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Meteorological Data Study and Forecasting Using Particle Swarm Optimization Algorithm

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Abstract**—**Weather systems use enormously complex combinations of numerical tools for study and forecasting. Unfortunately, due to phenomena in the world climate, such as the greenhouse effect, classical models may become insufficient mostly because they lack adaptation. Therefore, the weather forecast problem is matched for heuristic approaches, such as Evolutionary Algorithms. Experimentation with heuristic methods like Particle Swarm Optimization (PSO) algorithm can lead to the development of new insights or promising models that can be fine tuned with more focused techniques. This paper describes a PSO approach for analysis and prediction of data and provides experimental results of the aforementioned method on real-world meteorological time series.

Keywords**—**Weather, Climate, PSO, Prediction, Meteorological

I. INTRODUCTION

SINCE the starting of mankind, people have always been attracted in weather and have tried to discover different methods that would permit them to know the weather in advance. These methods evolved noticeably from the time of Admiral Robert Fitzroy (one of the pioneers of weather forecasting). Today, state of the art weather systems utilize satellite cameras that can zoom into local areas, Doppler radar that uses sound waves, and real-time computer-based data analysis [1-3]. However, most severe climatologists today have the same opinion with Robert A. Heinlein’s quote: “climate is what you expect, weather is what you get”. This quote expresses very well the close connection, and also the difference, between climate and weather. Weather is a depiction of natural situation over a short period of time, a “snapshot” of the atmosphere at a particular time. In one form or another, weather affects our actions, because it affects the major ingredients of life on Earth: water and heat. To guarantee our living, planners require expecting variation in weather.

Climate is the statistics of weather over a long period of time, i.e. a synthesis of the weather recorded for a particular window of time at a particular place. It offers precious information about the average conditions, extremes, or frequencies of events. While climate is not weather, it is defined by the same terms, such as temperature, rain, wind, and solar radiation. Many businesses employ climate and weather data to make up to date economic decisions [4]. Climate varies from one place to another (spatial variation), and, more significant, it varies from season-to-season, year-to-year, decade-to-decade, and so on (temporal variation), due to the natural climate changeability and the human-caused (anthropogenic) climate change. Differences in the timing, strength and duration of seasons can have a giant impact on the environment and people, as climate change impact assessments in relation to agriculture, forests, water resources, etc. Results from general circulation models usually offer neither the most likely scenario nor the full range of possible outcomes.

The main artificial intelligence methods for weather prediction currently in use include model output statistics, fuzzy logic, and expert systems. Some research has focused on using genetic algorithms [5] for various aspects of weather prediction. This paper describes a PSO approach for analysis and prediction of data and provides experimental results of the aforementioned method on real-world meteorological time series.

II. PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization (PSO) is a swarm intelligence class method which was invented in the mid 1990s [6]. The PSO is a population-based stochastic optimization algorithm and recently, it has acquired wide applications in optimizing design problems because of its simplicity and ability to optimize complex constrained objective functions in multimodal search spaces.

In the PSO each potential solution is referred as a particle and each set of particles composes a population. Each particle maintains the position associated with the best fitness ever experienced by it in a personal memory called pbest. Besides, the position associated with the best value obtained so far by any particle is called gbest. In any iteration, the pbest and gbest values are updated and each particle modifies its velocity to move toward them stochastically. This concept can be formulated as:

$$v_i^{t+1} = w.v_i^t + c_1 r_1.(pbest_i - x_i^t) + c_2 r_2.(gbest - x_i^t) \qquad (1)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1} \;\; ; i = 1, 2, \ldots, n \qquad (2)$$

v = particle velocity
x = particle position
n = number of particles
t = number of iterations
w = inertia weight factor
c_1, c_2 = cognitive and social acceleration factors

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$r_1, r_2 = uniformly\ distributed\ random\ numbers$

After the application of PSO algorithm, the algorithm continues with the evaluation phase. The function encoded by each particle in the population is evaluated on the fitness cases set. For each input set, the result of the function is compared with the expected output of that fitness case and the fitness of the particle is adjusted according to the results. In this paper, the fitness of a particle is computed as the sum of the absolute difference between the expected output value and the value returned by the particle, over all fitness cases:

$$fitness = \sum_{c \in C} \left| \exp ected_c - computed_c \right| \tag{3}$$

The best particles are the ones that return better approximations of the expected values the ones with a lower fitness. A particle A is better than another particle B if the fitness of A is lowers than the fitness of B or fitness of A is equal to the fitness of B and A has fewer nodes than B. The evolution-evaluation-selection cycle is repeated until a stopping criterion is met. We use a mixed stopping criterion: the algorithm stops when a maximum number of populations have been reached, or when an acceptable particle was found. The solution designated by a run of the PSO algorithm is the best particle throughout the search space.

III. SIMULATION RESULTS

Our experiments were carried out in Matlab 6 with MeteoLab toolboxes. MeteoLab was developed by Antonio S. Cofi´no, Rafael Cano, Carmen Sordo, Cristina Primo, and Jos´e Manuel Guti´errez as companion software for their book on weather prediction [7]. It is a collection of numerical weather prediction (NWP) algorithms, raw data of weather observations (precipitation, pressure and temperature observations) for European stations from the Global Climate Observing System (GCOS) Surface Network (GSN), and information of reanalysis projects. MeteoLab also includes algorithms for generation of simulation data and a routine for the representation of climate data.

The first experiment uses a data set of temperature observations collected every 10 days between January 1st and December 31st, 1999, in Rennes, France. We compared our PSO-based approach with results obtained by the Neural Networks (NN) toolbox Netlab.

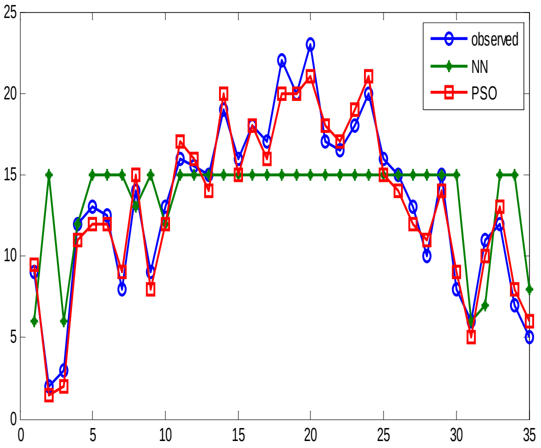

Fig. 1 Results for Rennes data set.

Figure 1 contains the plots of the models found by NN, and PSO. In this case, the mean error of Netlab's solution is 3.3289, while the mean error of the PSO model is 2.27.

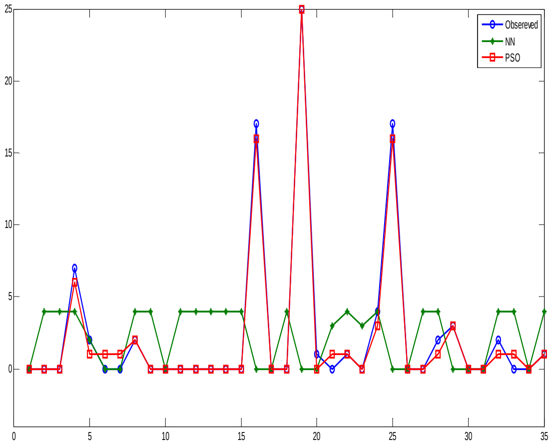

Fig. 2 Results for Ostersund Froson data set

The next experiment presents the results for precipitation analysis in Ostersund Froson, Sweden, during 2001, within a similar experimental setup as the previous experiment. In this case, the observed data has many null values (corresponding to dry days), with occasionally high peaks, making this a difficult data set.

Figure 2, which contains the plots of the models found by Netlab, and PSO, clearly shows the high quality of the PSO model. In this case, the mean error of Netlab's solution is 3.0390, while the mean error of the PSO model is 2.01.

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IV. CONCLUSION

This paper shows that PSO can outperform classical and modern methods (based on artificial intelligence) for the discovery of models in weather data. Moreover, the self adaptability of PSO allows it to work in an unsupervised manner and to discover relations hidden inside the data set.

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