A&QT-R 2002 (THETA 14)
2004 IEEE-TTTC International Conference on Automation,
Quality and Testing, Robotics
May 13 - 15, 2004, Cluj-Napoca, Romania

INDOOR AIR QUALITY EVALUATION

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Abstract:

The paper relates to a method of qualitative assessment of indoors comfort by the use of an electronic nose consisting of a conductive polymer gas sensor array, a data acquisition system and a pattern recognition system. The conductive polymer gas sensors are sensitive to gases polluting the indoors air but they are sensitive to indoors temperature and humidity as well. The data acquisition system overtakes the sensors specific response and outputs a characteristic pattern to the pattern recognition system. The latter, a fuzzy logic neural network based system, classifies the results of the measurements on qualitative grounds and takes decisions in terms of meliorating comfort inside buildings, houses and work conditions.

Keywords: air quality, electronic nose, indoor comfort, qualitative assessment.

1. INTRODUCTION

The quality of the indoors air (the overall comfort) is estimated by the values of the thermal comfort, purity and chemical composition of air, noise level, ionization of air, aesthetics of the environment, and so forth.

Assessment of the environmental comfort is both objective and highly subjective as well. For instance, some people feel comfortable in a warm humid, confined and slightly illuminated environment, while other people prefer drier, colder, quieter and brightly lightened environments while crossed by slightly ionized air flow.

Taking into consideration of the subjective factors biasing assessment of indoors comfort may be enhanced by use of artificial intelligence incorporated in systems of measurement and improvement of the micro-climate inside a room. This entails use of a learning air quality measurement and assessment system adaptable to the subject itself.

Qualitative assessment of a phenomenon or dimension, often immeasurable, subjective, as for instance: recognition of pattern, character, sound, odor, evaluation of the comfort, pollution level, etc., imposes dramatic change of the way of seeing things, notably a more human-like approach to overall sensing and thinking. At present, this may be carried out through sensor arrays and artificial neuronal networks, which through learning and subsequent use of the learned notions allow a rapid and accurate assessment of the qualitative changes in the studied dimension, closer to the human way of evaluating similar changes.

Given that, as concerns air, food and beverages quality assessment, one instinctively and primarily uses his/her olfactory sense, one got to the idea of devising an artificial nose, able to qualitatively determine atmospheric pollution and implicitly the comfort level attached thereof.

2. ELECTRONIC NOSE

The electronic nose for the qualitative assessment of the indoor air (environmental comfort), comprises a highly sensitive and lowly specialized *sensor array*, a *data acquisition system* and a *pattern recognition system*. [1]

Block diagram of an electronic nose, an intelligent system for qualitative assessment of the environmental comfort, is shown in the following drawing:

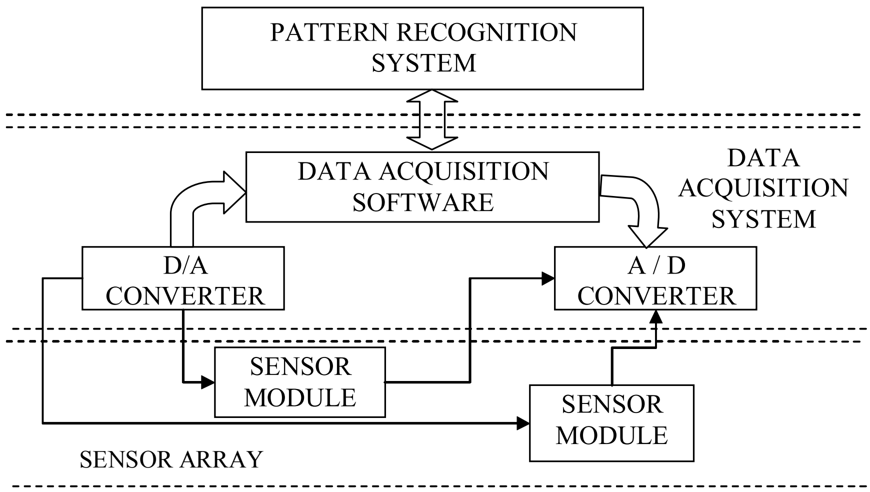

Fig.1. Block diagram of the electronic nose.

2.1. *Sensor Array*

The sensor array is composed of some conducting polymer sensors which may be, for instance, made of polypirols [2] or of polyalkylthiophenes [3].

Conductive polymer gas sensors are sensitive to various combustion and toxic gases, their sensitivity depending strongly upon air (environment) temperature and humidity. This triple-temperature, humidity and impurities concentration in air – sensor sensitivity allows use of these sensors in modeling comfort categories.

When a sensor is stimulated by an odorant, its polymeric film is affected by physical and chemical reactions, which produce a variation in the electric resistance of the film. The intensity of the variation depends on the type of odorant, temperature and humidity of the air. To measure the resistance variation a current flows between two pins of the sensor as shown in Fig. 2. The voltage generated by the polymeric film is measured by a high impedance voltmeter applied to the remaining pins. The ratio between the output voltage and the input current identifies the resistance change produced by the odorant on the polymeric film.

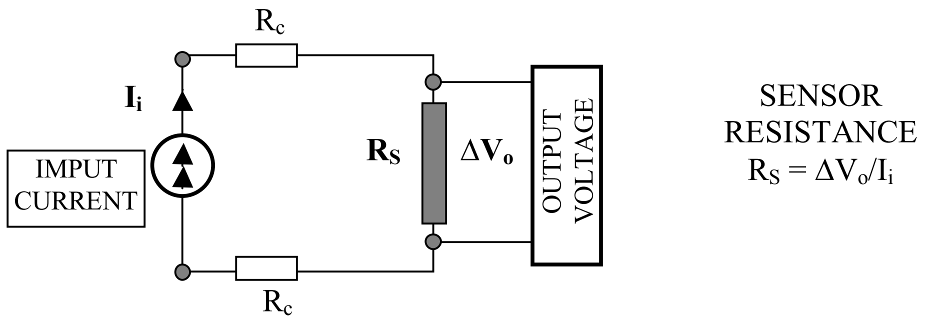

Fig. 2. Sensor equivalent circuit.

2.2. *Data Acquisition System*

The *data acquisition software* (Fig. 1.) controls a D/A *converter*. Each channel of the D/A converter can supply a *sensor module* with several thousands levels of input voltage with different waveforms [1]. The ***sensor module*** is presented in Fig. 3. The *voltage multiplier* can increase the number of the voltage levels. The voltage is input to a *current generator,* which produces a current proportional to its input voltage.

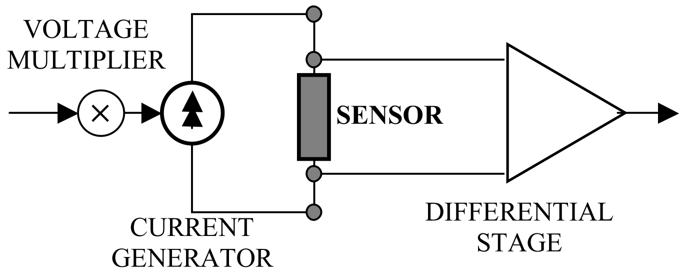

Fig. 3. The SENSOR MODULE .

The current flows into the sensor and generates a voltage, which drives the *differential stage.* Independently of the sensor resistance, the differential stage produces an output voltage, which always falls into the optimum operating range of the *A/D converter.* This allows using sensors with intrinsic resistance ranging from 500 Ω to 2 MΩ. The output voltage is proportional to the equivalent resistance of the sensor.

The *A/D converter* converts the analogue voltage into a digital signal that is acquired by the *data acquisition software.* The first sample of the signal is subtracted from the whole signal. This reduces the effects of the drift on the sensor response. The response produced by each sensor composing the array is analysed by the *pattern recognition system.*

The *data acquisition system* outputs the signal form corresponding to the maximum sensitivity on certain domains of interest to each sensor and takes over the sensor response for numerical processing thereof. It aggregates the sensor responses into patterns that it outputs *to pattern recognition system*.

2.3. *Pattern recognition system*

Pattern recognition is defined as process of identifying structure in data by comparison to known structure. Patterns are typically described in terms of multidimensional data vectors, where each component is called a *feature*. The aim of a pattern recognition system is to associate each pattern with one of the possible pattern *classes*. Obviously, different patterns should be associated with the same class or with different classes depending on whether they are characterized by similar or dissimilar features, respectively. In the case of the electronic nose, the patterns and the classes are, respectively, the responses of the sensor array to indoor air, and the comfort categories being considered. In order to develop a pattern recognition system, the sample data are split into two sets, namely, the *training set* and the *test set*. The training set is used to establish the design parameters of the pattern recognition system, whereas the test set contributes to evaluate the system performance. Typically, the performance of the pattern recognition system is measured by computing the percentage of correctly recognized patterns on all the patterns presented to the system. The performance of the pattern recognition system should be as independent as possible from how the sample data are split into training and test sets.

Several different data processing and pattern recognition techniques have been used in the literature to recognize signals produced by sensor arrays. These include linear pattern recognition techniques, such as principal component analysis and cluster analysis [2], and non-linear pattern recognition techniques, such as classical multivariate analysis and artificial neural network algorithms. As the relationship between the signal produced by sensor and an odorant concentration is usually non–linear, non-linear pattern recognition techniques are generally more successful then linear ones. However, the success of each technique heavily depends on the preliminary selection of the features, which are used in the recognition process.

The sensor responses are noisy and affected by a strong drift in their amplitudes. Non-linear algorithms, such as artificial neural networks and fuzzy systems, have generally proved to be able to handle noisy and uncertain data.

3. ELECTRONIC NOSE MODEL

Assessment, control and improvement of comfort inside buildings, houses as well as establishment of appropriate work conditions for each workplace result in a significant increase in work productivity, decrease of the overall fatigue and stress of people along with increases of the hygiene level at home and at work and reduction of the professional diseases.

The quality of the environment (the overall comfort) is estimated by the values of the thermal comfort, purity and chemical composition of air, lightening level, noise level, ionization of air, aesthetics of the environment, and so forth. Microclimate inside buildings may also be influenced by technological processes unfolding therein.

Conductive polymer gas sensors are sensitive to various combustion and toxic gases, their sensitivity depending strongly upon air (environment) temperature and humidity. This triple-temperature, humidity and impurities concentration in air – sensor sensitivity allows use of these sensors in modeling comfort categories.

The response of the sensor arrays consists of a "characteristic pattern" that is to be classified. Classification is made according to the user's needs.

Moreover, assessment of the microclimate by individuals is strongly biased by their physical and mental state (healthy, ill, joyous, upset, stressed, tense, etc) by the activities the individual is executing at certain time (work, studying, meal, rest, leisure, sleep, etc) and by the social environment the subject is located in (at home, alone, with family, in society, at work).

Figure 4 shows a general representation of multidimensional odour space, Ω_3. The dotted lines demarcate the primary aromatic notes. An electronic nose may be designed to map out all of these regions or more realistically a subset of them relevant to the needs of a particular end-user.

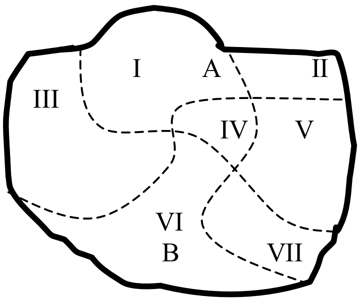

Fig. 4. Odours space.

Comfort categories (odour space Ω_3) may be of the following types: (warm, dry, normal), (warm, dry, impure), (pleasant), (unpleasant), (too hot), (too cold), (very humid), (too dry), (dangerous environment), (explosive environment).

Figure 5 shows the basic stages of signal processing in an electronic nose [4]. Sample space Ω_1 is defined by the chemical composition of the sample. The zero point represents odour-free air. The sensor array responds to the sample A and so maps one point in sample space onto sensor space Ω_2.

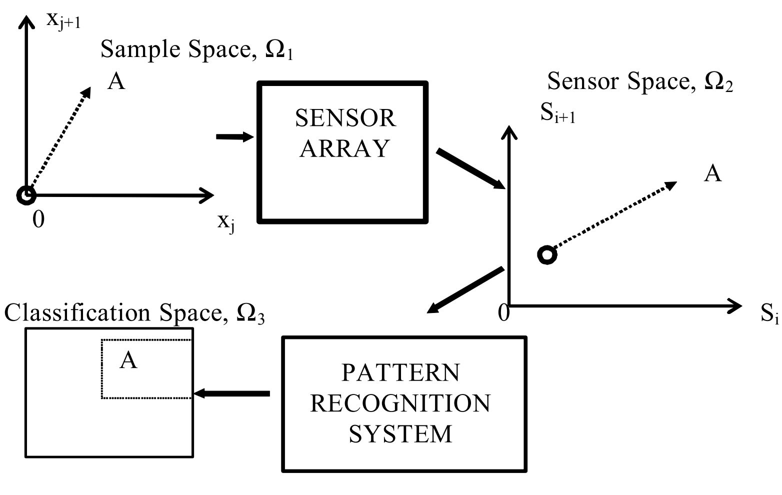

Fig. 5. Signal processing in an electronic nose.

The integrity of the output from the sensor array thus largely determines the performance of an electronic nose. Key parameters are the number and type of sensors, the specificity of the sensors, their noise level, stability, thermal sensitivity and so on. In other words, if the samples are not distinct in sensor space, then the pattern recognition system cannot be expected to discriminate them. Any attempt to do so will be unproductive, as the noise in sensor space will be mapped in proportion onto classification or odour space Ω_3.

One may easily see that such categories as the above ones are subjective and vague in most cases, and therefore susceptible of being processed by fuzzy logic and that they are also susceptible of being associated to fuzzy neural networks. But, it is difficult to model sensorial and psychological problems correctly.

4. CONCLUSIONS

The electronic nose, an electronic system of air quality control, inspired from the operation of human smelling, consists of a specialized gas sensor array, as a receiver (peripheral segment), a data processing, acquisition & transmission circuit (intermediate segment) acting as a data conveyance means and a neural network for processing the data and classification the odours (central odour perception segment).

The electronic nose described in this paper represents a step toward the assessment of a working strategy for indoor quality evaluation.

The decisions made by the electronic nose may be subsequently used in actuating heating and ventilation systems, in controlling air conditioning systems, methane supply of fire protection systems and security systems for buildings and personnel.

References

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