Energy efficiency through an on-line learning approach for forecasting of indoor temperature

F. Zamora-Martínez, P. Romeu, ***J. Pardo****, P. Botella-Rocamora*
juan.pardo@uch.ceu.es

Embedded Systems and Artificial Intelligence group
Departamento de ciencias físicas, matemáticas y de la computación
Escuela Superior de Enseñanzas Técnicas (ESET)
Universidad CEU Cardenal Herrera, 46115 Alfara del Patriarca, Valencia (Spain)

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SMLsystem

Introduction and motivation

- SMLsystem is a domotic solar house project presented at the SolarDecathlon.
- Indoor temperature is related with comfort and power consumption.
- Artificial Neural Networks (ANNs) are a powerful tool for pattern classification and forecasting.
- This work test the ability of on-line learning algorithms in a real forecasting task.

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Data details

Acquisition

- The data temperature signal is a sequence $s_1 s_2 \ldots s_N$ of values,
- Sampled with a period of 1 minute.
- Smoothed with 15 minutes averages.
- Multivariate forecasting based on previous work: indoor temperature ($^\circ$C), sun irradiance (W/m^2), current hour.
- Dataset: two consecutive sequences of $2\,764$ and $1\,373$ time instants (28 and 14 days respectively). Available at UCI machine learning repository.

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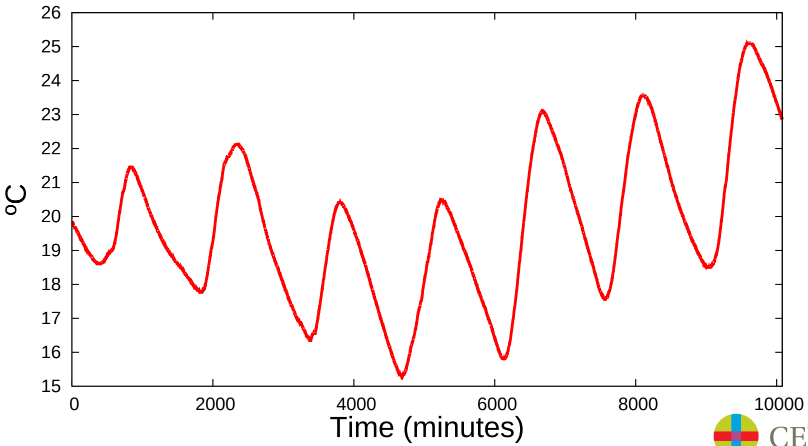
Segment of the dinning room temperature data



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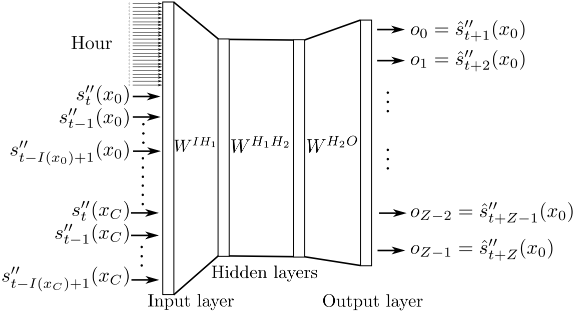
Neural Network description



- At time step i:
  - the ANN input receives:
    - the hour component of the current time (locally encoded);
    - a window of the previous temperature values (x_0);
    - a window of the previous sun irradiance values (x_1).
    - More inputs could be possible, but not done in this work.

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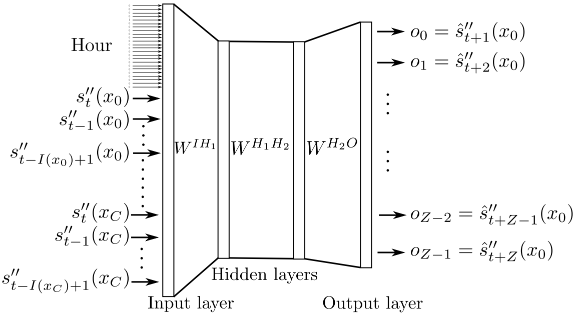
Neural Network description



- At time step i:
  - and computes a window with the next predicted temperature values (Z is forecast horizon):

$$s''_{i+1} s''_{i+2} s''_{i+3} \ldots s''_{i+Z}$$

Known as multi-step-ahead direct forecasting.

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Learning modes

For Gradient Descent (GD) learning, traditionally this learning modes are available:

- Batch mode allows fast matrix operations, not feasible with large datasets.
- On-line mode faster convergence than batch, but could be noisier.
- Mini-batch mode a trade-off between both strategies.

This work studies the on-line learning mode for the integration of predictive models in totally unknown scenarios.

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Training details

- Error back-propagation algorithm with momentum term.
- The ANN learn to map predicted output values (o_i) with corresponding true values $(p_i^\star)$,
- minimizing the MSE function

$$E = \overbrace{\frac{1}{2}\sum_i (o_i - p_i^\star)^2}^{\text{MSE}}$$

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Training details

- Error back-propagation algorithm with momentum term.
- The ANN learn to map predicted output values (o_i) with corresponding true values $(p_i^\star)$,
- minimizing the MSE function, adding weight decay L2 regularization

$$E = \underbrace{\frac{1}{2}\sum_i (o_i - p_i^\star)^2}_{\text{MSE}} + \varepsilon \underbrace{\sum_{w \in \{W^{HO} \cup W^{IH}\}} \frac{w^2}{2}}_{\text{weight decay}}$$

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Results

Evaluation measures

- Mean Absolute Error (MAE):

$$MAE = \frac{1}{N}\sum_i |p_i - p_i^\star|$$

- Root Mean Square Error (RMSE):

$$RMSE = \frac{\sum_i (p_i - p_i^\star)^2}{\sum_i (\bar{p}_i - p_i^\star)^2}$$

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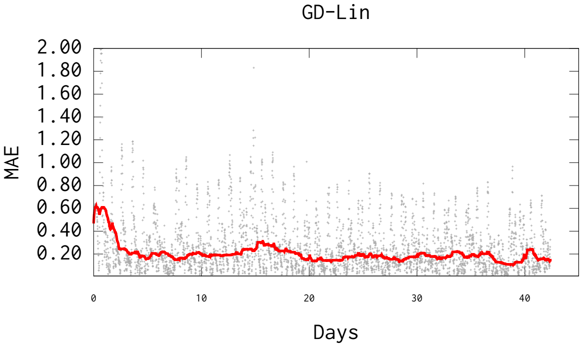
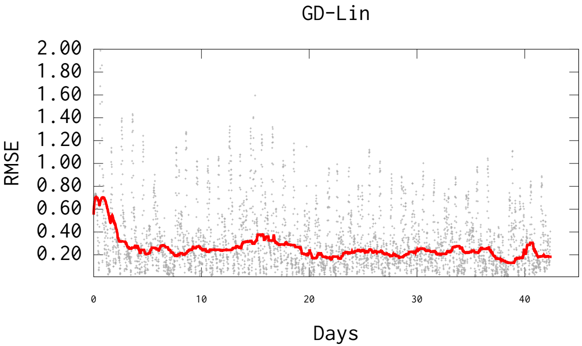
Results

Mean Absolute Error



Results

Root Mean Squared Error



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Conclusions

- An on-line learning approach was presented.
- It allows to integrate predictive models in totally unknown scenarios.
- A GD on-line algorithm has been studied, using linear models.
- Promising performance results has been obtained.
- A deeper analysis is needed in order to state the dependence between the dataset size and the model complexity.

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