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SINTA-CC: Adaptive Intelligent Systems for Modelling, Prediction and Dynamic Optimization in Clusters of Computers TIN2004-01419

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Abstract

The project undertakes the study and development of parallel intelligent procedures and systems for modelling, prediction, and dynamic optimization in high performance computing platforms, analyzing the synergy between diverse paradigms like neuronal networks, evolutionary computation, fuzzy logic and matrix transformations, that allow problems concerning learning, adaptation to changing conditions and presence of uncertainty to be tackled properly. Under this scope, the project also tries to continue the work of research made in the development of tools which take advantage of parallelism (using toolboxes which we have developed for the parallel processing in Matlab™), and to improve the benefits of communication in clusters of computers and the dynamic management of protocols in computation environments of GRID type. Therefore, the project tries to make contributions in: (a) the development of new procedures of modelling, prediction, and optimization that take advantage of the softcomputing techniques and the calculation capabilities that clusters do offer; and (b) the use of the new procedures in realistic applications for which there exists available data provided by diverse companies; (c) the improvement of the communications and the conditions of use of clusters of computers; and (d) to allow the access to the developed procedures and platforms through Internet.
Keywords: High Performance Computation, Intelligent Network Interface Cards, Soft Computing, Hybridization of Metaheuristic

1 Research Project Goals

This project is a continuation of the research effort carried out through the following projects belonging to the National Plan of Scientific Research TIC2000-1348 and DPI2001-3219 all of them accomplished by members of the CASIP (Circuits and System for Information Processing) research group, for the last ten years, and all been favourably evaluated under the corresponding annual reports. The project TIN2004-1419 meant the unification of different research lines within the CASIP research group in order to reach more ambitious goals. The initial hypothesis for our

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work is the productive synergy existing within the soft-computing field when integrating in just one unique platform, paradigms such as neural techniques, fuzzy logic, co-operative and/or co-evolutionary algorithms in order to solve, on parallel platforms, computational intensive and complex problems related to function approximation, classification, forecast and optimization.

This global goal can be divided into three main objectives, with different task:

Objetive 1.- Development of new soft-computing-based parallel methodologies based for adaptive systems in modelling, prediction and optimization problems. This objective involves the following three stages:

a) Design and development of new intelligent architectures for complex system modelling with self-learning and self-organization capabilities in real time. The task for this first stage are:

- *T.1.1.1. Algorithms to compute the degree of importance of input variables using hybrid statistical and soft-computing-related techniques*
- *T.1.1.2. Design and development of new neural and/or fuzzy architectures for the efficient exploitation of complex multi-dimensional problems*
- *T.1.1.3. Parameter optimization of the proposed architectures in multi-dimensional ill-defined spaces*
- *T.1.1.4. Use of parallel platforms for the global optimization of the proposed system*
- *T.1.1.5. Conception and implementation of intelligent control systems with self-learning and self-organization capabilities in real time*

b) Development of hybrid methodologies for time series modelling, characterization and prediction

- *T.1.2.1. Time series prediction and modelling by hybridizing classic statistical techniques with soft-computing systems*
- *T.1.2.2. Advanced prediction systems using soft-computing techniques*
- *T.1.2.3. Parallelization of hybrid techniques for time series modelling, characterization and prediction*

c) Hybrid methodology for parallel and distributed dynamic optimization

- *T.1.3.1. Development of a new multi-objective dynamic optimization procedure based on evolutionary computation*
- *T.1.3.2. Multi-agent implementation of the multi-objective dynamic optimization procedure developed*
- *T.1.3.3. Integration of the modelling and prediction procedures designed in tasks T.1.1.3 and T.1.2.3 within the developed distributed dynamic optimization scheme.*

Objetive 2.- Implementation, analysis and design of efficient parallel platforms for the simulation of intelligent systems. In this objective, the research group has been working in four specific research lines:

a) Optimization of the Communication Operative System support. The main task was:

- *T.2.1 Optimization of the CLIC protocol for Gigabit Ethernet*

b) Effective implementation of communication protocols in intelligent NICs to alleviate the CPU of communication-related tasks

- *T.2.2 Development of a PCI card with re-configurable hardware (FPGAs) to implement communication protocols*

c) Dynamic management of different communication protocols

- *T.2.3.1 Implementation of TCP/IP and CLIC protocols in the designed card with the possibility of dynamically select the protocol to use by means of a message*
- *T.2.3.2 Assessment of the communication performance with a protocol dynamic management scheme*

d) Development in MatlabTM of specific software for the integration of the proposed methodologies. The following four task has been carried out:

- *T.2.4.1 Extension of the developed system to MPI 2.0*
- *T.2.4.2 Improvement of the proposed system adding multi-threading support*
- *T.2.4.3 Translation of the designed system into Octave*

Objetive 3.- Application and dissemination of the proposed intelligent methodologies and architectures in real problems: modelling, classification, time series prediction and real time control. The dissemination and real application of the results and parallel procedures investigated through the afore-mentioned objectives is of great importance to provide the accomplished work with truly practical utility, and analyze its viability and effectiveness. Our aim in this objective is to work in four specific research lines:

a) Modelling and prediction of the water and electricity consumption pattern in the city of Granada. Application to the robust and on-line intelligent control of the water-supply network

T.3.1.1 Modelling and prediction of the sectorized and the global water consumption pattern in Granada

T.3.1.2 Adaptive real-time control of the more relevant elements in the system

b) Bio-medical applications: classification of several skin pathologies and digital mamographies

T.3.2.1 Entropic detection/classification using intelligent systems from digital mamography

T.3.2.2 Diagnosis of skin diseases from fluorescence techniques

c) Management of inventory chains of supply systems: application to a book supplier.

T.3.3 Application to a book supplier

d) Implementation of a web page for the project: Interface for the access to parallel resources through the Internet

T.3.4 Implementation of a web page for the project that allows us the access and execution of modelling, prediction and dynamic optimization applications in the developed platforms

Finally, the estimated schedule of the task proposed in the project is the presented in Table 1.

TASK	FIRST YEAR				SECOND YEAR				THIRD YEAR			
T111												
T112												
T113												
T114												
T115												
T121												
T122												
T123												
T131												
T132												
T133												
T21												
T22												
T231												
T232												
T241												
T242												
T243												
T31							-	-				
T32							-	-				
T33							-	-				
T34												

Sub-task | Exploitation and dissemination of results | - Data obtainment and pre-processing

Table 1. Task Schedule

2 Successful achievements of the Project TIN2004-1419

The level of success of the research developed until now is very satisfactory and relevant. We have solved the nearly all the tasks described in the previous section (some tasks of the objective 3 are not completely finished). The next three subsections are devoted to describe the results of the main

objectives. For each of them, we highlight the most relevant scientific and technological results, together with the publications generated.

2.1 Objetive 1: Development of new soft-computing-based parallel methodologies based for adaptive systems in modelling, prediction and optimization problems

a) Advanced neuro-fuzzy models for function approximation and time series prediction problems

Takagi-Sugeno-Kang (TSK) neuro-fuzzy models are widely used to solve modelling problems, due is its representative power, capable of describing a highly complex nonlinear system using a small number of simple rules. However, the optimization of a TSK model normally leads to a good general performance of the whole TSK fuzzy system give the idea of what it does, but the sub-models given by each rule in the TSK fuzzy system can give no interpretable information by themselves. An intensive research has been performed to refine the treatment of the two main goals in the training and design of neurofuzzy models. A preliminary result was obtained in [1] that uses a modified TSK neuro-fuzzy model, using a grid partitioning of the input space, to obtain a set of fully interpretable rules without decreasing the general performance in the modelling of the I/O data. The interpretability of the local models was obtained by using the Taylor Series Expansion (TSE) concept, since each rule consequent provides the behaviour of the global around the rule centre (the TSE of the global model around the rule centre). This research was extended and published in [2], obtaining a final formulation for the model (TaSe model), and presenting interesting results, that also showed up that using high order rule consequents in the TSK model can provide a better generalization capability of the model, but without loosing interpretability of the local models, since their TSE of the higher order is obtained. An statistical ANOVA test was performed and presented in [3][4], that in fact confirmed that using higher order rules in a general TSK model is able to provide a better generalization capability for function approximation problems. The TaSe model was also satisfactorily applied for time series prediction problems as was published in [5][6].

Normally TSK neuro-fuzzy models present a grid partitioning of the input space, however, they can also present a clustering-partitioning of the input space, which is more associated with the equivalent Radial Basis Function Network (RBFN) model. An important research was also performed for this type of models. First a preliminary work to extract interpretable rules using also the TSE concept from RBFNs was presented in [7][14], which was extended and compared with grid-based TSK systems in [8]. A second phase of work, to improve the initialization of the rule centres before the complete optimization of the model was presented in EUNITE Competition, which showed to bring excellent results. The methodology is based on the initialization of the centres such that the error surface along the input space is flatted. The idea is also supported by the fact that the generalization of the model is expected to improve by homogenizing the error along the input domain.

An important drawback of neuro-fuzzy models in general is the curse of dimensionality. This is specially crucial in grid based fuzzy models since the number of obtained rules is exponential in the number of input dimensions of the problem. However, grid-based fuzzy systems are important since they perform a full coverage of the input space. It is also essential to obtain rules with a low number of antecedents in order to obtain better interpretable models. On those purposes, a modified grid-based fuzzy approach was presented in [9] (MultiGrid Fuzzy System -MGFS-), that performs a subdivision of the input space and obtains a grid-based TSK model for each subdivision, joining the all the rules output as is done for general TSK fuzzy models by

weighted average. A complete learning algorithm was designed for the MGFS model, which also is able to perform variable selection. The application of the learning methodology was first applied for time series prediction problems, in which the input space has to be selected too to perform the modelling. A first work was presented in [10], and the MGFS model was applied to the CATS Benchmark proposed in the IJCNN conference in 2004, getting a good position in the time series competition [11], and being selected the work for publication in the CATS Neurocomputing Special Issue. The extended paper with the complete learning methodology exposition was accepted for publication [12].

It is also important to note the research carried out using multiobjetivo evolutionary algorithms, cooperative-coevolutionary optimization, and hybrid methods for function approximation and time series forecast [49]-[55], and its parallelization using multi-objective metaheuristics [69][70].

b) LS-SVM and Neuro-Fuzzy Models and long term Time Series Prediction

Time series forecasting is a challenge in many fields. It is a complex problem, which in general has several points in common with function approximation problems. The analysis of time series is based on the assumption that successive values in the data file represent consecutive measurements taken at equally spaced time intervals. There are two main goals of time series analysis: (a) identifying the nature of the phenomenon represented by the sequence of observations, and (b) forecasting (predicting future values of the time series variable). Those goals are normally joined by approaching the problem as a modelling I/O data task, which on the one hand, builds up a model that tries to identify the internal structure of the observed data, in order to, on the other hand, predict novel values of the series using that predictive model. Long term predictions require a more careful study, since long term data dependencies are more difficult to model. Two approaches can be taken to tackle this problem: direct prediction and recursive prediction. Several methodologies have been applied to the problem of time series prediction. Our research has been centred in the improvements of long term time series prediction using different strategies and techniques. In [13] a preliminary work using SVM and LS-SVM was performed to predict the product quality in a glass melting process (Eunite competition 2003). A modified strategy was used to perform the prediction, and the results exceeded those obtained in the official competition. A novel technique to improve recursive prediction was presented in [6], which showed up to improve the long term prediction using recursive models. The technique was checked using two completely different approaches as are the LS-SVM model and TSK models, and the results obtained confirmed its effectiveness. LS-SVMs showed to bring an excellent effectiveness while they are not interpretable. TSK models showed to bring a good performance, providing an interpretable set of rules.

Further works in [15][16] have been performed for long term time series prediction using LS-SVM and other traditional statistics techniques, showing the importance of including the seasonality information of the time series in the model. These works have been presented in the first ESTSP conference to also participate in a new benchmark competition. With respect to the problem of variable selection in modelling problems, a preliminary work has been presented in [17], that makes use of the concept of Mutual Information. It is a successful adaptation of a previous work for classification problems. Furthermore, time series prediction using the MGFS model and including variable selection, were studied in [10][11][12].

c) Radial Basis Function Neural Networks: Clustering and optimization algorithms in parallel platforms

The research was oriented to the development of new clustering algorithms that perform a more adequate initialization of the centers, concretely for function approximation problems. The research started from the basis established by the CFA algorithm [18]. This algorithm presented a new clustering technique oriented to design RBFNN using the concept of expected output of a center. This output represents the position of a center in the output axis. The CFA algorithm creates several partitions of the input vectors, one for each center, where an input vector only belongs to one partition. This kind of partition, know as a hard partition, was presented in the Hard C-means algorithm and later, was improved by the Fuzzy C-means algorithm which allows the sharing of the input vectors between the centers of the clusters. Several aspects of the CFA were improved, the first one was the use of a fuzzy partition instead of a hard partition [21][22], later, other aspects such as the convergence and efficiency were revised in [23]. Once the algorithm was refined, several applications were presented where the new developed algorithm obtained a satisfactory performance [24][25]. A further study on how the input vectors were distributed among the cluster was carried out considering other kind of partitions such as possibilistic and hybrid approaches, the results showed that if a mixed approach considering a fuzzy partition and a possibilistic partition is used in the initialization of the centers, the results can be improved [26][27][28].

One of the main drawbacks of genetic algorithms is their excessive computational time. The research then focused in optimizing the previously developed algorithm so the computational effort was decreased. Due to the intrinsic parallelism of the genetic algorithms, the algorithm was designed to be executed in parallel platforms. Parallel computing is a discipline that can be the solution for many problems that require a huge computational effort. The algorithm was divided into smaller algorithms executed in different processors, and periodically, a communication step allowed the isolated populations on each processor communicate with the others, this parallel paradigm is know as the island model[29][30]. One new aspect introduced during the research was the specialization of the different islands in the evolution of different parameters of the RBFNNs, this approach increases the exploration and exploitation capabilities of the algorithm, designing better RBFNNs as was demonstrated in [31][32]

Many aspects of the parallel algorithm could be studied in future research, as example, efficiency and speed-up must be calculated in order to determine the scalability of the algorithm, this aspect is not trivial since the algorithm is subdivided into 4 algorithms. Depending on the previous results, a load balancing algorithm could be applied in case one of the subalgorithms could require more computation, even the granularity level of the parallel design could be incremented to be able to make a proportionate load distribution. Besides the parallel algorithm, the design of the RBFNNs still has some aspects that should be studied: how to select the input variables and if a distribution of these variables among the RBFs could provide better results than feeding all the RBFs with the same input vector.

d) Dynamic Multi-objective Optimization Problems

The benefits that can be obtained from parallel processing of dynamic multi-objective optimization problems could the same that in static multi-objective optimization (lower processing times and bigger efficiency and diversity in the population), but also the possibility of improving the algorithm reaction to changes. This reduces the processing time required, and allows a set of non-dominated solutions near to the Pareto front to be reached earlier. Thus, dynamic optimization problems, where the change rate is faster, could also be tackled.

The results of our approach to the possibilities of parallel processing for dynamic multi-objective optimization are quite remarkable. First of all, we have developed a parallel procedure to reach solution sets quite near to the changing Pareto fronts in multi-objective problems [42][43]. This procedure is an adaptation to dynamic environments of the PSFGA algorithm for multi-objective optimization [46][47]. It uses a master process to distribute the population of solutions among the processors that evolve their corresponding subpopulations for genpar iterations. Then, the master collects the (partial) Pareto fronts independently determined by the worker processors, builds a whole Pareto front from the partial ones, executes genser iterations of the evolutionary algorithm, and distributes the obtained population of solutions again. In the master, there is a crowding mechanism for keeping the diversity and the distribution of the solutions on the Pareto front founded. So, after reaching a number of solutions, equal or above to a given percent of the population size, only the non-dominated solutions that are far enough of the other ones are chosen.

Thus, our procedure allows a continuous transition between a master-worker operation model, when genpar is set to 0 (the workers only compute the fitness of their subpopulations) and an island model (genpar>0) where the processors communicate through the master. The speedup results obtained by our procedure allow a reduction in the convergence times, and hence, the ability to satisfy stronger time restrictions in the dynamic problem. We consider that the super-linear speedups that have been observed in some cases show the usefulness of parallel processing in keeping up the diversity of the population, in the improvement of the reaction capability and in the algorithm adaptability. It is clear that there are many things to do yet. On one side, we think that many algorithm characteristics and parameters should be analyzed and optimized, both in the sequential and parallel versions of the algorithm. Thus, we plan to study the scalability and performance behaviour for different versions of the algorithm in which the worker and master processes run asynchronously, with different communication schemes (including the ability of direct communications between workers), and genser/genpar rates. We also plan to consider other more flexible schemes where, for example, more than one process acts as a master at a given time. Furthermore, it is also necessary to evaluate the performance of the procedure with a broader set of benchmarks and some real world applications. Up to now, we have considered the use of evolutionary computation in dynamic scheduling problems [45].

2.2 Objetive 2.- Implementation, analysis and design of efficient parallel platforms for the simulation of intelligent systems.

a) Efficient network interfaces

After considering the advantages of drawbacks of different alternatives for developing intelligent Network Interface Cards (NICs), we consider that the NICs based on network processors are the most adequate ones. This choice has been motivated by their programmability, the availability of libraries and programming and debugging tools, and by the kind of parallelism that network processor microarchitectures usually implement.

Network processors (NP) are programmable circuits that provide fast and flexible resources for high-speed communication functions processing. They are composed of multiple cores that are usually organized either into a parallel model in which each packet goes to a different NP core that processes it, or a pipeline model where each packet is pipelined through a subset of NP cores that together implement the code for packet processing. The use of these network processors has been driven by the increasing demand for high throughput and the flexibility required for packet

processing. As higher bandwidths are available simple Network Interfaces Cards (NICs) should be substituted by Intelligent NICs (INICs). Nevertheless, instead of using application specific processors in these INICs, the need for adaptability, differentiation, and short time to market brought the so called network processors (NP), application-specific instruction set processors that can be programmed quickly and easily to get the required network application. Among the different alternatives we have chosen the Intel IXP network processors. The Intel NP of the IXP2XXXseries implement highly parallel microarchitectures that include several programmable processors: one Intel XScale general-purpose processor (RISC processor compliant with ARM architecture) and 8 or 16 coprocessors optimized for packet processing, called microengines. This parallelism allows processing of multiple packets simultaneously, which can greatly increase the throughput of the processor. Each microengine has eight threads of execution with zero-overhead context switch (the microengine has registers and program counters for each thread in order to reach a quickly switch from executing one thread to another thread in the machine). This feature is very important to hide latencies and it is necessary to take advantage of it in order to achieve high performance. Moreover, the IXP2XXX processors offer flexibility through upgradeability, programmability, libraries and developing tools.

Thus, our research work is dealt with the programming and efficient use of the multi-core microarchitectures that network processors implement. Nowadays, as the technology trends make the multi-core microprocessor as the microarchitecture of choice, this research line is very relevant. We have been working on offloaded TCP/UDP protocols. Thus, we have some TCP and UDP implementations on a NIC based on the IXP2400 network processor (using the Radisys ENP2611 board) [37]. They allow us to demonstrate the correct operation of the offloaded protocols. Although we have reached a moderate latency reduction, the bandwidth improvements achieved are not significant. The reasons are that these first implementations do not use multiple microengines and their poor optimized use of multithreading. Model LAWS and the Moore's law can aid us to understand this situation, as we are offloading part of the communication work to a processor (the network processor) with lower clock frequency that the CPU and we are not using the parallelism provided by the offloading engine.

Nevertheless, some recent works provide experimental results to argue that protocol offloading, in particular TCP offloading, does not clearly benefit the communication performance of the applications. On the one hand, the reasons for this scepticism are the difficulties in the implementation, debugging, quality assurance and management of the offloaded protocols. The communication between the NIC (with the offloaded protocol) and the CPU and the API could be as complex as the protocol to be offloaded. Protocol offloading requires the coordination between the NIC and the OS for a correct management of resources such as the buffers, the port numbers, etc. In case of protocols such as TCP, the control of the buffers is complicated and could hamper the offloading benefits (for example, the TCP buffers must be held until acknowledged or pending reassembly). Moreover, the inefficiency of short TCP connections is due to the overhead of processing the events that are visible to the application and cannot be avoided by protocol offloading. Probably, these are not definitive arguments with respect to the offloading usefulness but they counterbalance the possible benefits. On the other hand, there are fundamental reasons that affect the possible offloading advantages. One of them is the ratio of host CPU speed to NIC processing speed. The CPU speed is usually higher than the processors in the NIC and, moreover, the increment in the CPU speeds according the Moore's law tends to maintain or even to increase this ratio in the case of the specific purpose processors in the NIC. Thus, the part of the protocol that is offloaded would require more execution time in the NIC than in the CPU, and the NIC could appear as the communication bottleneck. The use of general-purpose processors in the NIC

(with speeds similar to the CPU) could represent a bad compromise between performance and cost. Moreover, the limitations in the resources (memory) available in the NIC could imply restrictions in the system scalability (for example, limitations in the size of the IP routing table).

Some papers have recently appeared to understand the fundamental principles under the experimental results through models such as LAWS and EMO. Both models provide a good starting point to get accurate models and descriptions about the conditions where offloading could be advantageous. Nevertheless, they should be extended to include wider sets of application domains and benchmarks and they also require a more detailed experimental validation with these applications and benchmarks. We have been working in these problems by using simulation [38][39][40]. In these papers we propose the use of Simics to analyze protocol offloading. Although Simics presents some limitations and it is possible to use other simulators for our purposes, the resources provided by Simics for device modelling and the debugging facilities, make Simics an appropriate tool. Moreover, it has allowed us a relative fast simulation of our models.

The simulation results obtained shows the improvement provided by offloading heavy protocols like TCP, not only in the ideal case, in which we use ideal buses memory, but also in more realistic situations, in which memory latencies and non-ideal buses are modelled. Thanks to the Simics model, it is possible to analyse the important parameters and the conditions in which offloading determines greater improvements in the overall communication performance.

The results obtained in the experiments we have done show throughput improvements in all the cases considered by using a host processor and NIC processor with similar speeds. Moreover it is shown that offloading releases the 40% of the system CPU cycles in applications with intensive processor utilization On the other side, we also present results that show how the technology of the processor included in the NIC affects to the overall communication performance. The behaviour we have observed in our experiments coincides with the analyses and conclusions provided in other previous works. This situation constitutes an evidence of the correctness of our Simic model for protocol offloading. One of our papers,[39], can be downloaded from the web site of Virtutech, the Simics manufacturer [41].

2.3 Objetive 3.- Application and dissemination of the proposed intelligent methodologies and architectures in real problems: modelling, classification, time series prediction and real time control.

a) Intelligent control: Application to the Control of the Temperature of a Dynamic Room in Real Time, application to Water distribution networks scheduling in Granada and Mineral extraction factory in Cuba .

Substantial developments in optimizing control methods for different purposes have been made in the field of intelligent control in the bibliography. However, most of them are based on a known system model, whereas in practice such models are not usually available due to the complexity of the plant to be controlled. In this paper, we present a novel approach to achieve global adaptation in fuzzy controllers. The algorithm does not need a mathematical model of the plant or its approximation by means of a Jacobian matrix. Qualitative knowledge and auxiliary fuzzy controllers help the main controller to accomplish its task in real time [59][60][61]. One application was the Control of the Temperature of a Dynamic Room in Real Time [48]. Another important problem is the water supply system of Granada (Spain). We have developed a general procedure that can be applied to problems related to the scheduling of distribution networks. This procedure offers a very simple way of making good use of the computation capability of a cluster of computers to explore feasible control trajectories and avoids a complex modelling of the system

thanks to the incorporation of a prediction method we have developed, and which is use to forecast an approximate future consumption level. In the next figure we describe the system upon which the developed scheduling procedure has been applied. Briefly, the problem is to obtain the optimum water flow distribution given by the water treatment plant (E.T.A.P.), which can be seen inside the box, for the water tanks marked. The implemented system allows us to have a centralized and real time control over the Water Integral Cycle in the city of Granada. The central control room is located in the headquarters of the company EMASAGRA, from where we can establish our communications via radio (SPIRAL system by ICR developed by researched of our group) with several remote stations controlled by PLCs (Siemens Simatic S5) and other stations based on the distributed tele-control system SPIRAL-5000. In some places of the network close to the radio-linked remote stations, it has been utilized a field bus (Siemens Sinec L1/L2). The application software was developed from the software package SCADA INTOUCH.

Another research line has been carried out, to present a system that can be used to control and optimize the mineral extraction from source materials [62]. One of the modules that builds the system is in charge of predicting the final amount of extracted mineral from empirical data obtained previously. The module consists in an RBFNN, that is able to predict quite precisely the real output of material, and in a genetic algorithm that trains the network within the time frame required by the system. A multiobjective genetic algorithm that designs the RBFNNs for the prediction module was presented, obtaining a very good performance when it was compared against other techniques for the design of RBFNNs.

b) Biomedical application: classification of several cancer pathologies, digital mamographies and electro cardiogram signals

In this project we have considered the viability of a skin lesion diagnosis scheme based on fluorescence images. Three kinds of skin lesions are considered: actinitic keratosis, basal cell carcinoma and psoriasis. A wide and diverse set of simple parameters have been extracted and their discrimination potential is evaluated through an automatic diagnosis scheme based on the intelligent algorithm developed in previous section. We use a sequential scanning technique that automatically selects the most relevant parameters for the addressed problem. [19][20][71]

The new intelligent neural model presented in this project, has also been applied in electro cardiogram signals. The objective of the approximation is to be able to classify a heart beat in order to determine if it suffers pathology [19][24][47].

Another important application is image processing [66][68], specifically digital mammography. Digital mammography has been introduced in several countries over the last few years. The new technology requires new optimising methods considering for instance the increased possibility of changing the absorbed dose and the effect it has on the image processing and noise level. There is no agreement on the noise level that may be accepted and the absorbed doses needed. We have proposed a newly algorithms based on an entropic measure in recognizing cancer regions on mammograms, which is very robust against the presence of noise, low contrast or blurring in the image. This property makes it very suitable in digital mammograms because previous filter is not needed. Experiments show the performance of the proposed procedure using several digital mammography's. It can be shown that the algorithm is robust, effective and presents better results than other method presented in the literature [58].

Finally, it also important to note the application to automatic classification of prostate cancer using intelligent system [56][57]. We have proposed an automatic procedure for prostate cancer light micrograph based on soft-computing technique, for image interpretation, with increased accuracy.

We have proposed a feature subset selection algorithm that selects the most important features, used by a pseudo-gaussian radial basis function neural networks to classify the prostate cancer light micrograph. A high classification rate has been achieved which will reduce the subjective human invention and will increase the diagnostic speed.

3 Indices to measure the quality of the obtained results

The main indicators that show the results of the research carried out in the project TIN2004-1419 are classified in the following three categories: formation of students, publication and national and international collaboration.

3.1 Formation of students

Regarding the staff under formation, it is important to note that the project team members are advising the eleven different PhD dissertations in the project topics. Six doctoral thesis have been defended and five PhD students have presented their research projects as a previous step to present during this an next year their doctoral thesis. In particular :

1.- D. Mohammed Awad, PhD student in the Department of Computer Architecture and Technology (Granada), has finished his doctoral thesis titled: "Model complex system by hierarchical structured based on intelligent system" with Drs. Ignacio Rojas and Drs. Héctor Pomares as advisors. He presented it by June 2005

2.- D. Mouncef Filali Bouami, PhD student in the Department of Computer Architecture and Technology (Granada), has finished his doctoral thesis titled: "Development and Optimization of New Radial Basis Function Neural Model", with Drs. Ignacio Rojas and Drs. Carlos García-Puntonet as advisors. He presented it by July 2005.

3.- D. Carlos Castro Serrato, PhD student in the Department of Computer Architecture and Technology (Granada) in collaboration with SIEMENS (Munich, Germany), has finished his doctoral thesis titled: "Development of a high accuracy analogue-to-digital converter system: application in data logging units", with Drs. Ignacio Rojas, Drs. Alberto Prieto and Dr- Ing and Doctor Honoris Karl Goser as advisors. He presented it by May 2006 (European doctor)

4.- Dª. Manuela Alba Bueno, PhD student in the Department of Computer Architecture and Technology (Granada) in collaboration with SIEMENS (Munich, Germany), has finished her doctoral thesis titled: "Study and Characterization With Scanning Probe Methods of Employable Nanomaterials in new Architectures for Molecular Memories" with Drs. Ignacio Rojas, Drs. Alberto Prieto and Dr- Ing and Doctor Honoris Karl Goser as advisors. She presented it by May 2006 (European doctor)

5.- D. Suhail Musa Issa Odeh, PhD student in the Department of Computer Architecture and Technology (Granada), has finished his doctoral thesis titled: "Development of intelligent system for diagnosis and classification in medicine", with Drs. Eduardo Ros and Drs. Ignacio Rojas as advisors. He presented it by July 2006.

6.- D. Javier Díaz Alonso, PhD student in the Department of Computer Architecture and Technology (Granada), has finished his doctoral thesis titled: "Bio-inspired vision system. Architecture for movement processing and stereo-vision for high performance" with Drs. Alberto Prieto Espinosa and Drs. Eduardo Ros as advisors. He presented it by July 2006.

6.- D. Christián Agustín Morillas Gutiérrez, PhD student in the Department of Computer Architecture and Technology (Granada), has finished his doctoral thesis titled: "Model and Intelligent tools for visual rehabilitation" with Drs. Alberto Prieto Espinosa and Drs. Francisco José Pelayo Valle as advisors. He presented it by September 2006.

7.- D.Francisco Fernandez, PhD student in the Department of Computer Architecture and Technology (Granada), has presented his research project titled: "New intelligent system using Multiobjective RBFNNs Designer: Application for Mineral Reduction", with Drs. Julio Ortega Lopera and Drs. Ignacio Rojas as advisors. He has presented a first version of his doctoral thesis, and he will present it during next months.

8.- D. Alberto Guillen, PhD student in the Department of Computer Architecture and Technology (Granada), and actually assistant professor at the University of Jaen. He has presented in 2005 his research project titled: "Intelligent computation in parallel platforms: application to functional approximation and classification", with Drs. Ignacio Rojas, Drs. Héctor Pomares and Drs. Jesús González as advisors. He has presented a first version of his doctoral thesis, and he will present it during next months.

9.- D. Luis Javier Herrera, PhD student in the Department of Computer Architecture and Technology (Granada), and actually assistant professor at the University of Granada. He has presented in 2005 his research project titled: "Adaptive and intelligent systems for function approximation and prediction using high performance computation" with Drs. Ignacio Rojas and Drs. Héctor Pomares as advisors. He has presented a first version of his doctoral thesis, and he will present it during next months.

10.- D. Gines Rubio, PhD student in the Department of Computer Architecture and Technology (Granada). He has presented in 2005 his research project titled: "Implementation and application of kernel methods on high performance computation" with Drs. Ignacio Rojas and Drs. Héctor Pomares as advisors. He will present his doctoral thesis the next year.

11.- D. Pablo Cascón, PhD student in the Department of Computer Architecture and Technology (Granada). He has presented in 2006 his research project titled: "High performance computation and communication in clusters " with Drs. Julio Ortega as advisors. He will present his doctoral thesis the next year.

3.2 Publication

In summary, a total number of 93 publications have been developed during this project, distributed mainly in international journal and international conferences (78), and 15 in different national conference. All these publications will be available in the web page of the Research Group, to which the project team members belong (http://atc.ugr.es).

3.3 National and international collaboration

3.3.1 Joint activities organized:

The following events have been co-organized:

- The 8th International Work-Conference on Artificial Neural Networks (IWANN'2005) (Computational Intelligence and Bioinspired Systems), in Vilanova i la Geltrú (Barcelona, Spain) June 8-10, 2005.
- First International Workshop on Genetic Fuzzy Systems, March 17-19, Granada, Spain, in cooperation with: Genetic Fuzzy Systems Task Force, Fuzzy Systems Technical Committee, IEEE Computational Intelligence Society
- I Congreso Español de Informática (CEDI'2005), Granada, September 13-16, 2005
- I Simposio de Inteligencia Computacional, SICO'2007 (IEEE Computational Intelligence Society, SC), Granada, September 13-16, 2005

To be organized during this year:

- II Congreso Español de Informática (CEDI'2007), Zaragoza, September 11-14, 2007
- II Simposio de Inteligencia Computacional, SICO'2007 (IEEE Computational Intelligence Society, SC), Zaragoza, September 11-14, 2007
- 9th International Work-Conference on Artificial Neural Networks (IWANN'2007) (Computational and Ambient Intelligence) will take place in San Sebastián (Spain) June 20-22, 2007,

It is also important to note the organization of different invited sessions in international an national conferences (ESANN, GFS, SICO, CEDI, etc.), and the edition of two special issues in international journal (*Neurocomputing:* Alberto Prieto, Joan Cabestany and Francisco Sandoval (Eds.) Selected paper from IWANN 05, and IEEE Transaction on Fuzzy Systems, Special Issue: "Genetic Fuzzy Systems: What's Next?", O.Cordón, I.Rojas, R.Alcalá, (Eds.)).

3.3.2 National and International projects with different enterprices

Member of our group have participated with other Spanish and International research groups and enterprises in the following projects:

- Title: Module consumptions of the Cooling Area Network Systems (CANS). Reference: OTRI 2006-2324. Entity: CIATESA (CIATESA is a company dedicated to the design, production and commercialization of air conditioning teams, refrigeration, treatment of air and thermal exchanges.). Keywords: Intelligent system, Telecontrol, Web technology.

- Title: Module tariffication of the Cooling Area Network Systems (CANS).Reference: OTRI 2006-2325.Entity: CIATESA (CIATESA is a company dedicated to the design, production and commercialization of air conditioning teams, refrigeration, treatment of air and thermal exchanges).Keywords: Intelligent system, Telecontrol, Web technology.

- Title: Module Fuzzy of the Cooling Area Network Systems (CANS).Reference: OTRI 2006_2326. Entity: CIATESA (CIATESA is a company dedicated to the design, production and commercialization of air conditioning teams, refrigeration, treatment of air and thermal exchanges).Keywords: Intelligent system, Telecontrol, Web technology.

- Title: Advanced Tele-asistance, domotic and multimedia (TELEADM: Teleasistencia avanzada domótica y multimedia).Reference: CTA 06/0053. Entity: Coorporación Tecnologica de Andalucia (CTA). Consorcio de empresas Telefónica I+D y Sadiel.

- Title: eQuirófano: Multimedia Collaborative Envirotment (eQECM).Reference: CTA06. Entity: Coorporación Tecnológica de Andalcía (CTA), and Consergería de Innovación, Ciencia y Empresa.

- Title: Advanced teleasistance platform (PLATELA). Reference: FIT-350301-2006-10 TRACTOR-PRO.Entity: Ministerio de Industría, Turismo y Comercio, y consorcio de empresas. Programa Nacional de Tecnologías de Servicios de la Sociedad de la Información. Acción estratégica e-inclusión y e-asistencia. MITyC. Note: Consortium formed for: Telefónica I+D, Instituto Tecnológico de Aragón, Gotor Comunicaciones, MAPFRE Quavitae, Bioingeniería Aragonesa, y Universidad de Granada (Grupo CASIP - ATC). Date: 01/11/2006 to 31/12/2007

- Title: Development and Integration of new Technologies for supervision and control on industrial environment". Reference: F2284-01. Entity: Fundación Empresa Universidad de Granada and ICR (01-10-2004 to 31-09-2005). Keywords: Comunication networks, Distribuited control

- Title: Escalability and high computation in clusters of computers. Reference: P06-TIC-01935. Entity: Proyecto de Investigación de Excelencia de la Junta de Andalucía. Date: 01/01/2007 to 31/12/ 2009

- Title: Technological platforms for a remote unit terminal (UTR). Reference: FIT-330100-2006-60 PROFIT. Entity: Ministerio de Industría, Turismo y Comercio, y consorcio de empresas. Note: Consortium formed for: Telvent Energía y Medio Ambiente S.A., Asoc. de Investigación y Coop. Industrial de Andalucia, Universidad de Granada (CASIP) y CSIC (Centro Nacional de Microelectrónica. Date: 15/09/2006 to 31/12/2007

- Title: Intelligent and distributed control in agricultural hothouses. Reference: To be confirmed by Junta de Andalucia. Entity: Junta de Andalucia and Eurocastell Sociedad Agraria de Transformación

European Project:

- Title: Learning to emulate perception action cycles in a driving school scenario (DRIVSCO). Reference: IST-016276-2 (VI Programa Marc). Date: 01/02/2006 to

31/07/2009 . Entity: European Union. Participants: Universidad de Granada (España), University of Genoa (Italia), Katholieke Universiteit Leuven (Bélgica), University College London (Reino Unido), University of Göttingen (Alemania), Münster University (Alemania), Aalborg University (Dinamarca), Vytautas Magnus University (Lituania) y Hella KG Hueck & Co (Alemania).

In collaboration with Telefónica Investigación y Desarrollo, member of our reserach group also have presente dan CENIT Project, entitle: "Personal Digital Enviroment for the health and well-being", Reference: AmIVital. If is also important to note the collaboration with the European Commission's Research Infrastructuresactivity of the Structuring European Research Area programme, contract number RII3-CT-2003-506079 (HPC-Europa).

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