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IMPROVING A HARDWOOD FLOORING CUTTING SYSTEM THROUGH SIMULATION AND OPTIMIZATION

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ABSTRACT

Hardwood flooring mills transform rough wood into several boards of smaller dimensions. For each piece of raw material, the system tries to select the cutting pattern that will generate the greatest value, taking into account the characteristics of the raw material. However, it is often necessary to choose less profitable cutting patterns in order to respect market constraints. This reduces production value, but it is the price to pay in order to satisfy the market. We propose an approach to improve production value. We first use simulation on a training set of virtual boards in order to generate a database associating cutting patterns to expected production value. Then, we use an optimization model to generate a production schedule maximizing the expected production value while satisfying production constraints. The approach is evaluated using industrial data. This allows recovering approximately 30 % of the value lost when using the original system.

1 HARDWOOD FLOORING TRANSFORMATION PROCESS

Manufacturing hardwood flooring is a constant challenge. The process involves co-production (each piece of rough wood is cut to produce many pieces at the same time) and many different cutting patterns can be used. As each piece of raw material shows different physical characteristics (wood is a natural product) we need to carefully select the cutting pattern that will be applied to each piece of raw material in order to maximize production value.

In industrial practice, these decisions are made in real time, one piece of raw material after another. However, other production constraints force the system to dynamically deactivate some cutting patterns/finished products when it detects that the quantities of a given product are too high or too low. Therefore, current production systems used by the industry are said to be reactive (they deactivate some cutting patterns when they detect that a constraint has been violated) instead of being proactive. Consequently, the “optimizer” is sometimes obliged to choose less profitable cutting patterns in order to respect production constraints.

Adjusting the production in real time each time a constraint has been violated has a big influence on value/profits. One explanation is that the system is totally blind about what to expect next.

Here is a simplified case to picture this. Let’s suppose there are three different finished products that can be produced: **A** (highly profitable), **B** (profitable) and **C** (less profitable). Cutting patterns are defined such that for one given input board, we can produce either “**A and C**”, “**B and C**” or “**only C**”. We also have some market constraints: there should be no more than 20% of **A** and 50% of B in the overall production. Thus, the system starts the production trying to produce only “**A and C**” till the first constraint is violated (no more than 20% of product **A**). As a consequence, the system will then start producing “**B and C**” till the next constraint is violated (no more than 50% of product **B**). The system is then obliged to produce “**only C**” till **A** or **B** is no longer constrained. However, knowing how the raw material looks, it would have been much more profitable to produce a mix of “**A and C**” and “**B and C**” from the beginning, rather than sometimes to have to produce “**only C**”.

To overcome this, we propose a proactive approach that exploits simulation in order to forecast production, thus allowing optimizing the use of the different cutting patterns in advance. Simulating the cutting decision-making process by using the real system "offline" we train our system in order to be able to foresee the impact of deactivating/activating cutting patterns. With this information in hand, we then establish a production schedule using a linear optimization model we developed that is expected to process future boards in a manner that will maximize production value while satisfying production constraints.

2 PROPOSED APPROACH BASED ON SIMULATION AND OPTIMIZATION

We assume we dispose of a database of board images previously processed within the real production system. Then, while offline, the system is used to process the boards from the database (the system has no idea it is not processing real boards). Then, we process all the boards another time, this time deactivating production constraints (i.e. allowing all cutting patterns at any time). This allows measuring the value that is lost when one needs to satisfy production constraints. Furthermore, we can process the database again and again, each time allowing the system to use a different set of cutting patterns. This allows us to measure the impact of deactivating some specific products (that is, the expected production to be obtained when a given set of cutting patterns is available). These expected productions are recorded into a database.

With this information learned from the training database, solving a linear optimization problem we establish a production schedule which specify the percentage of production time during which each set of cutting patterns should be activated.

3 EXPERIMENTS

We had access to a database containing 389 boards. We divided the database into two sets: a training set and a testing set. Each board of the training set was processed using each of the 39 different sets of cutting patterns we were provided with. This allowed us to generate the expected production database.

We used this database to feed the mathematical programming model. We ran the model using Cplex. We then simulated the execution of this schedule. Boards from the testing set are used as raw material by the system which activates/deactivates cutting patterns according to the schedule.

We performed 10 different replications, each time testing the approaches using different training and testing sets of boards. In order to provide a base case, we also processed the boards from each test set using the original reactive system. Our approach increases value by $ 116 805 ± 82 213 (95% confidence interval) in comparison with the base case (the design of our case study conforms with the criteria of Common Random Numbers).

We also processed the boards of each testing set in a setup where all the cutting patterns were always available (i.e. without having to respect production constraints). Thus, we were able to establish that meeting production costs $ 235 630 ± 54 497 per year (compared to the base case). This puts in perspective the performance of our proposed approach: it allows capturing around 32 % of the maximum theoretical gain (Improvement / [Maximum theoretical gain – generated value of original reactive system]).

The relative gain (Improvement/Original system) can seem to be modest (0,3%) but one needs to consider that profit margin in this industry may be quite small (less than 4 %). Achieving such an improvement without investment in new machines or reorganization of the plant is a significant improvement.

4 CONCLUSION

Cutting decisions for processes involving co-production are almost always done in real time, one piece of raw material after another. Some cutting patterns need to be activated/deactivated in real time to meet market/production constraints. This reduces production value, but it is the price the industry is willing to pay in order to satisfy market/production constraints.

Our case study showed that making use of simulation to gain a better knowledge of the raw material/cutting pattern production yield, and using that information in production scheduling may lead to an improvement (in produced value) in the order of $ 116 805 ± 82 213 /year for an average hardwood flooring factory. This represents approximately 32 % of maximum theoretical gain.