Computer system of monitoring and forecasting of water level in rivers

M. Horbiychuk*[1], M. Shufnarovych[2]

*[1] Ivano-Frankivsk National Technical University of Oil and Gas;
15, Karpatska Str., Ivano-Frankivsk, 76019, Ukraine*

*[2] Ivano-Frankivsk National Medical University;
2, Galytska Str., Ivano-Frankivsk, 76018, Ukraine*

Received: 14.01.2014 Accepted: 14.11.2014

Abstract

Floods and overflow forecasting is a live issue in Ukraine today. There is offered the system of monitoring and forecasting of water levels in rivers to solve this issue. The computer system enables automated acquisition of information about weather conditions and forecasts a future river level. The computer system is based on the method of mathematical models making using genetic algorithms. The use of genetic algorithms ideas for making mathematical models enables us both to choose the optimal structure for an adequate model and to reduce significantly the number of calculations when the models are iterated. The system is implemented for monitoring and forecasting of water levels in rivers of the Precarpathian region. Implementation of an automated system will reduce flood damage and improve efficiency of flood situations management.

Keywords: *automated system, flood forecasting, genetic algorithm, water level sensor, weather station.*

Introduction

The floods take the first place among the natural disasters on the Earth by frequency and the occupied area.

Thus, the negative impact of floods and overflows experiences 27% of the territory of Ukraine (165 km^2), occupied by nearly a third part of the state's population [1]. The territories mostly influenced by the floods both in Ukraine and Europe are mountainous regions and the foothills of the Carpathians and the forming of floods in these areas differs significantly from the planes. Heavy precipitation and snowmelt (natural factors), destruction of natural drains, plowing of slopes and deforestation (anthropogenic factors) often cause the hydrological disasters in the Carpathian regions.

Over the past 15 years, intensive floods that occurred in 1995, 1997, 1998, 2001, 2008 and the flood in 2010 led to emergency situations. As a result, the population of the flooded areas and Ukraine's economy suffered significant losses. Thus, the average losses from floods in 1995–1998 amounted to 899.3 million UAH, 1999–2007 – over 1,500 million UAH, in 2008 – about 6,000 million UAH [1]. Particularly disastrous flood was in Precarpathian and Transcarpathian regions in 2008.

* Corresponding author:
gorb@nung.edu.ua

Analysis of works

For early prevention and protection of territories from emergencies caused by floods and overflows it is required a complete automated flood protection system, which would include a regular meteorological observations and forecasting of flood situations at all levels. The results of the system's operation would enable to develop a specific action plan for the prevention and protection of population, territories against losses caused by the negative effect of floods.

An important step in the study of floods and overflows is their forecasting. Flood forecasting will reduce risks of population and damages.

The successful flood forecasting requires proper hydrometeorological support that will result in reliable observations. Effective forecasting of river floods, especially in mountainous area, is possible in case of modern automatic measuring equipping of meteorological stations, the use of distance technologies of information acquisition, the use of advanced software modeling systems for hydrological parameters forecasting.

Mathematical modeling is the basis for flood forecasting. An important step of it is the choice of a modeling method because it determines the accuracy and the time spent to obtain the flood forecast.

The Ukrainian Meteorology Centre is able to forecast floods only 1–1.5 months before they start. The hydrological forecasts are usually formed only in the period of the greatest flood risks (in March and April); in all the other periods floods are unlikely. The reason for this is that the level of technical and technological equipment of most meteorological stations does not meet the needs of the present day.

At the state level, The State Committee of Ukraine for Water Management is engaged with issues of water management and land reclamation. One of the priority tasks of the Committee is to ensure the protection of citizens, centers of population, industrial facilities and agricultural land from the harmful effects of water, to minimize losses caused by it and to make safe living conditions of the population.

This Committee develops and implements several national target programs of flood protection. During their generation and implementation there are included the flood forecasting systems, namely [2]:

“The program of a comprehensive flood control in the Tysa River Basin in the Transcarpathian region in 2002–2006 and the Forecast till 2015” (it is approved by the Cabinet of Ministers of Ukraine of 24.10.2001 No 1388) provides the improvement of automated measurement information system "Tysa". The automated measurement information system (AMIS) "Tysa" is intended for efficient forecasting of flood hydrographs in rivers basin using special mathematical and information software; acquisition of accurate prognostic information about the flood parameters and its automatic transfer to the appropriate flood-warning services and flood prevention units; issuing recommendations for decision making regarding accident-free floods admission. The structure of AMIS "Tysa" in the Transcarpathian region includes 44 automated hydrologic stations, the communication system and analytical control point located in Uzhgorod. The system is linked to the same system of Hungary and enables to predict rainfall in the basin of the Tysa using the radar, located in Hungary. The levels and flows of water in the Tysa river and its tributaries are on-line tracked by the system; on this basis there is forecasted development of floods [3].

“The State Task Program of the Integrated Flood Protection in the basins of the Dniester, Prut and Siret” (approved by the Cabinet of Ministers of Ukraine of 27.12.2008 No 1151). The purpose of this Program is forming in the basins of the Dniester, Prut and Siret the complex of hydraulic and other structures to protect centres of population, agricultural lands and industrial facilities from the catastrophic floods, minimize damages and make conditions for life activities of population.

In 2009 the State Committee of Ukraine for Water Management developed the automated measurement information system (AMIS) "Prykarpattya". The AMIS "Prykarpattya" includes meteorological observations in the basins of the Dniester, Prut and Siret in seven regions: Chernivtsi, Ivano-Frankivsk, Lviv, Vinnytsia, Ternopil, Khmelnytskyi and Odesa. The main purpose of the system is the forecasting of floodings development, automated monitoring of rainfalls, water levels in rivers, the real time transmission of information to the central and regional centers of information processing to alert the population and respond to development of floodings [4].

The main problems of activities of these committees are the limited opportunities for early forecast of natural hydrometeorological phenomena and the lack of modern holistic set of protective measures.

The aim of the paper is the development of automated computer system for monitoring and forecasting of the Dniester River level. It should focus on the effective control of floods and reduction of flood damages caused by the negative effect of floods and overflows by the right decision making based on the results of monitoring and forecasting.

The computer system for monitoring and forecasting will perform automatic accumulation of weather information of the river and transfer it from observation points to the automated controller’s operation point. Here the database of the weather investigation will be formed and a specialized software module will forecast the water conditions of the river based on these data.

The computer system for monitoring and forecasting the river level will solve the following tasks:

remote monitoring of meteoconditions and water level in a river;

analysis and evaluation of water runoff;

forecasting of river conditions based on the observations;

flood control.

The main part

The developed computer system for monitoring and forecasting of Dniester River level integrates a subsystem of acquisition and processing of information on weather conditions and river level and a subsystem of analysis and forecasting of water level based on the received data. The subsystems are connected into a single computer network via communication channels to ensure timely exchange of data between them.

The system of monitoring and forecasting of the Dniester River has a four hierarchical structure (Fig. 1). The first and second levels of it cover the subsystem of measuring and gathering the monitoring data on weather conditions and water level. The third and the fourth levels are combined into a subsystem of analysis and forecasting of river level.

The lowest level of the system contains a set of weather station sensors OREGON LW 301 and a level sensor KROHNE BM 70 A, which are placed directly at the chosen observation points in a certain area. This level provides acquisition and transferring of information on the values of the measured weather parameters: air temperature, air humidity, wind speed and its direction, barometric pressure and rainfall amount to a higher level [5]. In addition the system measures the water level in the Dniester using the gauge [6].

The second level of the system is formed by single-board mini-computers (controllers) that perform local control of equipment at observation points. They provide a verification mode of sensors and make the notice in case of their failure. Equipment at this level also receives information about the magnitude of the measured parameters of meteo conditions and water level in rivers, processes this information and sends it to the next level.

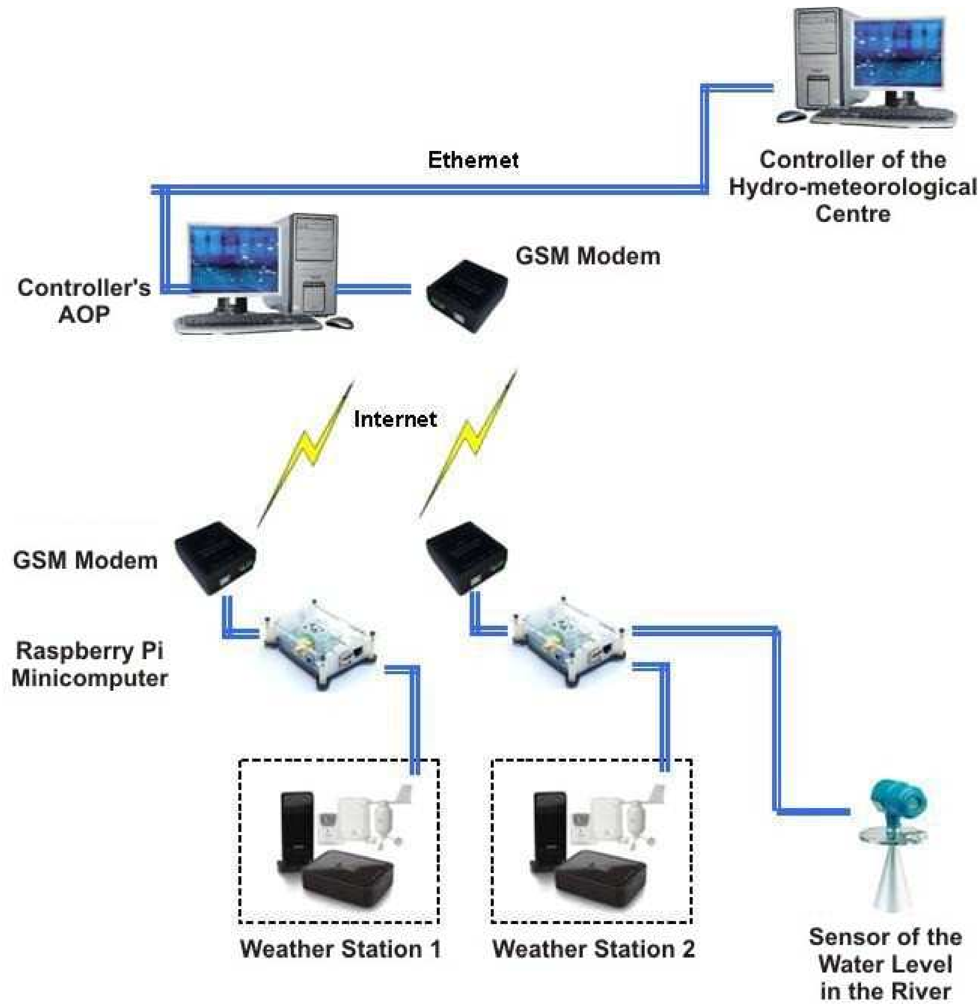


Figure 1 – Block diagram of a computer system

The third level includes an automated operating point (AOP) of a controller with a personal computer and specialized software. AOP of a controller is designed for processing, analyzing and storing the received information about current weather and river conditions in the database. At this level there are made calculations of forecasted water level of the river on the basis of the weather information. The use of special software of a controller's AOP, based on the method of empirical models with genetic algorithms [7, 8], enables to monitor distantly and forecast the ecological state of the object.

Some of the information on the controller's AOP is sent in the form of accounting documentation to the hydro-meteorological centre for analysis and decision-making.

The level sensor KROHNE BM 70 A is mainly used for continuous and non-contact level measurement of liquids, pastes, slurries, liquefied gases and some bulk materials in metal devices and storage facilities, as well as in concrete bunkers, even in the worst conditions [6]. The sensor KROHNE BM 70 A determines accurately the distance to the surface of the studied environment and is able to transmit a signal to the remote recording devices, controllers, automated management systems.

The level sensor KROHNE BM 70 A is used for measuring the water level of the Dniester River in a computer system of monitoring and forecasting of water level in the river.

The level sensor KROHNE BM 70 A (Fig. 2) generates and emits radio signal using antenna. The radio signal, which is reflected from the water surface, comes back after some time *t*, depending on the speed of light. Thus, the measured distance to the surface is determined by the following dependence: $h = \frac{ct}{2}$, where *c* is for the speed of light [6].

Since the level sensor KROHNE BM 70 A defines only the distance to the water surface, it is necessary to use the following formula for determining the water level of the river:

$$\tilde{H}_t = h_b + h_o - h_c \,, \qquad (1)$$

where $h_б$ is a basic level of water in the river, m; h_o is indices of the level sensor corresponding to $h_б$, m; h_m is current indices of the level sensor, m.

Determination of water level in the river is schematically shown in Fig. 3.

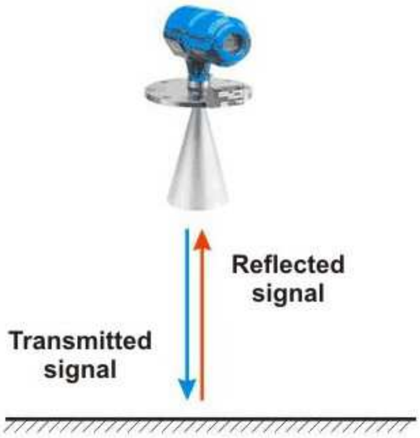


Figure 2 – Level Sensor KROHNE BM 70 A

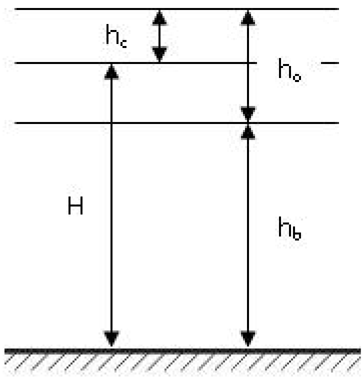


Figure 3 – Measurement of water level in the river by the sensor

In order to determine the current water level in the river there is recorded a baseline h_b using the measuring staff under the normal weather conditions for the certain area. The level sensor KROHNE BM 70 A is determined by the distance to the baseline – h_o. Thus, when we know the current value of h_c, the water level of the river can be calculated by the formula (1).

The level sensor KROHNE BM 70 A is mounted on a road bridge over the Dniester River in Nyzhniy village of Tlumach district. The sensor must be mounted close to the middle of the bridge, because at this point it is possible to obtain reliable data on the water level of the river. According to the technical characteristics of the level sensor KROHNE BM 70 A, the measurement range is 40 meters. Optionally, one can use an extension cord of antenna [6].

For remote signal transmission of the river level the sensor KROHNE BM 70 A is connected to a mini-computer based on the Raspberry Pi board (Fig. 4). In a computer system there is used a digital interface RS-485, which is compatible with the sensor KROHNE BM 70 A. This interface allows us to perform two-way connection. The computer sends a request and a level gauge KROHNE BM 70 A transmits in response information on water level. Using a PC one can configure any level gauge KROHNE BM 70 A (required converter RS-485/RS-232) using the software PC-CAT. The maximum length of the connecting cable with the amplifier is 2 km.

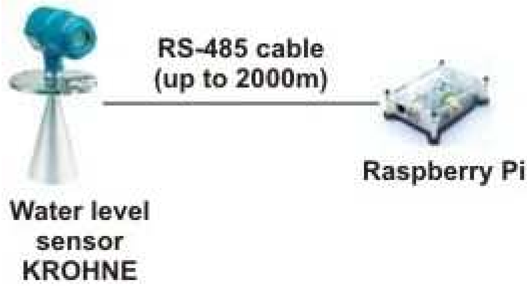


Figure 4 – Wiring of the water level sensor KROHNE to the Raspberry Pi computer

To determine the weather parameters in the certain area there are used meteorological sensors OREGON LW301 [5]. Up the Dniester River there are several observation points with active weather stations OREGON LW301.

Wireless weather station sensors OREGON LW301 measure temperature, humidity, wind speed and direction, barometric pressure, rainfall and send these data to the signal receiver WH200 (Fig. 5). There is allowed connection up to 8 temperature and humidity sensors. The allowable distance of the wireless sensors from the receiver is 100 m. The contact occurs in the internal interface of the weather station OREGON LW301 [5].

The weather station OREGON LW301 has the possibility to transmit the data on weather conditions in the Internet. The data received from the wireless sensors is read out by the WH200 receiver and transferred to the Internet connection module by a USB cable. The cable length is up to 5 m because there may be signal distortion when the cable length is greater.

Then the Internet connection module is connected via Ethernet cable to the Raspberry Pi mini-computer. According to the standard the maximum cable length without repeaters is 100 m.

An important feature of a computer system of monitoring and forecasting is a timely opportunity to receive the information on weather conditions. One of the solutions to this problem is the transfer of data via mobile connection from observation points to the system. In a computer system of monitoring and forecasting the transfer of data is implemented by a GSM modem and special software module that reads out the data from the sensors and transmits the information via modem to the receiving stations.

Consequently, having gathered information from the sensors, a single board Raspberry Pi computer sends the data to the Internet via the connected USB GSM / GPRS modem with a SIM card of a chosen mobile operator. The measured data are stored on the web server (www.osanywhereweather.com).

Every registered user who knows the weather station parameters and has chosen an appropriate area on the map can have a remote access to weather data from the smartphone or PC with the help of this connection diagram. In order to get the information on a smartphone we need to download the appropriate software – Anywhere weather [5].

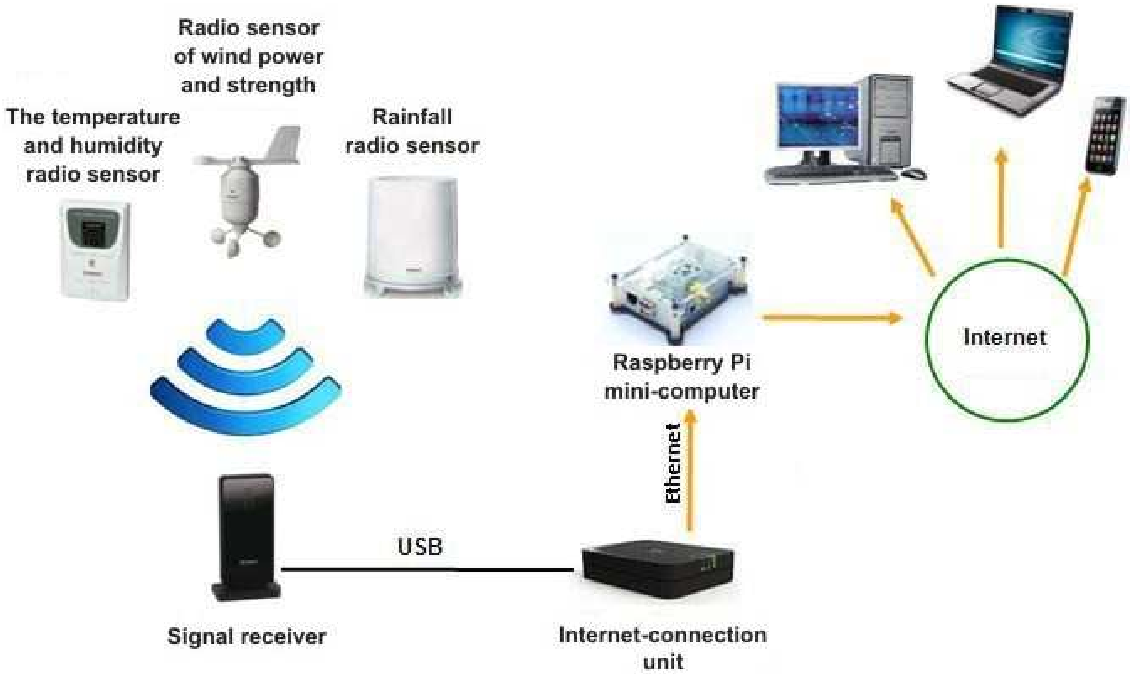
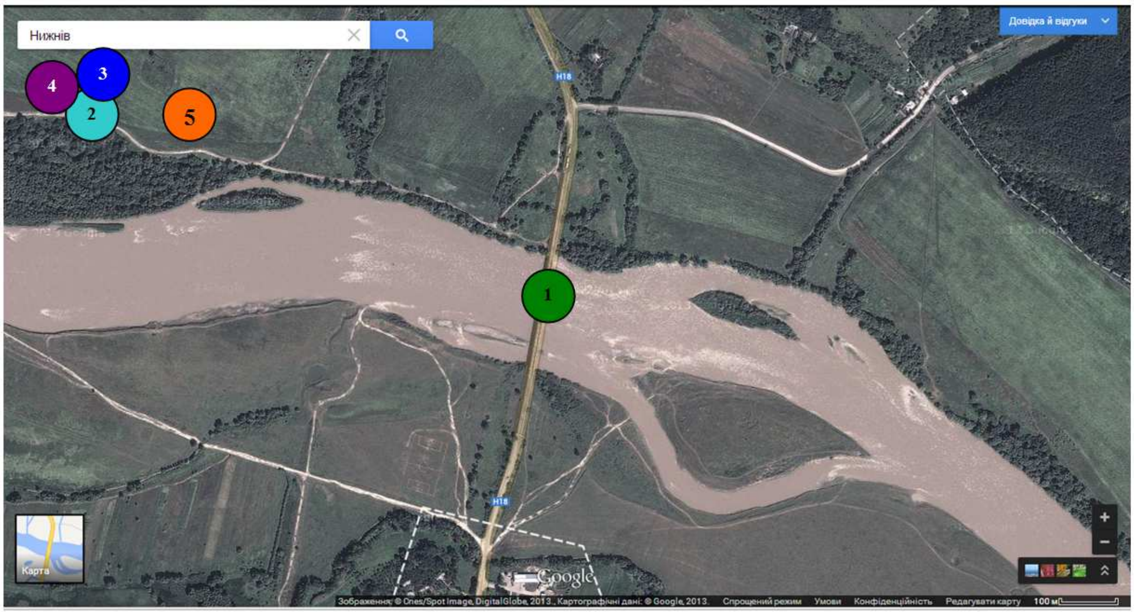


Figure 5 – Connection of components of the weather station OREGON LW301



1 - Water Level Gauge;

2 - Temperature and Humidity Radio sensor;

3 - Radio Sensor of Wind Power and Strength;

4 - Rainfall Radio Sensor;

5 - Signal Receiver.

Figure 6 – Location of sensors for data acquisition

There is showed a diagram of location of information gathering sensors on the map in the chosen area (the Dniester River, village Nyzhniv, Tlumach district of Ivano-Frankivsk region) (Fig. 6). Taking into account the fact that the flood wave in most cases moves much slower than the atmospheric front, meteorological sensors are placed in observation points upstream to interpolate the downstream water levels.

The information obtained from observation points is supplied to the controller's AOP (Fig. 6), where it is processed and stored in a database. The weather information obtained from multiple observation points is averaged at the controller's AOP. Since the sensor measures the distance of the current water level, it is determined at the controller's AOP with the help of the software application according to the formula (1).

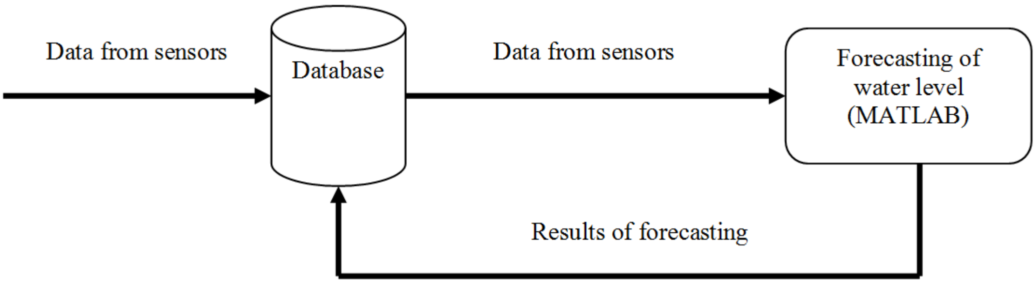


Figure 7 – The scheme of the data movement

Visualization of results is shown on the screen of the controller's AOP in the form of graphs of values change of weather conditions, facilitating the analysis of the received information.

There is implemented the forecasting of water levels at the controller's AOP with regard to weather conditions. Automated operating points of a controller and a weather centre are united into the Ethernet using the appropriate interface equipment and software.

There is designed a computerized system for monitoring and forecasting of the Dniester River, which is deployed as a controller's AOP based on a serial PC attached to the LAN Ethernet in order to implement the offered method. The basis of the controller's AOP is the software that processes the data received from the sensors according to the designed algorithm and reflects the results of such processing on the display screen.

In order to ensure effective automation of data acquisition on water regime of the river and weather conditions, efficient obtaining, storing and analyzing the collected information, to determine the current state of the river and to obtain reliable forecasts it is required a special software of a computer system that must integrate all the stages of research, analysis and forecasting of the river regime. These data will help to obtain reliable information about the current and projected state of the river and make the appropriate decisions for emergency situations caused by floods.

For efficient computer system operation of monitoring and forecasting of water levels in the river it was necessary to develop specialized software that would give an opportunity to solve the following problems:

a) to take automatically water level sensors and weather stations readings. At the same time the interrogator code should not depend on the type of sensors (to provide an abstraction);

b) to work with a relational database (to store incoming data from sensors on weather conditions and water level, and the results of calculations of the forecasted water level);

c) to use the existing Matlab code, which is based on the developed mathematical model for forecasting the water level depending on weather conditions.

Due to the mentioned requirements to the software of the computer system of monitoring and forecasting of water level in a river there is developed a specialized software module that manages the process of obtaining the forecast of the Dniester River level in accordance with the data on weather conditions gathered from sensors. The software for monitoring and forecasting of the Dniester River level is shown as an application module that is installed and allows one to control the entire computer system. Fig. 7 shows the interaction of the program blocks that provide a phased process of forecasting the water level in the Dniester River.

An information base of computer system is the information database about the water level of the Dniester River and weather conditions. The database is generated automatically and saves the current data on weather parameters – temperature, humidity, pressure, rainfall, wind direction, and water level data. These data are input parameters for calculation the predicted water level in the Dniester River [9]. The current information and the database archive in the proper format and amount come to an AOP for processing and forecasting according to the algorithms and reproduction in the form of graphs, tables and text information. Matlab-module performs calculations of the forecasted water level in the river according to the developed mathematical software. The calculations are stored in the database. In the future, they will be considered for planning of preventive measures and decision making to prevent emergencies related to floods.

Therefore, the computer system of monitoring and forecasting of water levels at the programme level includes the following stages:

A sensor's interrogator asks within a certain period of time (the time is specified in the program settings (from one second up to one year)) for the measurement results of the sensors. The obtained measurement data are deserialized (converted from text data into object) and stored in the database in the form of sorted records with dates of observation (Fig. 8). When you run the main stream of application the results of measurements are scanned from a database and saved in computer

Results | Messages

	Id	MensurationTime	Temperature	Humidity	Pressure	WaterLevel	RainFall	WindPower	WindDirection
1	1	2013-06-02 13:53:26.970	0	30	760	25	13	4	7
...	...	...	...	...	...	...	...	...	...

Figure 8 – Recording of the measurement data in the database

memory. A software module starts the Matlab-shell and performs calculations according to the developed method, bringing the calculation of the forecasted water level. The result of the forecasted water level is recorded in the database and displayed on the AOP monitor.

Conclusions

There is offered a structure of a computer system of monitoring and forecasting of water levels in the rivers of the Precarpathian region and there is provided its technical implementation using the system of devices and associated software, which allows one to gather and process information about weather conditions and water level on the particular territory.

Hardware implementation of computer system enables us to remotely perform data acquisition in the observation areas.

There is developed a specialized software of a computer system of monitoring and forecasting of water level in rivers, which allows forecasting the change of water level, depending on the derived parameters of weather conditions.

The introduction of an automated system of monitoring and forecasting of water levels in the rivers of the Precarpathian region will reduce the damage from floodings and improve the management efficiency of freshet situations that will help to prevent emergencies.

References

[1] *Flood protection. Information-analytical reference on problems of comprehensive flood-control measures for protection of Ukrainian regions from catastrophic floods and minimizing the losses from the harmful influence of waters.* [Electronic source]: Flood protection, State Agency of Water Resources of Ukraine. The official website. Available from: http://www.scwm.gov.ua/index.php.

[2] Zamihovskyi, LM, Klapoushchak, OI, *Analysis of methods and systems for monitoring and forecasting the level of flood waters,* Oil and Gas Power Engineering, no. 2 (15), pp. 99–105.

[3] *Basin management of water resources of the Tysa River*. [Electronic source]: State Agency of Water Resources of Ukraine. Official website. Available from: http://www.vodhosp/uzhgorod.ua/aivs_tisa.html.

[4] Klapoushchak, OI, *Modern equipment, materials and technologies for non-destructive testing and technical diagnostics of machine-building and oil industry equipment.*

[5] OREGON LW 301 [Electronic source]. Available from: http://www.oregoninstruments.com/LW301-Oregon-Scientific-Anywhere-Weather-Kit.data.

[6] Radar level gauge KROHNE BM 70 A/P. Manual on installation and maintenance [Electronic source].Available from:http://krohne.com/fileadmin/Picture_Gallery/KROHNE_companies/Russia/Manuals/BM_70_manual_rus.pdf.

[7] Horbiychuk, MI, *A method of constructing mathematical models of complex processes based on genetic algorithms* [Text], Horbiychuk, MI, Shufnarovych, MA, Artificial Intelligence 2010, no.4, pp. 50–57.

[8] Horbiychuk, MI, *A method of mathematical models synthesis of varying processes with nonmultiple frequencies* [Text], Horbiychuk, MI, Shufnarovych, MA, Scientific Bulletin of Ivano-Frankivsk National Technical University of Oil and Gas 2010, no.1 (23), pp. 105–112.

[9] Horbiychuk, MI, *A method of forecasting of water level in the Dnister River depending on weather conditions* [Text], Horbiychuk, MI, Shufnarovych, MA, The East-European Journal of advanced manufacturing sciences 2013, no. ¾ (63), pp.13–19.

УДК 519.687.6+502.08

Комп’ютерна система моніторингу та прогнозування рівня води у ріках

М. Горбійчук*[1], М. Шуфнарович[2]

[1] *Івано-Франківський національний технічний університет нафти і газу; вул. Карпатська, 15, м. Івано-Франківськ, 76019, Україна*

[2] *Івано-Франківський національний медичний університет; вул. Галицька, 2, м. Івано-Франківськ, 76018, Україна*

На сьогодні актуальним питанням залишається прогнозування повеней та паводків на території України. Для вирішення цього питання запропоновано систему моніторингу та прогнозування рівня води у ріці. Комп’ютерна система дає змогу автоматизовано збирати дані про погодні умови та виконувати прогнозування подальшого рівня ріки. В основу комп’ютерної системи покладено спеціалізоване програмне забезпечення, що ґрунтується на методі побудови математичних моделей за допомогою генетичних алгоритмів. Використання ідей генетичних алгоритмів до побудови математичних моделей дає можливість не тільки вибрати оптимальну за структурою адекватну модель, але й значно зменшити кількість обчислень у випадку перебору моделей. Система реалізована для моніторингу та прогнозування рівня води в ріках Прикарпаття. Впровадження автоматизованої системи дасть можливість зменшити збитки від повеней та підвищити ефективність управління паводковими ситуаціями.

Ключові слова: *автоматизована система, генетичний алгоритм, давач рівня води, метеостанція, прогнозування повеней.*