Concept of a Tactile Intelligent Sensory Substitution System

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Abstract

In this paper we present a novel approach to communication using the human's tactile sense. We propose an intelligent tactile information system that has the capability to generate a language suitable for tactile stimulation. This unknown language has to be evolved by an adaptive encoder in interaction with the user. The system is composed of four functional units: input device, learning encoder, tactile interface and mans perception.

1 Introduction

Human beings communicate with their natural and technical environment by using different channels for information exchange, e.g. seeing, hearing, smelling, touching, speaking, gesturing etc. Most part of human perception is processed through the visual and auditory channel, while the tactile channel remains rather unused. Although seldom used for technical supported communication tactile perception is a powerful information channel e.g. demonstrated by the Tadoma method [8] or by the users of braille displays.
There are versatile applications using the tactile sense [2] [4] [11]. Handicapped people can use the tactile channel as substitute for the lost channel of perception [3]. As an additional possibility private communication is possible because it is non-audible and non-visible and therefore not easily monitored by unwanted listeners. Furthermore the tactile sense can be used as a spatial orientation guide.
It is reasonable to subdivide the flow of information in a tactile information system from the real world to human perception into four units: an input device, an encoder, a tactile interface and human perception.
The input device receives the signals and transforms them into a convenient electronic representation. The encoder processes the information in a suitable way so that the tactile interface, the connection to the human being, can be optimally controlled. The final unit of a tactile information system is the individual itself with its cortical information processing that finally enables perception.
The complete information process from the input device to human perception is extremly complex and furthermore unknown. At the moment it is impossible to model this information process in a sufficient way. Thus we recommend that the adequate information processing is attained by an adaptive system in close interaction with a learning scheme.
We propose tactile systems should consist of an input device, an adaptive encoder [5], an actuator and human perception. The adaptive encoder is trained in special learning sessions [1] to obtain the required capabilities.

2 Architecture

The adaptive tactile system consists of four units as depicted in figure 1: input device, adaptive encoder, tactile interface and perception by the user.

- The INPUT DEVICE is designed to pick up the signals from the input space. There are different input spaces possible e.g. acoustical, visual spaces or data sources (computer). It is reasonable to preprocess the input data to achieve that the time for the adaption of the encoder becomes short. For example acoustical input could be filtered and classified into patterns of phonemes [9] [10] to reduce dimension of the data without destroying the relevant information.

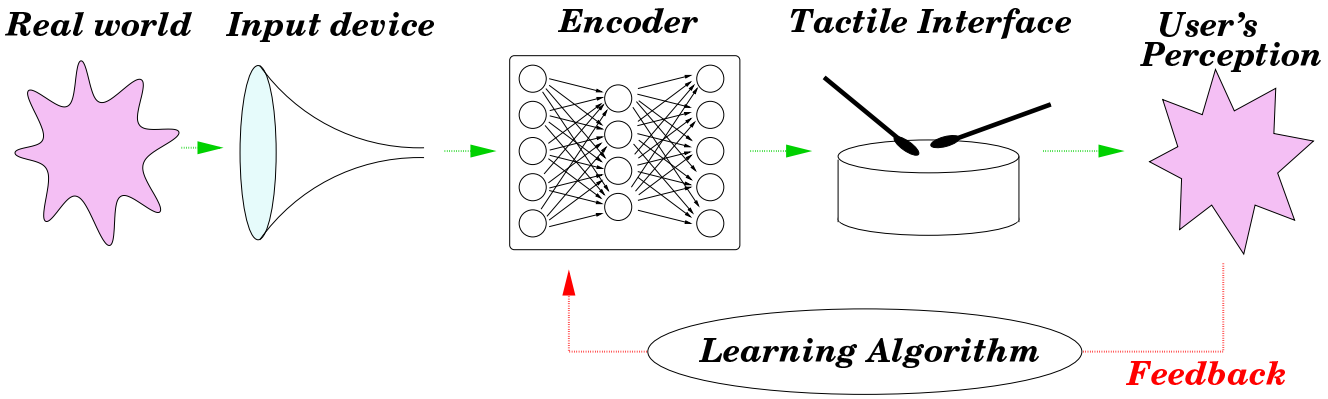

Figure 1: Scheme of tactile information system, consisting of Input Device, adaptive Encoder, Actuator, User's Perception

- The ENCODER obtains the preprocessed data from the input device. It processes the data and translates the information into a language adequate for tactile human perception. At the moment this language is unknown and thence the translation is impossible to calculate. A neural network with its approximation capabilities offers a feasible approach to solve this problem. Thus the encoder becomes versatile and adaptive with respect to the type of input signal and the individual user's perception.

- The TACTILE INTERFACE is the connector from the encoder to the user. The stimulators of the interface can be of different types such as vibratotactile or electrotactile [6] [7]. In the skin exist diverse types of mechanoreceptors. To obtain a higher bandwidth of information it is advantageous to be able to excite the receptors separately. Additionally the consumption of power should be low because the tactile information system needs to be portable.

- The USER is the unit of the system where the perception is finally generated. Tactile perception will be different for different users so that the individual adaptation of the encoder is a great advantage. For this adaptation feedback of the user is required. The presentation of the feedback depends on the implementation of the learning algorithm. The user too has to adapt himself in a way that he learns to interpret the presented tactile stimulation. The aim is to achieve a sensory substitution. Then the former tactile perception is replaced by a new type of perception resulting for example in an ability of hearing by means of the tactile sense.

3 Handling the system

We propose to install the tactile system in three phases:

- In the first phase the user has to be sensitized to this specific type of stimulation.

- During the second phase the system is adapted. For this purpose a finite set of the encoder's input signals, representative for the input space of the tactile system, is generated. To allow the user to distinguish and learn the presented patterns as good as possible, the parameters of the encoder are adapted by the learning algorithm having regard to the user's appraisal of the stimulation (feedback). As there are two learning parts in the tactile system (adaptive encoder and user), a learning scheme has to be carefully developed so that the two parts interfere in a constructive way.

  Although presenting only a finite set of input patterns, the encoder should afterwards be able to map unknown but similar patterns to a tactile stimulation that can be recognized and interpreted by the user. This generalization is a well-known feature of the neural network implemented in the encoder.

- Finally the system is adjusted and ready for day-to-day use. It may be necessary to readjust the system from time to time.

4 Conclusion

The introduced tactile information system offers an efficient way of communication. It establishes an additional channel of information exchange. With the use

of an adaptive encoder the tactile information system evolves a language suitable for tactile stimulation. By the aid of sensory substitution the information is received by the subconscious mind and does not divert the user from other tasks. With different types of input spaces the tactile information system offers a variety of novel fields it can be applied to.

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