Smart Information Gathering Support of Mechatronic System

Orest Ivakhiv, Markian Nakonechnyi, Oleksandr Viter, Radyslav Behota

Computer Technology, Automation and Metrology Institute, Lviv Polytechnic National University, UKRAINE, Lviv, 12 Bandera str., email: oresti@polynet.lviv.ua

Abstract: **The smart programmable systems often are very convenient for the measurement object semantic reducing. The object state analyzing unit is the core of the system. There is considered that an object behavior a priory is unknown. Corresponding to this mode it is necessary to observe an object state and prepare a proper survey program. The main characteristics of proposed system are investigated in this paper.**

Keywords: **smart, programmable, flexible, adaptive, activity, compression, system.**

I. INTRODUCTION

A mechatronic system involves a set of sensors, conditioners of sensors' signals, processing and decision-making unit and actuator [1]. Combination system software and hardware with Internet as a communication link give us a cyber-physical system [2]. Obviously, information-gathering support is realized as multiplex time division systems. They are widely shared in the different areas of human activity such as scientific research, astronautics, agriculture, space investigation, image processing and data monitoring systems for health care, which simultaneously monitors, transmits by radio a records data relating to a plurality of physiological parameters etc. [3-6]. Apart from the demands for small size, lightweight and long operational lifetime, the sensor systems should preferably also be flexible, versatile and intelligent [6]. The traditional approach of reconstructing signals or images from measured data follows the well-known Shannon sampling theorem, which states that the sampling rate must be twice the highest frequency. It was found that at any given time, only a fraction of the neurons were active therefore it was possible to reduce data by 97%. Therefore, it is necessary to use some compression techniques possibility.

The aim of data compression is to reduce redundancy in stored or communicated data, thus increasing effective data density. Data transmission, compression and decompression of data files for storage is essentially the same task as sending and receiving compressed data over a communication channel. Compressive sensing is a new type of sampling theory, which predicts that sparse signals and images can be reconstructed from what was previously believed to be incomplete information [7,8].

Sensors set which are checking behaviors of object parameters reflect an object state. Sampling interval of a sensor signal is corresponded with both signal frequency properties and desired error of analog signal renovation at the receiver side. It was taken partly stationary zero-mean random process as every signal mathematical model. Any stationary interval differs from another by the frequency properties, which are corresponded with the form of correlation function or its parameters values. These properties are discovered by every the *i*-th source activity manifestation. A proper regular type system-sampling program depends on this set of a priory known or estimated activities. If the object state a priory is poor known, it needs adaptation to the current object situation. It is typical remote investigated objects, i.e. the deep space invention instrumentation or dirty territory serving. In this case, the intelligent multiplex system implantation is considered as well operating and the intelligent measurement instrumentation functions should be extended by the implantation of the task of the observed object state identification, the inspected parameters real activities to the adopted sampling program adequacy learning and in this sense the external situation registration [9].

II. REGULAR TYPE SYSTEM STRUCTURE

The structure of the smart multi-channel tool (Fig. 1) includes a unit of a measurement object totality sources behavior analyzing BAU [10], an object state observing unit SOU, a unit of survey programs storage PSU, a unit CMU combining codec/modem functions, i.e., an analog-to-digital conversion, a noise immunity encoding and modulation, which is connected to the communication link (point1).

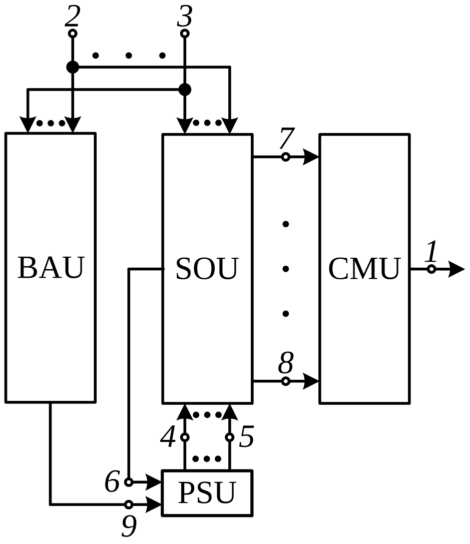

Fig.1. The structure of the multi-channel tool

Outputs of analog signal sources ($i = \overline{1,n}$) simultaneously are connected to the corresponding inputs of a unit BAU (points 2 and 3) and an observing unit SOU. A unit PSU sets for the unit SOU the sequence of source sampling procedure (points 4 and 5). A unit SOU observes the accumulation of absolute sampling errors from the sources totality and after analyzing procedure, if it is necessary informs the program storage unit PSU about the need to change the survey program using the signal at the point 6. Simultaneously, a unit BAU analyzes analog sources current activities.

II. OBJECT BEHAVIOR STATE ESTIMATION UNIT

For characteristics setting of this unit a compliance of survey software to the current situation can be accessed through tracking amount behavior of the sampling errors from all totality sources during a cycle of the survey. As well as there are added the random variables therefore relevant point and interval statistic estimates (thresholds) can be found for their sums. No exceeding of this threshold with a given confidence probability is identical to matching the real current situation at the measurement object, and its exceeding it is the message about the current situation change and demands on the need of transition to a more relevant survey program. Comparison of the threshold value and the sum of sampling errors is carried out at every step of the survey.

In this unit (Fig.2) outputs of analog sources are connected to the proper inputs (points 2 and 3) of unit SOU.

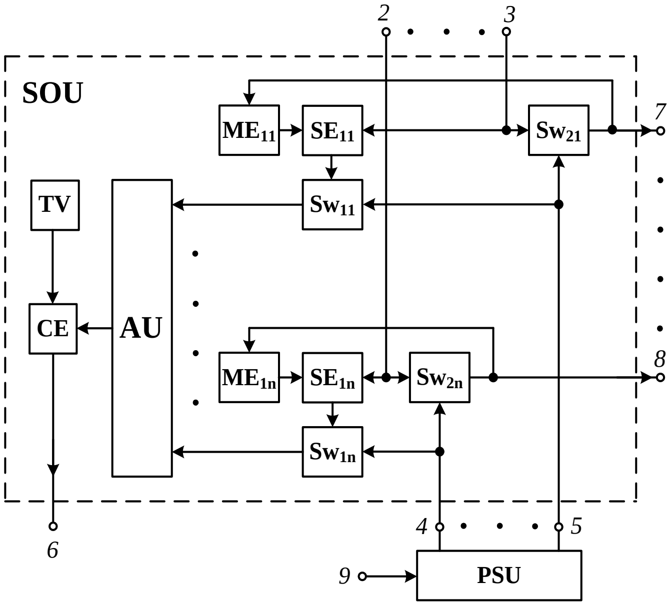

Fig.2.The structure of object state observing unit SOU

At the very beginning (at the first step) the sample values from each source ($i=\overline{1,n}$) are recorded in its memory element ME_{1i} through the open switch Sw_{2i}. At the second and subsequent steps the sample value of each source enters to the subtraction element SE_{1i} and passes through open switch Sw_{2i} and the Codec/Modem unit CMU to the device output, i.e., to the communication link (point 1) corresponding with a proper sampling program. The switch Sw_{2i} is open by the control signal from programmer storage PSU (points 4 and 5), if it is provided by the current sampling (survey) program. Meantime this signal closes the switch Sw_{1i} for the same *i*-th channel. Therefore, the difference from the *i*-th subtraction element SE_{1i} is disconnected from an adder unit AU, i.e., it does not take part in totality sources sum formation. In the element SE_{1i} the value recorded in the ME_{1i} at the previous step is subtracted from the current sampled value at the each sampling tact. On the next step, the subtrahend will be this new value, and not the first sample value of the *i*-th source

Let us consider that sensor analog signals are well described by mathematical model as zero-mean partly stationary random process. So, let us take some realization $u_i(t)$ of the *i*-th random signal (Fig.3) which is regular sampled in moments t_j and t_{j+1} with a sampling interval equal to $T_0 = t_{j+1} - t_j$. In this case, one can obtain an absolute and its relative value is as follow

$$\overline{\Delta u_{si}^2} = \frac{1}{3}\left(\omega_{1i} \cdot \sigma_i \cdot T_{oi}\right) \text{ or } \delta_{si}^2 = \frac{\overline{\Delta u_{si}^2}}{\sigma_i^2} = \frac{1}{3}\left(\omega_{1i} \cdot T_{oi}\right)^2, \quad (1)$$

here ω_{1i} and σ_i are mean-square frequency and mean-square deviation of the *i*-th signal, and thus, T_{oi} is its sampling interval ($\omega_{1i}^2 = \int\limits_0^\infty \omega^2 G(\omega)d\omega \bigg/ \int\limits_0^\infty G(\omega)d\omega$, here $G(\omega)$ is power spectral density).

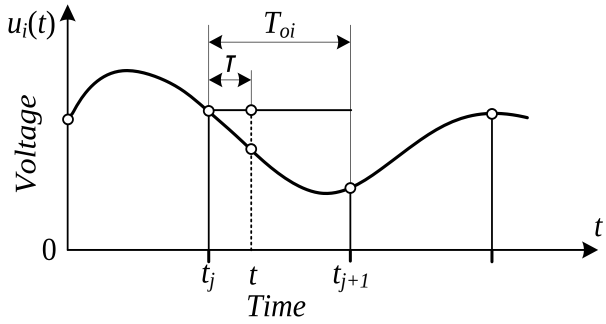

Fig.3. Sampling error vs time dependence ($\tau = t - t_j$)

If a sampling program coincides with an object current state then a sum of sampling error from all sources totality (at the output of adder unit AU) do not exceed the settled threshold value (of the output of unit TV). But when an object state changes due to its new environment situation then used sampling program becomes wrong, everyone source sampling error and its sum also become differ from supposed for same partly stationary interval. It demands to change sampling program and therefore corresponding signal appears at the output of comparative element CE (point 6).

Compliance of survey program to the current situation is determined according to mean-square deviation of summarized sampling error from all sources together. In accordance with the law of large numbers, it can be assumed that the total error as a random value will be well described by Student's or Gauss's distribution law. Therefore, with some credential probability P_{tol} one can set the guarantee interval for the total sampling error

$$x_{tol} = \pm t_\alpha \cdot \sigma_{s\Sigma} \text{ or } x_{tol} = \pm t_\alpha \cdot \delta_{s\Sigma}, \text{ and } \delta_{s\Sigma} = \sqrt{\sum_{i=1}^{n} \delta_{si}^2}, \quad (2)$$

here, t_α is the guarantee coefficient of the set credential probability. The resulting error from the output of AU is compared with the calculated by unit SOU threshold value (2) from TV element. Signal of excess is fed into the PSU unit (point 9).

Since the sampling error is sign-alternating, its average value is equial to zero and the variance coincides with the second raw moment. Therefore if errors of all channels of a multi-channel device are independent, total error variance is estimated as follows

$$\overline{\sigma_{s\Sigma}^2} = \sum_{i=} \overline{\Delta u_{si}^2} = \frac{1}{3}\left(\omega_{1i} \cdot \sigma_i \cdot T_{oi}\right)^2 \text{ or } \delta_{s\Sigma}^2 = \frac{1}{3}\sum_{i=}\left(\omega_{1i} \cdot T_{oi}\right)^2 \quad (3)$$

Note that since the power of the *i*-th measurement signal is described by expression $\sigma_i^2 = \frac{1}{2\pi}\int_0^\infty G_i(\omega)d\omega$ and generalized spectral power density $G_\Sigma(\omega) = \sum_i G_i(\omega)$, certain individual signals being independent, the following equality will be true: $\sigma_\Sigma^2 = \sum_i \sigma_i^2$

III. ANALYZING UNIT CHARACTERISTICS ESTIMATION

Here also was provided to analyze the object state by all totality sources activities observation. This procedure is realized by analyzing unit BAU (Fig.4). For example, it can be based on the adaptive switchboard principle using [11], i.e., at the every analyzing step it is chosen the most active among totality sources (fig.5). Each sensor activity measure is taken as the *i*-th signal current deviation from its previous sampled value until analyzed moment. This deviation is normalized after its mean-square deviation value. Larger normalized deviation is equivalent to more active source. Each *i*-th difference value is prepared by subtraction of the sample stored in memory element ME_{2i} from its current sample from the sources outputs (points 2, 3). They are fixed by the *i*-th subtraction element SE_{2i} then passed through divider D_i to the activity estimation element AEE.

This element notes the *k*-th most active source as well as puts a control signal at its corresponding output. It allows rewriting the value of the most active source in analyzed moment in the *k*-th memory element ME_{2k} through an open switch Sw_{3k}. This allowance is realized by opening a corresponding switch Sw_{3k}. It is a preparation to the next activity analyzing procedure. The number of each source activities manifestations during analyzing interval T_α is fixed in element AEE for the proper sampling program at this partly stationary interval formation. The sampling program of the current partly stationary object state is checked by estimation unit EU and passed to unit PSU (point 9).

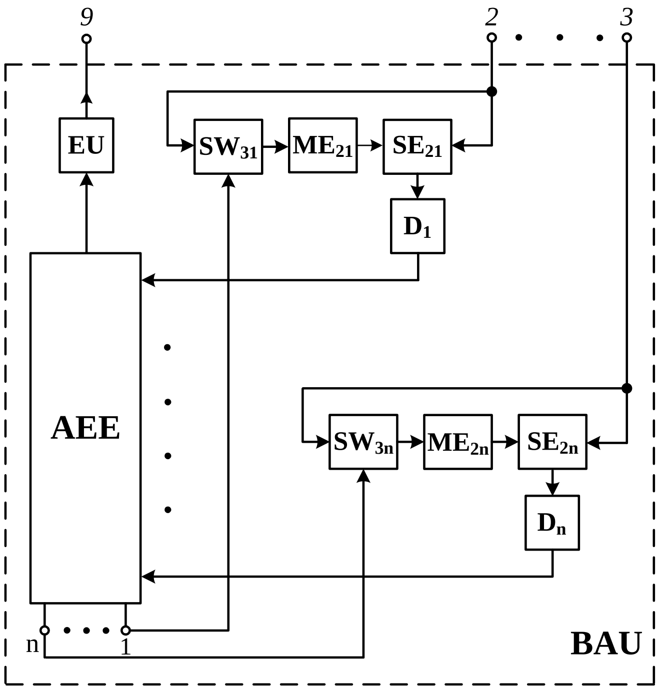

Fig.4. Behavior analyzing unit structure

In accordance with the principle of adaptive switchboard operation [11], the intensity of the *i*-th source λ_i is inverted to the average interval $\bar{\tau}$ between two serial activity manifestations of the same *i*-th source. Let us consider that any current error $\Delta(t)$ is described by random set of triangles (fig.6).

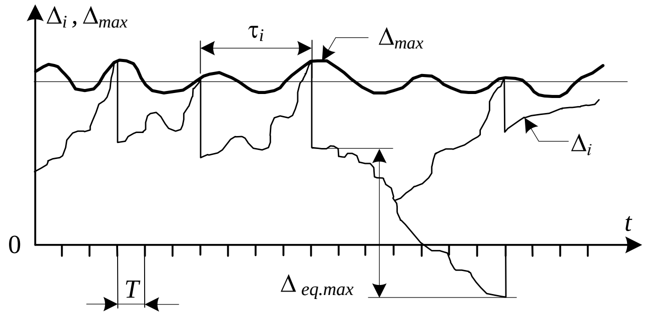

Fig.5. Formation of modulus of sampling errors maxima

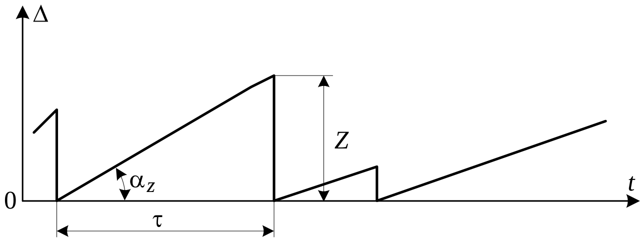

Fig.6. Dependence of sampling error in time

Interval τ is defined as $\tau = z / tg\alpha_z$. Since the random variables z and $tg\alpha_z$ are mutually independent, the approximate record looks like the following:

$$\overline{\tau} = \overline{z}/\overline{tg\alpha_z} \qquad (4)$$

The value of the average tangent of angle α_z is equal to an average value of source process derivative modulus as follow $\overline{(tg\alpha_z)} = \overline{\left|\dot{\xi}\right|}$. There is known expression for a normal law of the process distribution, i.e., $\overline{\left|\dot{\xi}\right|} = \sigma_{\dot{\xi}}\sqrt{\frac{2}{\pi}} = \sqrt{\frac{2}{\pi}}\omega_{1i}\cdot\sigma_i$, where ω_{1i} is a mean-square angular frequency (rad/s) of the *i*-th process; σ_i and $\sigma_{\dot{\xi}}$ are the standard deviation of the *i*-th process and its derivative, respectively. Namely,

$$\sigma_{\dot{\xi}}^2 = \frac{1}{2\pi}\int_0^\infty \omega^2 G(\omega)d\omega, \quad \sigma_i^2 = \frac{1}{2\pi}\int_0^\infty G(\omega)d\omega. \qquad (5)$$

The corresponding to the average interval $\overline{\tau}$ between the two serial activity manifestations of the *i*-th source (4) at the adaptive sampling [11] intensity is described as follows:

$$\lambda_i = 1/\overline{\tau} = \sqrt{\frac{2}{\pi}}\cdot\frac{\omega_{1i}\sigma_i}{C_2}, \qquad (6)$$

here C_2 is a constant value dependent on the frequency characteristics of measurement object sources totality and a synchronous channel tact.

For given equal probability of positive and negative current values of a sampling error, and therefore its equal zero expectation, one can write the expression for the mean square of the absolute value of the error, i.e.,

$$\overline{\Delta u_{s\,i}^2} = \frac{1}{3}C_2^2. \qquad (7)$$

The frequency of an adaptive switch analising procedure is defined by the sum of intensities from all sources of measurement object [11]. This value is used for analising unit BAU proper operation. Thus,

$$\frac{1}{T} = \sum_{i=1}^{n}\lambda_i. \qquad (8)$$

If to take the regular type sampling interval of each source equal to the estimated by analizing unit BAU one, then after a comparison of expressions (6) and (15) it is stated that a sampling error is less at the adaptive serving than at the regular one (in $\pi/2$ times).

IV. CONCLUSION

The regular serving procedure [12,13] is based on the number of everyone source activities obtained by BAU. As well as these results can be used for the entropy estimation of object state [14].

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