University of Puerto Rico at Mayagüez (UPRM)

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**NSF GRANT #99-77071**

# PRECISE Progress Report: AY2000/2001

## PRECISE – Program for Research in Computing and Information Sciences and Engineering

## 1. Introduction

The University of Puerto Rico at Mayagüez (UPRM) is a Land-Grant, Sea-Grant, and Space-Grant College funded in 1911. It ranks No. 1 in minority engineering baccalaureates granted and it is among the top 20 universities in engineering enrollment in the USA. The school of engineering is a leader in minority education. It awards the highest number of engineering degrees to underrepresented ethnic minorities in the USA. Women make up over 37% of our engineering enrollment, which is approximately double the national average. It has a long tradition of quality, starting with very selective admission criteria, and continuing with an intensive five-year program that produce graduates that compete very successfully for industrial employment and graduate school admission and fellowships.

### 1.1. PRECISE Project Background

UPRM NSF PRECISE (NSF EIA 99-77071) has as principal goal to "facilitate, enhance and strengthen current research environment in CISE at UPRM, making it more diverse, competitive and sustainable. It will also help in implementing the UPRM Ph.D. CISE model as an academic program". Together with previous CISE grants, this project continuous to work and complete a model program for minority-serving institutions in an effort to enter the mainstream competitive research and development arena in CISE. We can identify three (3) phases or levels of this model, namely:

**PRECISE, Phase I**:**(first CISE grant)** Enhance BS degree in Computer Engineering, develop infrastructure and start developing MS degree.

**PRECISE, Phase II**:**(second CISE grant)** Enhance infrastructure & R&D in CISE and initiate development of Ph.D. in CISE

**PRECISE, Phase III (current CISE grant)*: Entering the R&D Mainstream: Changing the Local Research Culture*.** Approve Ph.D. program, enhance infrastructure and firmly establish R&D Groups (set R&D goals/objectives, obtain competitive grants, publish papers in peer-reviewed journals, establish strategic alliances with other institutions and research groups, participate in CISE review panels, etc.)

The PRECISE Project has five (5) major tasks with specific goals and objectives as outlined in its strategic plan:

1. Research groups
2. Student training
3. MS & Ph.D. recruitment, and outreach
4. Outreach
5. Assessment

# 2. Accomplishments

## 2.1. New Computing Research Laboratory (CRL)

A new Computing Research Laboratory (CRL) was established during the first semester of this academic year (AY2000/2001). This laboratory is currently providing working space to all professors and students directly participating in the PRECISE Project. The Laboratory is also be open to any graduate student conducting research work in any CISE area. At the present time they are more than 80 people using the Laboratory on a 24-hour basis. Priorities for the use of the Laboratory have been set according to guidelines of the PRECISE Project.

### 2.1.1. Computational Resources

Currently, there are 2 SUN Ultra 10 Creator Workstations with operating system SOLARIS 2.8, one is used as master server and the other is a client. CRL has 7 E-4200 Gateway computers with Operating System Windows 2000 and Linux, and 6 Gateway computers with Operating System Windows 2000, one of these computers is configured as Windows 2000 server. Other shared resources include four printers: 2 Epson Color 900N, one Hewlett Packard LaserJet 8100N and one Hewlett Packard LaserJet 4M Plus (see Figure 2). There is a Gateway Portable computer available for presentations (**Fig. 1**).

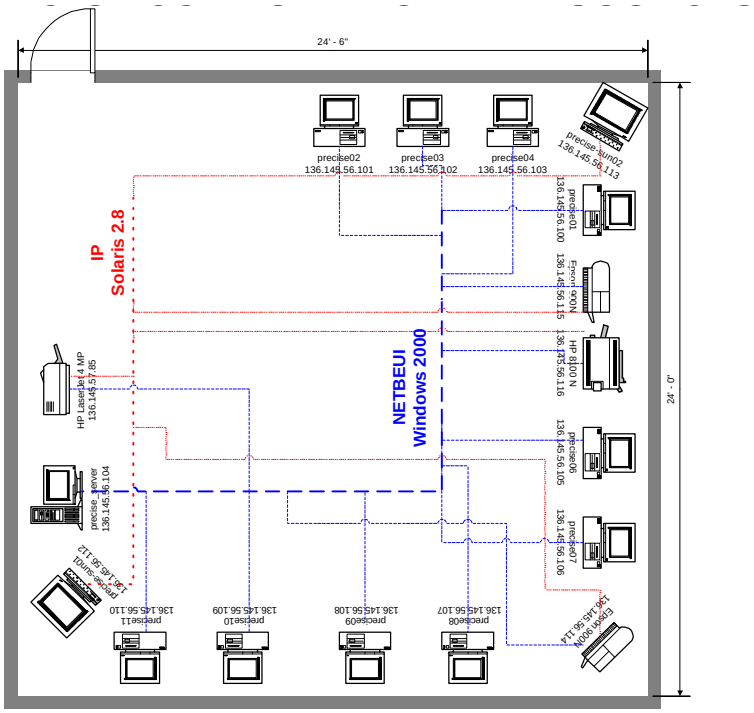
### 2.1.2. Software

Unix Installed programming tools include GNU compilers (C, Fortran, Java, Perl), and Matlab. Report tools include Star Office, Ghostview, GhostScript, and Latex.

Windows installed programming tools include Microsoft Visual C, Borland Java builder, Forte for Java, GNU Perl, Amzi Prolog, Clips, and Matlab. Report tools include Adobe Acrobat, Ghostview, GhostScript, Latex, WinEdt, Scientific Workplace, Miktex, Star Office, BitEdt, Tex for Windows, Texaide, Office 2000, Equation Editor. Secure connection is ensured through the use of Secure Shell. CRL counts with other audiovisual and didactic tools such as data display, transparency projector, VCR, and TV

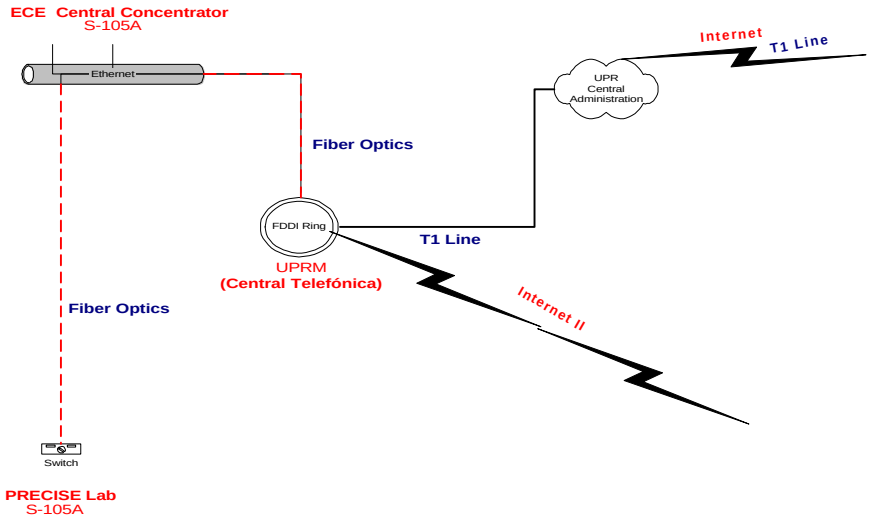
### 2.1.3. Additional Computing Resources

The physical space of the Computing Research Laboratory is much reduced when compared with the number users that it currently has. To ameliorate this situation, some graduate students directly supported by the PRECISE Project or enrolled in the Ph.D. CISE Program will benefit by utilizing new computing resources which will be physically located at the UPRM Research and Development Center grounds and facilities and housing the offices of the Ph.D. CISE Program. These new resources will be provided by funds from the Ph.D. Program and the PRECISE Project with special attention given to parallel and distributed computing.




• Figure 1: CRL Laboratory Setup

We are planning in the near future the replacement of the local hub with a switch and then a GB fiber optics connection to the soon expected Internet 2 infrastructure on the UPRM Campus (**Fig. 2**). The Internet 2 infrastructure will provide a fast web topology for conducting our large scale computing research efforts at various high performance computing facilities throughout the United States, including our own facility here in Puerto Rico (http://www.hpcf.upr.edu/)




• Figure 2: Future Internet 2 Access

• Figure 3 Computational Research Laboratory

## 2.2. Research Groups

We have, in general, identified the following six (6) characteristics as attributes shared by members in most computing research groups: Common Technology, Theoretical Formulations, Large Scale Computations, Prototypes Generation, Engineering and Scientific Applications, Data Management through the Internet. Members in a given research group in the PRECISE Project must share at least 50% of these characteristics in order to be considered an entity.

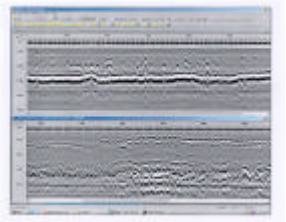
There are currently four (4) distinct research groups, with members of various departments and campuses, who have common research interests and are beginning to work together in joint research proposals and projects. These groups are: The Parallel and Distributed Computing (PDC) Group, the Automated Information Processing (AIP) Group, the Digital Systems Implementation (DSI) Group, and the Software Sciences and Engineering (SSE) Group. There a remains a group of faculty who are involved in the PRECISE Project and who are conducting research and supervising graduate students on an individual. New groups are currently in the process of being formed out of this set of professors working individually.

The following sections are highlights of the work being conducted by some of the research collaborators in the PRECISE Project. The research collaborators have been divided into two main classes: Fully supported research collaborators and partially supported research collaborators. The major difference is that fully supported research collaborators spend ¼ FTE (at least 270 hours) in research efforts directly related to the PRECISE Project. The works present diverse computing research topics and its applications such as distributed systems, signal processing systems, parallel and distributed computing, and digital systems. The sections provide examples of research work from each of the four (4) existing research groups in the PRECISE Project:

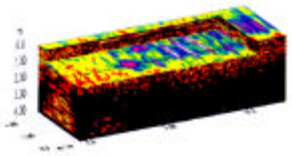
### 2.2.1. Multi-sensor Fusion Algorithm for Object Recognition Using Subsurface Image Data : Prof. Hamed Parsiani – Automated Information Processing Group – ECE Dept.

This research is conducted in collaboration with Dr. Marco Giardino, a NASA research scientist of Earth System Science Office, at Stennis Space Center. The multi-sensor data to be made available are obtained from a Ground Penetrating Radar, magnetometer, conductivity, 15 Band ATLAS satellite, and CCD array sensors. All are obtained from a geographically referenced archeological site, along with actual excavation data. The goal of this research is the creation of an algorithm (or algorithms) which can perform Automatic Object Recognition (AOR) using the archeological multi-sensor data as the test bed.

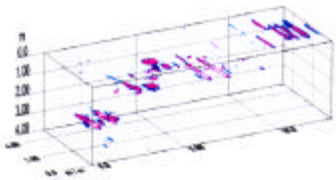
Presently, the work is concentrated on the GPR data which besides the valuable archeological information, includes clutter, and other noises. The subsurface GPR data can be read and displayed by the RADAN which is a user interactive software. It offers a toolbox to manage the data in a user specified form, can incorporate topographic changes with surface normalization, correct position, and provide scaling and distance normalization. It can apply filtering, such as Hilbert Transform, and allows local peak and interactive interpretations. It can perform migration and velocity analysis, among other things. RADAN can produce a 3-D section, or any 2-D subsections, of a survey area, and through proper transparency the buried features, of the 3-D cube. Work is in progress on object (or feature) classification, using $N_8(p)$ Connectivity, Fuzzy C-Means, and Neural Network classifiers.



Survey Data of Subsurf



3-D Subsurface Image A Section of



3-D Subsurface Section Highlighting Buried Features

• Figure 4 Subsurface Data Representation

### 2.2.2. High Order Parallelization and Coupling of Simulation Codes : Prof. Wilson Rivera – Parallel and Distributed Computing Group – ECE Dept.

Parallel computing has a potential for not only reducing the computational time, but also concentrating memories belonging to different processors to carry out larger calculations. Thus, the migration of sequential partial differential equations (PDE) simulators to multiprocessor platforms is well justified. When solving PDE using non-overlapping domain decomposition methods, one often needs numerical boundary conditions on the boundaries between subdomains [1,2,3]. These numerical boundary conditions can significantly affect the stability and accuracy of the final algorithm. The problem of numerical boundary conditions is more complicated if intercomponents and multidisciplinary computational simulations are considered. In addition, management and utilization of these engineering codes for coupled component simulations is a complex task requiring substantial experience and effort.

We propose a high-level parallelization and coupling of simulation codes through an extensive use of object-oriented programming techniques. The possibility of a modular implementation of mathematical abstractions, which is a direct advantage of object-oriented programming, gives rise to the generalization of computational kernels, which are reusable in many simulation applications from different disciplines of scientific computing. This data encapsulation feature makes it possible to hide computational details when needed. In addition, object-oriented techniques can produce sequential simulators with unified generic interfaces, which easily allow modification and extension.

As a consequence, reliable, flexible, and extensible multidisciplinary simulators can be developed based on an object-oriented paradigm. The practical issues that we have to deal with in this research include programming abstractions, portability, numerical accuracy, and computational efficiency.

#### 2.2.3. Genetic Algorithms and its Applications to Manufacturing : Prof. Gúrsel Süer – Industrial Engineering Department

Cellular manufacturing continues to be one of the significant areas both in the manufacturing world and academia. It is seen as part of Lean Manufacturing efforts in manufacturing companies. The researcher proposing this work organized a World Symposium in the area recently in San Juan, Puerto Rico and it was well attended. Several mathematical models have been developed and heuristics have been suggested to deal with the problem. However, GA applications in the area are very recent. In this study, we would like to deal with more realistic issues and problems which are usually NP-hard. GA has demonstrated that they are good tools to solve complex problems fast and with high accuracy. In summary, we'll develop tools that will help us to design robust and efficient cellular systems which are desired in most manufacturing companies.

In this work we'll focus on GA applications Cellular Design and Control issues. One of the completed works in the area will be extended to include other design strategies and comparisons will be made. The proposed application area is Cellular Manufacturing and the proposed tool is Genetic Algorithms. We would like to add machine duplication issues into the framework developed previously by other graduate students. Another target is to consider machine levels and operation sequences in the family formation process.

#### 2.2.4. Skip Loops Syntactic Parser Using Rule-Based Implementation : Prof. Jorge Ortiz – Electrical and Computer Engineering (ECE) Department

This research topic deals with the implementation of a syntactic parser using finite-state transition diagrams with skip loops to delete and remove unrecognized or out of syntax words. These words could be the effect of mixed streams of words or errors in the conversion from spoken language to characters. There is a need to introduce a certain degree of intelligence using current AI techniques to obtain an intelligent parser of the input information. The parser syntax can be defined to dynamically adjust to its model to follow a particular stream of information that sounds or looks appropriate for the particular context. The aim of the parser will be to model the process that resembles the human ability to follow a single dialog in an environment where there are many ongoing conversions.

Syntactic and semantic logic techniques can be added to the skip loops parser to improve its performance and resemblance to natural intelligence. Words association system can be implemented using probabilistic left-to-right associative chains in certain contexts that allows

considerable improvement and system reliability. A rule-based system written in logic programming language (PROLOG or CLIPS) will be used to model the rules and prototype implementation.

The parser will be tested using a model for the Air Traffic Controller's Commands. The figure below shows the actual model for an Air Traffic Controller's Command Language Grammar. The model allows parsing some of the commands. An enhanced model must be implemented adding all other grammatical representations that may require the command language. These enhancements will allow us to prepare a working prototype with all the required commands.

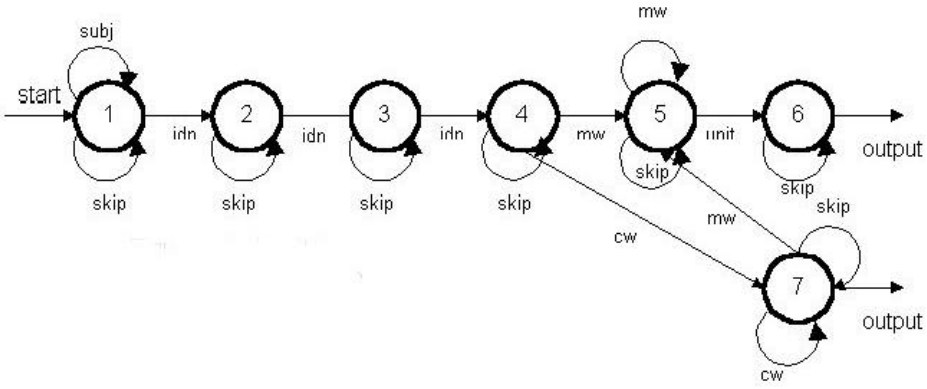



Figure 5 Finite State Transition Diagram for an Air Traffic Controller's Grammar with Skip Loops

### 2.2.5. Interactive Queries Hierarchies for Effective Information Discovery at UPR-Mayagüez: Prof. Bienvenido Vélez – Parallel and Distributed Computing Group – ECE Dept.

Advances in processor technologies suggest that future search engines will be capable of spending orders of magnitude more processing capacity per user request without inducing noticeably larger response times. A new information discovery technique called *query lookahead* invests additional computation on the eager evaluation of multiple queries automatically generated from an initial user query.

Query lookahead has the potential of improving search systems in at least two novel ways. First, it enables the deployment of anticipatory user interfaces capable of presenting the result sets of automatically generated refined queries ahead of time. Refined queries serve as categories upon which a large and imprecise result set can be organized. Second, query lookahead has the potential of improving the effectiveness of feature (e.g. term) selection algorithms. These algorithms can be improved by exploiting information about the result set induced by each potential feature when combined with the user query. This research focus on a new network search system, *InfoRadar*, exploiting *query lookahead* along these two lines. As shown in Figure 1, in response to a user query, *InfoRadar* displays a hierarchically organized selection of refined queries that we call an *interactive query hierarchy*. We have developed *InfoRadar* as a vehicle for testing our hypothesis that interactive query hierarchies can improve information discovery effectiveness. *InfoRadar* has three main software components: a multi-threaded Java applet, a server module and an indexing module. *InfoRadar* supports boolean queries using a syntax borrowed from the popular Altavista (www.altavista.com) search engine. In response to a query request from the applet, the *InfoRadar* server returns a hierarchy of queries together with their individual result sets.

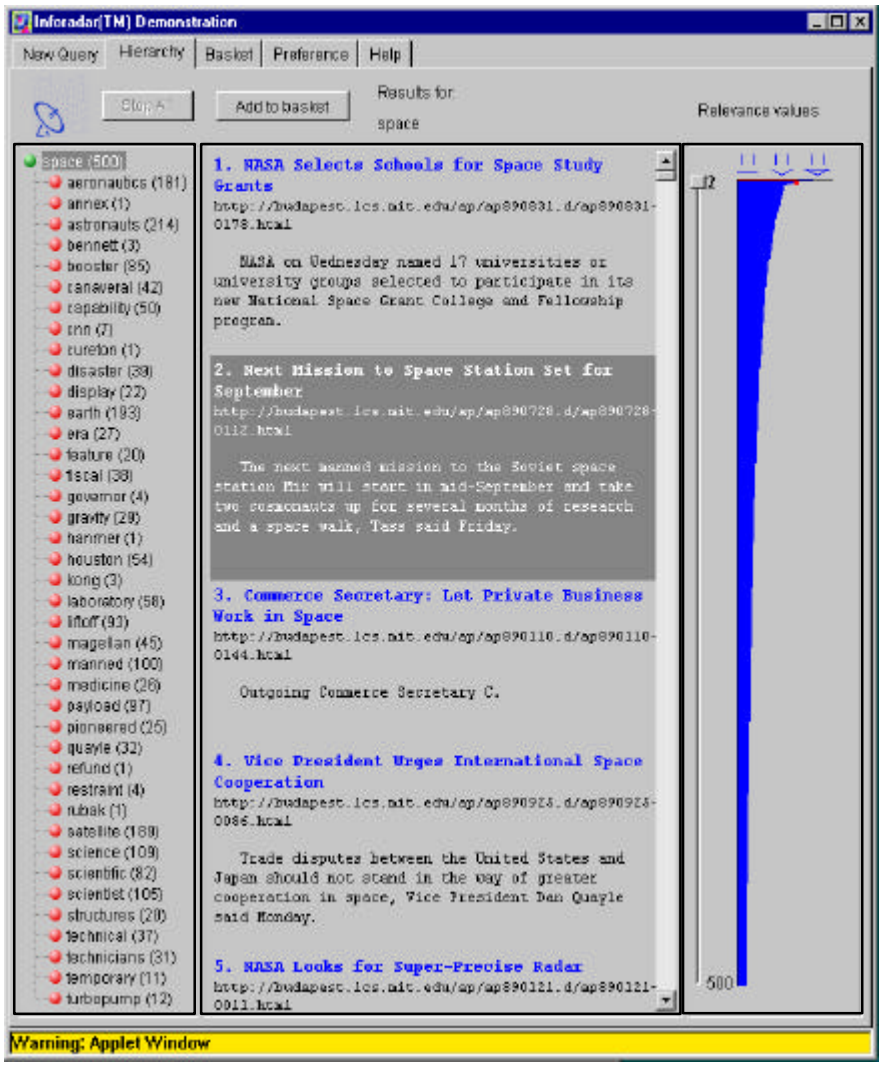



Figure 6 A Screen Snapshot of the *InfoRadar* Search System

### 2.2.6. Comparing Ensembles and Support Vector Machines for Classification: Prof. Edgar Acuña – Mathematics Department

Support Vector Machines (SVM) is a new classification technique developed by V. Vapnik ("*The Nature of Statistical Learning Theory*," Springer Verlag, New York, 1995) and it is gaining popularity due to many attractive features, and promising empirical performance. The technique can be seen as a new training algorithm for Polynomial, radial basis function and multilayer perceptron networks. Traditional neural network approaches have suffered difficulties with generalization, producing models that can overfit the data. This is a consequence of the optimization algorithms used for parameter selection and the statistical measures used to select the best model.The main idea behind SVM is to separate the classes with a surface that maximizes the margin between them, and its formulation embodies the Structural Risk Minimization (SRM) principle, which has been shown to be superior to the Traditional Empirical Risk Minimization (ERM) used in neural networks. Whereas SRM minimizes an upper bound on the VC dimension the ERM minimizes the error on the training data. This provides to SVM with a great ability to generalize, which is the goal of statistical learning.

Support Vector Machines has been applied in pattern recognition problems such as: handwritten digit recognition, object recognition, speaker identification, face detection and text categorization. This proposal is oriented to conduct research in order to compare the accuracy and running time of ensembles obtained by combining classifiers where the class conditional density is estimated using Kernel density estimators and Gaussian mixtures with Support vector machines classifiers. The comparison will be done using datasets available in the database for Machine learning at the University of California, Irvine. There exist benchmarks for misclassification errors of these datasets.

### 2.2.7. Special Purpose Fast Fourier Transform (FFT) Algorithms: Prof. Jaime Seguel Parallel and Distributed Computing Group – ECE Dept.

The FFT is crucial to scientifc computation. In several of these instances, the data to be transformed possesses special features such as symmetries, irregular shapes, or, as in physics, some degree of accuracy is demanded. The proposed research is intended to design and test algorithms for applications such as Volterra filters, Poisson solvers, and Crystallographic FFTs. This work concentrates on the use of mathematical properties for improving the computation of multidimensional FFTs of data sets endowed with special features such as symmetries or irregular shape, and improving the precision of FFT computations. The work contemplates implementations on parallel computing environments as well as the design of special purpose compilers for the efficient production of performance critical code segments.

In this work we study a simple approach, due to Beylkin, for evaluation of the Fourier transform of some functions based on projecting such functions on a subspace of a multiresolution analysis (MRA). In this way we obtain an algorithm which consists of three steps. The first step is the aforesaid projection. The second step is the same as in all algorithms of this type and involves the usual FFT. The third step is a correction step which involves multiplying values at each frequency by a pre-computed factor. In the construction presented in this work, it is chosen the MRA associated with spaces of polynomial splines. This allows us to use properties of the Battle-Lemarié scaling function, while computing projections only with B-splines. These are probably the simplest functions with small supports that are most efficient for both software and hardware implementation.

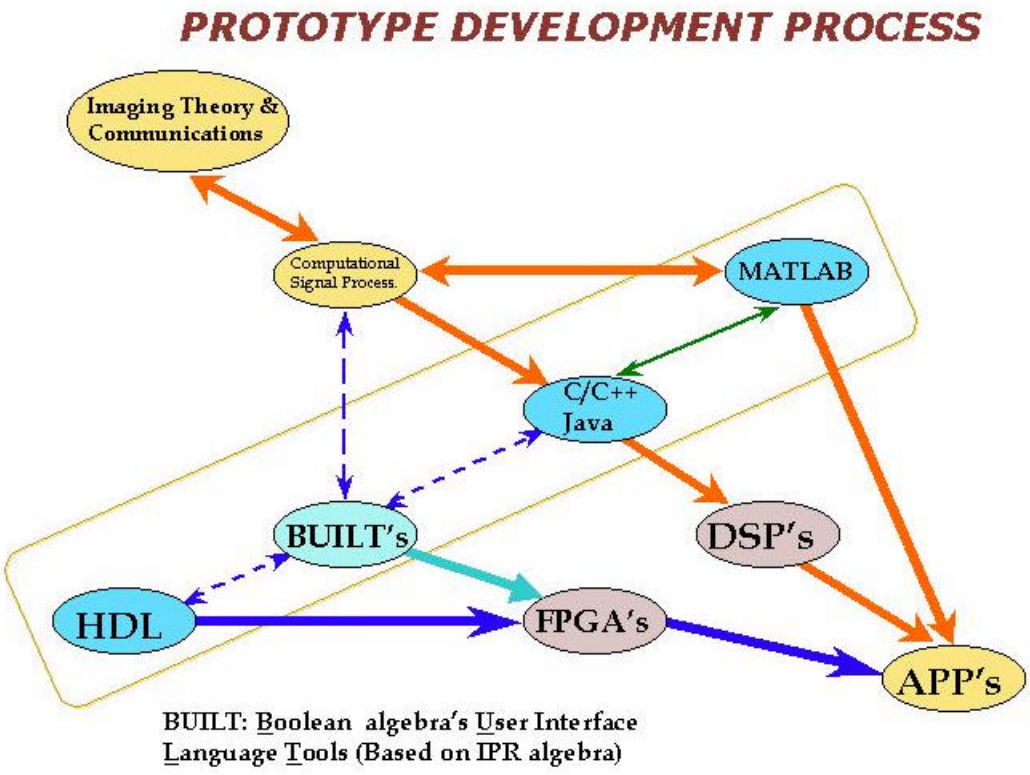
### 2.2.8. Scalable Computational Signal Processing Methods: Prof. Domingo Rodríguez Digital Systems Implementation Group – ECE Dept.

This work deals with the analysis, design, and implementation of communications signals and circuits for synthetic imaging in remote sensing applications with special emphasis given to synthetic aperture radar (SAR) image formation. The work concentrates on developing scalable computational signal processing methods for various stages of the transmitter and receiver circuits and systems in pulse Doppler imaging radar systems.

New digital modulation and coding techniques are being studied for signal transmission efforts in range and azimuth cell resolution enhancements and improved time-frequency energy distributions operations. This will, in turn, result in enhancements in the computation of point spread functions an essential component in the search for new high resolution SAR image formation algorithms. The attributes of a point spread function in a SAR signal processing system determine to a great extent the degree of quality improvement in the image formation process. At the present time we are concentrating on the modeling and simulation of SAR raw data generation and image formation systems.

For *hardware-in-the-loop* simulation and emulation efforts we are evaluating specialized, high performance, digital signal processing (DSP) computing units. The very large order of the SAR raw produced at our SAR data processing facility in Mayagüez, requires the use of high performance computing facilities to conduct overall modeling and simulation efforts for the SAR systems. We also developing new digital signal computing structures based on new field programmable gate arrays (FPGA) units such as the Virtex II and Virtex Pro, from Xilinx, Inc., as well as a new extended Boolean algebra methodology and programmable logic development tools (that include HDL synthesis).

These new FPGA computing structures are based in part on the mathematical formulation of certain classes of signal processing algorithms using what we call *core Kronecker array (CKA) algebra*. This CKA algebra is used as a language helps guide the reconfigurability and scalability process in a given signal processing algorithm mapping operation. A methodology is being formulated to integrate a new *group theoretic FPGA rapid systems prototyping technique* with traditional application prototype development work.




• Figure 7 Rapid Systems Prototyping for SAR Signal Processing

### 2.2.9. Improving the Efficiency of Backtracking Algorithms: Prof. Dorothy Bollman Parallel and Distributed Computing Group – Department of Mathematics.

Many fundamental problems of computer science and operations research that involve a search for a set of solutions or which require an optimal solution satisfying certain constraints can be solved by "*backtracking*" methods. Unfortunately, backtracking is not efficient, generally

requiring exponential execution time. For such an algorithm, there is necessarily an upper bound to problem size beyond which reasonable solution times are unattainable. Nevertheless, improvements in the algorithm can considerably improve this upper limit. This work is directed toward that goal.

In order to apply a backtracking method, each desired solution should be of the form $(x_1, x_2, \cdots, x_n)$ where each $x_i$ belongs to some designated finite set $S_i$ . The solution space for such solutions is organized as a tree, which is typically a subtree of a standard tree representing all possible permutations of $((x_1, x_2, \cdots, x_n)$: However, different organizations can greatly reduce the size. For example, we can show that a different organization for the problem of generating all permutations with the \adjacent differences" property results in a solutions space approximately $\frac{1}{n}$ the size of the standard solution space.

This work will contribute to the knowledge of backtracking, one of the most fundamental techniques in algorithm design. It has already yielded a new, faster algorithm for the classical *n-queens* problem. In the long term, it can provide new Costas sonar arrays, which are useful in encoding radar and sonar signals.

#### 2.2.10. Logical Operators for Texture Analysis: Prof. Ramón Vásquez Automated Information Processing Group – ECE Dept.

Texture classification is an image processing technique by which different regions of an image are identified based on texture properties. This process plays an important role in many industrial, biomedical and remote sensing applications. Early work utilized statistical and structural methods for texture feature extraction. Gaussian Markov random field (GMRF) and Gibbs distribution texture models were developed and used for texture recognition. Power spectral methods using the Fourier spectrum have also been used. DCT, Walsh-Hadamard and DHT have been used for recognition of two dimensional binary patterns. One of the major developments recently in texture segmentation has been the use of multiresolution and multichannel descriptions of the texture images. Logical operators have been used for Boolean analysis, minimization, spectral layered network decomposition, spectral translation synthesis, image coding, cryptography and communication.

Another related work deals with the research to be conducted to develop procedures and model invariance, color, luminance domains with known results from human-vision science and psychophysical experiments. Information has to be collected and reviewed from open literature to understand the existing level of perceptual vision models. Perceptual concepts will be mathematically formulated first, and best values for parameters will be estimated or derived from experimentation. This knowledge will be used to develop algorithms to be implemented for digital texture image recognition.

#### 2.2.11. Design and Implementation of a Ruled-Based Intelligent Event Service (RUBIES): Prof. Javier Arroyo – Software Sciences and Engineering Group – ECE Dept.

Although a number of standards for supporting heterogeneous distributed systems (HDS) already exist (e.g., RPC, CORBA, DCE, DCOM, Java RMI), there is still a lack of abstractions, services and tools for specifying, designing, implementing, monitoring, debugging and maintaining a HDS. For an effective support of these activities, a *conceptual view* of a distributed system is needed. We mean by conceptual view the specification of the system as seen by the community of developers, in terms of structure and behavior. It should be noted that existing environments

(or “middleware”) do well in specifying structure, i.e., attributes and structural relationships among system components. However, in terms of behavior, the specification is limited to the definition of function- or method- signatures. The *semantics* of behavior are hidden or "buried" inside the application code (implementation). Therefore, anyone interested in knowing the behavioral semantics of the system either has to look into the application code, or into a specification or design document (which probably will be "out of sync" from the implementation). Furthermore, existing environments do not allow incorporating changes in behavior dynamically; any change in the behavior will involve changes in the implementation of functions or methods, which in many cases requires recompilation.

This work is about the design and implementation of a Rule-Based Intelligent Event Service (RUBIES), which will provide services that will allow the definition of the semantics of HDSs in a high-level manner. RUBIES will have the following characteristics:

**Object-oriented model.** Similar to CORBA, DCOM and Java RMI, RUBIES should have an object-oriented model in which system components are treated as objects.

**Events.** RUBIES will use events as an abstraction for specifying system behavior. The specification of behavior is done in terms of events that trigger rules. A formal object-oriented event model will allow the systematic definition of events.

**Rules**. In RUBIES, ECAA (Event-Condition-Action-AlternativeAction) rules are used to specify system behavior. Rules are defined in terms of trigger events, conditions that need to be satisfied to apply the rule, and a set of actions and alternative actions to perform when the events occur and the conditions are satisfied. A formal object-oriented rule model will allow the design and implementation of a rule support system independent of any particular rule language syntax.

**Rule-based event handling.** Instead of being buried inside application code, event handling is performed by means of rules. ECAA rules (Events-Condition-Action-AlternativeAction) are defined in terms of event filtering specification (triggering events, priority, conditions), actions and alternative actions.

**Rule scheduling.** Rules can be scheduled to be active or inactive at different points in time. RUBIES will provide the functions for allowing scheduling of rules.

**Immediate and delayed event handling.** Both immediate and delayed event handling is supported by keeping events in an event queue during a specific period of time ("time-to-live") defined for each event. Delayed processing is carried out by inactive rules that, upon activation, are processed against events waiting in the queue.

**Distributable and replicatable architecture.** The architecture of RUBIES allows for the distribution of load among different instances of the service (for performance). Similarly, many replicated instances of RUBIES may co-exist in a HDS (for fault tolerance).

#### 2.2.12. Numerical Implementation of Ill-posed Problems and Quantum Computations: Prof. Lev Steinberg – Department of Mathematics

This work deals with the development of regularization algorithms for ill-posed PDE problems (IlP) arising in modeling and simulation of processes related with computational Materials Sciences at meso and macro-scale levels. In the early part of this century Hadamard declared his three principles that determined where a problem involving a PDE was well-posed. He required

that (a) there exists (b) a unique solution that (c) depended continuously on the input data. However a growing number of extremely important problems failed one of Hadamard's principles. Various Tikhonov's types regularization schemes were developed for their solutions. Some symbolic and numerical algorithms provide approximations the development of singularities in solutions to Nonlinear PDE.

We also study basics of Quantum Computations, which require quantum logic, something fundamentally different to classical Boolean logic. Importance of Quantum computations is related with their greater efficiency over its classical counterpart. We also will approach to Computer simulation of Quantum Computations and application to Material Sciences. The Numerical and Symbolic Algorithms for Ill-posed Nonlinear and Inverse problems are of great importance in studies of Nondestructive Material Evaluation. Research on Quantum computations are significant part in future physical implementations of quantum computers. Implementations of algorithms of the quantum computation is important part in numerical simulation of defect in materials.

#### 2.2.13. The Integer-Pair Representation: A Suitable Format for the Parallel Manipulation of Boolean Algebra: Prof. Manuel Jiménez – Digital Systems Implementations Group – ECE Department

The manipulation and optimization of large, complex digital circuits represented by systems of Boolean equations require computer programs and algorithms which can efficiently use both CPU time and system resources. Although many fast algorithms have been developed for manipulating such expressions, the way they represent binary valued variables is still far from optimal. Common formats include characters, integers, and even structures of integers, in the representation of Boolean variables, when a single bit per variable could suffice for an unambiguous representation.

One format suggesting this single bit per variable scheme is the widely known indexed canonical form of minterms in functions expressed as sum-of-products (SOP). This format assigns an *n*-bit integer to each possible product term resulting from a set of *n* binary variables taking values 0 and 1. This naive scheme, although being canonical, has two major disadvantages. First, any *n*-variable function requires 2*n* terms when it comes to operating expressions, especially when these involve partially reduced (non-canonical) product terms, this representation loses its attractiveness due to the lack of appropriate rules and properties which could allow the development of time efficient algorithms.

This work deals with the creation of a new format to represent binary terms in Boolean functions, called the Integer Pair Representation (IPR). This novel format uses an ordered pair of integers to compactly represent each cube of a Boolean function written as a sum-of-products in either canonical or non-canonical form. Properties of the representation have been formally established unveiling its advantages for developing algorithms enabling the concurrent processing of Boolean variables on SISD machines. In the current stage of development, these properties and algorithms have been combined to develop a prototype program for minimizing single-output binary valued Boolean functions.

### 2.2.14. PRECISE's Research Groups Information

The following tables provide additional information of the PRECISE research groups.

**Parallel and Distributed Computing (PDC) Group**

| **PDC** Group | Department | Students per faculty member | G/U | Sponsored by |
|---|---|---|---|---|
| Dorothy Bollman | Mathematics<br>UPR Mayagüez | 1<br>1<br>1 | U<br>U<br>U | PRECISE<br>AMP<br>AMP |
| Isidoro Couvertier | Electrical and Computer Engineering | | | |
| Pedro Rivera | Mathematics<br>UPR Río Piedras | | | |
| Wilson Rivera (Coordinator) | Electrical and Computer Engineering | 1 | G | PRECISE |
| Jaime Seguel | Electrical and Computer Engineering | 2 | G | PRECISE |
| Bienvenido Vélez | Electrical and Computer Engineering | 1 | U | PRECISE |

**Automated Information Processing (AIP) Group**

| **AIP** Group | Department | Students per faculty member | G/U | Sponsored by |
|---|---|---|---|---|
| Robert Acar | Mathematics<br>UPR Mayagüez | 0 | --- | --- |
| Hamed Parsiani | Electrical and Computer Engineering | 1 | G | PRECISE |
| Ramón Vásquez (Coordinator) | Electrical and Computer Engineering | 2<br>2 | G | PRECISE<br>NASA |

**Digital Systems Implementation Group**

| **DSI** Group | Department | Students per faculty member | G/U | Sponsored by |
|---|---|---|---|---|
| Manuel Jiménez (Digital Systems) | Electrical and Computer Engineering | 1 | G | PRECISE |
| Rogelio Palomera (Mixed Signals and Systems) | Electrical and Computer Engineering | | | |
| Domingo Rodríguez (Coordinator) (Digital Signal Proc.) | Electrical and Computer Engineering | 0 | --- | --- |

**Software Sciences and Engineering (SSE) Group**

| **SSE** Group | Department | Students per faculty member | G/U | Sponsored by |
|---|---|---|---|---|
| Javier Arroyo | Electrical and Computer Engineering | 1<br>1 | G | PRECISE<br>NSF |
| José Borges | Electrical and Computer Engineering | | | |
| Néstor Rodríguez (Coordinator) | Electrical and Computer Engineering | 1 | G | PRECISE |

**Other Research Collaborators Under PRECISE**

| Individual Research Collaborators | Department | Students per faculty member | G/U | Sponsored by |
|---|---|---|---|---|
| Edgar Acuña | Mathematics<br>UPR Mayagüez | 1<br>2<br>1<br>2 | G<br><br>G-May01<br>G | PRECISE<br>UPR-RUM<br>UPR-RUM<br>ONR |
| L. G. Steinberg | Mathematics<br>UPR Mayagüez | 1<br>1 | U<br>G | PRECISE<br>PRECISE |
| Daniel McGee | Mathematics<br>UPR Mayagüez | 1<br>1<br>1 | G | PRECISE<br>D.of Ed.<br>Not Sponsored |
| Jorge Ortiz | Electrical and Computer Engineering | | 1 | PRECISE |
| Gürser Süer | Industrial Engineering | 1 | G | PRECISE |
| Pablo Tarazaga | Mathematics<br>UPR Mayagüez | | | |

## 2.3. Education and Student Training

### 2.3.1. Ph.D. Program

The Ph.D. Program in Computing and Information Science and Engineering (CISE) has been a central theme in our project. Through this program we seek to increase the participation of women and minorities in graduate education. The Ph.D. in CISE officially started this Spring semester or 2001, with ten (10 ) applications for admissions. Five of those applicants were admitted to the Ph.D. Program and one of them, Ms. Vydia Manian, is being supported by the PRECISE Project.

### 2.3.2. Students in the PRECISE Project

The PRECISE Project has a strong commitment with the increase of the number of women and minorities going into graduate school. As presented by the 2000/2001 CRA Taulbee Survey Results, "current and future Ph.D. output will not satisfy demand for faculty." We feel that fostering a research environment for students to excel and creating a pipeline for our recently approved Ph.D. program is a step right direction towards strengthening our model for education in CISE. This year the following students were directly supported by the PRECISE Project:

| GRADUATE STUDENTS | ID NUMBER | STUDENT'S E-MAIL | PROFESSOR AS ADVISOR |
|---|---|---|---|
| Armando Vega | 841-95-9288 | vega@caribe.net | Dr. Ramón E. Vásquez |
| Dániza Morales | 804-94-4944 | danizamorales@hotmail.com | Dr. Jaime Seguel |
| Edwin Moulier | 842-94-5637 | emoulier@yahoo.com | Dr. Javier Arroyo |
| Gerardo Nieves | 843-94-4457 | gnieves@cs.uprm.edu | Dr. Jaime Seguel |
| Héctor T. Velázquez | 802-94-7657 | hectorv@ece.uprm.edu | Dr. Luis O. Jiménez |
| Hiriam Firpi | 620-98-2339 | hfirpi@caribe.net | Dr. Javier Echauz |
| Vydia Manian (Ph.D.) | 980-93-3842 | manian@ece.uprm.edu | Dr. Ramón E. Vásquez |
| Irvin Ortiz | 802-96-4684 | irvinof@caribe.net | Dr. Manuel Jiménez |
| Moraima Valle | 802-94-7373 | mory@amadeus.uprm.edu | Dr. Jorge Ortiz |
| Tolstoy Leonid | 402-00-7588 | leon_tol@yahoo.com | Dr. Hamed Parsiani |
| Viviam Murillo | 802-94-4341 | vmc@amadeus.uprm.edu | Dr. Néstor J. Rodríguez |
| Alejandro Mosquera | 402-99-4642 | almosquera@hotmail.com | Dr. Gursel Suer |
| Elisa Maldonado | 802-94-3501 | elimar@centennialpr.net | Dr. Daniel McGee |
| Freddy Martín Pérez | 402-00-5244 | freddy_perv@hotmail.com | Dr. Wilson Rivera |

| UNDERGRADUATES | ID NUMBER | STUDENT'S E-MAIL | PROFESSOR AS ADVISOR |
|---|---|---|---|
| Héctor Del Manzano | 802-97-2093 | xzano@hotmail.com | Dr. Lev Steinberg |
| Zoraida Morales | 802-95-4889 | moralesz@hotmail.com | Dr. Edgar Acuña |
| Alberto Santiago | 802-98-7661 | alberto@cs.uprm.edu | Dra. Dorothy Bollman |
| Juan A. Torres | 802-98-8496 | jantoniot@hotmail.com | Dr. Bienvenido Vélez |

### 2.3.3. New Laboratories and the Creation of New Courses

The PRECISE Project is supporting the establishment of a new Rapid Systems Prototyping (RSP) Laboratory for the graduate and undergraduate research activities of the DSI group. Prof. Manuel Jiménez will be creating four (4) new courses and Prof. Domingo Rodríguez will be creating one new course to support the work on this laboratory. Students in the RSP Lab will work closely with students in the newly created Communication and Signal Processing (CSP) Laboratory from a $220k DoD obtained by S. Hunt (PI) and Prof. Domingo Rodríguez.

## 2.4. Outreach and Dissemination

The Electrical and Computer Engineering Department, which has become the largest department in the Engineering Faculty, and the Mathematics Department, which is the largest in the Arts and Sciences Faculty, comprise the core of the educational and research development efforts in Computing and Information Sciences and Engineering in the last ten years in our campus. It is for this reason that we are paying special attention to our outreach activities. The PRECISE Project has conducted the following outreach activities for this AY 2000/2001:

The preparation of brochures in English and Spanish about PRECISE.

The preparation of a monthly newsletter in Spanish to disseminate PRECISE activities

Visit to six universities in Latin America to present the Ph.D. program in CISE at UPRM during the second week of March 2001 (traveling expenses were sustained by the Microsoft Corporation):

Pontificia Universidad Católica de Chile

University of Chile

University of Santiago, Chile

University of Buenos Aires, Argentina

University of Sao Paolo, Brazil

University of Campinas, Brazil

The following outreach activities are in process:

The development of a PRECISE Web page to integrate the all outreach activities.

The publication of a major article in the university newspaper "Diálogo" which reaches more than 60,000 university students in Puerto Rico.

The development of a full color poster to be sent to universities in the US, specially to Hispanic serving institutions.

A visit to three universities and a research center in Venezuela during the third week of May 2001:

Universidad Central de Venezuela

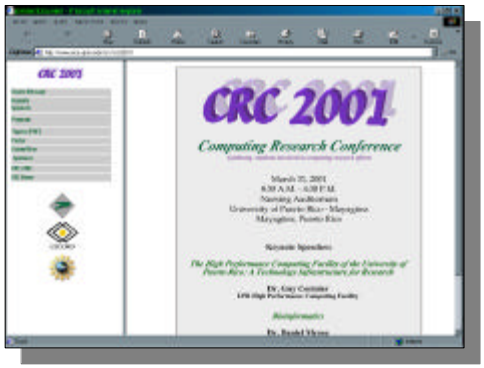
Universidad Simón Bolívar

Universidad de los Andes

Instituto de Ingeniería

### 2.4.1. Computing Research Conference

The Annual Computing Research Conference (CRC 2001) was held, again, this Spring on our Campus. The theme for this year was Computing Research Infrastructure . The message transmitted to the audience was that "The University of Puerto Rico needs to increase its research efforts in order to enhance its fundamental understanding of computing, information, and communications, and in this way contribute with the development of the information industry in Puerto Rico." (http://www.ece.uprm.edu/crc/crc2001/) One of our keynote speakers was Dr. Guy Cormier, Director of the University of Puerto Rico's High Performance Computing facility.(UPR-HPCf). The UPR-HPCf is presently developing a technology infrastructure and services to the research and education community of the University, including: Advanced Research Network, Core High Performance Computational Resources, Services in Support of Users of Computational Resources, Standards and Architecture, and Evaluation of Emerging Technologies. Of great importance to this infrastructure development process is the Internet 2 Project. This project presents the first comprehensive plan for a high speed research network link between the Island of Puerto Rico and U.S. Mainland. This network will connect the three major research campuses of the University of Puerto Rico, i.e., Río Piedras, Mayagüez and Medical Sciences, and the National Astronomy and Ionosphere Center with the existing Internet 2 infrastructure in the United States (http://www.hpcf.upr.edu/). Our second speaker was Dr. Daniel Mcgee, from our Mathematics Department. Dr. Mcgee talked about the tools being developed by him, with the help of his students, for the area of Bioinformatics. The research papers presented by the students at CRC 2001 showed results in diverse areas of computing and its applications. Among these areas were Human Computing Interaction, Parallel Computing, Quantum Computing, Distributed Systems, Computer Modeling and Simulation, Signal Processing, etc. Below we present a photo of the participating audience (**Fig. 4**) and the web site contains the PDF versions of the articles presented by the students at the Conference.





• Figure 4 Part of the Audience Attending CRC 2001

### 2.4.2. PRECISE's Technical Conferences and Seminars

The PRECISE Project held a series of technical conferences and seminars throughout the academic 2000/2001 academic year with invited guests from Puerto Rico and the United States Mainland. Among the most highlighted presentations were the ones provided by David Rind and Daniel Z. Sands, from the Harvard Medical School, who are collaborating with Prof. Néstor Rodríguez. Dr. David Rind discussed, among other things, in his presentation entitled "*Protecting the Security and Confidentiality of Medical Information*," the tradeoffs that must be made between access to information and confidentiality of information. Dr. Daniel Z. Sands, in his talk entitled "*Information Technology in Clinical Practice: Needs, Solutions, and Potential*," discussed potential tools offered by Information Technology which may help cure some of the ills experiencing the practice of medicine nowadays. In the table below we present a partial list of the technical conferences and seminars activities:

| Title of the Presentation or Seminar | Name | Institution | Remarks |
|---|---|---|---|
| Processing of Ground Penetrating Radar | Marco Giardino | NASA's Stennis Space Center | Presentation |
| The Arecibo Observatory Computer Network | Arun Venkataraman | Arecibo Oservatory | Presentation |
| Integer Pair Representation | Andres Díaz and Manuel Jiménez | Electrical and Compute Engineering Dept., UPRM | Presentation |
| Protecting the Security and Confidentiality of Medical Information | David Rind | Harvard Medical School | Presentation |
| Information Technology in Clinical Practice: Needs, Solutions, and Potential | Daniel Z. Sands | Harvard Medical School | Presentation |
| VTK: Visualization Toolkit | Elena Leyderman | UPR High Performance Computing facility | Four-hour Seminar |
| Introduction to IP Networking | Luis Morales | AT&T Bell Laboratories | Two-day Seminar |
| IP Networking | Samir Saad | AT&T Bell Laboratories | Two-day Seminar |

During this 2000/2001 academic year the PRECISE Project the first two biennial research workshops where research collaborators present the status of their research efforts. The first PRECISE Research Workshop was held in October 2000 and the second one was held in the month of February 2001. The third PRECISE Research Workshop (**PRW III**) will be held in the month of October 2001.

### 2.4.3. PRECISE's Graduating Students

Of the seven (7) MS students under the PRECISE Project last year, four (4) of them, Ms.Yvonne Avilés (Prof. Domingo Rodríguez, advisor), Ms. Yolanda Peña (Prof. Ramón Vásquez, advisor), Ms. Dilia Rueda (Prof. Domingo Rodríguez, advisor), and Ms. Marlene Vargas (Prof. Domingo Rodríguez, advisor), have graduated. A fifth student, Mr. Hiram Firpi (Prof. Javier Echauz, advisor), will be graduating by May 2001. The theses work of these students will be posted on the PRECISE's web page as technical reports. We will continue posting the thesis work of all graduating students under the PRECISE Project.

### 2.5. Assessment

As reported last year, PRECISE has developed and implemented an outcomes assessment strategy. The assessment coordinator, Prof. Lueny Morell, is part of the project Executive Committee. This year, a half-time support person has been recruited to assist Prof. Morell in the data collection process. The project is assessed in all of its tasks and components. The major results and recommendations of the assessment effort conducted for this AY 2000/2001 by Prof. Morell are included throughout this progress report.

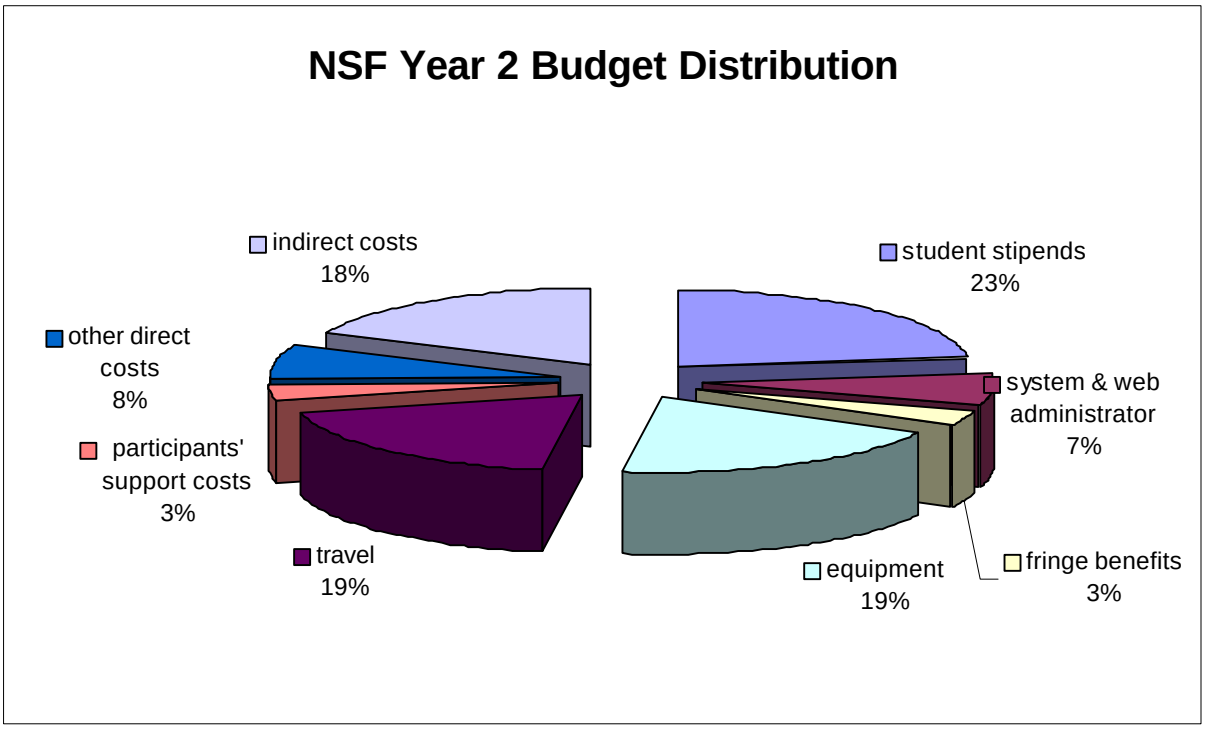
This is the second year of the 5-year grant. The first year of the project was primarily dedicated to ensuring that academic authorities approved the Ph.D. program (approved December 2000), and the development of the infrastructure needed to support the program. This second year attention was given to the organization of key research groups as well as carrying out activities focused on student training and development and program outreach (at local, national and international level).

The proposed PRECISE's Strategic Plan suggests carrying external reviews of the project's goals by creating a **PRECISE External Review Committee** which will come to the University of Puerto Rico and review its performance. This committee will provide the PI's with their views and feedback on how the project's goals and objectives are being met (formative assessment). At least two (2) external assessors will come to Puerto Rico at least twice during the project life span to study, assess and provide feedback as well as recommendations on the project's performance. These external assessors will be selected from schools or programs where similar research activities are being held. The PRECISE External Committee will meet for the first time in Spring 2002.

## 3. PRECISE Overall Budget

Use institutional resources appear is adequate. UPR contribution is primarily used to support the project's staff and release time for participating faculty, whereas NSF contribution supports research-related activities, 30% going directly to student stipends. We are experiencing the need to increase our technical staff in order to provide support to students and researchers. For this reason we are requesting the use of $30,000.00 from our equipment budget to defray the salary cost of the new personnel.

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | **Total** |
|---|---|---|---|---|---|---|
| NSF FUNDS | 409,850 | 314,149 | 329,446 | 231,257 | 214,554 | **1,499,255** |
| UPRM | 173,510 | 141,510 | 141,510 | 141,510 | 141,510 | **735,550** |
| UPR President | 125,217 | 136,935 | 156,687 | 160,476 | 180,302 | **1,499,255** |
| **Total** | 708,577 | 592,594 | 627,643 | 533,242 | 536,366 | ***2,998,422*** |




## 4. Conclusion

We have presented a progress report for our overall activities for the academic year 2000/2001. It is our view that the PRECISE Project is meeting the goals and objectives that it set out to accomplish. Year three (3) of this project will emphasize restructuring and strengthening our research groups so that we may focus on well identified research activities pertaining to closely tight, well orchestrated, naturally formed, smaller groups. Activities to facilitate interaction, teamwork and identification of research opportunities, conduct research as well as partnering with strategic institutions to foster the competitive research will be of high priority for us this coming year.

Finally, we will be ever guarding the endorsement and support of the higher administration for both our Ph.D. Program in CISE and the PRECISE Project infrastructure development works. We will, in turn, strive to enhance the quality and increase the number of our graduate students, advance the quality of our research, augment our publication efforts, and raise the efficiency and continue to raise the effectiveness of the PRECISE Project overall administration.

# 5. References

Below we provide references for refereed publications of part the research work conducted by PRECISE research collaborators for the period of April 1, 2000 to March 31, 2001.


E. Acuña, "Ensembles Based on Kernel Density Estimators and Gaussian Mixtures," 7th Conference of the IFCS, Namur, Belgium.

H. Firpi and J. Echauz, "Genetically found, neurally computed artificial features from relevant and irrelevant data," Group Technology/Cellular Manufacturing World Symposium, 2000, San Juan, PR, 2000, pp. 327-331.

V. Manian, Marcel Castro and R. Vásquez, "Texture based algorithm for color image classification," SPIE's AeroSense'2000 conference, Orlando, April 2000.

V. Manian, Michael Diaz, Ramón Vásquez, "Wavelet features for color image classification," Imaging and Geospatial Information Society, 2000 Annual Conference.

V. Manian, R. Vásquez and P. Katiyar, "Texture classification using logical operators," IEEE Transactions on Image Processing, In Print.

V. Manian, R. Vásquez and P. Katiyar, "Texture classification using logical operators," IEEE Transactions on Image Processing, vol. 9, No. 10, pp. 1693-1703, Oct. 2000.

V. Manian, Armando Vega and R. Vásquez, "Comparison of feature selection algorithms for texture image classification", SPIE AeroSense 2001.

J. Ortiz, "Finite-State Grammatical Model and Parser for Air Traffic Controller's Commands," Interservice/Industry Training, Simulation and Education Conference. (I/ITSEC), Nov. 2000.

H. Parsiani, R. Gonzalez, "Iterated Block Matching Fractal Image Compression with Parent and Child Quadtree", Proceedings of the IASTED International Conference, Signal and Image Processing , Signal and Image Processing , SIP'2000, Nov. 19-23, 2000, Las Vegas, Nevada.

W. Rivera, J. Zhu, and D. Huddleston, "An Efficient Parallel Algorithm with Application to Computational Fluid Dynamics." To appear in *Computers & Mathematics with Applications.*

W. Rivera, "Scalable parallel genetic algorithms." To appear in Artificial Intelligence Review, 2001

D. Rodríguez, M. Vargas, Y. Aviles, "DFT Beamforming Algorithms for Space-Time-Frequency Applications," SPIE's Aerosense 2000 Conference on Digital Wireless Communication, Orlando, Florida, April 2000.

D. Rodríguez, D. Rueda, "Kronecker-based Algorithms for SAR Imaging Kernel Formation," SPIE's Aerosense 2000 Conference on Algorithms for Synthetic Aperture Radar, Orlando, Florida, April 2000.

D. Rodríguez, "Kronecker Products Algorithms for on Board SAR Image Formation," EUSAR 2000, Munich, Germany, May 2000.

D. Rodríguez, "Characterizing Point Spread Signals for Subsurface Synthetic Imaging," SPIE's International Symposium on Subsurface Sensing Technologies and Applications, San Diego, California, August 2000.

J. Seguel, D. Bollman, J. Feo ``A Framework for the Design and Implementation of FFT Permutation Algorithms"IEEE Transactions in Parallel and Distributed Systems,Vol. 11, No. 7, pp 625-635 (2000)

G. Süer, R. Vásquez, Y. Peña, “Cellular Design to Minimize Investment Costs by Using Evolutionary Programming” with Submitted to the Journal of Engineering Valuation and Cost Analysis (accepted for publication).

G. Süer, R. Vásquez, J. Santos, “Evolutionary Programming for Minimizing the Average Flow Time In the Presence of Non-zero Ready Times” Submitted to the Computers and Industrial Engineering Journal (accepted for publication).

G. Süer, R. Vásquez, J. Santos, “Evolutionary Programming for Minimizing nT and Tmax in Single Machine Scheduling” Proceedings of the Third Asia-Pacific Conference on Industrial Engineering and Management Systems, Hong Kong, December 20-22, 2000

G. Süer, R. Vásquez, “Intelligent Software for Teaching Production Management,” Proceedings of the International Conference on Information Technology Based Higher Education and Training, Istanbul, Turkey, July 3-5, 2000.

G. Süer, "Genetic Algorithm Applications in Manufacturing," Tutorial, 10th Annual Neural Networks and Artificial Intelligence Conference, St. Louis, Missouri, November 5-7, 2000.