Human-Based Sensing – Sensor Systems to Complement Human Perception

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Abstract

The approach of human-based sensing is based on the assumption that sensor systems for individual use have optimal performance if coherent with the human perception system. The benefits of complementing the human sensing with sensor systems that strengthen the information and make the human able to perform more adequate and optimized decisions based on the sensor information, will improve the human capability. The arguments for designing sensor systems that increase the human ability in order to enhance the information from its surroundings are obvious. In this paper, an example of this approach, related to human-based sensing, will be demonstrated. The ability to strengthen the human capability, and complementing human perception with additional sensing, by the use of artificial sensor systems, will increase the human performance.

Keywords: Human-based sensing, artificial perception, artificial nose, artificial tongue

1 Introduction

In a world where humans tend to be overloaded with information, a need to complement human perception is in many cases desirable. The ability to mimic human perception using artificial sensor systems has been an area of continuous interest since the emergence of new sensor technologies in the late 20th century. To date, applications that involve, for example, artificial olfaction and taste capabilities include quality evaluation in the food industry, environmental monitoring and detection of hazardous contamination. Also applications using vision and auditory information are now frequently used in order to complement the human capabilities.

Many of these applications use, what is called, electronic nose, electronic tongue, hearing, touch and vision sensors. That is to say, sensing devices of various selectivity along with advanced pattern recognition components, trained to discriminate between both simple and complex human-based sensing. The output is an “environmental picture” describing the activity of interest. Also for us as individuals, there are various needs to perceive information from the proximity area, to direct information by sensing many sets of complementary devices and to merge it to meaningful information.

In this presentation, we focus on the goal to use artificial sensors to “extend” the human perception system. By extend, we mean to displace the point of sensing remotely from the human body. For example, instead of using an artificial tongue to assess the quality of a food product, an electronic tongue placed in close proximity could provide an equal (or even better) evaluation. The consequence is a new generation of sensors built for individual remote use that can provide fast and accurate human interaction with a more secure approach.

2 The Concept

In this article, a sensor approach is presented to extend information and provide indication, and demonstrated in a realistic application. The concept of human-based sensing is focused on the approach to find the coherent advantages complementary to human perception. The human perception has, in a historical perspective, been related to human safety aspects and often focused on the identification of hazardous situations or functioned as a warning system.
The human system has a remarkable ability to sense a dangerous situation in its close proximity, by using sophisticated perception (e.g. smell, taste, vision etc.) and merge this information with knowledge and earlier experience. The possibility to complement the human with a remote network of perception-related sensors requires in principle that, in case of hazardous or attention-demanding situations, a clear indication of the risk assessment is presented from a safe distance, i.e. before the object constituting the risk gets in close contact with the human body. Therefore, a complementary human-based perception ability, to inform about situations of interest, which are in coherence with the human perception, is clearly an advantage. The design principle of a sensor system, complementing the human, is therefore of high importance, including a perceptive interaction part between system and human.
An effective interface should also consider that mainly non-experts are interacting with this type of system. Therefore, a minimalistic yet effective output is favored over detailed and an overflow of information about the reasons for the attention. The approached model represents a new generation of sensors built for individual local use that can provide fast and accurate indications. In addition to existing large-scale measurement systems used today for general

protection and warning, e.g. tornado or earthquake monitoring, there is also a need for small sized monitoring. The example in figures 1 to 3 illustrates the human-based sensing principle, indicating a safety concept in close proximity to an individual, e.g. water quality evaluation at the tap. Figure 1 illustrates a normal state of drinking water, where the human perception normally indicates that the water quality is safe to consume, however often inside the body, i.e. in the mouth.

Figure 1. Example of the human perception.

In figure 2, an approach to indicate a complementary artificial sensor system that monitor the quality of the drinking water is illustrated. This technique is then considered as a complement to the human perception system and the human does not need to bring the food inside its personal safety sphere or in the mouth before testing the quality of the drinking water. Another motivation resides in a growing ability for artificial sensing systems to exceed the human perceptual competence in accuracy and precision in detection. For example, the human perception system is not always able to detect all chemicals or microorganisms in drinking water by taste alone and there is a benefit to use an electronic system that can find abnormal or unsafe compounds before humans will drink it.

Figure 2. Example of a sensor system using an individual monitoring system.

The communication between human and system needs to use an interface that is easy to understand. A simple example could be a warning system inspired by the traffic light concept. A green light corresponds to safe consumption and a red light indicates impurities of high concentration in the drinking water. Additionally, a zone of uncertainty can be added, represented as a yellow light. The yellow light corresponds to an ambiguity i.e. cannot guarantee safe consumption, and further analysis may be needed. Representing the results as a traffic light makes it easy for the user to understand the outcome of the sensor system.

In figure 3, the artificial sensing system complementing the human perception can be located at a distance from the individual, at for example the water purification plant and even at the water reservoir. In this paper, the concept described in figure 2 will be described in more detail.

The proposed example illustrates a simple aspect of artificial monitoring systems for human assessment at both individual and remote levels.

Figure 3. Example of a sensor system using remote monitoring and in close proximity.

3 A Proposed Model

The complex and advanced sensor development have created a need for better techniques in interfacing with the human ability regarding the perceived information. The current limitations in humans, artificial sensor and computer systems arise from the sensor interfacing inadequacy and the unbalanced results in a conflict with natural human behavior. There are a number of aspects related to the human-based sensor approach:

- How to make selective sensing
- How to perceive the sensor data
- How to extract important features
- How to make intelligent decisions
- How to exchange essential information

In the first aspect, the environment information is often imprecise and in some sense limited, often with uncertainties. Therefore, the performance of the sensor system needs to reflect the environmental picture. A major component in designing human-based sensor systems is considered to be the process of merging sensor data into relevant information.

The knowledge and earlier experience concerning the essential features of interest in an environmental picture have to be integrated in the extraction process.

Further, one aspect concerns the way of making relevant decisions based on the dynamic sensor data and the processing of essential information. Finally, the aspect of the exchange of essential information with the human is crucial, i.e. the human–artificial system interface. This interfacing process often controls the effectiveness of the whole human-based sensor system and when exchanging with human behavior, it could bring about trust and understanding of the whole system performance. When increasing the “intelligence” in the perception-based system, an effective user-related interface will strengthen the interaction between the human and the system (active perception) as well as perceptual interactions when considering complex environments.

It is necessary to understand the features of a perceptual system and the information extracted from the process in order to effectively make use of the information from the sensors. To describe the benefits of the proposed perception model, a structure is presented. The perception model process shown below demonstrates the combination between the human perspectives of merging perceptual information and a sensor system complementing the human abilities.

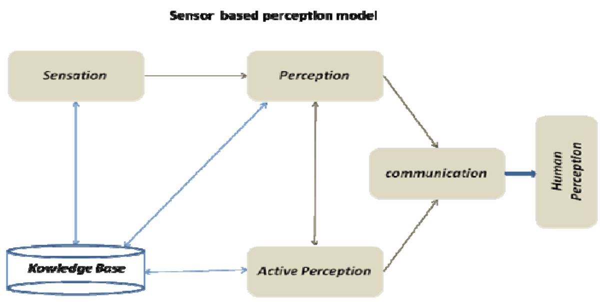

Figure 4 describes a sensor-based perception model with general abilities.

The model can be seen from [1]:

- a human-related perspective
- artificial-based sensor systems
- a computational perspective

and can be described as four aspects [2]:

- *Input interface:* a sensational process with similarities to human sensation and preprocessing activities, through a number of nuclei, of sensory information to the brain. A number of different sensor capabilities ensure the ability to connect dynamic activities in the environment that correspond to the “attention” of the artificial system.
- *Signal analysis:* a process that organizes the received data into a “structural picture” and extracts the requested information. This has similarities with the functionalities in the thalamus and cerebral cortex.
- *Decision-making:* handles decision-making in the system similarly to the motor cortex. In the case of artificial systems, interpretation is performed by implementing sensing as data acquisition with the help of pattern recognition.
- *Human-computer interface*: communicates the information to the human user in an effective and perceptive process.

Perception according to the model in [3] can be considered as active or passive. In this example, a process were the sensor system is only sensing and communicating relevant information, is here considered to work in a passive perception mode, i.e. not providing any feedback.

On the other hand, active perception-based models have been presented in a variety of applications, e.g. fire detection and target localization based on auditory and visual information [4],[5] with successful results.

4 Experimental

In this paper, we propose a concept of human-based sensing to complement human perception. A sensing principle describing an individual supportive sensor system is presented. The approach is based on a perception-based application consisting of one single sensor system used for complementing people in their home environment.

4.1 The Electronic Tongue

The sensor system used for the experiments in this thesis is an electronic tongue. The concept was developed in the beginning of 1990s from a taste approach similar to human perception. One of the first original research works in the field of the electronic tongue concept can be found in [6].

The electronic tongue concept uses different operational principles, e.g. [7],[8],[9],[10] and is designed for a number of applications [11],[12],[13],[14],[15]. This specific sensor approach has originally been developed for water quality assessments [16],[17]. The need for securing the drinking water by monitoring quality is in most countries around the world obvious. The proposed solution is considered to monitor the quality of the drinking water directly at the water tap before drinking the water. Then the sensor system, i.e. an electronic tongue, is able to continuously measure the water quality and act as a sensor system in close proximity to the human body and is considered to be a complement to the human perception. Figure 5 illustrates a sensor prototype able to measure the quality changes in drinking water. The communication is simple and effective - using visual indications like a green light for good quality and a red light indicating suspicious or bad quality [18]. The design of an electronic tongue is not supposed, or able, to replace the human perception. The artificial sensor system is intended to be a complement and a first indication located in the close human proximity, i.e. a simple and fast system able to measure quality changes.

4.1.1 The Measurement Procedure

The used electronic tongue in this approach has been developed at Örebro University. The aim was to design a smell sensor system able to detect changes over time in the total quality of drinking water.

The measurement procedure when monitoring the quality of the drinking water is simple, as shown in figure 6. The sensor contact point makes contact with the liquid and the measurement process using voltammetry starts. After receiving the sensor data, complex pre-processing and data analysis operations are performed and the outcome, i.e. a measure of the water quality, is presented to the human. In this context the response regarding the water quality from the electronic tongue differs from a human tongue.

Figure 5. The electronic tongue device on the water tap

The sensing points in this electronic tongue concept are based on a number of working electrodes, in this case from gold and a platinum material. In connection to the working electrodes, a reference electrode of stainless steel is needed. A potential is applied at the working electrode and the resulting current between the working electrode and the reference electrode is measured. When a potential is applied, an electrochemical redox reaction occurs at the electrodes surface and gives rise to the measured current. All particles in the measured sample that are redox reactive below the applied voltage will contribute to the response. The method used is called pulse voltammetry, which indicates that the input waveform is formed by pulses of varying amplitude. By using pulses of different amplitude the sensitivity is increased and the discrimination between samples will be improved. Depending on the chemical content of the drinking water sample, there will be a difference in the amount of particles contributing.

In the below figures 6 and 7, the design used in this specific application and response from a given input are shown.

The measurement data produced from an electronic tongue sensor is large and complex, containing large amount of data. Due to the large amount of information occurring in an electronic tongue measurement, some kind of pre-processing is needed.

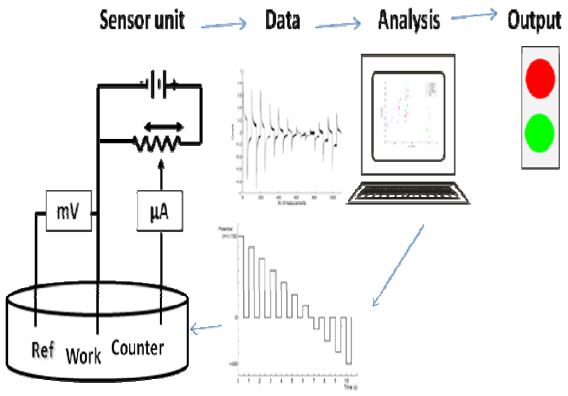

Figure 6: The concept of the electronic tongue system

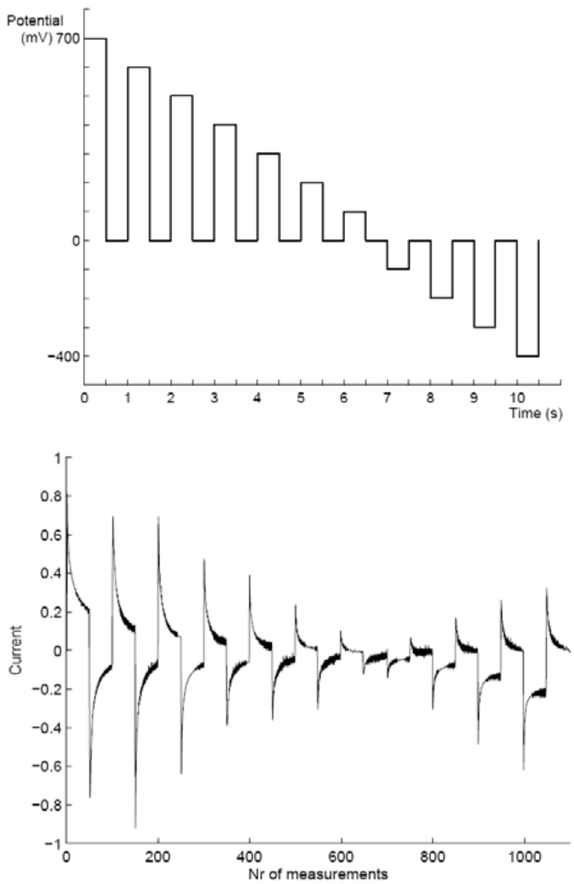

Figure 7. The electronic tongue sensor input (upper figure) and response (lower figure).

In most applications that use the Örebro University designed electronic tongue, the analysis was done with principal component analysis, PCA, [19]. But over the last few years, other data analysis methods have been tested with success.

In [17], an overview of the most common applications using different data analysis techniques is presented. Also, classification methods like artificial neural networks and fuzzy clustering methods will be addressed.

5 Conclusion and Future Work

In this paper, a concept of human-based sensing is presented and an illustrative design concept of the perception-based sensor system is discussed. The topic of human-based sensing has specifically been addressed in order to demonstrate an example; the monitoring the quality of drinking water outside the human body. Finally, an application has been presented and a perception-based model has been demonstrated.

The proposed perception model can be seen as one step toward developing artificial systems which mimic the human perception mechanisms. One of the advantages is that humans can communicate with them in a natural way and such systems are therefore more likely to be accepted by the users since they intuitively understand the system's principle of operation, regardless of the actual implementation of sensor concepts.

Ultimately, human-based artificial sensors provide an important and unique means to perceive our environment and therefore they are valuable components for many safety, health or general assessment systems.

6 References

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