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Neural networks in process life cycle profit modelling

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Abstract

Changes in operational environment of the process industry such as decreasing selling prices, increased competition between companies and new legislation, set requirements for performance and effectiveness of the industrial production lines and processes. For the basis of this study, a life cycle profit (LCP) model of a pulp process was constructed using different kind of process information including chemical consumptions and production levels of material and energy flows in unit processes. However, all the information needed in the creation of relevant LCP model was not directly provided by information systems of the plant. In this study, neural networks was used to model pulp bleaching process and fill out missing information and furthermore to create estimators for the alkaline chemical consumption. A data-based modelling approach was applied using an example, where factors affecting the sodium hydroxide consumption in the bleaching stage were solved. The results showed that raw process data can be refined into new valuable information using computational methods and moreover to improve the accuracy of life cycle profit models.

Keywords: Life cycle profit modelling; Neural network; Multi-layer perceptron; Variable selection; Pulp industry

1. Introduction

In the process industry the development of competitiveness of an existing production line has become a lifeline for many production units, because competition between companies has increased, new legislation has been published and the consequences of disturbances are bigger than before. Thus, it is essential to find process developing possibilities to increase profits and maximize returns and at the same time eliminate risks. These new demands set requirements not only for performance and effectiveness of processes but also for optimizing process life cycle profits.

However, the construction of large economical models of processes is too complicated using only process models which are based on natural laws. The connections between the units of the processes in large scale plants are usually so complex that modelling based on natural laws is unable to produce all the needed information for a decision-making process. On the other hand, modelling on the basis of natural laws requires lots of resources, like time and staff resources as well as economic and computational resources, and due to the these reasons modelling on schedule is often not possible (Soukka, 2007).

The applicability of life cycle modelling principles to the modelling of increasingly complex processes has been examined. Life cycle modelling (life cycle assessment and life cycle costing) collects data on the entire life cycle. For this reason it is obvious that everything cannot be modelled on the basis of natural laws. Life cycle modelling requires the easy collection of an immense amount of information on the different stages of the process life cycle, so that it is impossible to produce vast amounts of measurement data due to the restrictions of the resource reserved for the report. Thus life cycle assessment also uses estimated, calculated and literature-based information (Soukka, 2007).

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The life cycle profit (LCP) analysis has been developed for the purpose of evaluating the economic impacts of process changes with a model based on the production principles of information applicable in life cycle modelling. A life cycle profit model is based on several kinds of information. The measurement data of one point can be used to constitute a statistic distribution. The estimated information and data from literature are in turn information that can be regarded as unique (Soukka, 2007). Among the other things, data-based computational methods can be used in the production of calculated information and, particularly, in the identification of consequence-related effects including solving material and energy flows of the process (Räsänen et al., 2006).

It is essential that life cycle profit model has been constructed so that it reveals how changes are affecting revenues and costs of a production line. On the one hand, life cycle revenues can be increased by removing bottlenecks and production failures. These problems contain a high risk to cause production losses. On the other hand, costs can be reduced for example by affecting energy, chemical or water consumption of processes and the amount of effluents from processes.

Raw process data is one of the LCP models information sources and it can be used various ways. Industrial processes produce typically a huge amount of measured data describing each process performance. Several studies (Heikkinen, Kettunen, Niemitalo, Kuivalainen, & Hiltunen, 2005; Hiltunen et al., 2006) have shown that data-driven approaches are a fruitful way of developing for example the process state monitoring. Archived process data is also an important resource for the knowledge management of the process and it can be used for the optimization and improvement of productivity.

In this study, we combine data-driven modelling and process life-cycle profit modelling into more intelligent system to produce valuable and more accurate new information to decision making. The proposed methods were applied and tested using the data set of an industrial scale pulp bleaching process.

2. The process and the data

In this study life-cycle profit model (Soukka, 2007) was constructed for a paper mill, which produces newsprint and directory paper, coated and uncoated fine paper, coreboard and spruce timber. The paper mill contains also pulp production and refined mechanical and ground wood pulp are produced for newsprint paper production. Also ECF-pulp is produced for the fine paper production.

The life cycle profit model covers the whole production line of the pulp. However, in this study we concentrated on solving the missing or unknown correlations between process variables in the pulp bleaching process which is shortly described in Fig. 1. The objective of bleaching is to improve the brightness and the cleanliness of the pulp.

The raw process data was originated from measuring systems and it was collected from pulp mill databases. The used data set contained 35 variables and 1500 rows. The data set consists of the time period where pine was used as pulp raw material and the time resolution was one hour. Variables were selected by process experts.

3. Methods

3.1. Life-cycle profit modelling

The main purpose of the plants life cycle profit (LCP) model is to recognize the development possibilities, which can be achieved by process changes allocated to different stages of the process. The LCP model shows how life cycle profit varies in consequence of the process changes and owing to this it is possible to prioritize different possibilities to develop the process. The LCP analysis is originally used for modelling existing production lines but the model can also be used for strategic planning of new production lines. Therefore, it is possible to evaluate risks that can be actualized if big changes in the proportion of prices happen. Hunkeler (1999) has been presented that Life Cycle Profitability is an evolutionary means to conduct business practice under scenarios where envirotechnical imperatives

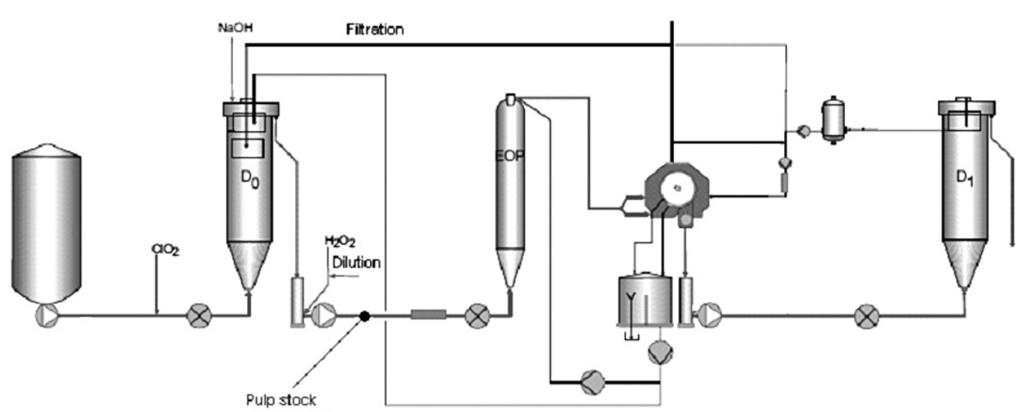

Fig. 1. Pulp bleaching stage contains several stages because target brightness of the end product cannot be achieved in only one bleaching step. Pulp is also washed between each stage.