TOWARD INTEGRATION OF KNOWLEDGE BASED SYSTEMS AND KNOWLEDGE DISCOVERY SYSTEMS

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Abstract

This paper presents a proposal for an architecture that integrates knowledge discovery systems (automatic acquisition) and knowledge based systems (experts systems). This work formulates considerations over the viability of the implementation of this architecture according to the advance of the technologies involved.

Keywords
Data Mining, Expert Systems, Knowledge discovery, Knowledge based systems, Systems architectures.

1. INTRODUCTION

Knowledge based systems (KBS) or expert systems emulate the human expert behavior in a certain knowledge area. They constitute aid systems to take decisions in different areas such as educational strategic selection [1], environmental variables control [2], neonatology fans configuration [3], agreement in judicial process [4] or the attended generation of activity maps of software development projects [5]. Knowledge based systems to aid decision taking is a particular knowledge based system.[6], [7], [8], [9], [10].

The knowledge base of an expert system encapsulates in some representation formalism (rules, frames, semantic nets among other) the domain knowledge that should be used by the system to solve a certain problem. The development methodologies of knowledge bases have been consolidated in the last 15 years [11], [12], [13].

Intelligent systems constitute the Computer Science field which studies and develops algorithms that implement the different learning models and their application to practical problems resolution [14], [15]. Among the problems approached in this field, we can find the one related to knowledge discovering [16], [17], [18], [19], [20], [21].

Knowledge discovery (KD) consists in the search of interesting patterns and important regularities in big information bases [22], [23]. When speaking of Knowledge Discovery based on intelligent systems or Data/Information Intelligent Mining [24] we refer specifically to the application of machine learning methods or other similar methods, to discover and to enumerate patterns present in this information. One of knowledge discovery paradigms is centered in knowledge evaluation [25], its structure [26], [27], [28], the distributed acquisition processes [29] and the intelligent systems technologies associated to the knowledge discovery [30].

The interaction between knowledge based systems and discovery systems has antecedents in the paradigm of integrated architectures of planning and learning based on theories construction [31], [32], [33], [34], [35], [36] and hybrid architectures of learning [37], [38], [39].

In this context, this paper introduces the problem (section 2), an integrative proposal is formulated (section 3), components are identified (section 3.1) as well as the interaction between them (section 3.2), an example is provided that partially illustrates how the workspace would work (section 4). Finally future research work lines are mentioned (section 5).

2. PROBLEM

Recent works in decision making systems in strategic – operational workspace based on KBS [36], like air control [9] or naval units readiness areas [40], show that it is an open problem to define how KBS can be integrated to knowledge discovery processes based on machine learning [35] that allow them to improve "on-line" the quality of the knowledge base used for decision making. Approaches for solving this type of problem are addressed for incremental improvement of decision making systems in office automation area [41], [42], [43], [44].

3. TOWARD AN INTEGRATIVE PROPOSAL

In this section the components of the integrative proposal are presented (section 3.1) as well as the interactions between these components (section 3.2).

3.1. Identification of the components

3.1.1. The bases. This section describes: the knowledge base, the concepts dictionary, the examples base, the records base, the clustered records base, the clustered/classification rules base, the discovered rules base and the updated knowledge base.

Knowledge Base. This base contains the problem domain knowledge deduced by the knowledge engineer, which contributes with the knowledge pieces (rules) applicable to the resolution of the problem outlined by the user of the system.

Concepts Dictionary. This base stores the registration of all the concepts used in the different knowledge pieces (rules) that integrate the Knowledge Base. For each concept it keeps registration of the corresponding attributes and the possible values of each attribute

Examples Base. This base keeps examples of elements that belong to different classes. The attributes of these examples should keep correlativity or should be coordinated with the attributes of the concepts described in the Concepts Dictionary.

Records Base. This base keeps homogeneous records of information which are associated to some process of knowledge discovery. (I/E clustering).

Clustered Records Base. This base keeps homogeneous records of information which are clustered in classes without labeling (clusters) as a result of applying the clustering process to the Records Base.

Clustering/Classification Rules Base. This base keeps knowledge pieces (rules) discovered automatically as a result of applying the induction process to the Clustered Records Base and the Examples Base

Discovered Rules Base. This base keeps knowledge pieces (rules) related to the problem domain as result of applying the labeling conceptual process to the discovered knowledge pieces (rules) that are stored in the Clustering/Classification Rules Base.

Updated Knowledge Base. This base encapsulates the knowledge that becomes from the integration of the problem domain knowledge pieces (rules) educed by the knowledge engineer and the knowledge pieces (rules) discovered automatically as a result of the application of the processes of clustering/induction to the Records Base or induction to the Examples Base.

3.1.2. The processes. This section describes the processes: cluster, Inducer, conceptual labeler, knowledge integrator and inference engine.

Cluster. This process is based on the use of self organized maps (SOM) to generate groups of records that are in the Records Base. These groups are stored in the Clustered Records Base.

Inducer. This process is based on the use of induction algorithms to generate clustering rules beginning from the records groups that are in the Clustered Records Base and Classification Rules beginning from the records that are in the Examples Base.

Conceptual Labeler. This process is based on the use of the Concepts Dictionary and the Clustering/Classification Rules Base to generate the Discovered Rules Base. This process transforms the knowledge pieces obtained into pieces of coordinated knowledge with the Knowledge Base.

Knowledge Integrator. This process generates the Updated Knowledge Base from the Discovered Rules Base and the Knowledge Base, solving all the integration problems between them.

Inference Engine. It is the process that automates the reasoning to solve the problem outlined by the user, beginning from the pieces of knowledge available in the Updated Knowledge Base or Knowledge Base.

3.2. Interaction among components

The interaction among the different components is shown in Figure 1. The Knowledge Base encapsulates the necessary pieces of knowledge (rules) for the resolution of domain problems. This interaction with the inference engine constitutes the Knowledge Based System (Expert System). Beginning from the concepts / attributes / values that are present in the different pieces of knowledge inside the Knowledge Base, the Concepts Dictionary is built. The pieces of knowledge (rules) that are in the Clustering/Classification Rules Base can present the characteristic of not being coordinated with the available pieces of knowledge in the Knowledge Base when: [a] a situation of knowledge discovery takes place because the Inducer generated a Clustering / Classification Rules Base, or [b] because this has become from an Examples Base or a Clustered Records Base resulting from applying the Cluster to a Records Base. In this context the Conceptual Labeler transforms the knowledge pieces of the Clustering/Classification Rules Base into coordinated knowledge pieces with those rules corresponding to the Knowledge Base generating the Discovered Rules Base. The Knowledge Integrator takes the Discovered Rules Base and (solving the emergent integration problems) integrates it into the Knowledge Base, generating the Updated Knowledge Base, that becomes the new Knowledge Base and the cycle is restarted.

4. AN EXAMPLE

Let us consider, for example, the operation costs establishment problem in a ships owner company in function of the ship type to operate in a certain port.

Consider the Knowledge Base whose rules are exemplified in table 1. Consider the Concepts Dictionary associated to this Knowledge Base shown in the table 2.

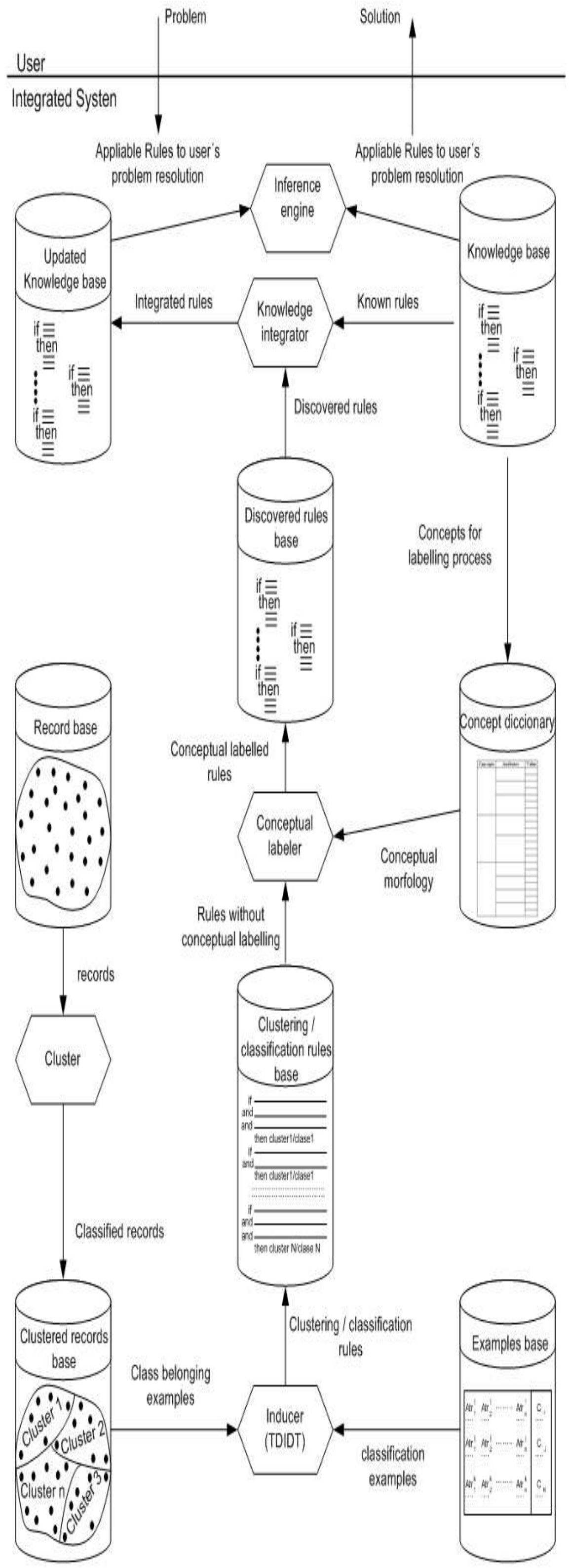

Figure 1. Interaction among different components

IF	SHIP.SHIP_TYPE= BULK CARRIER
AND	SHIP.SIZE= LARGE
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESSS= FREEWAY
THEN	COSTS.PIER_LONG= ENLARGE
AND	COSTS.MOORING_TIME= HABITUAL
IF	SHIP.SHIP_TYPE= BULK CARRIER
AND	SHIP.SIZE= MEDIUM
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESS:FREEWAY
THEN	COSTS.PIER_LONG= ENLARGE
AND	COSTS.MOORING_TIME= HABITUAL
IF	SHIP.SHIP_TYPE= BULK CARRIER
AND	SHIP.SIZE= SMALL
AND	PORT.PORT_FACILITIES:VERY GOOD
AND	ACCESSS= FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COSTS MOORING_TIME= SHORT
IF	SHIP.SHIP_TYPE= TANKER
AND	SHIP.SIZE= LARGE
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESSS:FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COSTS.MOORING_TIME:HABITUAL
IF	SHIP.SHIP_TYPE= TANKER
AND	SHIP.SIZE= MEDIUM
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESSS= FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COSTS.MOORING_TIME= HABITUAL
IF	SHIP.SHIP_TYPE= TANKER
AND	SHIP.SIZE= SMALL
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESSS= FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COTS.PORT.MOORING_TIME= SHORT
IF	SHIP.SHIP_TYPE= CONTAINER
AND	SHIP.SIZE= LARGE
AND	PORT- PORT_FACILITIES= V. GOOD
AND	PORT.ACCESSS:FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COSTS.MOORING_TIME:SHORT
IF	SHIP.SHIP_TYPE= CONTAINER
AND	SHIP. SIZE= MEDIUM
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESSS= FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COSTS.MOORING_TIME= SHORT
IF	SHIP.SHIP_TYPE= CONTAINER
AND	SHIP.SIZE= SMALL
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESSS= FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COSTS.MOORING_TIME= SHORT
IF	SHIP.SHIP_TYPE= PASENGER
AND	SHIP.SIZE= LARGE
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESS= FREEWAY
THEN	COSTS.PIER_LONG= REDUCED
AND	COSTS.MOORING_TIME= HABITUAL
IF	SHIP.SHIP_TYPE= PASENGER
AND	SHIP.SIZE= MEDIUM
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESS= FREEWAY
THEN	COSTS.PIER_LONG= REDUCED
AND	COSTS.MOORING_TIME= HABITUAL
IF	SHIP.SHIP_TYPE= PASENGER
AND	SHIP.SIZE= SHORT
AND	PORT.PORT_FACILITIES= VERY GOOD
AND	PORT.ACCESS= FREEWAY
THEN	COSTS.PIER_LONG= NORMAL
AND	COSTS.MOORING_TIME= SHORT

Table 1. Knowledge Base

Concept	Attribute	Value
SHIP	SHIP_TYPE	BULK CARRIER
		CONTAINER
		TANKER
		PASSENGER
	SIZE	SMALL
		MEDIUM
		LARGE
PORT	PORT_FACILITIES	VERY GOOD
		GOOD
		REGULAR
		POOR
	ACCESSS	FREEWAY
		ROUTE
		ROAD
		TRACK
COSTS	PIER_LONG	REDUCED
		NORMAL
		ENLARGE
	MOORING_TIME	SHORT
		HABITUAL
		EXTEND

Table 2. Dictionary of Concepts

On the other hand, consider the Examples Base described in the Table 3.

SHIP _TYPE	SIZE	PORT _FAC	ACCESSS	PIER _LONG	MOORING _TIME
Bulk Carrier	Large	Very Good	Freeway	Enlarge	Habitual
Bulk Carrier	Medium	Very Good	Freeway	Enlarge	Habitual
Bulk Carrier	Small	Very Good	Freeway	Enlarge	Short
Tanker	Large	Very Good	Freeway	Normal	Habitual
Tanker	Medium	Very Good	Route	Normal	Habitual
Tanker	Small	Very Good	Road	Normal	Short
Container	Large	Very Good	Freeway	Normal	Short
Container	Medium	Very Good	Freeway	Normal	Short
Container	Small	Very Good	Freeway	Normal	Short
Passenger	Large	Very Good	Freeway	Normal	Habitual
Passenger	Medium	Very Good	Freeway	Reduced	Habitual
Passenger	Small	Very Good	Freeway	Reduced	Short

Table 3. Examples Base

From the Examples Base the Inducer generates the Classification Rules Base shown in the table 4. The Conceptual Labeler identifies the belonging of values to the domain of attributes in Concepts Dictionary generating the Discovered Rules Base shown in the table 5.

```
IF      SHIP_TYPE= CONTAINER
THEN    MOORING_TIME= SHORT

IF      SHIP_TYPE= CONTAINER
THEN:   PIER_LONG= NORMAL

IF      SHIP_TYPE= BULK CARRIER
THEN    PIER_LONG= ENLARGE
```

Table 4. Classifications Rules Base

```
IF SHIP SHIP_TYPE= CONTAINER
THEN COSTS MOORING_TIME= SHORT

IF SHIP SHIP_TYPE= CONTAINER
THEN: COSTS PIER_LONG= NORMAL

IF SHIP SHIP_TYPE= BULK CARRIER
THEN COSTS PIER_LONG= ENLARGE
```

Table 5. Discovered Rules Base

The Knowledge Integrator analyzes the Discovered Rules Base, verifying that there are no integration conflicts and proceeds to integrate it to the Knowledge Base generating the Updated Knowledge Base shown in the Table 6. This last one becomes the new Knowledge Base.

```
IF       SHIP.SHIP_TYPE= BULK CARRIER
AND      SHIP.SIZE= LARGE
AND      PORT.PORT_FACILITIES= VERY GOOD
AND      PORT.ACCESSS= FREEWAY
THEN     COSTS.PIER_LONG= ENLARGE
AND      COSTS.MOORING_TIME= HABITUAL

IF       SHIP.SHIP_TYPE= BULK CARRIER
AND      SHIP.SIZE= MEDIUM
AND      PORT.PORT_FACILITIES= VERY GOOD
AND      PORT.ACCESS:FREEWAY
THEN=    COSTS.PIER_LONG= ENLARGE
AND      COSTS.MOORING_TIME= HABITUAL

IF       SHIP.SHIP_TYPE= BULK CARRIER
AND      SHIP.SIZE= SMALL
AND      PORT.PORT_FACILITIES:VERY GOOD
AND      ACCESSS= FREEWAY
THEN     COSTS.PIER_LONG= NORMAL
AND      COSTS MOORING_TIME= SHORT

IF       SHIP.SHIP_TYPE= TANKER
AND      SHIP.SIZE= LARGE
AND      PORT.PORT_FACILITIES= VERY GOOD
AND      PORT.ACCESSS:FREEWAY
THEN     COSTS.PIER_LONG= NORMAL
AND      COSTS.MOORING_TIME:HABITUAL

IF       SHIP.SHIP_TYPE= TANKER
AND      SHIP.SIZE= MEDIUM
AND      PORT.PORT_FACILITIES= VERY GOOD
AND      PORT.ACCESSS= FREEWAY
THEN     COSTS.PIER_LONG= NORMAL
AND      COSTS.MOORING_TIME= HABITUAL

IF       SHIP.SHIP_TYPE= TANKER
AND      SHIP.SIZE= SMALL
AND      PORT.PORT_FACILITIES= VERY GOOD
AND      PORT.ACCESSS= FREEWAY
THEN     COSTS.PIER_LONG= NORMAL
AND      COTS.PORT.MOORING_TIME= SHORT

IF       SHIP.SHIP_TYPE= CONTAINER
AND      SHIP.SIZE= LARGE
AND      PORT- PORT_FACILITIES= V. GOOD
AND      PORT.ACCESSS:FREEWAY
THEN     COSTS.PIER_LONG= NORMAL
AND      COSTS.MOORING_TIME:SHORT

IF       SHIP.SHIP_TYPE= CONTAINER
AND      SHIP. SIZE= MEDIUM
AND      PORT.PORT_FACILITIES= VERY GOOD
AND      PORT.ACCESSS= FREEWAY
THEN     COSTS.PIER_LONG= NORMAL
AND      COSTS.MOORING_TIME= SHORT

IF       SHIP.SHIP_TYPE= CONTAINER
AND      SHIP.SIZE= SMALL
AND      PORT.PORT_FACILITIES= VERY GOOD
AND      PORT.ACCESSS= FREEWAY
THEN     COSTS.PIER_LONG= NORMAL
AND      COSTS.MOORING_TIME= SHORT

IF       SHIP.SHIP_TYPE= PASENGER
```

```
AND     SHIP.SIZE= LARGE
AND     PORT.PORT_FACILITIES= VERY GOOD
AND     PORT.ACCESS= FREEWAY
THEN    COSTS.PIER_LONG= REDUCED
AND     COSTS.MOORING_TIME= HABITUAL

IF      SHIP.SHIP_TYPE= PASENGER
AND     SHIP.SIZE= MEDIUM
AND     PORT.PORT_FACILITIES= VERY GOOD
AND     PORT.ACCESS= FREEWAY
THEN    COSTS.PIER_LONG= REDUCED
AND     COSTS.MOORING_TIME= HABITUAL

IF      SHIP.SHIP_TYPE= PASENGER
AND     SHIP.SIZE= SHORT
AND     PORT.PORT_FACILITIES= VERY GOOD
AND     PORT.ACCESS= FREEWAY
THEN    COSTS.PIER_LONG= NORMAL
AND     COSTS.MOORING_TIME= SHORT

IF      SHIP.SHIP_TYPE = CONTAINER
THEN    COSTS.MOORING_TIME= SHORT

IF      SHIP.SHIP_TYPE= CONTAINER
THEN    COSTS.PIER_LONG= NORMAL

IF      SHIP.SHIP_TYPE= BULK CARRIER
THEN    COSTS. PIER_LONG= ENLARGE
```

Table 6. Updated Knowledge Base

5. RELATED WORK

The automatic discovery of useful knowledge pieces is a topic of growing interest in the expert systems engineering community [45], [46], [47]. Our work differs from those mentioned before in the proposal of a combined mechanism for rules obtaining, using self-organized maps based on clustering and induction algorithms. On the other hand, the identification of the necessary processes allows the autonomous assimilation of the knowledge pieces generated by the expert system. Knowledge discovery integration process models based on connectionist models [48], [49], [50], reasoning models based on cases [51], not expected patterns generation models [52], genetic algorithms [53], and technical categorization heuristics [54] have been proposed recently in order to dispose automatic processes for incremental improvement of the intelligent systems response applied to the specific problems resolution. This proposal differs from the one mentioned above in the fact that it proposes a knowledge discovery integration model (rules centered) with expert systems environment, identifying the technology needed to be used to solve this integration.

6. FUTURE LINES OF WORK

In the different processes and how these processes interact with the different bases, some problems have been identified, whose solution is foreseen to work: In the Inducer: how to use the support groups to provide a degree of credibility (trust) to the knowledge piece (rule) generated; in the Conceptual Labeler: [a] define the treatment to give to attributes values of concepts that are in the discovered rules but not in the Concepts Dictionary that emerges from the original Knowledge Base of the Knowledge Based System and [b] how to rewrite the ownership to a certain group (right part of the rule) in terms of values of attributes of well-known concepts when the knowledge pieces (rules) result from applying the Inducer to the Cluster. In the Knowledge Integrator, we should define the treatment to apply when the integration process between the rules of the Knowledge Base and the discovered rules arise: [a] conditions of dead point, [b] recurrent rules, [c] redundant rules, [d] contradictory rules, and [e] rules with conflicts of support evidence, among others. "A priori" measures should be developed to establish the quality of the knowledge discovery process and the degree of integrability to the existent Knowledge Base. The improvement of a Knowledge Base with discovered knowledge pieces in automatic way can lead to a degradation of the original Knowledge Base, so it is necessary to explore (theoretically at least) which are the curves of degradation of the quality process of knowledge discovery identifying border conditions for the model in the developed theoretical frame.

7. REFERENCES

[1] Sierra, E., Hossian, A. y García-Martínez, R. 2003. *Sistemas Expertos que Recomiendan Estrategias de Instrucción. Un Modelo para su Desarrollo*. Revista Latinoamericana de Tecnología Educativa. 1(1): 19-30.

[2] Sierra, E., Hossian, A., García-Martínez, R. y Marino, P.2005. *Sistema Experto para Control Inteligente de las Variables Ambientales de un Edificio Energéticamente Eficiente.* Proc. XI Reunión de Trabajo en Procesamiento de la Información y Control. pp. 446-452.

[3] Bermejo, F., Britos, P., Rossi, B y García Martínez, R. 2002. *Sistema de Asistencia para la Configuración de Ventiladores OAF en Neonatolgía.* Revista del Instituto Tecnológico de Buenos Aires. 28: 24-68.

[4] Gómez, S., Perichinsky, G. y Garcia Martinez, R. 2001. *Un Sistema Experto Legal para la Individualización y Acuerdos para Penas.* Proc. Simposio Argentino de Informática y Derecho. pp. 23-33.

[5] Diez, E., Britos, P., Rossi, By García-Martínez, R. 2003. *Generación Asistida del Mapa de Actividades de Proyectos de Desarrollo de Software*. Reportes Técnicos en Ingeniería del Software. 5(1):13-18.

[6] García-Martínez, R. y Britos, P. 2004. *Ingeniería de Sistemas Expertos.* Editorial Nueva Librería.

[7] Britos, P. 2001. *Sistema de Ayuda sobre Legislación Argentina en Riesgos de Trabajo*". Tesis de Magíster en Ingeniería del Conocimiento. Facultad de Informática de la Universidad Politécnica de Madrid.

[8] Rizzi, M. 2001. *Sistema Experto Asistente de Requerimientos*. Tesis de Magister en Ingeniería del Software. Escuela de Posgrado del Instituto Tecnológico de Buenos Aires.

[9] Ierache, J. y Garcia-Martinez, R. 2004. *Sistema Experto Aplicado al Control del Espacio Aéreo.* Proc. IX Congreso Argentino de Ciencias de la Computación.

[10] Hossian, A. 2003. *Sistema de Asistencia para la Selección de Estrategias y Actividades Instruccionales*. Tesis de Magister en Ingeniería del Software. Escuela de Posgrado del Instituto Tecnológico de Buenos Aires.
[11] Debenham, J. 1990. *Knowledge Systems Design*. Prentice Hall.
[12] Debenham, J. 1998. *Knowledge Engineering: Unifying Knowledge Base and Database Design*. Springer-Verlag.
[13] Gomez, A., Juristo, N., Montes, C. y Pazos, J. 1997. *Ingeniería del Conocimiento*. Editorial R. Areces. Madrid.
[14] Michalski, R. S. 1991. *Toward an Unified Theory of Learning: An Outline of Basic Ideas*, Proc. 3rd World Conference on the Fundamentals of AI.
[15] DeJong, G.F., Mooney, R.J. 1986. *Explanation-Based Learning: An Alternative View*, Machine Learning, 1: 145-176.
[16] Michalski, R. S., Carbonell, J. G., Mitchell, T. M. (eds.). 1983. *Machine Learning: An Artificial Intelligence Approach, Vol. I*. Morgan-Kauffman
[17] Michalski, R. S., Carbonell, J. G., Mitchell, T. M. (eds.), 1986. *Machine Learning: An Artificial Intelligence Approach, Vol. II*, Morgan-Kauffman
[18] Michalski, R. Bratko, I. Kubat, M (eds.) 1998. *Machine Learning and Data Mining, Methods and Applications*, John Wiley & Sons Ltd, West Sussex, England
[19] Michalski, R. S., Tecuci, G. (eds) 1994. *Machine Learning: A Multistrategy Approach, Vol. III*, Morgan Kauffman
[20] Mitchell, T. M. 1996. *Machine Learning*, McGraw-Hill.
[21] Michie, D. 1988. *Machine Learning in the next five years*, EWSL-88, 3rd European Working Session on Learning, Glasgow, Londres, Pitman.
[22] Fayad, U. M., Piatetsky-Shapiro, G., Smyth, P., Uhturudsamy, R. (eds). 1996. *Advances in Knowledge Discovery and Data Mining*, San Mateo, AAAI Press.
[23] Grossman, R., Kasif, S., Moore, R., Rocke, D. and Ullman, J. 1999. *Data Mining Research: Opportunities and Challenges*, A Report of three NSF Workshops on Mining Large, Massive, and Distributed Data, January 1999, Chicago
[24] Evangelos, S., Han, J, (eds). 1996. Proc. of the Second International Conference on Knowledge Discovery and Data Mining, Portland, EE.UU.
[25] Jensen D. 2002. *Knowledge Evaluation*. Handbook of Data Mining and Knowledge Discovery. Kloesgen, W. and J. Zytkow (Eds.). Oxford: Oxford University Press
[26] Utgoff P., V. Lesser, and D. Jensen 2000. *Inferring task structure from data*. University of Massachusetts, Department of Computer Science. Technical Report UM-CS-2000-054.
[27] Jensen D. and J. Neville 2002. *Schemas and models*. Proc. Multi-Relational Data Mining Workshop, 8th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining.
[28] Neville J. and D. Jensen 2002. *Supporting relational knowledge discovery: Lessons in architecture and algorithm design*. Proc. Data Mining Lessons Learned Workshop, 19th International Conference on Machine Learning.
[29] Jensen D., Y. Dong, B. Lerner, E. McCall, L. Osterweil, S. Sutton Jr., and A. Wise 1999. *Coordinating agent activities in knowledge discovery processes*. In Proc. International Joint Conference on Work Activities Coordination and Collaboration. pp. 137-146.
[30] Britos, P., Hossian, A., García Martínez, R. y Sierra, E. 2005. *Minería de Datos Basada en Sistemas Inteligentes.* 876 páginas. Editorial Nueva Librería. ISBN 987-1104-30-8.
[31] Fritz, W., García Martínez, R., Rama, A., Blanqué, J., Adobatti, R, y Sarno, M. 1989. *The Autonomous Intelligent System*. Robotics and Autonomous Systems, 5(2): 109-125.
[32] García Martínez, R. & Borrajo Millán, D. 1996. *Unsupervised Machine Learning Embedded in Autonomous Intelligent Systems.* Proc. XIV International Conference on Applied Informatics. pp 71-73.
[33] García Martínez, R. y Borrajo Millán, D. 1997. *Planning, Learning and Executing in Autonomous Systems*. Lecture Notes in Artificial Intelligence. 1348:208-210.
[34] García Martínez, R. & Borrajo Millán, D. 1998. *Learning in Unknown Environments by Knowledge Sharing.* Proc. Seventh European Workshop on Learning Robots. pp 22-32.
[35] García Martínez, R. y Borrajo Millán, D. 2000. *An Integrated Approach of Learning, Planning and Executing*. Journal of Intelligent and Robotic Systems 29(1):47-78.
[36] Sierra, E., García-Martínez, R., Hossian, A., Britos, P. y Balbuena, E. 2006. *Providing Intelligent User-Adapted Control Strategies in Building Environments*. Research in Computing Science Journal, 19: 235-241.
[37] Grosser, H., Britos, P. y García-Martínez, R. 2005. *Detecting Fraud in Mobile Telephony Using Neural Networks*. Lecture Notes in Artificial Intelligence 3533: 613-615.
[38] Felgaer, P., Britos, P. and García-Martínez, R. 2006. *Prediction in Health Domain Using Bayesian Network Optimization Based on Induction Learning Techniques*. International Journal of Modern Physics C 17(3): 447-455.
[39] Cogliati, M., Britos, P. y García-Martínez, R. (2006). *Patterns in Temporal Series of Meteorological Variables Using SOM & TDIDT*. Springer IFIP Series..
[40] Rancán, C. 2004. *Arquitectura de Sistema Híbrido de Evaluación del Alistamiento de Unidades Navales Auxiliares*. Reportes Técnicos en Ingeniería del Software. 6(1): 45-54.
[41] La Battaglia, J., Rodriguez, I., Thomas, P., Pesado, P., Bertone, R. 2003. *Tecnología aplicada a gestión distribuida*. Proc. de las XI Jornadas de Jóvenes Investigadores AUGM 2003. Universidad Nacional de La Plata – Argentina.
[42] Miatón, I., Pesado, P., Bertone, R. y De Giusti. 2003. *Agentes Basados en Sistemas Distribuidos*. Proc. V Workshop de Investigadores en Ciencia de la Computación.
[43] De Giusti E., Mollo Brisco G., La Battaglia, J., Pasini, A. y Pesado, P. 2004. *Sistema de Simulación de Escenarios y Decisiones Empresarias*. Proc. XII

Jornadas de Jóvenes Investigadores AUGM 2004. Universidad Federal Do Paraná - Curitiba, Brasil.

[44] Pesado, P. Feierherd G. y Pasini, A. 2005. *Requirement Specifications for Electronic Voting System*. Journal of Computer Science & Technology, 5(4): 312-319 .

[45] Hoffmann, F., Baesens, B., Mues, C. and Vanthienen, J. 2006. *Inferring descriptive and approximate fuzzy rules for credit scoring using evolutionary algorithms*. European Journal of Operational Research. (in press).

[46] Cao, H., Recknagel, F. Joo, G., Kim, D. 2006. *Discovery of predictive rule sets for chlorophyll-a dynamics in the Nakdong River (Korea) by means of the hybrid evolutionary algorithm HEA*. Ecological Informatics, 1(1): 43-53.

[47] Podgorelec, V., Kokol, P., Stiglic, M., Heričko, M., Rozman, I. 2005. *Knowledge discovery with classification rules in a cardiovascular dataset*. Computer Methods and Programs in Biomedicine, 80: S39-S49.

[48] Huang, M., Tsou, Y., Lee, S. 2006. *Integrating fuzzy data mining and fuzzy artificial neural networks for discovering implicit knowledge*. Knowledge-Based Systems, 19(6): 396-403.

[49] Kasabov, K. 2006. *Adaptation and interaction in dynamical systems: Modelling and rule discovery through evolving connectionist systems***.** Applied Soft Computing, 6(3): 307-322.

[50] Carpenter, G., Martens, S., Ogas, O. 2005. *Self-organizing information fusion and hierarchical knowledge discovery: a new framework using ARTMAP neural networks*. Neural Networks, 18(3): 287-295.

[51] Liu, D., Ke, C. 2006. *Knowledge support for problem-solving in a production process: A hybrid of knowledge discovery and case-based reasoning*. Expert Systems with Applications. (in press).

[52] Moreno, M., Quintales, L., García, F., Polo, J. 2004. *Building knowledge discovery-driven models for decision support in project management*. Decision Support Systems, 38(2): 305-317.

[53] Kim, M., Han, I. 2003. *The discovery of experts' decision rules from qualitative bankruptcy data using genetic algorithms* Expert Systems with Applications, 25(4): 637-646.

[54] Leigh, W., Modani, N., Purvis, R., Roberts, R. 2002. *Stock market trading rule discovery using technical charting heuristics***.** Expert Systems with Applications, 23(2): 155-159.