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CONTINUAL COMPUTING OF ENVIRONMENTAL FLOWS IN 'REAL TIME' GIS

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1. INTRODUCTION

The usual property of GIS is that map layers are not renewed continuously. It is a property for the information, which is not temporally variable. Important part of information is very changeable. It is for example processes of water flows and related accidents (floods, debris-flows, and other relevant processes). It is a problem to make GIS to be more adequate the changeable environment. The GIS technology should be essentially provided by the properties of 'real time', or 'vivified' GIS. The renewed GIS use a renewed data. These data consist on meteorology data (precipitation, temperature records), ground surface properties (moisture, vegetation), and current ecological accidents (fires, oil spills, floods). Those are remote sensing and spatially distributed data with a small temporal step, and even direct observations by gauge stations. The 'unending' mapping is necessary to incessant monitoring of environment, bur it is not sufficient because of a necessity in modelling for environment forecasting, disaster prediction, and prevention.

Two existing methods for environment service and management are statistic extrapolation of observed records, and mathematical modelling. The properties and peculiarities of both methods are discussed. The main restriction of statistical methods is that they deal usually with natural processes, which are almost chaotic by low correlations and autocorrelations, and usually cannot be a base for extrapolation. Often the natural records characteristic is 'white sound'. More, the data selections are non-stable, and observed records are two short for reliable criteria of trends. Statistic method cannot be a single base of forecasting. The second method is a mathematic modelling. If tasks of real time GIS are incessant service, monitoring, and management – the fit is the Simulation Modelling (SM). SM may use statistical or deterministic methods for describing of processes in past, current, or future. The simulation modelling is the main objective for elaboration of a GIS, which provides tasks of monitoring, management, and forecasting of dangerous processes.

- The following tasks are as follows:
- The SM relevance and necessity for 'vivified' GIS.
- The experience for simulation of opened un-equilibrium natural systems (river basins, etc.) as of continuous water/mass/energy flows and interactions.
- The experience for simulation of thresholds and disasters in the systems for the purpose of urgent warning.
- The properties for Information Flow through 'real-time' GIS.

2. NECESSITY OF SIMULATION MODELLING IN 'REAL-TIME' GIS

Firstly, a simulation modelling is a process, which is released and observed by computing. The model 'exists' in time, and generates new information through a time. The spatial-temporal resolution of data determines spatial-temporal resolution of a 'real-time" GIS. In other words, simulation repeats and corresponds the real-time real object existence. Any real object (a basin) and it tabletop simulation exists in time under external pressure and impacts, and under internal interactions. The necessity for regular input of spatial distributed meteorological and other data, caused by spatially unequal pressure and impact on a basin (precipitation, temperature, human activity). The simulation modelling (SM) is able to correspond dynamics and evolution of real prototype. Of course, a simplification of a model is successful if a few governing internal and external variables and parameters explain main system properties and dynamics. Secondly, the SM follows up and describes a natural system, and makes a new type of reliable information, which cannot be received directly from source data, but only through simulation modelling by making of a 'vivified' GIS. The simulation modelling is the obligatory part of monitoring. Simulation model grants ‘Real-Time GIS.’ Thirdly, the simulation modelling is after everything else is the core part of modelling. If to range the conference topics for the real-time GIS elaboration, they are as follows: ‘Real-time’ GIS is the aim, dynamic modelling of environmental processes is a direction, spatial/temporal features of disasters and natural resource monitoring and management are the model based GIS skills. For example, the integration of GIS and of simulation is efficient in the powerful Danish simulation model SHE, which provides pre- and post-processing facilities for the modelling and storage of data.

3. EXPERIENCE FOR NATURAL SYSTEMS DYNAMICS MODELLING

The discussed is experience on simulation modelling for various natural systems [1]. The systems may be as follows: river basin, coastal zone, river nets, in varied combinations, and in varied spatial/temporal scales. The simulation modelling uses observed or artificial records, through high frequency input in a model as an observed meteorology and hydrology data, received from distributed gauge station and by remote sensing. The central is a river basin simulation model (RBSM). The input data spread over 2D multiplayer grid. The grid layers are as follows: elevation, some soil properties, surface and underground water, snow cover, precipitation, air temperature, and other distributed and common parameters. The acting tabletop model of a river basin provides non-stop input of spatial external pressure, offers a mixture of flows through a basin, and interaction of flows (erosion/sedimentation, surface- groundwater interaction, and others), in reliance of meteorological regime and on land/soil property. Successfully validated was the medium scale RBSM (Figure 1). Small basins are often un-gauged by observed discharge data. Large basins have some gauge stations for distributed input. The RBSM uses strongly simplified governing empirical functions, but it describes environmental spatial/temporal flows in time with a high grid/temporal resolution. Being trained RBSM enables for self-detection of hazards. Being supported by uninterrupted computer mapping, the models became a prototype for 'real time' GIS, which consumes and elaborate new types of information – time-dependent computer multiplayer maps of environmental processes. Simulation model of an opened nature systems valuable depends on validation by independent records. The common peculiarity of SM is its capacity to create new information (spatially distributed discharge). For example, distributed non-stop input of precipitation/temperature on a ground with distributed soil properties SM reform to continuous mapping of surface flow cover and of water activity (sediment flows, contamination flows) as in natural so in human made conditions (land use scenarios, dam building, etc.). The main principle of simulation modelling is systematic estimation of water/mass flows through a river basin (or through a coastal zone), by water/mass/energy balance evaluation between all adjacent cells of a grid (involving a whole basin) for regular temporal steps. A model has a capacity for regular portray mappings. GIS can provide to make high quality maps for a chosen moment of a system existing. A numerous artificial scenarios are probable, including long-time consequences of human impacts.

4. COMPUTER MODELLING FOR DISASTER WARNING

The simple model of complex system is a table-top computer double of original system and has a lot of functions: estimation of water discharge/flood over a basin, computation of contamination spread, valuation of erosion sedimentation pattern – in actual and artificial in scenarios of land use and external/human impacts. The significant relevance is evaluation of floods in plain rivers and of debris-flows in mountains. The comparison of observed and computed processes resulted in satisfactory accuracy of disasters estimation. There is an experience of assessment of oil spills on a ground, river, and sea. Water/sediment discharge computer makes a real advantage for a 'real time' GIS for disaster mitigation, urgent prediction, and warning.

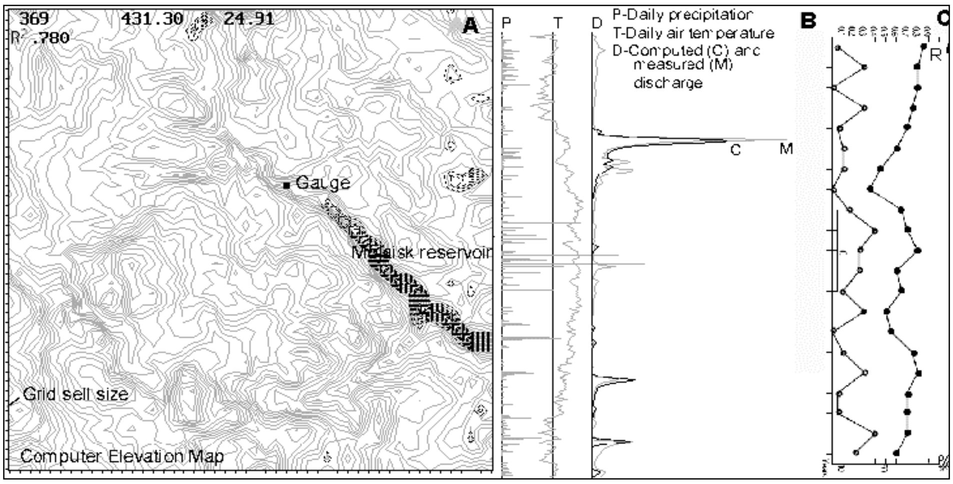

Fig. 1 A: The basin computer map in the end of a year, B: c- computed discharge, m- measured discharge, C: R^2 – statistic criteria for annual discharge calculation for the gauge (0.4-0.87), % - percentage error of snowmelt flood assessment (0-40%).

Co-processing mapping (Fig.1) demonstrates process of discharge/flood monitoring. The left-side computer map (A) shows the basin state in the end of year. The basin is covered by snow, and rivers are out of contour scale, with exception of reservoirs and lakes. The image is smoothly renewed daily in duration for many years. The mapping process corresponds simulation process. The corresponding graphics (B) are supplied daily and renewed annually. During a year, it is regularly filled by precipitation (p), air temperature (t) as meteorological information, and by control data of measured discharge (m). The observed discharge corresponds separately computed discharge for the site of gauge (G). An annual statistical R^2 criterion of validity is 0.78. Note, that the graphic may be calculated for every cell for the basin if necessary. Contours shows water content for all cells. The right graphics (C) demonstrates R^2 for about 20 years observation. 5 years of the record base the calibration. The adjacent graphic shows the error of snowmelt peak evaluation (between 0 and 40 %). Any basin management is available for flood forecasting and mitigation. The distributed meteorological input is necessary in big basins to prevent errors due non-equal precipitation. Corresponding processes in this portrait system are simultaneously evaluated, and may be screened by choice (erosion/sedimentation, soil properties, contamination spread, and cumulative environment response). The model is simplified example of a 'real-time' GIS.

The other case study is the incessant computer monitoring for debris flows in a mountainous basin [2]. The former precipitation/air temperature some years record was an information inflow into model by for some years record. Self-perceived and observed debris-flows coincide in date, in spite of the absence of water/sediment discharge records. Property of DFSM is multiple local increasing of stream velocity with non-linear growth of sediment transport capacity. The model automatically 'stretches' a time during debris-flows cases. Capability of the DFSM to perceive Debris-flows depends on 'a food' for the models, what is a lasting input of spatial distributed precipitation and air temperature, as of the processes drivers. The trained models deal with processes in the basin autonomously.

A discussed GIS must grant a regular input of spatial distributed data. Correction of air temperature in dependence of elevation, correction of soil properties in dependence of changeable moisture make changeable some distributed parameters. Models of natural systems (river basin, coastal zone, and others) became a heart of computer monitoring and of 'real time' GIS [3]. Remote sensing data provides regular information as follows: meteorology regime and changing properties of land/sea surface. The enormous information quantity should provide for urgent prediction of environmental accidents. This information should not fail in time. The simulation modelling uses new and former information for calculation of a system 'life'. The combine of water, precipitation, evaporation records, and of surface properties is a foundation for urgent assessment of floods, debris-flows and other water related accidents. Permanent forecasting of floods depends not only on future and former precipitation, but also on water move through catchments. Case studies results of floods assessment during record based monitoring, satisfactory results for computer monitoring of mountain basin in view to debris flows self-perceiving and tracking hopeful to overfill cost expensive data.

5. **CONCLUSIONS**

The heart of a real time GIS is a simulation model. Simulation is supported by databases of three types. The former records are for training. The real-time data input provides for monitoring and prediction. The active data base support decision support through artificial scenarios. A chosen layer of continually recalculated multi-layer grid is reformed in co-processing contour map. The tasks for modelling are following scenarios: land use policy, water retention, flood mitigation, and disastrous floods management. The responsibility of the modelling is effectual transformation of real-time information flows to incessant mapping of environmental flows for the purpose of self-detection and urgent warning of harmful processes.

The numerical method is repeated evaluation for water/mass interactions and flows between all adjacent cells of a system. The necessity for regular input of spatially distributed meteorological and other data depends on spatially unequal pressure/impact. Water/sediment continual flows through a system (rainfall, runoff, and others) are provided by continual input of information flows (former, current or proposed). The task for calibration needs for spatially distributed records for key parameters and flows. The models of opened natural systems (basin, coast, and combined ones) properties are systematic rewriting of computer maps (or its changes) with reforming of 2D grids to vector form maps.

Strong information flows are in agreement with information flows into the acting models. The simulation method is relevant to describe time-dependent system structure by property of the model to self-adaptation of flows to a system structure. The structure is also depends on water sediment flows in nature and in a model. The simulation algorithms afford self-recognition of thresholds (floods, debris-flows), caused by natural and human impacts, what is the mainstay. It is a condition to selection and extraction of necessary information from the information flows, and to provide capability of data formats in a model, in the GIS environment, and in the information inflow.

Finally, in accordance with the Conference themes the following conclusions are:

- The **Disaster management** must be provided by meteorology, hydrology, and others records, must be activated by simulation modelling for real and artificial scenarios of a systems response on natural and human pressure/impacts.
- Simulation model is a necessary computer tool for **dynamic modelling of environmental processes**, including all kinds of environmental flows and contamination spread.
- **Geodata usability** is a necessary 'food ' for the continual simulation modelling and monitoring.
- Real time **GIS needs for import of information flows in view to provide the modelling of environmental flows in natural systems.**

6. BIBLIOGRAPHICAL REFERENCES

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