Application of Bio-inspired Metaheuristics to Guillotined Cutting Processes Optimize in an Glass Industry

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Abstract. Nowadays, sustainability is becoming a strong worry of our society. It can be defined as using resources to meet the needs of the present without compromising the ability of future generations to meet their own needs. An optimized cutting process minimizes the materials waste and is an important factor for production systems performance at glassworks industries, impacting directly in the products final cost formation and contributing for more environmentally sustainable products and production processes. Several studies have shown that combinations of bio-inspired meta-heuristics, more specifically, the Genetic Algorithms (GA) and Ant Colony Optimization (ACO) are efficient techniques to solving constraint satisfaction problems and combinatorial optimization problems. GA and ACO are bio-inspired meta-heuristics techniques suitable for random guided solutions in problems with large search spaces. GA are search methods inspired by the natural evolution theory, presenting good results in global searches. ACO is based on the attraction of ants by pheromone trails while searching for food and uses a feedback system that enables rapid convergence in good solutions. The results from the combination of these two techniques, when compared with the results from usual processes, are encouraging and have presented interesting solutions to the problem of optimizing guillotined cutting processes.

Keywords: Genetic Algorithms, Ant Colony Optimization, Guillotined Cutting, Glass Industry, Sustainability.

1 Introduction

The resource allocation problems have been a great impact factor on the industrial production systems performance and, due to practical applications potential to optimize industrial processes and the difficulties to obtain exact solutions, these problems category has been the subject of intense researches in the Operations Research (OR) and Artificial Intelligence (AI). The study of these problems provides a common basis for analysis and solution of other problems that belong to the same category [1, 3, 4, 7, 9, 11, 12] and, in this context, the bio-inspired metaheuristics techniques is being increasingly used in solving such problems.

The guillotined cutting process is a complex combinatorial optimization problem, which consists in determining a cutting pattern of material pieces, so as to produce a set of smaller pieces, satisfying certain constraints. An optimized cutting process minimizes the materials waste and is an important factor for production systems performance at glassworks industries, impacting directly in the products final cost formation and contributing for more environmentally sustainable products and production processes. The Fig. 1 illustrates guillotined guillotine cutting process.

Consideration to the concept of sustainability is increasingly found in the management literature. It has been a subject with increasingly importance on scientific community, as the number of article written about it has grown considerable since the 1990's.

In addition, the companies 'environmental performance can be very important performance drivers to be measured in order to capture important information to be used to increase the competitive advantage. The findings of some researchers suggest that environmental criteria are increasingly important to develop sustainable business practices [5, 10].

Based in such factors, this paper approaches the application of bio-inspired meta-heuristics techniques, known as Genetic Algorithms and Ant Colony Optimization, to optimize guillotined cutting processes in a glass industry of Sao Paulo City, and thus contributing to making such processes more environmentally sustainable, through the material savings.

The applied approaches combines the search capabilities of these metaheuristics, aiming to minimize occurrences of local minima based solutions.

Fig. 1. The guillotined cutting process

Besides this introduction the paper is organized as follows: section 2 describes the bio-inspired metaheuristics used in this research, in section 3 we discuss the methodology, and section 4 dealing the results from this research and the conclusions.

2 The Bio-inspired Metaheuristics

The biologically inspired computing, or simply bio-inspired, is the research field that uses metaphors or theoretical models of biological systems in order to design computational tools or systems to solve complex problems. The results are algorithms or systems that have a similarity (often superficial) with phenomena or biological models studied [2].

The Genetic Algorithms and Ant Colony Optimization are bio-inspired metaheuristics techniques that, due to its efficiency in finding solutions in very large search spaces, is being increasingly applied to solve complex problems, especially combinatorial optimization problems.

2.1 Genetic Algorithms

Genetic Algorithms (GA) were first proposed by John Holland in the 60s and developed by him and his students during the subsequent years at the University of Michigan [8].

Holland presented the GA as an abstraction of evolution models in nature. Thus, GA are nondeterministic techniques for search and optimization, operating on a population of individuals (data structures that represent candidates for solving a problem) by applying selection mechanisms, crossover and mutation, generating new individuals every generation, they become more capable and therefore closest to the problem optimal solution. The GA is a robust and efficient method of searching for irregular, multidimensional and complex search spaces.

2.2 Ant Colony Optimization

The first Ant Algorithm was inspired by the observation of ant colonies that are able to find the shortest path between their nest and food sources [6].

The ants when foraging for food, randomly explore the environment around their nest in a seemingly disorganized. By walking this path, ants release a chemical substance called pheromone. At the same time, the ants are influenced by the presence of pheromones in the environment and has a probabilistic tendency to follow the direction in which the concentration of pheromones is increased.

The experiments with real ants demonstrated that indirect coordination between ants via pheromone trails produces a collective behavior of self-organization, where the shortest paths between their nest and food sources are gradually followed for other ants to enhance the trails pheromone on the best routes and eventually find the shortest path.

2.3 The Approach Used

For the experiments execution, was used a cooperative approach between Genetic Algorithms and Ant Colony Optimization, as can be seen in Fig. 2.

The processing occurs as follows:

- The GA processing was set at 500 generations;
- Every 50 GA generations the best chromosomes are used as ACO input;
- The ACO is executed 100 times;
- The best ACO are used as GA input.

Fig. 2. Flow diagram showing, in simplified form, the GA and ACO metaheuristics combination

2.4 The Packing Algorithm

The Assessment of GA individuals and ACO solutions is performed with the aid of the packing algorithm called First Fit Decreasing Width Decreasing Height (FFDWDH).

The calculation consists in fit the pieces in master blade, simulating the cutting process and discovering the unused area (waste).

Steps for FFDWDH packing algorithm (the resulting arrangement can be seen in Fig.3):

- the pieces are sorted in decreasing order by width and height;
- then the pieces are allocated from left to right within vertical stripes (columns).

Fig. 3. Pieces sorted in decreasing order by width and height, when. (adapted from [11])

3 Methodology

The development of this paper is based on the study, revision and implementation of bio-inspired computing techniques for solving combinatorial optimization problems.

It was made a literature review of two-dimensional guillotine cutting processes derived from production systems in glass industry, as well as the options for combining GA and ACO.

To implement the GA and ACO bio-inspired metaheuristics are used the Java and Java Script programming languages.

Were performed several experiments using a data set of requests from a glass industry in São Paulo city. During these experiments, the results of application of bio-inspired metaheuristics, GA and ACO, were compared with the results of usual cutting processes.

4 Results, Conclusion and Future Work

Several experiments were conducted with cutting orders provided by a real glass industry of São Paulo city.

During these experiments, were compared the waste resulting from the cutting of those requests in relation to the waste with application of optimization performed from the bio-inspired metaheuristics, GA and ACO.

The Table 1 shows the waste comparison between the usual and the optimized processes.

Table 1. Waste comparison between the usual and the optimized processes (with GA and ACO metaheuristics application)

Number of pieces per cutting order	Usual process waste	Optimized process waste
1056	32.28%	27.83%
351	16.72%	9.48%
32	53.15%	6.30%

Considering the glass cutting average of 600 square meters per day and applying the waste percentage shown in Table 1, we would have a reduction of wastage of up to 281 meters square. These results are interesting and encouraging and contribute to making the cutting process more environmentally sustainable.

In Figure 4, we can see the final result of applying the metaheuristics in a cutting order of 32 pieces.

Fig. 4. Output of the metaheuristics applied to a 32 pieces guillotine cutting problem

The purpose is to continue the research by changing the parameters and combination approaches of the GA and ACO and experimenting with other different bio-inspired metaheuristics like Bee Colony Algorithm.

References

1. Blum, C., Ibáñez, M.L.: *The Industrial Electronics Handbook: Intelligent systems*, 2nd. CRC Press (2011)
2. Castro, L.N., Zuben, F.J.V.: *Recent Developments in Biologically Inspired Computing*. Idea Group Publishing (2005)
3. Costa, F.M., Canto, N., Sassi, R.J.: Study of the Application of Genetic Algorithms in Optimization of Cutting Glass Sheets. In: *Proceedings of the 9th IEEE/IAS International Conference on Industry Applications, Industry Applications (INDUSCON) 9th IEEE/IAS International Conference*, São Paulo, vol. 1, pp. 1–3 (2010)
4. da Costa, F.M., Sassi, R.J.: Application of an hybrid bio-inspired meta-heuristic in the optimization of two-dimensional guillotine cutting in an glass industry. In: Yin, H., Costa, J.A.F., Barreto, G. (eds.) *IDEAL 2012. LNCS*, vol. 7435, pp. 802–809. Springer, Heidelberg (2012)
5. Cuthbertson, R., Piotrowicz, W.: Supply chain best practices – identification and categorisation of measures and benefits. *International Journal of Productivity & Performance Management* 57(5), 389–404 (2008)
6. Dorigo, M., Stützle, T.: *Ant Colony Optimization*. Bradford Book (2004)
7. Grosan, C., Abraham, A.: Hybrid Evolutionary Algorithms: Methodologies, Architectures, and Reviews. In: Grosan, C., Abraham, A., Ishibuchi, H. (eds.) *Hybrid Evolutionary Algorithms*. SCI, vol. 75, pp. 1–17. Springer, Heidelberg (2007)
8. Holland, J.H.: *Adaptation in Natural and Artificial Systems*. The University of Michigan Press, Ann Arbor (1975)
9. Hoseini, P., Shayesteh, M.G.: Hybrid Ant Colony Optimization, Genetic Algorithm, and Simulated Annealing for Image Contrast Enhancement. In: *2010 IEEE Congress on Evolutionary Computation (CEC)*, pp. 1–6 (2010)
10. Linton, J.D., Klassen, R., Jayaraman, V.: Sustainable supply chains: An introduction. *Journal of Operations Management* 25, 1075–1082 (2007)
11. Temponi, E.C.: *Uma Proposta de Resolução do Problema de Corte Bidimensional via Abordagem Metaheurística*, Dissertação de Mestrado. Diretoria de Pesquisa e Pós-Graduação, CEFET-MG (2007)
12. Zhang, D., Du, L.: Hybrid Ant Colony Optimization Based on Genetic Algorithm for Container Loading Problem. In: *International Conference of Soft Computing and Pattern Recognition (SoCPaR)*, pp. 10–14 (2011)