Genetic Algorithm Applied to the Arrangement of Cutting Patterns in Finite Materials

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ABSTRACT

In the present paper, a Genetic Algorithm (GA) was implemented and applied to nest cutting patterns in Finite Materials, in which a chromosome code of variable size was proposed, that contains the necessary fields to make the combination of the patterns in the material. The objective function is designed with the purpose of minimizing the waste in the material taking into account the patterns and overlapping pixels, which are not outside the valid accommodation area, and maximizing the area occupied by the patterns within the valid accommodation area. The initial population is randomly generated, each generation evolves by applying the selection, crossing and mutation operators. Each individual is evaluated by the aptitude function and the best is saved to be compared in each generation and return the best solution.

INTRODUCTION

The arrangement of cutting patterns in finite materials is a key process to be solved in a significant number of manufacturing industries: metallurgical, paper, textile, footwear, and glass, in which the arrangement of cutting patterns is indispensable for maximize the area of use and minimize waste using techniques of Vision, Computational Intelligence and Digital Image Processing [1]. There are different solution strategies to solve this optimization problem such as heuristic and metaheuristic methods [2][3][4]: simulated annealing[5], neural networks, swarm of particle, genetic algorithms [6][7], and linear programming methods; but there is still no global method given the complexity of the problem.

CHROMOSOME CODING

The chromosome contains a combination of patterns that will be accommodated. The size of the chromosome is variable because it is determined by the number of patterns involved in the arrangement. Each pattern is characterized by its identifier, its rotation angle, the position in row and column in the accommodation area and a flag that indicates whether or not the pattern will be taken into account to be accommodated (Figure 1).

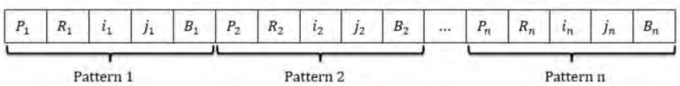

Figure 1. Choromosome Coding.

OBJECTIVE FUNCTION

Each chromosome is evaluated by the objective function (Equation 1), which is designed with the purpose of minimizing waste by avoiding overlaps between patterns and that there are no patterns outside the valid accommodation area, which leads to a better use of the area occupied by the patterns and at the same time minimize waste.

$$F= W_P \cdot (P_T - P_A) + W_W \cdot (A_T - A_{OC}) + W_{NO} \cdot Num_{Ov} + W_{NOA} \cdot Num_{OA} + W_{OP} \cdot Overlaps + W_{OA} \cdot Outside\_Area$$ Equation 1.

$W_{(XX)}$: weight assigned to penalize the objective function,
$P_T - P_A$: number of patterns not accommodated,
$A_T - A_{OC}$: area of waste,
Num_{Ov}: number of overlapping patterns,
Num_{OA}: number of patterns outside the accommodation area,
Overlaps: number of overlapping pixels,
Outside_Area: number of pixels outside the accommodation area.

GENETIC OPERATORS

Boltzmann Selection Method

$$T_i = T_{ini} \cdot \left(\sqrt[N]{\frac{T_{fin}}{T_{ini}}} \right)^{i \cdot \alpha},$$ Equation 2.

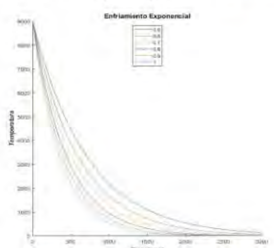

Figure 3. Boltzmann exponential cooling.

Mutation Method

$$t = 1 + \frac{\ln(1-u)}{\ln(1-P_m)},$$ Equation 3.

Figure 5. Logarithmic mutation.

Crossing Method

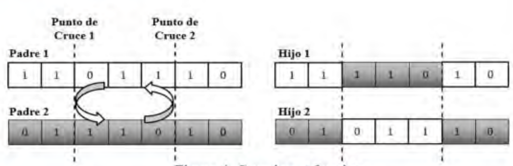

Figure 4. Crossing at 2 points.

RESULTS

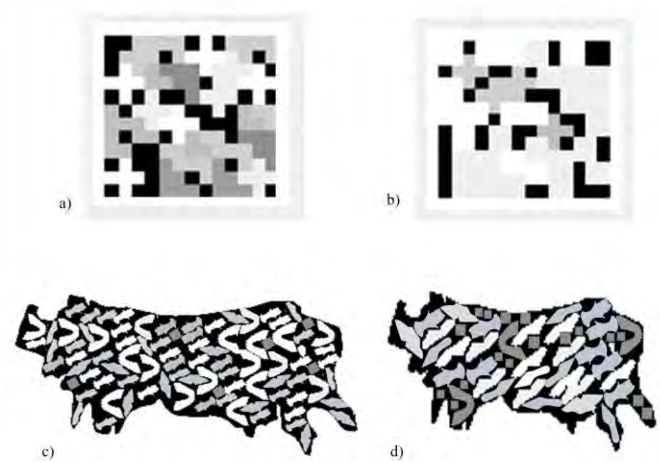

Figure 6. Result obtained. a) Regular patterns, 11% of waste. b) Regular patterns, 8% of waste. c) Real patterns 12% of waste. d) Real patterns 9% of waste.

CONCLUSIONS

- ✓ As a result of this research, it was demonstrated the strength and capacity of the implemented GA to solve the problem of accommodating cutting patterns in finite materials.
- ✓ The proposed chromosome coding is robust and effective as it allows the simple generation of combinations of the cutting patterns involved in the arrangement.
- ✓ The objective function is efficient because it makes it possible to guide the search to find a solution with the best use of the material and at the same time that it has the minimum waste.

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