A Classifier of Technical Diagnostic States of Electrocardiograph

Lubomir Lahtchev, Maya Dimitrova, David Rotger

Abstract: *The construction properties of electrocardiographs are described from a technical diagnostic knowledge perspective. It is established that their technical state is usually assessed by common-reasoning visual indication and by the form of the electrocardiogram. It is shown that the design of a classifier of technical diagnostic states is a prerequisite to enclose a list of faults or technical defects with apriori diagnosed origin, that can help the on-line technical diagnostics in cases of obvious disturbances of the ECG signal at normal indication. A sample algorithmic and construction solution for technical diagnostics is proposed in the form of a listing scheme and a controller for technical diagnostic states of an electrocardiograph.*

Key words: *Classifier, Model, Technical Diagnostics, Electrocardiograph.*

INTRODUCTION

Modern technology for medical investigation is rapidly developing towards contactless, surface and intravascular scanning of any dimensionality. Depending on the performed tasks, the range of electrocardiographs varies from mobiles of minimized design, computer-specialized to stationary-based of various compositions and in methods, applications and physical nature of the working signal. In multipurpose computer systems, as the one described in [2], the electrocardiogram (ECG) is collected and filtered with sound card of a workstation. The input signal is integrated in a sliding window in order to recover its original shape. Cardio-laptop and cardio computer series of Schiller [6] reflect some trends of expansion in this class of medical equipment.

With the increase of popularity, accessibility and importance of cardiological research and diagnosis via ECG, the logical follow-up step has been the expansion and application of electrocardiographs (ECGph) with defibrillators (ECGDfs). This characteristic design combination is an object of the European standard "Particular Requirements for the Safety of Electrocardiographs" [3] which, in practice, deal with the safety aspect of the technical diagnostics.

With the evolving quality of the working elements and construction units, that has reached high levels of precision and saturation, less common is to pay attention to the technical diagnostics in terms of reliability, workability and safety. Nevertheless, one independent technical-diagnostic subsystem is an appropriate supplement to the space of technical tool-reserve of this class of medical equipment.

The focus of this paper is the arrangement of a common classifier of technical diagnostic states of ECGDf as the basis for development of an algorithm and controller of real time technical diagnostics with examples presented below.

SYSTEM APPROACH TO THE PROBLEM OF TECHNICAL DIAGNOSTICS OF ELECTROCARDIOGRAPH

The problem of technical diagnostics and safety improvement of ECGph and ECGDf is complex and can encompass several groups of this type of medical appliances. For example, in [1] network disturbances are investigated in three types of two-electrode amplifier, oriented to a particular area of application for newborn children. The variety of types of ECGphs and ECGDfs is facilitated by the existence of a wide range of three-electrode ECGDfs, [5], [4], by the number and location of the electrodes, as well as by the method of their connection to the measurement-display block. The requirements for noise suppression, calibration, where necessary, compensation for the possible input asymmetry, suppression of syn-phase signals, when available, filtering of useful signal, indication of running parameters and idle states, filtering of power supply voltage, compensation for electrode capacity and fast suppression of residual effects from defibrillation influence on the construction features of ECGphs and ECGDfs.

The variations in the executable construction units determine the variety of properties for their classification and technical diagnostics. This variety can be organized by following the main features and the problem orientation of the kinds of ECGphs and ECGDfs based on the system approach.

Let for given sets ECGphs and ECGDfs, characterized by a set of functions, a set of structures, defining their utility, a set of connecting means to the environment and to the object of investigation, and by a set of functional-structural properties, construe logical and other relations of generality and function pre-history for the purpose of design of a system of classificatory features of their technical diagnostic states. Based on such a classificatory scheme, we propose an algorithm and technical diagnostics system of the existing ECGphs and ECGDfs.

CLASSIFIER OF DIAGNOSTIC STATES OF ECGph AND ECGDf

The origin of deviations in ECGph and ECGDf can be technical, medical, or mixed. According to the dipole theory, any ECG test records the bioelectrical currents from the body surface that are geometric projection of the electrical vector of the heart dipole on the axis of the ECG test. This and similar rules for the ECG record refer mainly to the normative medical basis for correct work with the ECGph and ECGDf, described in detail in the literature and are subject of investigation in the present paper to an extent, that concern the technical-diagnostic parameters of the device. At the same time, some aspects of tuning of the ECGph and ECGDf are specifically technical and are performed on test samples in the respective mode.

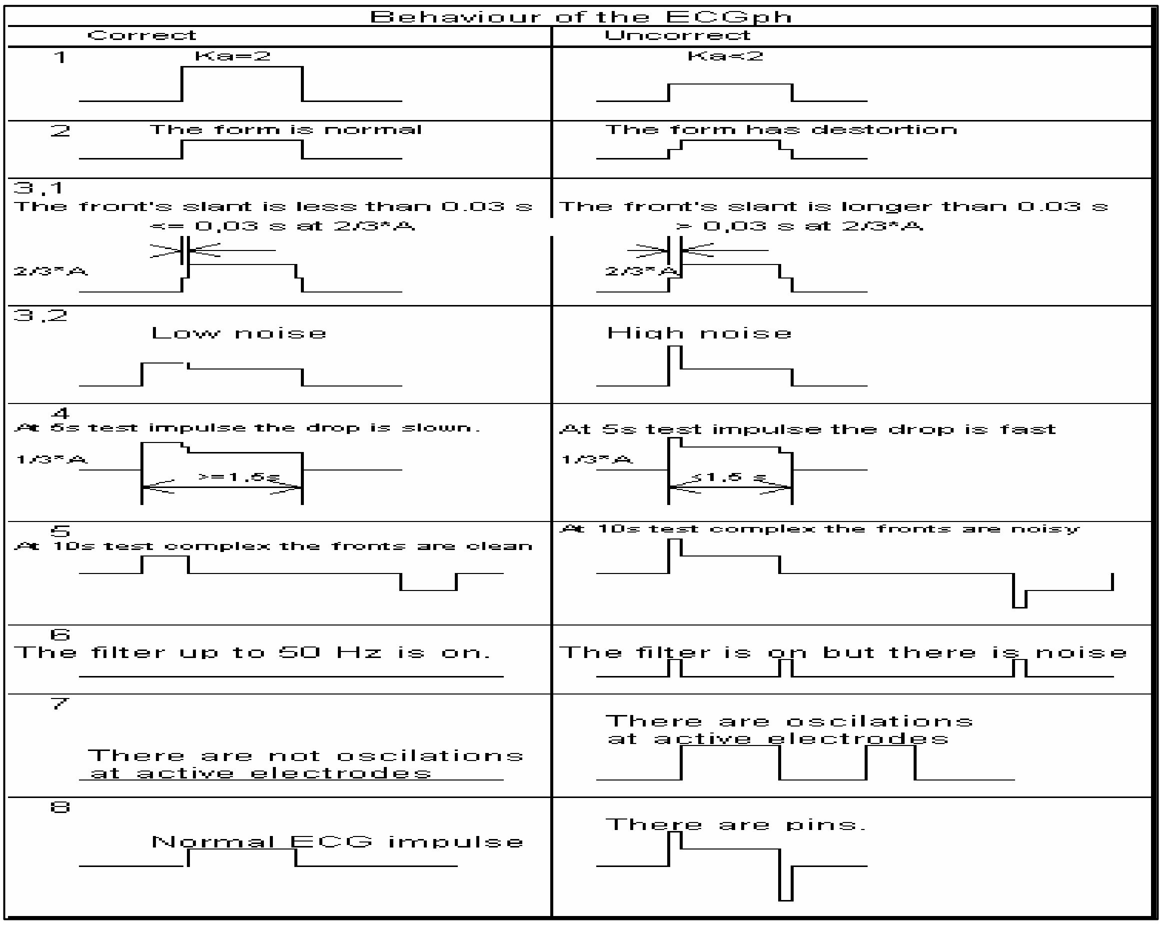
A common classifier of technical diagnostic states of the ECGph and ECGDf based on the collected experience with their usage is shown in table 1. In [4], for example, situations, when the mutual location of the power supply and patient wires influences substantially the amplification and quality of the ECG, are described. This invokes the necessity of appropriate technological solution for the composition of the shaft of wires. On the other hand, the presence of specific "gasp" of the patient also requires special solution for the ECG, sought, for the moment, in turning down the amplification, or in the activation of special low-frequency filter. In practice, these drawbacks can be overcome by the introduction of a parallel functioning acoustic spectral scanning, that make easy the differentiation of the different signals. These supplements, however, require including appropriate analog-digital converter (ADC) and spectral analyzers for lowfrequency and sub-frequency acoustic signals.

The motivation to use ECGph and ECGDf in any environment or in relative autonomy can be better supported with the inclusion of additional constructive unit for diagnostics of the basic technical set. This means that part of the mandatory tests, indications, enhancing performance without intervention of the staff, discussed above, can be performed in background mode and in real time via the inclusion of a controller for technical diagnostic states (CTDS). This controller working in active cycle can perform control of checks and separation of the operation modes in the ECGph and ECGDf. A common algorithm of CTDS operation is shown on fig. 1 and a common block-chart of a configuration of ECGph and ECGDf together with the controller is shown on fig. 2. The diagnostic work is triggered by the information from the inputs and outputs of every unit. The controller runs the diagnostic process by successively turning on and off of single units and by scanning of the respective input/outputs, if they are intermediate, or "input only"/"output only" units, if they are terminal for the given complex equipment.

Table 1 contains essential information for the structure of technical diagnostic knowledge. It presents the logical reason connection in the chain "feature – symptom –
Table 1. Common classifier of technical diagnostic states of ECGph and ECGDf

No	Classification feature	Symptom	Test time period	Behavior of the ECGph and ECGDf		Possible reason
				Correct	Incorrect	
1	Indication of operability of ECGph through test signal at 1 mV, 10 Hz, -5V – +5V	Indication of the ECG signal	Every time before cardiography investigation	The observed impulse corresponds to the rate of 5 – 10 mm	Indication breaks before amplitude decreases to 5mm	Deviations of the amplifier parameters
2	Precise calibration	Degree of amplify	Every time before cardiograph investigation	Rectangular impulse with amplitude of 10mm/1mV	Deviations of the impulse from the form and the size	Deviations of the calibration loop and its elements
3	Test signal form	The front and back of the test impulses are declined	At symptom appearance	The declination is less than 0.03s/ 2/3V of impulse amplitude	The declination is more than 0.03s/ 2/3V of impulse amplitude	Muscle effort is available
		The front has a sharp peak	At symptom appearance	Low curve peak on the impulse form	Strongly expressed HF drop impulses	Noise
4	Long time test impulse >5s	Impulse duration	At necessity	The impulse curtness with 1/3 level comes after 1.5 s	Deep HF dropping decrease of the ST-seg. and T-wave	Noise
5	Test-complex for 10 s with non-symmetrical impulse	Degree of non-symmetry of the impulse form	At necessity	Symmetry of the positive and negative impulses	Dissimilar forms of the positive and negative impulses	Weak electrical contact
6	Parasitic impulses	50 Hz impulses are seen on the ECG	After medical test	There are not such impulses	Periodically repeated 50Hz impulses	Technical fault of the ECGph
7	Medical artefact	Muscle effort	Several times for a patient	The sensitivity of the ECGph decreases		Medical nature
8	Heart intra-cameras complexes	Electrical position of the heart	At tall HF impulses and amplitudes of the ECG	The signal is rated	Tall amplitudes on the ECG	Parallelism of the patient wires or high noise breath disfunction

Table 2. Graphical interpretation of the behavior correspondingly to classifier features.



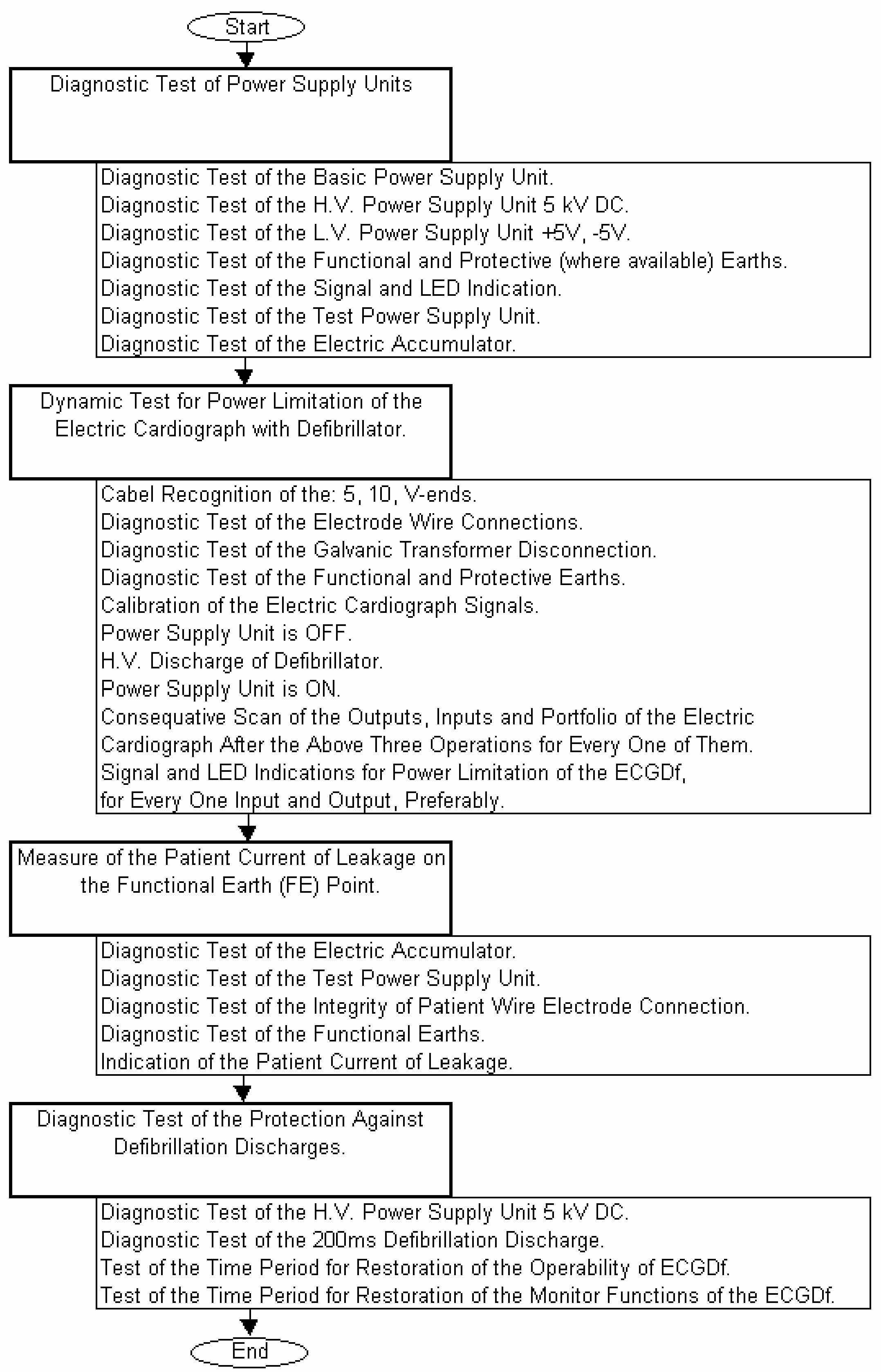


Figure 1. A sample algorithm of technical diagnostics and test of the ECGph and ECGDf.

– periodicity – behavior – reason" of common technical diagnostic features. The snaps of such chains – rows in the classifier table, can increase at appearance of defects of any origin. Table 2 shows the graphical interpretation of the behaviour of ECGph and ECGDf.

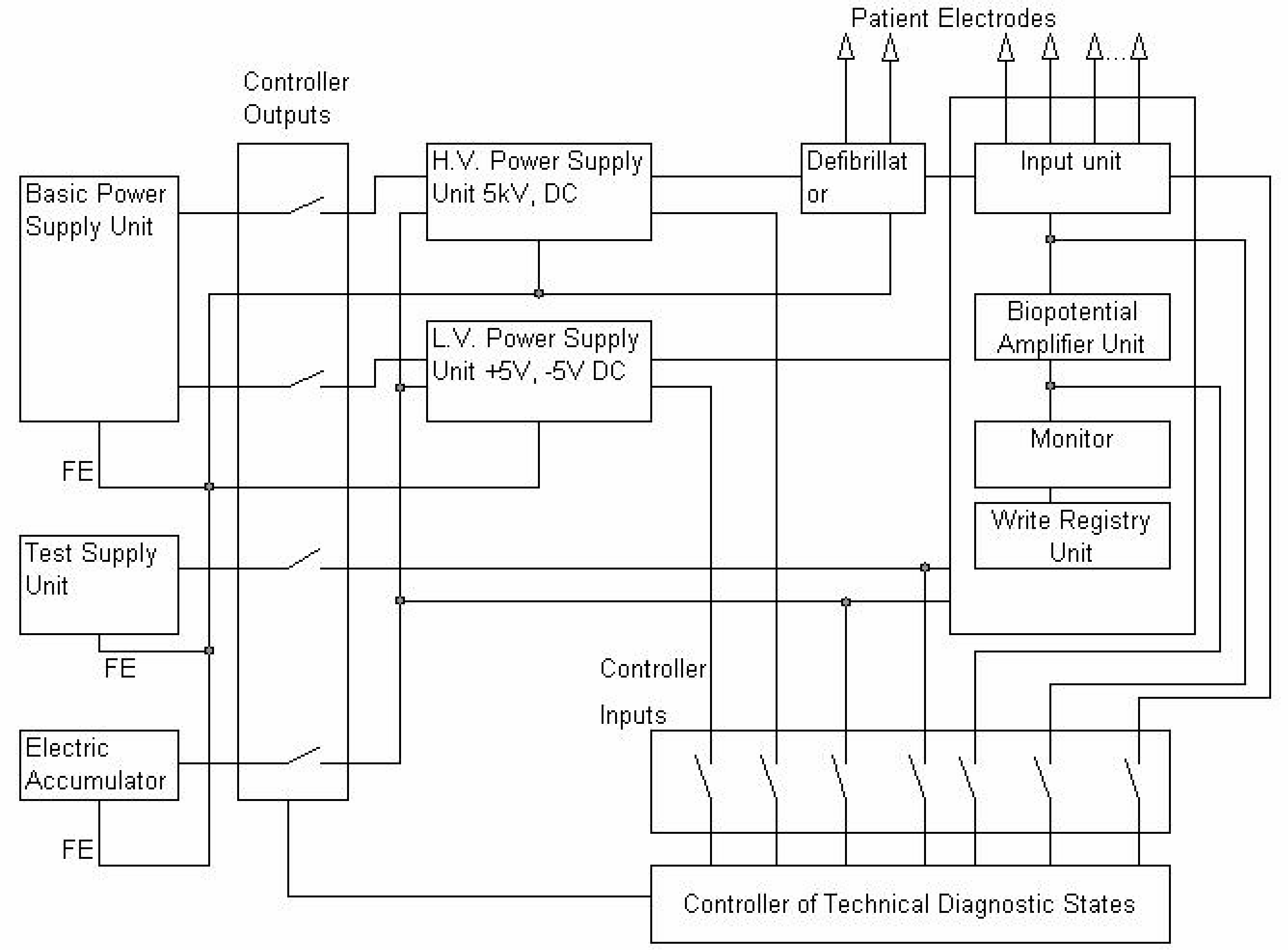


Figure 2. A common structure of the controller for technical diagnostic states with modules of ECGph and ECGDf.

The list of common algorithmic operations for technical diagnostic is written on fig. 1 and the device configuration, which can execute it, is shown on the fig. 2. Sample connections related to the algorithm and representing the base idea of the technical diagnostics of ECGph and ECGDf are drawn without details.

The power supply units are decomposed in two levels. The first one generates main supply voltages and includes the reserved electrical accumulator power supply. The second power supply level includes supply sources and stabilizers of the basic electrical voltages, which are related to executive modules of defibrillation and electrocardiograph.

The real electric design and wireness among sub-modules are more complicated and branched. For instance, the output of every power supply module can be connected to an ADC of the controller for reading. The separation of the first from the second level of power supply allows a single test measurement of every first level module at appearance of a sample technical diagnostic discrepancy. On the other hand, the second level modules of power supply and executive modules can be tested by self-scanning from the controller side. When these operations do not give any result, the controller can initiate intra-modular scanning, similar to the represented in the electrocardiograph module.

Such technical diagnostic schemes can be multiplied in any sub-module and in their intra-modular design components, for example, till level of an operational amplifier in the sub-module of bio-potential amplifier. In these constructive technical diagnostic scheme branches the logical chains – rows in the table 1 will increase until number of defects concerning the tested sub- and intra-modular components. The end number of these components determinates an end number of the technical diagnostic states. As a result, the classifier will include a full group of features of any level for a single construction of technical diagnostic system with an exhaustive list of technical diagnostic states.

CONCLUSIONS AND FUTURE WORK

An overall look on the effectiveness of ECGph and ECGDf showed the availability of a technical reserve that is the insertion of an additional function or technical diagnostic subsystem operating in real time on any level of details in the complexes of ECGph and ECGDf. A common classifier of technical diagnostic states of ECGph and ECGDf is suggested. An idea conception for real time active technical diagnostics and self-diagnostics is presented. The diagnostic tests for execution, where it is possible, are explained in the particular requirements of the European standard on this class of medical electrical equipment. A sample algorithm of operation and a prototype of controller configuration for technical diagnostics of ECGph and ECGDf are outlined, that will be further tested.

ACKNOWLEDGEMENTS

This work is partially supported by grant No MI-1509/2005 of the National Research Fund of Bulgaria for the research project on "Multimodal User and Sensor Interface for a Computer-Aided System for Cardiological Diagnosis and Intervention".

The authors express their thanks to Dipl. Eng. Chavdar Todorov for advice and methodical support.

REFERENCES

[1] D.P.Dobrev. A Comparison of Differential with Non-symmetrical Amplifier of ECG Signals. Proc of workshop. "Electronika 2000", October 5-6, 2000, Botevgrad, Bulgaria, pp. 199-205; (In Bulgarian.)

[2] D Rotger, M Rosales*;* J Garcia, O Pujol, J Mauri, P Radeva. ActiveVessel: A New Multimedia Workstation for Intravascular Ultrasound and Angiography Fusion. Proceedings of Computers in Cardiology. Tessaloniki, Greece, Sept. 2003, (In English.)

[3] IEC 60601-2-25/1993r. +A1/1999 "Particular Requirements for the Safety of Electrocardiographs". (In Bulgarian.)

[4] Il. Tomov, L. Tomov. Clynic Electrocardiography and Vectorgraphy. Medicine and Physical Culture Press, Sofia, 1975, 443 p. (In Bulgarian.)

[5] V.V. Murashco, A.V. Strutyinskii Electrocardiographs. Medpress, Moscow, 1999, 312 p. (In Russian.)

[6] www.schilleramerica.com – accessed 05.04.2006. (In English.)

ABOUT THE AUTHORS

Lubomir Lahtchev – PhD, Research Fellow at the Institute of Control and System Research – Bulgarian Academy of Sciences, Phone: +359 2 979 20 53, E-mail: lahchev@icsr.bas.bg,

Maya Dimitrova – PhD, Research Fellow at the Institute of Control and System Research – Bulgarian Academy of Sciences, Phone: +359 2 979 20 54, E-Mail: dimitrova@icsr.bas.bg

David Rotger – Research Fellow, Computer Vision Center, Autonomous University Barcelona, E-mail: rotger@cvc.uab.es