Maritime
Innovation
Update

M. Sc. Emin Nakilcioglu

Workload Forecasting of a Logistic Node Using Bayesian Neural Networks

Fraunhofer
CML

#MIU #FraunhoferCML

Fraunhofer CML

Fraunhofer Center for Maritime Logistics and Services CML

Maritime Innovation Updates, May 2022

Workload Forecasting of a Logistic Node Using Bayesian Neural Networks

Emin Nakilcioglu, Fraunhofer CML

Service is our business
HCS

mFUND
Das Startkapital für die Mobilität 4.0

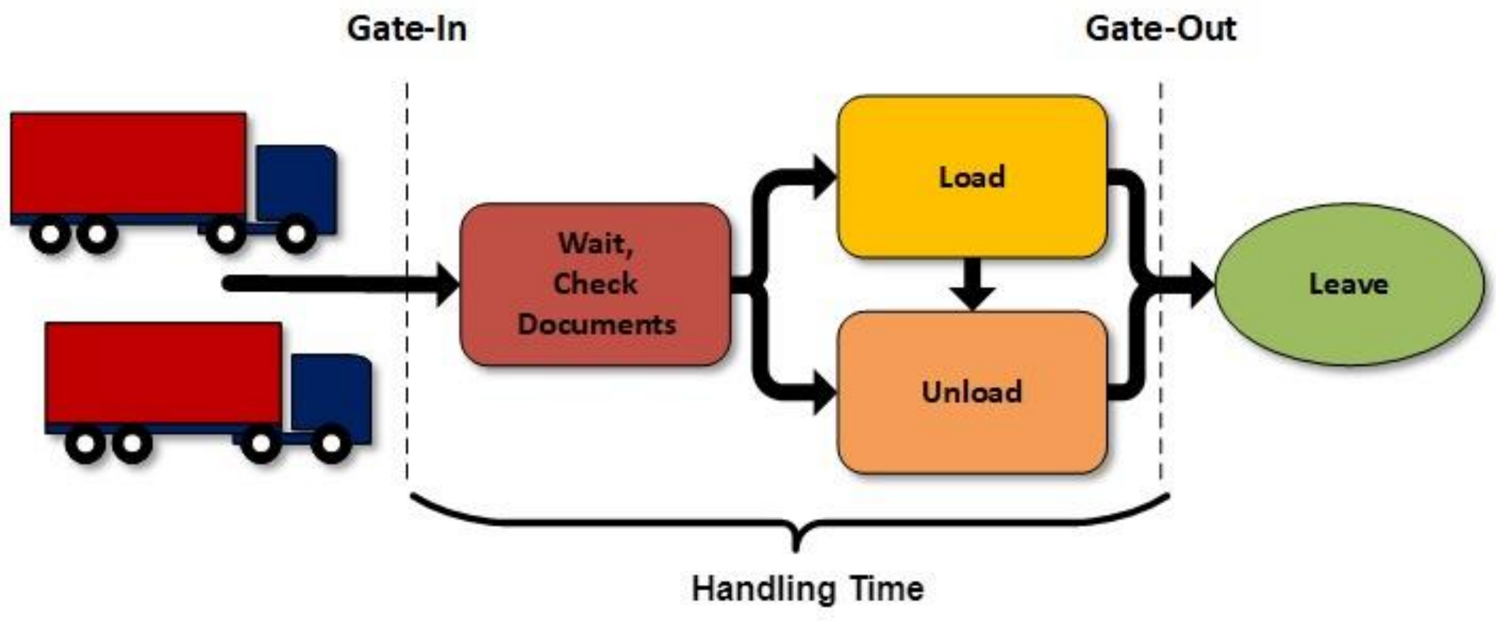
Gefördert durch:
Bundesministerium für Verkehr und digitale Infrastruktur
aufgrund eines Beschlusses des Deutschen Bundestages

Agenda

1. **Day-to-day Workload of a Logistic Node**
   - Use Case "Workload Forecasting for an Empty Container Depot"
2. **Datasets**
3. **Methodology**
   - Forecasting
   - Our Approach
4. **Experiments**
   - Experimental Setup
   - Results and Conclusion

Use Case "Workload Forecasting for an Empty Container Depot"

Empty Container Depot Handling Process



- Container trucks arriving at the empty container depot undergo certain operations, which are referred to as handling process.

- Research Question:
  - ➢ Is it possible to develop a reliable deep learning-based forecasting model which is capable of forecasting the hourly workload of an empty container depot given the recorded data of the depot from the previous years?

 17.05.2023

Fraunhofer CML

Data

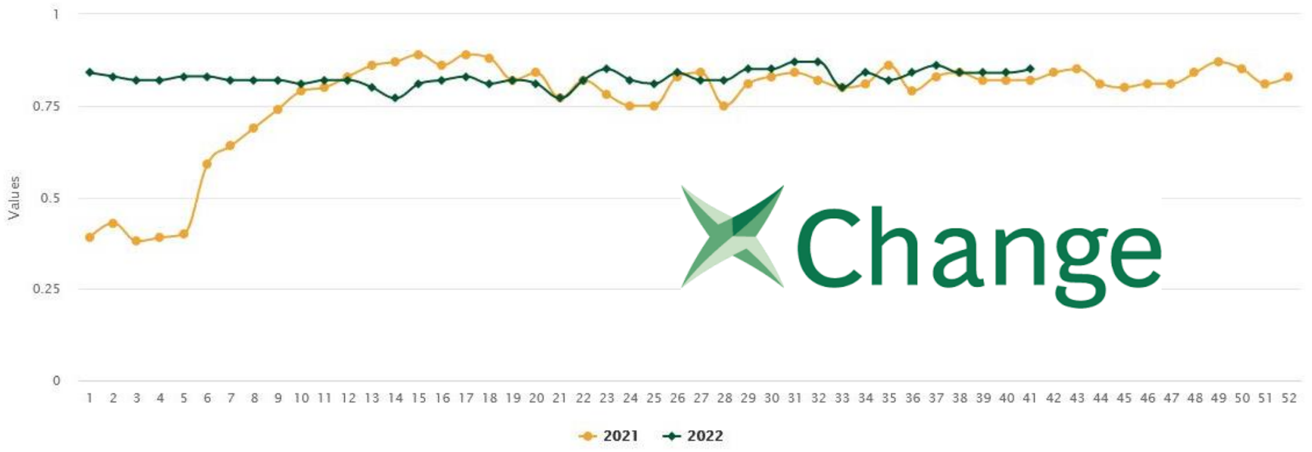
Datasets

Base Data

- Container Type
- Weekday/Holiday
- Load/Unload
- Gate In/Out Time

Additional Data

- Trucker Appointment System



2140 vessel's operations — of it displayed: 1000

arrival (scheduled)	arrival	terminal	callsign	vessel name	import voyage	export voyage	start of discharge	end of discharge	start of loading	end of loading	departure (scheduled)	departure	type of vessel
2022-06-16 00:30	2022-06-16 01:25	CTA	V2DO9	NEUENFELDE	2223W	2224E	2022-06-16 03:50	2022-06-16 21:42	2022-06-16 08:05	2022-06-16 21:55	2022-06-16 22:05	2022-06-16 22:00	feeder
2022-06-16 01:00	2022-06-16 01:36	CTB	PBRA	EMPIRE	2222W	2224E	2022-06-16 03:00	2022-06-16 14:25	2022-06-16 01:55	2022-06-16 14:10	2022-06-16 16:00	2022-06-16 15:48	seagoing vessel

Datasets

- Base Data: consists of data records regarding every container truck that is part of the traffic in the empty container depot in question.
- Trucker Appointment: an appointment system where the truck drivers give their expected arrival time in advance.
- CAx Data: information about the import and export moves of full containers around major ports. Greater than 0,5 more departure, smaller than 0,5 more arrival.
- Report Vessel Operations - Sailing list: information regarding the container traffic at the port of Hamburg.

Architecture

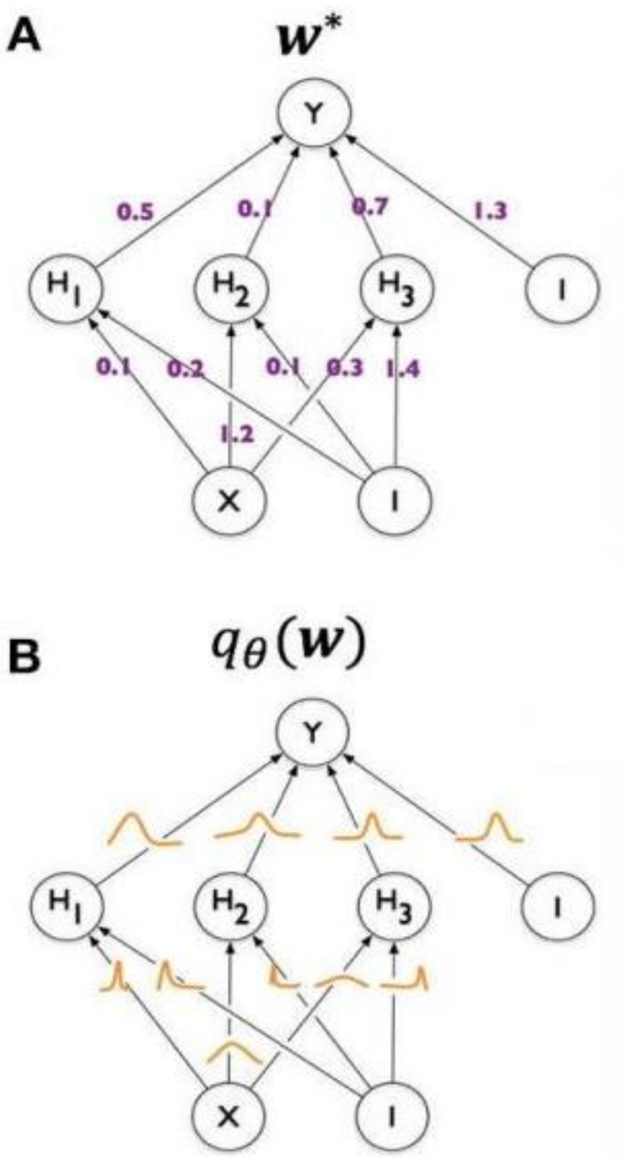
Bayesian Neural Network

Bayesian NN Architecture

- **An input layer** followed by the **hidden layers (two dense layers)** and **the output layer**.
- To introduce the **aleatoric uncertainty**, dense layers are combined with **probabilistic layers** where a **multivariate normal distribution** was introduced to the dense layer.
- Lastly, **KL-divergence regularizer** added to the output layer (acts as **priori** for the output layer).

- **Difference from deterministic model**:
  - A standard NN has **one weight for each of its connections** learned from the training set and used in generating a prediction for a test example.
  - A BNN has **a posterior distribution for each weight**. The process of training starts with an assigned prior distribution for each weight and returns an approximate posterior distribution.

$$p(w|x;y) = \frac{p(y|w;x)\,p(w)}{p(y|x)}$$



 17.05.2023

Fraunhofer CML

Experimental Setup

Setups

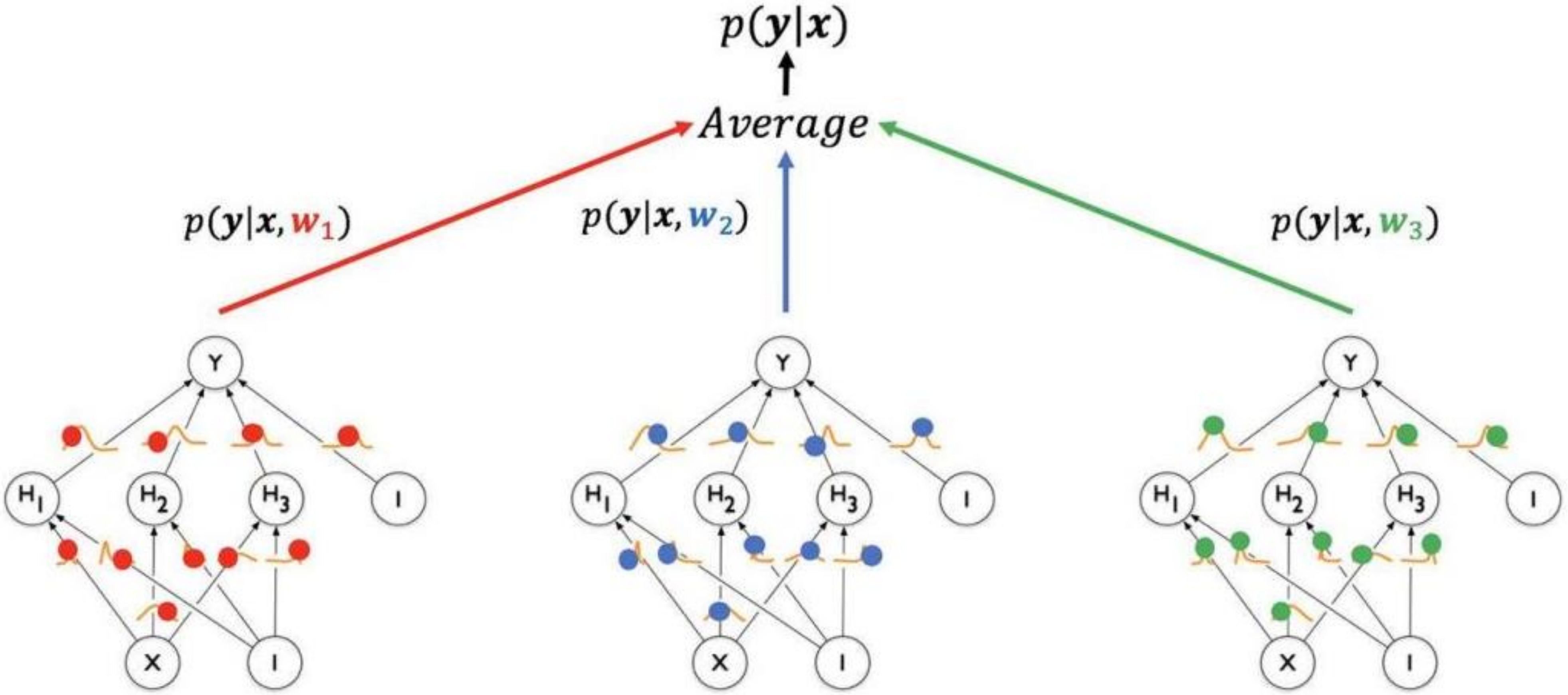
Setups

1. First Setup:
   - Performance comparison between LILIE and Bayesian (later refer to as KIK-Lee Base Model)
   - Both models were subjected to the same input data and expected to predict hourly truck rate and average handling time for 4 weeks of August, 2021
2. Secondary Setup:
   - additional experiments with extended input datasets generated by appending the relevant data extracted from new data sources to the base input data
   - The timespan of the input datasets in this setup;
   - January, 2021 - July, 2021.
   - Same prediction time window applies: 4 weeks of August, 2021

	Starting Date	End Date
First Set	January, 2017	July, 2021
Second Set	January, 2018	July, 2021
Third Set	January, 2019	July, 2021
Fourth Set	January, 2020	July, 2021
Fifth Set	January,2021	July, 2021

	Starting Date	End Date
KIK-LEE Base Dataset	January, 2021	July, 2021
Trucker Appointment	January, 2021	July, 2021
CAx Dataset	January, 2021	July, 2021
Sailing Dataset	January, 2021	July, 2021

Experimental Setup
Monte-Carlo



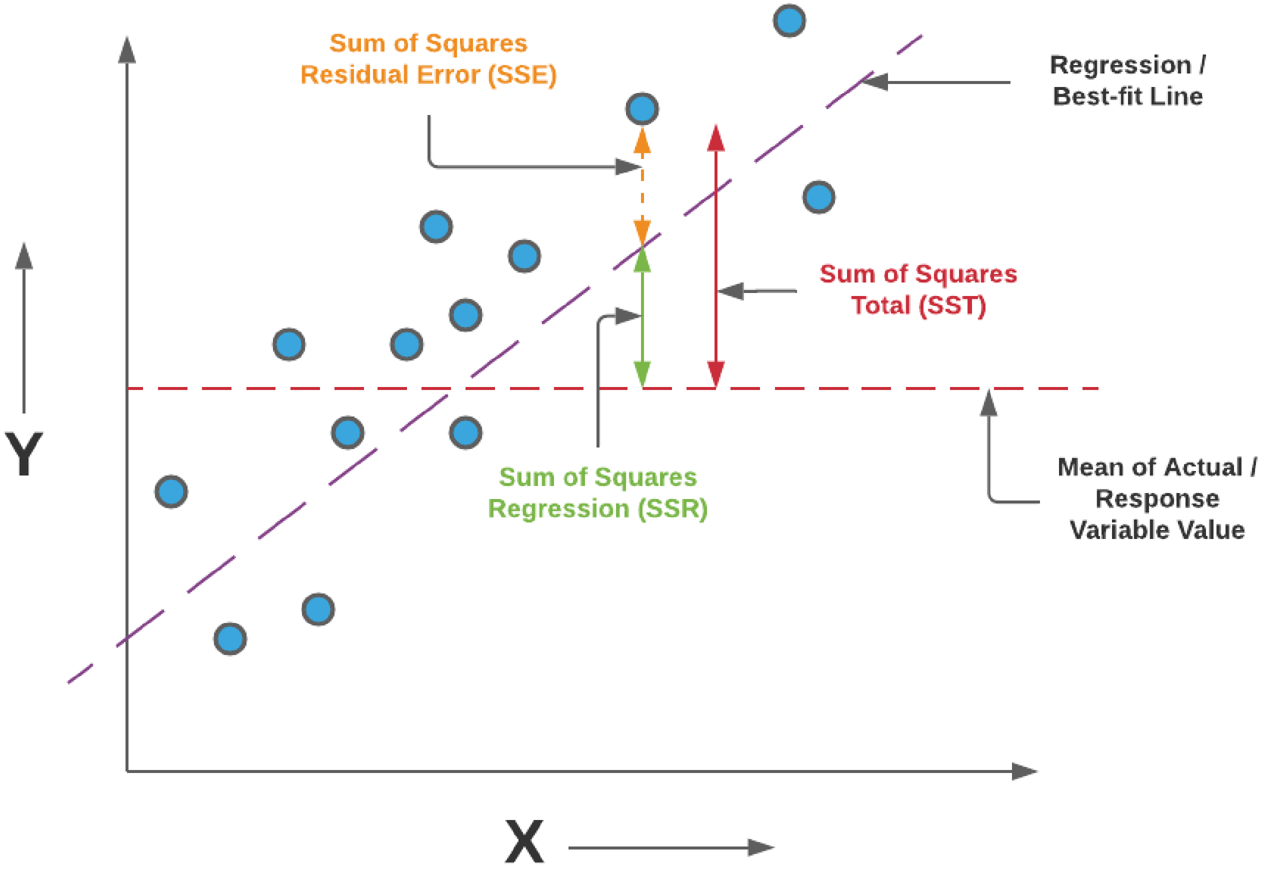
Experimental Setup

Metrics

Performance Metrics

1. Coefficient of determination (R-squared): a statistical measurement that analyses how differences in one variable can be explained by the difference in a secondary variable, when predicting the outcome of a given event.

- where y_i being true values and f_i being predicted values

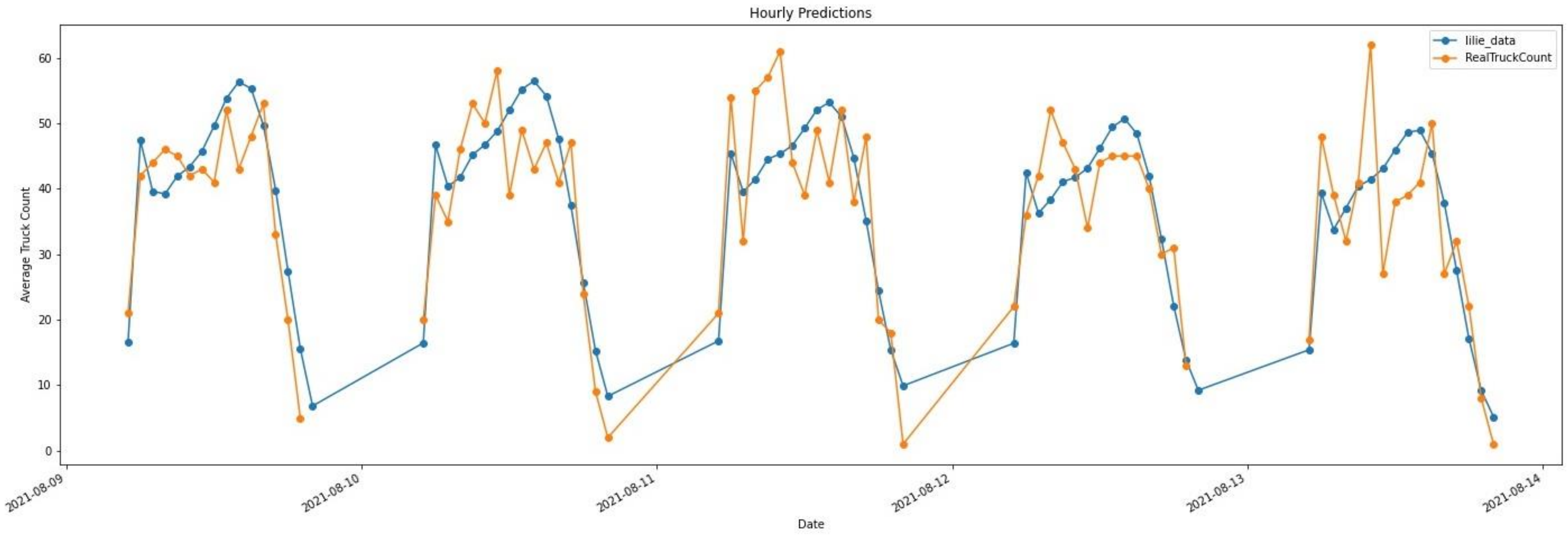


$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

$$R^2 = 1 - \frac{SSE}{SST} = \frac{\sum_i (y_i - f_i)^2}{\sum_i (y_i - \bar{y})^2}$$

Fraunhofer CML

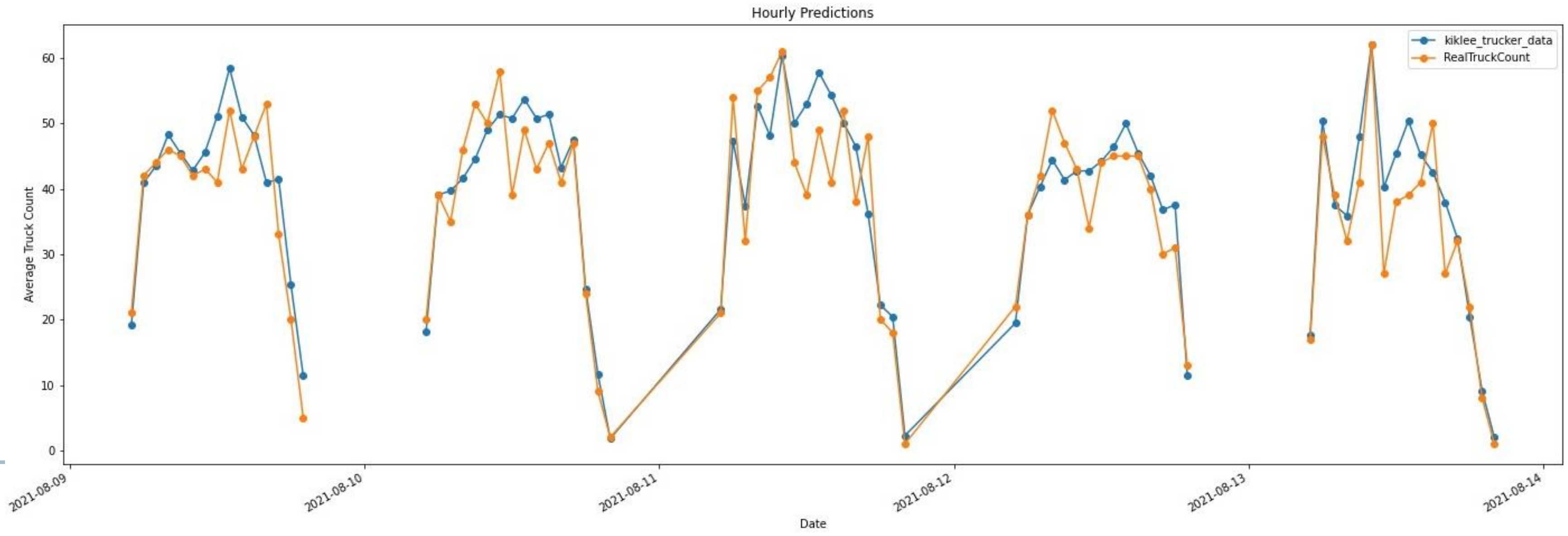
Experimental Results Comparison (Best Performances)



LILIE

Overall error rate of ±6,4 trucks for expected truck rate

Overall error rate of ±7,6 min for average truck dispatch time



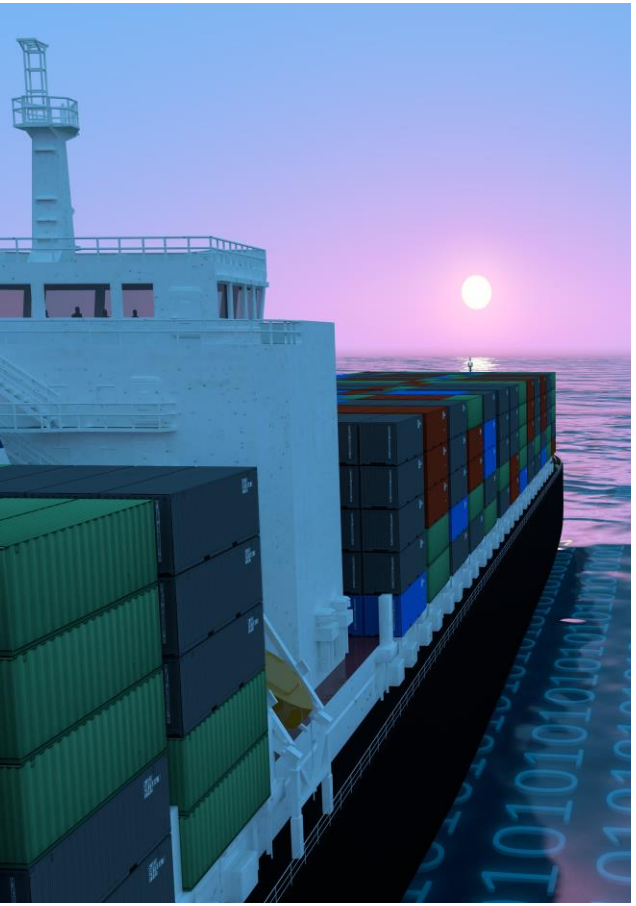
KIK-Lee (WaProLog)

Overall error rate of ±4,7 trucks (KIK-Lee Benchmark: 6,2) for expected truck rate

Overall error rate of ±6,7 min (KIK-Lee Benchmark: 7,6) for average truck dispatch time

Conclusion

Conclusion and Future Aspects



1

- **The proposed BNN (i.e. predictor)** is capable of forecasting the hourly workload in an empty container depot for upcoming weeks **more efficiently and more stable** than the previously developed **DNN-based model**.

2

- **~4% increase** in performance of hourly predictions of expected truck rate
  - Additional ~**15% increase** by using trucker booking system
- **~103% performance increase** in hourly predictions of average truck handling time
- **Faster predictions (~52%)** with less computational power (went down **from 20 min to 7 min**)

3

- Extracting more relevant information from the current data sources (**CAx, Sailing List** etc.) and introducing new relevant datasets,
- Capturing both the **epistemic and the aleatoric uncertainty** together in a further research.

4

- **Further development** work of the forecasting model
- **Automatizing the process** of publishing the forecast result.

Fraunhofer CML

Maritime
Innovation
Update

M. Sc. Emin Nakilcioglu

emin.nakilcioglu@cml.fraunhofer.de
+49 40 271 6461 - 1408

Fraunhofer
CML

#MIU #FraunhoferCML