Diagnostic-purpose Research of Biological Signals

Zoltán Benyó, Balázs Benyó, Levente Kovács, György Várallyay jr., László Török, Attila Reiss

Department of Control Engineering and Information Technology, Faculty of Electrical Engineering and Informatics, Budapest University of Technology and Economics, Magyar Tudósok krt. 2, H-1117 Budapest, Hungary
lkovacs@iit.bme.hu

Abstract: The paper gives a review of our actual research results obtained in two grants. During the OTKA T042990 research grant the results are focused on two programs: diagnostic analysis of the infant cry, respectively investigation of the relation between diabetes mellitus and hearing disorder in children. In the other, RET-04/2004, university-level grant, as one of the consortium members we have bidden with an own subproject. In this case we have several aims, but in fact these all come down on safety driving.

Keywords: infant cry, computer aided diagnosis, diabetes mellitus, hearing disorder, medical information system, safety driving.

1 Introduction

In the OTKA T042990 research grant titled "Diagnostic-purpose Research of Biological Signals using System Theory" we have proposed the investigation of different kinds of biomedical problems:

- Research of neurolinvistic tools for diagnosing and improving aphasia therapy;
- New phonocardiographic method in the fetal heart rate detection;
- Processing methods of MR brain images.

However, beside these research problems in 2003 two new bimomedical research project have started:

- Diagnostic analysis of the infant cry;
- Research possibilities of biomedical applications by modeling, identification of linear multivariable systems and detection of their

changes – investigation of the relation between diabetes mellitus and hearing disorder in children.

The paper focuses on the presentation of the actual results of the last two projects.

Finally, the aims of our working group in another four years research grant, RET-04/2004 is presented, which has started at the beginning of 2005.

2 Review of Actual Results in OTKA T042990 Grant

2.1 Diagnostic Analysis of the Infant Cry

The infant cry, mostly its medical, pedagogical and acoustical aspects are analyzed since a long time. In Hungary in the 70's Makói *et al.* [1] and later Hirschberg and Szende [2] had dealt a lot with this topic. They drew the attention not only to sense the infant cry as the sign of emotion, but also to treat it as an important sign of state of health.

In 2001 a new investigation was started at the Laboratory of Medical Informatics of the Budapest University of Technology and Economics, Department of Control Engineering and Information Technology. This research project is collaborated with the Heim Pál Hospital for Sick Children from Budapest. On one part our research was based on the knowledge which had been set a few decades before by the above mentioned researchers, on the other part there are several new methods in the field of signal processing which allows us to renew the problem.

Our main goal was to detect hearing disorders by the acoustic analysis of the infant cry. However, a few years later we universalized our aims in detection of all typical diseases in the babyhood by the analysis of the infant cry.

Several models of cry production have been theorized. The theory what underlies the most acoustic analyses of cry sounds is the sound-filter theory. This suggests that the waveform that impinges upon the listener's ear is a function of the source characteristics (*i.e.* the vibrating vocal cords) and its filters (*i.e.* the resonances of the supraglottal vocal tract and the radiation characteristics from the lips). Figure 1 shows a universal schema of the voice-production by Gordos *et al.* [1].

If a parameter of the before mentioned elements varies (*e.g.* sore throat) it affects more or less the produced sound – in our case the infant cry. We could also suppose by-effects of illnesses: *e.g.* deaf infants cannot hear their produced crying, so they cannot control their sound production as healthy infants can.

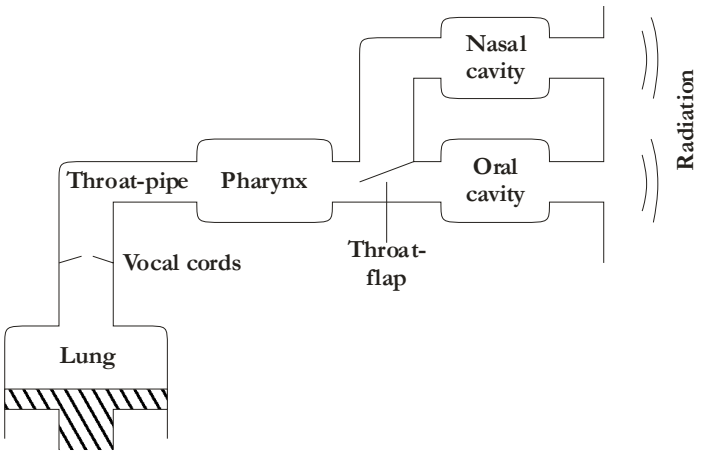

Figure 1
Universal schema for the voice-production by Gordos et al [3]

Our research team investigates acoustic parameters of the infant cry in the time domain as well as in the frequency domain. Till now we have been recorded and tested more than 300 infant cries. Sound recordings were mainly performed in the Heim Pál Hospital for Sick Children, but a few months before the B.A.Z. Central Hospital of Miskolc joined to our team and started a new data collection for our research. We were obtained and compared a lot of parameters of the infant cry in the last years: duration of crying, crying-to-pause ratio, statistics in the time domain, fundamental frequency, further special frequency components, melody contour, rising time of the melody, formant structure, etc. [4-8]. However, from these attributes we haven't found significant differences between the cry of healthy and diseased infants, we have reached only intermediate results (as differences between statistical parameters in the cry of male and female infants). As a result, we concluded that it is necessary to accomplish a multivariable analysis using the before mentioned parameters and also to involve new signal processing methods and parameters for this investigation.

We will soon publish our experiments and developed methods as co-authors in a technical book in the United States what will deal with abnormal crying sounds.

2.2 Investigation of the Relation between Diabetes Mellitus and Hearing Disorder in Children

Nowadays health experts refer to diabetes mellitus as the "disease of the future". The newest statistics of the World Health Organization (WHO) predate an increase of adult diabetes population from 4% (in 2000) to 5.4% by the year 2025. This number will mean more than 300 million people worldwide.

It is well-known that diabetes mellitus generates complications on the long run like hearing loss, cardiovascular disease or eyeshot degradation. However, in children and youngsters these effects are not obvious at all, because the rapid changes in parameters of a well developing active child. It is assumed though that a direct relation exists. The Biomedical Engineering Laboratory of BUTE and the Heim Pál Hospital for Sick Children from Budapest have proposed to investigate the question in a joint research program.

The first step of this research proposed for the 2003-2005 period was to build up a Hungarian medical monitoring and diagnosing information system for diabetes mellitus and hearing loss (based on a vast database).

In case of the diagnosing system of diabetes mellitus, after several consultations made with the doctors of the Pediatric Department from Heim Pál Hospital (Dr. Antal Czinner head of department, dr. Zsuzsa Almássy doctor-in-chief) we have concluded to monitor the following parameters:

- Blood glucose level: fasting, actual, initial values;
- Hemoglobin (Hb) A1c;
- Lipids (Cholesterol, Triglyceride, HDL);
- C-peptid value;
- ABPM (Blood pressure, percentile curves);
- Thyroid hormons (T3, T4, TSH);
- Astrup (Ph, Be, Beecf) values;
- Antropometric parameters (heigh, mass, BMI, skin state);
- Epilepsy diagnosis;
- Neuropathy diagnosis;
- Endomysial antibodies (EmA);
- Hospital admission/year.

To create the database of our software we have collected more than 5000 measurements of 110 children. The measurements were carried out in the Heim Pál Hospital between 1999 and 2003.

Results are stored in a database built under Microsoft Office Access platform using Open DataBase Connection (ODBC). This open structure gives the opportunity for further development of the system, even for Internet Protocol (IP) based networks, or for Local Area Networks (LAN). However, the software now is an off-line software and the Heim Pál Hospital uses it only for research purposes.

Data are structured on two levels: on the first the personal data of a child is stored, while on the second his/ her measurement values. The database is using the social security number of a person as primary key. The measurement value types in case of diabetes mellitus are presented by Figure 2.

To optimize the storage capacity of the database, a new table was created for each different set of measurements. As a result, empty fields and memory allocation are avoided.

Some of the monitored parameters can be controlled only showing their numerical values, but in some cases graphical interpretation is required (like the percentile curve in case of diabetes mellitus, or different measurements in case of hearing disorder). By this it is possible to make a prediction of the mentioned disease.

To monitor and diagnose hearing disorder, the class hierarchy was kept and the same steps were done, as in diabetes.

At the Heim Pál Hospital divers objective and subjective hearing disorder methods are used: pure tone audiometry, tympanometry, otoacustical emisson, brainstem evoked auditory response (BERA). For the proposed hearing disorder monitoring and diagnosing system our aim was to implement both objective and subjective methods. After also several consultations with the doctrors of the Ear-Nose-Throat Department (Dr. Katona Gábor, head of department, Dr. Farkas Zsolt doctor-in-chief) we have implemented two hearing disorder method: pure tone audiometry (subjective method), BERA (objective method).

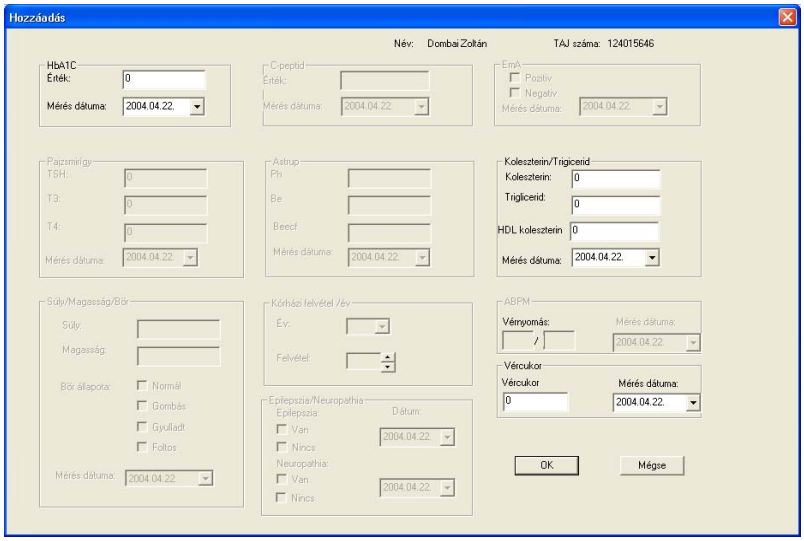

Figure 2

Entering selected measurement values in case of the diagnosing system for diabetes mellitus.

Since 1992 the Heim Pál Hospital efficiently uses a BERA measurement device. This software used for visualizing, monitoring and diagnosing the BERA curves had been written by Dr. József Pytel, professzor of the Medical University of Pécs. However, the software was created in QBASIC for DOS operating system. As a result, an additional request of the Heim Pál Hospital was to rewrite the software for Windows operating system, being able to connect off-line to the Pytel-software, to keep the same functionality (navigation, reading and saving in the same kinds of datafiles), but is able also to make an efficient analysis and diagnosis of the measured values.

To create the database of this software, every measurement made from 1992 (more than 4000 measurement) have been imported in a database, and the proposed aims have been all realised (Figure 3). The software is now in the use of the Heim Pál Hospital, but being off-line it is also used only for research purposes.

During this project until now 4 diploma thesises have been written and several publications appeared, [9-11].

From September 2005 we have entered in the second step of the research, namely the concrete investigation of connection between the two mentioned diseases.

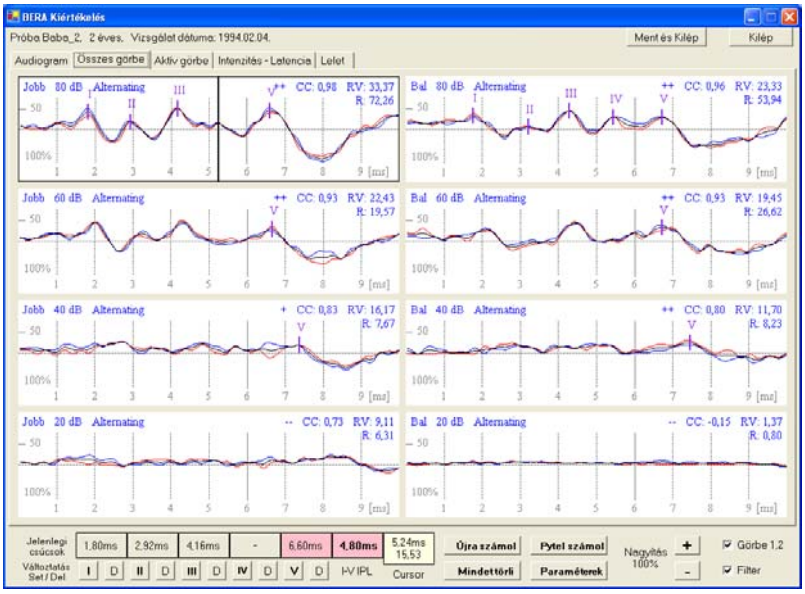

Figure 3

BERA measurments investigation in case of the hearing disorder diagnosing system

3 Aims of RET-04/2004 Grant

The aim of the four year, university-level grant RET-04/2004 is to collect a know-how for the automotive industry. In this project, our research group have bidden with an individual subproject titled “Human factor in controlled vehicle systems”.

Improving the safety of the traffic is a social interest. Accidents are not only caused by poor technical conditions of the vehicles, but also by tired, indisposed, or bad state-of-minded drivers. As a result it can be concluded that the safety and efficiency of today's road traffic over the technical and technological environment is also highly dependent on human behavior. Road users play an essential role in regulating road traffic system. It is possible to influence driver behavior by structural changes in traffic control strategies, road design and vehicle characteristics. Specifications for intelligent driver support systems such as navigation and collision avoidance systems can be developed on the basis of knowledge about traffic participants' reactions.

The managing of human factors needs the control, recording and monitoring of the most important vital parameters of the driver. The most important human factors are the driver characteristics, driver health, mood states and personality factors, driver fatigue, driver decision-making, inattention /distraction and hazard perception.

The aim of this subproject is on the one hand to investigate the possibility of creating a sensor-net (Figure 4), which is suitable for recording the driver’s vital parameters; on the other hand to develop a human model, which deals with the data collected by the sensors.

For this subproject we are working together with two other departments (as consortium members) of BUTE: Department of Transport Automation (Faculty of Transportation Engineering) and Department of Road Vehicles (Faculty of Transportation Engineering).

The proposed human model should be able to make a systematical description of the interaction between the driver and the vehicle(s) and the environment for a better roadworthiness and efficiency. We are keen on making a pilot system, which is able to develop a prototype in the most important areas (monitoring of rousedness, behavior recognition, path stabilization with image processing, optimizing the running of the vehicle).

During the first year (2005) of the project, the involved consortium members made mostly a literature review, and have presented their results at an internal Workshop. The aim of this discussion was to define how from the 2006 year the different areas can be connected together by establishing a common policy to follow.

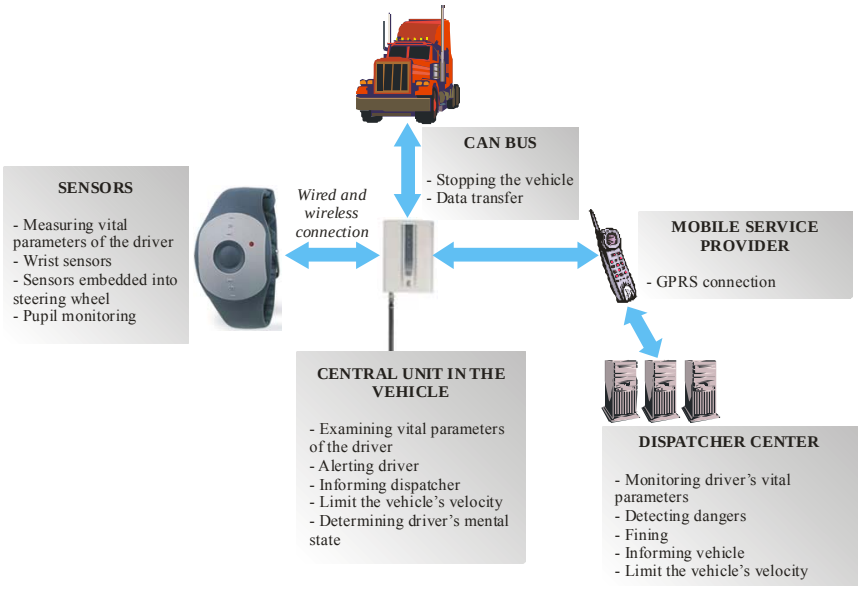

Figure 4
Informatical diagram of the imagined monitoring system for the driver's vital parameters

Our research group has summarized the existing driver-behavior models presented in the literature as well as the behavior estimation possibilities by physiological parameters (eye movements, PERCLOS (percentage of eyelid closure), tracking of gaze, EOG (elektro-okulogram); brain activity, EEG; ECG; facial muscle activity, facial tracking; lane-related measures (the relative position of the car to the lane border); heading/lateral acceleration related measures; combined methods), while the other consortium members has examined the expectations which are expressed between the presence of human and vehicular traffic processes in modeling respect (basic modeling theories and methods; most important factors of human attributes in a vehicular model specific way; risk-analysis of transport models) [12].

Conclusions

In case of OTKA T042990 grant we have obtained promising results for the proposed aims. At this time we predict that within two years we will be able to finalize these research projects.

In case of RET-04/2004, we target to develop environments in the future that will be proper to achieve more effective models of human behavior within simulation frames. For this reason we wish to work on developing a super-microscopic model which contains not only the vehicle-route duality, but can also solve the vehicle-driver partition as well within this. Therefore, we also plan building a simulator which will help us to provide the necessary phisiological measurements.

Acknowledgement

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