STUDIA INFORMATICA 2001
Volume 22 Number 3 (45)

Rafał DUNAL
ESA s.c.

COMPUTER SYSTEMS FOR MONITORING PARAMETERS ASSOCIATED WITH NATURAL ENVIRONMENT PROTECTION

Summary. The article focuses on a general structure and tasks of monitoring systems as well as basic stages of their creation. Selecting equipment and its influence on the functioning of a system whose aim is to collect and process data describing changes in natural environment and traffic on chosen road sections is also discussed.

KOMPUTEROWE SYSTEMY MONITORUJĄCE PARAMETRY ZWIĄZANE Z OCHRONĄ ŚRODOWISKA

Streszczenie. W artykule omówiono ogólną strukturę i zadania systemów monitorujących wraz z podstawowymi etapami ich tworzenia przez firmę programistyczną. Poruszony został również problem doboru sprzętu i jego wpływu na funkcjonalność systemu, którego zadaniem jest gromadzenie i przetwarzanie danych dotyczących zmian obserwowanych parametrów środowiska naturalnego i ruch na wybranych odcinkach dróg.

1. Introduction

In the times in which almost each of us, consciously or unconsciously, has at least one microprocessor-like equipment in a household, computer systems for monitoring natural environment appear as a fact. Advanced technologies and computational power of the present-day computers enable in real time to collect and process data that allow for effective supervision of area subject to monitoring system. Still, even now such systems are not free of problems that will grow as government organisations and private companies are more and more interested in them.

I will try in this article, at least partly, to describe general structure of such systems and characterise mechanisms operating in them. Opinions presented here are based on observations made during my work on creating and modifying the system of Eco series in the Italian company Project Automation and the RWIS roads monitoring system, software for which was created by Esa company.

2. Functions and parameters of the system

2.1. Selection of parameters

What do we intend to monitor? When designing computer system that is to monitor a desired area, many persons ask themselves, or, at least should ask this question. Of course, the first step is to choose the parameters that can be measured by means of available electronic equipment, from which data is taken directly into a computer system. At present, practically each system has a wide range of measure instruments it can co-operate with. Some of them are specialised systems that collect data concerning e.g. air pollution only. Others, more universal, allow for monitoring a series of completely independent factors. Most specialised systems have better possibilities for processing and presenting collected data than their more universal versions but they are usually less scalable.

While choosing a set of parameters, the changes of which are to be monitored, much attention must be paid to the sampling frequency available by an offered computer system. It is particularly important when analysing continuous events, e.g. in examination of atmospheric phenomena. Depending on speed and change frequency of a given factor, time slice between the consequent samples must be chosen in such a way that the received results would be representative samples describing actual changes.

In case of Eco systems the main task was to collect information concerning chosen air parameters within an examined area (at present this system is being adjusted to water monitoring as well). Basing on information received from EcoRemote station an alarm that informs about smog occurrence in the Milan area is activated.

RWIS system is responsible for collecting data that describe conditions on chosen road sections. One of its most important tasks is to inform traffic services about glazed frost. This kind of information proves very well the need to use several instruments in system's input, on the basis of which „moderate" number of very important output information is received. Both systems input and output information are presented in Figure 1.

In both cases the systems were destined to analyse events occurring at chosen points, situated usually within a radius of several dozen kilometres. Such localisation is conditioned

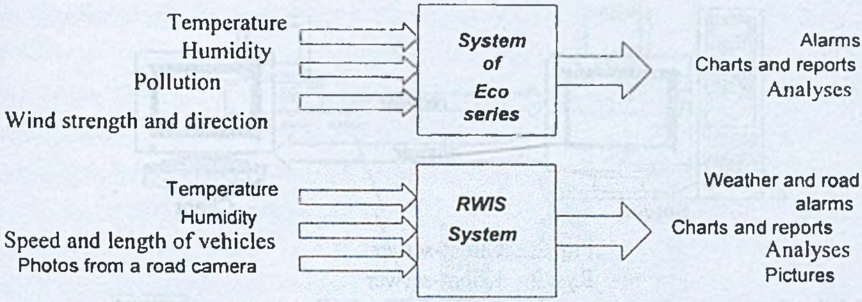

Fig. 1. Exemplary input and output data of monitoring systems

Rys. 1. Przykładowe dane wejściowe i wyjściowe systemów monitorujących

only by organisational structure of services that use these systems. The reaction time for occurrence of certain events within a given area is often a very important element. From the system's point of view a distance does not influence its functioning and received results.

2.2. Client – server technology

Computer monitoring systems are mainly sets of computers, equipped with measure instrumentation, which collect, process and exchange data among themselves. Such a structure perfectly fits technological guidelines of a client-server type, which divide computers into computers performing services and computers using the services. Obviously, in a real system, such a division often fades away and some computers function both as clients and servers.

In case of systems monitoring parameters that describe natural environment protection, computers that are located within a given area act as servers for data received from measure instruments. Computers that function as centres become their clients at the same moment they are connected to them in order to acquire data for central databases, collected in measure stations. Situation is different when it is a measure station that initialises connection with the centre and sends e.g. an emergency information. Generally speaking, the party that starts connection in order to exchange information is a client, who is connected to a listening server. However, the division is not directly visible for an average system's user. Nevertheless, it is necessary for an administrator responsible for proper work of the whole system to be aware of such a division when single computers are configured. Suitable selection of tasks performed by single parties enables to optimise the system as far as the amount of data sent via net and load of machines that work in a system are concerned.

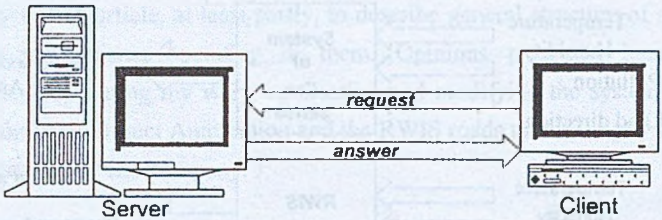

Fig. 2. Client-server
Rys. 2. Klient-serwer

"My" systems use the presented technology practically at every step. It has, among all, a great influence on modular structure of monitoring programmes, which will be presented further. It allows several clients for simultaneous access to chosen resources without the necessity of activating next instances of the same programme, which would cause unnecessary overloading of processor and computer's memory.

2.3. Communication

Undoubtedly, the key element of each monitoring system is communication between its single elements. Only properly working data exchange ensures that user's work with the system to be highly comfortable and guarantees the information taken from measure stations to be reliable and up-to-date. Selection of a suitable way of information exchanged is conditioned mainly by localisation of particular measure stations within an area as well as by the size and type of exchanged data packet.

The following methods of communication between the system's centre and monitoring stations can be used:

- **commutated phone connection** – the solution used most often, enables the stations to be situated within an area restricted only by access to phone lines (or cell phone base stations). This method turns out to be useful in systems in which time of centre-stations connections is much shorter than the time in which the system works in an off-line mode. Most operations are performed in measure stations which collect data that is preliminary processed before being sent to the centre.
- **rented phone lines** – method practically equivalent to the one mentioned earlier but used mainly in solutions that require constant (or often long-lasting) connection between the centre and the stations.

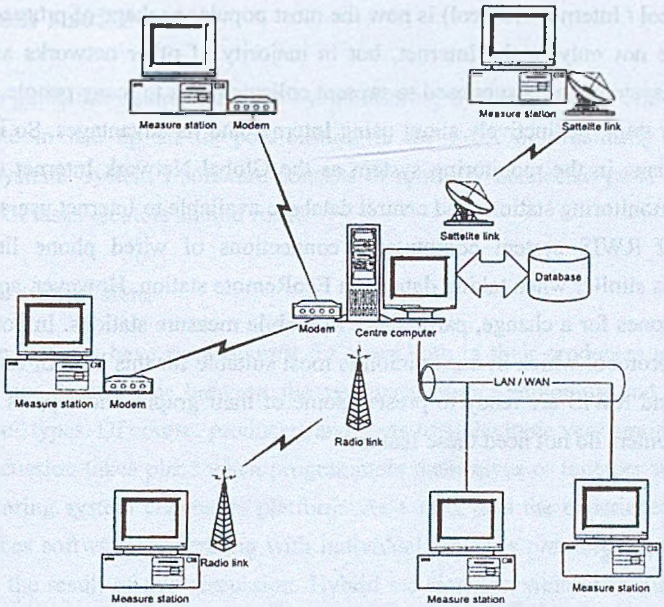

Fig. 3. Methods of communication between the centre and measure stations
Rys. 3. Metody komunikowania się centrum ze stacjami pomiarowymi

- **computer network** – depending on the monitored area it can be network of LAN type for small areas or WAN type for monitoring of e.g. the whole country. The solution rarely used because of quite a big effort and high cost born at creation such a network. Well-created network ensures high speed of data forwarding but it is usually difficult to extend, since new stations must be located in places having direct access to means of transmission.
- **ground radio connection** – the solution allowing for data exchange via radio waves. This method, depending on frequencies used, emission type, power of emitters and applied antennas, enables to transmit data between the stations less or more distant from each other. In most cases radio connections require suitable permissions (in Poland issued by Public Radio Agency).
- **satellite link** – method used only when monitoring vast areas, where equipment of other types cannot be used. A very expensive solution that depends on covering a given area by telecommunication satellites.

Some computer systems use hybrid solutions e.g. they use simultaneously two or more of the mentioned solutions.

Regardless of the chosen method of communication their main goal is to maintain quick data exchange without errors. Having a proper data exchange, designers of media system have to choose communication protocol that can meet users' requirements. TCP/IP (Transmission

Control Protocol / Internet Protocol) is now the most popular package of protocols because of its wide usage not only in the Internet, but in majority of other networks as well. While designing any system that is supposed to present collected data to many people, programmers sooner or later think instinctively about using Internet and its advantages. So if they use the same mechanisms in the monitoring system as the Global Network Internet uses then it is easy to make monitoring stations and central database available to Internet users.

In case of RWIS system commutated connections of wired phone lines are used. The situation is similar when taking data from EcoRemote station. However, some customers use mobile phones for a change, particularly in mobile measure stations. In both systems we used TCP/IP protocol which in our opinion is most suitable for this kind of monitoring jobs. EcoSystems and RWIS are ready to present some of their graphs and reports on web pages but some customers do not need these features.

3. Hardware

The selection of well-cooperating computer and measure equipment lays the foundations of a good monitoring system. Practically, the construction of each system starts from it. When we select the equipment with which our system is going to work we can divide it into two parts: of purely "computer" character (computers, monitors, modems, etc.), and of measuring type. While choosing a computer we can decide on a "civil" version (e.g. computers that are present in most offices), or specialised industrial computers (e.g. products of Advantech company). Specialised computers are characterised by higher resistance to changeable weather conditions, have case amplifiers, together with embedded air filters as well as mechanical locking of various types. This equipment is accordingly more expensive and not every company decides on such a solution.

What counts most while selecting measure equipment is interface effectiveness of a given device and the range of equipment offered by its producer. It is generally advised to use measure equipment of one producer since it has one standard protocol of data exchange between the instruments and a computer. It makes it easier for a programmer to create universal methods of access to the data collected by measuring equipment.

In some cases companies that create monitoring system are forced to use the equipment that a customer already possesses, which definitely restricts the space for displaying possibilities of its creators. Such a situation happens mainly in companies that try to minimise the costs of the whole project, which usually has a negative influence on the whole system's effectiveness and is often the reason for its unstable work.

4. System's software

However good the equipment used by monitoring system is, only effectively working software, able to use up all its possibilities, is the heart of practically each computer monitoring system. System's software consists of mutually connected parts the selection of which is one of tasks creators should fulfil.

4.1. Operating system

Operating systems have risen interest for years both in their producers and users. There has been a long-lasting war between the potentate from Redmonton and the systems of "Open Source" types. Of course, producers and users treat the topic very emotionally as well.

Main discussion takes place when programmers themselves or together with future users of the monitoring system choose its platform. As a rule, it is the experience of a company which produces software cooperating with individual system's platforms that has a decisive influence on the result of this discussion. Hybrid solutions, in which measure stations work under control (often not user-friendly) of real time systems (e.g. RTX DOS, Real 132) and central computers take advantage of systems with extended graphic user interface (e.g. Windows, some distributions of Linux) can be also applied here.

It is difficult to decide which solution is the best one. Practically each system, which is to monitor several fast-changing processes, must be multitasking and quick. If any of these basic premises is not fulfilled we cannot expect that software created for such a system will meet the requirements of its future users. The next criterion for selecting operating system is its availability for drivers of measure instruments, with which monitoring software will communicate. Most measure instruments use serial link RS-232 for exchanging data with a computer but instruments that require higher speed of data transmission have their own cards stuck directly into a computer.

Undoubtedly, a significant advantage of each operating system is its ability to start itself after computer restart. It cannot happen that e.g. as a result of break in a power supply the system, without user's help, is unable to activate all modules necessary for proper work of a whole measure station.

The systems managing the work of centres do not have to be so free-service since they are usually in continuous administrator's care, whose main task (and sometimes the only one) is to take care of a proper work of a system. In this case, however, great emphasis is placed on a friendly graphic interface, which enables a person unfamiliar with a computer to use the system (e.g. workers of traffic service supervising conditions on roads).

Table 1

Requirements for operating systems

Requirements for SO measure station	Requirements for SO centre
• High stability of work • Multitasking • Service of specialised cards for measure equipment • System's ability of self starting after computer restart • Ability of remote administrating the system	• Good graphic user interface allowing for presentation of collected data • Possibility of cooperation with database servers • User-friendly in service • Controlling user access to system's options, the system of user accounts together with passwords.

Systems discussed by me use at present Windows NT 4.0 platform, although older versions of EcoRemote measure stations use RTXDOS system. Certainly, some modules of centre service can work also under the control of Windows 9x, though it is not advisable because of much less stability.

4.2. Database

Data collected from instruments and forwarded to the centre should be somewhere stored. It is the moment at which the system needs database. Of course not all information is saved in a database e.g. current measurements, which only enable a user to estimate conditions existing now at a station, are not saved. It does not however change the fact that a database is the heart of each monitoring system and its effectiveness depends to a great extent on its speed and capacity.

We use practically two types of databases in the discussed systems, which are local databases situated at measure stations and databases situated in the centres. Such a division is necessary since there is usually no continuous connection between measure stations and the centres. Data are collected currently at local stations, and then, after some time, forwarded into the central station. Such a solution allows for preliminary processing of collected data and forwarding to the centre only the records it is interested in. In such a situation it is necessary to ensure a proper updating of the central base with records collected at individual stations. Otherwise some information can be lost as a result of e.g. overwriting it with new records or deleting by an operator of a different centre.

Designers of monitoring systems that choose databases use one of the two solutions:

- the same type of database in a measure station and central station,
- small and cheap databases in measure stations and effective database servers in a central station (solution applied in Eco and RWIS systems).

The first solution is good for systems in which a number of records collected in a station's database is comparable with a number of data stored in a central computer. Such a situation happens very seldom since, by definition, a number of records stored in a central station is a sum of data collected by single measure stations. Undoubtedly, this solution has one advantage, it is easier to transmit data between databases. From a point of view of programmers creating software for computers at stations and centres, it is possible to use the same methods of access to a database and identical functions of reading/saving records (e.g. the same SQL statements in case of relational databases are used).

However, using the same types of databases is not a good idea when it is necessary to use expensive and very effective database servers (e.g. ORACLE Server, Sybase Server) for at least one computer. In such cases the price of enterprise rises rapidly because, firstly, one must bear the cost of licence for each computer working in a system in which a database is installed and, secondly, a computer must have accordingly more memory and a better processor.

Programming companies prefer using different types of bases for storing data in a central and measure station. Free databases (e.g. .mdb files of MS Access) are often used in measure stations in order to lower the cost, or individual mechanisms of data storage are used. Another solution is to use cycle binary files, to which previously defined number of records was ascribed. Access to data collected in files of this type is fast (particularly saving) but data selection together with an extended list of preliminary conditions require from programmers more work at the designing stage. The mentioned cycle character of files is connected with a fact that time and number of data stored in stations are usually limited. If information stored in a database is no longer necessary for further calculations it can be deleted just after it is imported to a central computer. However, gradual replacement, starting from the oldest, is more often used than deletion of all taken records.

In some huge systems it is recommended to consider using datawarehouses which will allow their users to have very quick access to tentatively processed data, especially data which users need most often. This problem usually exists in systems responsible for monitoring wild geographical areas. For this kind of computer monitoring systems it is usually necessary to exchange huge amount of data between local centres' databases. To maintain satisfying data transfer in such an extensive system designers should create a fast network that will connect all central computers.

4.3. Monitoring programme

Having defined operating system and databases we can start to create application that collects and processes data. The elements mentioned above can be similar or even the same in different systems, but monitoring application is this part that is practically different for each producer.

The first, and for some users the most important, difference between systems offered in a market is a graphic user interface of these applications, via which a system's operator communicates with its single parts. Similarly as it happens in operating systems here as well producers decide to use textual or graphic mode. An outlook of an application itself is to a great extent determined by programming tool by means of which it was created, and operating system under which it is supposed to work. In case of RWIS system graphic user interface (GUI) was written in Delphi (Borland), while Project Automation company uses programming environments offered by Microsoft such as: Visual Basic, Visual C++ and Access. A well-designed GUI together with a properly prepared user manual can satisfy an average user, who often takes advantage of only some functions offered by a programme. Other modules can (and sometimes even should) be invisible for such a person.

Depending on the complexity degree and programmers' favourites a number of remaining modules can be very different. Dividing tasks into single sub-tasks is used mainly in measure stations, which must perform many, often various tasks, at one time. The main advantage of such a division is the fact that in case an error occurs, causing one of modules to be closed, other can still work.

In systems I got familiar with the problem of simultaneous performing tasks was solved by applying many processes and threads. The structure presented in Figure 4 describes control of managing single elements of monitoring programme, which is aimed at making sure that each of them works properly. The figure shows only connections (e.g. by means of socket or pipes technologies) between supervising process and other modules. Connections between modules also occur in a system.

The main task of supervising programme is "asking" subordinate units throughout a given time period and checking whether a chosen programme works properly. Each module has implemented mechanisms that allow receiving remote commands. When a user closes the whole programme, it is actually a supervising programme that is responsible for sending suitable commands finishing single processes. It is particularly important in case of programmes in which what counts is the sequence of closed tasks.

Remaining tasks of monitoring system are, first of all, counting and presenting collected data. Counting data is aimed at obtaining more reliable statistical data, which can mirror a set of processes occurring within an examined area. The second aim is to eliminate an

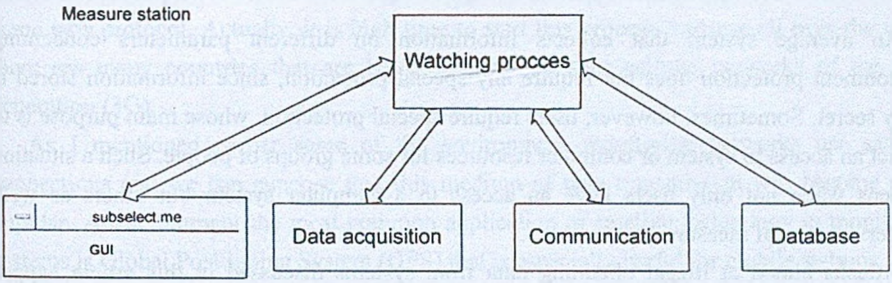

Fig. 4. Monitoring of single modules
Rys. 4. Monitorowania poszczególnych modułów

excessive number of records stored in a database. One of the methods is calculating hourly average and then, on their basis, an average for single days. Such prepared data enable to create weather forecasts and long-lasting analyses. Basing on them a system can prepare charts and reports of various types. By means of their generating a user can define initial conditions such as e.g. time periods or reference point for performed measurements.

4.4. Programmes working in centres

This part of software is usually less complicated than the one directly responsible for collecting data from instruments, but sometimes it is the only part of the system known by most of its users.

Programmes working in centres are mainly responsible for:

- getting data from remote stations,
- a data visualisation,
- remote configuring monitoring stations.

In big systems there should be possibility of simulating data transfer from one centre to another one in standard 'centre-station' mode. In this situation the slave centre is being treated the same as remote monitoring station. This mode is implemented in EcoSystem and it is used during getting data from dependant networks.

This software must take all advantages of the operating system GUI to ensure optimal data visualisation and easy operating of all system's functions. To achieve best results, software designers use tools that easily allow creating professional user interfaces, even if they cannot be used for complicated multitasking programmes.

5. Problem of system's safety

An average system that collects information on different parameters concerning environment protection does not require any special protection, since information stored is rarely secret. Sometimes, however, users require special protection, whose main purpose is to restrict an access to system or computer resources for some groups of people. Such a situation happens when not only users have an access to a computer system but others as well, e.g. servicemen of measure instruments.

Attacks aimed at illegal obtaining data from systems discussed in this article happen rather seldom. Such a problem can occur in systems that monitor e.g. areas important for country's defences. In such cases, however, specialised software and equipment are applied, focussed on full protection of collected and forwarded data. In most normal systems basic protection is used, offered by operating systems and databases. It is an administrator who is responsible for confidentiality (if required) of data sent via net. Of course, producers of computer equipment help in this domain as well since the range of various protection means is bigger and bigger each year.

In systems monitoring parameters connected with natural environment the problem of safety has also the second dimension. It is the problem of influence that measurements received from instruments have on subsequent steps taken by special services. Let's imagine the situation in which a smog alarm for a big urban agglomeration is announced, as a result of falsely read or intentionally falsified values concerning air pollution. The cost of such an event can be extremely high, and the higher probability of this situation is the fewer protections are used in a system. Unfortunately, modules that protect a system are the next position where customers search for savings. But as it turns out in case of emergency the money is saved only apparently.

6. Future trends?

Basing on our present knowledge about the progress of almost all computer systems, which took a place during the last twenty years, we can be sure about their future. In my opinion, computer systems performing any kind of monitoring tasks will mainly increase their own speed, capacity and precision. It is certain that they will be more and more integrated with Internet or there will be a world-wide network created, connecting different monitoring systems. I hope that some open-source monitoring systems will enter the market so that the cost of such a system will decrease without loosing its functionality.

Probably future systems will become more integrated with cellular networks and each user of a mobile phone will be able to get a required piece of information via his/her WAP or some new protocol. Actually, it is high time to start this process, because all over the world there are many countries that are being prepared to start cellular networks of the third generation (3G).

As I mentioned earlier some of the environment monitoring networks use satellite connections and we can suppose that this medium of data transmission will become more popular. At the moment the most common application of satellite technology in monitoring systems is Global Positioning System (GPS) that is especially useful for mobile stations.

As far as roads monitoring is concerned, in my opinion, cars' producers are going to produce cars in which computer systems will be installed in all models. That will allow all drivers to get continuous access to information about weather and traffic conditions on main roads.

7. Conclusions

General structure of systems that monitor parameters connected with natural environment protection presented here surely does not reflect all aspects of such systems. In practice many of them have unique solutions which make it better for a certain type of measurements. It is very difficult to perform direct comparison of available systems because solutions applied in them by various companies are kept in secret. Systems created by one producer apply similar, already checked, solutions.

Undoubtedly, lack of defined standards concerning format of data stored in database is a problem. It prevents exchanging information between different systems and makes it unavailable for e.g. specialised Internet portals.

Despite these problems monitoring system surely have a rosy future since an issue of polluted natural environment is still growing. Fortunately, more and more people realise that extended systems which monitor phenomena occurring in our environment become a very powerful tool that enables the man not only to examine but also influence them.

BIBLIOGRAPHY

1. Documentation of RWIS road monitoring system by ESA s.c. and Optimus S.A.
2. Documentation of Eco series systems by Project Automation S.p.A.

3. GEMS Monitoring and Assessment Research Centre, United Nations Environment Programme; UNEP, World Resources Institute; WRI. 1988. United Nations Environment Programme environmental data report. London: Basil Blackwell.
4. Project Automation web site – http://www.p-a.it .
5. United States Environmental Protection Agency web site – http://www.epa.gov .
6. American "Road Weather Information System" web site – http://rwis.th.gov.bc.ca .

Recenzent: Dr. Mauro Cislaghi

Wpłynęło do Redakcji 2 marca 2001 r.

Streszczenie

W artykule zostały przedstawione poszczególne elementy, fazy tworzenia i sposoby wykorzystywania komputerowych systemów monitorujących. Opinie w nim przedstawione oparłem na obserwacjach poczynionych podczas mojej pracy przy tworzeniu i modyfikowaniu systemu serii Eco włoskiej firmy Project Automation S.p.A. oraz systemu monitoringu dróg RWIS stworzonego przez firmę ESA s.c., której jestem pracownikiem.

Systemy monitorujące to przede wszystkim komputery uzbrojone w wyspecjalizowane urządzenia pomiarowe, które zbierają dane z monitorowanego obszaru oraz komputerowe bazy danych i stacje robocze znajdujące się w centrum, gdzie z reguły przeprowadza się analizę i prezentacje wyników (rys. 1). W zależności od zadań pełnionych przez dany system monitorujący stosowane są różne metody komunikowania się komputerów centralnych ze stacjami pomiarowymi umieszczonymi w terenie (rys. 3). Komunikacja taka oparta jest na technologii klient-serwer, w której poszczególne komputery, w zależności od akurat realizowanych zadań, mogą pełnić rolę zarówno klienta, jak i serwera.

Dobrze zaprojektowany, zarówno od strony sprzętowej, jak i programowej, system potrafi dostarczać użytkownikom kompleksowej informacji na temat monitorowanego wycinka rzeczywistości. Zespół programistów musi w pełni poznać możliwości instrumentów pomiarowych oferowanych przez producentów tego typu sprzętu, ze szczególnym zwróceniem uwagi na interfejsy, poprzez które komunikują się one z komputerem. Konieczne jest dostosowanie poszczególnych modułów oprogramowania do zadań przez nie pełnionych oraz wybranie platform systemowych wraz z odpowiednimi bazami danych. W systemach badających procesy szybkozmienne konieczne jest odpowiednie dobranie czasu pomiędzy kolejnymi próbkami, aby uzyskane dane obrazowały faktyczny stan rzeczywistości.

Problem monitorowania wybranych parametrów związanych z ochroną środowiska na pewno nie zostanie rozwiązany poprzez stosowanie nawet najlepszych systemów komputerowych. Mam jednak nadzieję, że poprzez ich popularyzację, coraz więcej instytucji państwowych i prywatnych postanowi zainwestować w tego typu systemy, co z pewnością przyniesie korzyść nam wszystkim.