Use of self-organizing maps in studying ordinary air emission measurements of a power plant

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1 Introduction

Air pollutants such as SO_2, NOx and CO are measured and observed in the power plant because the values have to be reported to the authorities. The results are described with mean values in the internal reports in the power plant. In daily operation, the emissions are observed also by using trends. Nonetheless, it may sometimes be more illustrative to observe emissions with other ways of visualization.

SOM (the Self-Organizing Map or also called Kohonen map) is likely one of the most used artificial neural network algorithms with unsupervised learning (Kohonen 2001). SOM is an efficient tool for data visualization and preliminary analysis and can also be used for modelling and data preprocessing purposes, as well as clustering, see (Vesanto and Alhoniemi 2000). SOM is a visual data analysis method as exploratory data analysis (EDA) (Tukey 1977). SOM has been used, for example, to study process monitoring in a fluidized bed boiler (Räsänen et al., 2006). The dependencies among process variables can be investigated by using SOM, with the purpose of obtaining a preliminary idea of variable effects and interdependence in a power plant (Lohiniva and Leppäkoski 2010).

2 Objectives of the research

In process industry, a massive amount of data is collected and stored. Data is collected considering the plant operator point of view which affects the later use of data. Data is often presented both in numerical form, for example monthly reports, and as trends. However, the collected data is not intensively utilized. Several different techniques exist and are to be investigated during the research; some methods provide numerical results, others such as SOM provide visual results.

3 Results

Flue gas emission measurements (SO_2, NOx, CO, O_2) were retrieved from the process database and analyzed. The data has been obtained from a bubbling fluidized bed boiler which delivers both power and district heat. The data used in analysis represents the normal functioning of the power plant.

SOM was used to analyze the flue gas measurements. In this case, SOM represents qualitative analysis and relative differences between variables are studied. The calculations were quite inexpensive to conduct and investigating alternatives was quite easily feasible.

Component planes present the values of each variable as separate maps. Map units in component planes are linked by their position: the component values of a certain map unit can be read from the hexagons in this certain position in all component planes.

The U-matrix illustrates the difference between adjacent map units. U-matrix has more map hexagons than the component planes. Additional hexagons are located between neighboring map units and repre-

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sent their difference. Cell coloring in the U-matrix expresses the difference between adjacent prototypes. Dark even areas represent groups (clusters) of similar prototypes. Lighter streaks and areas tell of increase in deviation between prototypes and these areas represent potential cluster borders.

By looking at the U-matrix, a deviating cluster in the left bottom corner can be discovered (Figure 1). Because the variable values in this small cluster deviate clearly from other values, the bottom corner affects the scales of the component planes and blurs some of the smaller differences in rest of the maps. This has to be taken into account when results are interpreted.

Figure 1 *The U-matrix, scale from dark blue (small difference) to dark red (high difference).*

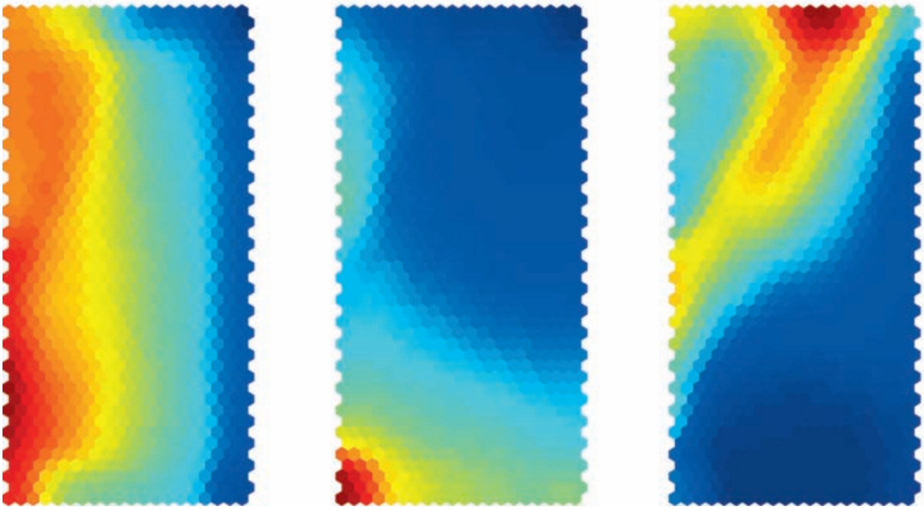

Figure 2 *Component planes of SO_2, NOx and CO emissions, scale from dark blue (low value) to dark red (high value).*

Figure 2 presents the component levels of SO_2, NOx and CO emissions. SO_2 and NOx do not seem to correlate. The independence is probably due to rather independent and varying sulphur and nitrogen contents in the fuel. The plant uses peat, considered a semi-fossil fuel, as the main fuel. NOx and CO emissions show very weak inverse correlation at some parts. In process experiments performed earlier, NOx and CO have showed clear inverse correlation.

Three parallel flue gas oxygen content measurements are illustrated in Figure 3 by using component planes. The planes look quite similar. However, they have some differences which suggest that the measurements may require closer investigation.

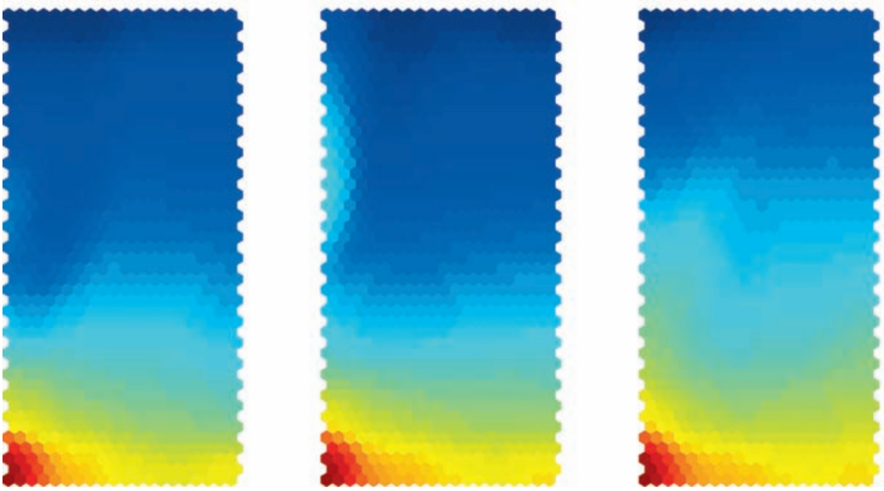

Figure 3 *Component planes of three parallel flue gas oxygen content measurement, scale from dark blue (low value) to dark red (high value).*

As seen in Figure 4, live steam flow and CO content in flue gas seem to correlate. Live steam flow and NOx seem to correlate only weakly although process experiments performed earlier have shown a stronger correlation. The results from the normal functioning of the power plant are not probably as clear as the results from process experiments where the changes in variables are planned.

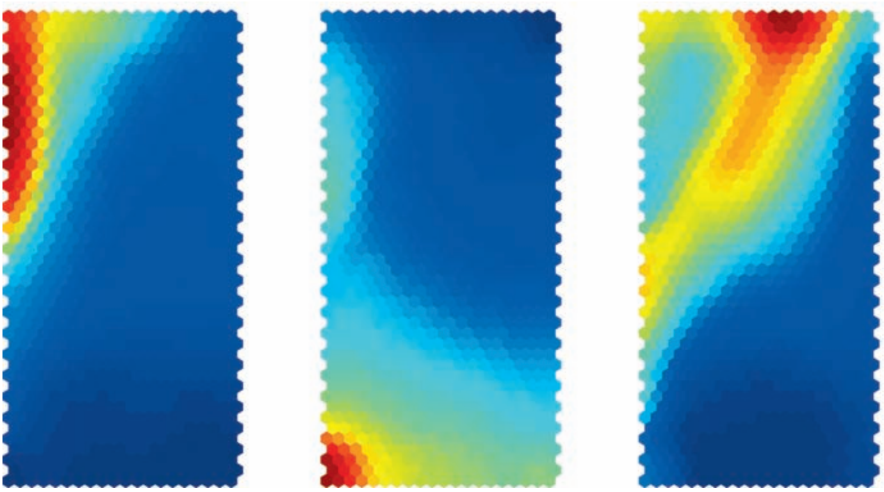

Figure 4 *Component planes of steam flow, NOx and CO, scale from dark blue (low value) to dark red (high value).*

4 Relevance of the research

The demand of better process data utilization is definite; the methods have to be informative enough and feasible. There are many techniques to illustrate data, and one of them is briefly demonstrated in the paper. The interpretation of results is a question to be solved. The method presented here is linked to continuous process monitoring. Furthermore, the goal is to maintain optimal process conditions.

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Reference to this article:

Leppäkoski K. and Lohiniva L. (2010) Use of self-organizing maps in studying ordinary air emission measurements of a power plant.
In: Pongrácz E., Hyvärinen M., Pitkäaho S. and Keiski R. L. (eds.) Clean air research at the University of Oulu. Proceeding of the SkyPro conference, June 3rd, 2010, University of Oulu, Finland.
Kalevaprint, Oulu, ISBN 978-951-42-6199-2. pp.129-132.

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