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Feature extraction and data reduction techniques for groundwater monitoring based on neural networks

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In recent years, the absence of a sound water policy resulted in an incorrect use of water resources. This is particularly dangerous in the Mediterranean regions that are experiencing a long drought period. Particular attention must be paid to a correct monitoring of groundwater resources, which are very often contaminated by pollutants coming from different civil or industrial sites, or by saltwater intrusion. Such contamination is often recognized to be caused by events occurred in indefinite preceding time. Moreover, the quality of groundwater varies from one place to another and can locally evolve with time, restricting the possibility to use the resource if a suitable monitoring action is not performed. In this context, the determination of initial conditions for the pollution seems to be of major interest.

In the present paper, Artificial Neural Networks are investigated as tools to locate the source and define the temporal duration of a contamination process in an isotropic, three-dimensional, groundwater flow. Tests are performed under the hypothesis of a single pollutant injected in a single point.

Traditional feed-forward MultiLayer Perceptron (MLP) networks are trained to find the functional relationship between the geometrical and chemical properties of the pollutant and the hydrological map of the basin, sampled in prefixed measurement points. This approach consists of inputting to the neural model the knowledge of the distribution map of the pollutant at different time steps, and associating it, as desired outputs, the geometrical coordinates of the injection wells and the time step before the injection occurrence.

The network is then used to solve the inverse problem of locating the source of the pollutant, and how many time steps before the event occurred.

Training patterns are constructed by simulating hydro-geological scenarios by means of a commercial tool for flow-transport modelling. In particular, PMWIN (Processing Modflow for Windows) has been chosen as numerical simulator. PMWIN is a simulation system integrated with several modules: MODFLOW is a modular three-dimensional finite-difference groundwater flow model, developed by U.S. Geological Survey, which has been used to describe and predict the behaviour of the groundwater systems; moreover, MT3D has been used as transport model, which utilized a mixed Eulerian–Lagrangian approach for the solution of the three dimensional advective-dispersive-reactive transport equations.

The huge amount of data carried out by each time step simulation of the domain is not suitable to be inputted to a neural network. So, feature extraction and data reduction techniques, as Fast Fourier Transform (FFT) or Principal Component Analysis (PCA), have been implemented to reduce data dimensionality.

In a previous work [1], different networks have been used to predict the coordinates of the pollutant source and the pollution time on a simple test case. The results were good for the identification of the source coordinates, but the network was not able to identify the time required to the contamination process, with sufficient precision.

In the present paper, the effectiveness of the proposed data processing to optimise the network input and to reduce data dimensionality is investigated. Moreover, a cascade-form neural network architecture is presented, with the purpose to provide to the less efficient network (devoted to find the time duration of the contamination process) further data input, obtained by the other, more efficient, neural networks (devoted to find the location of the pollutant source).

The proposed approach has been tested on benchmark cases close to real cases, and the obtained results are encouraging.

[1] A. Fanni, G. Uras, M. Usai, M.K. Zedda “Neural Networks for Monitoring Groundwater” Fifth International Conference on Hydroinformatics Cardiff UK 1-5 July 2002.