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A Voltammetric Electronic Tongue

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Introduction

When an array of sensors with partially overlapping selectivities is utilized, many information variables with low specificity on each variable are obtained. Even though the specificity of each variable is low, considerable information can be extracted through the combination of several selectivity classes. The information in the vast number of data material processed with the help of multivariate data analysis (MVDA). One sensor system using this technique is the voltammetric electronic tongue which was developed at Linköping University (Winquist *et al.*, 1997). This sensor system can be used to measure foodstuffs in order to try to mimic the human tongue, as the name 'electronic tongue' suggests, but it is far from the only application. Often it is desirable to be able to differentiate between one good situation and all other possible (bad) situations. Examples of such applications include monitoring a factory process or a biological growth process to ensure that the process is going the way it is suppose to, or controlling liquid flows or sample reiteration to ensure the same quality through and between batches. Voltammetric methods provide high sensitivity, a wide linear range and simple, robust instrumentation.

Measurement principle and data analysis

In voltammetric measurements a current is measured between the metal working electrode and the counter-electrode when a voltage pulse is applied over the working electrode and the reference electrode. A set of pulses can be put together to form a pulse train in order to extract as much information as possible from the solution. When the potential is applied, electro-active compounds that react to that potential will be reduced or oxidized and a current, that can be measured, will arise.

In measurements with the voltammetric electronic tongue, data are collected over the whole pulse and not only at the end of the pulse, as in traditional electrochemistry. This is done since it has been found that extra information is also found at the beginning of the pulse (mainly conductivity and mobility).

The electronic tongue creates a data matrix that is treated with MVDA, e.g. principal component analysis (PCA). PCA explains the variance in the experimental data and reduces the large data set to plots that can be easily surveyed. PCA produces a 'score plot' that visualizes differences between the experiments. This can be used for classification or grouping of the experiments.

Equipment

The electronic tongue consists typically of four working electrodes made of the metals gold, iridium, platinum and rhodium, an Ag/AgCl reference electrode and a stainless steel counter electrode. A relay box is used, enabling the working electrodes to be connected consecutively to form four standard three-electrode configurations. The potential pulses/steps are applied by a potentiostat which is controlled by a PC. The PC is used to set and control the pulses, measure and store current responses and to operate the relay box. The set-up is illustrated in Figure 1.

Results

Extensive research has been conducted on the voltammetric electronic tongue. Examples of investigations of foodstuffs include juices (Winquist *et al.*, 1997), milk (Winquist *et al.*, 1998), spirit (Comina *et al.*, unpublished data) and tea (Ivarsson *et al.*, 2001). However, most of the work has focused on supervising processes, including water cleaning processes (Krantz-Rülcker *et al.*, 2001), dishwasher processes (Ivarsson *et al.*, 2003), the wet-end process of a paper machine (Carlsson *et al.*, 2001) and the process of mold growth (Söderström *et al.*, 2003). As an example of such a process, a score-plot of a dishwasher process is shown in Figure 2. The process from the main wash through the two rinses can be observed.

It is also possible to combine the electronic tongue with other sensor systems. An electronic tongue based on the combination of

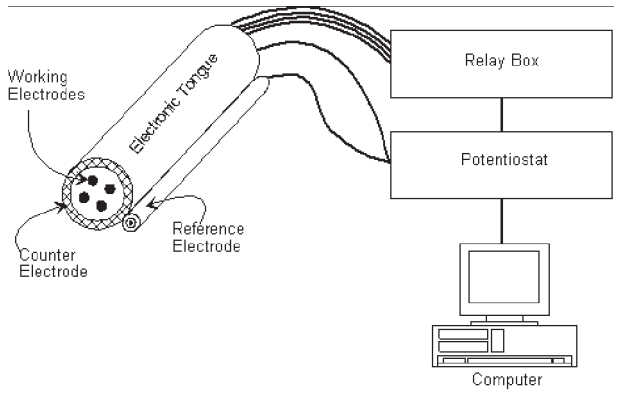

Figure 1 Schematic of a voltammetric electronic tongue.

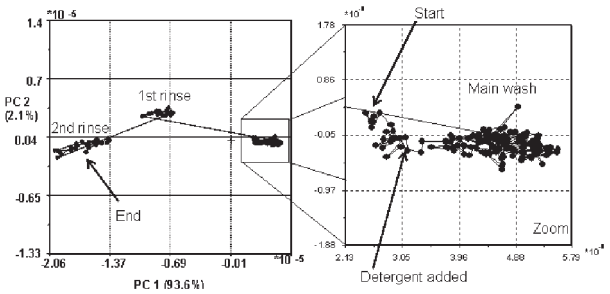

Figure 2 PCA score-plot of one of the dishwasher runs with the points connected with a line. Main wash to the right and second rinse to the left, with the first rinse in between. The main wash is enlarged and the beginning of the run and point of detergent is addition are marked.

potentiometry, conductivity and voltammetry techniques has been constructed (Winquist *et al.*, 2000). Additionally, a combination of the voltammetric electronic tongue and the electronic nose (Winquist *et al.*, 1999) has been investigated.

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