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Connectionist and Rapid Prototyping for Analyzing and Forecasting Data Series TIC2003-08807-C02

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Abstract

Data series are multidimensional variable sequences which are indexed by means of the values of a one-dimensional variable. Classic methods for analyzing these data series impose restrictions which are rarely satisfied in real problems. As a result, research began several years ago in order to adapt pattern learning and recognition techniques developed in the field of artificial intelligence to data series analysis, and this project is set within this line. We shall examine not only dynamic recurrent neural networks, decision trees and hybrid methods but also numeric learning and quick prototyping tools for analyzing and predicting data series. In addition, the obtaining of the equivalent rule-based systems allows implicit knowledge to be described in the series in terms which are acceptable for the users. Theoretical developments shall be contrasted through experimentation on real data. We shall focus on two types of problems: the analysis of data from the management of both public and private economic units, paying special attention to problems such as predicting economic-financial risks, value models, etc.; and the study of data series modeling in biomechanics, and in particular the series from the sampling of the characteristic variables of human arm and leg movement.

Keywords: Data Series, Dynamic Recurrent Neural Networks, Time Series, Evolutionary algorithms, Multiobjective Optimization, Temporal Fuzzy Chains, Biomechanical modeling.

1 Project aims

1.1 Introduction

Data series are sequences of values of a multi-dimensional variable which are indexed by means of another, usually one-dimensional, variable and which generalize the time series idea. Classic methods for analyzing and forecasting these data series are basically statistical, and generally impose restrictions which are rarely satisfied in real problems. For this reason, a fruitful line of research began several years ago into adapting pattern learning and recognition techniques

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developed in the field of artificial intelligence to data series analysis. As the hypotheses of these adapted techniques are much more lenient than those imposed by classic methods, they therefore have greater applicability. If we refer to specialist literature, we can see that research has been carried out into various tools which have become known as “intelligent computation” (artificial neural networks, flexible computation, evolutionary algorithms, regression trees, etc.), revealing the appearance in recent years of ad hoc-developed techniques within the emerging approach known as “data mining”.

It is evident that connectionist models (neural networks and associative memories), and also certain fuzzy system models, which have been designed “ad hoc” due to the difficulty of identifying them in the case of time dependent data, have so far generally produced the best results. The employment of dynamic recurrent neural networks has also been analyzed in order to identify an automaton which symbolically describes the overall behavior of a series. We shall pay special attention to this matter by using the results of some of our previous research and by combining dynamic recurrent neural networks with evolutionary algorithms.

Although decision and regression trees are pattern recognition tools which are not widely used in the field of time series, they have been successfully applied in order to identify extremely efficient description rule-based systems, which are both predictive and causal of a specific time series. For this reason, we shall explore in greater depth the possibility of analyzing and predicting data series by means of regression trees.

In this project, we therefore propose to examine the use of dynamic recurrent neural networks and hybrid methods as numerical learning tools for analyzing and predicting data series and the obtaining of equivalent rule-based systems which allow the results (the implicit knowledge in the series) to be described in terms which users can accept and understand. Our general aim is to enrich the panorama of tools for analyzing and predicting data series, which is of interest in many fields, and we shall focus on two of these: firstly, the description of the behavior of an economic unit, and secondly, the description of human movements.

The experiments of the first subproject shall focus on predicting the behavior of an economic unit, while those of the second shall focus on describing human movements; the models obtained shall then be shared and compared. The key to the advantages obtained from coordination lies in the fact that both the description of the behavior of an economic unit and the temporal space description of a human movement may be formulated in similar way to a set of evolving variables. The final result shall be to have a wider battery of contrasted prediction tools in problems of a very diverse nature and origin, although all within the analysis and prediction of data series.

In the following sections, in addition to the general objectives which we have previously described, we shall break down the objectives for the different subprojects, including in each case the work which must be carried out within the scheduled coordination.

1.2. Subproject 1 Objectives: Connectionist Models and Hybrid Methods for Analyzing and Predicting Data Series (MONADA)

General objectives

- To research specific design and learning methods based on evolutionary algorithms for recurrent dynamic networks which are more efficient than current ones.

- To study the problem of analyzing and predicting data series, mainly in the sphere of economic-financial risk prevention, assessment, corporate trajectory (using the models developed in O.1 for this purpose). Similarly, the results obtained shall be compared with those provided by other classic and non-classic techniques.
- To compare the techniques and models developed in this subproject with those obtained in Subproject 2. We shall place special emphasis on the data series prediction experiments of the economic-financial risk of both private and public economic units.
- To develop (if required) the necessary economic models for interpreting the results of the previous experimental studies.
- To develop the necessary software tools for implementing the obtained results.

Specific objectives

- To develop methods to determine the optimum topology of a dynamic recurrent network.
- To develop training methods which are more efficient than current ones (mainly based on error minimization by means of decreasing gradient).

For the development of specific objectives, we propose that evolutionary algorithms be used, in particular classic genetic algorithms with real coding (generational model, stationary model), multimodal evolutionary algorithms, and multiobjective evolutionary algorithms. Beginning with data series about the evolution and viability of economic units, we shall establish a segmentation criterion by means of dynamic recurrent networks which have been constructed and trained to enable the economic-financial risk of economic units to be predicted, and we shall study assessment models which can be applied to these. The results obtained will be contrasted with those generated by classic and non-classic techniques, particularly with other connectionist models such as associative memories.

1.3. Subproject 2 Objectives: Soft-Computing Methods for Analyzing and Categorizing Data Series (DIMOCLUST)

General objectives

- To research the improvement of the methods studied (i.e. ADRI and Temporal Fuzzy Chains) which enable their inference quality to be increased in order to reduce their estimated error.
- To study the possibility of establishing metrics which enable us to compare structural models such as ADRO or CDT.
- To focus the field of study on the data series of human movements for biomechanical analysis and study.
- To compare the techniques and models studied in this subproject with those obtained in Subproject 1.

- To develop the necessary software tools to implement the obtained results.

Specific objectives

- To incorporate mechanisms to minimize error on a local level. To research the effectiveness of evolutionary methods such as classic genetic algorithms.
- To study the improvement of the models studied, when expert information is incorporated a priori in the form of linguistic labels.
- To research methods and algorithms in order to equip our models with the facility of identifying cycles in the data series.
- To quantify the models by means of measurements on the number of elements, structural complexity, etc.
- To see whether it is possible to establish a segmentation of the models studied by using the suggested measurements.

1.4. Time diagram

In order to achieve these objectives, we have subdivided the work into the following subtasks:

- T1.1 Review of the techniques for designing and learning dynamic recurrent neural networks (9 months).
- T1.2 Review of the techniques for designing and learning dynamic recurrent neural networks based on the use of evolutionary algorithms (21 months).
- T1.3 Software specification and construction (18 months).
- T1.4 Review of the techniques for analyzing and predicting the behavior of an economic unit (9 months).
- T1.5 Adaptation and use of the methodologies developed in this subproject for analyzing and predicting the behavior of an economic unit (21 months).
- T1.6 Analysis and prediction of movement series (18 months).
- T1.7 Setting up, running and maintenance of an information and development server through the creation of a small Intranet which would enable us to use collaborative tools; development of centralized software; and publication of all developments and results (30 months).
- T2.1.1 Training in motion capture instrumentation to be used (3 months).
- T2.1.2 Capture and digitalize motion images of people (both top-class athletes and sportspeople and also amateurs) doing sport (27 months).
- T2.2.1 Study and updating of local model adjustment techniques (9 months).
- T2.2.2 Selection of alternative techniques and their incorporation into current software (9 months).
- T2.2.3 Running of model induction using constructed software (12 months).
- T2.3.1 Study and updating of techniques for parametric and non-parametric segmentation (clustering) (9 months).

- T2.3.2 Study and updating of segmentation and identification techniques based on expert knowledge (9 months).
- T2.3.3 Study of hybrid segmentation mechanisms based on data and expert knowledge (12 months).
- T2.4 Analysis and prediction of economic time series (18 months).
- T2.5.1 Creation and setting up of a group corporative server (18 months).
- T2.5.2 Development of an application to standardize all the achievements of the subproject (12 months).
- C1 Exchange of models and techniques. Study and monitoring of the development of the combined models (30 months).
- C2 Specification and description of the software to be developed (24 months).
- C3 Standardization of results (6 months).
- C.4 During project execution, at regular intervals, meetings will be held as necessary between the two main researchers and team components to monitor the development of the work and the landmarks reached.

Table 1 below shows the time diagram for the coordination of the different tasks.

Table 1: Time diagram and task distribution

<table>
<tr><th>Tasks</th><th>First year</th><th>Second year</th><th>Third year</th></tr>
<tr><td>T1.1</td><td>x|x|x|x|x|x|x|x|x| | |</td><td>| | | | | | | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>T1.2</td><td>| | | | | | | | |x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | |</td></tr>
<tr><td>T1.3</td><td>| | | | | | | | | | |</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td></tr>
<tr><td>T1.4</td><td>x|x|x|x|x|x|x|x|x| | |</td><td>| | | | | | | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>T1.5</td><td>| | | | | | | | |x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td></tr>
<tr><td>T1.6</td><td>| | | | | | | | | | |</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td></tr>
<tr><td>T1.7</td><td>| | | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>T2.1.1</td><td>X| x| x| | | | | | | | |</td><td>| | | | | | | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>T2.1.2</td><td>| | | x| x| x| x| x| x| x| x</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td></tr>
<tr><td>T2.2.1</td><td>X|x|x|x|x|x|x|x|x| | |</td><td>| | | | | | | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>T2.2.2</td><td>| | | | | | | | |x|x|x</td><td>x|x|x|x|x|x| | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>T2.2.3</td><td>| | | | | | | | | | |</td><td>| | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | |</td></tr>
<tr><td>T2.3.1</td><td>x|x|x|x|x|x|x|x|x| | |</td><td>| | | | | | | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>T2.3.2</td><td>| | | | | | | | |x|x|x</td><td>x|x|x|x|x|x| | | | | |</td><td>| | | | | | | | | | |</td></tr>
<tr><td>T2.3.3</td><td>| | | | | | | | |x|x|x</td><td>| | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td></tr>
<tr><td>T2.4</td><td>| | | | | | | | | | |</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x| | | | | |</td></tr>
<tr><td>T2.5</td><td>| | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>Coordination</td><td></td><td></td><td></td></tr>
<tr><td>C1</td><td>| | | | | |x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>C2</td><td>| | | | | | | | | | |</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td></tr>
<tr><td>C.3</td><td>| | | | | | | | | | |</td><td>| | | | | | | | | | |</td><td>| | | | | |x| x| x| x| x|x</td></tr>
<tr><td>C4</td><td>x|x|x|x|x|x|x|x|x|x|x|x |</td><td>x|x|x|x|x|x|x|x|x|x|x</td><td>x|x|x|x|x|x|x|x|x|x|x</td></tr>
</table>

2 Project progress and achievements

According to the work schedule proposed in Table 1, after slightly over a year and a half of work, the state of the evolution of the project is on course. In accordance with the proposed actions (see Section 1.4), the relevant results obtained are outlined in the following section.

2.1. Summary of the scientific results and techniques obtained for Subproject 1.

The proposal of this subproject includes both the theoretical development and the construction of software which enables it to be applied in data series prediction problems. Research is currently quite well advanced, borne out by publications in national and international congresses and journals. The experiments carried out have shown the viability of the project, producing satisfactory results in benchmark problems which have been widely used in the bibliography and also in certain real applications.

The theoretical models are currently being modified so that full advantage may be taken of their potential. In parallel, the smooth running of the models is being checked in real problems for predicting data series of a financial-environmental nature and social indicators, and also the comparison of results with the different models of feedforward networks previously used in the chosen field of application. In terms of the theoretical contribution, this has so far consisted in studying and developing new evolutionary techniques to improve the training of dynamic recurrent neural networks.

Evolutionary algorithms are search, optimization and learning algorithms which have been applied to a large number of problems, and have obtained suitable results. For example, in the research field of grammatical inference and time series prediction, the use of genetic algorithms for training recurrent neural networks has produced better results than those obtained by classic gradient-based training algorithms. Due to the good behavior of the genetic algorithms applied in this field, a research line is presented which promises encouraging results.

Some classic techniques, however, which improve the power of gradient-based algorithms such as certain Quasi-Newton methods and other non-linear programming techniques have proved to be suitable tools for training dynamic recurrent neural networks in time series prediction problems. While evolutionary algorithms carry out a heuristic search of the solution space and attempt to find optimum solutions, the Quasi-Newton algorithm search is based on the information provided by the gradient. In order to exploit the advantages of each methodology and so as to achieve better results, we have developed hybrid techniques which combine the characteristics of evolutionary algorithms and Quasi-Newton algorithms, and which improve the training of dynamic recurrent neural networks.

Finally, the development of multi-objective optimization techniques has enabled us to obtain both the optimum structure of the network and the trained network itself. The proposal has the following advantages:

- Easy adaptation to different models of neural networks.
- Capacity to solve the problem of obtaining local solutions which appears in classic gradient-based algorithms and other heuristic techniques (e.g. taboo search and simulated annealing.

- Integration of the optimization stages of the structure and training of a DRNN, thereby reducing the number of experiments which need to be performed.
- Generality for its application in different types of problems.

On a practical level, the methodology developed presents certain innovative aspects for solving data series prediction problems:

- Capacity for modeling systems where the temporal relations between data vary with time (adaptation to dynamic systems).
- Reduction in the number of experiments in the neural network input and output structure selection stage.
- Capacity for processing data patterns of variable length.
- Capacity for learning complex temporal relations in the long and short term.

The proposed models are being validated with financial data about the indebtedness of town councils in the Autonomous Community of Andalusia in collaboration with these.

Our current work focuses on the theoretical improvement of hybrid and multi-objective models. Another line of research focuses on the construction of a web system which enables remote access to the data of the results using either PCs with Internet connection or mobile devices. Some prototyptes about abstract architectures and multiagent systems to implement that kind of web systems with remote access have been already developed and cheked. Some papers about that have been also published.

Due to the good results obtained so far, it is hoped that project completion may culminate in an important contribution in the research field of neural network training and optimization.

2.2. Summary of the scientific results and techniques obtained for Subproject 2.

The achievements of this subproject may be divided into two blocks: scientifically-endorsed theoretical achievements and practical results where they may be incorporated.

Among the theoretical achievements obtained, it is worth mentioning the definition of Temporal Fuzzy Chains (TFCs) as a mechanism for representing systems which evolve in time, which we shall call "Dynamic Systems". This formalism is based on the specification of fuzzy states (which represent the stable system), and the identification of the transitions between states. This representation enables a linguistic transcription of the model, obtaining a qualitative tool for the description of this type of system. The use of intervals and predetermined linguistic variables increases the descriptive character of the model.

For TFC construction, a set of algorithms have been proposed which are directly induced from a dataset monitoring the system or which are obtained by means of the temporal ordering and grouping of a set of fuzzy rules which describe the dynamic system. When we begin with a model of fuzzy rules which define the system, these rules are ordered in a way which reflects their sequentiality. This ordered type of rule sequence has been called a temporal fuzzy model.

All these models and methods have been accepted in different national and international scientific fields, where they have been presented and discussed (as demonstrated by the series of publications which endorse them).

Another of the most outstanding aspects of the theoretical results of the project is the creation of a line of research into handling information on Internet. From the initial work for the use of deformable prototypes in the sphere of temporal complex systems, new techniques have been formed where the treatment of term imprecision, similarity and concordance and also the introduction of new ontologies enable a greater exploitation of large databases or enormous amounts of information, as in the case of Internet.

From the practical point of view, the theoretical results of TFCs have been used to describe simple human movements, such as jumps or steps, with good results; meanwhile, search and information handling techniques have provided systems for e-mail management and Internet search engines (FIS-CRM, GUMsen).

3 Performance indicators

3.1. Trainees

- Mr. Manuel Pegalajar Cuellar, FPU grant-holder, is working on the subject from project TIC2000-1362-02. He shall defend his doctoral thesis in approximately one year's time.
- Mr. Oscar Pérez Piñeiro, FPI grant-holder in the grant associated with this project joined the team in June 2004. He shall defend his doctoral thesis in approximately three years' time.
- Mr. Carlos Gonzalez Morcillo, part-time teacher at the University of Castilla la Mancha, shall defend his doctoral thesis in approximately three years' time.
- Mr. Luis Rodríguez Benítez, Professor at the University School at the University of Castilla la Mancha shall defend his doctoral thesis in approximately three years' time.

3.2. Summary of publications

Table 2: Summary of publications

Type	Number	References
Papers in SCI journals	6	[6] [7][8][9][10][11]
	2	[20][36]
Papers in other international journals	1	[4]
International Conference papers	5	[1][2][13][14][15]
	12	[20][21][24][25][28][29] [31]-[33][35][37][39]
National Conferences papers	4	[3][5][12][16]
	8	[17][18][19][22][23][27] [34][38]

3.3. Technological Transfer (patents, contact with other projects, etc.)

As we have emntioned before he proposed models are being validated with financial data about the indebtedness of town councils in the Autonomous Community of Andalusia in collaboration with these.

On the other hand, the execution of this project has enabled strong links to be forged with important biomechanical research groups both on the level of data analysis and of common structures. This multidisciplinary connection is apparent in the laboratories and establishments, and also in the personal contact between those at the Escuela Superior de Informática in Ciudad Real and the Facultad de Deporte in Toledo (University of Castilla-La Mancha), as revealed by the composition and participation of various thesis committees.

Similarly, the results obtained in previous projects, and also the exploration in greater depth of these within the project, have favored the concentration around J. Angel Olivas of a *National Thematic Network on soft-computing-based systems for accessing web information: SCIA*, sponsored by the Ministry of Science and Technology.

3.4. Teaching

The theoretical results have been used for teaching on the two doctoral courses:

- *"Advanced models for modeling and predicting chronological series"* on the doctoral program *"Design, analysis and applications of intelligent sysems"*, and
- *"Soft computing techniques"* on the doctoral program *"Architecture and management of information and knowledge in networked systems,"*

both doctoral programs awarded the Mention of Quality.

3.5. Dissemination of results

According to the task schedule, web pages have been constructed with information about the evolution and results of the project and this can be accessed at the following addresses: http://oreto.inf-cr.uclm.es and http://drimys.ugr.es/proyectos/PM2003.

4 References

[1] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., "An application of non-linear programming algorithms to train recurrent neural networks in time series prediction problems", Proceedings of ICEIS05, Vol. 2, pp. 35-43, Miami, 2005.

[2] Cuéllar, M. P., Delgado, M., Fajardo, W., Pérez-Pérez, R. "An information system to perform services remotely from a web browser", Proceedings of ICEIS05, Vol. 2, pp. 91-100, Miami, 2005.

[3] Cuéllar M. P., Delgado M., Pegalajar M.C., "Redes neuronales recurrentes para predicción de series temporales" in Proceedings of SICO'05 (Accepted).
[4] Cuéllar M. P., Delgado M., Pegalajar M. C., "Multiobjective Evolutionary Optimization for Elman Recurrent Neural Networks, Applied to Time Series Prediction", in Fuzzy Economical Review, vol. X, no. 1, pp. 17-34, May 2005.
[5] Cuéllar M. P., Delgado M., Pegalajar M.C., "Algoritmos evolutivos híbridos para entrenamiento de redes neuronales recurrentes", in MAEB'05 (Accepted).
[6] Delgado, M., Fajardo W., Gibaja, E., Pérez-Pérez, R. "BioMen: an information system to Herbarium", Expert System with Applications. Vol. 28/3 pp 507-518.
[7] Delgado, M., Olavarrieta, P., Vergara, "Fuzzy Sets Tools in Process Quality Control", International Journal of Uncertainty, Fuzziness and Knowledge-based Systems (Submitted)
[8] Cuéllar, M. P. , Delgado, M. , Pegalajar, M. C. , "Training Fully Recurrent Neural Networks with Different Evolutionary Techniques", Neural Networks (Submitted).
[9] Cuéllar, M. P. , Delgado, M. , Pegalajar, M. C. , "A Multiobjective Evolutionary Algorithm to find optimal Fully Recurrent Neural Networks", International Journal of Approximate Reasoning, (Submitted).
[10] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., "Memetic Evolutionary Training for Recurrent Neural Networks. An application to Time Series Prediction", Expert Systems, (Submitted).
[11] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., "Extraction of Fuzzy Rules from Recurrent Neural Networks", IEEE trans. On Neural Networks, (Submitted).
[12] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., "Extracción de reglas difusas para describir la dinámica de redes neuronales recurrentes", Proc. ESTYLF'04, Jaén 2004 (Spain), pp. 483-489
[13] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., R. Perez-Perez, "A comparative study of evolutionary algorithms for training Elman recurrent neural networks to predict autonomous indebtedness", Proc. ICEIS'04, Porto 2004 (Portugal), pp. 461-465
[14] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., R. Perez-Perez, "An adaptable time delay neural network to predict the Spanish economic indebtedness", Proc. ICEIS'04, Porto 2004 (Portugal), pp. 457-460
[15] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., "Multiobjective evolutionary optimization for Elman recurrent neural networks, applied to time series prediction", Proc SIGEF04, Reggio-Calabria (Italia), 2004
[16] Cuéllar, M. P., Delgado, M., Pegalajar, M. C., Pérez-Pérez R., "Predicción de series temporales mediante redes neuronales recurrentes y algoritmos evolutivos", Proc MAEB04, Córdoba, 2004, pp. 593-600.
[17] Abián Vicén J, Alegre Durán L M, Fernández Rodriguez JM, Jiménez Linares L, Sánchez Amador L, Aguado Jodar X. "Variabilidad en la Capacidad de Amortiguación de Caídas Después de Ejercicios Intensos", Archivos de Medicina del Deporte: I Jornadas Internacionales de Medicina del Deporte, Zaragoza, 26-27 November 2004.
[18] Abián Vicén J, Alegre Durán L M, Jiménez Linares L, Sánchez Amador L, Aguado Jodar X. "Tests de Salto con Plataforma de Fuerzas en el Ingreso de una Facultad de Ciencias del Deporte". Archivos de Medicina del Deporte: I Jornadas Internacionales de Medicina del Deporte, Zaragoza, 26- 27 November 2004.
[19] Amador J. Sánchez, Javier Abián Vicén, Luis M. Alegre Durán, Luis Jiménez Linares, Xavier Aguado Jodar. "Medición Directa de la Potencia con Tests de Salto en Voleibol Femenino". Archivos de Medicina del Deporte, Volumen XXII (2), March-April, 2004, p 111-120.

[20] Francisco P. Romero, José A. Olivas, Pablo J. Garcés, "Using Soft-Computing for e-mail management", Proceedings of the Tenth International Conference on Information Processing and Management Uncertainty in Knowledge-Based Systems, IPMU 2004, Volume 3, p 1783-1790, Perugia, Italy, 4-9 July 2004.

[21] Francisco P. Romero, José A. Olivas, Pablo J. Garcés. "A Soft-Computing based Tool for Intelligent e-mail Management", Proceedings of the International Conference on Artificial Intelligence, IC-AI-04, Volume I, p 56-61, Las Vegas, Nevada, USA, 2004.

[22] Francisco P. Romero, José A. Olivas, Pablo J. Garcés. "Metodología de Tratamiento Inteligente del Correo Electrónico Mediante Técnicas de Soft Computing", Actas del XII Congreso Español Sobre Tecnologías y Lógica Difusa, p 503-508, Jaén, 15-17 September 2004.

[23] J. Moreno-García, L. Jiménez, J.J. Castro-Sánchez, L. Rodríguez. "Conversión de Modelos Difusos Temporales a Cadenas Difusas Temporales". Actas del XII Congreso Español Sobre Tecnologías y Lógica Difusa, p 621-626, Jaén, 15-17 September 2004.

[24] J. Moreno-García, L. Jiménez, J. J. Castro-Sánchez, C. González, R. Manjavacas, S. García, X. Aguado. "Fuzzy Modelling of Sport Movements", 1st International Working Conference IT and Sport & 5th Conference dvs-Section Computer Science in Sport, p 21-22, Cologne, Germany, 15-17 September 2004.

[25] J. J. Castro-Sánchez, R. Manjavacas, J.L. Castro, J. Moreno. "Design of a merchant broker agent based on fuzzy logic as mediator in e-commerce", Proceedings of the Tenth International Conference on Information Processing and Management Uncertainty in Knowledge-Based Systems, IPMU 2004, Volume 3, p 1833-1840, Perugia, Italy, 4-9 July 2004.

[26] J. J. Castro-Sánchez, L. Jiménez, J. Moreno, L. Rodriguez "Using fuzzy repertory table-based technique for decision support", Decision Support System 39 , 293-307.2005

[27] Javier de la Mata, José A. Olivas, Jesús Serrano-Guerrero. "Desambiguación de Significados en GUMSe basada en el refinamiento del sentido". Actas del XII Congreso Español Sobre Tecnologías y Lógica Difusa, p 315-320, Jaén, 15-17 September 2004.

[28] Javier de la Mata, José A. Olivas, Jesús Serrano-Guerrero. "Improving Web Search Using Query Customization with GUMSe", Current Issues in Data and Knowledge Engineering, p 325-333, Warszawa, Poland, 2004.

[29] Javier de la Mata, José A. Olivas, Jesús Serrano-Guerrero. "Overview of an Agent Based Search Engine Architecture", Proceedings of the International Conference on Artificial Intelligence, IC-AI-04, Volume I, p 62-67, Las Vegas, Nevada, USA, 2004.

[30] Jesús Serrano-Guerrero, José A. Olivas, Javier de la Mata. "Relaciones Conceptuales para la Construcción de Ontologías con GUMSe", Actas del XII Congreso Español Sobre Tecnologías y Lógica Difusa, p 669-674, Jaén, 15-17 September 2004

[31] Jesús Serrano-Guerrero, José A. Olivas. "Discovery of conceptual relations for ontology construction in GUMSe", Annual Meeting of the North American Fuzzy Information Processing Society, NAFIPS 2004, p 647-651, Banff, Alberta, Canada, 27 - 30 June 2004.

[32] José A. Olivas, Javier de la Mata, Jesús Serrano-Guerrero. "Ontology Constructor Agent for improving Web Search with GUMSe", Proceedings of the Tenth International Conference on Information Processing and Management Uncertainty in Knowledge-Based Systems, IPMU 2004, Volume 2, p 1341-1348, Perugia, Italy, 4-9 July 2004.

[33] José Jesús Castro-Sánchez, Juan Moreno-García, Ramón Manjavacas, Carlos Gonzalez, "Assisting Negotiations and Supporting Decisions in Small E-Business", Proceedings of 2004 IEEE International Conference on Fuzzy Systems, p 855-860, Budapest, Hungary, 25-29 July 2004.
[34] Juan Moreno-García, Carlos González, Ramón Manjavacas, "Inducción Directa de Modelos difusos temporales", Actas del XII Congreso Español Sobre Tecnologías y Lógica Difusa, p 615-620, Jaén, 15-17 September 2004.
[35] Juan Moreno-García, Luis Jiménez, José Jesús Castro Sánchez. "A Direct Induction Algorithm of Temporal Fuzzy Models", Proceedings of 2004 IEEE International Conference on Fuzzy Systems, p 635-640, Budapest, Hungary, 25-29 July 2004.
[36] Juan Moreno-García, Jose Jesus Castro-Sánchez, Luis Jiménez "A fuzzy inductive algorithm to model dynamical systems in a comprehensible way ", IEEE Transactions on fuzzy system. (Submitted).
[37] Pablo J. Garcés, José J. Castro-Sánchez, Ramón Manjavacas, José A. Olivas. "A suppliers searcher agent based on FIS-CRM used in E-commerce websites", Proceedings of the International Conference on Artificial Intelligence, IC-AI-04, Volume I, p 50-55, Las Vegas, Nevada, USA, 2004.
[38] Ramón Manjavacas, José Jesús Castro Sánchez, Juan Moreno García. "Agente vendedor difuso para entornos de negociación automática en comercio electrónico", Actas del XII Congreso Español Sobre Tecnologías y Lógica Difusa, p 645-650, Jaén, 15-17 September 2004.
[39] Romero, F. P.; Olivas, J. A.; Garcés, P.: "A Methodology for Intelligent e-mail Management", Proceedings of the Seventh International Conference on Enterprise Information Systems, ICEIS 2005, Miami, USA, ISBN: 972-8865-19-8, pp. 11-16.