Българска академия на науките. Bulgarian Academy of Sciences
Аерокосмически изследвания в България. 10. Aerospace Research in Bulgaria
София.1993.Sofia

Some peculiarities of the biosignals digital processing in space using the "ZORA" system for data acquisition and processing

Roumen Nedkov, Svetozar Simeonov, Stojan Tanev

Space Research Institute, Bulgarian Academy of Sciences

The present work is dedicated to the assessment of a problem that is of primary importance for the space and ground-based missions, i. e. — to the human organism as a complex biosystem and focus of all projects for space exploration and utilization. This problem is not to be solved without the automatic digital systems for data acquisition and processing for study of the psychophysiological status and working ability variation mechanisms in closed ecosystems characterized by processes dynamics during space missions of varying duration [1, 2].

The fundamental problem for the processes dynamics study of that complex biosystem — the human organism — in long-term space missions (over 30 days) is solved using a closed technological circuit of the functional model synthesis, as shown on Fig. 1. The studies include theoretical and engineering

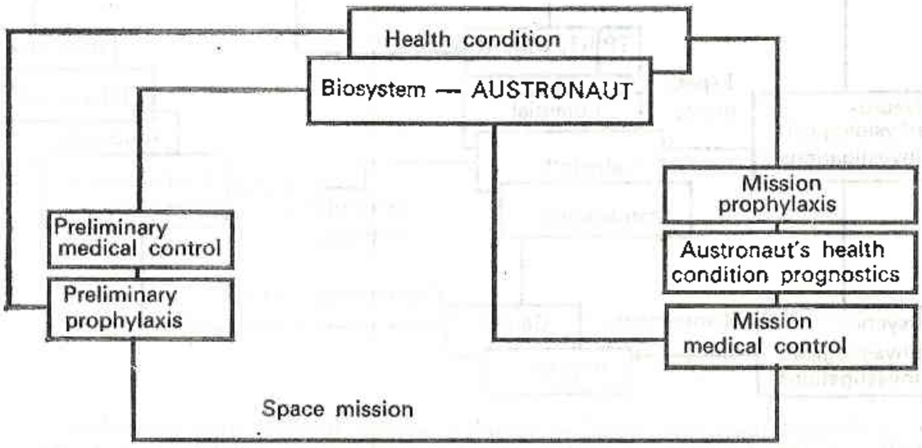

Fig. 1. General functional model of a medical control and prophylaxis technology for long-term space missions

modelling of the obtained biosignals using automatic responding DAPDS [1, 2, 6].

The first step for the solution of that problem is the Bulgarian automatic on-board multicomputer system for data acquisition and processing "ZORA". The DAPDS "ZORA" is the nucleus and the instrument for the realization of a new technology of complex medical analysis connected with the problem of the working ability and the psychophysiological status of the astronauts in space missions of varying duration.

The essence of the new technology is the following: in real time mode and during space missions of varying duration to study the processes and mechanisms of the astronauts' psychophysiological status and working ability deviations for the purpose of their health status assessment and prognostics.

A complex test program is developed including the following experiments:

—"LABYRINTH" — Analysis of the ocular-vestibular interactions distortion mechanisms and development that follow into the group of the space motor disease. An assessment is made of the optokinetic and vestibular stimulation during vestibular and ocular-motor malfunctions.

—"STATOKINETICS" — Study of the mechanisms of posture control, the characteristics of the various groups of motions and the locomotory afferention with the occurrence of dislocations.

—"POTENTIAL" — Study of the muscular fibres membrane stimulation vector.

—"LEISURE TIME", "QUESTIONARY" — Study of the astronauts' individual psychophysiological adaptation to space flight conditions and the readaptation processes. An assessment of the psychophysiological status and an improvement of the mechanisms to keep up that status are made.

The synthesised functional model of that technology for complex medical analysis during space missions is shown on Fig. 2. The contribution in this

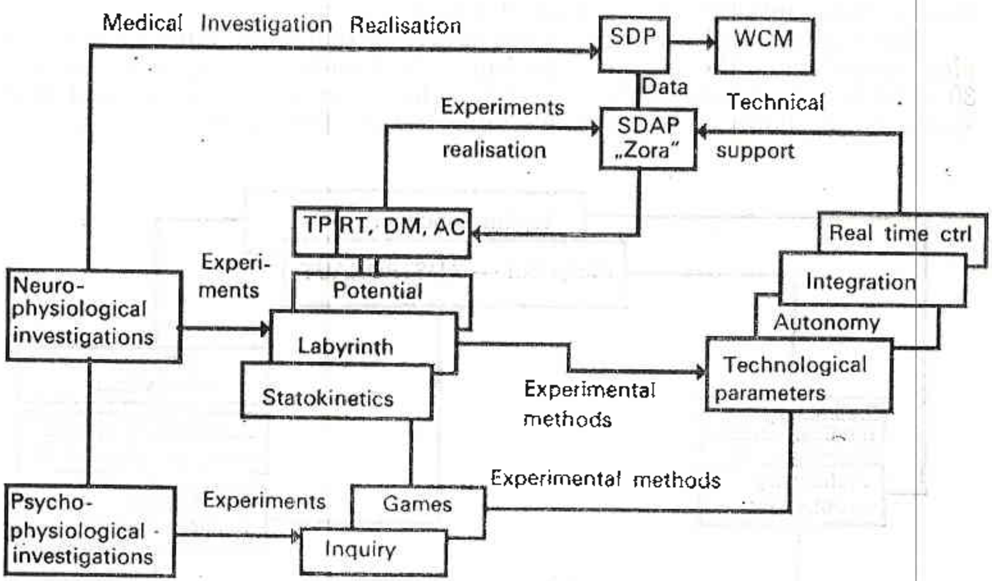

Fig. 2. General functional model of complex medical investigations technology
SDAP — system for data acquisition and processing; TP — telemetric port; RT — real time; DM — data memory; AC — automatic control; SDP — secondary data processing; WCM — work capability monitoring

case is the use of an expert filtration in determining the source and character of the biosignal in real time and automatically [1, 2, 8].

The biosignals carry information for the complex processes taking place in the human biosystem and their processing is specific. The need of automatic digital processing from clinical point of view arises from the further improvement of the reliability and quality of the obtained results.

The advantages of the automatic digital signal processing are well known and have been the subject of numerous monographs and publications [3, 4, 5]. The biosignals are efficiently processed using the digital methods and systems [6, 7, 8].

The automatic biosignals processing allows the quick estimation of a large volume of bioinformation applied further in the biopotentials processing (ECG, miograms — MG, ocugrams — EOC, EEG, etc.).

The use of digital biosignals processing methods eliminates the phase distortions characteristic for the analog systems. Thus, high precision and objectiveness of the diagnostics is reached.

Using the linear systems theory the requirement for lack of distortions in the processed input signal can be presented analytically as follows:

$$H(j2\pi f)=|H(j2\pi f)|e^{-j\varphi(2\pi f)}=Ke^{-j2\pi f t_0}, \tag{1}$$

where the phase characteristic $\varphi(2\pi f)$ is linear, hence the output signal delay compared to the input is constant and the amplification K remains unchanged in the given frequency line.

An analog multiplexor, a tracing and storage circuit and an analog-to-digit converter "ADC" are used for the biosignals digital processing, obtained from sensors, converting physical quantities. The biosignals thus converted into digits are inserted into the input of a multicomputer system (MCS) where their actual processing takes place [1, 2, 6, 8].

In that case a blocking discretization with signal mean value is used in the convertion.

The mathematical conversion processing model of this type of discretization is given with the following equations:

$$\bar{x}_{kT_D}=\frac{1}{\tau}\int_{kT_D-\tau}^{kT_D} x(t)dt, \tag{2}$$

where $\bar{x}_{kT_D}$ is the input ADC signal and τ is the mean interval. T_D is the discretization period.

Using a function of the following type:

$$W_{0,5\tau}(t)=\begin{cases}1 & \text{if} \quad |t|\leqq 0{,}5\,\tau\\ 0 & \text{if} \quad |t|>0{,}5\,\tau\end{cases} \tag{3}$$

for the input ADC signal $\hat{x}(t)$

$$\hat{x}(t)=\frac{1}{\tau}[x(t)*W_{0,5\tau}(t)]\sum_{n=-\infty}^{\infty}\delta(t-nT_D) \tag{4}$$

is obtained. For the output frequency range, the discrete signal value is obtained

$$TF[\hat{x}(t)]=\left[X(f)\frac{\sin\pi f\tau}{\pi f\tau}e^{-j\pi f\tau}\right]*F_D\sum_{n=-\infty}^{\infty}\delta(f-nF_D), \tag{5}$$

$$X_1(f)=X(f)[\sin(\pi f\tau)/(\pi f\tau)]e^{-j\pi f\tau}, \tag{6}$$

where $TF\,[\hat{x}(t)]$ is the Fourier discrete conversion, $X(f)$ is real spectrum, and

$X_1(f)$ is the real spectrum after processing. From (6) it is that the spectrum amplitude module has changed $\sin(\pi f\tau)/(\pi f\tau)$ times while the phase is $\varphi=\pi/\tau$. The error ε for the $\hat{x}(t)$ spectrum is:

$$\varepsilon=\frac{X(f)-X_1(f)}{X(f)}=1-\frac{\sin \pi f\tau}{\pi f\tau}e^{-j\pi f\tau}. \tag{7}$$

In that case in order to minimize the error it is necessary to follow the conditions, namely:

$$[\sin(\pi f\tau)/(\pi f\tau)]\geqslant 0{,}999, \tag{8}$$

$$\varphi=\pi f\tau\leqq\Delta\varphi, \qquad \Delta\varphi=1^\circ\div 5^\circ. \tag{9}$$

The solution of that equations shows that $\xi=\tau/T_D$ the coefficient of fullness be smaller or equal to 0,05 while the amplitude error is 0,1% and the phase error is 2%.

When the mean interval is approaching zero the amplitude error and the phase error are decreasing. As the frequency of the input signal is low (for the miogram $f_{max}=1$kHz, $f_{min}=2$Hz and for the oculogram $f_{max}=25$ Hz, $f_{min}=0{,}1$ Hz) and the conversion period $T_{conv}=10$ µs is several times smaller, the conversion error is minimal and practically negligible [1, 2, 6, 8].

Some methods of processing give considerable effect, very favourable for diagnostics.

a) under low frequency filtration ($f=40\div 50$ Hz) the muscular tremour noise level is lower;

b) under line filtration at the pre-determined frequencies the EEG rhythms are α_i, β_i.

The necessary frequencies are observed against the background of noise that depends on the potential variations and the neurons activity, as those signals pass a great distance from the source to the electrodes. It is necessary to obtain the image of Fourier of the autocorrelation function.

This method is not frequently used as there are no specific calculation methods for determining in real time the correlation function.

The only method of comparison of two EMG is the visual. It takes a two-three year's period for a specialist to master the comparison methods using the Catalogue of the real EMG and be able to find out the similarities and differences between a real EMG and those in the catalog.

For the solution of that problem a minimal expert system is used consisting of data about some characteristic functions given in table form describing the model biosignals and some of their characteristics necessary for the expert filtration, the express on-board processing and the secondary ground processing.

That allows the discrimination of the human factor in the results assessment and leads to higher objectivity of the estimation. At the same time the decision-taking period is shortened.

That fact determines the importance of the new technology for study of the processes taking place in the complex biosystem — the human being — in space environment.

Using that new technology on board the "Mir" orbital station in varyng in duration space missions (up to 10 days — the Bulgarian-Soviet and Soviet-Afghanistan missions and up to and over 30 — Soviet missions) [1, 2] definite results have been obtained.

The development of medical space laboratory with distributed resources is advisable as a distributed expert system on the basis of automatized systems for responding data acquisition and processing and remote sensors for boisignals registration.

Such a minilaboratory in space environment will be used for obtaining results that are vital for the long-term space missions (e. g. flights to Mars). In the case in order to solve the above mentioned problem a number of analysis are necessary to be conducted for the scientific problems, as follows:

1. Modelling and development of automatic responding DAPDS and technologies supplying measurement and evaluation of a number of parameters of the bio- and phychophysiological status under varying ecosystems;

2. Development of modifications of ground-based technological equipment for early diagnostics of the bio- and phsychophysiological status caused by deterioration of the ecological parameters;

3. Study of the mechanisms influencing the change rate of the human bio- and psychophysiological status.

Above all it is necessary to know in details the problems occurring in the reactions of the human organism under the influence of the new factors and ecoenvironment.

The studies will contribute to the determination of the impact of various ecosystems on the mechanisms and rate of change of the bio- and psychophysiological status of the human being under the conditions of various ecosystems for the purpose of short and long term prognostics of the health status.

References

1. Недков, Р. и др. Комплексное исследование работоспособности космонавтов по проекту „ШИПКА". — Тезисы докладов, XXII Совещание ПДРГ по космической биологии и медицине, Варна, май 1989.
2. Недков, Р. и др. Техническое и технологическое обеспечение медико-биологической программы проекта „ШИПКА". — Окончательный отчет, БАН, 4, 1990.
3. Rabiner, L., B. Gold. Theory and Application of Digital Signal Processing. New Jersey, Prentice-Hall, Inc., Englewood Cliffs, 1975.
4. Блейхут, Р. Быстрые алгоритмы цифровой обработки сигналов. М., Мир, 1989, 18—31.
5. Oppenheim, A. Theory and Application of Digital Signal Processing. New Jersey, Prentice-Hall, Inc., Englewood Cliffs, 1978.
6. Недков, Р. и др. — Космическая биология и авиакосмическая медицина, 1991, No 5, 56—59.
7. Фор, А. Восприятие и распознавание образов. М., Машиностроение, 1989, 98—108, 113—122, 212—216.
8. Система сбора и обработки данных „ЗОРА". Космическая медицина 01. 001. 00. 00 — Техническое описание, ИКИ—БАН, 1987.

Received 22. 11. 1991

Някои особености на цифровата обработка на биосигналите при използване на системата за сбор и обработка на данни „ЗОРА“

Румен Недков, Светозар Симеонов, Стоян Танев

(Резюме)

В статията са изложени някои особености на използваните в системата за сбор и обработка на данни (ССОД) „ЗОРА“ принципи и методи на цифрова обработка на сигнали. Разгледани са конкретни математически модели, методи за цифрова обработка и тяхното приложение в космически условия. Направени са изводи за перспективите на развитие на ССОД като елементи на космически медико-биологични лаборатории.