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NUMERICAL APPROACHING TO NONLINEAR FLOOD ASSESSMENT

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Abstract. In our days, theoretical investigations are involved and used in a huge class of research domains. An important aim in the most such works is to obtain the mathematical model for considered system or process. The common approach is therefore to start from measurements of the behavior of the system and the external influences (inputs) and try to determine a mathematical relation between them without going into the details of what is actually happening inside the system. Accepting this way, could be investigated the climatic phenomena in a very sensible area of the Lower Danube zone where, in the past years, a series of climatic failures had been happening and the ambiance risk factors 'management is a necessity. Using a huge historical evidence data warehouse, in this way, could be considered and designed a nonlinear model for analysis of water floods' dynamics in the area. In the initial step, it was considered mathematical model building' procedures, employing neural networks' simulations in order to succeed in reaching the correlation between the upstream recorded water rains' amounts and the downstream rivers' flood levels evidences. This approach is an initial phase toward a DSS - Decision Support System, aiming the climatic risk management. In the second step, is was proposed a physics model which includes the land shape representation, Manning equation exploiting and watercourse sections' depiction, in order to obtain a good correlation with the rivers flood levels' evidences. For this stage, was used a particular GIS system in correlations with a specific computer software package which included a series of numerical evaluation methods in order to succeed in reaching a good connection with the recorded data. The aim of this paper is to present this specific approach.
Keywords: neural network simulation, numerical evaluation.

1. Introduction

In the last five decades, natural climatic factor actions had been involved a sequence of calamities and disasters [1-5]. An important aspect is raised by theirs' amplitude of the human and material loss. During the time, it could be noticed a growing tendency of these natural catastrophes' hammering although climatic phenomena have the same frequencies. As an example, it should consider that between 1950 and 1959 were recorded 20 catastrophes with 42,2 billion dollars loss. During the same period, between 1990 and 1999, were recorded 89 natural disasters with 652,3 billion dollars loss.

In the last decade, the evidences reveal dramatically grows. Solely in 2001 were registered 700 natural climatic factor actions din including two earthquakes: in El Salvador at 13-th January with 845 human lives loss in 10.000 land sliding occurrences and 1,5 billion dollars beating, and the other one in India at 26 – th January with 14.000 human lives loss and 4,5 billion dollars beating. In August 29 2005, the Hurricane Katrina caused severe destruction.

At least 1,836 people lost their lives in the actual hurricane and in the subsequent floods, making it the deadliest U.S. hurricane since the 1928 Okeechobee Hurricane. The storm is estimated to have been responsible for $81.2 billion (2005 U.S. dollars) in damage, making it the costliest tropical cyclone in U.S. history.

Romania is not an exception. In The World Bank Bulletin, Washington DC, the author Christoph Pusch wrote in his paper *Losses:Saving Lives and Propriety Through Hazard Risk Management* (October 2004, pages 66-67) that in Romania 57 percent of economic defeats are due the water floods and land sliding events. In the same way, in the paper *Natural Disaster Hot spots, Disaster Risk Management Series*, Washington DC 2005, page 90, is revealed that in Romania 37,4 percent of the country surface is on a risk state, 45,8 percent of country population live in a risk condition and 50,3 percent of country budget is affected by the natural climatic factor actions.

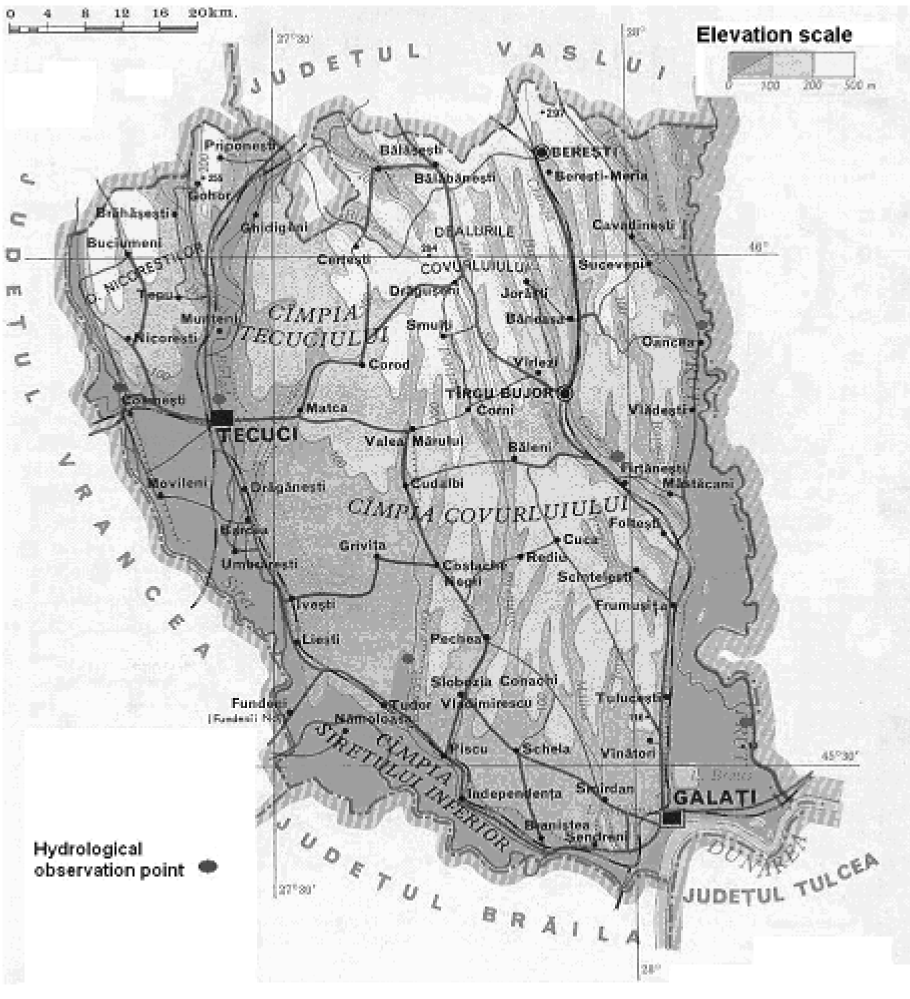

FIGURE 2. The Galati County with the river and elevation representation

Our work is focused on a very sensible area. The Lower Danube zone which includes Galati city is a confluence point of the Siret, Prut and Danube river. In these conditions, the hydrological aspects have great importance for the citizens and local economy. In figure 1 is presented this area of interest, presenting the three rivers which surround the city.

In this point of view, should be remembered that in the last years, a series of water flood events revealed a great problem of these citizens. As an example, in April 2006 when Danube River discharge reach a top level, the national authorities were asked to react very quickly in order to limit the human lives loss and the material hammering.

Long lead-time forecasts are required in early flood alert systems but, as an event progresses, more accurate forecasts with shorter lead times are required for warning purposes. As forecast reliability necessarily decreases with increasing forecast lead times, some compromise must be reached in order to minimize losses due to flooding. A Decision Support System (DSS) is welcome and considered as a necessity.

During the time, a series of local or regional problems were studied in a systematically approaching. Frequently, the result of the revising work was exposed in a complex model which integrates representations for the most important aspects of the considered problem.

The main advantage of a model making approaching consists in the possibility to build and study specific scenario in order to succeed in preventing future hazardous situations.

It is easily noticed that every model has limits and a series of particular conditions which allow to be considered helpful. During the time, these conditions are changing and thus the capability of every model is restricted in time.

In a general approaching, a data based model is build following some consecrated steps. The research work often starts with a study over the main parameters set for the studied problem and this first step stops with the structure design of the main data base. In the subsequently step, after the evidences' collecting time, is investigated the system representation. There are multitudes techniques to examine and refine a reliable depiction of considered problem. For our particular problem of water flood assessment, different approaching procedures are applied with certain success. In this way, a beautiful discussion on the system identification procedures is presented in [1]. In the same time, the neural network use or estimation with efficient recursive Kalman filter are already developed [2-5]. On this point should be underlined that together with a linear-quadratic regulator, the Kalman filter solves the linear-quadratic-Gaussian control problem [2]. On the other hand, the use of neural networks knows a greater importance during the last years.

There are still uncertainties associated with the identifiably of parameters; with the computational burden of calculating distributed estimates of predictive uncertainty; and with the adaptive use of such models for operational, real-time flood inundation forecasting [6]. Moreover, the application of distributed models is complex, costly and requires high degrees of skill.

In a previous paper [7], it was utilized a mathematical model basing on a global concurrent neural network simulation. That model was built basing on a feed – forward neural network with logistic activation function. Input information coming intro the model through special, non-processing inputs nodes (neurons) was fed to a number of inner, hidden nodes. Hidden nodes perform a two-fold function: first they compute a signal x_j from all incoming information using the following relation

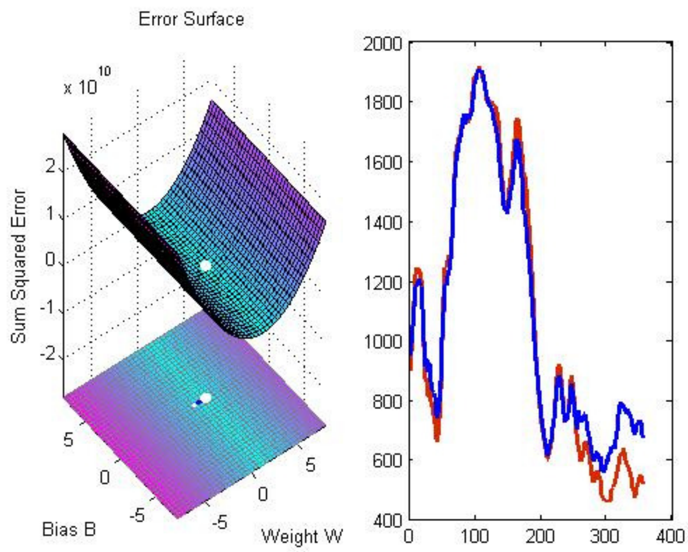

FIGURE 3. Error surface and simulation results after the training stage using a global neural network. The comparison between the system outputs and the recorded data

$$x_j = \sum_{i=1}^{N} \left(\omega_{i,j} u_i\right) - b_j \qquad \text{a)}$$

where $\omega_{i,j}$ is the weight associated with the connection from node j, u_i is the input variable value and b_j is the threshold value, which is different for each node. Second, the neurons transform the inputs using a non-linear sigmoid activation function

$$y_j = g\left(x_j\right) = \frac{1}{1 + exp\left(-x_j\right)}\ , \quad y_j \in [0, 1] \qquad \text{b)}$$

Implementation and calibration of this global neural network were realized using our MATLAB platform developed tool. The calibration of the model also called as training stage, is performed in order to achieve the minimum of the square error magnitude with regard to real recorded data, using the well known back propagation error algorithm to correct the weights [1, 7].

$$E_r = \sum_{k=1}^{nl} (y(k) - y_S(k))^2 \qquad \text{c)}$$

Corrections of the value of the weights corresponds to moving along the error surface (Fig. 1) E_r toward the local minimum following the direction of the steepest gradient, basing on the relations

$$\begin{Bmatrix} \left(w_q^i\right)^{K_P}(i_i, j_i) = \left(w_q^i\right)^{K_P-1}(i_i, j_i) - \eta \cdot 2 \cdot e_{q+1}^i(j_i) \cdot A_q^i(j_i) \\ \left(b_q^i\right)^{K_P}(i_i) = \left(b_q^i\right)^{K_P-1}(i_i) - \eta \cdot 2 \cdot e_{q+1}^i(j_i) \end{Bmatrix} \qquad \text{d)}$$

where w_q^i is the weight and b_q^i is the bias for the i - th subsystem input at the corresponding discrete time moment. The error which is back propagated through the connection between neuron j_i (from layer i of neural network) and downstream neurons are described by the relations:

$$e_q^i(j_i) = \frac{dF_q(X_q(j_i), B_q(j_i)) \cdot E_i^{i+1}}{dt} \cdot \sum_{k_i=1}^{S_{q-1}} e_{q+1}(k_i) \cdot w_q^i(j_i, k_i) \qquad \text{e)}$$

In our work, it is followed a different strategy. In this way, basing on previous considerations, we developed a numerical analysis in order to succeed in reaching the water river system representation considering the Manning equation

$$V = \frac{k}{n} R^{2/3} S^{1/2} \qquad \text{f)}$$

where V is the average velocity, k is a constant coefficient equal to 1 for the metric units, n is Manning's roughness coefficient, R is hydraulic radius and S is the water surface slope for uniform flow. Using this expression, for different gauging points belong the water courses, could be drawn diagrams for river discharge vs. channel depth (Fig. 2) for different roughness coefficient values. In the same time, considering the historical data evidences, for each affluent of Siret River and for each gauging point, were exemplified such charts (Fig. 3).

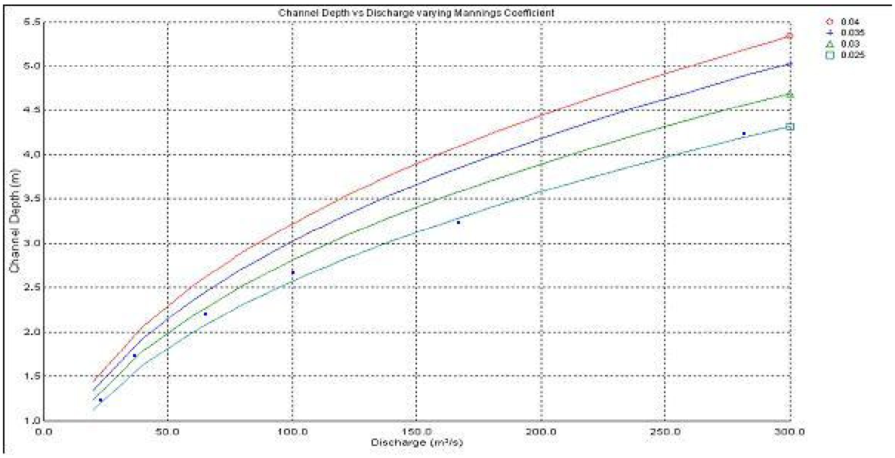

FIGURE 2. Diagrams for river discharge vs. channel depth for different roughness coefficient values using Manning law

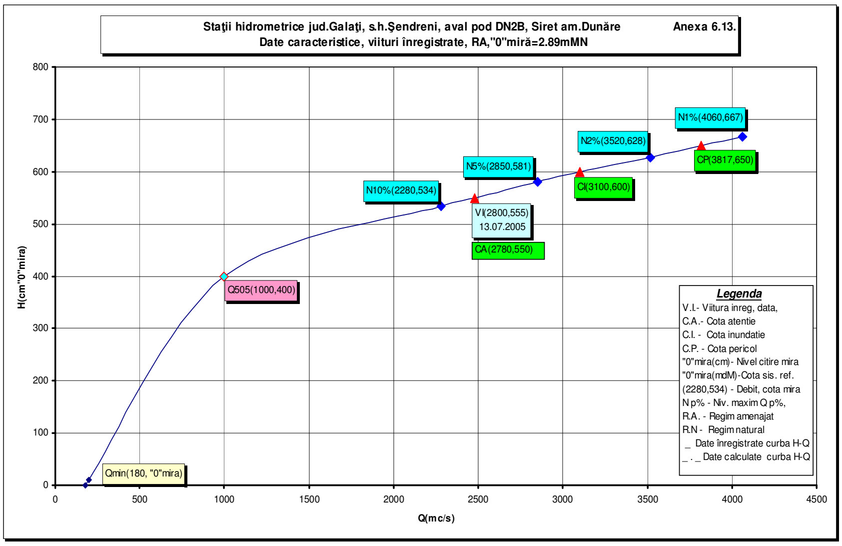

FIGURE 3. Diagrams for river discharge vs. channel depth for Siret River at Sendreni gauging point basing on historical evidences

For each drawing, we succeed in building and training specific concurrent neural network, in order to succeed in simulating the river behavior at each water flood regime. For the watercourse sections' drawing, was used information model from the, Cadastral, Geodesy, Photogrammetry and Tele-detection National Institute (C.N.G.C.F.T.). The land shape representation is a very important component which allows building a specific Geographical Interface System (GIS). In our model are included fields' records data for different parameters. There is evidenced surface element' position and slope and the grid resolution was 500 m, enough for preliminary testing procedures.

2. Results and discussion

The discharge formula can be used to manipulate Manning's equation by substitution for V. Solving for the discharge magnitude then allows the calculation of the volumetric flow rate without knowing the limiting or actual flow velocity.

The Manning formula is typically used to estimate flow in open channel situations where it is not practical to construct a weir or flume to measure flow with greater accuracy. Error rates of +/- 10% are common using the Manning formula while error rates within +/- 5% are possible with properly constructed weirs or flumes.

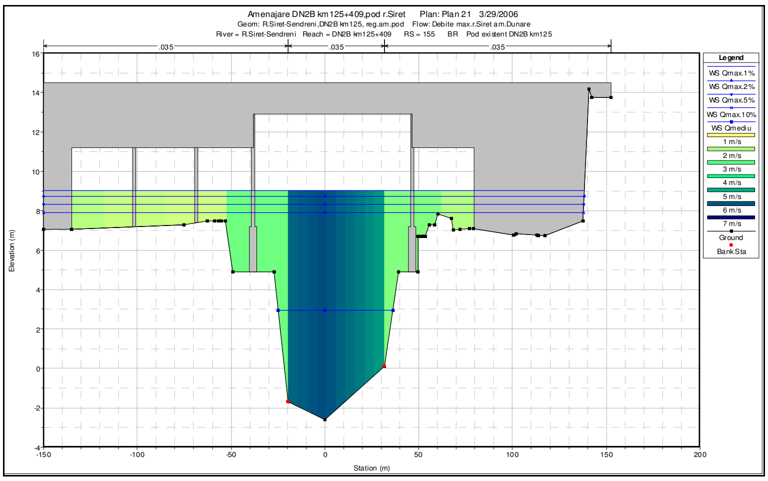

FIGURE 4. Transversal profile for Siret River at Sendreni gauging point for different water levels

In our first attempt, the transversal surfaces were approximated to trapezoidal shapes. For the future versions, the estimation will be improved.

Operational flood forecasting systems include three major elements: a real time data acquisition system; hydrological and/or hydraulic models for simulation; and a system for updating. This paper is a sequel to an earlier paper [7, 8] that considered a catchment's model and associated forecasting system, including nonlinear rainfall-level and linear level (stage) routing models.

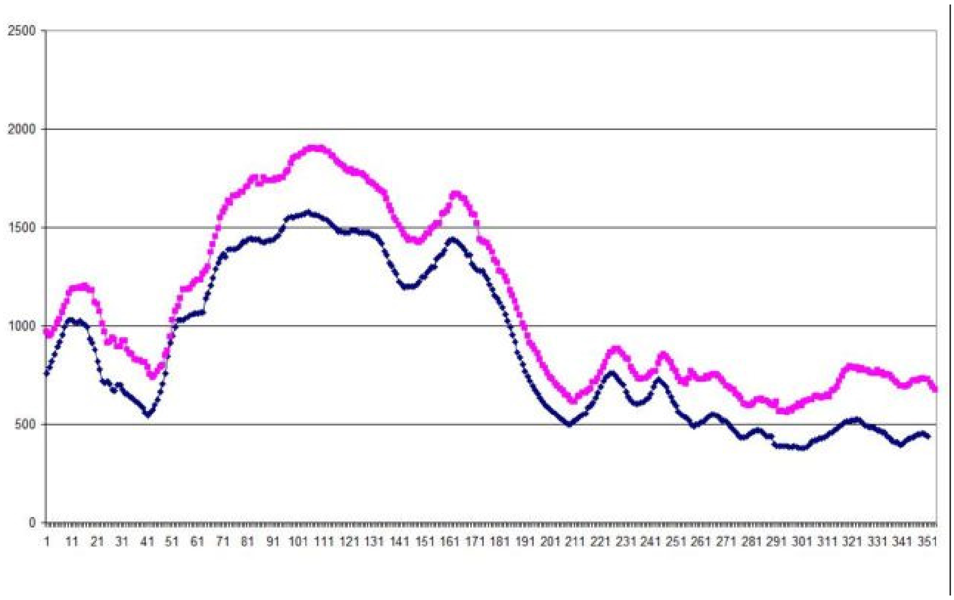

FIGURE 5. Numerical simulation response (blue) vs. the recorded evidence (red) for the downstream gauging point

It is necessary to first understand the mechanics of riverine flooding in order to grasp current policy related flood problems. Riverine flooding is the product of the amount of run off, or total water flowing in a stream. [6]. The amount of run off is often a factor of many other variables which include drainage area, topography of an area, natural drainage patterns, existing land use practices and type of soil [6]. Many of these variables are difficult to model or capture since they are often affected by day to day and long-term human activities.

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