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PRODUCTIVITY IMPROVEMENT IN THE WOOD INDUSTRY USING SIMULATION AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

The objective of this article is to present the results obtained after using a simulation optimization methodology applied to a production line from a secondary manufacturing wood processing plant of a well known Chilean mill. For this reason a simulation model constructed in ARENA, was integrated to a genetic algorithms heuristic. The results obtained show that using a different configuration of the plant resources, it is possible to reduce the total average cycle time in 18%. The resource configuration needed to reach this result was obtained evaluating just 1.6% of the total number of possible combinations.

1 INTRODUCTION

Simulation optimization can be defined as the combination of an optimization method with a simulation model to determine the input variable settings that maximize the performance of the simulated system. Several different optimization methods could be used for this purpose, even though, genetic algorithms have become one of the most popular search engines.

Simulation optimization has been used to solve several real life problems. The manufacturing environment is where most cases are reported. Different applications of simulation optimization in manufacturing can be found in Pierreval (1997); Sammons and Cochran (1996); Azadivar Shu and Ahmad (1996); and Rosenblatt Roll and Zyse (1993). Other situations are reported by Azadivar and Shu (1998) where simulation optimization was utilized for selection and implementation of maintenance policies. Brady and McGarvey (1998) report the utilization of simulation for optimization of staffing levels in a pharmaceutical laboratory and Kleinman Hill and Ilenda (1998) make use of this technique for optimization of air traffic delay cost.

This article shows the results of applying the simulation optimization methodology to a simulation model of a Chilean wood process. A brief description of the process is presented next.

2 SYSTEM DESCRIPTION

The company under study produces several products, being the radiata píne (*Pinus Radiata* D. Don) wooden mouldings and panels the most important ones.

The most relevant steps in the process are:

- Raw Materials Reception: The green timber is left on a storing field. Forklift tractors retrieves batches of timber to transported to the drying plant.
- Drying Plant: This process delivers dry wood with an 8% of humidity at a rate of 300 cubic meters per day. This wood is transported in forklift tractors to the remanufacturing process.
- Secondary Process: This process is divided in two sub-processes, moulding production and panels production. The working centers involved in the remanufacturing process are explained next.

2.1 Remanufacturing Process

The remanufacturing process is composed by several working centers. A brief explanation of them is presented next:

- Planer Center: The wood is polished and given the appropriate dimensions for the following processes.
- Crosscut Saws: In this working center, all the defects are removed from the wood. This is performed based on predefined quality standards.
- Finger Joint Center : The wooden blocks resulted from the last step are joint together to form parts

with a predefined length. This is performed using fingerjoint machines and wood adhesive.

- Moulding Process: The wooden pieces are introduced into the molding machines. Here the parts that have been destined to mouldings, are given different shapes and especial cuts required for the final product. In the case of panels, the process require more work, the wood enters to a molding machine and then follows three more steps:

    1. Panel Machines
    2. Polishing
    3. Final Assemble

The production process is represented in a simulation model constructed in ARENA 4.0.

3 OPTIMIZATION PROCESS

The objective of this study was to optimize the performance of the system. To achieve this, the first step is to define the objective function or measure of effectiveness of interest. Then, it is necessary to determine all the control variables that are considered important in the process. For this particular problem it was considered that the average time in system of the products represents a very important response variable to be minimized, and was selected as objective function. The control variables selected are five and correspond to the availability of the resources considered critical by the experts in the process. The selected variables and the feasible range of variability are shown in Table 1.

Table 1: Control Variables

Variable	Minimum	Maximum
Polishing Machines	1	10
Sawing Machines	1	4
FingerJoints Machines	1	4
Molding Machines	1	8
ForkLifts Cranes	1	7

Using this information the genetic algorithm chromosome was constructed. It consists of five genes in an integer representation with the following structure, *[var1, var2, var3, var 4, var 5]*.

Considering the range of each variable, it is possible to calculate a total of 8960 different configurations. Each one of them represents a simulation scenario that requires approximately 5 minutes to run. A complete enumeration strategy would require approximately 31 days of simulation. Of course, in this case a complete enumeration does no represent a feasible solution to the problem, given the amount of time and the risk of computer failure that this represents. Exploring just a fraction of the total space of possible solution is the strategy used by the genetic algorithms heuristic. This methods offers a very reliable and efficient way to explore the solution space. Table 2 shows the parameter selected for the GA.

Table 2: Genetic Algorithms Parameters

Parameter	Value
Population Size	10
Max. Number of generations	20
Crossover Probability	0.95
Mutation Probability	0.1
Stopping Criteria	3 generations without significant change

The GA was implemented in based on a public library called Galib (Wall, 1996) written on C++. In addition to this it was necessary to connect the simulation model constructed in ARENA with the GA heuristic. To achieve this, an interface was constructed in Visual Basic. This interface interacts with the two computer programs in order to automate the searching process. The interface interact with the user too, for this reason it was made very user friendly. Figure 1 shows the main screen of the user's interface.

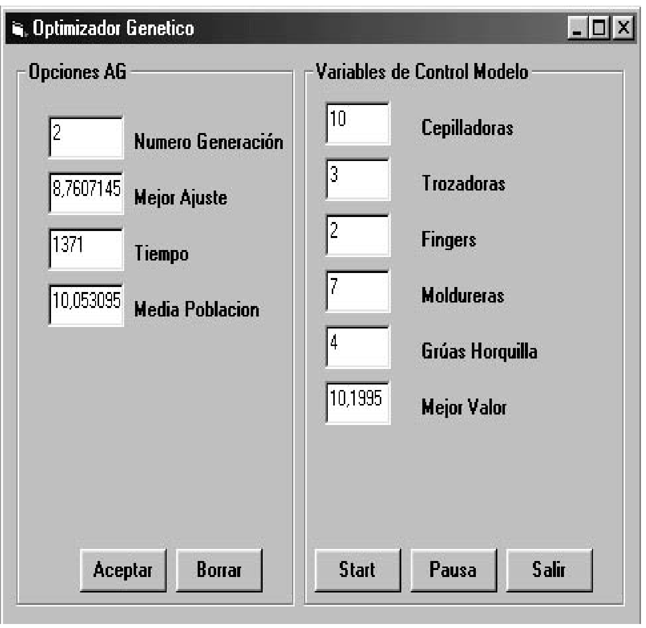

Figure 1: User's Interface

The left half of the screen shows information regarding to the evolution process, generation number, best fit, time, and population mean. The right half presents the information related to the chromosome values. First are shown the values of each one of the 5 variables (genes) at the present generation. In addition to this the fitness value associated to that chromosome it is also presented.

4 RESULTS

The optimization process was carried on for 15 generations. The stopping criterion of no improvement in the fitness value in 3 consecutive generations was reach at generation number 12. The behavior of the fitness value was monitor through the whole evolution process. Figure 2 shows the plot of the average fitness within each generation.

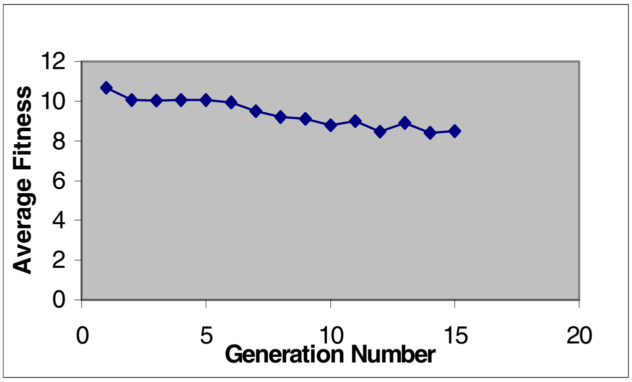

Figure 2: Average Fitness Plot

The plot shows a decreasing trend in the average fitness value until generation 13. At this step it was not possible to obtain a better solution than the one reach in generation 13. The best solution found is presented in Table 3.

Table 3: Genetic Algorithms Results

Resource	Value
Planers Machines	7
Crosscut Saws	4
FingerJoint Machines	2
Moulding Machines	8
ForkLift Cranes	5
Fitness value (Average time in system in hours)	6.94

Table 3 shows the final solution generated by the GA. This configuration of resources lead to an average time in system of the products of 6.94 hours. This solution was obtained exploring just 143 scenarios. This represents a 1.6% of the whole search space.

In order to evaluate the quality of this results, the current plant configuration was simulated. Table 4 presents the results of the *As-Is* scenario compared to the suggested solution obtained by the GA.

The comparison of both alternatives shows that the propose solution leads to a decrease in the products time in system from 8.48 to 6.94 hours. This means an 18% less time require to finish the complete cycle of a product.

This solution shows an important increase in the number of planer machines, moulding machines and forklift cranes. The number of crosscut saws and fingerjoint machines remains the same. This probably means that this two types of resources are not bottlenecks. The GA recognizes this issue and maintains the same number of these machines in the proposed solution.

Table 4: Comparison of Alternatives

Variable	As Is Scenario	Propose Solution
Planer Machines	5	7
Crosscut Saws	4	4
FingerJoint Machines	2	2
Moulding Machines	4	8
ForkLift Cranes	1	5
Fitness value (Average time in system in hours)	8,48	6.94

The implementation of this alternative requires an investment in three types of machines, two more planers, four more moulding machines and four more forklift cranes. It is important to mention that the current number of forklift cranes is 1, this means that the proposed solution requires a 400% increase in the capacity of this resource. This is explained by the need of minimization of the work in process inventory. The forklift cranes are basically in charge of transporting material from one working center to next one, that is why a more synchronized system requires more transportation resources.

The implementation of this solution has to be evaluated by the company, since requires an important investment in machines and cranes. It is important to mention that the feasibility of this solution has to be evaluated, because of the increase in forklifts cranes flow inside the plant. It could need a redesign in a section of the plant layout. If the implementation of the complete solution results to be infeasible, some important issues can be highlighted. The bottlenecks are not the fingerjoints machine and neither the crosscut saws, especial attention has to be assign to the planers and moulding machines. Finally the forklift cranes seem to be one of the critical resources and the impact in their availability is essential for the process flow.

5 CONCLUSIONS

This article shows the results in the application of a simulation optimization methodology in a wood processing plant. The solution achieve using the methodology converged to an alternative that decreases the average time in system of the products in approximately 18 percent. This results were obtained evaluating just 1.6% of the whole solution space. The implementation of the propose solution has to be evaluated economically by the company, since important investments are required.

Finally, it is recommended for future research to repeat the analysis using different GA configurations. The use of other search techniques such as, simulated annealing and tabu search could offer interesting results in terms of efficiency and quality of the solution achieve. To explore alternative objective functions and a combination of them could be of interest. The area of multi-response simulation offers an almost unexplored field in the simulation optimization area.

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