Analysis of attention mechanisms for the prediction of ship fuel oil consumption

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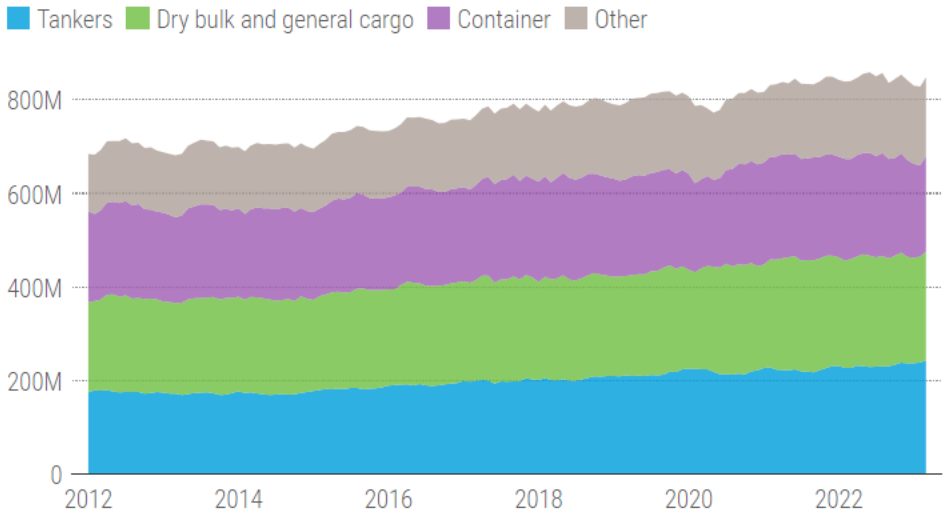
Greenhouse Gas Emissions

Shipping emissions are headed in the wrong direction

Carbon dioxide emissions by main vessel types, tons, 2012–2023



Note: The group "other" includes vehicles and roll-on/roll-off ships, passenger ships, offshore ships and service and miscellaneous ships.

Source: UNCTAD based on data provided by Marine Benchmark, June 2023. • Get the data • Download image

Most ship-owning countries have seen a rise in emissions

Carbon dioxide emissions (tonnes) in 2012 and 2022 for 29 main countries of vessel ownership

Search in table

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	Country	2012	2022
1	China	43,493,613	102,317,721
2	Japan	99,628,524	101,254,900
3	Greece	69,330,862	95,968,419
4	United States of America	43,859,245	45,656,717
5	China, Hong Kong SAR	18,822,466	39,060,933
6	Germany	86,588,074	37,040,384
7	Singapore	19,806,355	32,522,147
8	Korea, Republic of	24,324,282	28,736,060
9	Denmark	23,473,417	28,007,662
10	Norway	25,748,700	26,496,768

Note: Carbon dioxide emissions from vessels' main and auxiliary engines, calculated based on bunker fuel from the Automatic Identification System.

Source: UNCTAD, based on data provided by Marine Benchmark, June 2023 • Get the data • Download image

Report obtained from https://unctad.org/publication/review-maritime-transport-2023.

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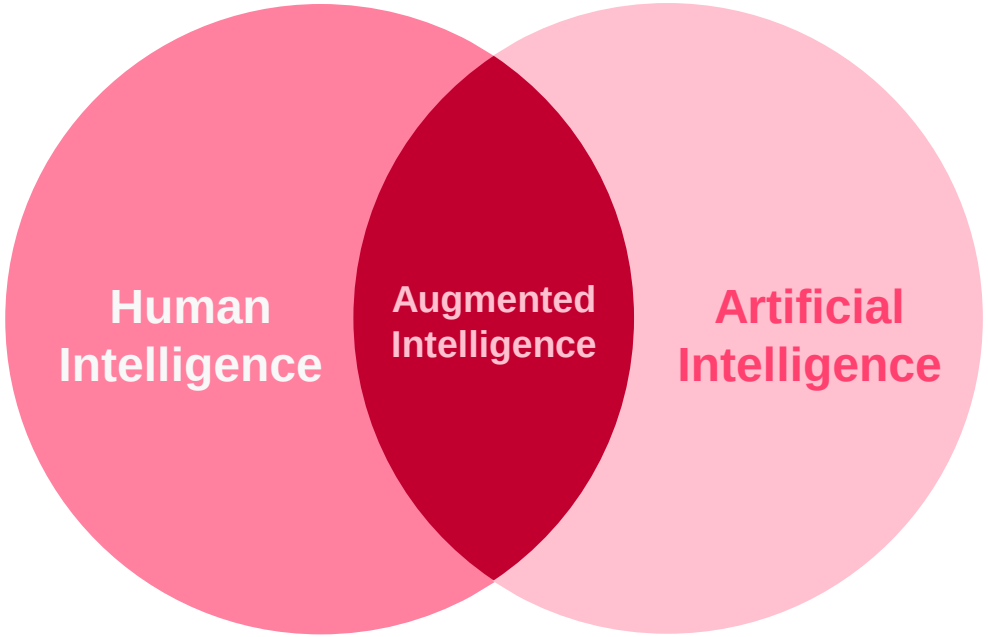
Augmented Intelligence

"Augmented intelligence is a design pattern for a human-centered partnership model of people and artificial intelligence (AI) working together to enhance cognitive performance, including learning, decision making and new experiences."

"La inteligencia aumentada es un patrón de diseño para la aplicación de modelos de asociación centrados en el ser humano para que los humanos y la inteligencia artificial interactúen con el fin de mejorar el rendimiento cognitivo, incluyendo el aprendizaje, las tomas de decisiones y nuevas experiencias"

— Gartner



*The definition of the Augmented Intelligence concept has been obtained from https://www.gartner.com/en/information-technology/glossary/augmented-intelligence.

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Augmented Intelligence

Machines that assist processes that must be carried out by humans.

Suggest decisions.

Selective mimicry of the human brain.

Robots and humans working collaboratively. Intelligent drones operated by humans.

*The icons utilised in this section have been obtained from https://www.flaticon.com/free-icon/.

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Augmented Intelligence & Fuel Oil Consumption

Predictive Analytics

Operation Optimisation

Effective Maintenance

Energy Management

Environmental Impact Reduction

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Augmented Intelligence & Fuel Oil Consumption: AS IS

Deep Learning (DL) models are accessible today through several open-source packages and frameworks, such as **Tensorflow**, **Pytorch**, and **Keras**. However, they have a nominal presence in literature regarding the exploitation of the prediction of ship fuel oil consumption.

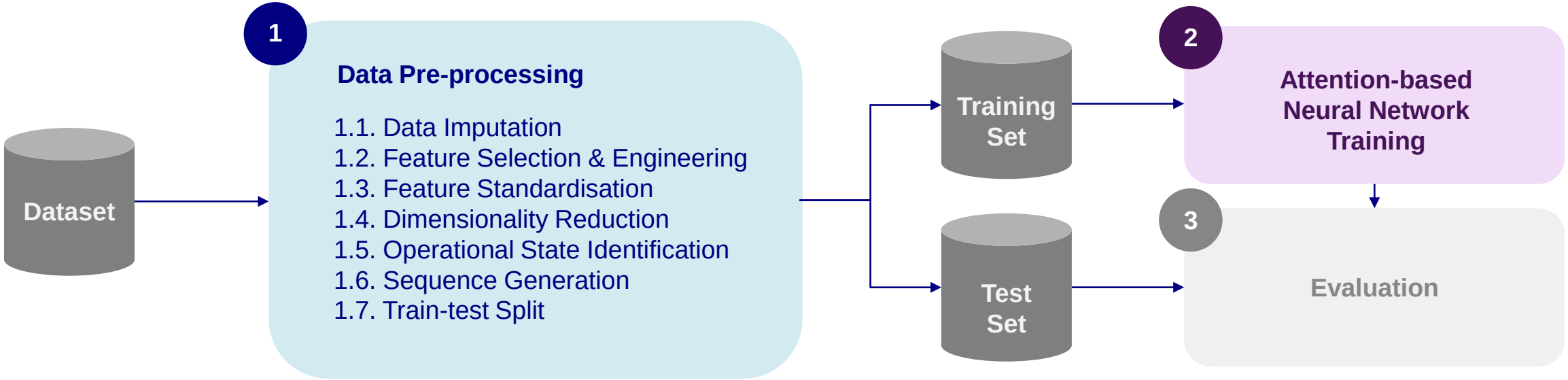
Examples of Deep Learning models that have been already implemented for the prediction of fuel oil consumption

- Bidirectional – Long Short-Term Memory Neural Network [10].
- Long Short-Term Memory Neural Network [11].
- Artificial Neural Networks [13].

Main Contribution

Propose a novel method to predict fuel oil consumption onboard ships using an attention mechanism–based deep learning model.

Methodology (I)



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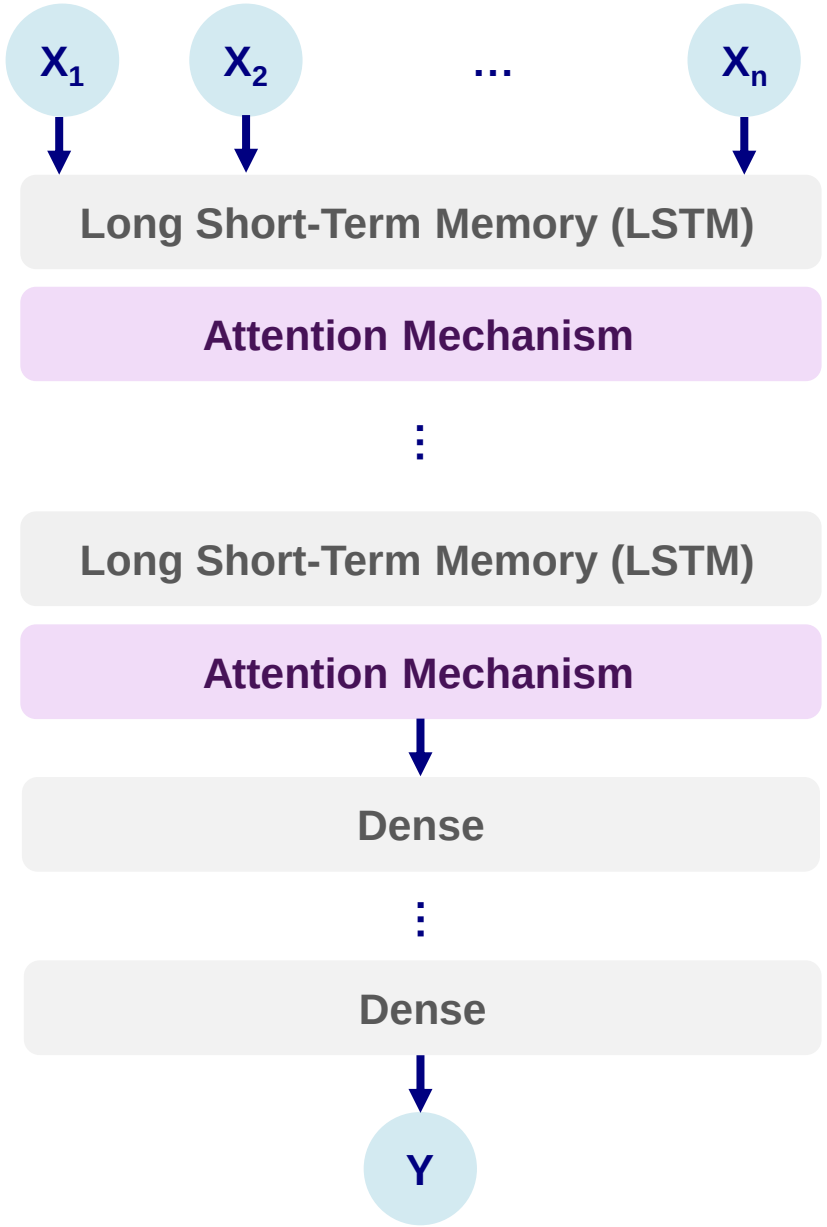
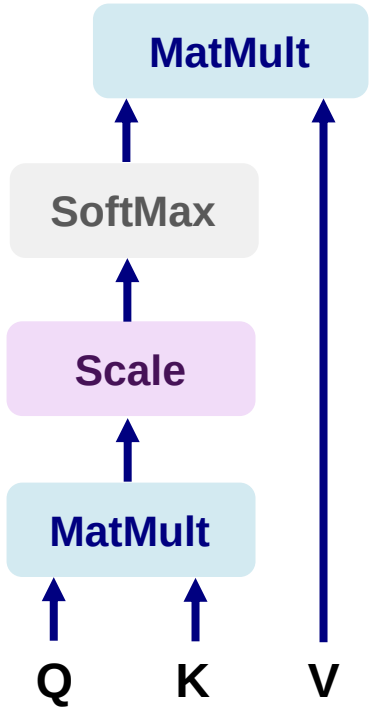
Methodology (II)



Scaled Dot-Product Attention



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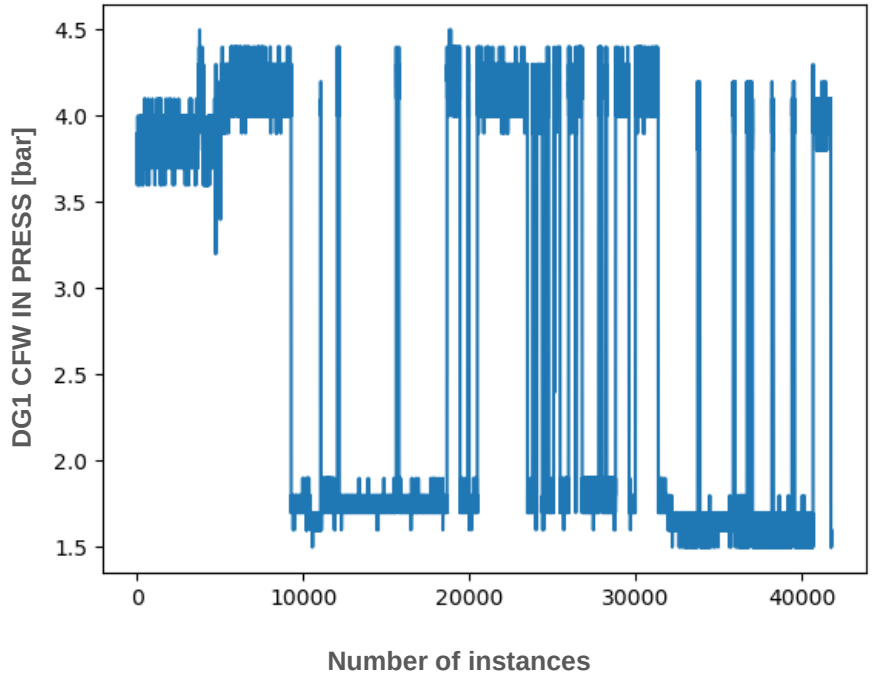
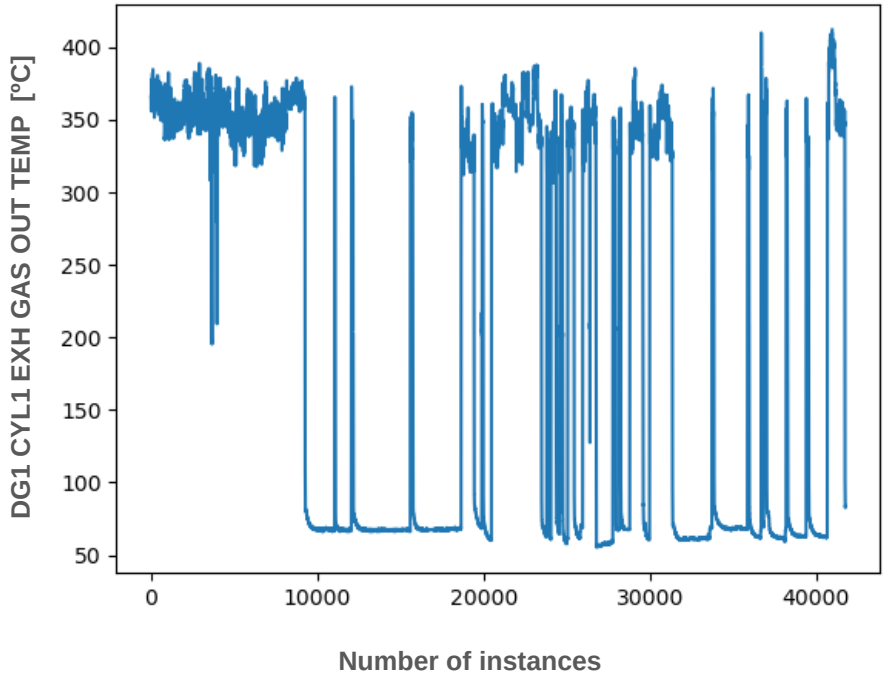
Case Study

- Diesel generator of a tanker vessel.
- A total of 26 ship machinery and weather condition parameters are considered.
- More than 40,000 instances are analysed.





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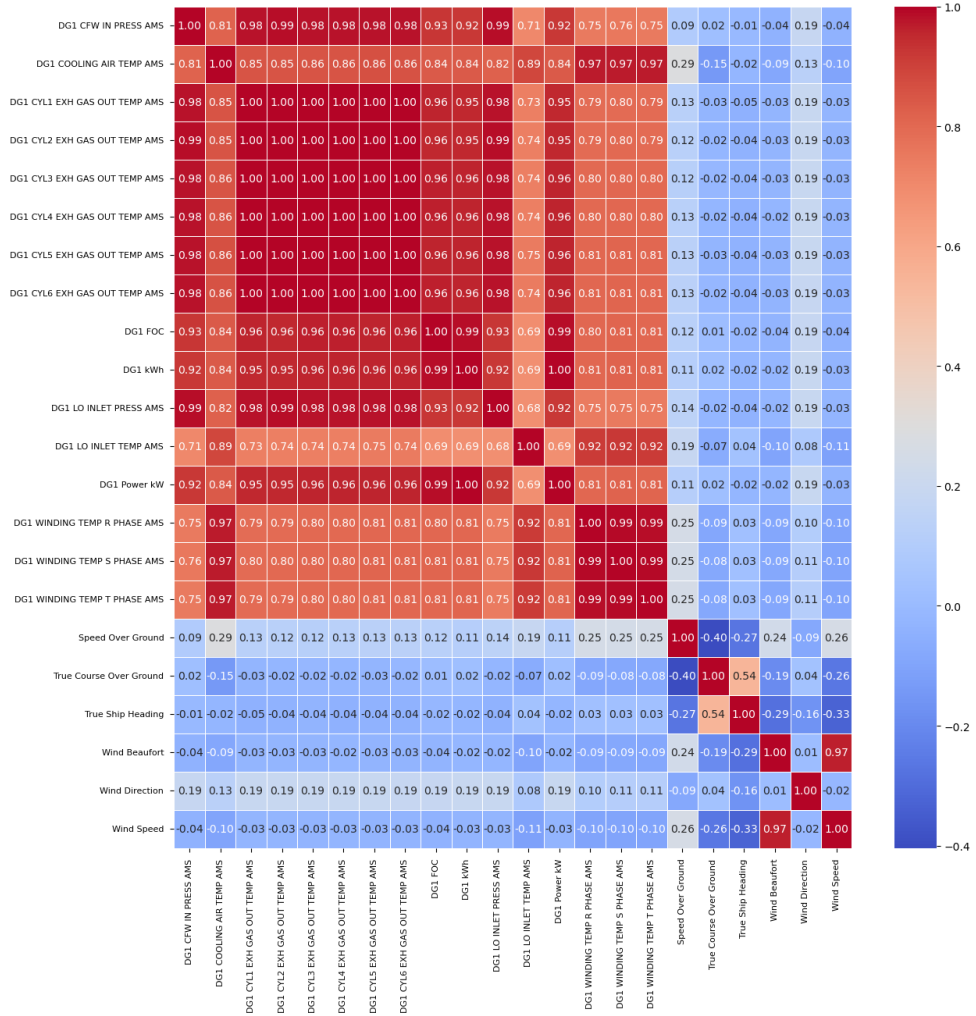
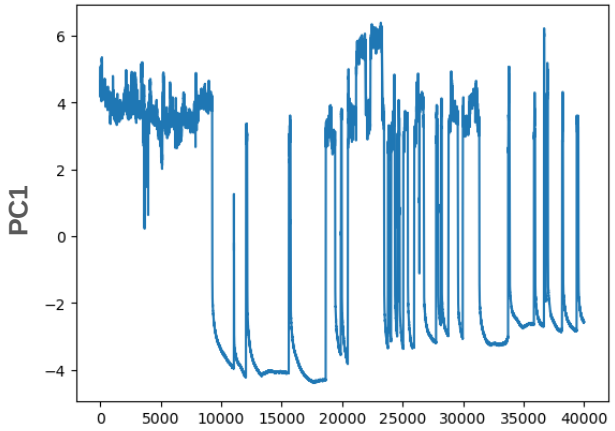
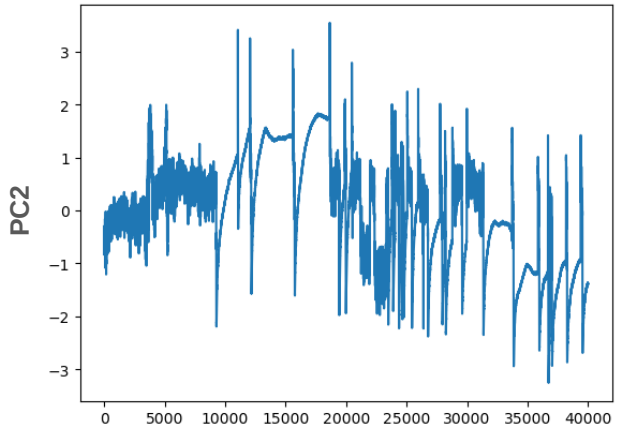
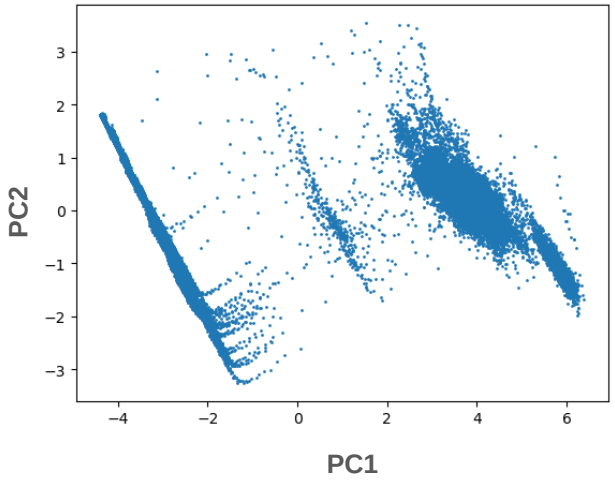
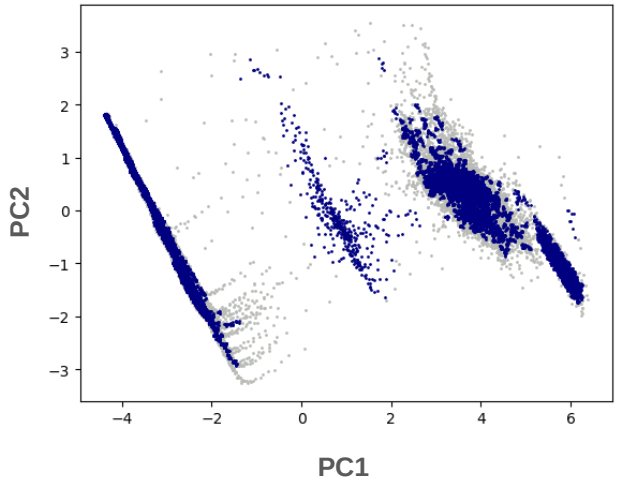
Data Pre-processing











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Results

Configuration of the developed neural network.

Layer Type	Output Shape
Input	(None, 240, 2)
LSTM	(None, 240, 104)
Attention	(None, 240, 104)
LSTM	(None, 24)
Attention	(None, 120)
Dense	(None, 104)
Dense	(None, 104)
Dense	(None, 1)

Configuration of the developed neural network.

Evaluation Metric	Attention-based Neural Network Result
MSE	0.02
RMSE	0.14
MAE	0.07
Max. Error	1.28

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Conclusions & Future Work

- Initial results indicate adequate precision in predicting fuel oil consumption based on marine machinery parameters.

- Further analysis needs to be conducted. For instance, a comparative study needs to be implemented to evaluate the results obtained.

- Self-attention has been considered through the implementation of scaled dot product attention. Other attention mechanisms should also be considered.

- Specific ship voyages should be considered to have a more accurate evaluation of the predictive capabilities of the suggested model. For instance, estimations of fuel oil consumption can be facilitated for long trips comparing different routes and operational profiles.

- Analyse how AI can be utilised to carry out Life Cycle Assessment for different vessel types and profiles.

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