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Machine learning tools for analyzing the quality of fiber-based corrugated medium

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1 Background

Modelling of processes in the wood processing industry is challenging for several reasons. For example, in certain cases it is important that the models are functional in real time or almost real time conditions when it comes to fast decision-making. Process dynamics typically makes it necessary for the models to be able to adapt to dynamically appearing fluctuations and condition changes. Manufacturing of corrugated medium, or fluting, is a good example of a dynamical, complex manufacturing process within the wood processing industry. The fluting manufacturing process involves numerous sub-processes which are typically in mutual interaction and which are controlled by many control loops, which complicates the understanding of the mutual reactions within the total process.

2 Aims

In this paper, we demonstrate how modelling tools may be useful in actions for process improvement by facilitating data analysis and process development work. We validate the selected modelling techniques by analyzing a data set acquired from a real manufacturing process.

3 Materials and methods

3.1 Case study

We have selected an ammonium sulfite based process for manufacturing SemiChemical fluting (NSSC, neutral sulfite semi chemical) for a case study. In this process, wood is first softened in a relatively fast cooking stage. After this, the medium is refined in three stages to get a type of pulp that is the most suitable for the manufacturing of fluting.

The experimental data used in this study were extracted from the databases of the SemiChemical fluting manufacturing plant. The produced fiber-based fluting medium serves as a partition that separates the liners in corrugated board.

3.2 Adaptive models

A single model based on a large data set may not be effective enough in a dynamical manufacturing process. For example, the model may not be accurate enough to catch periodically occurring phenomena. The time of year is a good example of this. In wood processing, the quality of the raw material is highly dependent on the time of year when the wood is cropped. For this reason, it is preferable to use an adaptive model structure, which means that the model will be designed to adapt to changing conditions in the course of time.

It is characteristic for almost all industrial environments that there are a large number of conducted measurements, and therefore measured variables, involved. Due to this, it is not always clear which variables should be included to the model to achieve the best possible result. In addition, the variables that give the best result in modelling may not remain the same all the time. One solution to this would be an algorithm that is based on the sample-wise moving window approach [1]. In practice, one way of applying this would be to create a new model regularly or even every time the model is called (for example, when a predicted value is desired).

3.3 Subtraction analysis

The self-organizing map (SOM) [2] is an unsupervised neural network that is based on mapping n-dimensional input vectors to structural units called neurons, which are formed and updated during the training. Each neuron is characterized by a specific reference vector, which represents the typical features of the data associated with the neuron concerned.

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In the subtraction analysis, two vectors are subtracted from each other in order to extract the differences between these vectors [3]. By means of the center (i.e., average) vectors of two given areas on the SOM, the following formula can be used:

$$s = C_\alpha - C_\beta,$$

where s is the subtracted result vector, C_α symbolizes the center vector of area α, and C_β denotes the center vector of area β. This technique can reveal the differences between two differently behaving process conditions. An example of applying the subtraction analysis in the fluting case can be seen in Figure 1.

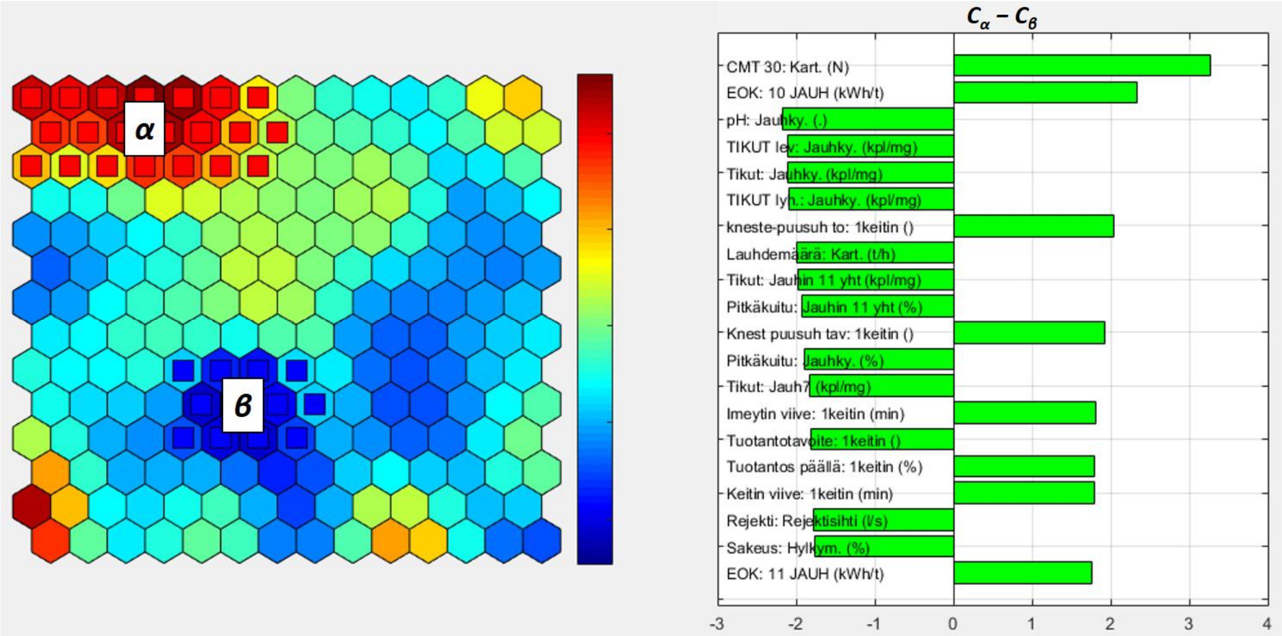

Figure 1. An example of the subtraction analysis in fluting manufacturing. The SOM and the selected areas (α and β) on the component plane of fluting quality (CMT) are shown on the left. The color bar indicates the value of CMT on the map (blue = low, red = high). On the right, the result of the subtraction analysis (C_α - C_β) is shown.

References

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