7. Workshop Automatisierungstechnische Verfahren für die Medizin vom 19. - 21. Oktober 2007 in München

„AwaCon-Project: First Results for a Multi-Modal Awakening Controller"

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Band: Fortschritt-Bericht VDI Reihe 17 Nr. 267 „Automatisierungstechnische Verfahren für die Medizin, 7. Workshop, Tagungsband"
Editors: Ralf Tita, Robert Riener, Martin Buss, Tim C. Lüth
ISBN: 978-3-18-326717-0
Pages: 23-24

AwaCon-Project: First Results for a Multi-Modal Awakening Controller

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INTRODUCTION

First applications with the dynamic tilt table 'ERIGO™' showed that there is a positive effect on the alertness and awareness of patients in vegetative state.

However, it is not known, which modality or combination of modalities has the best effect on the awakening process [Zieger2004]. Furthermore, quantitative measures to describe the level of alertness and awareness are still missing [Klein2000]. The objective of this project is to develop a method to detect, quantify, and interpret the state of alertness and optimize the awakening process in vegetative and minimal conscious state patients.

METHODS

The basic idea is to expose the patient to a variety of different sensory modalities (multi-modal input $\vec{I}$) and record his/her physiological reactions (multi-modal output $\vec{O}$) in order to assess and optimize the physiological state of alertness.

The technical principle is shown in figure 1. Before, during and after exposing the patient to the stimuli $\vec{I}$ = (S_{aud} S_{vis} S_{olf} α_{tilt} F_{load} f_{step} A_{step}) (auditory, visual, olfactory, tilt angle, loading force, frequency and amplitude of stepping patterns, respectively) a variety of physiological signals $\vec{O}$ = (V_{EEG} V_{EP} V_{EMG} f_{HR} p_{sys} p_m f_{resp} R_{GSR} c_{O2} T_b) (EEG signals, evoked potentials, EMG signals, heart rate, systolic blood pressure, mean blood pressure, respiration frequency, galvanic skin response, oxygen saturation and body temperature, respectively) were recorded.

The study is still under progress and the challenge will be to estimate the state of alertness from the physiological signals measured. Based on these results, the first goal will be an awakening controller that adjusts the display of sensory input $\vec{I}$ so that the state of alertness can be modulated in order to accelerate the awakening process in a save and mild way towards the patient.

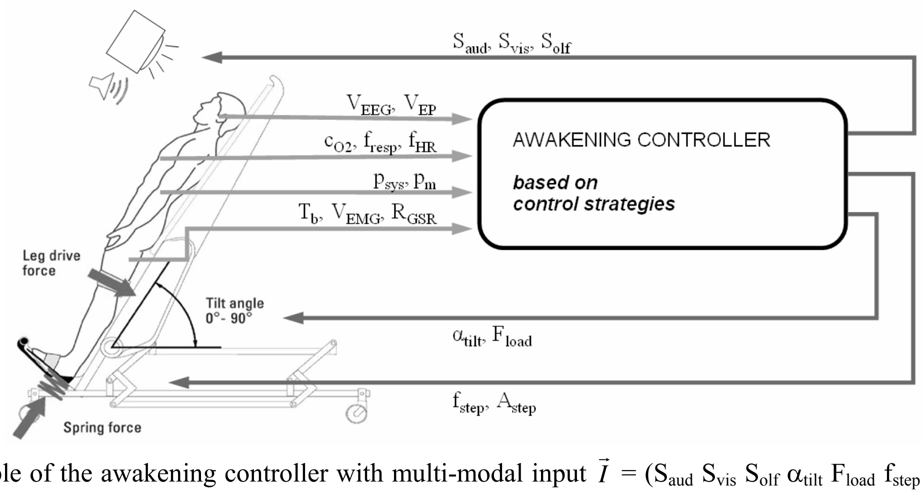

Figure 1: Principle of the awakening controller with multi-modal input $\vec{I}$ = (S_{aud} S_{vis} S_{olf} α_{tilt} F_{load} f_{step} A_{step}) and multi-modal output $\vec{O}$ = (V_{EEG} V_{EP} V_{EMG} f_{HR} p_{sys} p_m f_{resp} R_{GSR} c_{O2} T_b) from the patient's point of view

Different 'levels of alertness' have to be defined that are based on the same vector elements as the multi-modal output $\vec{O}$. The different levels will be part of the interpreter (figure 2). The interpreter has to be developed and identified on the basis of intensive experimental investigations. Hence, the reference vector with predicted values $\vec{O}_d$ will be the input to an inverse dynamic model describing the physiological processes of the patient. The model determines the required input signals fed to the display devices (feedforward loop).

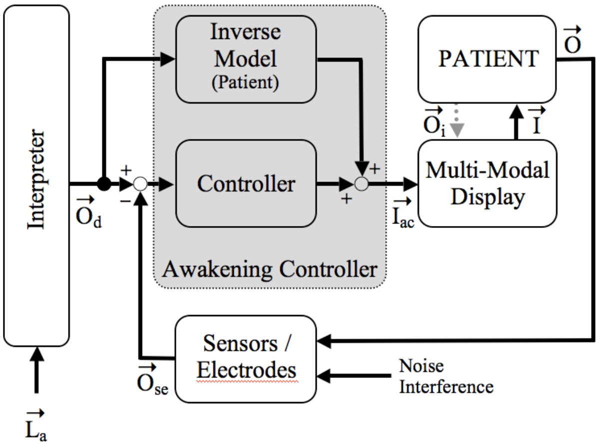

Figure 2: AwaCon control strategy. $\vec{L}_a$= levels of alertness; $\vec{O}$ = physiological output signals; $\vec{I}$= input signals; d = desired signals; ac = awakening controller; i= interaction; se = sensors and electrodes

In the feedback loop we will measure the real physiological output $\vec{O}$ of the patient by means of sensors and electrodes recording non-electrical and bioelectrical signals, respectively. Recorded signals $\vec{O}_{se}$ will be compared with the reference values $\vec{O}_d$ and fed into the controller. The control output and the output of the inverse dynamic human model will define the input $\vec{I}_{ac}$ to the multi-modal display. The display will expose the patient to the defined sensory modalities $\vec{I}$. The patient will show a physiological output $\vec{O}$ and as the case may be react with an interaction $\vec{O}_i$ to the display (e.g. reflex).

In a first step we derived a simple model to describe some cardiovascular relationships. The ERIGO™ inclination angle α_{tilt} for tilting the subject, the stepping frequencies f_{step} and the force for performing the stepping patterns F_{load} was chosen as an input to the model. The output includes mean blood pressure p_m and heart rate f_{HR}. We used a non-linear dynamic 2nd order model composed of linear, exponential and sigmoid-functions. The identification of the model was done with the least squares method.

RESULTS

A preliminary evaluation of the heart rate while tilting a healthy subject is shown in figure 3. The physiological system reacts with an overshoot and turns back into the predicted value of 74 bpm after approximately 20s (mean error: ±2 bpm). The experiment was done with 3 healthy subjects and the standard deviation of Δf_{HR} was 8.6 bpm.

The model is also capable of describing the relation of further inputs (f_{step} and F_{load}) and output (p_m).

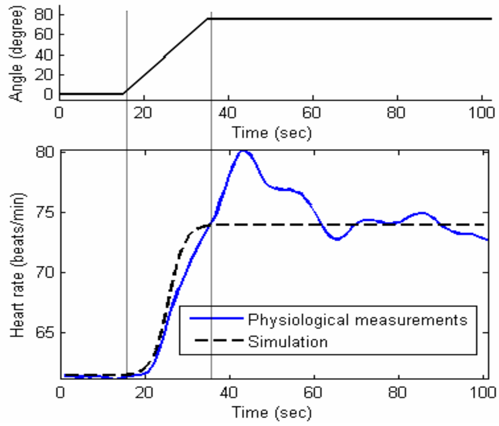

Figure 3: Physiological reaction of one subject with predicted data of the model on the heart rate during tilt

DISCUSSION AND OUTLOOK

A general issue is the variability between the subjects. A standard deviation of 8.6 bpm among healthy subjects is quite high and should be considered carefully while continuing the experiments with additional subjects.

The model does not predict the overshoot, which was observed in the measurements. Moreover, symptoms of vasovagal syncope, which some human subjects develop during tilt, cannot be predicted. Although the model does only predict the global behavior of the heart rate, it is sufficient for the use in the awakening controller. The system is based on discrete states of alertness and from that point of view the approximation of the global reaction is satisfying.

The model will be extended in order to allow a continuous estimation of blood pressure and further physiological effects.

ACKNOWLEDGMENTS

This project was funded by the NCCR (National Center of Competence in Research) Switzerland.

LITERATURE

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