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Study of the Application of Genetic Algorithms in Optimization of Cutting Glass Sheets

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***Abstract-* Evolutionary computing has proven particularly useful in solving complex problems involving combinatorial optimization. These are problems with various parameters or characteristics that need to be combined in the search for optimal solutions. This project consists of the study, development and implementation of solution methods based on evolutionary computation, specifically in genetic algorithms, to optimize the cutting of glass sheets. Due to technical and operational constraints involved in this process, the optimization cutting of glass sheets is a pretty difficult combinatorial optimization problem.The experimental results of evolutionary computation reported in this project confirm the genetic algorithms as an efficient tool in solving problems involving combinatorial optimization.**

I. Introduction

The resource allocation problem has been a great impact factor on the industrial production systems performance. Such problems can be found in various industrial processes, such as task allocation, logistical problems and materials packaging/cutting processes. The solutions to such optimization problems are of great importance in shaping the final product cost and development and industrial competitiveness.

Due to the potential of practical applications to optimize industrial processes and difficulties in obtaining exact solutions, this problems category has been the subject of intense research in the Operations Research (OR) and Artificial Intelligence (AI), since the study of such problems provides a common basis for analysis and solution of other problems that belong to the same category.

Optimization cutting of glass sheets is an arising problems from production systems and consists of determining an arrangement of pieces to be cut, maximizing the utilization of glass sheets, but respecting the constraints imposed by the equipment used for completion of the cut (the arrangement of the parts should be guillotine) and the production flow (an acceptable processing time).

The Evolutionary Computation, specifically genetic algorithms (GA) has proved particularly useful in solving complex problems that involve optimization does not always guarantee the optimal solution, but a very good solution with low computational effort.

In this work we demonstrate the use of Evolutionary Algorithms to solve the problem of optimal cutting of sheet glass by using development approaches based on genetic

algorithms and a variation of the packing algorithm known as *First Fit*.

II. Glass Cutting problem

The Optimization Cutting of glass sheets problems are an important class among constraint satisfaction problems [9] [10]. In particular, the problem is two dimensional pieces arrangement and cutting in different sizes and formats in order to minimize loss of material. Traditional approaches to the two-dimensional cutting can be divided into two categories: linear programming (LP) and heuristic (MH), being the most popular heuristic methods in solving real problems. However, the use of genetic algorithms (GA) in solving problems of restriction has grown and technology has become an important tool for modeling and solving this class of problems.

III. Genetic Algorithm for Optimization Cutting of Glass Sheets

The AG developed to solve the problem of cutting sheets of glass is a version that selects from n pieces of varying sizes, an optimal sequence that, after the application of algorithms packaging, seek to minimize the leftovers in the standard glass slide . The Table I shows the example of a cutting request order containing 32 pieces.

TABLE I
EXAMPLE OF REQUEST TO BE OPTIMIZED

Piece number	Dimensions (mm)	Pieces
1	720 x 220	14
2	515 x 2150	2
3	915 x 1410	6
4	250 x 1850	5
5	900 x 1320	2
6	370 x 900	2
7	400 1300	1

a. Chromosomes Encoding

Since the goal of GA is to find the most optimal sequence of parts of the distribution, cutting sheets, we are using an encoding order based on individuals (Linden, 2008). This codification is a list whose elements represent the sequence of fitting each piece in a glass slide.

Examples of individuals to a request from nine parts:

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Chromosome 1: (1, 2, 4, 8, 3, 5, 7, 9, 6)
Chromosome 2: (2, 4, 5, 1, 3, 8, 9, 6, 7)

b. *GA Initial Population*

The chromosomes of the initial population, or the first generation are generated randomly from the quantity of parts to be optimized by following the encoding described in the previous item.

c. *Fitness Calculation*

The chromosomes fitness calculation of each generation will be accomplished with the aid of the algorithm for bin packing called First Fit Decreasing Width Decreasing Height (FFDWDH).

The process of calculation is to fit the pieces of the individual sheets and discover the unused area (waste).

d. *chromosome selection*

The chromosomes selection method used in the proposed GA is called roulette wheel. In this method, assigns to each individual a probability proportional to the relative fitness of each individual in the population.

e. *Crossover*

The proposed algorithm uses the crossover operator from two points with a fixed rate of occurrence among individuals. For this operator, two chromosomes are selected (parents) that give rise, after the recombination, the two new chromosomes (children). The Fig. 1 illustrates the process of crossover applied to a pair of chromosomes.

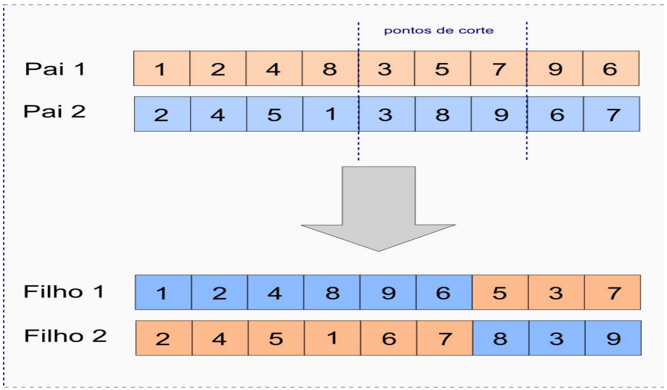

Fig. 1. Crossover applied to a pair of chromosomes.

f. *Mutation Operator*

In developed GA the mutation operator is the inversion between the values of width and height of a particular piece. The mutation operator application is made only on a pre-defined percentage of the chromosomes of each population.

g. *Elitism*

The transition rules of an AG are random and not deterministic, to ensure that the best combinations are not lost over the generations, we use the concept of elitism.

The elitism is to pass automatically to the next generation the best individuals of the population n chain.

IV. First Fit Decreasing Width Decreasing Height Algorithm

For implementation of the algorithm FFDWDH:

A. The pieces are sorted in decreasing order by width and height and then, as can be seen in Fig. 2.
B. Then the pieces are allocated from left to right within vertical stripes (columns).
C. Attempts are made to insert the part in the first available column of glass slide, if it does not fit, then tries to insert it in the next column and so on, until the method finds some column with sufficient space to allocate it.
D. If the piece does not fit into any existing column, then creates a new column.

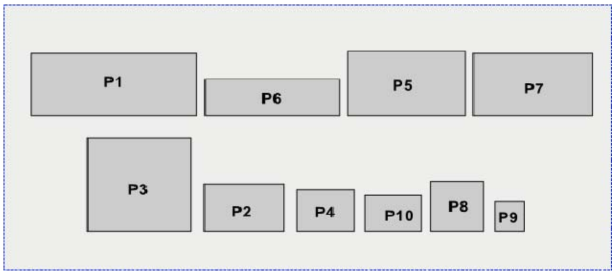

Fig. 2. Pieces sorted in decreasing order by width and height, when.

As the parts are pre-sorted before insertion, the width of the columns is determined by the first part to be inserted

In Fig. 3 we have the pseudo-code of algorithm FFDWDH and in Fig. 4, we can see the outcome of algorithm applied.

```
procedure FFDWDH
begin
W ← sheet width}
H ← sheet available heigth
hi ← piece i heigth
wi ← piece i width
wdlj ← wi {column j available whidth
hdlj ← H {column h available height}
j ← 1;
for i = 1 to i = n do
  while (wi > wdlj) ou (hi > hdlj) do
    j ← j + 1
  end-while
  wdlj ← wdlj-wi {insere a peça i na coluna j}
  hdlj ← hdlj-hi
end-for
end
```

Fig. 3. pseudo-code of FFDWDH Algorithm.

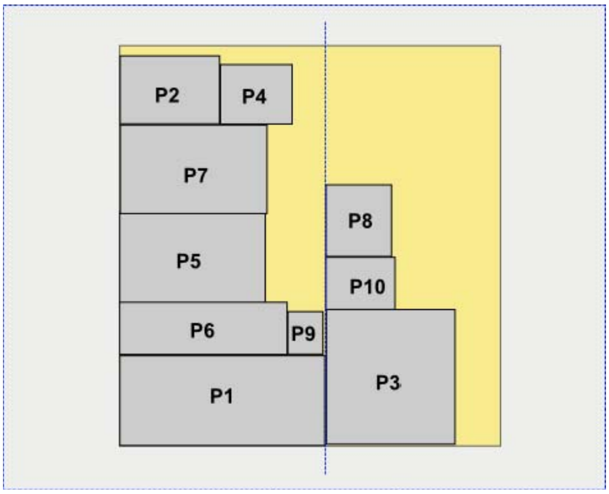

Fig. 4. Result of FFDWDH algorithm applied.

V. CONCLUSION

After performing several tests, the parameterization of the GA at 500 generations with 200 chromosomes was the one with the lowest rates of waste, in an acceptable processing time, considering the demand of "cutting requests" waiting for optimization process.

After application of all crossover methods and definition of the best suited parameters for convergence to an acceptable solution, it was possible to find an arrangement of parts which, applied the bin packing algorithms, maximize the use of glass sheets. GA was able to distribute the parts of "cutting requests" in the original glass slides optimally.

Fig. 5 shows an example "cutting request" with 32 pieces, which were distributed to court optimally. For this application, the processing of GA lasted about 10 seconds and achieved a rate of only 6.16% of wasteful, distributing the 32 pieces to cut in just one sheet of glass.

Fig. 5. Result of processing an cutting request order with 32 pieces.

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