test. This is located in the ep_dg knowledge structure.

Inference Engine.
Facilitate processing of the data, specific knowledge memory ep_dg climbs (see Table 4). In this way the data are loaded into the matrix by reducing the cost of processing between the application and the knowledge base.

Structure Data matrix.
Once the user click on button "infer" ep_dg data are uploaded to memory, (see Table 4). This reduce to call n times to the knowledge base during data processing.

The results of test 16PF applied to each candidate or employee in Company are compared with the data found in ep_dg memory. This comparison is performed through a set of production rules. The data resulting from the application of 16PF test for each candidate or employee in Company are also uploaded to memory, another matrix structure. Almost two symmetric matrices in magnitude. This further processing and inference in the results.

Table 4. 16PF primary factors and global dimension located in memory

MATRIX MEMORY KNOWLEDGE PROCESSING (EPDG)				
TYPE (0,0)	DETAIL (0,1)	DATA1 + - (0,2)	DETAIL (0,3)	DATA2 + - (0,4)
PS	RESERVED	5	OPEN MINDED	3
PS	CONCRET	6	ABSTRACT	9
PS	EMOTIONALLY CHANGEABLE	8	EMOTIONALLY STABLE	2
PS	DIFFERENTIAL	9	DOMINATE	3
PS	SERIOUS	4	LIVELY	7
PS	NONCONFORMING	2	DUTIFUL	7
PS	SHY	2	SOCIALLY BOLD	7
PS	UNSENTIMENTAL	4	SENTIMENTAL	8
PS	TRUSTING	7	SUSPICIOUS	7
PS	SOLUTION-ORIENTED	4	IDEA-ORIENTED	8
PS	GENUINE	8	DISCREET	4
PS	SELF-ASSURED	4	SELF-DOUBTING	7
PS	TRADITIONAL	7	EXPERIMENTING	3
PS	GROUP-ORIENTED	3	SELF-RELIANT	8
PS	FLEXIBLE	8	PERFECTIONISTIC	3
PS	PATIENT	8	TENSE	3
GD	STRESS-RESILIENT	8	STRESS PRONE	3,2
GD	INTROVERTED	5	EXTRAVERTED	7
GD	UNRESTRAINED	7	SELF- CONTROLLED	4
GD	ACCOMMODATING	7,8	INDEPENDENT	3
GD	RECEPTIVE	7	TOUGH- MINDED	4

Graphical Interface User

This interface allows users to register the result of 16 pf test. System infer and feedback with result of profile. Depends of values, the result could matched with a social engineer profile.

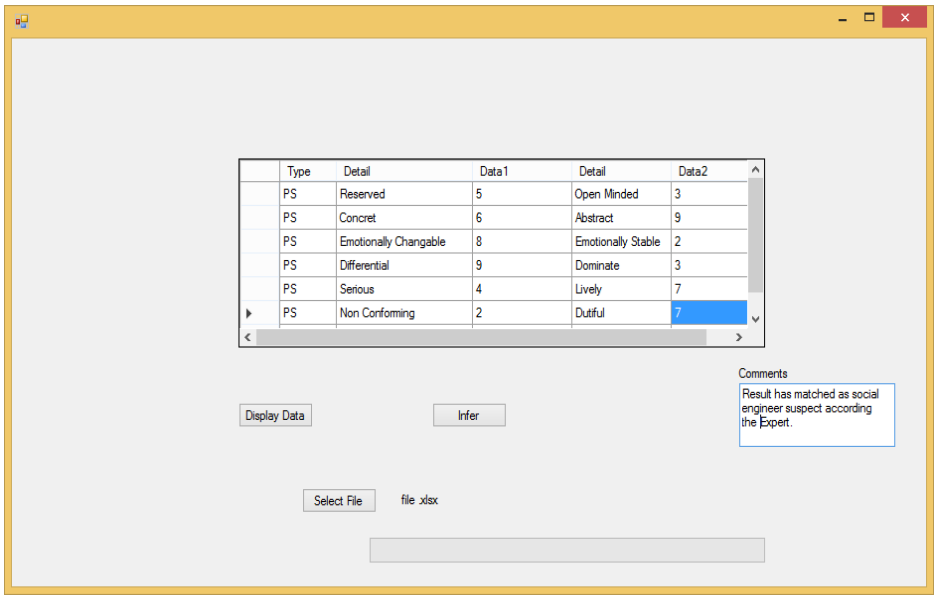

Fig. 3. Knowledge Base Graphical Interface. The Personal Human Resource, use this interface to upload the result of 16PF test. System infer with the information stored in data base knowledge. Feedback depends of information registered by Expert previously.

4.2 Base Rule

Matrix_epdg: contains the general knowledge base to characterize an evaluated as social engineer profile.

Matrix_r16pf contains the results of each candidate of employee evaluated using the 16PF test.

```
Profile Employee Test Program (Output)
  Memory_payload  file_results_16pf (employee)
  Memory_payload file_results_16pf (knowledge base ep_dg)
  For  i=1;i<=21;i++
    Get matrix_epdg(i,2), matriz_r16pf(i,2)
    If  matrix_r16pf(i,2) > = matrix_epdg(i,2) then
      Print matrix_epdg(i,3)
    Else
      Print matrix_epdg(i,1)
    End If
    If  matrix_r16pf(i,4) >= matrix_epdg(i,4) then
```

```
      Print matrixz_epdg(i,1)
    Else
      Print matrix_epdg(1,3)
    End If
  End For
  Close_  file_results_16pf (employee)
  Close_ file_results_16pf (knowledge base ep_dg)
End.
```

5 Case Study

To test the knowledge base system five employees in a Law Firm (name reserved) were evaluated using the 16PF. In order to keep the confidentiality of information, non all data are disclosed.

Case Data File 1.
User ID: private
Name: Private
Position: Office Manager
Role: Information System Manager
Employment relationship: Employee

Human Resource.
Human Resource ID: Private
Name: Private
Password: Private
Role: Human Office Manager

Inference.
Date: 25/04/2015
Human Resource ID: Private
User ID: private
Value_ep, Detail_ep, Value_dg, Detail_dg: see Table 5.
Comments: The profile result has matched as social engineer suspect according the Expert.

Table 5. 16 PF test result from an evaluated employee (matrix of memory knowledge processing (EPDG))

TYPE (0,0)	DETAIL (0,1)	DATA1 + - (0,2)	DETAIL (0,3)	DATA2 + - (0,4)
PS	RESERVED	5	OPEN MINDED	3
PS	CONCRET	6	ABSTRACT	9
PS	EMOTIONALLY CHANGEABLE	8	EMOTIONALLY STABLE	2
PS	DIFFERENTIAL	9	DOMINATE	3
PS	SERIOUS	4	LIVELY	7
PS	NONCONFORMING	2	DUTIFUL	7

TYPE (0,0)	DETAIL (0,1)	DATA1 + - (0,2)	DETAIL (0,3)	DATA2 + - (0,4)
PS	SHY	2	SOCIALLY BOLD	7
PS	UNSENTIMENTAL	4	SENTIMENTAL	8
PS	TRUSTING	7	SUSPICIOUS	7
PS	SOLUTION-ORIENTED	4	IDEA-ORIENTED	8
PS	GENUINE	8	DISCREET	4
PS	SELF-ASSURED	4	SELF-DOUBTING	7
PS	TRADITIONAL	7	EXPERIMENTING	3
PS	GROUP-ORIENTED	3	SELF-RELIANT	8
PS	FLEXIBLE	8	PERFECTIONISTIC	3
PS	PATIENT	8	TENSE	3
GD	STRESS-RESILIENT	8	STRESS PRONE	3,2
GD	INTROVERTED	5	EXTRAVERTED	7
GD	UNRESTRAINED	7	SELF- CONTROLLED	4
GD	ACCOMMODATING	7,8	INDEPENDENT	3
GD	RECEPTIVE	7	TOUGH- MINDED	4

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Automatic Classification of Context in Induced Barking

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Abstract. In this study, we present the results of classification experiments of induced dog barks in different contexts of behaviour. We applied four validation schemes to trained models in order to determine the level of individuals dependency for context classification. We did an analysis based on feature selection techniques to determine the best acoustic low-level descriptors for this task. Results showed that classification performance decreases when the model is evaluated leaving out acoustic information of individuals in the training stage. The acoustic feature set used in our experiments shown better results in comparison with other works using the same data.

Keywords: Barking classification, acoustic characterization, machine learning

1 Introduction

The bark is the most distinctive vocalization of dogs. It occurs very frequently in a wide range of contexts and situations. For humans, many times this chaotically noisy vocalization is annoying. However, people are able to recognize their dogs by their barks [9], to categorize dog barks correctly [12] and even to perceive emotional information from acoustic parameters of dog barks [13]. Some authors say that it has an important function for expression, becoming more and more sophisticated during dog domestication.

Dog barking and other vocalizations of dogs have been studied from different points of view. On one side, researchers have been trying to answer to research questions regarding the function and type of the information carried by dog

barks. For example, in [14] the possible communicative function of dog barking is discussed. Lord et al. [7] explored the functional hypothesis that barking is associated with mobbing behaviour and the motivational states that accompany mobbing.

Other studies have been focused on the acoustic properties of dog vocalizations and mainly on barks. Interesting acoustic patterns have been found from the analysis of the relation between regular and irregular components of the signal. For example, [9] studied the harmonic-to-noise ratio to rank dog vocal utterances from noisy to clear by quantifying the amount irregular energy. Molnar et al. [10] found that individuals are more successfully identified by humans when they listen to a low harmonic-to-noise ratio barks. Some authors have parametrized vocalization of dogs using objective techniques to describe the relationship between sound structure, signal function and social context. For example, in [4] they used sonography to determine the complexity of the dog's vocal repertoire and its communicative value.

Classification of barks based on context has been aboard by some authors. Yin et al. [18] analysed spectrograms of 4,672 barks from 10 dogs generated in 3 different contexts: disturbance, isolation and play. They found specific particularities in frequency and amplitude measurements for each context. Molnar et al. [9], analysed tonality, frequency and intervals between barks produced in 7 different contexts. They tested the ability of human listeners to discriminate between dogs when the context in which bark was recorded changes. For example, they found that for listeners it is easier to recognize the individual dog when barked at a stranger than if they listen when the dog was separated from its owner.

More recently, artificial intelligence techniques have been utilized to automatically classify barks and other dog's vocalizations. In [8] they used a Bayesian classifier for two classification problems, recognition of dogs and categorization of barks into context. They constructed a set of acoustic descriptors using an evolutionary algorithm and feature selection techniques. Larrañaga et al. [6] compared several supervised machine learning methods for four classification tasks: sex, age, context and individual. They tested four machine learning methods and a set of 29 acoustic measures extracted from each barking recording. In the case of context classification, they tested for two learning settings, a single model for all dogs and one model per each dog. Both works were done using a database of Mudi dog barks.

In this work we used the same database of Mudi dog barks previously analysed in the works by Molnar et al. and Larrañaga et al. Our contributions and goals with this work are motivated by two research questions:

1. Which are the best low-level descriptors for barks context classification?
2. How individual dependant is bark context classification?

We analysed the pertinence of a set of low-level acoustic descriptors that has been used for emotion recognition in voice. We implemented a *leave one dog out* validation scheme and compared with other validation schemes to evaluate the accuracy of our models and individual dependency. The main goal with this

project is to train classification models for bark context classification to classify new dogs.

2 Data

We used in our experiments the data collected by Pongrácz et al. [15]. They captured Mudi dog barks, a medium sized Hungarian breed of shepherd dogs. Barks were induced in dogs by performing a predefined protocol of seven different behavioural contexts described below:

1. Alone: The owner and the experimenter take the dog to an outdoor area. The owner leaves the dog tied and walked out of the dog's sight.
2. Ball: The owner holds a ball or toy 1.5m in front of the dog.
3. Fight: The trainer attacks the owner and the dog. The owner keeps the dog on a leash.
4. Food: The owner holds the dogs food bowl 1.5m in front of the dog.
5. Play: The owner plays a game with the dog.
6. Stranger: The experimenter appears at the dog garden or in front of the dog.
7. Walk: The owner behaves as if he/she is preparing for a walk with the dog.

The barks were recorded in a different number of bouts for each dog. With an exception of the contexts Alone and Fight, all recordings were done at the dog's residence. Recordings were made with a tape recorder and a microphone. During recordings, the experimenter stood in front of the dog and faced it while holding the microphone within 1 to 4 meters of the dog. Barks were digitalized with a 16-bit quantization and 22.05 kHz sampling rate. Waveforms were rescaled so that its highest amplitude peak was at -6 dB.

2.1 Annotation and Segmentation

Original recordings were manually segmented at single bark sound level. Segment length ranges approximately from 0.1 to 0.8 seconds. Original recordings and segments are separately stored by dog ID and context. In Fig. 1 (generated by Praat [2]), we can see an original recording that is segmented, eliminating the pause periods and keeping the single bark fragments which are the analysis unit in our experiments.

The data set consist of 6,614 single barks distributed in seven contexts as shown in Table 1. In this same table, it is shown the number of samples of each context used for the different validation methods used in this work. Validation methods are explained in section 5. The barks correspond to 12 dogs as shown in Table 3. As we can see in this table, we have an unbalanced number of samples per class. We can also notice that not all dogs are represented in all contexts. This is due to the complexity of the bark induction protocol implementation. It is a fact that not every dog reacts in the same way and with the same proportion to the stimuli.

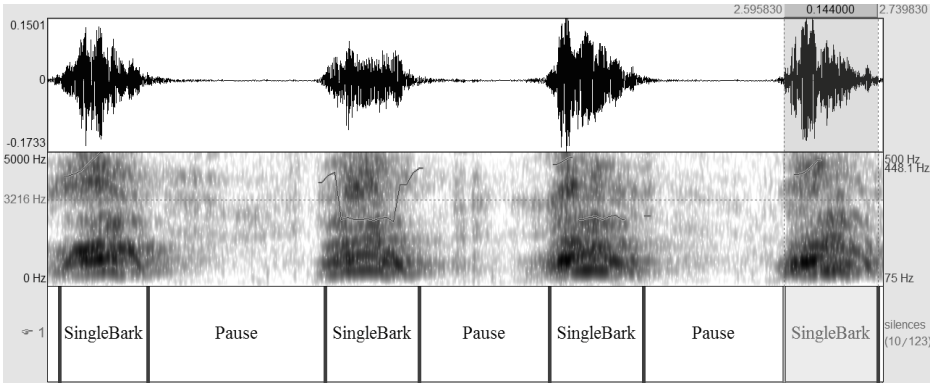

Fig. 1. A recording containing four single bark sounds. Each single bark is stored in a separated audio file.

Table 1. Number of instances used in validation method for each context

OMPD, 10FCV and LODOV	Resample	Context
758	83	Alone
1,004	132	Ball
1,056	143	Fight
833	109	Food
752	119	Play
1,425	226	Stranger
786	100	Walk
6,614	912	Total

3 Acoustic Features Extraction

We used the openSMILE [3] software to extract the following Low-Level Descriptors (LLDs) included in the large openSMILE emotion features set. This acoustic features set was designed for emotion recognition in the human voice.

Melspec N-band Mel / Bark / Semitone - frequency spectrum (critical band spectrum) by applying overlapping triangular filters equidistant on the Mel / Bark / Seminote - frequency scale to an FFT magnitude spectrum.

MFCC The first 12 Mel-frequency Cepstral coefficients are computed on the critical band spectrum.

Energy Computes logarithmic (log) and root-mean-square (RMS) signal energy from PCM frames.

Spectral Bands Computes energy in the given spectral band by summation of FFT bins in the band. The bands computed are 0-250, 0-650, 250-650 and 1000 - 4000.

Spectral Roll Off Compute X*100% spectral roll-off point. The X*100% spectral roll-off point is determined as the frequency below wich X*100% of the total signal energy fall.

Table 2. F-measure for each context obtained in deferent validation settings

OMPD	10FCV	Resample	LODOV	Context
0.93	0.80	0.67	0.30	Alone
0.80	0.67	0.62	0.28	Ball
0.95	0.84	0.81	0.57	Fight
0.82	0.67	0.72	0.31	Food
0.84	0.72	0.59	0.20	Play
0.92	0.79	0.76	0.47	Stranger
0.79	0.64	0.57	0.32	Walk
0.87	0.74	0.69	0.37	Weighted Average

Table 3. Number of instances used in validation for each dog

OMPC, 10FCV and LOCOV	Resample	Dog
275	106	d05
1,007	112	d12
465	115	d14
219	0	d18
968	101	d23
1650	105	d24
693	114	d09
336	131	d16
686	128	d20
124	0	d27
108	0	d10
83	0	d26
6,614	912	Total

Spectral Flux Computes spectral Flux for N FFT bins
Spectral Centroid Computes spectral centroid at time t.
Spectral MaxPos Computes the position of the maximum magnitude spectral bin
Spectral MinPos Computes the position of the minimum magnitude spectral bin.
Voice Prob Computes the probability of voicing via a Cepstrum based method.
F0Env F0 envelope (exponential decay smoothing)
F0 Computes the fundamental frequency via an ACF based method.
ZCR Computes these time signal properties:

LLDs are computed using a frame size of 25 ms and a frame step of 10 ms. A smoothing data contours process is applied by a moving average filter. Delta and double delta regression coefficients are calculated for the values of LLDS in each frame. In order to have the same number of attributes for each single bark recording, regardless of its duration, 39 statistical functions are calculated over the values of the LLDs, its deltas and its double deltas coefficients in each frame

Table 4. F-measure for each dog obtained in deferent validation settings

OMPC	10FCV	Resample	LOCOV	Dog
0.95	0.82	0.89	0.20	d05
0.99	0.97	0.93	0.91	d12
0.97	0.91	0.91	0.65	d14
0.98	0.94	-	0.71	d18
0.98	0.95	0.88	0.86	d23
0.99	0.98	0.94	0.93	d24
0.96	0.94	0.92	0.65	d09
0.95	0.93	0.93	0.73	d16
0.94	0.90	0.87	0.73	d20
0.94	0.87	-	0.67	d27
0.94	0.83	-	0.20	d10
0.94	0.92	-	0.02	d26
0.97	0.94	0.91	0.76	Weighted Average

of the recording. Finally, we obtain a total of 6,552 attributes for each single bark sample. Table 6 shows the number of acoustic features per each LLD.

4 Acoustic Features Selection

After an experimentation stage with several feature selection methods, we decided to use the *Relief Attribute* evaluation method as implemented in Weka [5]. This method as shown the best the best accuracy rates when we took the 500 best-ranked attributes. These features were individually evaluated from the original feature set of 6,552 attributes in order to obtain the best attributes and reduce the dimensionality of the attributes vector. Table 6 shows the number of selected acoustic features per each LLD.

5 Evaluation of Classification of Context and Dog

We used the machine learning technique *Support Vector Machines*(SVM) using a polynomial kernel [5] to classify by context and by dog. We selected SVM given that this technique has shown good results in previous works using a similar acoustic feature set [11]. The validation was made by four methods:

One Model per Dog (OMPD) with the objective of measuring the impact and dependency of individuals in the classification, we implemented a scheme of validation where a classification model is trained with the samples of only one dog. Then the trained model is evaluated by 10FCV. Accuracy statistics is calculated on the accumulated confusion matrix. We included this validation scheme to test the opposite scenario to a dog independent model.

10 Fold Cross Validation (10FCV) In this validation scheme a classification model is trained using the 90% of the samples in the dataset and tested it with the 10% left out. This validation round is repeated 10 times, each time leaving out a different set of samples. We used this validation scheme to have a baseline accuracy. However, given that several samples are extracted from the same recording, they could generate an effect of pseudo-replication.

Resample Dogs with the fewest samples are discarded. We eliminated the four less represented dogs. After this step, we applied the Re-sample method as implemented in [5] to obtain a random subsample of the dataset. We kept the 15% of the samples with a bias to uniform the number of samples from each dog, without replacement of samples. The number of kept samples for each dog is shown in Table 3. Classification accuracy is evaluated using this reduced dataset and 10FCV. We included this validation scheme in order to compare our results with the reported by [6] where they used the same data and similar method for re-sampling.

Leave One Dog Out Validation (LODOV) with the objective of measure the impact and dependency of individuals in the classification. We implemented a scheme of cross validation where a classification model is trained using all the samples of N-1 dogs and tested it with the one left out. Where N is the total number of dogs in the data set, 12 dogs in our case. This validation round is repeated N times, each time leaving out a different dog. Accuracy statistics is calculated on the accumulated confusion matrix.

Table 2 shows the results, in terms of F-measure, of automatic classification per class. F-measure is a classification performance metric that is calculated as the harmonic mean of precision and recall. It may be obvious to expect that any setting that mixes dogs identities during training is going to have a better classification performance but, it is important for the goals of this work to have a clear idea of how big is the impact. We can see that there is a significant difference in classification performance depending on the evaluation scheme. While we can observe an excellent performance for OMPD relatively good performance for 10FCV and Resample, for LODOV we obtained a low performance. Classification performance per context was similar in the four evaluation schemes. Fight was the context with the best results in the four schemes followed by Stranger. The contexts with the lowest performance were Ball, Walk and Play.

When we evaluated by Resample, we obtained an F-measure of 0.69 (as shown in Table 2) and an accuracy of 68.64%. This represents an improvement on the results reported by Larrañaga et al. [6] using the same data and the same evaluation scheme. They obtained an accuracy of 55.50% using a k-nearest neighbour classifier and a wrapper feature selection method. The acoustic features they used were mainly spectral energy and voice cycle measurements.

Table 4 shows the results for individuals classification. Even when dog identification is not the main target of this work, this experiment is important to illustrate that the barks of each dog have evident acoustic particularities regardless the context. It is a fact consistent with contextual plasticity, the extent to which the behaviour of a given animal varies across contexts [17].

We evaluate dog classification with the same four validation schemes used in the previous experiment. For the third scheme, we leave one context out instead of one dog. As we can see, in general, it was an easier classification task. Dogs were classified with a high accuracy except the ones with few samples.

6 Context Grouping

In Table 5 we show the results of automatic classification when grouping contexts. We defined some group according to Arousal and Valence, which are frequently used as human emotion descriptors [16]. Arousal is the level of awakeness or reactivity to stimuli.Valence is the intrinsic attractiveness (positive) or aversiveness (negative) of an event. Contexts were grouped in the following way:

Experiment 1 Negative Valence (Fight, Stranger, Alone) vs Positive Valence (Walk, Ball, Play, Food)

Experiment 2 High Arousal (Fight, Stranger, Walk, Ball, Play) vs Low Arousal (Alone, Food)

Experiment 3 Negative Valence and High Arousal (Fight, Stranger) vs Positive Valence and High Arousal (Walk, Ball, Play) vs Low Arousal (Alone, Food)

Table 5. F-measure for each dog obtained in contexts grouping

Groups	10FCV	LODOV
Experiment 1	0.85	0.71
Experiment 2	0.85	0.72
Experiment 3	0.78	0.58

We performed these experiments to test the acoustic similarities among barks according to the probable emotional state. Table 5 shows that the criteria used to group barks allowed to obtain a relatively good classification performance.

7 Acoustic Features Analysis

Table 6 shows the results of our analysis on acoustic features classification performance. This table shows the number of features originally extracted and also shows the number of selected features for each LLD. The F-measure for each LLD was calculated by group and individually. As mentioned above, we extracted 5,552 features from each single bark. These features are organized into six LLD groups. We tested the performance of LLDs by group and individually to have a better understanding of the discrimination capabilities of these acoustic descriptors. These results were obtained by evaluating separately the features set

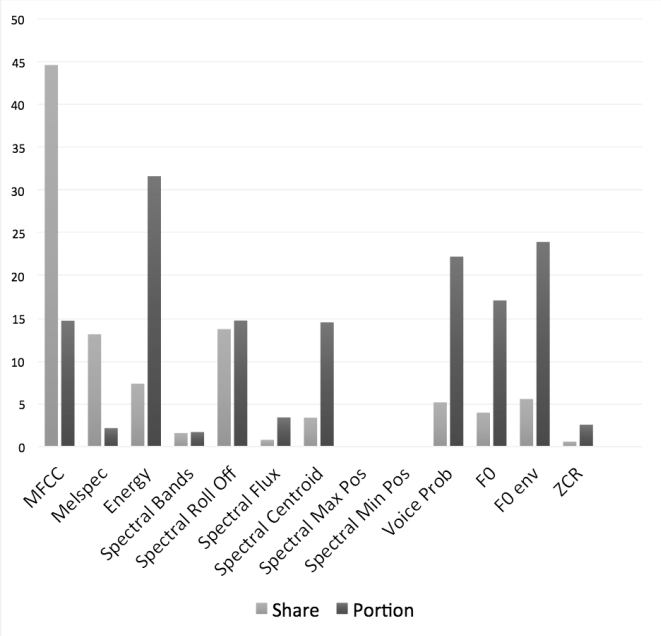

Fig. 2. Share and Portion metrics computed for each LLD.

from each LLD. The validation scheme for this experiment was 10FCV. MFCC was the best LLD. Using only these features we obtained an F-Measure of 0.69, while using all LLDs we obtained an F-Measure of 0.74, as can be seen in Table 2. Melspec was the second best LDD. Energy, Spectral Roll Off and Spectral Centroid also showed an important contribution. On the other hand, there were LLDs that did not provide information, such as Spectral Max Pos and Min Pos.

In Fig. 2 we plot Share and Portion which are measures proposed in [1] to assess the impact of different types of features on the performance of automatic recognition.

Share shows the contribution of each LLD to the selected set of acoustic features. It is computed as the percentage of selected features of one LLD from the total number of features in the selected feature set.

Portion shows the contribution of each LLD weighted by the number of features per type. It is computed as the percentage of selected features of one LLD from the number of features of that LLD included in the original feature set.

As we can see MFCC is the LDD with highest Share. The 45% of the selected features belong to MFCC group. This amount of MFCC features represent the 15% of the MFCC features originally included. Energy is the LLD with the highest Portion The 7% of the selected features belong to Energy group. This amount of Energy features represent the 32% of the Energy features originally included.

Table 6. Number of features for each LLD and number of selected features. F-measure for LLD calculated in groups and individually.

LLD Group	F-Measure	LLD	F-Measure	SelFeatures	F-Measure	OrigFeatures
MFCC	0.69	-	-	224	0.69	1,521
Melspec	0.48	-	-	66	0.67	3,042
Energy	0.41	-	-	37	0.44	117
Spectral	0.47	Bands	0.21	8	0.34	468
		Roll Off	0.41	69	0.40	468
		Flux	0.18	4	0.38	117
		Centroid	0.33	17	0.40	117
		Max Pos	-	0	0.35	117
		Min Pos	-	0	0.26	117
Pitch ACF	0.38	VoiceProb	0.25	26	0.34	117
		F0	0.18	20	0.18	117
		F0 env	0.18	28	0.18	117
		ZCR	0.17	3	0.34	117

Melspec is an interesting case. This LLD have a good performance for classification as shown in Table 6 even when its representation in the selected set is not as significant as other LLDs (Share 13.1%, Portion 2.2%).

8 Conclusions

From the results obtained we can conclude that there is a high dependency on individuals in context classification of barks. In other words, each dog shows a particular way to bark in each context. We saw that context recognition when building models for each individual have very good results, 80% F-measure or higher for all contexts. On the other hand, when we leave one dog out of the training, and then use its samples to test the model, F-measure is not higher than 0.57%. The more dog specific was the evaluation the better the classification performance was.

Dog recognition seems to be an easier classification task than context classification. We obtained good classification performance even when the classification models were evaluated leaving one context out. This mean that a dog can be recognized among other dogs by its barking regardless the context of barking induction.

We were able to corroborate that MFCC, a widely used LLD for human voice analysis mainly speech and speaker recognition, is a good acoustic descriptor to bark context classification task. Using only this descriptor, it is possible to characterize dog barks and build classifiers with a similar performance than classifiers built with a much larger set of descriptors. Energy is also a good LLD for bark classification. This type of acoustic feature provided a high portion of features to the selected set. Melspec features are able to characterize dog barks using a relatively low share and portion from the original number of features.

An interesting result was obtained when dog bark contexts were grouped by Valence and Activation, two primitives used for human emotions modelling. We saw that barking could be analysed in terms of emotion-related information.

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Crime Data Mining: Combining Socio-economic and Spatial Analysis

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Abstract. Public security is an important issue for a society. With the massive increase in electronic data availability over the last few years, characterising and predicting crime has become a task that can be approached using different data mining techniques. However, previous studies have concentrated on the spatial patterning of crimes without investigating potential predictors or causes. In this paper, we use a range of data mining techniques to analyse criminality using a data base of crimes from the municipality of General de Escobedo in Nuevo León, México. We show that different types of crime - domestic violence, residential robberies and business robberies - have quite different profiles, both from the point of view of the characteristics of the robberies themselves and from the underlying socio-demographic and socio-economic factors that influence them. We create predictive models for these three crime types and discuss how the results can be used to predict and reduce crime risk.

Keywords: Data mining, Bayesian analysis, crime, spatial data mining, crime types

1 Introduction

Crime and security are issues that are almost always at the forefront of the publics mind. There are a wide variety of crimes that can afflict a society or a certain population: from business robbery, home robbery and domestic violence to homicides and kidnappings. There are many questions that can be posed that are relevant to understanding both crime patterns and also the risk factors associated with different crimes. Are all populations equally at risk for

a given crime? What are the underlying socio-demographic and socio-economic factors associated with a given crime? In this big data age, recently, data mining techniques have been brought to bear on this type of problem [1–5]. Many of these studies have focused on the spatio-temporal patterns of crime using unsupervised learning. Such analyses, although providing useful intelligence, do not make potentially causal links to underlying socio-economic and socio-demographic variables as potential risk factors that characterize or profile a particular type of crime. There is also the related question of to what extent one type of crime differs from another in terms of its predictive profile. For instance, are the predictive drivers of all types of robbery the same or do they differ between one robbery type and another? In this paper, we consider those three crime types with the greatest incidence in the municipality of General de Escobedo in Nuevo Leon, México. The three crimes types were: domestic violence, business robbery, and burglary. Criminal data were obtained from the reports of the police officers who attended the crimes. These reports contain valuable information, such as the hour, day, week, month etc. of the crime. However, they do not contain a description of the type of population which is affected by the crimes. This information was obtained from the AGEBs (Basic Geostatistics Area, in English) provided by INEGI [10]. We performed several different types of analysis, ranging from basic exploratory analysis, using simple statistics, to a more sophisticated classification model using a Naive Bayesian classifier. The classifier was used to determine risk profiles for different crime types and perform a spatial risk analysis at the level of AGEBs using, for example, heat maps as a visualisation tool.

1.1 Data Characteristics

The data which we analysed comes from reports made by police officers of the municipality of General de Escobedo in 2012. There are 17 distinct crime types in the data with the highest incidence being associated with domestic violence, business robbery and house robbery. In Table 1 we show the frequencies of the different crime categories.

The original data displayed many inconsistencies and errors, such as typographical errors, domain errors in an attribute and a variation of the field format in the months. As with most data mining projects a substantial amount of time was spent cleaning the data.

1.2 Preliminary Analysis of the Data

We will first illustrate the type of exploratory analysis that is possible with this type of data restricting attention to the case of BR (Business Robbery). BR was chosen due to the greater precision with which it could be located geographically and due to the fact that the associated data was of higher quality - less data errors or missing fields. Similar analysis was performed for other crime types but will not be presented here due to space restrictions.

Table 1. Frequencies of the distinct crime categories

Abbreviation	Number	Type of crime
HOMICIDE	21	Homicide
AR	27	Attempted Robbery
W	27	Breaking and entering
ST	52	Simple Theft
JD	70	Judicial Dictum
CPD	72	Car Pieces Robbery
DP	79	Damage to Property
A	100	Another
I	106	Injuries
G	134	Gangs
FT	160	Failed Theft
VTR	213	Vehicle with Theft Report
VR	237	Vehicle Robbery
TP	290	Theft from person
HR	419	House robbery
BR	675	Business Robbery
DV	1047	Domestic Violence

Each BR event was associated with a small set of descriptor variables. From these variables initial preliminary analysis could be carried out. The BR characteristics which we worked with are:

X_1: Police shift - morning, evening, night, and early morning.
X_2: Time at which crime was reported
X_3: Colonia (Neighborhood)
X_4: Codigo postal (Zip code)
C : type of business robbed

Some representative results can be seen in Figures 1 and 2. In Figure 1 we see an increased incidence for BR at weekends and in Figure 2 an increased incidence at night time. With respect to other features, such as month of the year, day of the month etc. no relevant trends were found in the preliminary analysis. However, it was seen that different types of business exhibited different profiles in terms of the above variables. For instance, convenience stores were much more likely to be robbed at night when compared to other business types.

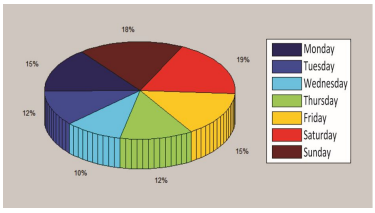

Fig. 1. Percentages of BR by day of the week

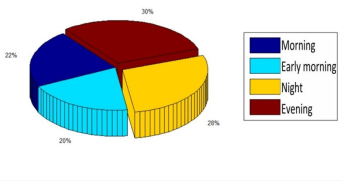

Fig. 2. Percentages of BR by time of day

2 Feature Selection and Model Construction for BR

In order to determine which features are correlated with and therefore potentially predictive of a given crime we must look for the characteristics X_i which are correlated with the crime type considered as a class C. In order to determine these features that are relevant for classifying and predicting a given type of crime we use the statistical diagnostic in equation (1).

$$\varepsilon\left(C|X_i\right) = \frac{N_x\left[P\left(C|x\right) - P\left(C\right)\right]}{\left[N_x P\left(C\right)\left(1 - P\left(C\right)\right)\right]^{1/2}}, \tag{1}$$

where $P(C|x) = \frac{Nc(x)}{Nx}$ and $P(C) = \frac{N(c)}{Nt}$ and:

N_x=number of times that x appears,
$P\left(C\right)$=is the probability that my class has,
$N_c\left(x\right)$=is the number of times x appears in my class,
$P\left(C|x\right)$=the probability of belonging to the class given that we have the characteristic x,
$N\left(C\right)$=number of times that it my class appears,
Nt=total number of records that we have.

ε is a binomial test that determines the statistical significance of the observed distribution of co-occurrences of the class C and feature X_i relative to the null hypothesis that they are uncorrelated. The associated distribution is binomial but may be approximated in most circumstances by a normal distribution. In this case, $|\varepsilon\left(C|X_i\right)| > 1.96$ corresponds to the 95% confidence interval that the observed co-occurrence of C and X_i would not have occurred by chance. Hence, we may determine which features are correlated with or predictive of a given crime type.

Having determined those features which are correlated with the class C we may construct a classifier (score function)

$$S\left(\mathbf{X}\right) = \ln\frac{P\left(C|\mathbf{X}\right)}{P\left(\bar{C}|\mathbf{X}\right)}, \tag{2}$$

where $\bar{C}$ is the complement of the class C and $\mathbf{X}$ is the vector of relevant features. As $P(C|\mathbf{X})$ is potentially a high-dimensional joint probability it cannot be estimated directly. We can proceed however using Bayes rule and adopting the Naive Bayes approximation. Using Bayes rule

$$P(C|\mathbf{X}) = \frac{P(\mathbf{X}|C)P(C)}{P(\mathbf{X})}, \tag{3}$$

we wish to determine the likelihood function $P(\mathbf{X}|C)$. As mentioned, due to the high-dimensional nature of the feature space these likelihoods cannot be determined directly. In the Naive Bayes approximation we assume that the features X_i are not correlated therefore

$$P\left(\mathbf{X}|C\right) = \prod_i P(X_i|C) \qquad P\left(\mathbf{X}|\bar{C}\right) = \prod_i P(X_i|\bar{C}). \tag{4}$$

We thus obtain for our classifier

$$S(X) = \ln \frac{\prod P(X_i|C)}{\prod P\left(X_i|\bar{C}\right)} + \ln \frac{P(C)}{P(\bar{C})}, \tag{5}$$

where $\ln \frac{P(C)}{P(\bar{C})}$ is a constant independent of the features X_i.

A high positive score value indicates a higher probability of belonging to the class C, while a high negative score indicates a low probability of belonging to the class. In the case at hand, in order to use this formalism it is necessary to be able to identify events in $\bar{C}$. However, the provided data base consisted only of crime events not "non-crime" events! There are several ways to overcome this. In the case of BR for instance, if one had access to a data base with all businesses in the municipality one could determine which businesses had not been robbed and these businesses would form $\bar{C}$. Another way to proceed, whch we will adopt here, is to consider C to be a subset of crimes within a wider set. For instance, BR could be the class C and $\bar{C}$ the class of all robberies that were not BR. In this way we will characterize and profile crimes one relative to another rather than in absolute terms. Thus, for instance, we will determine what are the particular predictive drivers of BR relative to other types of robbery.

3 Socio-demographic Variables

By having just few variables that can characterize the different crimes, we looked for other sources of information that would have a better characterization of the offences. The source of this new information is the AGEBs (Basic Geostatistics Area, in English) with which you can get 188 variables that describe the population in a particular area.

For the municipality of General de Escobedo INEGI has a division of 121 AGEBs, not all the territory of the municipality is divided, there are areas, mostly in the periphery, where there are irregular settlements that do not have assigned a AGEB, causing that some socio-demographic data cannot be assigned for some reported crimes.

The variables are grouped into population, migration, indigenous population, disability, educational characteristics, economic characteristics, health, marital status, religion and housing; the vast majority of these variables are accounted with regard to the number of people with those characteristics.

4 Models

The first we did was to geo-code each crime and determine in which AGEB they belong to. From 121 AGEBs in total, we could locate at least one crime in 67 AGEBS, for the remaining AGEBs, there are not records of any crime, which does not mean that the crime was not committed, but is not possible to establish the offence-AGEBs relationship. The possible factors for the preceding situations are:

a The AGEB is an unpopulated area.
b Lack of information regarding that area.
c Irregular settlement.
d Inconsistent information to geographically locate the crime.
e The crime was not reported to the corresponding authorities.

The previous data are some aspects why you cannot set a relationship between the crime and AGEB.

From the 67 AGEBs with at least one offence a coarse-grain is done due to the fact that each variable has a unique value by which a count could not be done by the value in the variables of the AGEB.

Table 2. COARSE-GRAIN.

AGEB	POBTOT	POBMAS	STANDARDIZATION	COARSE-GRAIN
0043	4435	2165	0.488162345	1
0062	151	70	0.463576159	1
0151	3857	1975	0.512056002	8
0166	2348	1155	0.491908007	1
0185	1057	535	0.50614948	5
0202	5293	2621	0.495182316	2
0221	4279	2184	0.510399626	7

Table 2 shows how coarse-grain takes place: first it must be normalized each of the variables, by which POBTOT which is the total of population should be divided between POBMAS which is the total male population; that is how we got the column STANDARDIZATION. This is repeated for the 67 AGEBs and for the 188 variables, then each column corresponding to each variable STANDARDIZATION should be ordered from the least to the greatest, then proceeds to divide the column of STANDARDIZATION into equal sections. In this case as they are 67 AGEBs it was determined to divide them into 8 groups, with which the order creates a new coarse-grain column and assigns the value 1 to the first 8 records, the value 2 to the following 8 records, and so on to assign the value 8 in the last records. Finally a join is done with the records of crimes.

4.1 Domestic Violence Model

To create this model we applied the equation 1 and is taken as "domestic violence" class for the type of offence.

The variable male population from 15 years and over with primary school (last level of studies completed) with the value of 8 has the highest epsilon, 8 value indicates that it is in the coarse-grain that contains more people of this type. What can we infer from the information above?

Table 3 which contains the 10 records with the highest epsilon, we can see clearly the trend of the domestic violence crime with respect to the level of education; most of the population have either primary completed or incomplete,

Table 3. Variables with higher epsilon for family violence .

Variable	Value	Epsilon
Population 15 years old and over with unfinished secondary school.	6	9.0692
Private inhabited house with car property.	1	9.0940
Private inhabited house with fixed telephone line.	1	9.1247
Male population from 0 to 2 years.	6	9.2146
Population from 12 years old and over.	3	9.3088
Male population from 15 years old and over with primary incomplete.	7	9.3385
Female population aged 15 years old and over with primary school finished.	7	9.3845
Female illiterate population from 15 years old or more.	7	9.6971
Male illiterate population from 15 years old or more.	7	9.9840
Male population from 15 years old and over with primary school completed.	8	10.0506

there are some even illiterate. The previous information leads to an economic adverse situation by not having sufficient studies to get a well-paid job.

This is confirmed by the variables private inhabited house with car property and private inhabited house with fixed telephone line, both with a value of 1. Which indicates the existence of population with low purchasing power so that it is below the level of houses with a car or without telephone line, which also indicates a high degree of marginalization.

Table 4. Variables with higher epsilon for family violence .

Variable	Value	Epsilon
Private inhabited houses with one bedroom.	6	7.7072
Population with no health service.	6	78.016
Population from 12 to 14 years old who do not attend school.	6	7.8171
Male population born in another entity.	8	7.9968
Private inhabited houses with two bedrooms or more.	2	8.0916
Private inhabited houses with a computer.	1	8.4723
Private inhabited houses with piped water.	2	8.4739
Occupants per room average in private inhabited houses.	6	8.6375
Illiterate population from 15 years old or more.	7	8.8522
Population 0-2 years old.	7	9.0056

Table 4 shows other relevant variables for domestic violence (these are not the variables that continue in table 3) as you can see, the trend of the economic level is maintained. The variable male population born in another entity with a value of 8 indicates that the majority of the population has emigrated to the municipality, which means they have to rent a room or, in a better case, a social interest housing, there is also the possibility of arriving with a family member, which looks reflected in the variables average of occupants per room , in private occupied houses, private inhabited houses with a bedroom, both with a value of 6, which shows a tendency to have many people living in a small space, while the variable private inhabited houses with two bedrooms and more with value of 2 shows that the majority of dwellings where there is high incidence of domestic violence are houses with no more than two bedrooms. Having more people living

in reduced inhabiting spaces, in precarious economic situation and low education level leads to high rates of domestic violence.

In Figure 3 there is a heat map regarding the incidence of domestic violence in each AGEB (red color indicates a higher incidence, white color means little or no presence) as we can see there is a clear trend to the furthest areas from the municipality which are belonging to the periphery of Monterrey city, adjacent to uninhabited areas, some are irregular settlements. The mentioned areas coincide with the variables of the previous analysis.

In the table 5 we have 10 variables with the more negative epsilon, as it is visible, it can be considered the against part of table 3. For example, the variable private inhabited houses with fixed telephone line with the value of 8 and epsilon - 8.95, it is the opposite to the variable with the same name in the table 3 but with value 1 and epsilon 9.124. In the table 5, we can see that variables which involve education are those that indicate a higher education level than those with only basic education. All these variables have a value of 8 or 7 and belong to the coarse-grain that brings a greater number of people who have the post-basic education. On the other hand, the variables of education indicate an incomplete or complete basic education with a value of 1 which belong to the coarse-grain with the least number of people of this type. The private houses inhabited with a washing machine with a value of 8 indicates a socio-economic level better than those described in the variables of table 3.

This indicates that the incidence of domestic violence is far less than expected as the level of education rises, the same applies to the economic level.

Table 5. Variables with lower epsilon for family violence.

Variable	Value	Epsilon
Male population from 18 years old and over with post-basic education.	8	-9.3353
Private inhabited houses with fixed telephone line.	8	-8.9527
People from 18 to 24 years old attending school.	7	-8.8008
Population from 18 years old and over with post-basic education.	8	-8.7268
Female population from 18 years old and over with post-basic education	8	-8.7268
Female population from 15 years old and over with secondary school incomplete.	1	-8.6027
Population without religion.	1	-8.4974
Private inhabited houses with radio.	8	-8.4072
Private inhabited houses with a washing machine.	8	-8.4072
Female population from15 years old and over with secondary school complete.	1	-7.9293

4.2 Business Robbery Model

Now, we will analyze the model for the crime business robbery and determine what characterizes this offence from others.

As seen in table 1 657 businesses robberies are registered, in table 6 you can see the first 10 variables with higher epsilon, there are four variables 10 regarding the location. This allows us to infer that business robbery is characterized by the geographic area of incidence. The rest of the variables tells us where to open

a new business more than characterize the business robbery, in other words, the variables as private inhabited houses with washing machine, private inhabited houses with fixed telephone line with a value of 8, all these data indicates the economic level of the area where a business is established. So that, in order to exist a business robbery there must exists a business there. So, where a business must be set?, In a low or in a high socio-economic level area?, It is clear that in an area where the purchasing power of people allows them to purchase products or services offered by a business. Therefore, economic variables, which characterize a business robbery, determine where it is it more feasible to find a business or where people can open one.

Table 6. Variables with higher epsilon for Business Robbery .

Variable	Value	Epsilon
AGEB	236	9.2405
Private inhabited houses with radio.	8	9.2906
Private inhabited houses with washing machine.	8	9.2906
Neighborhood.	FOMERREY LA UNIDAD	9.4290
Private inhabited houses with fixed telephone line.	8	9.6649
Population 18 years old and over with post-basic education	8	9.8197
Female population from 18 years old and over with post-basic education.	8	9.8197
Neighborhood.	HACIENDAS DEL CANADA	9.9128
Neighborhood.	RIBERAS DE GIRASOLES	9.9128
Male population from 18 years old and over with post-basic education.	8	10.9389

Figure 4 shows a heat map for the incidence of business robbery, which is concentrated in the adjacent area of San Nicolas de los Garza municipality, the red areas describe shopping areas or industrial zones.

There exist several types of businesses that can share characteristics and others that can be unique for each business in particular, we did a drill-down to select a business subset.

In the country there is a large number of convenience stores, whether they are family or franchise stores (OXXO with 11,000 stores , SEVEN or EXTRA) [9], which work 24 hours a day, this exposes them to certain risk conditions of being stolen, but this condition is not the only variable that determines the possibility of theft. The total revenue of the year 2012 for the convenience stores in Mexico was 6,948.8 million, and has an estimated increase of 36% in this sector for the year 2017 [6] , which turns to this type of business highly relevant for the national economy. But like any other business, it is exposed to theft. According to the national criminal traffic light during the years 2012 and 2013, the business robbery in Nuevo Leon was over the national average [7] and in the criminal traffic lights of the municipality of General de Escobedo during the years 2012 and 2013 there was an increase over the historical average. [8] The gas stations share some features with the convenience stores, the most outstanding is that they are available 24 hours a day, in many cases a convenience store, OXXO

- SEVEN - EXTRA, is physically located in a gas station. What we aim is to classify the convenience stores and gas stations robberies by means of different characteristics; for example, the time of the crime, location, etc.

The variable with greater epsilon is the EARLY-MORNING Turn with 6.1941. The table 7 shows the four values for the variable turn, where the occurrence trend of crime type GSO is clearly seen at nights, increasing substantially in the early morning and down on the day and in the evening. This is most visible in table 8 where you can see how from 8 pm the epsilon has a positive sign and this trend is maintained until 6 am o'clock, We also see that the value of epsilon grows from 9 pm until 2 am, then it decreases, but maintains a positive sign up to 7 am. The time is an important variable for businesses as gas stations, OXXO - SEVEN - EXTRA since all these establishments work 24 hours.

Table 7. Epsilon turn.

Variable	Value	Epsilon
Turn	AFTERNOON	-4.6823
Turn	DAY	-1.9121
Turn	NIGHT	1.5137
Turn	EARLY MORNING	6.1941

Table 8. Epsilon Hour.

ONLY HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12
Epsilon	2.64	3.60	3.37	2.17	2.22	1.14	2.16	0.56	-3.85	-0.60	-2.03	-0.92	-1.95

ONLY HOUR (cont.)	13	14	15	16	17	18	19	20	21	22	23
Epsilon	-3.83	-1.74	-2.51	-0.03	-2.29	0.09	-0.30	.55	.48	.87	1.81

4.3 Business Robbery Subset Model

In figure 5 there are some series of bars representing the number of incidences of type (GSO), for this case there were used very specific points due to we obtained the location (coordinates) from the establishments type GSO. As you can see the incidence is higher in those establishments which are located in important ways of communication as opposed to those found within the neighborhoods. For example, at the beltway intersection from Saltillo to Nuevo Laredo and the road to Colombia (see Figure 5 on the right) there are two establishments that have a total of 42 theft from 270 over a period of a year. This is because they offer a 24 hours service and its location has different escape routes coupled with they are settled on the periphery between the municipality and Monterrey city.

In the case of the gas station with a bigger number of theft, 12 robberies from 71, is highly insulated and the way in which the crime is committed is; when a vehicle is loading fuel and gets underway without paying it, this is encouraged by the isolated gas station because it is located in the beltway from Saltillo to Nuevo Laredo and there are only uninhabited lands.

4.4 House Robbery Model

For house robbery there are recorded a total of 419 crimes. In table 9 we observed a series of variables with higher epsilon, which outline house robbery. With these variables, we see a trend of home theft determined by the location and the socio-economic level where the dwelling is located.

Table 9. House robbery.

Variable	Value	Epsilon
Private inhabited houses with fixed telephone line.	7	6.3344
Private dwellings houses with internet.	7	6.3687
Private inhabited homes with electricity, piped water and drainage.	6	6.6232
Private inhabited houses with radio.	7	6.9621
Private inhabited houses with TV.	6	6.9644
Private inhabited houses with 3 bedrooms or more.	7	7.0361
Female population from 12 to 14 years old who do not attend school.	1	7.4953
Population from 18 years old and over with post-basic education.	7	7.5056
Private inhabited houses with a washing machine.	7	8,4
AGEB.	679	8.7419
Zip code.	66085	9.2692
Male population from 18 years old and over with post-basic education.	7	9.8030
Neighborhood.	PRADERAS DE SAN FRANCISCO	10.0007

With the help of Figure 6 see the geographical location of the areas with the highest incidence of r house robbery, mostly in the northeast, also it was located a small signal regarding the possible timetable of house robbery which is from 4 pm to 8 pm, but we have to keep in mind that the time is the moment in which it the crime was reported. Therefore it can be assumed that the reason for this time is that during this schedule is when people return to their houses and becomes aware of the offence, which also allows us to assume that the vast majority of house robbery is performed when there are no people in the housing.

5 Conclusions

In this paper we have modeled three different crime types using a Nave Bayes classifier using data taken from the municipality of General Escobedo in Nueva Leon. One of our chief conclusions is that in order to develop tools for decision support or intervention in crime in Mexico it is first necessary to develop a

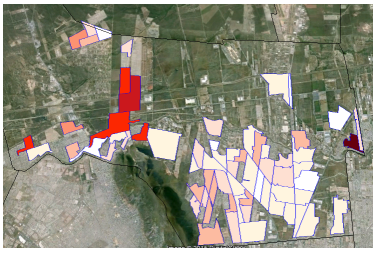

Fig. 3. Domestic violence

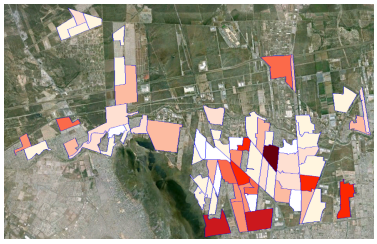

Fig. 4. Business robbery

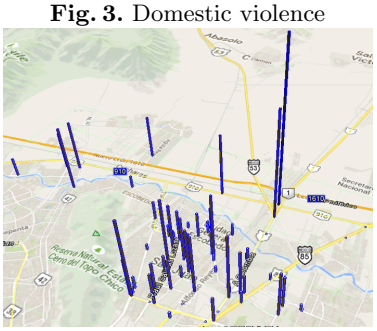

Fig. 5. Gas station and convenience store robberies

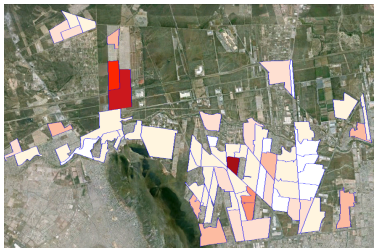

Fig. 6. House robbery

framework in which crime data can be reported and recorded in a faithful and timely fashion. Effectively, if we wish to predict crime we need to first plan to predict crime. There are several key elements associated with this notion: First of all, it is necessary to be able to record at the crime scene relevant characteristics of the crime. This could be simply done with a smart phone app. In particular, the crime should be georeferenced. Next the data should be transferred to a central data base from which any relevant analysis could be carried out.

Another important conclusion is that crime is complex. What we mean by that in the current context is twofold: First, that there exists an extremely large universe of potential predictors that are risk factors for crime and, secondly, that there is a rich hierarchy of crimes themselves each with its own predictive profile. For instance, as we saw in this paper, the profile for business robbery and the sub-group of convenience stores and gas stations share different characteristics but others are quite defining for the sub-group, the time variable is an example, even within the subset of the type GSO we can separate only stores or gas stations only and see how it affects the businesses location differently. How isolated an establishment is can result in an increased number of thefts, as this was the case for convenience stores that are on the periphery of occupied areas and are therefore quite isolated. The same applies to the gas stations with the largest number of robberies.

In spite of the complexity of the problem and the sparse data available we have shown that first of all a data mining approach to predict many different

types of crime is possible and that, indeed, there is a substantial degree of predictability; and secondly, that risk profiles for a crime type can be determined which can then lead to possible directed interventions by the authorities or local communities. In particular, by appending socio-economic and socio-demographic data from the Mexican census we saw that rich profiles associated with where the crimes took place could be generated for the different crimes types. Drill downs can be performed by neighborhood, zip code, AGEB, crime, it can even be done by each establishment type, but it will always be conditioned to the data quality.

We found that domestic violence in particular was associated with a very characteristic profile in terms of the socio-economic and socio-demographic characteristics of the areas where domestic violence events were more common. Among these were low educational achievement, presence of very small children, relatively large immigrant population and cramped living conditions. All these are social stress factors that together paint a coherent picture of the circumstances under which domestic violence is more likely. However, here we see their relative contributions as measured by the Nave Bayes score in a multifactorial setting. Of course, we must emphasise that here we are not necessarily identifying direct causal factors but, rather, statistically significant correlations.

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Integrating Business Process Management and Data Mining for Organizational Decision Making

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Abstract. Organizations are measured in different ways. In specific terms, organizations that are managed through business processes use KPI's as measuring elements. However, it is uncommon for companies to use data yielded by information systems to improve or monitor the indicators suggested by the organization's reality. This paper presents a proposal to guide the improvement of processes on the basis of data mining, which can be performed with amounts of information that organizations consider relevant throughout time. To this end, the literature that supports the foundation and measurement of processes, as well as data mining applied to information management in processes is initially reviewed. Then, data mining is described in the context of information management that improves processes. Finally, the proposal is validated through a case study, which yields applicable results. From this paper, it can be inferred that data mining applied to amounts of data that support processes in certain periods of time can improve their management, as well as the efficient achievement of organizational goals.

Keywords: Key performance indicator, business process management, data mining, analytic process

1 Introduction

Strategic decision making in real time is very beneficial to organizations, since it can offer solid solutions and suggest projects according to business policies. In order to achieve this, it is necessary to have the support of results presented in management reports, which show the state of each value chain process in the organization. This state indicates the process management with regard to the goals that each process must achieve. The goals depend on a set of activities that have to be monitored and measured

periodically for the purpose of evaluating process performance. Monitoring makes it possible to observe the state of quantitative data as related to each process task.

The data are retrieved from analytical databases, whose purpose is to support decisions, and are separate from operational databases in the organization. Analytical databases support information processing by providing a solid platform of consolidated historical data for analysis [1]. Quantitative data are retrieved as KPI's (Key Performance Indicators), which assess the success and performance of a solution or activity. KPI's are commonly used for assessing a company's or a product's success [2].

KPI's are measured through performance measurement systems, which are a set of measures that quantify the effectiveness and efficiency of a company's activities and processes [3]. They have become an important and critical part to measure the success of business processes, and provide information about management. They are mainly based on KPI's, and are important in order to learn about processes and increase the understanding of performance and results. This helps to decrease uncertainty and make appropriate decisions. KPI's accumulate numerical parameters in order to measure process efficiency generated by data mining [4].

Data mining emerges as a support for this process in the analysis of data warehouses. Their use is based on data warehouses created under business rules, or data analytics that provides minimum elements to determine current and future organizational patterns and behaviors [5]. It is the acquisition of knowledge through databases. It is also known as pattern analysis in databases, or retrieving of data by a data miner. It may be classified in two categories: descriptive or predictive. Tasks related to descriptive mining are characterized by the general properties of data in a database, while predictive tasks make inferences based on current data in order to make predictions [6]. It is a technique for exploring data flow related to the processes that make up a specific system. It shows the state of business processes in real time [7]. It is a technology related to business process management. Its goal is to discover, analyze, control and improve processes by retrieving knowledge from data recorded in the databases (called entry events) of an organization's information systems. In order to gain the necessary knowledge from these entries, each event must contain important data, such as the name of the activity, a name of the case, user identification, time, etc. It is focused on the exploration and development of the process, and provides information about how people and procedures really work [8]. The main contribution of process mining is providing the analyst with a better understanding of the process, and the models that best describe reality. In the process, mining retrieves information about the processes of entry events, which list activities that have an origin or beginning. Events have a time label, have an order, and are associated to data generated by a result, for example, making decisions related with business process management BPM [9].

BPM emerges as an efficient tool, whose main goal is supporting the design, administration, setup, disclosure and analysis of business processes. The final goal of BPM is the promotion of process management in order to meet a company's goals [10]. It is the identification, understanding and management of business processes related to the organization's employees and systems. The BPM cycle is made up of diagnoses, process designs, system setups and disclosure of processes [11]. It is viewed as an integral management focus that promotes business efficiency through innovation,

flexibility and integration into technology [12]. BPM is a key factor to increase efficiency in business operational processes. In order to improve processes, the appropriate information is needed to identify, analyze and re-design them. Management uses diverse ways to measure performance in order to get the correct information, which is essential to reduce uncertainty and make appropriate solutions [4].

There are models to make data mining match process management, and generate greater knowledge for an organization. Business process management adjusted to data mining can be momentous for an organization because it makes decision making easier by providing a holistic view of processes, which helps the company improve its productivity, services, cost savings, etc. It also propels the company to a strategic and competitive positioning [13]. Many business process management systems still lack sophisticated means to analyze recorded data [14]. This is why the use of data mining in business processes is more common every day but has yet to reach the appropriate level of the potential benefits it may yield [15].

Gaining knowledge with data analytics provided by the various data mining methods or models will guide an organization's productivity with regard to goals, strategies, internal and external factors. This paper presents a proposal to guide the improvement of processes on the basis of data mining, which can be done with amounts of information that organizations consider relevant throughout time.

To this end, the literature that supports the foundation and measurement of processes, as well as data mining applied to information management in processes is initially reviewed. Then, data mining is described in the context of information management that improves processes. Finally, the proposal is validated through a case study, which yields applicable results.

The first section shows a conceptual background of the subject under study. The second section shows the conceptual material that characterized the methodologies and techniques used for establishing the model's components. The third section presents the results of the model proposed, and a functional description of its components. The fourth section expounds the validation of the model through a case study.

2 Research Methodology

To develop the proposal was adapted the methodology of design science research in information systems [16]. In the first cycle of Relevance, the problem is identified around the effectiveness of the business process. In the Rigor cycle the state of the art was analyzed in order to have more clarity about the problem. Finally, the design cycle the proposal was built and assessed.

3 Background

The 90's brought a growing problem of data excess in the world of science, business and government. This generated an urgent need for methodologies, techniques and tools to acquire knowledge [17].

An organization's capacity to analyze data is an important factor for success in business. The main industries in the world are supported by information and

communication technologies in order to process great amounts of data electronically. Data mining is an integral part in these industries. Tasks such as advertising or recommending products, or discovering a fraud have become fields of data mining application, and show serious business benefits. In order to model a data mining process, the scope of the contribution of data mining, and which portion of the data will be part of the process must be defined. The data must be adjusted to specific needs, and steps indicated in methodologies to acquire knowledge, such as the CRISP-DM, must be followed [18].

Marcano and Talavera clearly explain each of the techniques that help solve an organization's particular problems based on the data it has. They perform an analysis of data mining applicability in business for a natural evolution of information technology. They state that data mining, used appropriately, becomes a strategic tool that increases competitiveness levels in the ever-changing world of business [5].

Aalst and Van Der show the applicability of mining in business processes with algorithms and tools. They show the feasibility of a practical application of business process mining in a model for recording events using techniques incorporated into the PROM framework. Records that keep track of processes through analytical databases can be evaluated through data mining models that provide explanations for the behavior observed in the results retrieved from the evaluations. It is important to point out that neither the evaluation of indicators, nor their optimization is included in the process [13].

Liu and Hsu propose an algorithm incorporation method based on transaction databases for real time data mining. The paper explains the benefits of applying data mining to transaction systems in order to avoid creating a historical data repository, and having to execute tasks that feed the data warehouse from the transaction systems. These tasks are very time- and resource-consuming. With this, the organization's data can be accessed in real time without a delay of information of at least 12 hours, as is the case of traditional business intelligence systems. The benefits are presented with very little theoretical support [19].

Rupnik and Jakli present data mining as a support for decision making on a tactical level, as well as in operational business processes, namely project management. In addition, it presents JDM API (Java Application Data Mining Interface), a tool that offers the possibility to apply data mining models in transaction systems. It suggests the CRISP-DM methodology, which incorporates four tasks into the deployment phase: implementation planning, monitoring and observance of the plan, production of a final report, and review of the project [15].

Ngai et al. present important aspects to analyze and study in CRM systems when applying data mining. These aspects are: identifying, attracting, keeping and developing customers. They define which data mining models should be applied when the purpose is acquiring knowledge from customer data (association, classification, grouping, forecast, regression, discovery sequence and visualization), and the algorithms implemented by these mining methods (association rules, decision trees, genetic algorithm, neural networks, K nearest neighbors, and linear/logistic regression). The paper shows clarity and validity in the study carried out by supporting with references the models and algorithms applied to data mining processes. On the other

hand, the paper shows that with complete data about customers, data mining can provide business intelligence to generate new opportunities. It also supports assumptions or previsions about the effects of a CRM strategy [20].

Wegener and S. Ruping state that integrating data mining into business processes is increasingly becoming an integral part of doing business. The paper develops and suggests the CRISP-DM methodology for implementing data mining methods in organizations. The proposal is focused rather on business processes. It does not show the use of data mining in the processes of events generated by analytical databases [18].

Bal et al. study the competitive edge offered by data mining. They also describe in which areas data mining has been used, and stress that in most cases, implementations are customer-oriented. Their paper supports a series of competitive edges that mining offers organizations. On the other hand, the paper explains a series of strategies and algorithms to implement data mining in an organization [17].

Vukšić et al. show the importance of linking BPM to Business Intelligence Systems (BIS) for better business performance. It is clear how BPM and BI are aligned, which creates an integrated data structure that could solve data problems [14].

It may be said that an activity is an event that is executed. The event is interpreted as an action that takes place at some point. Activities are executed automatically by systems, or manually by people.

4 Development of the Proposal

The integration model is based on three components. One of them is for managing processes in any organization.

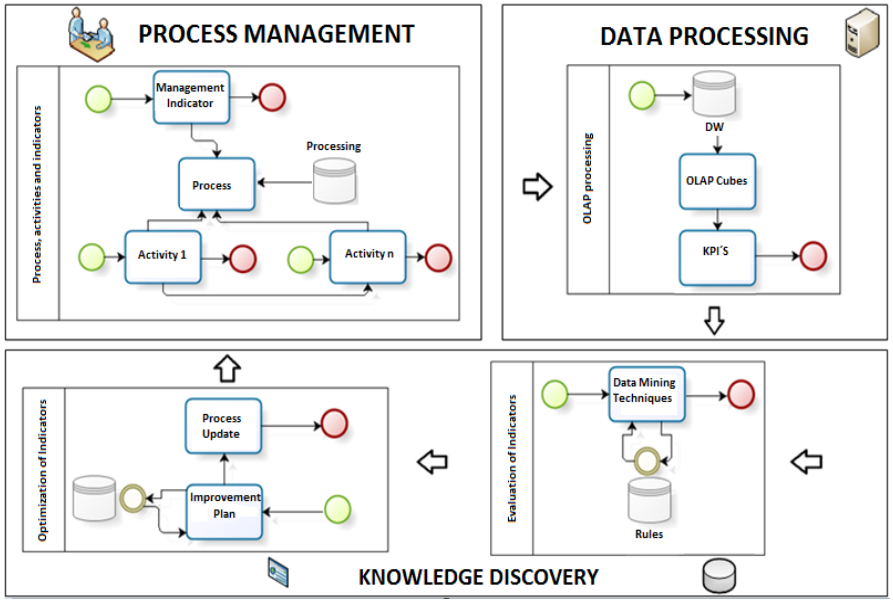

Fig. 1. Analytical Model

That is, the organization data, processes, sub-processes, activities and variables are set up correspondingly.

Another module for data processing. Process indicators are obtained at this stage from a data warehouse through an OLAP cube. Then, there is an optimization module of the KPI's obtained through data mining. Concretely, the association technique is used, see Fig. 1.

4.1 Process Management Component

First, the characteristics of the process being evaluated are specified. The name of the organization that the process belongs to is indicated. Likewise, the name, type, goal, person in charge, scope and limit of the process are indicated. With this information, the process management component begins. At this stage, the activities and indicators of process management are specified.

The name and specification of all the variables related to the activities of sub-processes that make up the process under study are made known.

Each variable has a value that will be used for monitoring and evaluating. The characteristics of the criteria available are shown in Table 1.

Table 1. Criteria for Assessing Variables

CRITERION	MEANING	ID	%
Enough	The data related to the variable indicate that it has the appropriate amount to execute an activity.	E	100
Not Enough	The data related to the variable indicate that it does not have the appropriate amount to execute an activity.	NE	50
Qualified	The data related to the variable indicate that it has the appropriate quality to execute an activity.	Q	50
Not Qualified	The data related to the variable indicate that it does not have the appropriate quality to execute an activity.	NQ	50
Available	The data related to the variable indicate that it may be used unrestrictedly to execute an activity.	A	100
Unavailable	The data related to the variable indicate that it may not be used unrestrictedly to execute an activity.	UA	50
Updated	The data related to the variable indicate that it is current enough to execute an activity.	U	100
Not Updated	The data related to the variable indicate that it is not current enough to execute an activity.	NU	50
Justified	The data related to a variable justifies an activity.	J	100
Unjustified	The data related to a variable does not justify an activity.	UJ	50

For each process, the sub-processes and variables are specified. In this case, the variables are related to each criterion established in this form: Process Name, Subprocess Name, Activity Specification, Variable Specification, and Criterion (%).

For each process management indicator, a rule is provided. This rule is made up of a base value and a percentage. These parameters are previously established by organization experts. The rules are expounded in Table 2.

Table 2. Rules for Indicators

RULE	
Base	%
Ideal	>=90
Alarming	>=70 <=89
Critical	>=0 <=69

Then, the data to set up the indicators and the characteristics for each activity related to each sub-process are established. In the first two columns of the format the activity name and specific indicator are given. Then, the formula for (total of items affected/total of population items) is inserted. Similarly, the frequency is established. It may be measured by minutes, hours, days, weeks, months or years. See how these items are specified: Activity Description, Indicator, Formula, Frequency, and Base Value.

4.2 Data processing component

Using analytical processing through an OLAP cube, key process indicators are obtained. The processing is carried out in the data warehouse using the cube's dimensions and de facto measures. The cube shows in a multi-dimensional way the relation between the dimensional attributes and the measures, which, in this case, are the expected KPI's. See Table 3.

Table 3. Evaluation of Specific Sub-Process Variables

PROCESS	NAME: Information Systems Management	
SUB-PROCESSES	NAME: Equipment Maintenance	
VARIABLES	EVALUATION CRITERION	**%**
Human Resource	E,Q	100
Technology	A,E,U	100
Quality	Q	100
Time	U	100

4.3 Component for Acquiring Knowledge

The integration of the data mining association technique into a set of rules previously established in a database indicates KPI states. KPI's may be in an ideal, alarming or critical state. Besides, KPI’s are evaluated in relation to the dimensions and variables that simultaneously monitor the state of processes. The process records are shown by the date of all the data related to the analytical model dimensions and the KPI measures. The relation of measures is established on the basis of items required and items taken

care of. The model presents a measuring percentage, which makes establishing the state of each process record easier.

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The relation to the process monitoring variables and KPI states allow the organization to know in detail not only KPI states, but also the process variables influencing that result, and the concrete dimensions where the event is taking place. With the integral evaluation about the dimensions, variables and measures of the model proposed, an improvement plan is then suggested, which the model automatically yields according to the variables highlighted on the basis of their state. See Process Name, Sub-Process Name, Activity Specification, and Improvement Plan.

5 Case of Study

Organization Data

Organization Name	Fundación Clínica del Norte (FCN)
Management Process	Information Systems Management
Process Type	Support
Process Goal	Guaranteeing the proper management of resources for the generation, storage, safekeeping and purging of information in order to provide structure and consistency of clinical and administrative information, so that relevant decisions are made, and the requirements of institutional customers and regulatory bodies are met.
Person in Charge	Information Systems Leader
Scope	It backs up processes related to strategy, mission, and support.
Limit	It begins with the definition of policies and information access restrictions, and ends with feedback to information systems management staff at FCN.

5.1 Process Management Component

Variable Characteristics

Human Resource:	Staff constantly trained and qualified to perform functions
Technology:	Computers and peripherals, Server, Website, Intranet, e-mail, pop-up messages, internal communication system, systems of communication with users, physical information storage systems.
Quality:	Mandatory System of Guaranteed Quality Health Care.
Time:	Per trimester or semester.

Knowledge of sub-processes and variables

There is a database with the sub-processes and characteristics of the variables as regards the evaluation criteria.

5.2 Data Processing

Original data from the data warehouse

Table 4. Transaction Processing of OLTP Data (Monitoring of Sub-Processes in Relation to the State of Variables)

DATE	PROCESS	HR	TC	CA	T
29/08/2014	Equipment Maintenance	E,Q	A,U	NQ	E
28/11/2014	Equipment Maintenance	E,Q	A,U	NQ	E
27/02/2015	Equipment Maintenance	E,Q	A,E,U	Q	NE
29/025/2015	Equipment Maintenance	E,Q	A,U	NQ	NE
29/08/2014	Malfunctions reported: 28, Solutions to malfunctions in telecommunications: 28	E,Q	A,E,U	Q	E
28/11/2014	Malfunctions reported: 17, Solutions to malfunctions in telecommunications: 17	E,Q	A,E,U	Q	E
27/02/2015	Malfunctions reported: 24, Solutions to malfunctions in telecommunications: 21	E,Q	A,E,U	Q	NE
29/025/2015	Malfunctions reported: 12, Solutions to malfunctions in telecommunications: 12	E,Q	D,E,U	Q	E

Table 5. KPI State According to General Relation of Variables

DATE	PROCESS	KPI	%	STATE
29/08/2014	Equipment Maintenance	180	75	Warning
28/11/2014	Equipment Maintenance	200	83	Warning

DATE	PROCESS	KPI	%	STATE
27/02/2015	Equipment Maintenance	222	92	Ideal
29/25/2015	Equipment Maintenance	170	71	Warning
29/08/2014	Malfunctions Reported: 28, Solutions to Malfunctions in Telecommunications: 28	28	100	Ideal
28/11/2014	Malfunctions Reported: 17, Solutions to Malfunctions in Telecommunications: 17	17	100	Ideal
27/02/2015	Malfunctions Reported: 24, Solutions to Malfunctions in Telecommunications: 21	21	88	Warning
29/025/2015	Malfunctions Reported: 12, Solutions to Malfunctions in Telecommunications: 12	12	100	Ideal

Table 6. Dimensions

Section	ST	Systems (S), Portfolio(P), Customer Service (CS), File (F), Medical Units (MU),
Time	TM	T1(29/08/2014), T2(28/11/2014)
Requierement	RQ	R1(Perform equipment maintenance), R2(Malfunction report)
Location	LC	Administration(A), Operational (O),
Task	TK	TK1(Equipment Maintenance), TK2(Solution to Malfunctions in Telecommunications)

Table 7. Analytical Processing of OLAP Data (Details of Some KPI's in relation to the Dimensions of the Organization)

Facts		Information Systems Management DIMENSIONS						
ST	TM	RQ	Total Required Items	LC	TK	Items Taken Care of Value	**%**	Total Accumulated (KPI)
S	T1	R1	30	A	TK1	20	67	
P	T1	R1	10	O	TK1	6	60	
CS	T1	R1	30	O	TK1	20	67	180
F	T1	R1	10	A	TK1	4	40	
MU	T1	R1	160	O	TK1	130	81	
S	T1	R2	1	O	TK2	1	100	
P	T1	R2	1	A	TK2	1	100	
CS	T1	R2	7	O	TK2	7	100	17
F	T1	R2	1	O	TK2	1	100	
MU	T1	R2	10	A	TK2	7	100	
S	T2	R1	30	O	TK1	30	100	

Facts		Information Systems Management DIMENSIONS						
ST	TM	RQ	Total Required Items	LC	TK	Items Taken Care of Value	%	Total Accumulated (KPI)
P	T2	R1	10	O	TK1	10	100	200
CS	T2	R1	30	O	TK1	30	100	
F	T2	R1	10	O	TK1	10	100	
MU	T2	R1	160	A	TK1	120	75	
S	T2	R2	1	A	TK2	1	100	28
P	T2	R2	1	O	TK2	1	100	
CS	T2	R2	7	O	TK2	7	100	
F	T2	R2	4	O	TK2	4	100	
MU	T2	R2	15	O	TK2	15	100	

Table 8. Association of KPI's and Variables of the Sub-Process Monitoring Database

DATE	Process	HR	TC	CA	T	KPI
29/08/2014	Equipment Maintenance	E,Q	A,U	NQ	E	180
28/11/2014	Equipment Maintenance	E,Q	A,U	NQ	E	200
27/02/2015	Equipment Maintenance	E,Q	A,E,U	Q	NE	222
29/025/2015	Equipment Maintenance	E,Q	A,U	NQ	NE	170
29/08/2014	Malfunctions Reported: 28, Solutions to Malfunctions in Telecommunications: 28	E,Q	A,E,U	Q	E	28
28/11/2014	Malfunctions Reported: 17, Solutions to Malfunctions in Telecommunications: 17	E,Q	A,E,U	Q	E	17
27/02/2015	Malfunctions Reported: 24, Solutions to Malfunctions in Telecommunications: 21	E,Q	A,E,U	Q	NE	21
29/025/2015	Malfunctions Reported: 12, Solutions to Malfunctions in Telecommunications: 12	E,Q	A,E,U	Q	E	12
29/08/2014	Quality Indicators	NE,Q	A,E	NQ	NE	6
28/11/2014	Quality Indicators	E,Q	A,U	NQ	NE	7
27/02/2015	Quality Indicators	E,Q	A,E,U	Q	E	9
29/025/2015	Quality Indicators	E,Q	A,E,U	Q	E	9

Association Rules
Maximum support (MS): 50%
Maximum confidence (MC): 90%

Table 9. Obtained Associations

PROCESS	PREMISE (Variables)	CONCLUSION (KPI)	MC 90%	MS %
Equipment Maintenance	E,Q, A,U, NQ, U →	180	100	50
	E, A,U, NQ, U →	200	100	50
Telecommunications Solution	E,Q, A,E,U, Q, U →	28	100	75
	E,Q, A,E,U, Q, U →	17	100	75
	E,Q, A,E,U, Q, U →	12	100	75

Table 10. KPI Evaluation

S	29/08/2014	Perform equipment maintenance	30	A	Equipment Maintenance	20	67
P	29/08/2014	Perform equipment maintenance	10	O	Equipment Maintenance	6	60
CS	29/08/2014	Perform equipment maintenance	30	O	Equipment Maintenance	20	67
F	29/08/2014	Perform equipment maintenance	10	A	Equipment Maintenance	4	40
MU	29/08/2014	Perform equipment maintenance	160	O	Equipment Maintenance	130	81

Table 11. Relation of KPI's and Their **Dimensions** to the Process Variables

Process	VAR I	%	VAR II	%	VAR III	%	VAR IV	%	KPI
	HR		TC		CA		T		
	E,Q	100	A,U	50	NQ,U	50	E	100	180
Equipment Maintenance	E,Q	100	A,U	50	NQ,U	50	E	100	200
Telecommunications Solution	E,Q	100	A,E,U	100	Q	100	E	100	28
	E,Q	100	A,E,U	100	Q	100	E	100	17
	E,Q	100	A,E,U	100	Q	100	E	100	12

For the KPI's worth 180 and 200, related to equipment maintenance.

The human resource is enough and qualified, the technology for maintenance is available and updated, the time the staff has to perform the task is enough, but the service quality is not good, since the human resource is not qualified to perform it.

For the KPI's worth 28, 17 and 12, related to assistance in telecommunication malfunctions:

The human resource is enough and qualified, the technology for maintenance is available and updated, and the time the staff has to perform the task is enough, but the service quality is not good. This indicates that the number of requirements has been taken care of successfully 100%.

Table 12. Improvement Plan

PROCESS NAME: Information Systems Management **SUB-PROCESS NAME:** Equipment Maintenance	
VARIABLE	**IMPROVEMENT PLAN**
CA: Quality	1. Train staff with techniques, methods and technology tools 2. Test updated knowledge frequently 3. Keep track of activities carried out by employees in charge of maintenance

6 Conclusions

The automatic way in which results are obtained at each stage of the model is used as input to execute the following stage, which accelerates the managing and recording process to monitor, evaluate and improve process activities. Therefore, it is possible to present indicators that better suit organizational goals.

The results of the case study show that integrating process management, analytical processing and data mining is a good strategy for organizations.

By applying this strategy, business processes, sub-processes and activities are replenished. The organization model shows how to improve KPI's through the improvement plan.

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Computer Adaptive Testing and Cloud Computing

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Abstract. Computer Adaptive Testing (CAT) is an example of a Computer Based Test (CBT) and is one of the main trending topics in the area of knowledge testing and, more recently, in e–learning or in Intelligent Tutoring Systems scenarios. The Item Response Theory (IRT) defines the theoretical basis of a CAT implementation, which assumes the existence of a repository of properly calibrated items that is used during the testing process of a particular examinee. The calibration and adaptation are based on an Item Characteristic Curve (ICC) related to an specific model, being Rasch's models the most widely used. CAT systems require high computational cost to implement the calibration and evaluation processes and the amount of concurrent users at a time could be large enough. Thus, the platform must support high concurrency and availability to perform a desired level of functionality. Technological tendencies in computing offer each time better platforms to develop and manage big collections of data for its processing and relevant information extraction. This paper presents a perspective of using new technologies in CAT as an alternative of implementation. Particularly, the use of a cloud computing platform as current alternative for online CAT systems using the capabilities of multicore processing and big amount of RAM that offers the cloud, to resolve the proper mathematical equations related to psychometric models and the operations described in their algorithms in a real evaluation scheme.

Keywords: Computer adaptive testing, item response theory, cloud computing, big data, multicore processing

1 Introduction

Computer Adaptive Testing (CAT) is an example of an informatic system oriented to knowledge, skills and behavior explorations, among others questions,

related to a person in an specific working area. Recently, this kind of systems has become very well known in online e–learning scenarios, as a result of the several benefits that these platforms provide in comparison with those given by Classical Testing Systems (CTS) [8]. CAT systems assume the existence of a pool of perfectly calibrated items, which are used during the testing of an specific person. The calibration process allows to determine the value of the parameters associated to certain psychometric features of the examinees and the items.

The essential idea in CAT systems consists in presenting to a given examinee one item after another, depending on the responses given to previous items along the testing process. If the response is incorrect, then the next item has a lower difficulty than the current one; on the other hand, if the response is correct, then the next item has a higher difficulty. This characteristic makes the entire process adaptable, which means that the item presentation adapts to the examinees' knowledge, in opposition to what classical testing does.

The implementation of this kind of environment is not trivial, since mathematical models and sophisticated algorithms are used for items' calibration and the adapting testing process itself. Particularly, the calibration process requires to find the solutions of a system of non–linear equations, while the adaptive testing computation needs at least to search for the solution of one non–linear function in *quasi* real time. In addition to this, the users can access the system in a concurrent way, which obviously impacts the system's and the hosting platform's performances.

Currently, there do exist informatics environments where a CAT system can be hosted with the aforementioned features, and they provide services over the Internet. In this sense, technological advances have changed the paradigm of implementing the solution in–house ('on–premises') to implement the solution on the Cloud ('off–premises').

Cloud computing is every day a more often used concept in computer systems. The Cloud–based service providers offer each time more and better management options, as well as benefits related to the accessible cost which depends of the user needs. So that nowadays it is possible that every individual has her/his own personal Cloud, which makes a proper environment for the hosting, creation and maintenance of applications for a wide variety of topics such as, for example, the automatized testing systems [8]. Cloud computing is an information service that offers software, platforms and infrastructure to an organization. Cloud computing technology incorporates different types of private, community, public and hybrid Clouds [8].

In the technology industry, Cloud computing is exponentially changing the implementation of information technology services. This is due to the fact that Cloud computing is a new information technology platform, that will positively change the nature of information management systems in the organizations.

The Cloud, which is another name for Cloud computing, is sometimes referred to as utility computing, since it uses interconnects networked devices to share information resources [12]. The online software and virtual maintenance of Internet infrastructure are among the benefits of Cloud computing for organizations,

and they can be synchronized from any geographic location [1].

Cloud computing uses the power of large computing devices that work on a common software format making parallel networks possible [10]. The large processing power of Cloud computing makes multiple systems on the Internet work by the interaction with virtual physical resources that conform the service architecture. In [1] Cloud computing is defined as Internet–based applications that can provide different information systems services including networking, filing and storage.

The innovation of using Cloud computing as a platform for the implementation of an information system inside an organization is due to the simplicity of configuring and programming the features that the providers offer [12], since by combining different hardware and software modalities in a virtual environment can increase the efficiency [4]. The authors in reference [1] highlight that cloud computing is the on–demand and expandable technology service offered over the Internet from data centers.

The next sections in this paper are organized in the following manner. In the second section the problem of the implementation of a CAT system in on–premises enviroments is explained. The third section deals with the solution proposal that involves the use of Cloud computing. The fourth section gives an introduction to CAT systems and its relationship with Cloud computing is explained. The fifth section shows and explains some screen test of the implementation of a prototype of CAT in Microsoft Azure Cloud platform. Finally, the sixth section provides some conclusions.

2 The Problem

Computer Adaptive Testing (CAT) is a technique that assumes the construction of items related to a previously given knowledge topic, which are then used to evaluate the abilities of a person in the aforementioned topic. This technique allows to finish the testing process in several ways and one of them consists in verifying that the most recent abilitie's values do not change within a given precision.

CAT systems based on IRT require a great computing capacity, since they are platforms that need high processing, availability and concurrence capacity. These needs arise from the fact that a proper CAT system requires the calibration of huge amount of items, which are related to a psychometric model containing a finite number of parameters, whose values depend on the corresponding item. In real scenarios, there does exist the possibility of handling at least one hundred items in a calibration process at a given instant of time, which means that one hundred parameters are required in the simplest case of the 1PL model or Rasch's psychometric model. In addition to this, and as a consequence of mobile devices development, CAT system must allow that the users access the testing service from any smart device, like cellphones or tablets, producing in this way the possibility of a huge demand on the part of the users and, as a consequence, a high concurrence of simultaneous access to the platform.

Even worse, a CAT system considers three main actors or user types; namely, the administrators, the evaluators and the examinees. Furthermore, since the system can offer the service to different educational institutions, which can consider very diverse topics of any knowledge area, several students and evaluators can access the system over the Internet demanding a very robust hardware and software infrastructure for the correct function of the platform, and as a support for the future growing on the demand of the users.

Therefore, CAT systems pose the problem of satisfying the need of great power of processing while granting a high availability, a flexible growing storage, an acceptable bandwidth size to support the high concurrence and a management easiness in the whole resources for the good platform's performance. These needs are not easily obtained under the standard use of personal servers landed on–premises and some services offered by the Internet providers.

3 Use of the Cloud Computing as an Alternative Solution

As it has been written above, the implementation of a CAT system nowadays presents several challenges, mainly those related to the requirements of hardware and software introduced at the end of the previous section. For this to be successfully solved, this paper presents an alternative of solution through the use of a Cloud Computing infrastructure currently offered by Microsoft, which is called Azure. The reason of using this particular cloud computing provider is centered mainly on the author's knowledge about Microsoft's technologies; however, future work implies to make a deeper analysis about the features that other providers offer, in order to determine which one could fit the best for a CAT system implementation.

4 Computer Adaptive Testing Systems and their Relationship with Cloud Computing

CAT systems are platforms for testing some given knowledge areas commonly used in e–learning or Intelligent Tutoring systems (ITR) [5]. A CAT system has a very solid mathematical support tipically defined by the Item Response Theory (IRT), which contains the basis for the implementation of a calibration mechanism for the items that will conform the tests [9]. In other words, the system must initially contain a repository of calibrated items, which are fitted through a calibration algorithm previously selected. The algorithms for calibration require the specification of a psychometric model, which is defined in terms of parameters. In consequence, the calibration process searches for the proper values of the parameters related to every item, based on the selected psychometric model. The selection of the psychometric model depends on the scenario where the test is applied, and the system must give reliable information about the abilities of the examinee, the dificulty of the items and the test in general.

When the values for the parameters are obtained, then these values can be useful in e–learning environments, Intelligent Tutoring Systems and CAT systems, which are examples of scenarios where a reliable and inmediate diagnostic is required to give support to the teaching–learning process.[7].

However, the implementation of a CAT system is not trivial since, as it has been aforementioned in this work, the system must completely cover the specific requirements to grant the correct operation of a platform of this kind. Nowadays, the digital revolution has transformed even the manner of teaching in the classroom and the testing of students, in such a way that a present–day testing mechanism is needed to bring both, the institutions and the students, to carry out these testing process by means of their digital devices. Internet is the more immediate alternative by making use of Cloud Computing service providers. In this way, a CAT system can be configured inside a platform that uses virtual physical resources, which interact in the infrastructure already hosted in a data center having the necessary support to host big amounts of informations systems, giving facilities for the access, configuration and management on the part of the users through a big bandwidth.

4.1 The Cloud and the Virtual Machines

Nowadays the cloud providers offer, as part of their services, the possibility of creating virtual machines with several combinations of resources that include memory sizes, hard disk storage capacity and the number of processor cores to be used. These benefits are important points to consider, when the creation of an online platform allowing the test of abilities in some knowledge topic is desired.

The considerations must include the high disponibility of the platform, which is granted by the right configuration of the virtual machine, the installation of an operating system in server version, the adequate assignment of the storage capacity, given that the system will have an extense number of items inside a repository and these items might contain hypermedia; in other words the items can include, in addition to plain text, embedded images, audio files, video or PDF documents. Then the necessary storage for all those items demands to the platform a big space in virtual hard disk.

On the other hand, it should carry out the right installation and configuration of the database manager, since it must create a database of non–calibrated items, a database of calibrated items, a database of testing results and a database with the information of the users and their access keys to the system. This represents an exponential growing in the databases due to the amount of users per educational institution having access to the platform.

Furthermore, there is the need of processing the CAT algorithms of the tests currently taken, applying the selected psychometric model and calculating the best item item choice along the test process. This leads to think in the concept of a real time system such as in the concurrency of the users, since in a same instant of time, the system could be testing a big amount of persons belonging to different educational institutions located in several geographic points [2], in different topics or knowledge areas, accessing from several types of digital and

mobile devices. By being a platform online that is processing the answers for all the items in an intelligent manner, it requires a huge processing power, which tipically is expressed by the number of cores of the processor that can be assigned in the virtual machine.

If all these things will be implemented in only one physical server, like used to be so, then it will lead to the fast saturation of the capabilities and, in consequence, to the impossibility to bring a testing service of high availability with no possible scaling to cover the needs. Moreover, the considerations of publishing a system of this kind over the Internet must include the security topic, since the security of the already stored information should be granted [11][13], and the privacy of the registered users data should be kept, as well. Some of the concerns and effects occurring when the Cloud Computing is used as a host of a system with educational orientation can be find in some references [1].

4.2 Microsoft Azure as a Cloud Computing Platform

Azure is the cloud portal of Microsoft and offers very good options of services with a relative low cost in accordance to the needs that somebody may have. In other words, Azure allows to the users the creation of virtual machines, web sites, mobile services, among others, in a wide gamma of options that the management portal has. If advanced services to create Internet based systems are required, then Azure is one of the main platforms for Cloud Computing that can be used nowadays.

The present work precisely suggests how well the implementation of a prototype of adaptive testing system, in the cloud of Azure, allows the use of features of scalability that guarantee the correct operation of the platform, the high concurrency and enough space for data storage, which give an advice that this kind of implementations are an excellent alternative to get the computing capabilities that a CAT system really needs.

4.3 Architecture of CAT System in the Cloud

Some research results show an architecture of adaptive testing mounted over a web access platform [6]. However, the work uses the traditional structure consisting of a server in–house which, through a public IP over TCP/IP protocol, makes the system accessible from any device. The present work proposes a similar architecture, but inside the space offered by one Cloud service provider, which allows inmediate scalability, growing flexibility in the virtual physical resources on–demand, in addition to better bandwidths that can satisfy the high traffic and the user's concurrency.

The Fig. 1 shows the architecture that has been designed for the implementation of the Ariya Framework in the Cloud Computing service of Microsoft Azure.

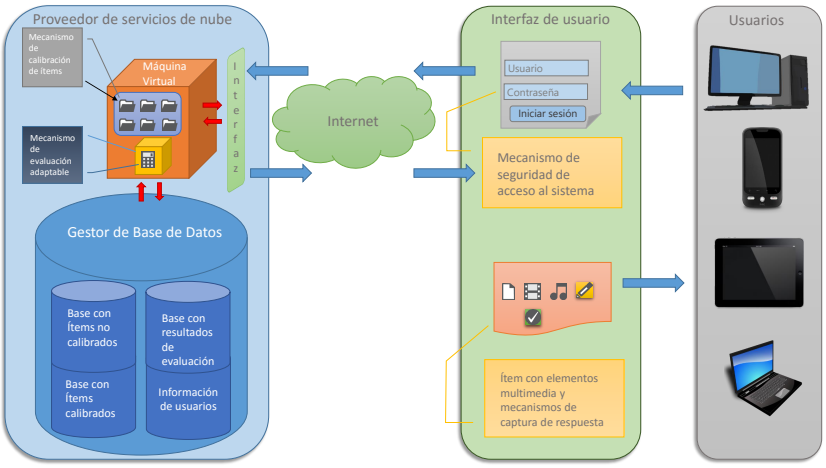

Fig. 1. Architecture diagram of the Framework Ariya in Azure

5 Implementation of the Framework Ariya in the Azure's Cloud

The implementation of the Framework Ariya in the cloud of Azure uses a Bizspark program consumer account to access the Azure management portal. Once inside the portal, the configuration of a virtual machine type A4 with 8 processor cores and 14GB of RAM memory is carried out . There is a fee for using the features of the cloud, but thinking in terms of the capabilities offered, like high processing and big RAM amount, the cost is worth to be payed. On the other hand, if one thinks for a while that the service will be given to different educational institutions to make their corresponding tests over this platform, it makes sense to think that the cost of the initial operation will be covered by the payed cuotes of rent for the Framework Ariya, as well.

With no doubt, the making of a business model to offer the services of the platform Ariya is necessary; however, the discussion about this component is left as a future work since the correct configuration of the prototype, and the making of the corresponding tests to garantee the right operation, should be made beforehand. The Fig. 2 shows the screencapture where the registration of a new cloud service for the Framework Ariya, inside the portal of Azure, appears.

5.1 Configuration of the Virtual Environment in Azure for the Framework Ariya

The Fig. 3 shows the screen capture of the virtual machine configured with the features previously described, relative to the Azure's management portal. The Fig. 4 shows the register of a virtual hard disk asociated to the platform Ariya with a Linux operating system. A version of Ubuntu server as the host for the

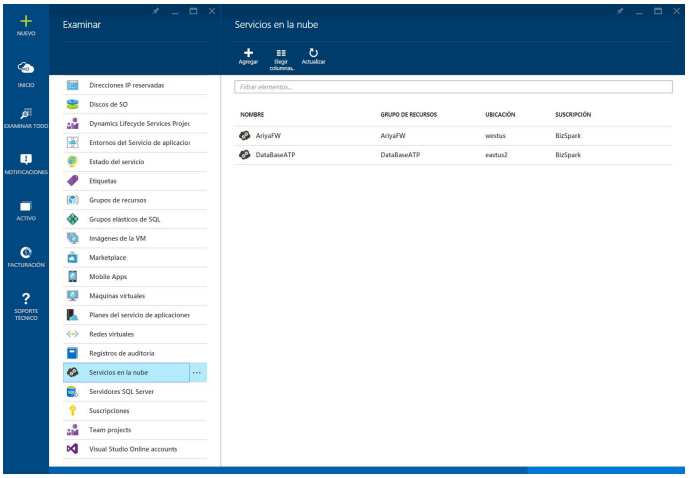

Fig. 2. Ariya cloud service in the portal of Azure

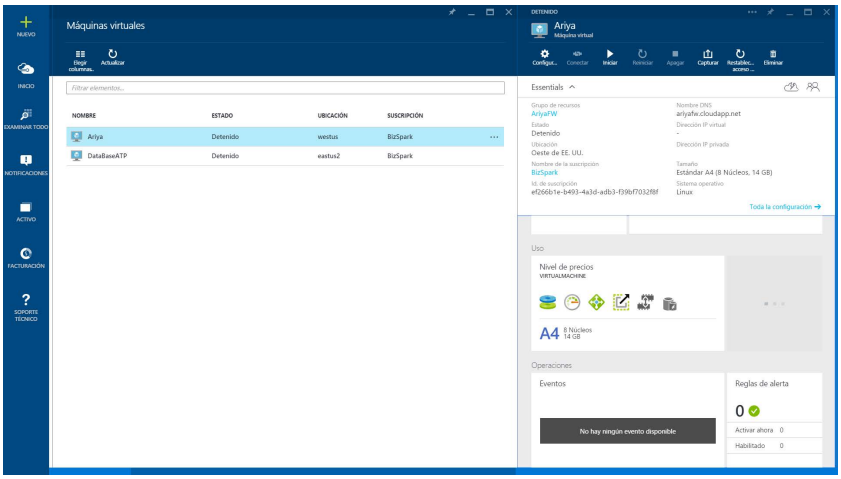

Fig. 3. Configuration of the virtual machine for the Framework Ariya in Azure

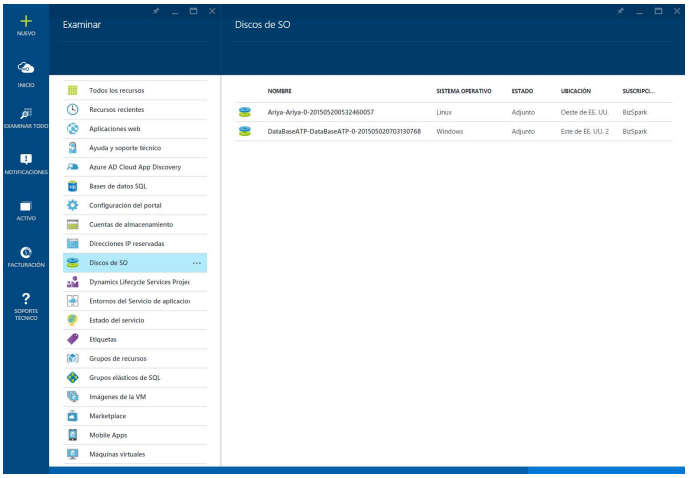

Fig. 4. Disk of the operating system assigned to Ariya's virtual machine

Fig. 5. Start user interface of the Framework Ariya

CAT system has been configured in this implementation.

The start screen of the user interface for the Ariya system, ready to be accessed by a user through her/his user name and password, can be appreciated in the Fig. 5.

6 Conclusions

This work presents a proposal of implementation for a CAT system using the benefits that the Cloud Computing service providers offer nowadays. In particular, the use of the Microsoft Azure cloud service case is shown. The implementation of the Framework Ariya offers a pilot test of how this kind of adaptive testing systems could be worked in order to bring to the users the functionalities when this kind of platforms is used. The easiness for accessing the system from any digital or mobile smart device that the users can already own is among these functionalities, since this characteristic does not require the installation of any additional software, it is enough to have an Internet connection and to access from the web browser of the device.

The implementation of the CAT system in the Cloud allows the use of the great processing power of the multicore processors, from which the virtual machines can be configured, in addition to the sharing of storage space in the database and in the hard disk for the calibrated items, the richness of multimedia contents and the results of the tests. The adaptive testing mechanism will use the resources of processing power in order to calculate, almost in real time, the results of the adaptive testing and the items' calibration.

Furthermore, this paper discusses the implementation of a prototype of the Framework Ariya which intents to have all the elements of a fully operational CAT system, so that the adaptive evaluation tests using different psychometric models can be made in a future work, integrating inclusive more complex and resource demanding mathematical techniques [3].

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Mechatronic Approach to an Intelligent Machine: the Case of an Assistive Device

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Abstract. Today, one of the most important research fields is concerned to the Engineering Design Process, which is focused on designing better electro-mechanical systems with a low impact on the environment and a most efficient use of the energy. Currently the design process can take advantage of many computational-aided tools, which play a key role in the modern methods of optimization and reduce the cost of prototyping. This work presents the design process of an assitive device implementing a mechatronic approach. The mechanical design is carried out, as well as the electronic and control. The integration of all the modules of the system is done with the use of a graphical user interface to give easy access to manage and control the entire system.

Keywords: Intelligent machine, mechatronics, assisted device, hospital bed

1 Introduction

In response to medical requirements presented by hospitals and more important by patients, new mechanical devices must be designed to fulfill successful health-care services. One of the devices that most impact has is the hospital medical bed [16, 15]. Several mechanical designs of hospital beds have been proposed to alleviate the very intensive labor and the lack of qualified personal (nurses and stretcher-bearers), mainly in developing countries. In Ching-Hua [4] a hospital bed with auxiliary functions of lateral positioning and transferring patients is described. Three mechanisms are described which assist in complicated maneuvers of moving patients from hospital beds to the stretcher.

Andhare [1] makes a design that attempt is to reduce the amount of assistance required in managing these patients. Special focus is made on the mechanism synthesis stage. Kittipichai [8], proposed an optimization procedure for the structure design of a hospital bed using genetic algorithms. The novelty of the bed structure is that it can support the left and or right leg for patient's leg splint.

Some goals of the design are to reduce the mass of the bed structure. In the work of Shih-Wei [14] the Mechanism Design and Mechatronic Control of a Multi-functional Test Bed for Bedridden Healthcare is presented. The design considers two beds, one main bed, and one nursing bed with transferring capabilities. A remarkable feature is that the designed bed is built by mechatronic engineers and qualified healthcare personnel simultaneously.

Kap-Ho [7] presents the development of an intelligent bed robot system, which is a particular bed equipped with two robot arms and an array of pressure sensors attached to the mattress capable of estimate the pose of the patient.

Mohammed [9] present a new design of a Multi-Functional Portable Patient Bed which is used to carry and transfer a patient's body. The most interesting novelty of the approach is that the design is demand-based, i.e. the proposed design of the bed is formulated based on literature survey as well as consult the medical staff.

This design approach for the hospital bed goes beyond, and it is based on Latin-American patients, nurse and stretcher-bearers demands. Hospital human resources are the people in daily contact with real situations and needs. For this reason, their feedback is essential to producing a useful hospital bed. This renders the basis to consider a functional set of positions demanded by real bed needs. Then, for each required position a mechanism synthesis stage brings a solution for the motion of each required tool. Finally, using tools of mechanical engineering, the complete design can be developed. It is important to mention that the bed construction involves the design and manufacturing of various areas (mechanical, electronic, industrial and graphic design). This integration produces a functional device in combination with an intelligent system [3].

2 Mechanical Design

This section describes the positions and special feature requirements achieved by a serious study at Hospital Juarez de México (HJM) over two months of applying our diagnostic methodology [16, 15]. About three hundred medical experts were asked to define such requirements. As a benchmark for the requirements, Latin-American patients' height was considered as an essential part of the design process, see [2].

2.1 Positions

Several hospital bed manufacturers provide a broad range of models that are suitable either for intensive therapy or hospitalization. Depending on specific requirements, some positions are rendered by each bed model. The most common configurations are orthopedic, cardiac, fowler and Trendelenburg. Nevertheless, other useful positions are foot elevation, panning or tilting and sit, [5]. From the universe of possible position, our proposal provides twelve positions based on the results of our study in HJM and their medical requirements. All these positions are depicted in Figure 1.

Fig. 1. Twelve required positions for the hospital bed

It is important to indicate that home position implies vertical motions that render the adjustable height of the hospital bed. To achieve the desired positions, different mechanisms were synthesized to provide the desired ranges of motion. Such ranges were also obtained by an ergonomic study carried out at the Center for Investigation in Industrial Design (CIDI-UNAM), see [11].

2.2 Special Features and Functions

Traditionally, specialized functions are offered by manufacturers as a concrete and expensive extensions of standard models of hospital beds. Nevertheless, our approach is to satisfy the requirements of the market, i.e. the users of the bed.

The results obtained from our study in the Hospital Juárez of México, indicate the necessary requirements to work in all possible scenarios. It also provided information about the usage by the hospital people and maintenance of a hospital bed. From these results, we defined a list of general requirements that must be fulfilled to achieve an appropriate working relationship and successful using of this specialized medical device.

Also, to satisfy this feature set, additional considerations complying with IEC-60601-52 standard were taken into account. The final set is listed below:

- Ensure the stability of the device in any of their positions.
- For security, no user should have contact with mechanical parts.
- The railings must have free movement in any position.
- Access controls should be comfortable and live (even without electric energy).
- Access medical peripherals and accessories must be free and comfortable in any position.
- The position of the device should not limit the use of peripherals.
- It must attend medical user to find the right position for the patient in different circumstances given by the condition of the patient.
- The rails and feet-board should allow visibility of the medical staff at any time should obstruct patient monitoring.

- Should allow access for perform common tasks toilet.
- Ensuring stability in patient transfer conditions on the device, even with two more people on it.
- The device should provide a good service (maintenance) to the user during their stay in hospital.
- It must make the patient's stay comfortable taking into account as far as possible the emotional aspect of it (eg, sense of stability and safety during movements).
- It should avoid, prevent and/or minimize any risk both use and health for all users, especially for the patient
- A safety loading of 3000 [N], corresponding to two patients of an average weight of 150 Kg, must be resisted by the mechanical structure.
- A minimum and maximum height of 47 cm and 90 cm must be provided by the bed. It will be useful for the Help to stand-up position.

2.3 Mechanism Synthesis

To simplify the mechanism synthesis, a group of subsets of the mechanism is described below. It is important to indicate that to render appropriate motion to each mechanism linear actuators of specific trademark were selected due to it certification with the International Standard IEC-60601-52, which is the standard dedicated to electrical beds. Mechanism synthesis is performed by using the required ranges of motion for each position obtained by the ergonomic study [11], then by using standard optimization methods and working on mechanism analysis [13].

Figure 2.3 shows the mathematical model used to synthesize the elevation mechanism. Using the standard notation for mechanism analysis, the six bar mechanism responds to the following set of equations.

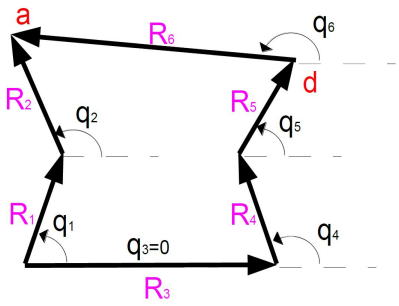


Fig. 2. Schematic of the lifting mechanism

Base The base of the bed must provide enough stability to prevent falls by a patient or any other from the bed in rest and handling. Our device must not cause

any dangerous situation for the patient's health. To reaching our objectives, a rectangular base is proposed as shown in figure 2.3, coupled with the elevation mechanism.

To render mobility to the bed a set of four Tente © castor Wheels were firmly attached to the base. Moreover, they have the function of directional brake or total brake to ensure the safety of the patient when the bed is in the rest.

Lifting Mechanism This mechanism consists of two slider-crank mechanisms coupled to a six bar mechanism which allows vertical and longitudinal displacements of the sectioning mechanism. The lifting mechanism is also responsible for Trendelenburg and anti-Trendelenburg positions, and it is mounted on the base of the robotic bed, as in Figure 3.

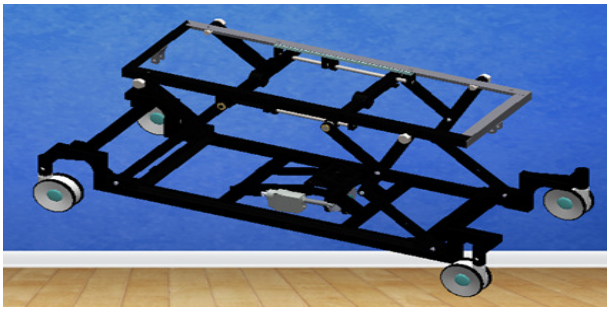


Fig. 3. Lifting mechanism for the hospital bed

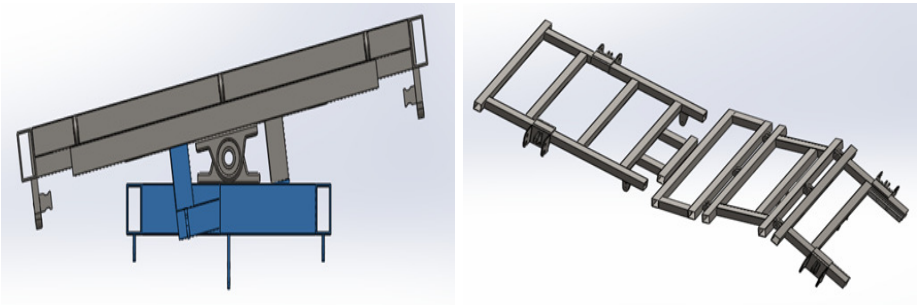
$$r_1 e^{\mathbf{j}q_1} + r_2 e^{\mathbf{j}q_2} = r_3 e^{\mathbf{j}q_3} + r_4 e^{\mathbf{j}q_4} + r_5 e^{\mathbf{j}q_5} + r_6 e^{\mathbf{j}q_6} \tag{1}$$

where $e^{\mathbf{j}q_i} = \cos(q_i) + \mathbf{j}\sin(q_i)$. In this mechanism, all vectors r_i are constant while the angles q_i are time varying.

Note that when $q_6 = 0$, components in direction $\mathbf{Y}$ of points a and d in figure 2.3 are at the same elevation. Moreover, their Cartesian positions can be described using model 1. By using the minimum and maximum height of 47 [cm] and 90 [cm], a set of angular position constraints can be defined. Next, using standard mechanism synthesis tools the elevation mechanism is completely specified by selecting the length of the links.

Tilt Mechanism This mechanism is directly coupled to the elevation mechanism by six SAE-grade 1 screws and nuts.. Its motion is controlled by a slider-crank mechanism with a special linear actuator, coupled to a hinge-like mechanism, see figure 4(a).

This mechanism causes the sections mechanism to rotate in the sagittal plane of the bed. Thus, it handles the Right and Left tilt positions in Figure 1.



(a) Tilt mechanism (b) Sections mechanism

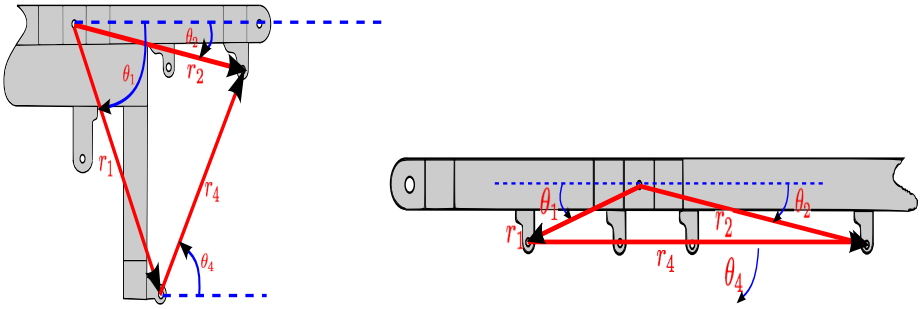
Fig. 4. Tilt an Sections for the Hospital Bed

Sections Mechanism Figure 4(b) depicts the sections mechanism. It is a set of hinge-like open chain mechanism where the whole body of the patient must rest. The first link of this open-chain mechanism corresponds to the backrest, which is coupled to the slide-guard mechanism, described in the next section. In the second link of the sectioning mechanism the patients' hip rests. This link is welded to the tilt mechanism. The third and four links correspond to the legs and feet mechanisms, respectively. The whole mechanism is isolated in figure 4(b).

Leg Mechanism This section is designed as an inverted rod-cranck mechanism, see 5(a). The equations modeling this mechanism are

$$r_2 e^{\mathbf{j}q_2} = r_1 e^{\mathbf{j}q_1} + r_4 e^{\mathbf{j}q_4} \tag{2}$$

In this case, vector r_1 is fixed while vector r_4 represents a linear actuator which render a rotational motion to vector r_2 through angle q_2.



(a) Legs mechanism (b) Feet mechanism

Fig. 5. Mechanisms in the hospital bed to care lower extremity

Feet Mechanism This section is also designed as an inverted rod-cranck mechanism, see figure 5(b). The equations modeling this mechanism are

$$r_2 e^{\mathbf{j}q_2} = r_1 e^{\mathbf{j}q_1} + r_4 e^{\mathbf{j}q_4} \tag{3}$$

In this case, vector r_1 is fixed while vector r_4 represents a linear actuator which render a rotational motion to vector r_2 through angle q_2. Note that, vectors r_1 and r_2 are fixed. Moreover, vector r_1 is fixed at the legs section.

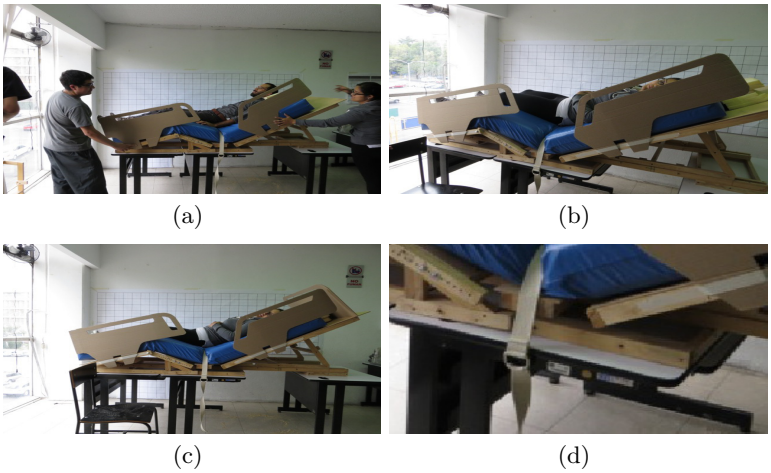
Slide-guard Mechanism This mechanism is a slider-crank coupled to the backrest link of the sections mechanism, see Figure 7. The kinematic model for this mechanism is described by equation 4. Then, the synthesis stage follows the procedure as for the elevation mechanism.

$$r_1 e^{\theta_1} + r_4 e^{\theta_4} = r_2 e^{\theta_2} + r_3 e^{\theta_3} \tag{4}$$

The design of this mechanism is motivated because it allows to adjust the size of the bed while the backrest is moving. To the best of the authors' knowledge, this mechanism is the first of this kind implemented in a robotic hospital bed. To determine the slider dimension, an ergonomic study was carried out, see Figure 6.

In this study, the backrest and hip sections were studied to obtain a linear displacement between them which renders comfortable motion and less stress for the back of the patient.

It concludes that it is required to consider a transfer of 11 [cm] linear adjustment mechanism at the hip section, (regardless of the setting of the backrest in degrees). If this is considered, anthropometric needs of an average Mexican population are covered, from female to male percentile 5 to percentile 100, [11].



(a) (b)

(c) (d)

Fig. 6. Some positions of the ergonomic study for the robotic bed.

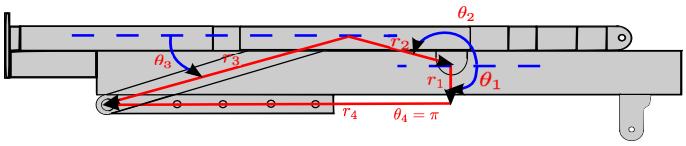


Fig. 7. Slide-guard mechanism for the hospital bed

Railings Mechanism Railings are designed as a four bar mechanism. The main objective of this mechanism is to keep each railing in vertical position tin order to guarantee patient's safety, as depicted in Figure 8.

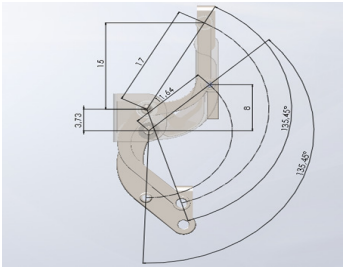
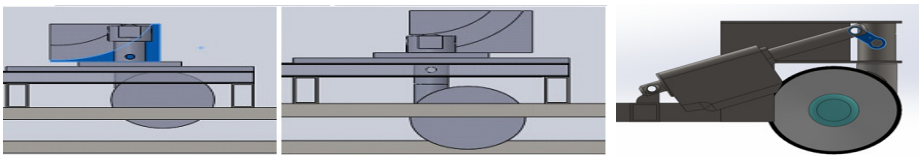


Fig. 8. Railings mechanism for the hospital bed

Fifth-Wheel Mechanism The goal of the fifth-wheel is to improve the maneuverability of the robotic bed while transporting a patient. For this reason, the fifth-wheel is only active during any transportation task. The mechanism is a cam coupled to a slider-crank mechanism. This allows to deactivate the fifth wheel when the bed is in the rest, see figure 9(a).



(a) Fifth-Wheel (b) Brake mechanism

Fig. 9. Additional mechanisms in the hospital bed

Brake Mechanism To guarantee the whole robotic bed stay in rest, a brake mechanism is required. This mechanism is provided by the set of four Tente© wheels. Our design only considered a bar to activate the brake on each pair of wheels as shown in figure 9(b). The bar is coupled to a slider-like mechanism.

2.4 Mechanical Design Methodology

For the design and selection of the machine and structural elements of the robotic bed, the resistance and rigidity criteria were selected. This is because no high velocities are considered. Thus, a static behavior can be assumed. The resistance criterion in mechanical design establishes that there is not any mechanical element that will overcome its elastic limit behavior, thus guaranteeing that fault will not appear, i.e. the material does not break down. The rigidity criterion establishes that the deformations due to the loads on any mechanical element will not stay within the elastic limit of the selected material, thus ensuring that no permanent deformations will appear.

Both criteria allow us to determine the geometry and the material of each mechanical element of the structure of the robotic bed.

For the structure of the bed, the standard A-36 standard steel was selected in this stage of prototype manufacturing. This material has excellent welding properties and it suitable for cutting, grinding and a variety of well-known manufacture processes.

Considering this material as a specification for the design, SolidWorks © was used to draw and perform finite element analysis to the geometries of the robotic bed. Square profiles were selected as the geometry of the structure. As the A-36 steel is ductile, the Von-Misses main strains were selected as the resistance criterion. This analysis considered 3000 [N] of the mechanical load as required. Nevertheless, it is omitted in this paper due space constraints.

The final render of the mechanical design obtained is depicted in figure 10.

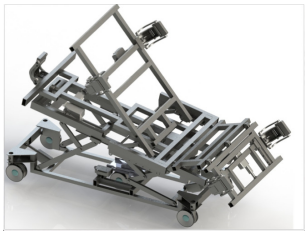
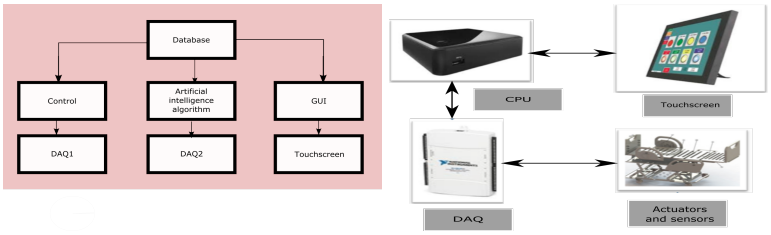


Fig. 10. Final

3 Control

This section presents how the software components interact to achieve the desired behavior specified by the user. They communicate between them trough a database. Figure 11(a) shows the architecture of the control system where the three different parts of this device are shown. Part 1 is the communication with the control system responsible for giving overall mobility; this is done by through the DAQ. Stage 2 is the distribution processing system and means with which it has to interact with users through artificial intelligence algorithm. Finally, in step 3 GUI where the end user can interact with the physical system through the touchscreen shown. In Figure 11(b) is displayed as the entire system is constituted physically.



(a) (b)

Fig. 11. Flow and physical diagram

4 Integration using a GUI

In constant operation of the lifting mechanism, measured position is presented in the graphical interface, and it must display the real position of the physical system. Therefore, the user must have real information to observe and handle the variables in the machine. Additionally, this development takes into account the implementation of a function call [6],to isolate the design and constructibility of the GUI. Therefore, this work is done considering the flexibility of the entire system.

In Figure 12 is presented a screenshot with all the elements available to the final user. The guidelines of multi-modal interface design [12] and cognitive decision approach [10] were taken into account to finally obtain the showed distribution in the GUI.

This picture contains an interactive way to manage the positions of the system with easy handle method. The combination of colors was selected by considering different situations of usage and the variety of the user that are going to be interacting with the system.

(a) (b) (c)

Fig. 12. GUI

5 Conclusion

Our diagnosis methodology is a way to perform the identification of the assistant robotics needs in a hospital; this leads to the identification of opportunity areas for the development of robotic devices. It is important to have a methodology that assures that the solutions proposed respond to real needs. This method can be applied to rehabilitation engineering and the clinical fields providing concrete solutions to the most critical needs detected in hospitals. Once a technical proposal is qualified as viable according to our methodology, the robot or the assistant device can be manufactured.

In this work was presented a successful appliance of a mechatronic approach to the assistive robot. The mechanical structure was synthesized according to the needs identified previously. The mobility of the robotic mechanism renders the required positions while comfort and patient's safety is guaranteed. The full design will allow to integrate mechanical and electronic components together with industrial design, resulting in an affordable device.

The intelligent system applied in this work shows a strategy to endow robotic assistants ability to detect risk scenarios to patients. In this case, when the robotic bed is moving can generate situations of risk if patients perform any bodily movement that is inappropriate to such a step. This represents an advance in medical care since through such devices can treat patients without medical personnel does not risk an injury when moving patients personally. In this case, the robotic bed can be programmed in such way the appropriate medical personnel may attend to other patients while applying certain movement therapy

automatically by medical monitoring. Although our bed is working correctly, currently a second version could be carried out to attain the reduction in costs, improvement in manufacturing and integrating processes and to include some other functions to the device.

Acknowledgment. All authors acknowledge support from CGSTIC-Cinvestav IPN.

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Resource Creation for Automatic Translation System from Texts in Spanish into Mexican Sign Language

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Abstract. Mexican Sign Language (LSM) has been recognized as part of the official cultural background of Mexico since 2005. However, nowadays there is no federal program that considers the creation of lexical resources for LSM, standardization of its syntactic rules and unification of its vocabulary. It is important to mention that LSM is an agraphic language, i.e., it has no writing system. On the other hand, computing sciences face an important challenge regarding the creation of digital resources for specific text processing tasks. This paper describes the creation of linguistic resources that are necessary in the automatic translation from written Spanish into LSM. We also present an approach that we use for automatic translation from written Spanish into LSM and the system, which implements it.

Keywords: Mexican Sign Language (LSM), automatic translation, natural language processing, LSM dictionary.

1 Introduction

According to Mexican National Institute of Geography and Statistics (INEGI) official numbers, there are 5,739,270 persons, i.e., around 5.1% of the Mexican population, that are disabled for hearing to some extent, and 694,270 of these have hearing impairment.

Persons with hearing impairment can be classified into three categories: first, persons having this deficiency since they were born, next, there are persons who could hear normally, but they lost this ability in an accident or a disease, and, finally, those who lose gradually the hearing by aging.

Again according to the INEGI information in 2006, 60% of deaf persons in Mexico can use Mexican Sign Language (LSM, *lenguaje de señas mexicano*), out of these just 20% can read and write in Spanish. Deaf persons, who can read and write in Spanish, use a variation of the LSM, in which they try to follow the correct grammar rules. This language is called Signed Spanish. There are only few cases when persons who can hear perfectly seek to learn sign language.

The main purpose of our work is to develop a tool that simplifies the communication between persons who can read and write Spanish and deaf persons who understand and use the LSM.

2 Theoretical Framework

In this section we describe the antecedents and the essential features of the Sign Languages (LS, *lenguajes de señas*), as well as the general concepts regarding the automatic translation and the translation process as such.

2.1 Sign Languages

Sign language is the natural language for deaf persons and like all languages it emerges from the necessity to establish communication between persons. LS is three-dimensional and agraphic language [1].

Sign languages have their own rules, they are not a copy of the oral languages nor their representation, although the influence of the dominant spoken language is undeniable.

Deaf persons are born with the biological capability for learning a language, however, their hearing impairment impedes to acquire the oral language spoken around them.

Unlike oral languages, the sign language focuses its operation on the visual perception, while oral languages are based on the auditory perception. The key differences between spoken languages and sign languages are shown in Table 1 [2].

Table 1. Differences between spoken and sign languages.

Oral languages	Sign languages
Auditory attention	Visual attention
Auditive memory	Visual memory
Linear space	Three-dimensional space
Vocal emission	Body-space transmission
Sequentiality	Simultaneity

There are significant geographical variations of LSM in Mexico. There are variants in Mexican northern regions, where the LSM is influenced by the ASL (American Sign Language). Southern states have their own variant. Finally, there is an alternative sign language in the state of Yucatán.

The lack of a writing system leads to a general lack of historical (written) documents, which would allow the study of grammar of the language in its evolution.

2.2 Automatic Translation

Automatic translation is the process when a computer application converts a natural language text written in any language (source) into another language (destination). The

main goal of the translation techniques is to "catch" the meaning in the original text and to transmit it as a full coherent text in another language.

The evolution of the automatic translation studies shows two leading standpoints: translation based on rules and translation based on a corpus.

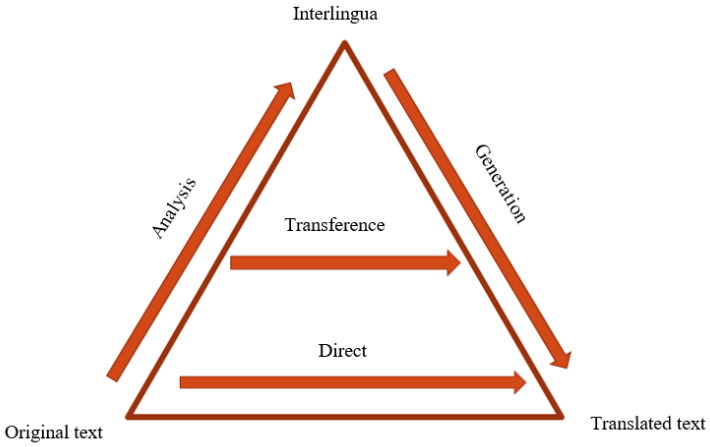

Fig. 1. Bernard Vauquois´ pyramid. Interlingual Machine Translation.

The corpus based translation uses statistical techniques to make the translation as accurate as possible, using previously translated texts as the basis. This type of translation provides high quality, when there are available very large monolingual and bilingual corpora that allow construction of the statistical models of translation.

The purpose of the rule-based translation is to achieve semantic equivalences based on concepts of generative linguistics and artificial intelligence by using dictionaries and a wide-range set of linguistic rules that identify the elements which represent a whole language. Usually, tree structures are used to represent structure of sentences.

General scheme of the automatic translation is presented in Fig. 1. There are three possibilities: direct translation, transference rules, and interlingua, when the phrases are translated first into an intermediate language and then the output is generated.

The direct method is the simplest method, which usually obtains poor results. A minimum analysis is done, syntactic analysis is omitted. The translation is made word by word and lacks of any intermediary stage.

The indirect method obtains a representation of the source text, from which the target text is generated. Indirect methods are divided into two categories: interlingua based methods and transfer methods.

Interlingua performs the translation in two stages using a universal intermediate representation. The first stage involves an analysis of the text in the source language, whose result is an abstract semantic representation, also called interlingua. The second phase establishes the relationship between the interlingua and the output text, i.e., the translation is created from the interlingua. Regarding this technique, the representation between languages is neutral, so it works for any language pairs.

Transfer technique suggests two intermediate representations, one for each language of the translation being at the same time dependent on the used languages.

The execution of this method implies the creation of three modules for each language:

- The analysis module, which obtains lexical, syntactic and semantic representation.
- The transfer module, which creates equivalences between the representations of the languages.
- The generation module, which starts working after the transfer module. The text itself is generated for the specific target language.

The transference is done at three levels:

- Lexical transfer, finding the corresponding terms in the target language, is performed using dictionaries.
- Syntactic transfer, when the parsed tree of the source language sentence is transformed into an equivalent tree of the target sentence.
- Semantic transfer, when deep representations are transformed as patterns of diverse cases, semantic networks or logical structures.

3 Related Work

In this section, we describe the work related to the automatic translation between the written Spanish and the sign languages (for various natural languages). The Mexican Sign Language (LSM) has different characteristics as compared to those used in other countries, so, the state of the art techniques described below should be adjusted and adapted.

3.1 TextoSIGN: Text Conversion into a Sign Language

TextoSIGN system for text conversion into a sign language [8] is developed by the Technological Institute of Castilla and Leon and XUL Social Media Company in 2011. The system is able to show the requested sentences by using sign language. It contains 350 signs. The signs or words that are not in this list are spelled.

The translator essentially permits two different uses: the export of the phrases into a video format sentences in order to be loaded on any web page or the real time visualization as a training tool, which allows to see the translator from any position while learning the execution of different signs.

3.2 CONSIGNOS: Converter and Automatic Statements of Sign Language

The system CONSIGNOS [9] was developed in 2008 in the Polytechnic University of Madrid and the University of Castilla L. The system uses the following techniques:

- Automatic speech recognition based on Hidden Markov Models, combined with statistical language models using lists of examples.
- Syntactic and semantic rules.
- Statistical algorithms based on subsequences of phrases and finite-state transducers.
- Algorithms of integration of different translation strategies.
- Nonlinear animation techniques for the independent actions arrangement.
- Description of the actions in an independent matter.
- Description of actions independently of the avatar using descriptors based on quaternions and methods of inverse kinematics.
- Mesh deformation methods (Vertex Blending).
- Generation of realistic representation output as a black box for the other modules.
- Transparent incorporation of distributed realistic synthesis based on the GRID.

3.3 Natural Language Translation System into Spanish Sign Language

Natural Language Translation System into Spanish Sign Language [10] was developed in 2012 by Colas-Pasamontes and Lopez-Colino from the Autonomous University of Madrid. It is based on two modules: the translator and the sign language synthesizer. The translator was designed as generic and independent from the context. This element makes use of grammatical and syntactic analysis systems including a set of over 75,000 words in Spanish. The sign language synthesizer utilizes a design based on philological studies applied to the Spanish Sign Language. In addition, the graphic library JSR-184 is used.

3.4 Online Signs Languages Translator

Online Signs Languages Translator [11] was developed in 2012 by Leal Rodriguez. It uses a vocabulary and a set of grammar rules for translation. The system states that the sign language has the following linguistic peculiarity: using a single sign, it is possible to display an entire sentence. The system (1) reads the sentence, (2) labels it, (3) breaks the phrase into proper grammar rules, (4) finds in the database the required words, (5) searches in the database the existence of any combination of words that can be expressed in a single sign, and (6) the words that are not found are spelled using signs. Once this procedure is finished, the written phrase is translated into a sequence of signs that is displayed image by image.

4 Methodology for Creation of the Dictionary

We had the assistance of the Integral Attention Center for disabled persons of the Cuauhtémoc District in Mexico City. We recorded 1,790 signs in a JPEG format 10 frames per second. The words were extracted from the dictionary “Manos con voz” (“Hands with voice”) [4] and “Mis manos que hablan” (“My hands speak”) [5]. We

also added words using vocabulary for the signs of the Mexican northern, center and southern areas, with the collaboration of *Seña y Verbo* Association.

A corpus that contains one hundred sentences in Spanish was developed. These sentences were mapped taking into account the Spanish sign language grammar structure. The corpus is useful for analysis of the grammatical relations between both languages. This mapping is the first experience in the field. It was validated using the proper syntactic structures, mentioned in *Gramática de la Lengua de Señas Mexicana* [7]. The examples of translated sentences are presented in Fig. 2.

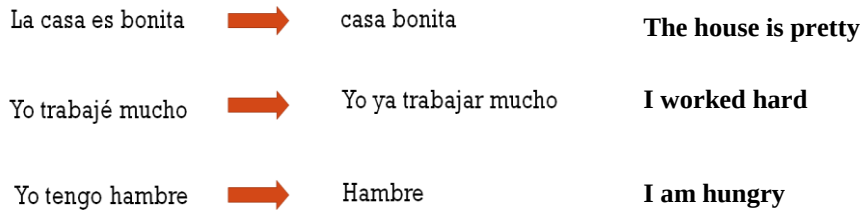

Fig. 2. Example of translated sentences.

The labeled sentences correspond to previously established grammar rules. Besides, they represent the simplest structures in Spanish. All these sentence structures are listed below:

1. Art- Noun -Verb- Adj
2. Art- Noun - Verb- Adv
3. Art- Noun - Verb- Noun
4. Art- Noun - Verb- Art- Noun
5. Art- Noun- Verb- Adv- Adj
6. Art- Noun - Verb- Adv- Prep- Art- Noun
7. Art- Noun - Verb- Prep- Art- Noun
8. Art- Noun - Verb- Art- Noun - Prep- Art- Noun
9. Art- Noun - Verb- Adv- Prep- Art- Noun - Prep- Art- Noun
10. Art- Noun - Conj- Art- Noun- Verb- Prep- Art- Noun
11. Art- Noun - Conj- Art- Noun- Verb- Adv- Prep- Art- Noun
12. Art- Noun - Conj- Art- Noun- Verb- Adj
13. Art- Noun - Prep- Art- Noun- Verb- Adj

The developed resource can be used in making of the automatic translation, which has the following features:

– The translation is held in a single direction, from the written Spanish to the LSM.
– There is a restricted vocabulary related to the home environment only.
– A limited group of grammatical structures is used.

The system overview is presented in Fig. 3. To achieve the translation, the system takes the text in the source language and processes it using Freeling [3]. Having identified the elements of the sentence, there is a verification whether the words are part of the defined vocabulary or not. For the moment, the system only translates using the specified vocabulary and the unknown words are not spelled. Still, if we would like the system to work at the full scale, a deaf person would need to know how to spell the unknown words.

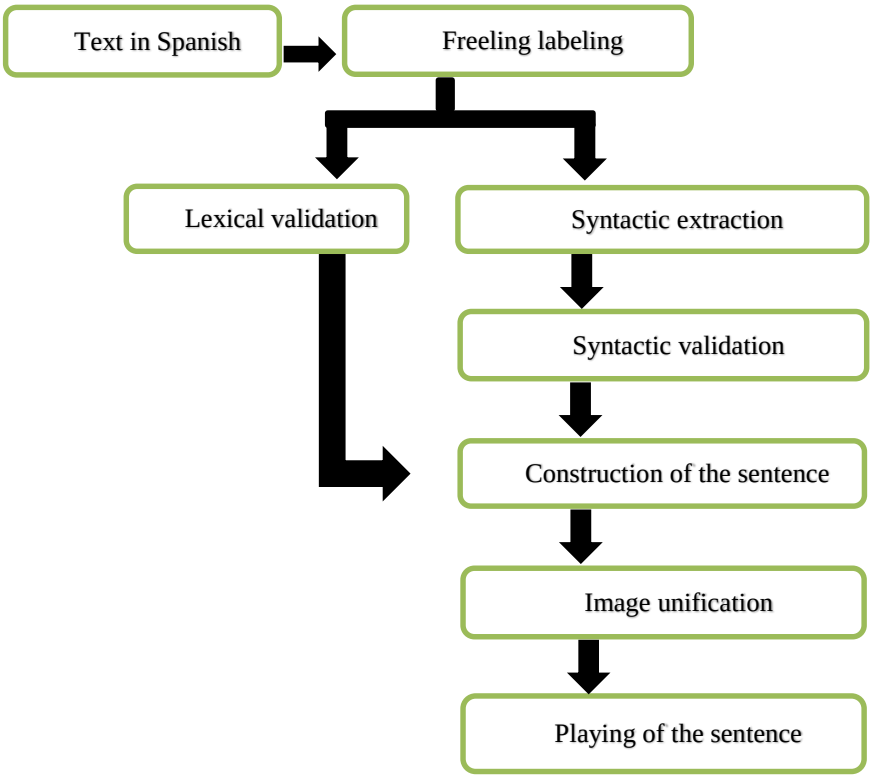

Fig. 3. System overview.

Once the vocabulary is authenticated, the syntactic structure as an outcome during the labeling step is checked out, so that the correspondent syntactic item is found in the database and is matched. If the grammar structure is included in the database, it is mapped with the equivalent structure in the LSM.

When the grammar is verified and identified, the system seeks in the database the corresponding sign video, gathers those items using image management tools and reproduces the final set as a phrase in the LSM.

The system also considers expressions in Spanish that have more than one word while the LSM only has a single sign to represent it. The database contains a catalogue with around one hundred items having this feature.

5 Experiments

The experiments were conducted in collaboration with the House of Culture of the deaf in the Cuauhtémoc District of the Mexico City. The center of attention has 4 teachers including two listeners. The tasks were performed by one of the not listeners' teachers.

It was requested to perform the translation of written sentences in Spanish into LSM. In total, 150 sentences were translated, 10 sentences for each structure were considered. We identified a set of 100 signs that can represent a complete sentence.

Sentences translated into LSM belong to any of the thirteen grammatical structures that the system recognizes as valid and which are referred to in previous sections. It was observed that when a deaf person does not know a sign that corresponds to a particular word, then he spells the unknown word.

At this moment, we conducting broader experiments, when the translation of the same set of sentences is made by 10 deaf persons, 5 of them are deaf persons who are literate and five more are deaf persons who are not literate. With this, we expect to find the differences between a Spanish translation into LSM with and without influence of the written Spanish.

At this moment, the system can perform the literal translation, i.e., it divides the sentence into words, the words are searched in the database of the system and are reproduced in the order they were found in the sentence.

Also, the system has a list of signs that correspond to particular statements. The corresponding module searches in the set of signs and if there exists a sign that corresponds to a full expression, it will be reproduced.

6 Conclusions

The following conclusions can be drawn:

- This paper presents a resource (dictionary) for automatic translation from written Spanish into LSM.
- We made several experiments for usage of the developed dictionary in the translation.
- The resources generated in this study are unique to the region of Mexico City and the metropolitan area, but they can be used also use in the rest of the country, maybe with certain adaptations.

The following more general considerations related to LSM were discovered during the work on the project:

- The mapping of the syntactic elements in written Spanish to LSM sentences requires, in most cases, a visual reference that associates the components in the proper context, for example, the prepositions of place.
- As all languages, LSM has several ways to map the syntactic structure of a sentence. One of these versions corresponds to sign Spanish.

- During the work on this project, we found that the concept of regionalism in LSM may correspond both to the different geographical areas of a country and the local variations between what are called different "families". In case of Mexico City, there are at least three "families", each with variations in vocabulary and structure.
- LSM-related works have to specify the "family" or group of persons with whom they work.
- Unlike the ASL and LSF the government of Mexico does not have a unification project of vocabulary or structure of LSM.
- There are no sufficient corpora to achieve a good translation using the ruled based translation approach.
- We used the restrictions on sceneries and vocabulary to start working on the experiments on automatic translation into LSM.

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Adaptation of Weights in a Neuron Using an Integrated Filter

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Abstract. This paper presents a description of application of stochastic weights in a neuron, problem solved through the adaptive estimation achieved with dynamical combination between the identification and estimation; having an adaptive structure that updates the estimated parameters into the integrated filter. The weights are dynamically adjusted in the neuron based on stochastic gradient, affecting the neuronal performance allowing that its response converges to the reference signal. In addition, the error is applied in identification as an innovative gain adjusting the neuron in its inputs and consequently its dendrites signals that are applied into gradient filter adjusting the neuron weights in accordance with the desired signal requirement. Such that the gradient estimation is built based on the Black-box scheme with unknown internal weights. All simulations were developed using Matlab® software.

Keywords: Estimation, stochastic systems, neural net, digital filter, identification.

1 Introduction

An artificial neural net is a computational model that imitates the biological actions: observing that the neurons adapt their gains using the learning process as it occurs in the brain or neural sensor subsystems. Different effects depend on the output stimuli (Nikola, 1996) (Medel, 2008). So, the artificial net considers the weights adaptation as a requirement, in accordance with the reference signal and the stimuli of the inputs.

The neuron maintains an electrical potential interval from 35×10^{-3} to 65×10^{-3}volts; but when a neuron is fired, an electrical impulse is increased; this is an electric energy generated by chemical effects, releasing an electrical potential from 90×10^{-3} to 110×10^{-3} volts. This impulse through the neuron is transmitted from 5×10^{-1} to 1×10^{2} metres per second and is distributed on average in a $1 \times$

10^{-3} *second*. In addition, the fast repetition rate corresponds on average to 10×10^{-3} seconds per firing. A computer, where signals travel on average at $2.0 \times 10^{8} \frac{m}{s}$ (electrical speed energy in a wire is *0.7* faster than in air), may repeat an impulse each 10×10^{-9}*seconds*. So, the computer device has in average two thousand times more speed in signal transmission and a thousand times in the fire signal repetition with respect to natural neuron action (Passion, 1998), because it uses the solid state instead of chemical reactions. But, for example, the main advantage of the brain with respect to other electronic devices is the possibility of "*self-programming*" with the changes of external stimuli, known as "*adaptability*". In other words, it can learn dynamically and in variable conditions. Naturally, the brain neurons change their response to new stimuli, having similar responses to similar events. The brain adaptability corresponds to survival actions, while a device that just accomplishes a sequence of commands.

1.1 Neural Network Structure

The computational neural net structures are based on biological neural configurations. The basic neural net is based in a neuron model, shown in Figure 1, consisting of Multiple Inputs and a Single Output (MISO form).

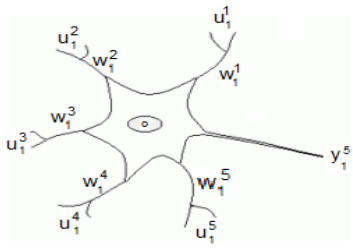

Fig. 1. Neuron model.

Each input is modified by a *weight*, which multiplies the input values. A neuron combines dendrite weight inputs and if the soma biological actions exceed a threshold, then the nucleus (in a biological sense) activates a function and determines its output answer. In a computational device, as shown in Figure 2, a behavioural additional condition has the answer close to the real neuron actions (Rajen, 2006).

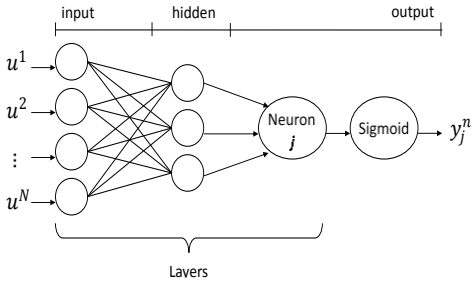

Fig. 2. Neuron device computational model.

Meanwhile, understanding how an individual neuron operates, many researches generate the way neurons organize themselves and the mechanisms used by neuron arrays to adapt their behaviour to external bounded stimuli. There are a huge number of experimental neural nets, and actually, laboratories and researchers continue building new neural net configurations in order to develop intelligent and autonomous systems.

The common computational neural net used is named as a *back-propagation network* and is characterized with a mathematical structure model that knows its behavioural stability conditions (bounded inputs and bounded output, BIBO conditions).

Intuitively it is built taking a number of neurons and arrays them forming a *layer*. A layer is formed having all inputs and nodes interconnected with others nodes, but not both within the same node. A layer finishes with a node connected with a succeeding layer or outputs giving the answer. The multiple layers are arrayed as an input layer, multiple intermediate layers and an output layer is shown in Figure 3, where the intermediate layers do not have inputs or outputs to the external world and are called *hidden layers* (Marcek, 2004).

Back-propagation neural networks are usually *fully connected* to improve the learning process. This means that each neuron is connected to every output from the preceding layer.

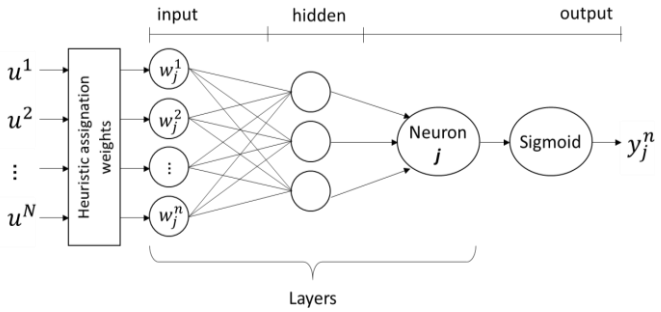

Fig. 3. MISO Back-propagation Network with three layers.

The layers are described as: input, distributing signals from the external world; hidden, categorizing the signals; and the output, collecting all features detected and producing a response. However, the problem of the layers has many descriptions considering the set of optimal weights.

1.2 Neural Network Operation

The output of each neuron is a function of its inputs and weights, with a layer as described recursively in (1) (Huang, 2006).

$$W_j^N = w_j^n u_n + W_j^{N-1}, \tag{1}$$

where the basic function has the form $W_j^{N-1} = \sum_{n=1}^{N-1} w_j^n u_n$.

The output neural net answer is a convolution operation, shown in (2).

$$Y_j^N = (F \circ W)_j^N. \quad (2)$$

The W_j^N value is convoluted with a threshold value giving an approximate biological neural net answer; but in a computational sense, it is active considering a t_j^N known as an activation function. The activation function usually is the sigmoid function.

The output vector answer Y_j^N is the neural net response, observing that the threshold function corresponds to biological electrical potential of 90×10^{-3} to 110×10^{-3} $volts$ needed in synopsis operations.

The biological or computational fire answers correspond to threshold conditions that accomplish the excitation functions generating an answer giving many inputs. Generally, the weights are selected intuitively in the first step; but with adaptive considerations, they can be adjusted to seek the desired answer (García, 2008).

2 Net Adapting its Weights Using Stochastic Filtering

Adaptation in a neural net means adjusting its weights with a law action, seeking the convergence to the output desired. The difference between the desired and actual response is known as convergence error, defined as (3) and shown in figure 4.

$$e_j^N = \hat{Y}_j^N - Y_j^N. \quad (3)$$

The filtering action could be a sliding mode, proportional gain in its weight and other non-linear models that allow the neural net convers to the desired answer with respect to the input set, but instead of it, in this paper we propose the identification technique shown in figure 4, that adjusts the inputs, predicting how many gain is required to minimize the inputs with respect to the desired reference signal.

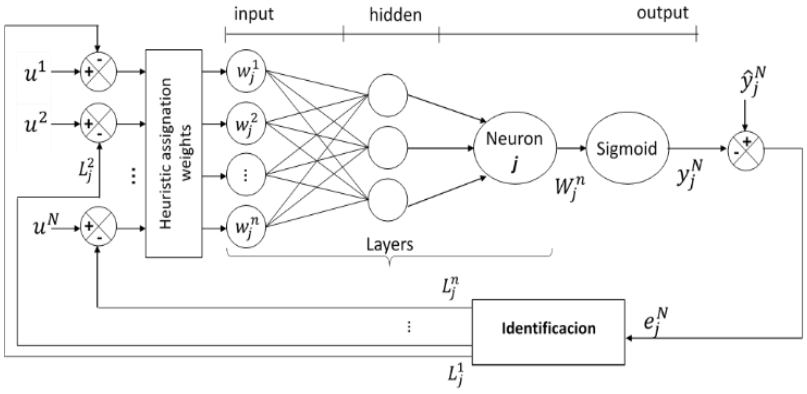

Fig. 4. Neural weights adjustment using an identification action.

The adaptive *back-propagation* procedure is described in (4):

$$u_j^{n\prime} = u^n - L_j^n, \quad (4)$$

where L_j^n corresponds to identification action considered by neural net designer.

Now, applying the concept considered above with respect to neural net, it adjusts its weights using stochastic estimation giving a great advantage over traditional inference weights assignation heuristically.

The neural net has adaptive weights based on an identification with its estimation, associating the output filter information with the neuron answer (Huang, 2006), building the control volume described as $T^N = \{(y_j^n, \hat{y}_j^n)\}_{n-\overline{1,N}} \subseteq R^2$ where a variant scheme has the form $G_N: (Y_j^N \times \hat{Y}_j^N) \times T \to \{((y_j^n, \hat{y}_j^n), \tau)\}\Big|_{n-1}^{N} \subseteq R^3$ (Margaliot, 2000), with dynamical adjusted moments (Gustafsson, 2001) in accordance with the reference previously defined in a distribution sense.

The neuro-stochastic filter is based on the back-propagation algorithm, because its weights have a dynamic actualization (Ali, 2003) (Amble, 1987) (Haykin, 1996) with different levels for each interval iteration (Huang, 2006), using the error described partially as $e_j^n \in R$ defined as $e_j^n := \hat{y}_j^n - y_j^n$, considering that its distribution function (Marcek, 2004) (García, 2008) is bounded and the statistical results have stationary conditions. Filter is shown in Figure 5, using the estimation weights (Passino, 1998) (Medel, 2008).

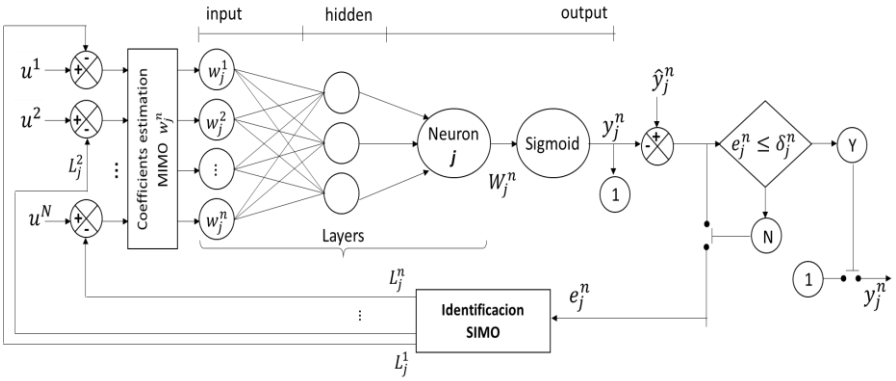

Fig. 5. Neuro-stochastic Digital Filter Process.

The error $(|e_j^i|)$ has an interval limit $[0, \varepsilon]$ and ε is described as a positive value with $\inf\{|e_j^i| : i, j \in Z_+\} \underset{n\to\infty}{\longrightarrow} \delta_j^n$ (Morales, 2002).

Stochastic filter applied into neuron considers the concepts described in (Abraham, 1991) and (García, 2011), having the elements needed in its basic description: back propagation neural net scheme, adaptive weights considering the estimation and identification, convergence answer, the error as an innovation process e_j^i with its bounded probability moments, in a metric sense, [19]. Activation function is the stage where the answer filter is transformed into a natural answer approximating to minimal convergence error region, and neuro-stochastic filter has a natural actualization

obtaining its weights dynamically based on second probability moment into the basic estimation action (5) considering de gradient description.

$$J^n = \frac{1}{n^2}\left[e_j^{n^2} + (n-1)J^{n-1}\right], \in R_{[0,1)}\ n \in Z_+. \tag{5}$$

The functional error J^n has an exponential convergence and stationary conditions if the weights set into filter established a stationary reference $\lim_{n\to\infty} |J^n| \to m$, considering that $0 < \{|e_j^i|\} < 1$ and (6).

$$J_{min} = \inf_m \{\min J(y_{i-0}^j, \hat{y}_j^i)\}_n. \tag{6}$$

Considering the gradient estimation in accordance with the desired signal and filter action, firstly, the filter process adjust the inputs, and these are applied into the gradient estimation adjusting the weights and generating in the same time the adaptive process guarantying the convergence rate (Rajen, 2006). Then, the weights $\{w_j^i\}_{i=\overline{1,n},j=\overline{1,m},}, n, m \in Z_+$ affect the neuron elements and consequently will give the correct answer $\hat{y}(k)$ (Ash, 1970), with MISO (Multi Inputs Single Output) properties. It means that (5) without concurrence has the form $J^n = \mathbf{E}\{e_j^n\}^2 =, \in R_{[0,1)}\ n \in Z_+$, with $e_j^n = y_j^n - \hat{y}_j^n\ and\ \ y_j^n = Wy_j^{n-1} + Bu_j^{n\prime}$. Such that, the functional error with symmetric conditions has the form with explicit output results as $J^n = \mathbf{E}\left\{W^2 y_j^{(n-1)^2} + B^2 u_j^{n\prime^2} + \hat{y}_j^{n^2} - 2\left(Wy_j^{n-1} + Bu_j^{n\prime}\right)\hat{y}_j^n\right\}$. The gradient of J^n, allows to have the neuron weights $\widehat{\boldsymbol{W}}_j^n = \left(\boldsymbol{E}\{y_j^{n-1}\hat{y}_j^n\}\right)\left(\boldsymbol{E}\left\{y_j^{(n-1)^2}\right\}\right)^{-1}$.

2.1 Weight Properties

The filter weights estimation uses the adaptive criterion, in order to adjust them dynamically, considering the stochastic properties and bounding each of them using a transition function maintaining the stability. The weights set $\{w_j^i\}_{i=\overline{1,n},j=\overline{1,m},}, n, m \in Z_+$, in each layer accomplishes the condition $\sum_{i=1}^n w_j^i \leq 1$, without losing the Transition Function (TF) (García, 2008):

i. Each weight has a Dynamic Transition Function (DTF): 1) $\ln(\Phi_j^i) < \infty$, 2)$\ln(\Phi_j^i) > 0$, 3)$\ln(\Phi_j^i)\,\tau^{-1} < 1$.

ii. The weight is described using the Transition Function (TF) in $w_j^{1-i_0} = \ln(\Phi_j^i)\left(\ln(\Phi_j^i)(i-i_0)\right)^{-1}$.

iii. The velocity changes are limited inside the transition function $\ln(\Phi_j^i) \leq \ln(\Phi_j^{i_0})(i-i_0)^T$, $\ln(\Phi_j^i) \leq \ln(\Phi_j^{i-1})\,(i-1)^T$.

The transition functions sum is bounded in each layer $0 \leq \left|\sum_{i-1}^n \Phi_j^i\right| \leq 1$. In accordance with the value of $\Phi_j^{i_0}$, the weights are bounded accomplishing with $w_j^{1-i_0} \leq \ln \Phi_j^{i_0}$.

The identifier described as $\widehat{x_i} = w_j^i(i - i_0)\,\hat{x}_{i-1} + K_i\widehat{\omega}^i$ considering from (i) to (iii), where K_i is the function gain and is a functional identification error, defined by the second probability moment (5), $\widehat{\omega}^i$ is the innovation process with $\{\widehat{\omega}^i\} \subseteq N\,(\mu_{\widehat{\omega}^i}, \sigma^2_{\widehat{\omega}^i} < \infty)$.

3 Results

The MISO stochastic filter considers the digital filter structure (Haykin, 1996) with the transition matrix bounded in accordance with the functional error criterion (Ash, 1970). The soft system (statistic in variance sense) considers the evolution times bounded and the processor performance at τ intervals with an average evolution time of 4×10^{-3} $sec \pm 2 \times 10^{-5} sec$. This section uses the first order difference discrete ARMA (1, 1) model (7) representing a reference system.

$$x^{i+1} = W_i x^i + \omega^i. \tag{7}$$

And the output described as (8):

$$y^i = Cx^i. \tag{8}$$

where $y^i \in R, W_i \in R^{[n\times n]}_{[0,1)}, \boldsymbol{x}^i, \boldsymbol{\omega}^i \epsilon R^{[n\times 1]}, C = I$. x^{i} is the internal states vector, W_i is the parameters matrix, $\{\omega^i\} \subseteq N\left(\mu_{\omega^i}, \sigma^2_{\omega^i} < \infty\right)$ is the vector noise into the system, y^{i} is the reference vector and $\hat{y}^i$ is the desired system signal. The filter process established the stochastic weights adjusted in agreement to the functional error convergence. Figure 6 describes the reference signal and its identification without knowing the internal matrix weights considering the estimation results $\widehat{\mathbf{W}}_{\mathrm{j}}^{\mathrm{n}}$. Figure 7 shows both overlapping densities considering the same time interval. Figure 8 shows the evolution functional error described in (5).

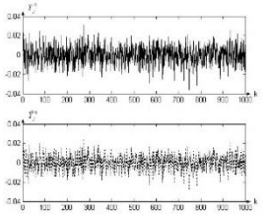

Fig. 6. Neuro signal Y_j^n and its identification $\hat{Y}_j^n$.

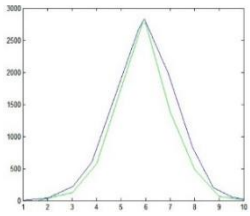

Fig. 7. Overlapping y_j^n and $\hat{y}_j^n$ densities.

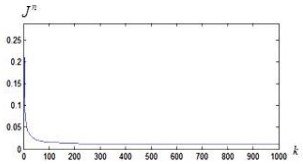

Fig. 8. Functional error (5).

The digital filter time evolution response was less than the reference process time state change, proposed with a value of 5×10^{-2}sec, and is delimited by the processor, considered in ($\hat{y}_j^n$). The convergence time is 862×10^{-4} sec, described in (Medel, 2008).

4 Conclusion

Neural net in identification sense, considered the adaptation process adjusting the weights dynamically using the estimation condition. Nevertheless, in many cases, these applications generate convergence problems because the gains increase the neural net weights positive or negatively without converge to desired value. In the black-box computational scheme the internal weights are known; but in real conditions it is impossible and only has a desired or objective answer, adjusting in some sense to their dynamically needing estimation process with smooth movements with respect to functional and identification error (5). Therefore, an option considered to estimate these in the new environmental circumstances, is based on gradient structure without losing the stability with respect to a reference system and on the Hausdorff condition, where the filter converge to the desired output system in distribution sense.

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