INTERNET REMOTE LABORATORY SYSTEM (IRLS)

Emil Michta, Wiesław Miczulski, Piotr Powroźnik, Dariusz Eljasz

University of Zielona Góra, Institute of Electrical Metrology, Podgórna 50, 65-246 Zielona Góra, Poland
E.Michta@ime.uz.zgora.pl

Abstract: *In the article, the evolution of remote laboratory architectures is presented and the benefits following from the use of an application environment in the form of Web services are pointed out. It is suggested that an education space comprising remote laboratory domains managed by a service broker, co-operating with clients and a laboratory server should be distinguished. A remote metrology laboratory solution is presented.*

Keywords: *Remote laboratories, Distant learning, Web Services.*

1. INTRODUCTION

The ubiquity of the Internet is beginning to have an increasing influence on the organization of the education sector on BSc courses. The specificity of such courses consists in the fact that in educating engineers a very important role is played by laboratories, which are also the most expensive component of the training process. Utilizing the contemporary capability of IT and taking into account the trends in the new organization of a communication infrastructure in the form of NGN networks based on IP and MPLS, there is a possibility of creating within the service layer such an education space (ES), in which selected laboratory activities could be carried out via the Internet [2,4]. This means that the laboratory stands would be accessible for students 24 hours a day, and access to them would be possible from any Internet accessible location. The implementation of such functionality calls for organizing the environment of an education space in such a way that the actual laboratory stands would be operated by laboratory servers, and on the client's side, an Internet browser would be the basic user interface.

2. TRADITIONAL AND ALTERNATIVE METHODS OF CONDUCTING EXPERIMENTS

Laboratory activities are one of the most important factors in the process of educating engineers, greatly influencing their practical skills, which are often taken into account by prospective employers. The significance of laboratories in such a process follows from the fact that during laboratory activities students verifies their theoretical knowledge, learn

teamwork, use real equipment, and carry out an analysis of data obtained during an activity.

However, maintenance of laboratories is costly both because of their equipment and the staff employed during activities. Therefore, in the light of the above the level pertaining to the content of a laboratory is a compromise resulting from the economic circumstances, which limits access to the most modern technologies on the training stage. Moreover, upgrading classic laboratories is limited by the expenses connected with maintenance and modernization of commonly occurring IT infrastructure. The ubiquity of IT infrastructure is naturally conducive to replacing real laboratories with virtual ones or with simulations in which application packages simulating real experiments are used [3]. An unquestionable benefit of such an approach is the possibility of using typical computer equipment, which influences the cost and facility of laboratory stand preparation and operation. A virtual laboratory does not put any time constraints on access to experiment, and conducting it is not linked to any particular location. A virtual laboratory proves its usefulness during a concept clarification phase, whereas its drawbacks are virtual data manipulation and lack of user interaction with real equipment. A laboratory of this kind can be used on BSc courses, but as a supplement or an introduction to real experiment, i.e. students perform some activities in a real laboratory, and some with the use of a virtual one or a simulator.

From an education point of view, a considerably more effective way of conducting experiments, but more difficult to implement and more expensive than virtual laboratories is a remote laboratory con-

cept. In it, it is assumed that the user has access to real equipment from a Web browser level with the possibility of watching real equipment through a camera. In the case of a collective experiment, a group channel or a chat function can be activated. It seems that currently remote laboratories constitute the best alternative to real ones, because besides the possibility of choosing the time of conducting an experiment, the user has remote access to real laboratory equipment and receives real data for analysis. Popularising a remote laboratory concept may represent a breakthrough in the technology of both educating students and conducting postgraduate courses [1]. In the article, a metrology remote laboratory realized in the Institute of Electrical Metrology is presented.

3. REMOTE LABORATORY ARCHITECTURE

Because of its purpose and the mode of operation, remote laboratory architecture depends to a large extent on the available network and IT technologies. Two basic parts of this architecture are: the side of a service provider, i.e. a remote laboratory with a server and a set of devices for conducting an experiment and the user's (student's) side, using a service from a Web browser level (Fig. 1).
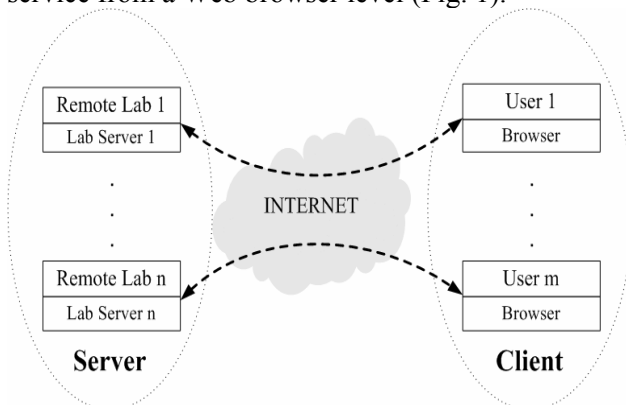

Fig. 1 - Two-element remote laboratory architecture.

Most of the contemporarily used IT applications functioning on the Internet are based on a client-server architecture requiring dividing the managing and processing functions between the server and client sides. In the case of a two-part architecture, all functions connected with laboratory stand operation, reservation and gathering experiment data, as well as identification and authorization functions, are performed by LabServer. Access to a remote laboratory is possible from any Internet accessible location, but since it requires creating on a laboratory server a separate account for each user and performing the remaining managing functions, such a solution for practical reasons is limited to local use. An increase in the number of clients quickly leads to the exhaustion of the resources of the laboratory server and

limits the possibility of upgrading it. In the light of the above, there is a need to separate the server function from contact with a client. The laboratory server should be busy mainly with operating the equipment used during an experiment and should be relieved of the performing of managing functions, whereas a client should be attended to by a new, allotted part in remote laboratory architecture, a so-called service broker, which is presented in Fig. 2 [2]. Clients and services in the form of laboratory stands are registered on a service broker. In this architecture, a client only contacts a service broker, which takes over the mentioned earlier managing functions. After authentication, authorization and gathering from a client data necessary for conducting an experiment, the service broker orders the laboratory server to perform a service. If the server is busy, the service order lands in a queue. The position in a queue of experiments waiting to be conducted depends on a queue discipline, in which tasks can be performed according to the FIFO principle or with regard to a user priority. Tasks waiting to be performed can be filtered by means of access lists.

The remote laboratory architecture shown in Fig. 2 is of an SOA class (Service Oriented Architecture). It is an IT system creating concept, in which the main emphasis is put on defining services which will satisfy the user's demands. The SOA concept comprises a set of organizational and technical methods aiming to better link the organization business aspect with its IT resources.
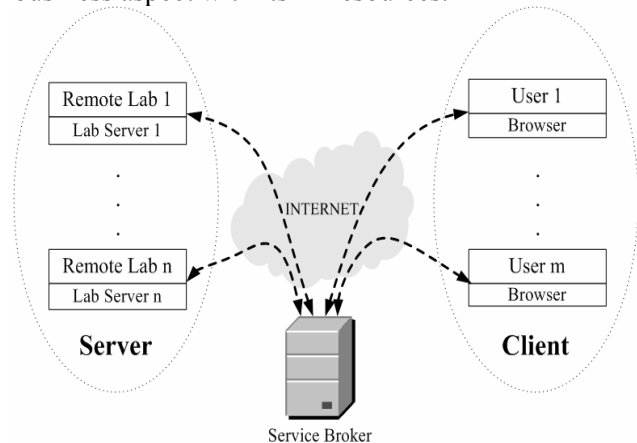

Fig. 2 - Three-element remote laboratory architecture.

The term *service* refers here to every software element able to function independently of the others and possessing a specified interface, with the help of which it makes the performed functions available. The mode of operation of each service is entirely defined by an interface hiding implementation details - invisible and unimportant from clients' point of view. Additionally, there is a common, accessible to everybody communication medium, enabling free data flow between the platform elements. The SOA architecture is similar to distributed objects, though

it describes solutions at a higher level of abstraction. Service interfaces are usually defined in an abstract fashion and independently of the programming platform. Also, services themselves are often implemented on the basis of various technologies and made available by means of an independent communication protocol.

The introduction of a third element into a remote laboratory architecture enables to build an education space (ES) made up of education domains co-operating through service brokers (Fig. 3). An ES is organized in such a way that access to a service in a form of a remote laboratory can be gained via one's own local service broker, which acts similarly to a register, and diversion servers in Internet telephony based on the SIP protocol. A service broker receives an order to perform a service and then checks where this service can be performed the fastest.

An application environment for a structure defined like this can be Web Services. A very important advantage of this environment from an ES point of view is the fact that a Web Service is a platform- and implementation-independent program component, providing specific functionality. A Web Service can be defined by means of the service description language, WDSL, based on XML and published and searched out in the service register by means of the UDDL standard mechanism. The UDDI searching system enables to register services on the Internet and allows applications to search for such services and to exchange data. If a Web service is paid, then a payment making procedure may be included. To function correctly on a global scale and before a service is made publicly available; it requires a very precise definition of all the details of its operation.

Web services can be called remotely by a defined interface and can constitute part of other Web services or be their composition. These properties of Web services allow on their basis to construct distributed systems and applications. Applications communicate with Web services utilizing Internet protocols and data formats. The protocol most often used for communication with Web services is SOAP, and the best known XML-, UDDI- and SOAP-enabled platforms are .NET and Java.

Utilizing Web services allows the program components to interact via the Internet independently of their location and implementation details. Owing to this, they will be able to replace older solutions designed for private networks, such as CORBA or DCOM, while thanks to their relative construction simplicity they may gain considerably greater popularity.

The mentioned basic features of Web services fulfil a set of essential requirements for an education space and constitute an application environment appropriate for it.
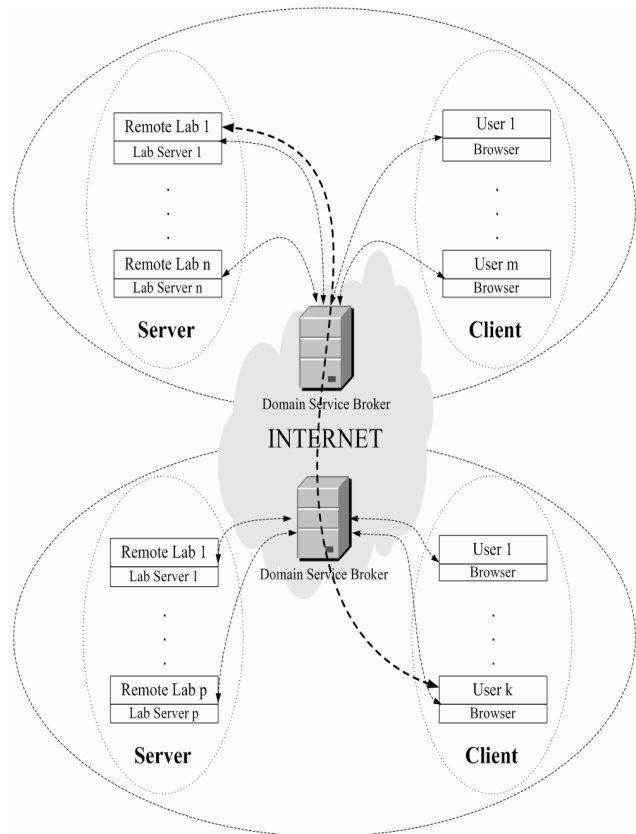

Fig. 3 - Education space ES.

4. REMOTE LABORATORY

In a remote laboratory, each laboratory stand is a computer controlled measurement system (Fig. 4), and after being equipped with a Web camera, it constitutes a client unit (CU) managed by a laboratory server (LS) (Fig. 5).
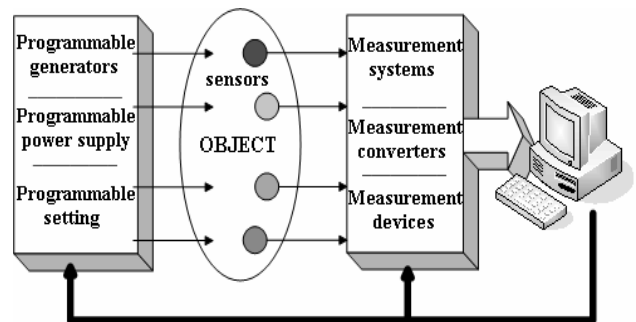

Fig. 4 - General block diagram of a laboratory stand.

A set of a specified number of laboratory stands with cameras and LS constitute a remote laboratory in a given subject. Such a laboratory should also be treated as a CU within an Internet remote laboratory system managed by a service broker (Fig. 3).

At the present stage of IRLS implementation, it has been assumed that a service broker is located on a faculty server, on which an education e-WEIT Portal is installed.
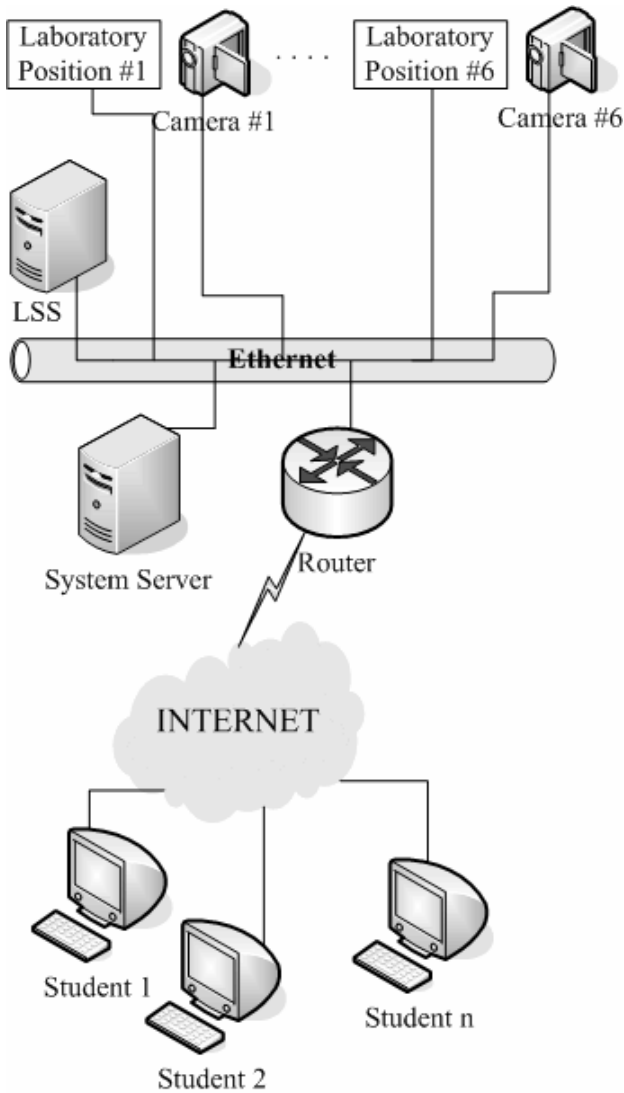
Fig. 5 - Functional structure of an Internet remote laboratory system.

and date from the server. The most important and the most extended class is the Analysis Class. In it, a method is put which launches an executable (exe type) file receiving parameters setting the operation of devices forcing signals fed onto the researched object, collecting samples of the researched object input and output signals, as well as saving the obtained measurement results into an XML format file. In this class, error messages are also generated. Sending a reply to a client (Transport Class) is followed by appropriate calculations on sent in data (Count Class), presenting them in a table (Table Class) and displaying them on a chart (Chart Class).
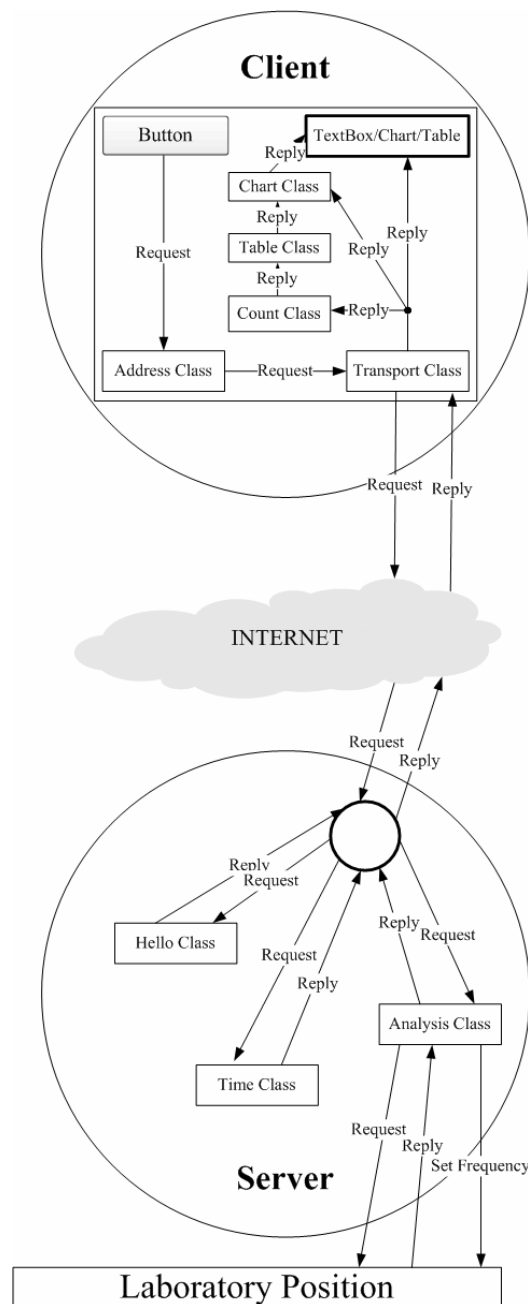
According to the assumed concept of the IRLS structure for data transfer between a student (WWW browser) and a server, the XML technique has been employed. All operations connected with launching and doing an activity are realized according to safety principles required for working on the Internet. A logical diagram of a prepared Java application allowing doing an activity is shown in Fig.6. On pressing any button (in Fig.6 it is symbolically represented as "Button"), an applet communicates with the Address Class, in which the server address is put and the port, on which the server operates. Next, the Transport Class, used for server-client communication, is called. In it, all information needed to establish a connection is stored. A connection is established by means of a local LAN or the Internet. Depending on a chosen operation (button choice) on the server side, one of the three classes is called: Hello, Time, and Analysis. The Hello Class contains a character string connected with welcoming a student. The Time Class is used to take the current time

Fig. 6 - Logic diagram of an application allowing doing laboratory activities in an IRLS.

5. EXAMPLE LABORATORY STAND

A description of remote laboratory functioning is shown on the example of a laboratory stand at the Institute of Metrology. From among a group of 24 laboratory activities available there, the following have been chosen for activities within a distant learning framework:

- Phenomena and Object Modelling,
- Analysis of Measurement Result Accuracy,
- Researching the Static Properties of Measurement Converters,
- Researching the Dynamic Properties of Measurement Converters,
- Digital Voltmeter,
- Rotational Speed Measurement.

The syllabus of the activities mentioned above and their hardware and software make-up allows distant learning to be implemented. Those remaining syllabus activities in which a hand-on approach is required, will be carried out in a traditional way.

To present the functioning of a distant laboratory, an activity titled "Researching the Properties of Dynamic Measurement Converters" has been chosen. In this activity, for the researched converter, an amplitude characteristic is determined. A block diagram of the laboratory stand is shown in Fig. 7.
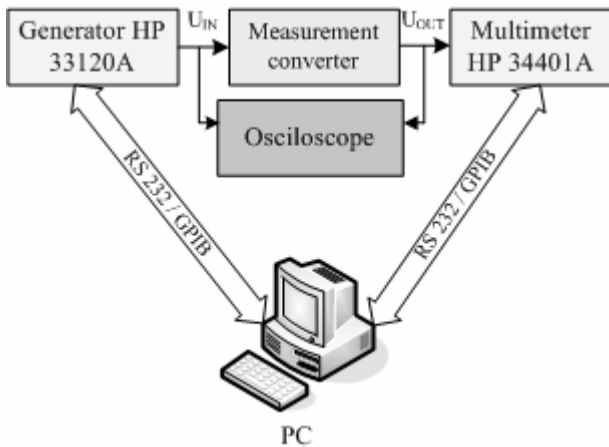

Fig. 7 - Block diagram of an example laboratory stand.

At the earlier reserved time, a student checks in at the service broker via the Internet and selecting an appropriate activity performs it following its framework. On the student monitor, an activity operating panel is displayed, through which an HP 33120A generator (Fig. 8) is controlled. In the Cyclic Measurement Tab, such generator parameters as the sinusoidal signal amplitude, the frequency range and the increment are entered. After launching a command to perform a measurement sequence (Measurement Button), the given voltage values of a sinusoidal signal being an input voltage of the researched converter are automatically, with an appropriate time

interval, set on the generator. For every input signal frequency value, the output signal rms value of the measurement converter is measured by means of an HP 34401A multimeter. The preselected frequency values of the test signal and the results of the measurement of the researched converter output signal are displayed on-line in an activity operating panel. In an adjacent window of this panel, an amplitude characteristic of the researched converter is plotted in real time. On its basis, the student makes a decision whether to supplement the measurement points or to finish this activity part and save the obtained results into a .csv text file, and the characteristic into a .png graphic file. The results constitute a basis for writing an activity report.
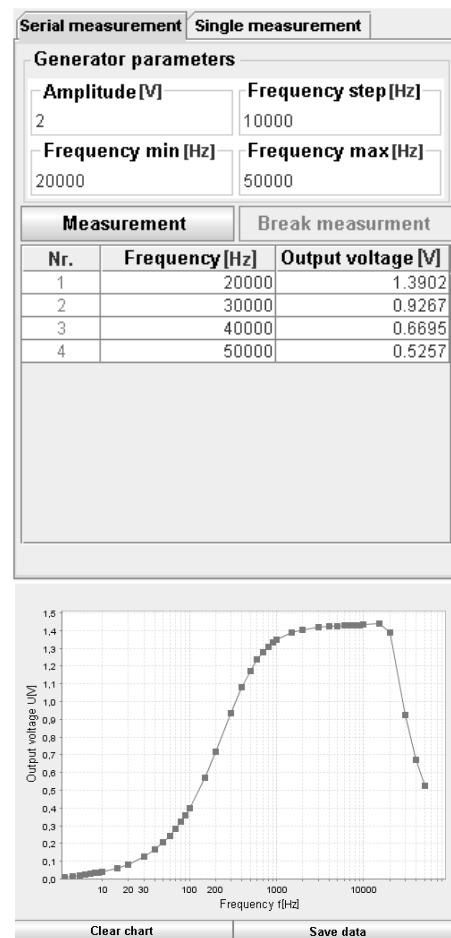

Fig. 8 - Laboratory activity operating panel.

In order to compare dynamic properties of various measurement converters, it is possible for a student to do a further part of the activity for a measurement converter having a different amplitude characteristic. On the measurement stand, there is a Web camera allowing the student to observe the generator and multimeter display panels, as well as a two-channel oscilloscope screen. The camera is connected directly to the Internet, and the image from it (Fig. 9) is on the student's demand displayed on the monitor.
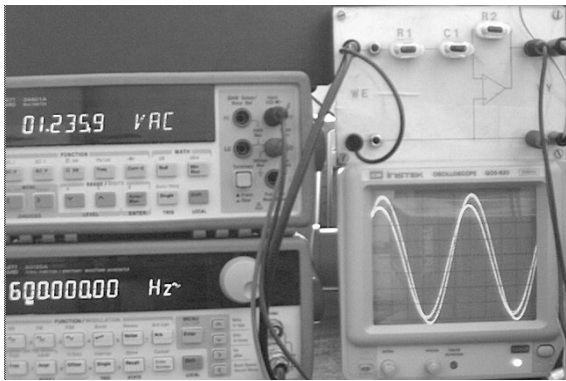
**Fig. 9 - Web camera image of the laboratory stand.**

6. CONCLUSION

An operating condition test of the presented IRLS stand was conducted within the University Network and via the Internet. The most serious limitations come from Web camera image transmission. For the employed camera, providing 1Mbs transfer rate ensures adequate transmission to a student computer.

Currently, work is being done on the improvement of the safety of a remote laboratory, operating via the Internet; on launching another remote laboratory in electrical engineering; as well as on an Internet database allowing, among other things, to reserve the time of performing a particular activity by a student and ascribing the parameter configuration of a researched object (e.g. time constant value) and forcing signals (e.g. signal amplitude, frequency range).

7. REFERENCES

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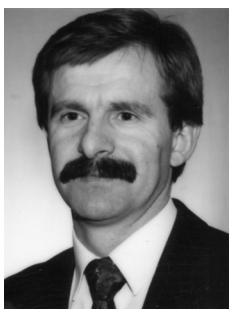
Emil Michta, PhD – *Assistant Professor at the Institute of Electrical Metrology of the University of Zielona Góra. Received a PhD in Technical Sciences from the Wrocław University of Technology in 1989. Participated in internship programs at the University of Minho in Braga, the University* of Bristol, and the Research Center in Haifa. Research interests focus on issues connected with intelligent measurement and control apparatus, measurement and control systems, as well as industrial networks and Internet technologies.

Wiesław Miczulski, PhD, DSc *– UZ Professor at the Institute of Electrical Metrology of the University of Zielona Góra. Received a PhD in Technical Sciences from the Wrocław University of Technology in 1989, and a postdoctoral degree from the University of Zielona Góra in 2002. Specializes in the area of theory and construction of intelligent measurement devices and measurement data exploration, and issues of technological objects and processes. Many of his measurement apparatus projects have been successfully implemented in production. Currently member of the Metrology and Scientific Apparatus Committee of the Polish Academy of Sciences.*

Piotr Powroźnik, *MSc – Assistant at the Institute of Electrical Metrology of the University of Zielona Góra. Graduated in Computer Science at the Faculty of Electrical Engineering, Computer Science and Telecommunications of the University of Zielona Góra in 2004. Research interests focus on the area of building and software of measurement and control systems in technological novelty solutions.*
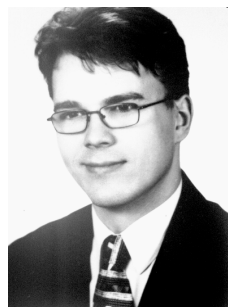
Dariusz Eljasz, *MSc – Assistant at the Institute of Electrical Metrology of the University of Zielona Góra. Graduated in Computer Science at the Faculty of Electrical Engineering, Computer Science and Telecommunications of the University of Zielona Góra in 2004. Research interests focus on the area of wireless communications.*