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REVIEWS - LETTERS - REPORTS

MEASUREMENT ON THE THRESHOLD OF THE THIRD MILLENNIUM

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The advancement of science and technology is matched by a parallel progress in the art of measurement. It is thus axiomatic that sophisticated science and technology are associated with sophisticated measurements, while simple- minded science is associated with only elementary measuring techniques. It can be said that the quickest way to assess the state of a nation's science and technology is to examine the measurements that are being made and the way in which the data accumulated by measurements are utilised.

K e y w o r d s: measurement, metrology, standardisation, virtual instrumentation, distance learning.

1 INTRODUCTION

All of you must have witnessed that some prognoses did not materialise. Not only those forecasting the end of the Earth existence, but also those connected with visions of technology development in a number of areas (outside the areas of space research and computers). Therefore we are not going to hazard a guess of the kinds of new measuring equipment or methods to be invented, or precision of measurement of individual values, but we would like to touch on the importance of measurement in industry, business and science.

Measurement is of importance to industry in all the phases of the production cycle. Starting in research, through quality management to the final quality control. If products are more complex, measurements are necessary also in the stage of their installation. There is a constant demand on quality increase in the existing measurement methods, as well as a demand on development of new methods in areas such as environment, biotechnology, all kinds of diagnostics, or in food quality control. If you are unable to measure, you are unable to produce.

Semiconductor devices reduce their size by a half in about every 18 months. The required resolution capacity of microscopes comes close to the size of atoms. The lifetime, reliability and low consumption of car engines depend on production tolerances, which are in the range of micrometers. This is approximately the size of bacteria. The frequency range and required precision of generating (measurement) frequency and time in (not only) satellite communication systems are of tens of GHz and fractions of microseconds.

Measurement is a basic way of obtaining information in natural sciences. It is a key allowing introduction of automatic control technologies for machine and process control. It is the basic prerequisite for successful marketing. It is a means allowing an increase of safety in all activities performed by people and in quality monitoring. The role of measurement in medical diagnostics and in the choice of medical procedures is increasing as well. Its importance in environment monitoring and protection is undeniable. It is of vital importance for national economy.

Modern measurement technologies arose by integration of different technologies, such as information technologies and knowledge systems, sensor technology, which includes the latest knowledge in physics and chemistry, as well as optical and acoustic technologies application, or semiconductor element technologies.

There are a variety of technologies integrated by the measurement technology, as well as a variety of measurement applications. It may imply that measurement is an area of technology with apparatuses randomly linked to different methodologies created as a by- product of research in basic sciences, or that these technologies arouse as an incoherent array of data obtained from individual applications. This attitude towards measurement technology might have been true in the past, but not today. Modern measurement technologies are based on sensible construction of apparatuses and systems by using the latest support means. They are based on the principle of association of apparatuses and methodologies suitable for individual applications. There is a wide range of generally applicable measurement methodologies and ways of data and equipment evaluation. Technologies created for partial needs can be used in a wide spectrum of tasks for different kinds of customers.

Measurement technologies are scientifically grounded on the fact that measurement is perceived as an information process and measurement equipment as an information engine. This knowledge follows from the concept and principles of information theory as well as knowledge and system engineering. This results into a need of a systematically organised knowledge database of methods and solutions used.

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In the industry, engineers have to face working with rather outdated technologies. But if the level of our products is to be raised so that they can stand competition, introduction of the top measurement technologies is inevitable.

2 MEASUREMENT AS A PART OF SYSTEMS OF QUALITY

Experience shows that it is rather hazardous to understand measurement only as an "inevitable evil" lurking at the end of a production cycle. Then the role of measurement is seen only as a means of control of the final product quality (as for standards or legislation) and not as an integral part of planning and realising of the whole production cycle. Only in the latter case, it can bring about progressive technology and strategic benefits. The increase of complexity of systems produced requires an increase of demands on the quality of produced parts *(components)*. Thus the precise measurement of final quality parameters of technological operations and a successive selection of semi-finished products become absolutely inevitable.

The complexity of modern power, automation, computation, telecommunication, radio-communication and other systems requires development of new measurement, diagnostic and testing methods. These should be used to check if the systems work properly and really have the required features (specifications of performance). Technical or program measurement modules are necessary components of each of such complex systems. Their role is to keep these systems running or to diagnose possible problems and their causes, again either of technical or program nature. When a high performance system is required, a more sophisticated approach is necessary. The automated test and measurement system performance depends not only on the used hardware but on the software as well. Comparisons (comparative measurement) of computation technology or of software used become also a subject of great interest.

The above check up of systems meeting the features required excludes just those characteristics which are directly related to the purpose of the product usage, as well as all those features which might negatively influence the environment where the product is to be used, and also those features which might, even if indirectly, lower the quality (*eg* by reliability decrease) of the product. A typical example can be electromagnetic compatibility of electrotechnical products. It is a field of study applying basic physics to complex electrical and electronic systems with the aim of enabling them to co-exist harmoniously. If this is achieved then they perform their tasks in a satisfactory manner. The requirements on electromagnetic compatibility, created by the European Union legislative regulations, as well as individual European Union members' legislative regulations, result in a necessity of introduction of such regulations also by Slovakia. They should be applied not only in the development stage but also in the production cycle of more complex products. There is a requirement of extending the mass of production and at the same time decreasing the cost of such measuring and other systems.

3 ADVANCES IN METROLOGY AND LEGAL ASPECTS

Research in primary metrology is motivated by a constant need of correct and effective measurements in science, technology and international trade. Here we deal with areas of primary standards, measurement methods, apparatuses and systems. Today, there is an obvious attempt to switch from the "classical" measurement standards made up of prototypes (*platinum-iridium bar, Weston cell, etc.*) to the realisation of standards based on essential physical constants (velocity of light, Josephson's effect, ...). In some cases metrological research led to new physical discoveries. Due to this fact, it is possible to improve the uniformity of measurements in international scope, abridge the traceability and offer quality standards and measuring apparatuses directly to production, or as components of measuring and other systems.

Further expansion of world trade requires effectual employment of local metrology institutions to ensure global uniformity and correctness of measurements. Instead of costly and lengthy international comparisons of all the entities in all the ranges, an association of individual laboratories formed by a network of local institutions, linked by key comparisons, can be insured.

To overcome obstacles in international trade it is not sufficient "merely" to allow access and uniformity of measurement in different countries. At the same time, it is necessary to produce a sufficient number of international technical standards and harmonised regulations, and to make agreements on mutual recognition of measurements which would lead to obtaining the status: "Once measured — far and wide accepted".

In Slovakia a law dealing with technical requirements of products and testing has been prepared. By this law the recent Slovak national testing system will come to terms with the law requirements of EU member countries. This law shall protect citizens against products which may have harmful effects on their lives, health or property. It has to be done mostly by a market inspection system which at the same time will allow Slovak producers to export goods to EU market with a less complicated administrative procedure which will simultaneously decrease export costs. On the other hand, the law will force the producers and importers to assess how their products meet the given requirements. Declaration of conformity issued by the producer together with the law regarding responsibility for the damage caused by a faulty product makes producers and importers more responsible for the safety of their products. At the same time it offers a means of detecting the producer or importer. Most duties allocated by the law to the producer and importer also apply to the distributor.

The above law gives more responsibility to the producers, importers or salesmen for the goods which they produce, import or sell. This will require a higher standard of their testing (measuring) equipment and personnel. In fact this results in the highest working load of producers. Small and medium enterprises may be in a need of funding by the state to cope with the requirements on metrological and testing equipment used in their production process.

4 TECHNOLOGY AND VIRTUAL INSTRUMENTATION

The development of technology, above all microelectronics, has lead to the enhancement of measuring apparatuses parameters such as miniaturisation, increase of speed or frequency range, digitalisation of measurement and their user friendliness. It has given rise to fundamentally new approaches *eg* to construction of oscilloscopes, signal generators, and counters, as well as to new measuring apparatuses for telecommunication, computer networks, diagnostics and detection of failures in power engineering *etc*.

The computer revolution is driving a change in what is considered to be an instrument. The availability of low-cost, high-performance computers, along with advanced software and graphical user interfaces, allows users to emulate and even surpass the capability of traditional instrumentation. Instead of boxes, each representing the unique personalities of a traditional instrument, basic measurement function can be supplied on printed circuit boards, which are inserted into an extension box or the computer itself. There are no buttons, knobs, or sliders to control the measurements. There is no room. And there certainly is no room for dials, readouts, CRTs, or other displays. Instead, the computer emulates the front panel of an instrument through advanced graphical displays while the user controls the instrument through the computer's standard interfaces, such as a keyboard, mouse, or touch screen. The software may do as little as displaying a traditional front panel on the computer's display, or it may emulate the entire personality of several complex instruments, reconfiguring the plug-in measurement cards to acquire the necessary data. In either case, this capability of using graphical software and a personal computer for the processing and display of measurement results has been referred to commonly in the industry as "virtual instrumentation".

From among the economic factors that influence the measuring technology, we would like to mention the formation of the free energy market in some European countries which has initialised development of theoretical works and development of measuring apparatuses and systems to measure the electric power quality. Most of the notions used in this area have been known for some time. Still only the economic reasons will move the not much appreciated theoretical or even 'academic' works to a very realistic platform.

From what we have just said may follow that the fast development of measuring and computer technology may only be envied and observed in Slovakia, but the situation is not so simple. Even if the more complex and 'intelligent' measuring apparatuses and systems offer new opportunities, very frequently only educated and skilled operators can appreciate their real potential, choose the appropriate apparatus from the wide range offered, make overall design of measurement process, evaluate the measurement results and take steps meeting the aim of measurement. There are new tasks the existing hardware still can cope with. However it is necessary to upgrade it with a new program, creation of which is neither easy nor unambiguous. Assessment of uncertainties in measurement results has become a part of many measurements. Although the definition of measurement uncertainty is simple, its practical calculation very much depends on the kind and required quality of measurement as well as on experimentator's skill and experience. There is still a lot of work to be done in this area. Internet is not merely an information highway. The rapid growth of Internet applications greatly changes the appearance and operation of industrial and commercial products in many aspects. Modern instrumentation integrating control, communication and measurement for laboratory or factory automation will ultimately be dependent on its Internet technology base.

Instrumentation, interaction, and virtual environments provide a challenging triplet for the next generation of instrumentation and measurement tools. As such, they are the logical continuation of an increasingly important software component within (virtual) instrumentation. Despite these changes, however, the measurement paradigm remains unaltered. This might be the proper platform to structure this new development.

To make this triplet a ready-to-use tool, a substantial software effort will have to be undertaken. The past has shown that unless proper standards are available, diversification due to ad-hoc solutions will slow the progress in the field. Thus, it seems a proper challenge for the next millennium to start thinking about standardisation of virtual instrumentation and virtual environments.

5 INSTRUMENTATION EDUCATION

That is why also in the coming millennium there is an important role of education and explanation of the role of measurement and metrology in economy. Due to the complexity and interdisciplinary character of this area, 'a driving licence in measurement' must become a part of training in all the (technical?) areas of human creative activity. The mass production of books has brought education to many and provided the means for the system of mass education we have today. Now, at the dawn of the information age, available infrastructure and technologies are well poised to bring education to everyone in such a way that the individual can take more responsibility for his/her own learning and achieve independence of thought and action. Information technology (IT) will propel conventional education systems to a form that is more learner-centred, case-based, contextualised and democratic.

The Internet is the world's largest, most powerful computer network, connecting personal computers, sophisticated mainframes, and supercomputers around the globe. The World Wide Web (WWW), as the fastest-growing Internet service, is seen as an effective tool for distance learning. The WWW project seeks to build a "distributed hypermedia system". In essence, the Web is a vast collection of interconnected documents, spanning the world. It provides Internet users with a uniform and convenient means of accessing the wide variety of resources (pictures, text, data, sound, video) that are available on the Internet. Popular software interfaces, such as Internet Explorer and Netscape, facilitate navigation and use of the Web. In effect, the Web is a distributed multimedia environment, which potentially can provide a truly integrated teaching and learning environment.

Most distance learning facilities developed so far are focused on online lectures and tutorials. Most of these can be presented as text-based materials and sent across the Internet easily. This paper explores the wider territories of executing a laboratory session via the user- friendly Web browser environment. In a sense, the user is controlling a piece of laboratory equipment at a remote location and recording real-time experimental data via the Web browser.

Although virtual experiments have been reported before, they have mainly involved a digital or analogue interface to the pilot plants used in the experiment. As a result, the typical virtual experiment set-up has been mainly one plant per experiment. A practical session on instrument control using a bus-based input/output (I/O) system over the Internet will be developed through the setting up of a virtual laboratory session. The General Purpose Interface Bus (GPIB), a well-know parallel bus interface, is used as the medium connecting several instruments. Unlike many virtual experiments in which only the control parameters are communicated between the server and client, it is possible to patch up the entire control algorithm at the client end and run it remotely at the server. The objective is for the user to be able to control GPIB devices from a remote location and to obtain data from them using a Web browser. This approach can easily be extended to monitoring and controlling production processes via the use of GPIB instruments in real production plants.

6 CONCLUSION

The role of this article was not to make a detailed analysis of problems in measurement and measurement technology. Our aim was to evoke ideas which would bring you to a deeper analysis of the measurement process that you will inevitably need to be faced with in your work.

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