MARSchine Learning: Prediction of Mars meteorological variables using artificial neural networks

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Abstract

Weather forecasting (the task of determining the future state of the atmosphere) has been done for the Earth' system for a long time, but never for Mars. This work provides a Martian weather forecast tool based on experimental atmospheric data obtained from REMS instrument (meteorological station present on Curiosity, the Mars Science Laboratory mission).

The study of the meteorological variables has been done using an artificial neural network which has been trained and tested for this purpose.

1. Introduction

The artificial neural network (hereafter ANN) structures were developed from known models of biological nervous systems and the human brain itself. The processing units, called artificial neurons, are simplified models of a biological neuron. These models were inspired by how a cell membrane of a neuron generates and propagates impulses [1].

The ANNs are part of the area known as intelligent systems or computational intelligence. Computational intelligence refers to the ability of a computer to learn a specific task from observation. The methods used are similar to the human's way of rationale, and it is able to produce control actions in an adaptive manner. In particular, ANNs allows the system to learn experiential data by operating as a biological one with a purely data-driven approach.

2. Martian weather prediction

Currently, Mars' weather prediction is based on the application of deterministic and complex fluid physics models with many variables. On the contrary, in this work, we rely solely on the empirical knowledge of the Martian atmosphere following a probabilistic approach using AANs.

The proposed methodology is complementary and it is not intended to replace fluid physics, but rather to provide new tools to understand the processes of the Martian atmosphere.

The advantage of a fluid dynamics model is that it provides information on the underlying physics of the process but with extreme complexity, while the data-driven approach provides results with greater simplicity but does not give information on why the system has a particular behavior.

This proposed approach can be very useful in case of lack of measurements (e.g. adverse weather conditions or stops to adjust the software) or when validating other codes or new data.

3. Experimental setup

ANNs have been extensively used on Earth with satisfactory results to predict the weather in different regions [2], rainfall prediction [3], meteorological variables parameters during premonsoon thunderstorms [4], etc.

In this work, we make use of ANNs techniques to forecast Mars' weather using REMS (Rover Environmental Monitoring Station) data from 2013 to 2018. REMS instrument onboard Curiosity rover provides measurements of pressure, humidity, air and ground temperature, UV radiation and wind speed and direction [5].

The ANN developed to forecast predicts on a complete daily basis, given the measured data from the actual sol, calculates next sol: pressure and air temperature on an hourly basis.

The initial training set of the network consists of 1637 Martian solar days. The variables from the set which were used were:

- sol
- hour
- air temperature
- pressure
- orbit (LS)

The initial dataset was split into two major groups, 75% to feed the network (first 1227 sols), and 25% to validate the results (last 410 sols).

The first dataset was used to develop the network; within this process the network learns the relationship between inputs and outputs, generalizing solutions, meaning that the network produces an output that approximates the expected output of a given input value.

The second dataset, which is unknown to the network, was used to validate the accuracy of the forecast given by the network.

4. Results

The correlation coefficient obtained between the predicted and training data set is 0.9995, indicating an extremely accurate mapping of the data.

The validation of the network was performed using the second dataset. The correlation coefficient for the unknown cases was 0.99035.

Figure 1 shows the air temperature prediction versus air temperature measured for 5 sols from the second data set (unknown data set)

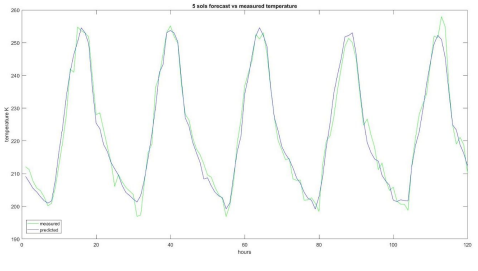

Figure 1: Measured air temperature and its prediction.

The following graph shows the pressure prediction versus pressure measured for 5 sols from the second data set (unknown data set)

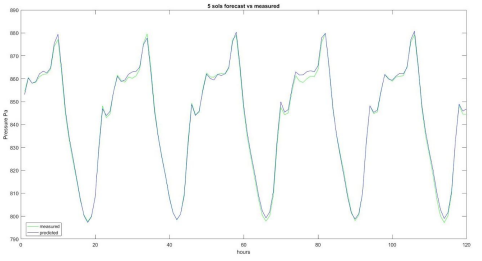

Figure 2: Measured pressure and its prediction.

5. Conclusions

The analysis presented in this work prove that the application of artificial neural networks to forecast Martian meteorological variables is a valid approach, useful to complement current models, gain insights on Mars' atmosphere and analyze data from the future meteorological stations on Mars.

6. References

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