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Development and Evaluation of Metaheuristics for Constrain Satisfaction Problems

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1 Introduction

The main purpose of this project is to develop advanced techniques and tools for solving constraint satisfaction problems (CSPs), with a special interest in scheduling problems. It is well known that many real problems belong to this family and that scheduling problems are in fact a paradigm of constraint satisfaction problems. Consequently developing general purpose strategies for these problems is an interesting issue.

In this project, we plan to exploit a number of artificial intelligence techniques such as heuristic, evolutionary algorithms, state space search, parallel processing and models to cope with uncertain knowledge. We will try to combine them in order to reach a threshold of efficiency that allows us to obtain effective solutions to scheduling problems. The development of systematic methods to combine heuristics for complex problems is expected to be one of the main contributions from the methodological point of view.

In addition to the formal techniques, another relevant contribution of the proposed project will be the implementation of tools incorporating these techniques, which will allow us to work on massive sets of experiments. In order to do that, these tools must be enhanced with both a user interface for experiments setup and experimental results management, as well as an execution environment that distributes the processes on a cluster of heterogeneous processors.

For experimental studies, we will use problem instances taken from conventional repositories, as well as problems with particular characteristics. In the case when problems of this class are not available, we will make our own proposal.

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2 Main Objectives

The main objectives of this research project can be summarized as follows

2.1 New strategies for Scheduling problems with Genetic Algorithms and State Space Search

- New seeding methods for solving the Job Shop Scheduling (JSS) problem with GAs
- Combining Local Search, Structured Populations and Heuristic Seeding in GAs
- Solving Scheduling problems other than JSS, such as Open Shop and Flow Shop
- Solving the JSS problem with Brach and Bound and A* like algorithms. Heuristics development for these search paradigms, and study of alternatives that require less computational resources

2.2 Implementation of a tool for massive experimentation with GAs in a distributed hardware

- Here our objective is incorporating the standard models of parallelism in GAs: farm and islands, into our logical model of GAs. We extend our GA object model in this task by using standard parallel environments such as MPI or PVM.

2.3 Parallel Implementation of GAs

- Here our objective is adapting and exploiting a parallel virtual machine that we have developed in a previous project (to implement a parallel interpreter of logic programs) for parallel execution of GAs.

2.4 Study of some formal aspects of GAs for Scheduling

- Here the main goal is to compare various codification schemas suitable for Scheduling and related problems, trying to explain the different be-

haviour between them, and if possible design new and better codification schemas

2.5 Design and Implementation of a prototype tool for production scheduling

- The objective is to develop a general purpose scheduler that could be adapted to standard real manufacturing industries or workshops, similar to some current commercial tools

2.6 GAs for problems other than Scheduling

- Here we aim at applying the same or similar techniques used for Scheduling to other problems of combinatorial nature such as, for example, the Knapsack Problem, String Equations or Vehicle Routing

2.7 CSP formulation is the framework of Possibility Theory

- First we will try to formulate some heuristics, in particular the variable and value ordering heuristics for JSS, within this theory in order to compute them more efficiently
- Moreover we will confront CSPs problems with uncertainty or flexible constraints, for example JSS problems with uncertain durations and flexible due dates. Here we will try to define a clear semantics for the solutions to the problems, and generalize the methods used with crisp problems

3 Main Changes with Respect to the Initial Objectives

From some suggestions of the project referees we have done a change in the previous objectives in order to confront some truly real problems in addition to the academic ones, so making this project more useful in practice. We have opted for eliminating objective 2.5, and look for some real problems in our industrial environment instead. The result is that we have contacted two different companies that proposed two interesting problems for us to solve. First, the Spanish rail company (RENFE) has proposed to us a challenging problem that consists in organizing the timetable of train drivers. The second company manufactures rolls of plastic film. In this case the problem consists in optimizing the cut plans in order to minimize the amount of plastic that has to be thrown away as well as the cutting machine arrangements between different cuts. In both cases we have a multiobjective CSP.

4 Summary of main results up to date

As many of the project tasks require much programming effort, we have offered a great part of this work to undergraduate students on Computer Science, so that they have the opportunity of doing their graduation project at the same time that, in many cases, provide us a valuable collaboration and gain some experience in research activities. We also participate in doctoral program of the Department of Computer Science of the University of Oviedo, hence we also supervise doctoral students that collaborate with us in doing their research work and Phd. In the three following subsections we indicate the set of undergraduate student projects, the papers we have published related to this research project, and the doctoral students that collaborate with us.

4.1 Student projects

The following graduation projects were carried out by the indicated undergraduate students within the scope of this research project

- Resolución de Problemas de Scheduling con el Algoritmo A*. *María R. Sierra Sánchez*
- Un Algoritmo Genético para el problema de planificación de proyectos con tareas multimodales. *Lorenzo García Suárez*
- Planificación de turnos de trabajo de personal de conducción de trenes de mercancías. *Juan Fernández Rodríguez*
- Resolución de Problemas de Planificación con búsqueda tipo Backtracking restringida al espacio de planificaciones activas. *Jorge Sánchez Rodríguez*
- Un modelo probabilista para incorporar conocimiento heurístico en un algoritmo genético. *Javier Blanco Rodríguez*
- Representaciones extendidas en Algoritmos Genéticos. *David Serrano Riestra*
- Diseño de un Algoritmo Memético para Problemas de Scheduling con Representación Gráfica Interactiva. *David Moreno López*
- Un algoritmo evolutivo para el problema Field Technician Scheduling Problem. *Andrés Cifuentes Pla*
- Análisis, Monitorización y Síntesis de Poblaciones en Algoritmos Genéticos. *Daniel González Fernández*
- Combinación del entorno LEKIN con un Algoritmo Genético para problemas de Scheduling. *Eduardo García Pérez*
- Monitorización de Algoritmos Evolutivos. *Elias Alvarez Granda*

- Algoritmos evolutivos para el problema de Asignación de Frecuencias. *Francisco González Bulnes*
- Desarrollo de una libreria de clases para aprendizaje con sistemas borrosos. *Manuel Espina Álvarez*
- Desarrollo de una librería de clases para aprendizaje de descripciones Lingüísticas. *Miguel Ángel Pastor Olivar*
- Cálculo de soluciones aproximadas y cotas inferiores para el problema de secuenciamiento de una máquina. *Miguel Angel González Fernández*
- Editor Web de planificaciones de Tareas. *Hernán Díaz Rodríguez*
- Entorno Web de ejecución distribuida de algoritmos genéticos. *Antonio Espín Ballesta*
- Un Algoritmo de Ramificación y Poda para Problemas de Scheduling. *Omar Enrique Somoano Fernández*
- Algoritmos Genéticos y Búsqueda en Espacios de Estados para el problema DCMST. *Beatriz Cueto*
- Estudio de Operadores Genéticos e Inicialización Heurística para el problema Flow Shop Scheduling. *David Fernández*
- Estudio de la Búsqueda Local para el problema Job Shop Scheduling. *Rubén García*
- Sistema de Ayuda a la Enseñanza de los Algoritmos Genéticos. *Covadonga Flórez*
- Algoritmos evolutivos para la resolución de sistemas de "Word Equations. *Fátima Drubi Vega.*
- Resolución de sistemas de ecuaciones de palabras mediante algoritmos evolutivos. *Davinia Jurado Santiago y Leticia Reigada Suárez.*

4.2 Published papers

In addition to some papers that are under review process in some journals and conferences, we have published the following papers in the last two years which are related to the objectives of this research project

A new Chromosome Codification for Scheduling Problems
Varela, R., Vela, C. R, Puente, J., Serrano, D., Suárez , A.
Information Processing with Evolutionary Algorithms: From Industrial Applications to Academic Speculations. Ed. Springer, 2004.

Induction of Fuzzy Prototypes with Feature Selection
González Rodríguez, I., Lawry, J.
Soft Methodology and Random Information Systems (Advances in Soft Computing Series). López-Díaz, M., Gil, M.A., Grzegorzewski, P., Hryniewicz, O., Lawry, J. (eds.), Springer-Verlag, pp. 471-478, 2004.

Heuristic Rules and Genetic Algorithms for Open Shop Scheduling Problems
Puente J.; Díez, H.R.; Varela, R.; Vela, C. R.; Hidalgo; L.P.

Current Topics in Artificial Intelligence, LNAI-3040. Springer-Verlag, pp. 394-403, 2004.

Some Issues in Chromosome Codification for Scheduling with Genetic Algorithms.
Varela, R., Puente, J. and Vela, C. R.
Workshop on Constraint Satisfaction Techniques for Planning and Scheduling Problems. ECAI 2004. Valencia, 24-27 Agosto 2004.

Word Equation Systems: The Heuristic Approach
Alonso, C. L; Drubi, F.; Gómez García, J.; Montaña, J. L.
Advances in Artificial Intelligence- SBIA 2004 LNCS (Serie LNAI 3171) Eds. Ana L. C. Bazzan and Sofiane Labidi. Springer. pp. 83-92. 2004

An Evolutionary Strategy for the Multidimensional 0-1 Knapsack Problem Based on Genetic Computation of Surrogate Multipliers
Alonso, C.L., Caro, F., Montaña, J.L.
Edited by: J. Mira and J.R. Álvarez. IWINAC 2005, LNCS 3562 (ISBN: 3-540-26319-5), Springer-Verlag, pp. 63–73, 2005.

New Codification Schemas for Scheduling with Genetic Algorithms
Varela, R., Serrano, D., Sierra, M.
Edited by: J. Mira and J.R. Álvarez. IWINAC 2005, LNCS 3562 (ISBN: 3-540-26319-5), Springer-Verlag, pp. 11–20, 2005.

An Evolutionary Approach to Designing and Solving Fuzzy Job-Shop Problems
González Rodríguez, I., Vela, C. R, Puente, J.
Edited by: J. Mira and J.R. Álvarez. IWINAC 2005, LNCS 3562 (ISBN: 3-540-26319-5), Springer-Verlag, pp. 74–83, 2005.

Búsqueda Heurística para Problemas de Scheduling
Sierra, M.; Varela, R.
IX Congreso de Ingeniería de Organización, Gijón, 8 y 9 de Septiembre, 2005.

Optimal Scheduling with Heuristic Best First Search
Sierra, M., Varela, R.
9th congress of the Italian Association of Artificial Intelligence (LNCS), Sep. 23-25, Milano, 2005

Some Issues in Chromosome Codification for Scheduling with Genetic Algorithms
Varela, R., Puente, J., Vela, C. R
Planning, Scheduling and Constraint Satisfaction: From Theory to Practice. Volume 117 Frontiers in Artificial Intelligence and Applications
Edited by: L. Castillo, D. Borrajo, M.A. Salido and A. Oddi. (ISBN: 1586034847)
IOS Press, pp. 1-10, 2005.

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Un algoritmo meta-heurístico para la resolución de problemas P//∑Ci
Noelia González, Camino R. Vela
IV Congreso Español sobre Metaheurísticas, Algoritmos Evolutivos y Bioinspirados, MAEB'2005, Granada, 2005

Un algoritmo evolutivo para el Problema de la Mochila Multidimensional basado en el uso de un esquema de aproximación polinomial para el problema unidimesional
Alonso, C.L., Caro, F., Montaña, J.L.
IV Congreso Español sobre Metaheurísticas, Algoritmos Evolutivos y Bioinspirados, MAEB'2005, Granada, 2005

4.3 Doctoral students

Currently we are supervising two doctoral students: Ms. María Sierra and Ms. Noelia Sánchez. Both of them have completed the 2-year doctoral program and presented their research works

Búsqueda Heurística para problemas de Scheduling: Cálculo de cotas inferiores y superiors. *María Sierra*

Resolución de problemas Flowshop Scheduling mediante estrategias evolutivas y heurísticas. *Noelia González*

Now they are working on their Phd. María Sierra is funded by a grant from the regional government (FICYT BP04-021) during the period 2004-2008 and Noelia Sánchez works in a private company and is also half-time assistant lecturer in the Dept. of Computer Science.

5 Future Work

During the next year, the last one of the research project, we plan to complete all the project objectives. Our main interest will be focused on the two proposed practical problems: the time tabling of train drivers and the optimal cutting of plastic film. At the moment both of these problems are well-formulated and we are currently working on the first prototype implementation.
We hope that some of the papers already submitted for publication both at international conferences and journals will be accepted. We are also confident that the completion of all project objectives will provide us with ideas and results for new publications.