# MEASURING AND DIAGNOSTIC SYSTEMS – REAL AND VIRTUAL MEASURES IN BIOMEDICAL EDUCATION

## Krzysztof Jellonek, Malgorzata Kotulska*

Wroclaw University of Technology, Department of Medical and Measuring Instruments,
Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland.

*Abstract: A rising demand for specialists in Measuring and Diagnostic Systems (MDS), able to apply multidisciplinary knowledge from measurements, automation and medicine, became the reason for launching the course in this field for students of Biomedical Engineering in Wroclaw University of Technology. The specialists should be trained in system design, development and implementation. The course curriculum and web-centric approach to laboratory equipment is presented.*
*Keywords: medical measurements, virtual laboratory, metrological education.*

## 1 INTRODUCTION

Modern technology development induced a rising demand for engineers competent in measuring and diagnostic systems, skilled to implement and employ their multidisciplinary knowledge to specified tasks. Measuring and diagnostic systems provide all technological tools necessary for object investigation, estimation of its principal parameters and model generation.

The educational process should take into consideration current technology tendencies. Therefore, the course of Measuring and Diagnostic Systems (MDS) was introduced to students of the fourth year M. Sc. program in Biomedical Engineering at Wroclaw University of Technology.

Medical systems [8, 12], supporting diagnostic process, deal with a very complex subject to investigate a human. Typically, a complex system examination needs a mathematical model [2] for theoretical analysis, validated by experimental research. The real-life situation, which is to be emulated during the course, does not provide any full and reliable mathematical models of the human medical state. For this reason, a good design of experimental processes is so essential. A complete medical system requires data acquisition, data processing, interpretation and visualization of the results [8]. In telemedicine systems data and results transmission is also of great importance [11].

At all these stages a designer has to make an appropriate choice of theoretical methods and technological tools. Therefore, a complete and fully integrated medical system for measurements and diagnostics refer to various distinct fields of knowledge and technology [12].

The curriculum of the MDS course assumes that students have already achieved a certain level of theoretical knowledge in biology, physiology, mathematics, physics, computer science, and electronics [1]. During the course students are faced with real-world problems from the field of medicine. The project-like approach to the subject activates their role in searching for theoretical and practical solutions. It evokes a problem-based learning and compels students to refer to various fields of knowledge from their previous theoretical courses.

During the course a special impact is exerted on the technological solutions that can be involved into final measuring and diagnostic system realization. In general, the curriculum of the MDS course has to involve:

- biological and physiological basis for the investigated problem,
- classical metrology methods for data acquisition, error source analysis and results validation,
- telecommunication tools for fast and confidential data transmission,
- theory of data processing (digital filters, transforms, data compression, image processing),
- artificial intelligence methods (neural networks, expert systems, fuzzy logic),
- computer science methods to build up a software for optimal data acquisition, processing, and storage, to design network applications, to create graphical user interface [6].

As a result the course provides training for designing and assembling tools dedicated for medical measurements and diagnostics, linking modern technology with traditional measurement approach and a biological (non-technical) quantities.

Correspondence to: krzysiek@pwr.wroc.pl

## 2 WHAT IS MEASURING AND DIAGNOSTIC SYSTEM COURSE ABOUT?

In general, a measuring and diagnostic system forms a net composition of interrelated subsystems (Figure 1).
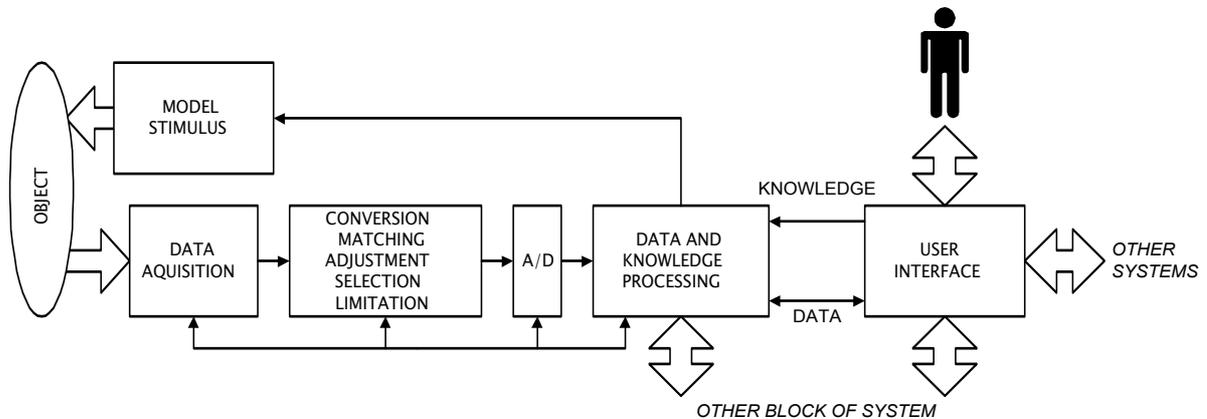


Figure 1. Typical Measuring and Diagnostic System (MDS) structure.

The elements of diagram define the knowledge branches that are necessary to design an integral system. They range from object modeling through data acquisition and advanced data processing to graphical user interface designing. Therefore, a complete MDS includes the following components:

OBJECT (object modeling techniques, signal definition and registration techniques, proper experiment conditions defining),

TRANSDUCERS (physical principles of transducer construction, characteristics, calibration, selection criteria, application of intelligent transducers),

MATCHING CIRCUITS (selection and design techniques, application of integrated amplifiers and specialized circuits),

ANALOG / DIGITAL CONVERSION (quantization, coding and sampling techniques, principles of integrated A/D converters, technical aspects of A/D converters in MDS),

DATA PROCESSING

- tools: microprocessors (GPP, DSP, Fuzzy Logic, ASIC, ASSP), optimal parameters selection, programming techniques, debugging tools, PLC (structure and block selection, tools and programming techniques), computers (choice of interface for computer-device communication, PC boards, operating systems implementation and development, principles of application design),
- algorithms: digital filters, fuzzy logic techniques, neuron networks, statistics methods, transforms (Fourrier, Walsh, wavelet, etc.),
- knowledge processing: expert systems, artificial intelligence techniques,

USER INTERFACE (programming methods and tools, ergonomic aspects of GUI design),

COMPUTER NETWORK AND INTER-NETS [5, 9] (data transmission, network topology, network administration: tools and procedures, client - server structure, Internet, Java programming, applets, www pages, network security),

The basic material can be provided to students within one-year course. The course consists of lecture series (concerning only essential topics), access to manuals and databases with more detailed knowledge and project-like laboratory classes. The practical part of the course is run in the problem-based mode. The whole group (of about 10 students) is responsible for solving a general biomedical problem. They are expected to carry out the theoretical research, establishing basis for the measuring and diagnostic system and selecting appropriate technological tools. Next, the group of students divided into smaller subgroups designs, assemblies and tests all parts of the system. For example, a group that developed the system for a general practice doctor support, worked together on the general project assumptions, while problems concerning measurements of individual medical parameters, common database and data teletransmission development, were assigned to individual subgroups of 2-3 students.

The problem-based approach addressed to the whole group of students mimics the real-life commercial projects, teaches multidisciplinary approach and collaboration within topic groups. We

noticed also that the relevance of the project topics to the real problems is very motivating for the students.

## 3 MDS LABORATORY BASE - REALITY AND TENDENCY.

Equipment of the standard MDS laboratory, where students design and assemble their systems, is based on typical instrumentation used for measurement and automation university courses. All student stands are equipped with:

- personal computers with specialized software and unlimited access to Internet,
- A/D and D/A conversion modules based on AD 7895 or LM2400 with serial SPI communication interface,
- dual channel digital oscilloscopes with internal memory,
- signal generators,
- power suppliers,
- various medical instruments,
- sensors and transducers of medical quantities,

The software part of the project is created in LabWindows/CVI environment (National Instruments), which is a specialized system for assisted C-language programming. The major advantage of this software over traditional C or C ++ environments comes from the fact that CVI provides many useful ready-to-use functions for data acquisition and transmission, as well as a rich library for data analysis. The great asset of the system is also its very intuitive and graphical way of GUI (Graphical User Interface) designing, which vastly simplifies the programming process.

However this standard laboratory equipment proved sufficient for basic students' activity, it would be valuable if the base could be constantly extended and updated. Costly investments into laboratory equipment, for the course purposes, cannot be considered. What is more, in the present web-centric technologies it does not seem necessary.

Unlimited access to Internet has introduced a new potential for university laboratories and it is likely to play a key role in the forthcoming years. Very current information on new solutions and technologies can be obtained almost immediately. In the field of measurement technology, where insufficient laboratory base can impede any progress, new technology of Internet-based virtual instrumentation raises great expectations. Similarly, new wireless technologies of data transmission such as Ethernet and TCP/IP protocol in Internet, bluetooth technology and extensively developing mobile phone technologies, providing easy, economical and confidential data transmission, may prove revolutionary. These Internet-centric technologies offer new perspectives of low-cost access to the newest measurement technology with low need for expensive laboratory equipment.

The web-centric environment for MDS course should base mainly on four components:

- Software tools supporting designing, assembling and testing projects (software for measurement applications, e.g. LABView, HPVEE or another, software for API-based driver design, software for numerical simulations, e.g. Matlab, software for designing and testing microprocessor systems, e.g. AVR Studio – Atmel or Visual DSP – Analog Devices, software for designing network applications of client-server, tools for designing artificial intelligence systems such as neural networks, expert systems. Some of these tools could be available through Internet. (A similar solution can be observed for systems supporting FGPA circuits design).
- A series of Internet multimedia seminars provided in the form corresponding to NETSEMINAR portal (www.netseminar.com),
- Data bases with elements, devices and software tools useful for MDS purposes,
- Knowledge bases and databases with research results, publications and manuals of commercial companies.

An important factor to keep pace with technological progress is closer contact between university and commercial companies, which brings benefits to both sides. Currently, numerous university laboratories take advantage of software license on preferential terms. Similarly, testing and implementation of the latest electronic elements that are received as "free samples" is quite popular. Nevertheless, a thorough and complete solution is needed. In all university laboratories students can use only one set of tools for designing measurement and automation systems. It concerns also software environment. Typically, it is either LabWindows CVI (National Instruments) or LabView (National Instruments) or HP VEE (Hewlett Packard) or TestPoint (Keithley). Ideally, the course participant should be given an opportunity to make contact with more than one environment and choose the most suitable tool for the task, also with regard to the individual preference. Companies that supply university labs on very preferential conditions are becoming aware of the marketing aspect of this strategy. Students who get acquainted with a certain tool during their university courses are

more inclined to choose it for commercial applications in their professional work. Thus, companies are now more cooperative in supplying universities with new software for very low prize or even for free. It gives universities much better access to hot technologies and up-to-date tools.

Another important issue in university-company communication is closer contact between student courses and commercial projects. Students who can participate in the real-world commercial projects gain much better orientation in the current market needs. Following the whole process from the designing stage to the final product gives them practical knowledge and results in better relevance between student projects and the newest commercial solutions. Practice of involving students into commercial projects becomes increasingly popular and provides companies with free access to human resources for their present tasks and more effective employment policy in the future.

## 4 CONCLUSIONS

A general outline of the Measuring and Diagnostic System (MDS) course was presented. We emphasized the need for educating students in this field, analyzed teaching methods, necessary tools and optimal curriculum. It was stressed that an approach typical for most university courses in measurement technology, in which students base on local laboratory equipment, does not apply for such wide multi-disciplinary subject. Therefore, the tendency to web-centric tools will prove very effective [3, 4,7]. In this system collaboration between distinct universities and companies is also more straightforward. We would be very pleased to find partners to develop the program of MDS course, probably with support of an educational Leonardo da Vinci program. An experimental web-centric and multi-center course will bring about a new approach for training specialists of the future – able to synthesize and apply theoretical and practical knowledge from very distinct fields of technology and medicine.

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