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DIGITAL PROCESSING METHODS FOR ANALYZING VEGETATIVE SIGNALS

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The following paper deals with some of the results of a joint research of Medicor Works and Semmelweis University of Medicine. Methods, similar to the described ones are now being used in recently developed micro-computer controlled medical instruments os Medicor Works.

The aim of our research was to identify the characteristics of two so called vegetative diseases: the hypertension and the ulcus duodeni; in their early stages, and to compare these characteristics between the two groups of patients and a control group. We even limited the scope of our investigations to the analysis of some significant response patterns evoked by psychophysiological stimuli.

ABOUT THE COURSE OF OUR MEASUREMENTS

In order to analyse the vegetative reactions, 3 signals were measure: The galvanic skin resistence (GSR), the pulse curve and electromyogram (EMG), all with surface electrodes. (fig.1.) The subjects were seated in a comfortable armchair in a sound protected, dark room. After 7 minutes of relaxation the effects of verbal, noise and light stimuli were measured. The stimuli followed each other with an interval of about 45 seconds, played from tape-recorder. The electrodes were fixed on the supported hand of the subject. The 3 signals had been

recorded on an analogue FM tape-recorder, together with a fourth one, which served as synchron channel during the processing phases. This way we gained about each subject approximately 4 times looo seconds long analogue recordings. The sampling and all of the processing was carried out with the aid of a PDP 11/45 installation (fig.2.) by programs written in BASIC-PLUS language.

With the sampling frequency of 21 c/s, we hand 4 times 18 Kwords digital samples about each subject. The total amount of data, stored on magnetic tape - was about 20 Mbytes.

In the following sections of my paper, Ishall deal with two methods of the analysis, which proved to be specially useful an nyelded interesting results.

1. INTERACTIVE BAYES-DECISION

An interactive program was developed for the analysis of the GSR curves, using the Bayes decision.

Let us consider the binary decision problem briefly. (fig. 3.) The two density functions represent the two possible choices or hypotheses. The decision problem is equivalent to chosing one of the two density functions on the basis of one or more observations. It is obvious that decision problem arises only if the observed phenomenon is of probabilistic nature.

If we assume a threshold at ξ_T, then if the observation α is less then ξ_T, we accept H_o, if α is greater then ξ_T, we accept H_1. To determine the optimal threshold, we define The Bayes risk B, as the expected value of the cost for the two possible type of errors. The best threshold is the one, where the Bayes risk B, is minimal.

$$B=C_{10}\cdot P_{H_o}+\int_{-\infty}^{\xi_T}[-C_{10}\cdot P_{H_o}p_o(\alpha|H_o)+C_{01}\cdot P_{H_1}p_1(\alpha|H_1)]d\alpha \qquad (1)$$

If we differentiate the expression of B with respect to T, we get that the necessery condition of the minimum is:

$$C_{o1} \cdot P_{H_1} \cdot p_1(\alpha|H_1) - C_{10} P_{H_o} p_1(\alpha|H_o) = 0 \qquad (2)$$

From (2) the Bayes-decision is:

$$\frac{p_1(\alpha|H_1)}{p_o(\alpha|H_o)} \quad \begin{matrix} \text{accept } H_1 \\ \gtrless \\ \text{accept } H_o \end{matrix} \quad \frac{C_{10} P_{H_o}}{C_{o1} P_{H_1}} \qquad (3)$$

Where C_{o1} and C_{10} are different costs associated with the errors.

During the analysis of the GSR signals we had to solve the problem, how to handlethe great amount of samples and data. For this purpose we developed an interactive method, where the operator has to intervene only in the case when the computer decision has to be overriden. In the GSR signals we looked for the resistence-fall waves and for their characteristics. To be able to use the Bayes-decision efficiently, a transformation had to be carried out on the signal. (fig.4.) As it can be seen we produced such a point series which consists of only the differencies of the local maximums and minimums of the original sample. We considered, that in order to determine the responses for a stimulus in the GSR curve, we have to determine in the compressed sample the places of great differencies, and the small differencies are considered as measurment noise from our point of view. This is a simple decision problem, where we want to detect a constant signal in the presence of additive noise. The distribution of the noise is assumed to be zero-mean gaussian, and the amplitude of the signal is m. In this case the two density functions belonging to the two hypotheses are:

$$p_o(\alpha|H_o) = \frac{1}{\sqrt{2\pi}\,\delta} e^{-\alpha^2/2\delta^2} \qquad (4)$$

$$p_1(\alpha|H_1) = \frac{1}{\sqrt{2\pi}\,\delta} e^{-(\alpha-m)^2/2\delta^2} \qquad (5)$$

And the Bayes-decision test in this case:

$$\alpha \underset{\text{accept } H_o}{\overset{\text{accept } H_1}{\gtrless}} \frac{m}{2} + \frac{\delta^2}{m} \ell n \frac{P_{H_o} C_{10}}{P_{H_1} C_{o1}} \qquad (6)$$

With the aid of the maximum-minimum compression, described above, we achieved that this decision criterion had to be used for a single sample only 2-3 hundred times instead of 18 ooo times, if used it for each sample point.

About the operation of the program: The original curve was displayed on a raster-display and a sign was put on each point found, one after the other. The operator could change the place of the point with the aid of a moving cursor. After identifying the desired interval, the program calculated further characteristics of the reponse, like duration, slopes, integral value, reaction time etc.

Figure 5. shows a screen, where all answers were found automatically, indicated by the short vertical lines set on the curve. (The vertical lines below indicate the places of stimuli.) Figure 6. shows a screen where operator intevention was necessery (dotted vertical lines).

In about 20 to 25% of the cases was neceserry to override the decision of the algorithm manually.

2. FREQUENCY DOMAIN DATA REDUCTION

In the case of the pulse curve analysis a completely different method was used, which is interesting from the data reduction point of view. Here I would like to emphasize that in this case our purpose was to compare the reactions between the groups, so we did not even strive for quantitative results.

The processing of the pulse curve was carried out in two steps. The task of the first step can be seen on fig. 7. The peak values and locations of the single pulse waves were determined by a peak detections algorithm. The outputs of this program are the peak values and the beat-to-beat pulse times.

This is presented on fig. 8. The size of these outputs are about 10% of the size of the input files.

To characterize the relation of the stimuli and the responses in the curves, we used the cross-correlation function. For this purpose we constructed a square-wave function from the synchronizing signal as it can be seen on fig. 9. Since the information about the responses in the cross-correlation function is still in a "distributed" manner, there was a need for further data compression to make possible the comparison of the great amount of samples. In order to do this we computed the Fourier-transform of the cross-correlation functions, that is the cross-power spectra. Figure 10. gives an example for these spectra. We found that the first 30 spectrum lines contain over 75 % of the total energy, these 30 data are sufficiently enough to characterize the vegetative response function in the frequency-domain. By sufficient we mean that it can be used for differentiating curves belonging to different groups. With the help of this method we could make the feature selection desired, with the 0.2% of the original 18 Kw of data. Figure 11. shows to typical spectra belonging to the hypertensive and to the control group.

To compare the spectra between groups we used the relative energy contents of the spectrum lines. Even with this relatively rough method there were significant differences found between the spectra of the two groupes, referred above, at 1/40 c/s which is the stimulation frequency, and at the 3. and 5. harmonics. There were no significant differencies between the spectra of the control and the ulcer duodeni group.

Without explaining the medical significance of our findings, the two methods which were presented very briefly proved to be efficient digital analysis methods for these common physiological signals. Some of this methods are being, or can be applied in biomedical instruments as well.

REFERENCES

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МЕТОДЫ ДЛЯ АНАЛИЗА ВЕГЕТАТИВНЫХ СИГНАЛОВ

В настоящей статье приведены некоторые результаты совместных исследований, проведенных Объединением "Медикор" и Университетом Медицинских Наук им. Семмельвейса. Аналогичные указанному методу анализа сигналов процедуры нашли применение и в Объединении "Медикор" в разработанных в последние годы микропроцессорных медицинских приборах.

ÖSSZEFOGLALÁS

VEGETATIV JELEK ANALIZISÉRŐL

Jelen cikk a Medicor Müvek és a Semmelweis Orvostudományi Egyetem közös kutatásának néhány eredményét tárgyalja. Az ismertetett jelanalizis módszerekhez hasonló eljárások alkalmazásra kerültek a Medicor Müveknél az utóbbi időben kifejlesztett mikroszámitógépes orvosi müszerekben is.