Control Model of Photometric Complex Based on Asynchronous Finite Automaton

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Abstract: A possibility is examined for synthesis of the control model of a photometric complex for investigation of the middle atmosphere night glow on the basis of asynchronous finite automata. The means for implementation of the suggested approach are examined. The advantage of this approach is expressed in the model flexibility.

Key words: Real time embedded systems, Automaton theory, control model, parallel process.

INTRODUCTION

The night glow of the earth atmosphere produces valuable information for the physical and physical-chemical processes, occurring in its upper layers. The study of these processes dynamics is possible on the basis of weak emissions registration by means of spectrophotometric methods. The course of the registered emissions can point indirectly to large-scale transfer processes as well as to wave processes of different character. The temporal variations in the intensity of the registered emissions have periods of several minutes to several hours. That, possessing period smaller than several minutes, are probably due to turbulence and acoustic wave processes. It is accepted that the variations with period, larger than six minutes, are connected with internal gravity waves.

The measurements at different wavelengths allow solving a wide range of scientific tasks. Each scientific task requires the performance of measurements at definite spectral lines with specific requirements for statistical reliability. There are two operating instruments for night measurements at the Stara Zagora Department of the Solar-Terrestrial Influences Laboratory: Zenith Photometer (ZPh) and Spectrometer Air Temperature Imager (SATI). A Scanning Photometer (SPh) and an Attendant Measurement Photometer (SMPh) are being developed.

Description of the complex parameters (Fig. 1):

- A zenith photometer [1]: The instrument contains a photoelectron multiplier for registration of weak signals and three interference tilting filters, whose replacement as well as their tilting is done on the basis of a Maltian mechanism. Each filter tilting can be changed at 520 steps. In each position a measurement can be performed by the photomultiplier as the time can be selected within the interval (1-10) sec. The minimum time for a complete cycle, including only the mechanical replacement is below 5 sec. The dark current can be measured after the measurements, made for each filter. Depending on the number and duration of the conducted measurements of the respective filters, the total time for one cycle is different. When measuring in three tilting positions for each of the three filters as well as for one measurement of the dark current for each filter, the complete time for one cycle, including the time for execution of the commands code (the latter depends on the computer speed) does not exceed 30 sec.

- A scanning photometer [2]: The device includes a photoelectron multiplier for registration of weak signals and three interference tilting filters. Each filter tilting can be changed at 180 steps. The time periods for filter change and selection of tilting are connected with mechanical movements and are accepted to be within the terms of one second each. The performance characteristics of the photomultiplier are the same as those of the zenith photometer. On the basis of a
suspended system, the direction change of the visual axis is possible in 12 positions along two mutually perpendicular directions. The time for one step in one direction is expected to be about a second. When measuring in three points, analogously to the zenith photometer, the complete time for one cycle is expected not to exceed 120 sec.

- **A photometer for parallel measurements;** the photometer includes a disc with eight filters. The time for filter change and the measurement duration are one second each. The photometer is developed as an autonomous system with microprocessor control, and the data are transmitted to a computer by means of a standard interface RS232.

- **Spectrometer Air Temperature Imager (SATI) [6];** the instrument forms images on a CCD matrix at four wavelengths, corresponding to the transmission of narrow interference filters, located on a rotating disc. A PC-controlled step motor rotates the disc.

**PURPOSES OF THE CONTROL MODEL DEVELOPMENT**

The development of the control models of the separate instruments has specific goals [5]. They are connected with flexibility of the control model, possibility for model change without any need to change the control program, optimization of the time for a cyclogram execution.
In the development of the control model of the whole complex, the aim is to solve scientific tasks on the basis of the separate instruments – mutual influence between the directions of the separate instruments. The purpose is to examine the possibilities for achieving adaptive control, following the registered emissions, connected with the research targets.

FORMULATION OF THE PROBLEM

The control of the zenith and the scanning photometer [1,2] and the SATI Instrument [4] is based on developed commands, modelling the motion, the registration as well as many other actions. Different actions, corresponding to one cyclogram for instruments operation, after initial initialisation, takes a finite interval of time, in which the computer can redirect its operation to another one, for control of another instrument. For example, the time interval for execution of one step of the step motors is 0.1 s, the time for accumulation of the photomultiplier is 1 s, and the time to calm down the filters at the zenith photometers is $0.1\div0.2$ s. The time for one position movement at the scanning photometer is expected to be 1 s and it is a relatively long interval of time in order to engage the processor with that action only. With the SATI Instrument the mechanical transitions between two filters need only several seconds and the registration time is 120 sec.

The cyclograms for instrument control contain commands, connected with expectation of time intervals. When in a given cyclogram such command is reached, this is a precondition for redirection of the computational resources to other cyclograms. As a result of the cyclograms parallelization, it is possible when using one computer to make compatible the control models of the separate instruments. The decomposition of the control model of one instrument, on the other side, allows in each specific case to reveal the additional capacities. Thus, for example, with the zenith photometer, the mechanical movement of the filters can be done simultaneously with introduction of the information, stored in the control computer. With the scanning photometer, the control of the mechanical subsystem can be separated by the registration system and in addition, the two motions can be separated, too. Instead of consecutively, they might be executed simultaneously (pseudo-simultaneously). This leads to a substantial decrease of the time, necessary for selection of measurement directions. In this way the minimum time for execution for the scanning photometer control cyclogram can be decreased with about a half. This is important with a view to conducting the measurements.

Besides, an interesting opportunity is afforded during real-time information processing by the zenith photometer. When reading situations, connected with, let’s say, a possibility for registration of the so-called internal gravity waves, the cyclograms for the scanning photometer operation might be changed as well as for the SATI Photometer, too.

CONTROL MODEL FOR THE PHOTOMETRIC COMPLEX

In order to achieve the above requirements to the photometric system operation and control, in the development of the control model was applied the formal approach, based on its treatment as a finite automation [1]. Each finite automaton of general type $F$ is characterized by six elements [2, 3].

$F=\langle Z,X,Y,\phi,\psi,z_0 \rangle$, where $Z,X,Y$ designate the multitudes of the internal system states, the input and output signals, respectively; $\phi(z,x)$ is a transition function and $\psi(z,x)$ is an exit function, respectively, and $z_0$ – is the initial state. In [1] the commands and their parameters are examined which the automation reads and executes as well as the
operation principle. These are commands, which conditionally can be referred to the different subsystems of the whole photometric system – mechanical and registering, as well as an entity of commands of system character and with user's designation. [5]. Thus, for example, we have commands for initialization of the mechanical subsystem, for filter change, for filter selection, for replacement of a definite number of steps, for filter omission. The commands, referring to the registering system, are connected with measurement initialization and, when ready, a command for data storage in the computer. The system commands include such, connected with information display, information recording on the disc.

The further development of the idea is connected with the decomposition of the examined automation as an entity of three asynchronous automata which operate parallel: $F_1=<Z_1,X_1,\phi_1>$ which corresponds to the mechanical subsystem, $F_2=<Z_2,X_2,Y_2,\phi_2,\psi_2,Z_02>$, corresponding to the registering system and $F_3=<Z_3,X_3,Y_3,\phi_3,\psi_3,Z_03>$, performing situational analysis, connected with the physical conditions for conducting observations. The operation of automata $F_1$ and $F_2$ is synchronized as a result of which we can present the transition function for the $k^{th}$ operation cycle $\phi_1(t_k,Z_1,X_1,Z_2,Y_3(t_{k-1}))$ and $\phi_2(t_k,Z_2,X_2,Z_1,Y_3(t_{k-1}))$.

The idea for the decomposition of the zenith photometer control model and for its presentation as an entity of three finite automata, performing asynchronously, is based on the circumstance that the whole operation cyclogram consists of three linear sections. The one is connected with the filters mechanical movements and their tilting, the other one services the data registration and storage. The third one provides the measurement processes with situational analysis of the measurement conditions (suitable values of the zenith angle of the Sun and Moon). These three processes in the common case, examined in [1], follow one another but they might be executed parallel, too (pseudo-parallel) in the time (Fig. 2). For their correct execution operation synchronization of the three automata is necessary [3].

The input signals band contain the so-called timed words; $\omega_i=(x_i,t_i)$, where $x_i \in X$ and $t_i \in T$ – the real (or system) time commands connected with verification of the system time and the respective restrictions. This, on the other side, allows fixing the execution time for one cycle as well as the correct operation of the mechanical subsystem, achieving flexibility of the control model. Timed automata are finite-state machines whose transitions are constrained with timing requirements so that they accept (or generate) timed words (and thus define timed languages); they were proposed in as an abstract model for real-time systems with finite control.
Automation $F_3$ executes commands, connected with computation of the observation conditions – each of the commands corresponds to a portion of mathematical computations, connected with the position of the Sun, the Moon, co-ordinate transformations, etc. The operation of automata $F_3$ and $F_2$ depends on the results $Y_3(t)$ of $F_3$.

An interesting possibility exists for the scanning photometer. The mechanical movement decomposition of two independent movements along the basic directions and their description by two independent cyclograms allows their pseudo-parallel execution. This yields a considerable time decrease for execution of the respective commands and, as a result, time decrease for execution of the instrument cyclogram. Analogously we have two automata $F_4=<Z_4,X_4,\phi_4>$ and $F_5=<Z_5,X_5,\phi_5>$ representing the control models of the two mechanical movements and $F_6=<Z_6,X_6,Y_6,\phi_6,\psi_6,z_06>$, connected with filter selection, tilting angle and the measurement itself.

The examined approach for parallellization of the mechanical movements and data storing does not produce substantial decrease of the time, necessary for command execution, especially with the zenith photometer. With the SATI Instrument, however, where the motions are slower and the information much more, the effect of this approach is expected to be significant. Analogously we might have three automata $F_7=<Z_7,X_7,\phi_7>$, $F_8=<Z_8,X_8,\phi_8>$ and $F_9=<Z_9,X_9,Y_9,\phi_9,\psi_9,z_09>$.

**CASES OF NON-LINEAR CONTROL**

The change of the instruments control cyclograms is possible on the basis of analysis of the real-time registered data. We have non-linear control when, as a result of some new conditions, a change of the control cyclogram becomes necessary. It is possible when a new condition appears, the cyclogram change to be connected with selection among several control versions.

The decomposition of the non-linear model of separate alternatively executed sections allows by blocking some of them and by allowing the execution of others the necessary cyclogram to implement such type of control. Such a model can be presented by alternative automata. This approach results in simplification of the cyclograms and release of their non-linear character. This influences the choice of commands, necessary to compose the cyclograms. Therefore it is not necessary to develop commands for conditional transitions. In order to implement the examined approach, the development of commands for conditional change of the cyclograms priority is necessary.

**CONCLUSIONS AND FUTURE WORK**

The development of a model of a photometric complex, based on asynchronous automata, allows flexibility, easy progress, a possibility for modification and adaptation of the measurements to the scientific tasks.

In the development of the examined approach, the purpose is to afford to the experimenter accessible means for measurements control within the frame of a complex of photometric instruments.

**REFERENCES**


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