An Intelligent Analysis of Spatial and Spatiotemporal Data

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INTRODUCTION

The presentation outlines web-GIS GeoProcessor 2.0 and GeoTime 2.0 case studies. Both GIS's are intended to analyze spatial and spatiotemporal properties of the environment. The main problem domain is scientific research on seismic hazard assessment and earthquake prediction. These problems demand comprehensive analysis of complex data types. GIS's are written in Java (http://www.geo.iitp.ru/GeoProcessor-2/new/index.htm, http://www.geo.iitp.ru/geotime/all.htm). This made it possible to develop a platform-independent environment that combines high interactivity of the analysis with the flexibility to integrate dynamically the data and plug-ins distributed on network servers and on the user PC (the latter provides confidentiality of the user's data).

GEOPROCESSOR

Web-GIS GeoProcessor (Gitis, 1998) is implemented as a Java-applet. We present two applications of the technology.

Earthquakes Damage Evaluation

In this example we examine the North Caucasus cities with population more than 100,000 inhabitants (initial data: http://www.geo.iitp.ru/GeoProcessor-2/new/Caucasus2.htm). The problem is solved with the help of several analytical transformations (Gitis, 2004): (1) To calculate a grid-based layer of maximal intensity of earthquakes $I = (\lg A - 0.014)/0.3$, where A is the initial grid-based layer of maximal peak ground acceleration (Giardini, 2003). (2) To calculate the grid-based layer V equal to the share of the destroyed buildings 7KP: V=0 if I<7, V=3.5% if I=7, V=11.9% if I=8, V=37% if I=9. (3) To calculate the shares of destructions located at a distance less than 5 km in the vicinity of the cities. Assuming that the area comprising 7KP buildings is homogenous within the zones with selected size, the result can be accepted as an evaluation of the damage from a maximal earthquake. Figure 1 shows the grid-based layer of 7KP building destructions in percentage terms, the size of circles corresponds to the damage values for the cities. Below it is shown that the share of destruction for the city Derbent is equal to 27%.

Seismic hazard assessment

Let us examine an example of detecting the potential earthquake source zones with magnitudes $M \geq 6.0$ for the Caucasus (initial data: http://www.geo.iitp.ru/GeoProcessor-2/new/ARMEAST2-e.htm).

We present the simplest solution using only a grid-based layer of the velocity gradient module of the vertical motions in the post-Sarmatian time (feature X_1) and a vector layer of the thrust faults, active in the Cenozoic era. At the first step a grid-based layer of the distances to the thrust faults is calculated (feature X_2). At the second step the decision rule in the form of a preference function (Gitis, 2004) is derived:

IF the velocity gradient of the vertical tectonic motions in the post-Sarmatian time (X1) exceeds 10 conventional units (CU), **OR IF** (X_1)>6.4CU **AND** the distance to the thrust faults (X_2) <6.75km, **THEN** seismic sources with M >6.0 are possible.

The potential earthquake source zones (Figure 2) correspond to seismotectonic state-of-the-art. Forecast of the zones in the sea, south and south-east areas is not made due to the absence of the geodata.

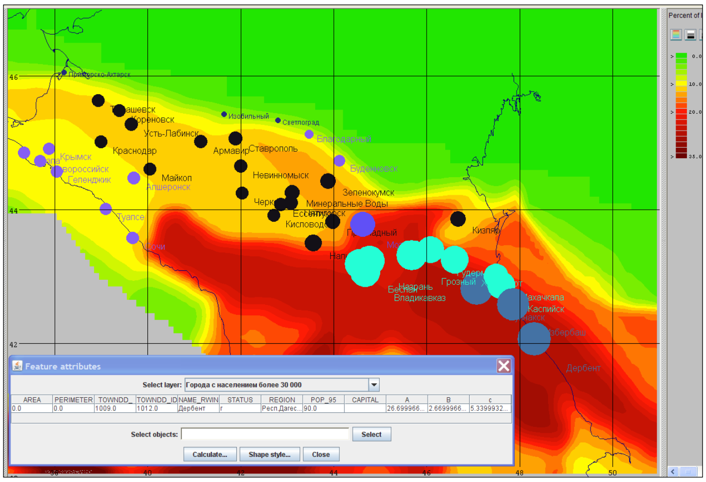

Figure 1: The damages for the cities from maximal earthquakes.

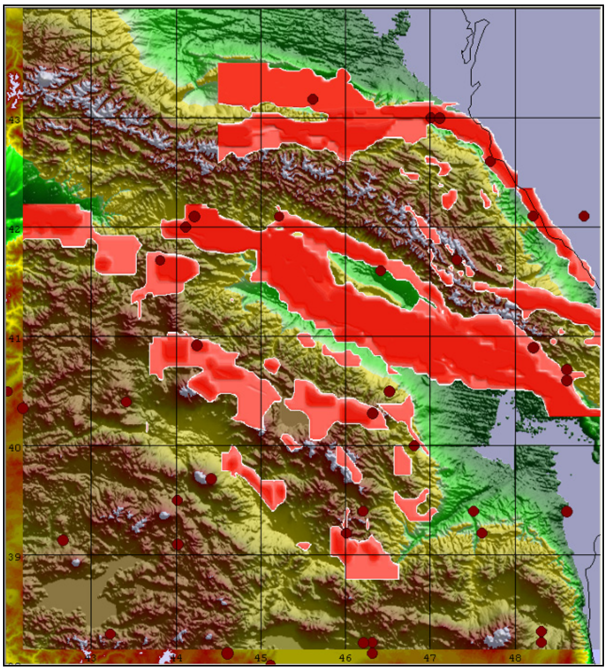

Figure 2: The potential earthquake source zones with $M \geq 6.0$.

GEOTIME

Web-GIS GeoTime is implemented as a Java application that is loaded via Java Web Start. GIS is mainly oriented to analysis of spatiotemporal seismotectonic processes. The processes are represented by geographically localized time series and earthquake catalogues. For the analysis this data is transformed into 3D and 4D grid-based layers. Data processing demands great volumes of memory and extensive calculations. To rise computational speed parallel calculations on multiprocessor/multicore user PC are supported.

We describe an example of GeoTime technology application analyzing the Susamyrsky earthquake precursors.

Susamyrsky earthquake with magnitude *M*=7.2 and co-ordinates λ=73.63°E, φ=42.06°N occurred on 19.08.1992. The earthquake catalogue has the following parameters: 16329 events, magnitudes *M*=2–7.2, co-ordinates 40.4°N–44°N and 71°E–81°E, time 1980–2001. We processed the subcatalogue up to the day before the earthquake had occurred.

At the first stage a 3D grid-based layer of density of earthquakes is calculated.

At the second stage a 3D grid-based layer of anomalies is calculated. The anomaly detection algorithm is grounded on a method of testing of statistical hypothesis (Gitis, 2004).

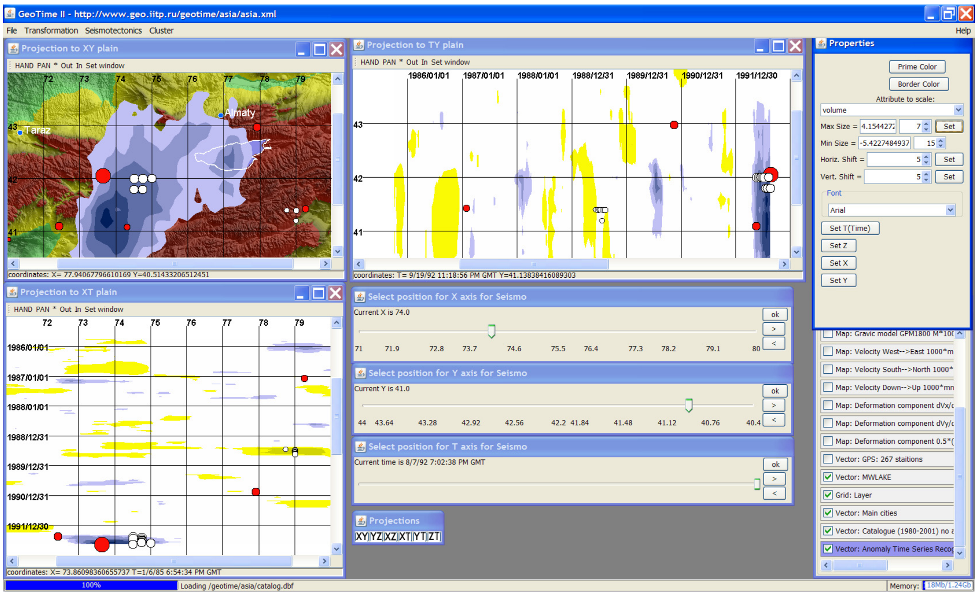

Figure 3: A pattern of Susamyrsky earthquake precursor.

At the third stage the size and coordinates of the anomalies *X* (longitude), *Y* (latitude), and *T* (time), and accuracy of approximation of the anomaly by Gaussian are estimated. The *XY*, *XT*, *YT* projections of 3D anomaly field are represented in the Figure 3. Yellow and blue colors correspond to significant negative and positive anomalies. Tint corresponds to increasing of anomaly value. Projection *XY* corresponds to *T*=28.07.1992 (21 days before earthquake), projection *XT* corresponds to *Y*=41°, projection *YT* corresponds to *X*=74°. Projection *XY* shows extensive negative anomaly. The earthquakes $M \geq 5.5$ are shown in all projections as red circles. The greatest size of the circle corresponds to the Susamyrsky earthquake. White circles show the co-ordinates of the anomalies that are approximated by Gaussian with high level of accuracy. Figure 3 shows two such anomalies. Small white circles correspond to positive anomaly that is not attributed to a strong earthquake. Big white circles correspond to negative anomaly that precedes the Susamyrsky earthquake. This approach can be used for earthquake prediction.

CONCLUSION

The considered examples testify to efficiency of application of GIS GeoProcessor 2.0 and GeoTime 2.0 with respect to complicated research tasks in Earth sciences. We shall continue refining the architecture, enriching the functionality and advancing the technology of application of our systems to wider range of subject domains.

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