Time Series Forecasting

USING LSTM

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OVERVIEW

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INTRODUCTION

- Accurate daily weather prediction model using LSTM networks.
- Relevant for sectors like agriculture and urban planning.

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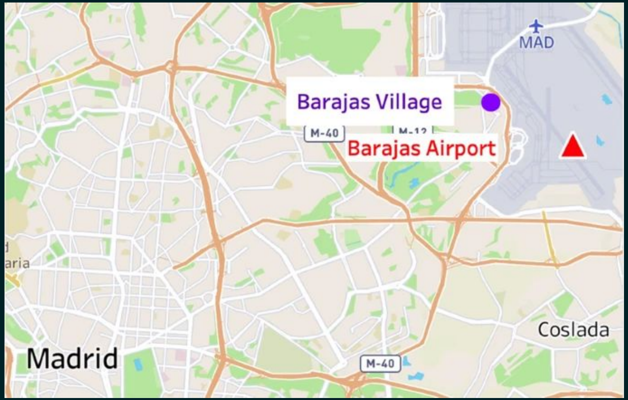
STATE OF THE ART

Modelling time series with multiple seasonalities: an application to hourly NO pollution levels (by M. Avila, A. Alonso & D. Peña) [1]



Air quality station in Barajas, Madrid

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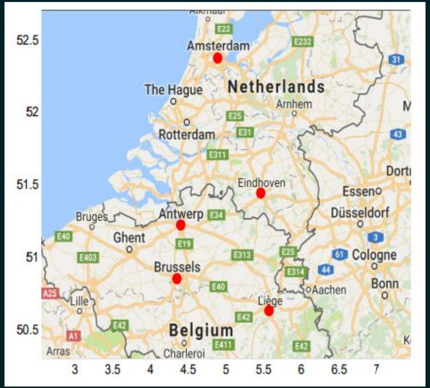
STATE OF THE ART

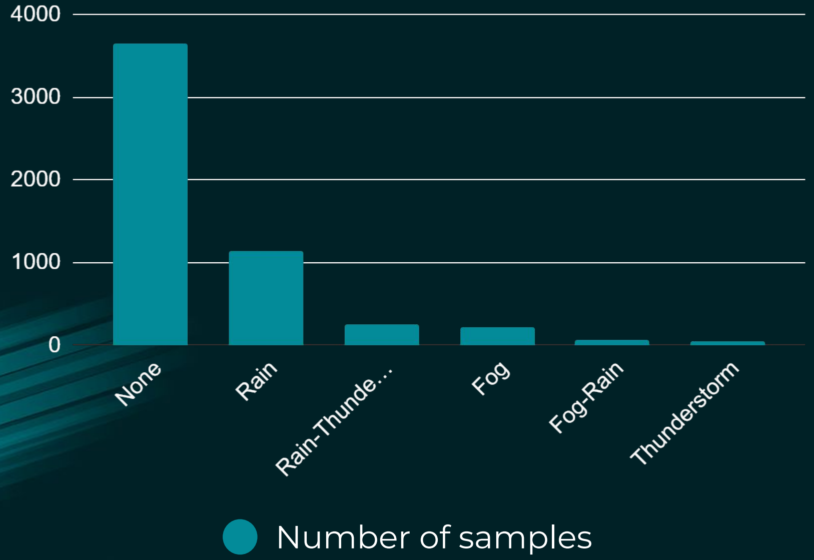
Spatio-temporal Stacked LSTM for temperature Prediction in Weather Forecasting (by Z. Karevan & J.A.K. Suykens) [2]

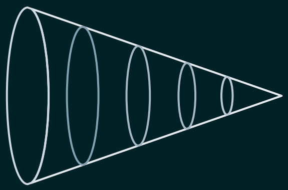


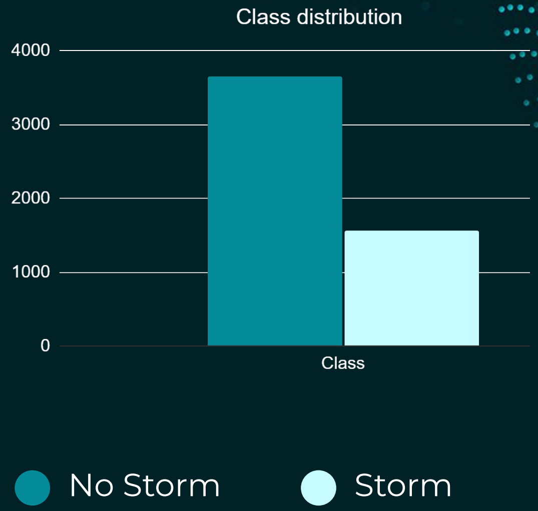
Map of weather stations in Belgium and Netherlands

DATA ANALYSIS

Cleaning events label:







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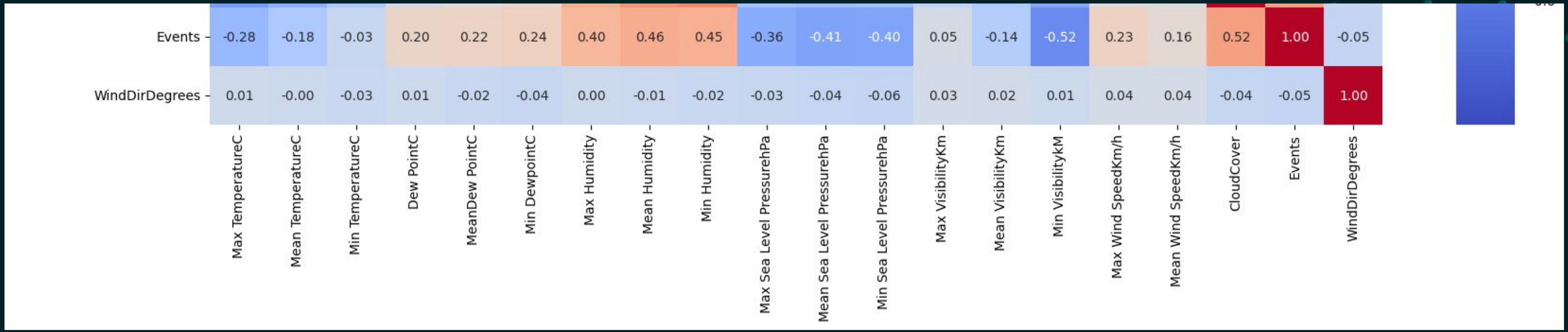
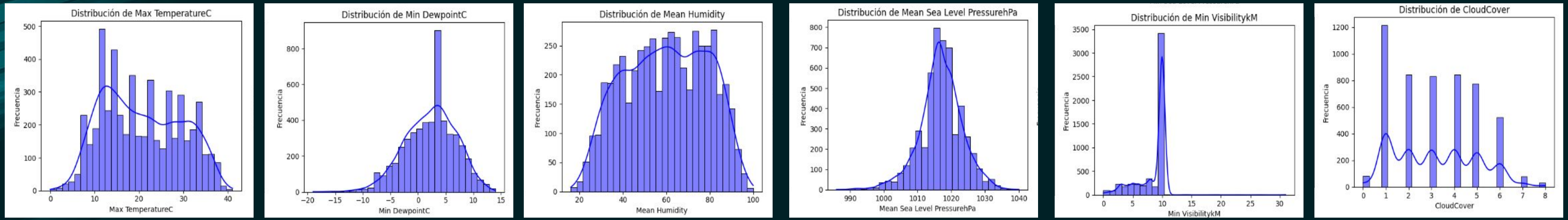
DATA ANALYSIS

Deciding the features:



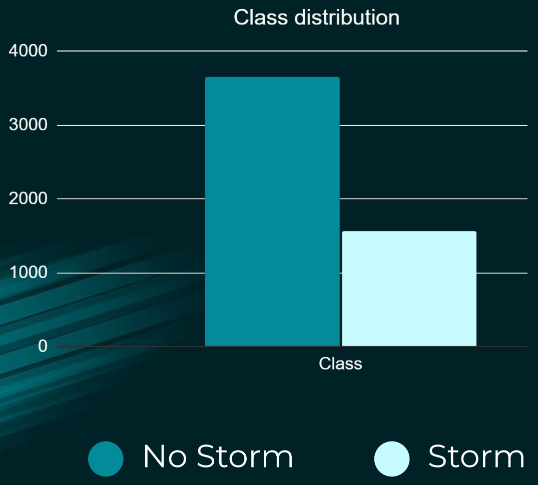
Part of correlation matrix

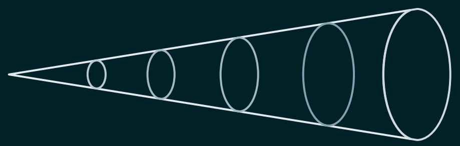


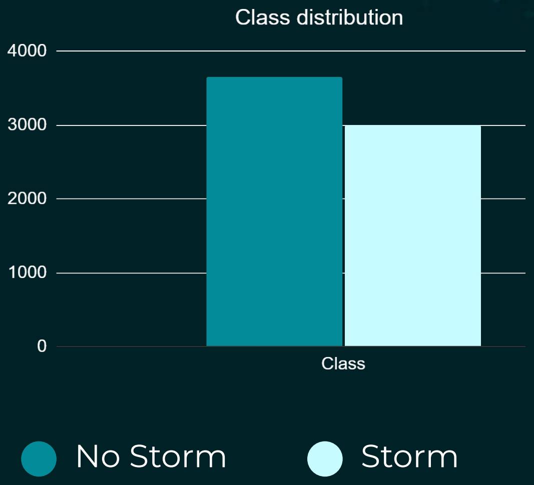
Distribution of features that have high correlation with Events

DATA ANALYSIS

Data augmentation:







MODELS AND OPTIMIZATION

Architecture

We implemented a LSTM architecture

Training procedures

Supervised training using Adam optimizer with backpropagation over multiple epochs

Loss functions

We used the binary cross entropy function

Hyperparameter s

Hyperparameters include input size, hidden size and number of layers

EXPERIMENTS

- Cross Entropy vs Binary Cross Entropy
- Giving importance to recall
- Other metrics: loss, accuracy, precision, auc-roc

		Predicted	
		0	1
Actual	0	TN	FP
	1	FN	TP

Example of confusion matrix

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

Computation of precision and recall

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RESULTS

Hidden size	Number of layers	Test loss	Test accuracy	Test recall
32	1	0.4275	80.39%	77.33%
64	1	0.4033	81.74%	80.33%
128	1	0.4008	81.22%	75.67%
32	2	0.4208	81.67%	79.67%
64	2	0.4019	82.12%	79.33%
128	2	0.3953	81.44%	81.83%

Test results of the model with differents hyperparameters

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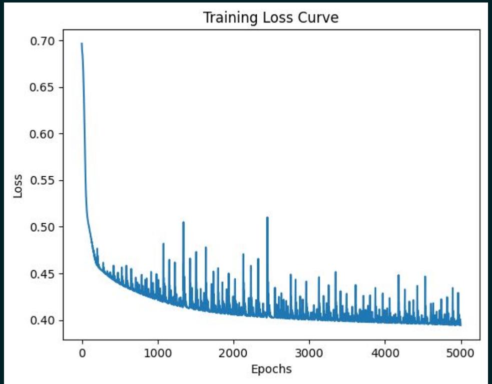
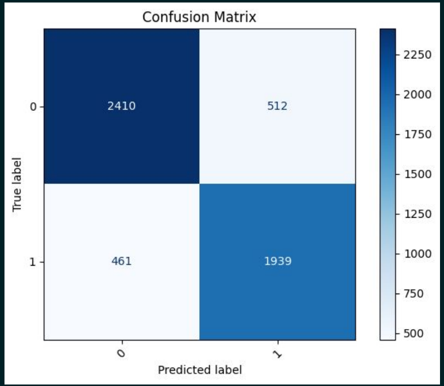
RESULTS

Training results of LSTM with HS = 128 & L = 2:

Loss	Accuracy	Precision	Recall	AUC-ROC
0.3949	81.72%	79.11%	80.79%	90.04%



Training Loss Curve



Training Confusion matrix

Loss, accuracy, precision, recall and AUC-ROC of training set

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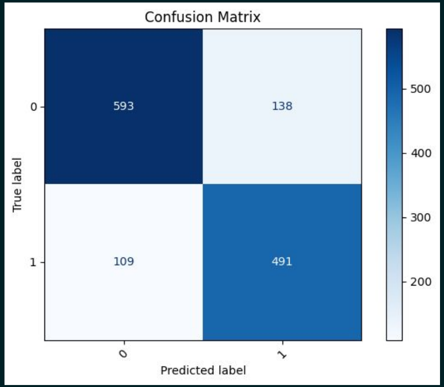
RESULTS

Testing results of LSTM with HS = 128 & L = 2:

Loss	Accuracy	Precision	Recall	AUC-ROC
0.3953	81.44%	78.06%	81.83%	90.11%

Loss, accuracy, precision, recall and AUC-ROC of testing set



Testing Confusion matrix

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DISCUSSION

- Increasing hidden size (32 → 64) improved accuracy, recall, and reduced loss
- More layers (1 → 2) led to better recall and lower loss in most cases
- Best model: 2 layers, 128 hidden units

- Limitations:
  - Larger models didn't always outperform simpler ones
  - Limited size of the dataset

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CONCLUSION

- Main findings:
  - LSTM work for time series forecasting
  - Higher complexity usually leads to better performance
  - Importance of cleaning and prepare data
- Challenge: Balancing complexity vs. generalization
- Possible improvements:
  - Try different activation functions (tanh, ReLU, ...)
  - Test on more and better datasets to validate generalization

REFERENCES

- [1] Avila, Matias & Alonso, Andres & Peña, Daniel. (2023). Modelling multiple seasonalities with ARIMA: Forecasting Madrid NO2 hourly pollution levels. https://doi.org/10.1007/s00477-025-02958-6
- [2] Karevan, Z., & Suykens, J. A. K. (2018). Spatio-temporal stacked LSTM for temperature prediction in weather forecasting. arXiv. https://doi.org/10.48550/arXiv.1811.06341

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THANKS!

Do you have any questions?

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