XXXIX
Congresso da Sociedade Brasileira de Computação
14 a 18 de Julho | Centro de Convenções da Amazônia | Belém - PA

Realizado por: SBC Sociedade Brasileira de Computação

Applying the Long-Term Memory Algorithm to Forecast Loss of Thermoregulation Capacity in Honeybee Colonies

Antonio Rafael Braga, Lia Sucupira Furtado,
Antonio Diego M. Bezerra, Breno M. Freitas,
Joseph A. Cazier and Danielo G. Gomes

X Workshop de Computação Aplicada à Gestão do Meio Ambiente e Recursos Naturais (WCAMA 2019)

Agenda

1. Introduction
2. Related works
3. Material and methods
    3.1. Dataset
    3.2. Preprocessing
    3.3. Detection and removal of anomalies
    3.4. Data Resizing (Min-Max scaling)
    3.5. Long Short-Term Memory (LSTM)
    3.6. Experiment Setup
    3.7. Evaluation Metrics
4. Results
5. Discussion
6. Conclusion

1 - Introduction

- Motivation
    - Bees are the most important group of **pollinators** [Klein et al. 2007, Brown et al. 2016];
    - Honeybee colonies have dwindled in rates of 30% colony deaths overwinter due to **climate change** and the use of **agrochemicals**;
    - Whatever the causes, they all converge to the same point; harming the **thermoregulation capacity** of the colonies.

Figura 1. Abelhas em atividade de polinização. Fonte: http://www.jornalentreposto.com.br/99-arquivos/1481-insetos-polinizadores-melhoram-produtividade-agricola

1 - Introduction

- Apicultura de precisão
  - RSSF e IoT;
  - Monitoramento remoto de apiários;
  - Mineração e análise de dados.
- Proposta
  - In this paper, we used machine learning techniques to predict homeostasis loss.
  - We apply the Long Short-Term Memory (LSTM) algorithm to forecast the thermoregulation capacity (i.e. homeostasis) loss in honeybee colonies.

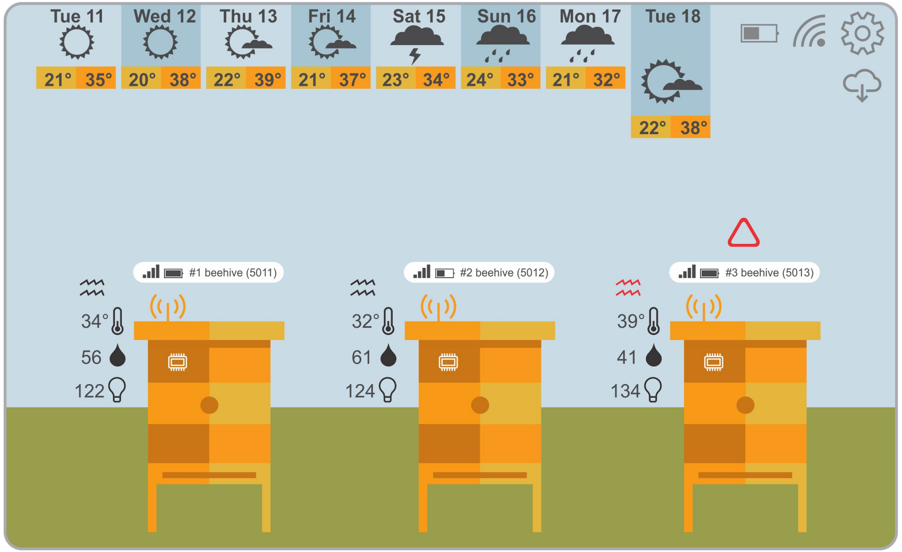


Figure 2. Dashboard overview of a general remote beehive monitoring system.

2 - Related works

- In tropical climate, [Kridi et al. 2016] recognized thermal patterns to detect bees' pre-abandonment scenarios;
- In temperate climate, the hotter the bees perform the foraging, which impacts the development of the pupae and the division of labor of the bees [Winston 1991];
- The seasons of the year are also very important to the colony behavior [Maciel et al. 2018].
- Thus, the loss of internal temperature control is an important indicator related to the colony health, and may indicate if it is facing a problem.

3 - Material and methods

- Dataset
  - Six different beehives;
  - An apiary located in the city of Newcastle upon Tyne, England;
  - Collected from September to November in 2017;

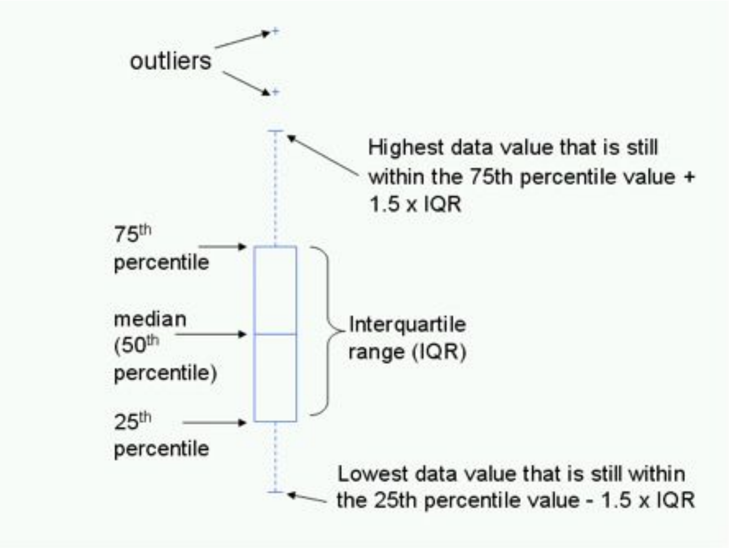
Table 1. Summary of beehive analyzed with good thermoregulation

beehives	latitude	longitude	#samples	period	sampling	therm.
9803	-1.628	54.971	603	Sep 3th-Nov 6th	2hs	w.r.
9837	-1.516	54.994	1456	Sep 3th-Nov 6th	1h	n.r.
9841	-1.617	54.979	638	Sep 5th-Nov 6th	2hs	n.r.
9848	-1.599	55.016	502	Sep 5th-Nov 2th	2hs	n.r.
54440	-1.628	54.971	606	Sep 3th-Nov 6th	2hs	n.r.
54460	-1.616	54.970	1024	Aug 5th-Nov 6th	2hs	w.r.

3 - Material and methods

- Preprocessing
  - Exploratory Data Analysis (EDA)
    - Basic statistics (mean, the standard deviation, and quartiles), and the skewness.
- Detection and removal of anomalies
  - Interquartile Range;
- Data Resizing (Min-Max scaling)

$$x_{new} = \frac{x - x_{min}}{x_{max} - x_{min}}.$$



Describing Interquartile Range and Outliers
Fonte:
https://images.app.goo.gl/KXWyySHj21uSkP9z5

3 - Material and methods

- Long Short-Term Memory (LSTM)
  - Long Short-Term Memory (LSTM) is a specific RNN architecture that was designed to model temporal sequences and their long-range dependencies more accurately than conventional RNNs [Sak et al. 2014].

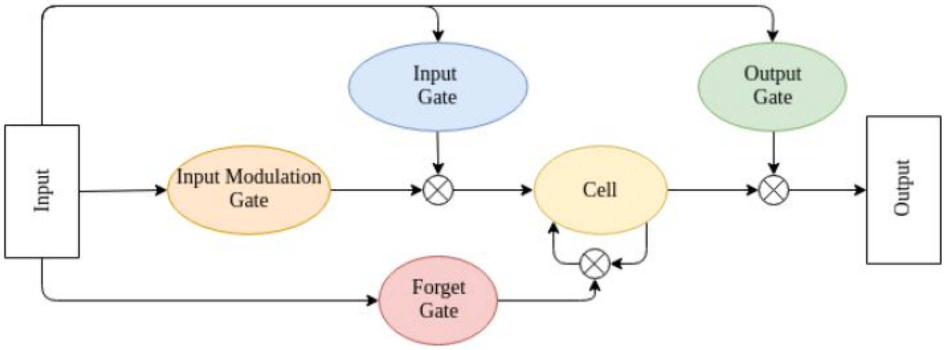


Figure 2. A LSTM memory cell

3 - Material and methods

- Experiment Setup
  - The data was separated in train (67%) and test (33%) sets;
  - LSTM architecture with 4 hidden layers;
  - A number of epochs equal to 100;
  - The back propagation parameter (look back) was setted in 4 timestamps.
- Evaluation Metrics
  - (i) MAE is the mean for all recorded absolute errors;
  - (ii) MAPE is the mean absolute percentage error;
  - (iii) RMSE measures the average of the squares of the errors, that is, the average squared difference between the estimated values and what is estimated;
  - (iv) R 2 provides a measure of how well observed outcomes are replicated by the model, based on the proportion of total variation of outcomes explained by the model.

Results

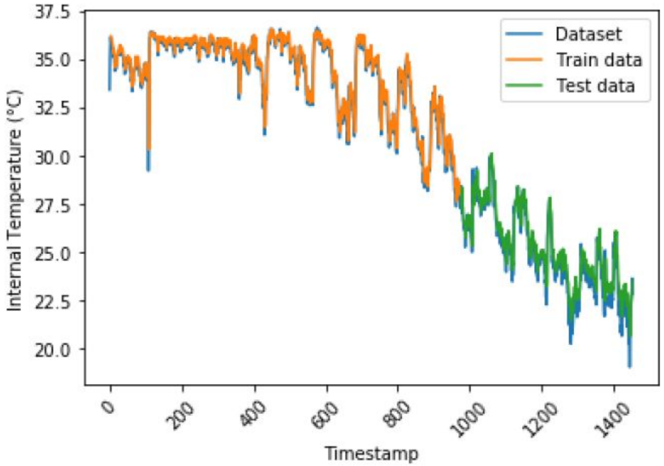


Figure 3. LSTM fitting (hive #9837)

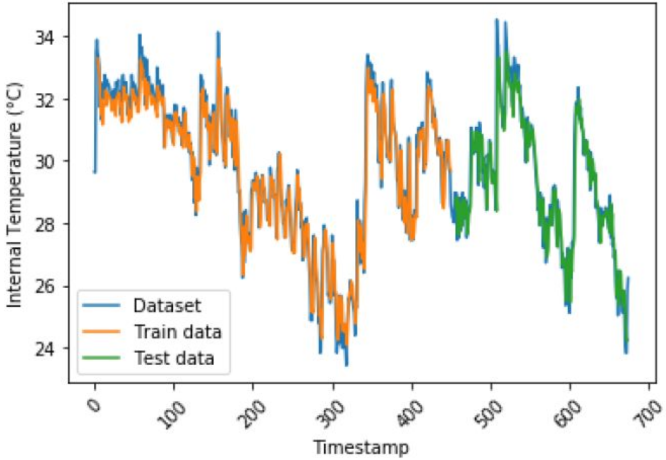


Figure 4. LSTM fitting (hive #9841)

Results

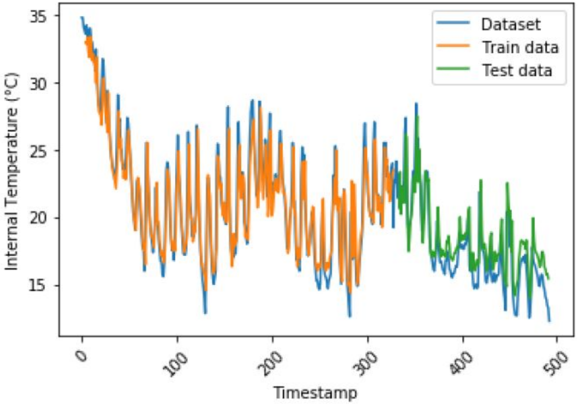


Figure 5. LSTM fitting (hive #9848)

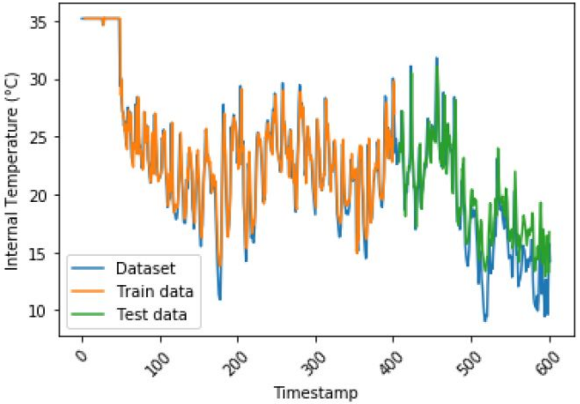


Figure 6. LSTM fitting (hive #54440)

Table 2. Evaluation Metrics for LSTM Algorithm for not thermoregulated beehives

Beehive	RMSE Train	RMSE Test	MAE	MAPE	R^2
9837	0.49	0.73	0.5651	2.3424	0.8876
9841	0.77	0.83	0.5658	1.9388	0.8543
9848	1.79	1.72	1.4282	8.3675	0.6978
54440	1.74	2.46	2.0794	13.614	0.7427

Results

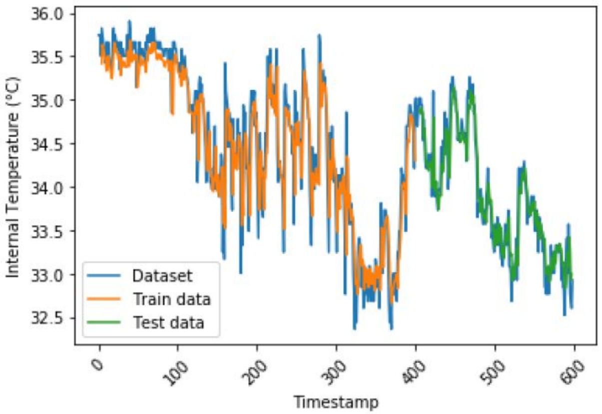


Figure 7. LSTM fitting (hive #9803)

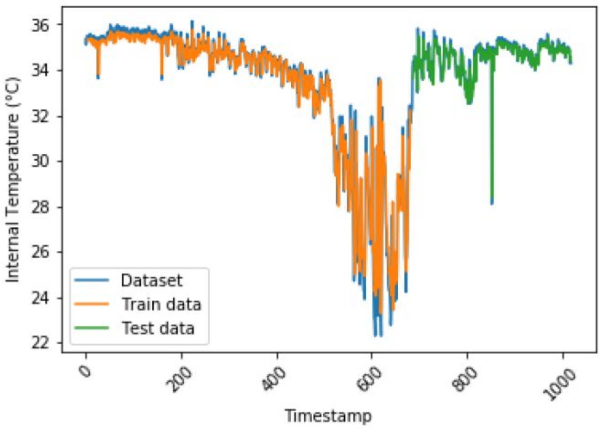


Figure 8. LSTM fitting (hive #54460)

Table 3. Evaluation Metrics for LSTM Algorithm for thermoregulated beehives

Beehive	RMSE Train	RMSE Test	MAE	MAPE	R^2
9803	0.38	0.25	0.1854	0.5478	0.8677
54460	0.93	0.64	0.3102	0.9098	0.1276

Discussion

- The **high amplitude** of temperature and a declining pattern indicate a sign of thermoregulation losses;
- According to [Heldmaier 1987] the colony capacity to survive cold depends on maintenance of a steady state temperature, about **35°C**;
- Some beehives the temperature fell more than **10°C**, this could already be a sign of trouble;
- In extreme conditions of cold weather the bees take a protective behavior and start a phonomena called the **diapause**.
- Loss in the thermoregulation capability <-> **high temperatures**;
    - brood death, wax melting, honey dehydrated;

Conclusion

- General proposal objective
  - Predict thermoregulation loss;
- Main contribution
  - A trained Long Short-Term Memory (LSTM) algorithm to forecast the thermoregulation capacity loss;
- Results
  - Our results showed an error of only **0.5%** in prediction for well-thermoregulated beehives;
  - The proposed solution was capable of predicting the thermoregulatory capacity loss of a colony up to **8 hours** before the homeostasis is lost in the nest.
- In perspective
  - We intend to inform others features to LSTM, like internal humidity, hive activity, mean fanning, mean flight noise, weight, external temperature, and external humidity.

Perguntas?

Obrigado!

antoniorafaelbraga@gmail.com

UNIVERSIDADE FEDERAL DO CEARÁ

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Grupo de Redes de Computadores Engenharia de Software e Sistemas