II SELASI

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FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

II European-Latin-American Workshop on Engineering Systems

The II European-Latin-American Workshop on Engineering Systems (SELASI), will be held June 21 - 23, 2006 in Faculty of Engineering of Porto University, Porto, Portugal.
Submission deadline for papers is by May 12, 2006
Acceptance of papers May 26, 2006
Sponsored by the Alfa Project net: Engineering Systems for Preparing and Making Decisions under Multiple Criteria (SistIng)

Welcome you to submit your articles. Will you please contact: selasi@fe.up.pt
or, personally, Prof. Adriano Carvalho: asc@fe.up.pt

The Organizing Committee may suggest you the most appropriate ways for your travel and stay helped by the travel agency Agência Abreu [http://www.abreu.pt/].
Please forward this preliminary announcement to your co-workers and colleagues that may be interested in participating.
After the Workshop you'll can experience the unique event of St. John's night on the streets of Porto, besides of visiting the historic centre of Porto, World Heritage by UNESCO.

THE AIM OF THE WORKSHOP

The inherent complexities of the engineering, that are derived of the descriptive complexities of the studied processes have come stimulating in the last decades the realization of special researches to develop the different tools that are required to elaborate procedures for preparing and making properly based decisions. Among the more important fields of Engineering where these researches have acquired higher relevance may be included the following ones:
. Engineering Design
. Technologies generation
. Process Operation
. Production Planning
. Maintenance
. Logistic Systems

It is difficult to overestimate the economic and scientific repercussion of the solution of engineering problems. In particular, the subjects of the analysis and the synthesis of systems for

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HOTEL INFORMATION

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2.05 - 12.30	W2.1 W2.2 W2.3	Robustness Analysis in Evolutionary Multi-Objective Optimization – with a Case Study in Electrical Distribution Networks Solving a Robust Version of the Minimum Spanning Arborescence Problem An Algorithm for 1-Facility Multicriteria Ordered Median Problems on Networks	Carlos Barrico Henggeler Antunes Eduardo Conde Stefan Nickel Jörg Kalcsics Edmundo Vergara

LUNCH

			Chairperson: Obidio Rubio
14.30 - 15.50 14.55 - 15.20 15.20 - 15.45 15.45 - 16.10	W3.1 W3.2 W3.3 W.3.4	Determination of Routes for Picking up Solid Residuals in Huaraz City using Multiple Criteria An Application of Multicriterial Analysis to take Environmental Decision on Drainage System to Problems of Watertable Solving Cutting Path Problems by Memetic Algorithms Método de Elementos Finitos aplicado a un Modelo Matemático de flujo de Agua Subterránea	Giovanna Coral Jesús Espinola J. Peralta- Castaneda José Arzola Obidio Rubio Ana Rodrigues J. Soeiro Ferreira Adriano Carvalho Obidio Rubio Luis Lara

COFFEE BREAK

			Chairperson: Edmundo Vergara
16.30 - 16.55	W4.1 W4.2	A Simulation System for the Footwear Industry	Juan Marques J. Soeiro Ferreira

Solving Cutting Path Problems by Memetic Algorithms

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Abstract

Components of irregular shapes must be cut from circular (expensive) plates, in a continuous way and while minimising the cutting path/time.

This real industrial complex path-planning problem is basically modelled as a Rural Postman Problem and is solved using an approach based on Memetic Algorithms. Computational results are presented.

Key words: Cutting Path, Memetic Algorithms, Rural Postman Problem

Introduction

A class of complex path planning problems rising in the manufacturing of irregular components for woodworking tools is considered. The discussion is essentially based on an important Portuguese industry of that sector.

Components of small size and of irregular shapes must be cut from circular (expensive) plates made of tungsten with a thin diamond layer, using an electrified copper string-cutting tool. This procedure must be carried out in a continuous way, the cutting tool never leaves the cutting surface, and it is particularly important to minimise the cutting path/time (see Fig.1). Other practical restrictions must be taken into account. Moreover, there is an obvious connection to the related nesting and visibility checking problems, what is an extra contribution to the complexity of these path optimisation problems.

A new resolution approach based on Memetic Algorithms is considered, after modelling the problem as a Rural Postman Problem (RPP). Memetic Algorithms (MA) can be understood as Genetic Algorithms with a local search operator to aggregate memetic information, i.e., after the recombination and mutation phases, a local search is applied to the resulting solution. 'Memetic' results of the word 'meme' that denote the idea of imitation in cultural transmission.

Other approaches are mentioned namely one based on a constructive algorithm, which proved to be quite effective in the factory environment, is also referred.

Computational results are included allowing for the comparison of different approaches, and they are illustrated by industrial cases.

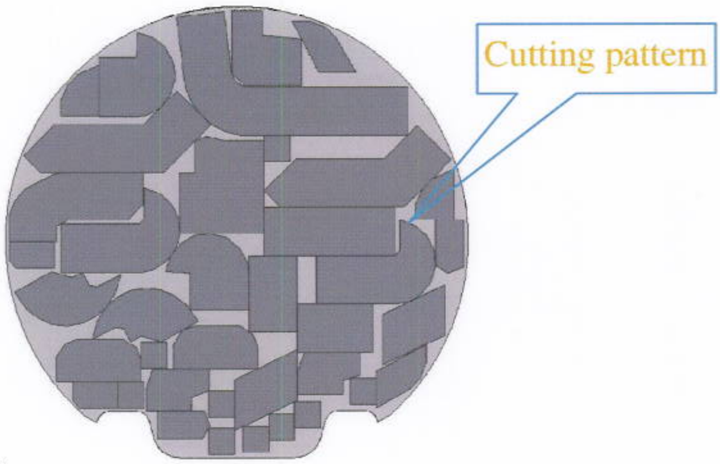


Fig. 1

Nesting Problem

To start considering the Path Optimisation problems it is fundamental to generate good layouts, in the circular plates, of the irregular pieces to be cut. Visibility checking problems must also be solved, but this will be considered in the next section.

Nesting Problems deal with the good usage of material. One or more pieces of material (big items – circular in this case) must be divided into smaller pieces – the components to be cut, under some geometric constraints, for instance, no overlap is allowed. The usual main objective is to minimise the waste.

The solution procedures used are based on the methods proposed by Oliveira et al [16], and Gomes et al [10]. They are constructive heuristic methods supported by the geometric concepts of the no-fit-polygon and the inner-fit-rectangle.

Visibility Check

After getting a convenient layout of the components to be cut, it is necessary to create ways of connecting these components, so that the cutting tool may move among them. These bridges (edges) between pieces to cut are obtained after solving Visibility Checking Problems. No way to avoid this task – it is not possible to turn off the cutting tool, during the cutting procedure.

When no obstructions are present between two nodes (vertex) of different pieces, the nodes are said to be visible to each other; otherwise, they are called a pair of invisible nodes. This problem of inter-visibility, called here Visibility Check, is based namely on Williams [17]. It involves the application of plane geometry. The final goal is to ascertain the visibility of any other point from a given point.

Rural Postman Problem

Which ways to follow to cut all the components? These Path Optimisation Problems are modelled as a Rural Postman Problem (RPP). Arc Routing Problems (ARP's), see Eiselt et al [5, 6] occur in a variety of practical contexts. The aim is to determine a least-cost transversal of a specified arc subset of a graph. A well-known problem is the Chinese Postman Problem, the point being the determination of a minimum length walk covering each segment (edges) at least once. When it is required to traverse only a subset of the

arcs, the problem is known as the RPP. A definition: for a given connected and undirected graph G=(V, E), with a node set V, an edge set E and a nonnegative cost vector c indexed by the edges of G, and given a set of required edges $E_R \subset E$ ($E_R \neq \emptyset$), the RPP consists of finding the shortest tour of G such that each edge in E_R is traversed at least once.
An obvious relationship to the case study: the required edges are the edges of the pieces and the non-required edges are the edges determined during the visibility-checking phase.
The RPP is NP-hard which makes the search of the global optimum a very difficult task. Although mathematical programming techniques could have been considered, see Eiselt et al [6], Christofides et al [1], Córberan et al [3] and Ghiani et al [8], other authors used heuristics (metaheuristics) to deal with this problem, see Frederickson [7], Cook et al [2] and Córberan 94 [3], the authors decided to resort to more flexible approach - Memetic Algorithms, this mainly due to the dimension and practical restrictions involved in the problem.
The authors are not aware of any applications of MA to the RPP.

Memetic Algorithms

Recently, a new class of "knowledge-augmented Genetic Algorithms (GA)", also called "hybrid GA", appeared. The basic idea of these methods is to include all knowledge from the problem domain. Later, Moscato, 89 [11], they started to be recognized with the term "Memetic Algorithms" (MA), meaning evolutionary algorithms in which local search plays a significant part. The word "meme" has been introduced by Dawkins in his book "The Selfish Gene" to denote the idea of a unit of imitation in cultural transmission.
MA may be seen as GA with a local search operator to aggregate memetic information - after recombination and mutation, local search is applied to the resulting solutions.
The process begins with a certain number of individuals. For each individual the initial state (solution) can be randomly chosen or given according to a heuristic. After the initialisation, each individual makes local search trying to find a local optimum or to improve up his fitness to a predetermined level. The next step is the interaction between the individual and other members of the population. A number of distinguishable individuals compete and cooperate with the other individuals during the search, see Norman [15], Moscato 92 [12] and Moscato 89 [11].

The Cooperation behaviour can be understood as the interchange of information like the mechanism of crossover in GA. The Competition behaviour is similar to the selection process in GA (the selection of better individuals by a procedure where individuals subsume each other's positions according to their relative fitness).

A description follows of how MA are used to solve the RPP.

In the method implemented, the population is composed of 13 agents, with initial solutions, as a ternary tree of three levels, i.e., subpopulations of four individuals each, where each node represents one agent, thus:

Each subpopulation is composed by one "leader" node and three supporters (follower)

The leader of a subpopulation (or cluster) is always better fitted than its supporters.

At any moment in time, each agent of the optimising population will be handling two tours. They are:

Pocket Tour - the best tour found or received by that agent;

Current Tour - the one actually being optimised, by the heuristic assigned to that agent.

The best tour of each agent is updated each time a new "current" tour, of a smaller length, is obtained, Moscato 94 [13].

To maintain the organized structure of the tree, the three points below are crucial:

Whenever a Current is better than its Pocket, they are switched, so that the latter plays the role of a "memory" of good solutions;

- If the Pocket solution of the follower is better than the Pocket solutions of a leader, the results are exchanged to keep the hierarchy;
- Keep the agents of a subpopulation in an increasing order of their values in "Pocket"

All agents optimise their "current" tours with periods of local search. After they have reached a local minimum the tree is updated and they recombine.

A new population arises with feasible solutions, that must be organized according to the fitness of their agents and all the process will be repeated.

After a series of recombinations and local search steps, the population naturally loses diversity. To avoid this situation some procedures must be taken, such as:

- recombination, that usually take place between individuals of the same subpopulation, must occur, sometimes, between individuals of different subpopulations;

- if Pocket and Current references stay without switch for a "long time", a mutation operator must be applied.

Other Solution Methods

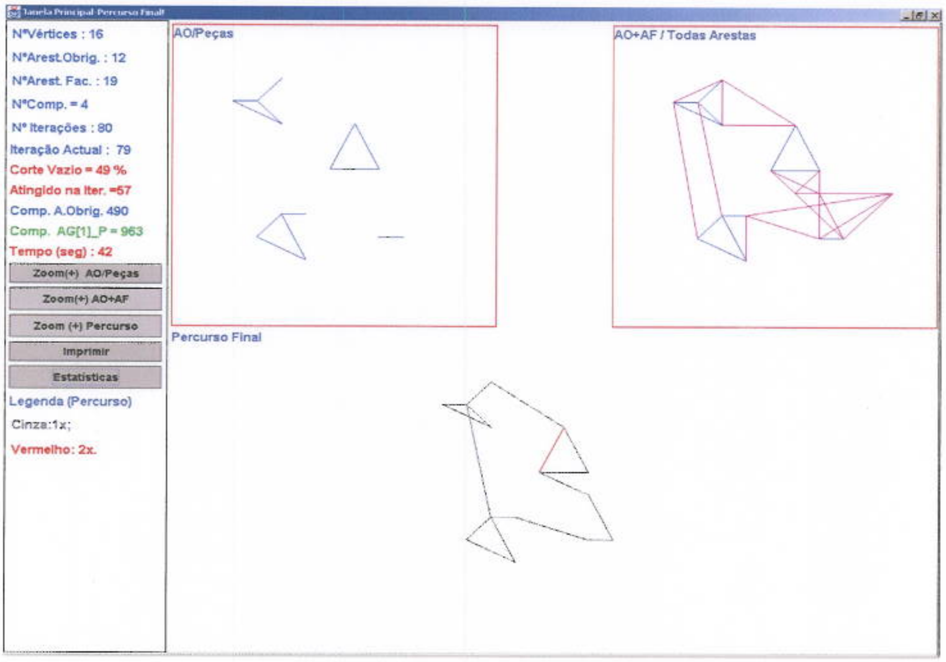
The authors developed other approaches before, such as Monte Carlo Methods, Galvão and Ferreira [4], and Constructive algorithms, Moreira [9].

Monte Carlo methods can be loosely described as statistical simulation methods. The idea of this approach [1] is to simulate a vehicle randomly moving over a graph. The vehicle starts in a arbitrary piece's, keeps jumping from one node to another of its adjacent nodes selecting the destination on the basis of certain probabilities. A specified number of travels is tried, and the shortest one is selected. The solution obtained depends upon the way probabilities are assigned to the edges (they change during the iteration procedure).

A Constructive Method developed is VMA 'Uppermost Node Heuristics', which assigns priority to the movements over required edges (cuts), far from the support of the plate, the upper part region: given a node, the choice of the next node falls on the uppermost candidate, among those reachable from edges not yet cut, which fulfil the requirements.

Computational Results

Computational results are presented. They illustrate the application of the Memetic Algorithms approach to 'simple' cases (RPP's) taken from the literature, see Fig.2, and to real industrial applications, see Fig 3 and Fig 4. Results obtained by other methods are also included, what allows for a discussion about the relative advantages of the various approaches.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NºArest.Obrig. : 12
NºArest. Fac. : 19
NºComp. = 4
Nº Iterações : 80
Iteração Actual : 79
Corte Vazio = 49 %
Atingido na Iter. =57
Comp. A.Obrig. 490
Comp. AG[1]_P = 963
Tempo (seg) : 42
Zoom(+) AO/Peças
Zoom(+) AO+AF
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Cinza:1x;
Vermelho: 2x.
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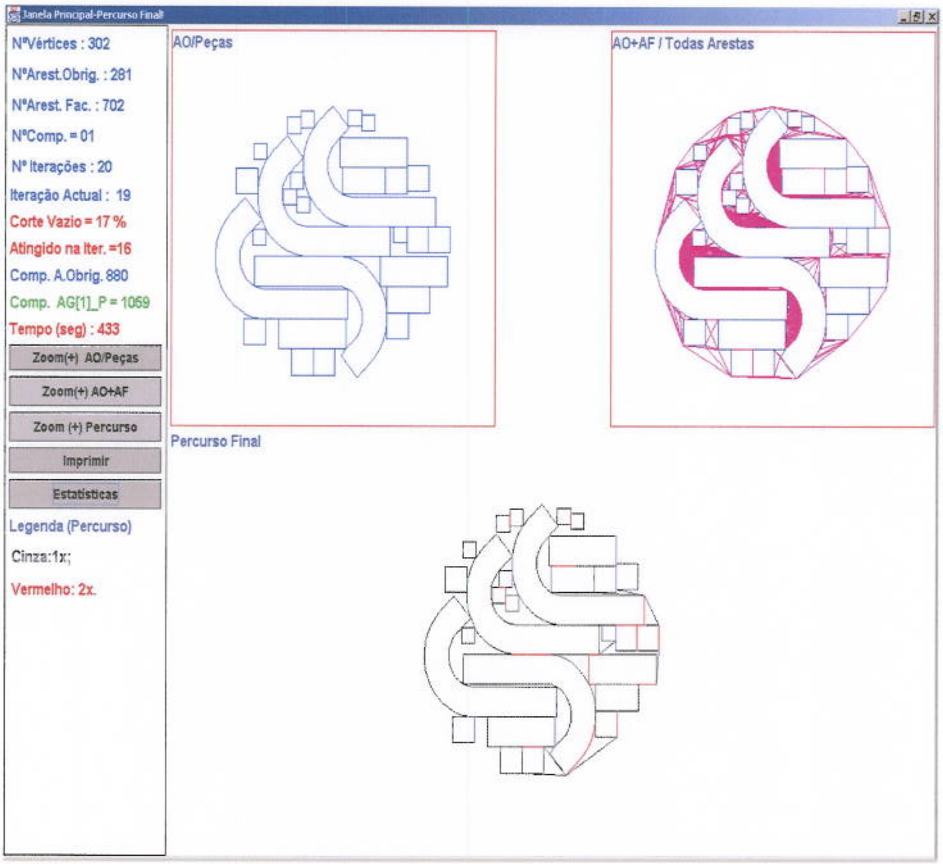
Fig. 2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NºArest. Fac. : 702
NºComp. = 01
Nº Iterações : 20
Iteração Actual : 19
Corte Vazio = 17 %
Atingido na Iter. =16
Comp. A.Obrig. 880
Comp. AG[1]_P = 1059
Tempo (seg) : 433
Zoom(+) AO/Peças
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Fig 3

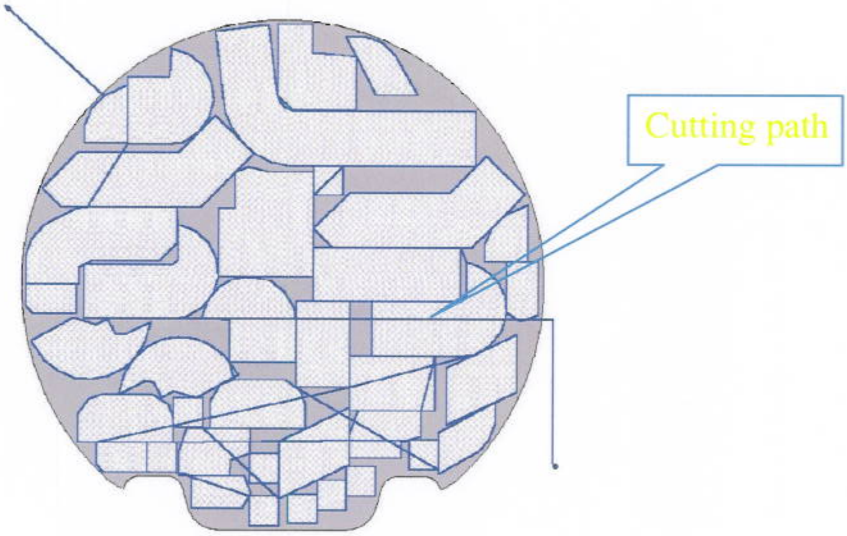

Fig. 4

The authors may also conclude, based on the industrial validation, that the integrated system (nesting, visibility checking, and path optimisation) is effective to deal with the problems in the factory environment. And this was a main objective of this work.

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