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IMMUNITY-BASED NEURAL NETWORKS TO MACHINE LEARNING FOR COMPLEX PREDICTION PROBLEMS

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SAMM: Statistics, Analysis and Multidisciplinary Modeling

Four Major Issues

- How to characterize and to exploit big data?
- Which statistical machine learning instruments for understanding big data?
- What an interest of an Artificial Immune System (AIS) approach in machine learning?
- How to predict complex Natural hazards like landslides with major issues?

CONTENTS

- INTRODUCTION:

  Data Characteristics; Data Collection and Exploitation; Knowledge Discovering Data (KDD).
- I. STATISTICAL MACHINE LEARNING:

  Regression and Classification Tasks; Feature Extraction Techniques.
- II. ARTIFICIAL IMMUNE SYSTEMS:

  Bio-Inspired Algorithms; AIS: Principles, Implementation, and Applications.
- III. COMPLEX PREDICTION PROBLEMS

  Monitoring and Predicting Natural Hazards; Grey Prediction Models; Landslide Forecasting.

INTRODUCTION : EXPLOITING BIG DATA

● DATA CHARACTERISTICS :

✓Data sets: massive, high dimensional and varied available data + generated data from connected objects + real-time monitored data;

✓Big data definition (4Vs): Volume + Velocity +Veracity + Value;

✓Fields: astrophysics, meteorology, biology, finance, marketing, security, Natural hazards, etc.

● DATA COLLECTION PROCESS & EXPLOITATION :

✓Collection process: data generation + feature extraction + classification;

✓Analytics: traditional tools and advanced methods;

✓System properties: flexibility+adaptability,+reactivity

● KNOWLEDGE DISCOVERING DATA (KDD):

✓Dimensionality reduction (linear PCA, and ICA);

✓Discovering hidden features;

✓Knowledge discovering process: gathering, selection, pre-processing (detecting, cleaning, filtering), transformation (reducing complexities, sampling, coding), data mining, and evaluation.

I: STATISTICAL MACHINE LEARNING 1/2

● REGRESSION AND CLASSIFICATION TASKS :

✓Regression for quantitative valued features/predictors:
□*Regression model between predicted event y and p predictors:*

$$\hat{y} = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p$$

✓Classification for qualitative categorized features/predictors:
□*Logistic model between conditional probability* $p(X) = \Pr(y = k | X = x_o)$
and p predictors: $\log\left(\frac{p(X)}{1 - p(X)}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p$

✓Naïve Bayes classifier (*p* independent features, *m* classes): $X_1, X_2, \ldots, X_p$
□*The posterior probability* $p(C_k | X)$ *is based on more information than the prior probability* $p(C_k)$

✓K-nearest neighbors (KNN) applying when the conditional distribution is unknown, and other classification methods;

I: STATISTICAL MACHINE LEARNING 2/2

● FEATURE EXTRACTION TECHNIQUES :

✓<u>Exploratory data technique</u> are notably Principal Component Analysis (PCA) and Independent Component Analysis (ICA)

✓<u>PCA method</u> consists of reducing a large set of features observed to a smaller set

□*PCA method is an unsupervised approach since it involves the features* $X_1, X_2, \ldots, X_p$ *without associating a response y. The first principal component is expressed by* $Z_1 = \phi_{11}X_1 + \phi_{21}X_2 + \cdots + \phi_{p1}X_p$ *where the loading vector* $(\phi_{11}, \phi_{21}, \ldots, \phi_{p1})^T$ *is estimated.*

✓<u>ICA method</u> is based on the independent extraction signals (not only the non-correlation). It is related to higher statistics.

✓The <u>signal received</u> by a sensor is the superimposition of elementary signals emitted from other sources

✓<u>ICA method extracts</u> the different sources from the signal received without a priori information. This is called <u>blind identification procedure</u>.

□*A transformed mixing matrix A is estimated by maximizing an objective function that is related to a non-Gaussianity of the components.*

II: ARTIFICIAL IMMUNE SYSTEM 1/2

● BIO-INSPIRED ALGORITHMS:

✓Artificial Immune System (AIS) is one of the numerous algorithms that are inspired from Nature. There are two types of immune systems (ISs)

✓The innate or acquired IS that refers to unchanged mechanisms for the detection and destruction of invasive organisms

✓The adaptive IS that responds immediately to recognized pathogens (presented in the past and memorized).

● PRINCIPLES:

✓Negative selection mechanism. Is able to detect unknown antigens. A tolerance is provided for self-cells (those of the body)

✓Clonal selection mechanism. Only those cells that recognized the antigen proliferate.

✓Hypermutation. New cloned cells mutate with high rates. This genetic process generates antibodies with higher affinity with antigens

II: ARTIFICIAL IMMUNE SYSTEM 2/2

● IMPLEMENTATION:

✓ Three types of decisions: initializing and encoding schemas, defining an affinity measure between antibodies and antigens, configuring selection and mutation processes.

✓Pseudocode of CLONALG algorithm in literature with flowcharts of different versions of AIS

● APPLICATIONS:

✓Extensive and diverse applications in anomaly detection (image analysis, prediction of infections, analysis of medical data), machine learning (pattern recognition, clustering, data classification), global optimization (multivariate, multi-objective, many-objective, combinatorial).

III: COMPLEX PREDICTION PROBLEMS 1/3

● MONITORING AND PREDICTING NATURAL HAZARDS:

✓ Damaging phenomena include earthquakes, landslides, tsunamis, hurricanes, typhoons and tornadoes, volcanic eruptions, etc.

✓ Monitoring and forecasting systems are installed notably in the US, in China, and Japan.

✓ Methods used for predictions are: 1) The prediction of earthquakes with neural networks, 2) The protection of high- quality fresh water in Croatia with artificial neural networks (ANNs) and recurrent neural networks (RNNs) with back loop, 3) The prediction of landslides can use grey prediction systems from the system theory

III: COMPLEX PREDICTION PROBLEMS 2/3

● GREY PREDICTION MODELS:

✓Such models predict uncertain systems with imperfect information.

✓Grey models are time-series predicting models. They predict future values using only the most recent data.

✓The most used Grey model is 1-order 1-variable GM(1,1)

✓More technical details about construction and solution:

□*Data are set all positive + use of a 1-order generating operator 1-AGO*

□*GM(1,1) is a 1-order ODE where and series is the 1-AGO of the original data*

$Dx^{(1)}(t)+ax^{(1)}(t)=b,$ *where* $D\equiv d/dt$ *and series* $x^{(1)}$ *is the 1-AGO*

Parameter b denotes the Grey developmental parameter and the control parameter. Both parameters are estimated by OLS method and initial condition.

□ *Time response equation of GM(1,1) is* $\hat{x}^{(1)}(k)=\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-a(k-1)}+\frac{b}{a}, k=2,3,\ldots,K$

□ *Predicted value of the primitive data at time is* $\hat{x}^{(0)}(k+p)=\left(x^{(0)}(1)-\frac{b}{a}\right)e^{-a(k+p)}\left(1-e^{a}\right)$

III: COMPLEX PREDICTION PROBLEMS 3/3

● LANDSLIDE FORECASTING:

✓An illustration of such earth movements is the Danba landslide in the eastern margin of the Tibetan Plateau.

✓Experimental data come from monitoring points and cover 76 observation periods.

✓The landslide deformation is highly nonlinear, non-stationary and random with a sharp peak.

✓Grey GM(1,1) was used to predict landslide deformations. Authors combined this model with other forecasting methods or generalized GM(1,1).

THANK YOU FOR YOUR ATTENTION

BOOKS OF THE AUTHOR

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- Keller A.A. 2010, *Time-Delay Systems With Application to Economic Dynamics and Control*, Lambert Academic Publishing, Saarbrücken DE.

Figure 1

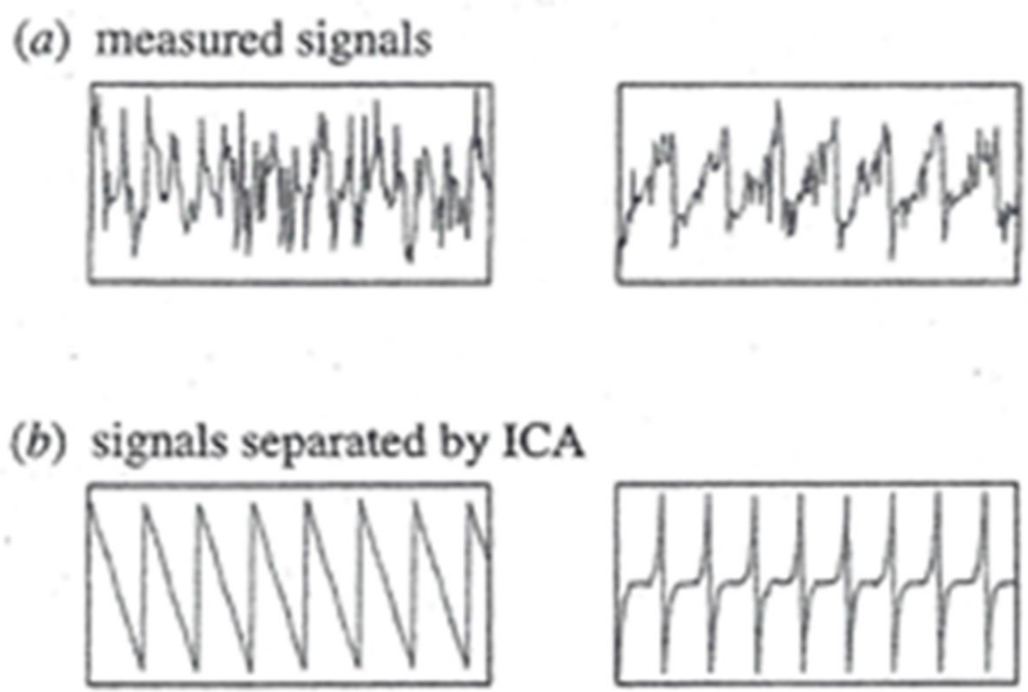

Figure 1 Measured signals and recovered sources by using ICA
(extracted figures of Figure 1 from [Hyvärinen, 2013, p. 3])

Figure 2

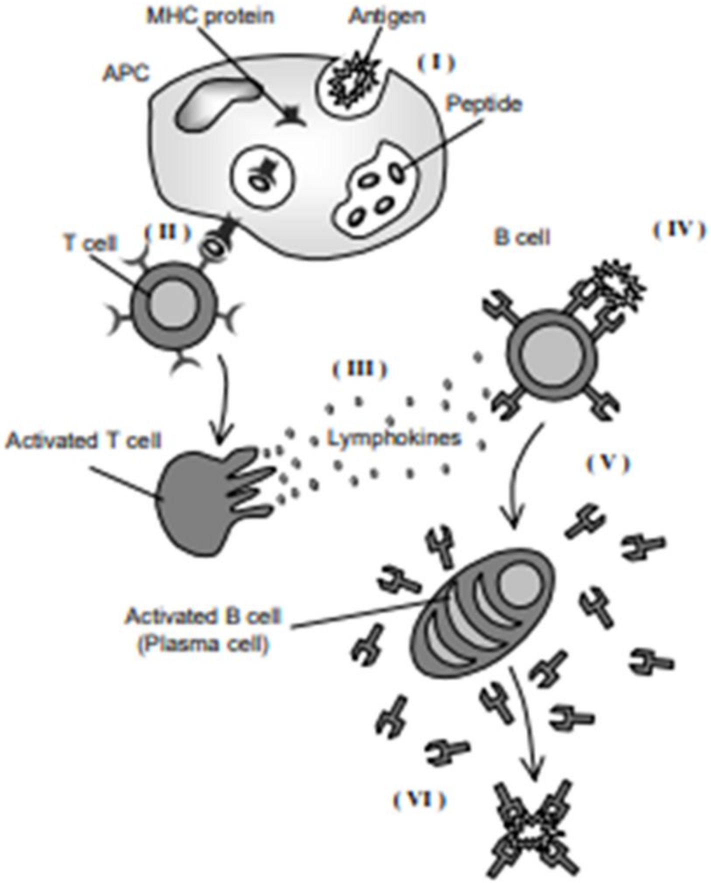

Figure 2. Acquired Human Immunological Mechanisms for the Defense Against Foreign Pathogens (Reprint of Figure 6 from [de Castro and von Zuben, 1999, p. 12])

Figure 3

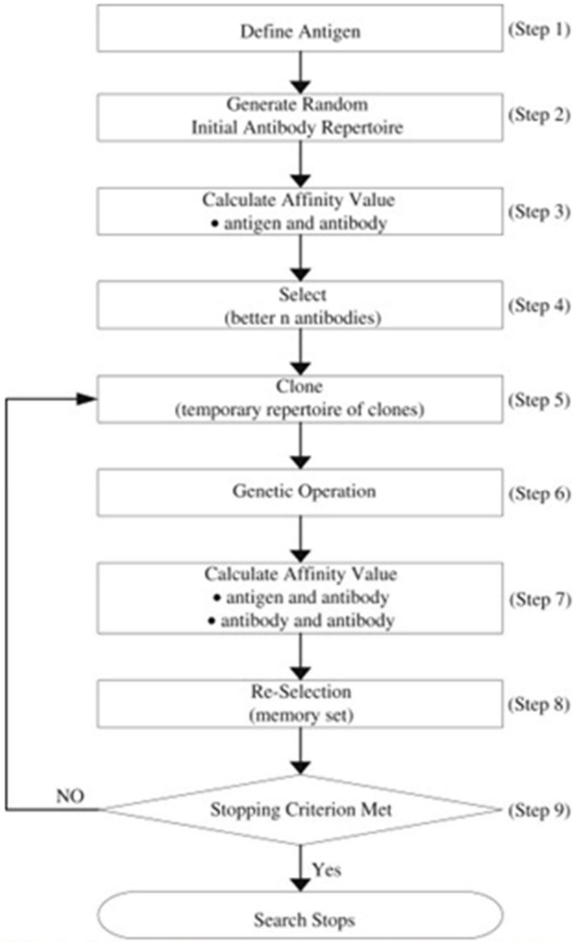

Figure 3. Flowchart of the immune algorithm [reprint of Figure 1 from [Chu et al, 2008] DOI: 10.1016/j.mcm.2008.02.008)

Figure 6

Figure 6 Danba landslide location in the eastern margin of the Tibetan Plateau (reprint of Figure 2 from S. Xie et al [Xie et al, 2017])

Figure 7

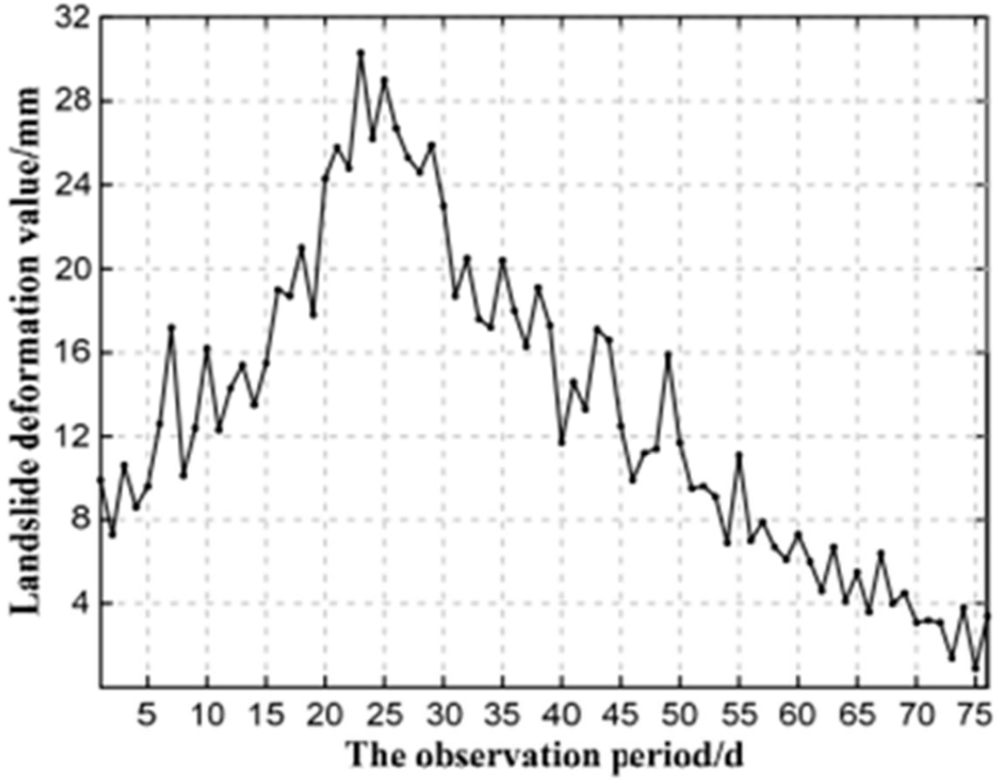

Figure 7 Deformation sequence of the Danba landslide displacement (reprint of Figure 3 from S. Xie et al [Xie et al, 2017])