Neural network and CFD simulation applied for determination of leak location

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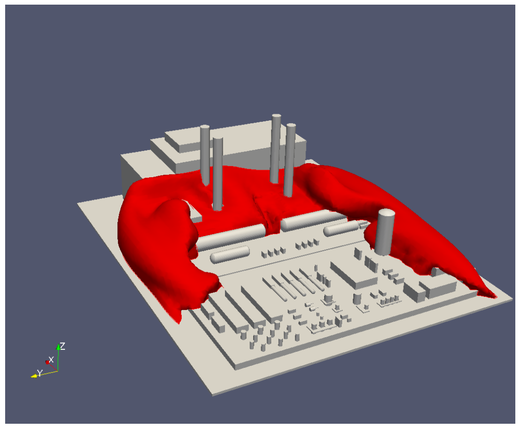
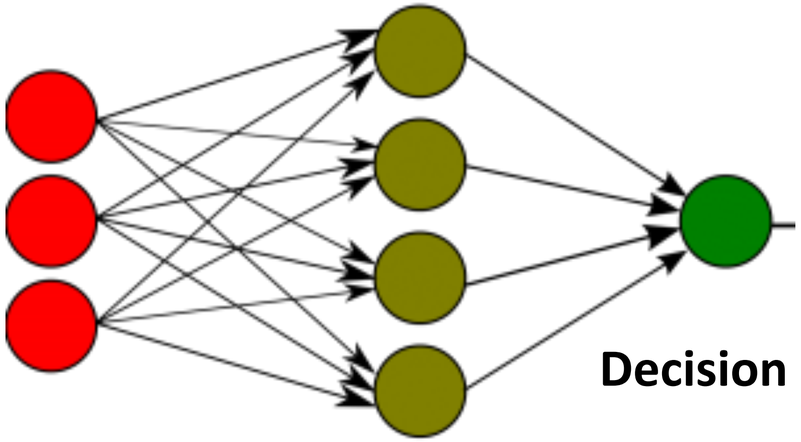
Contents

Introduction

Given the wind speed, wind direction and localised gas concentration, is it possible to identify the leak location ?



CFD data

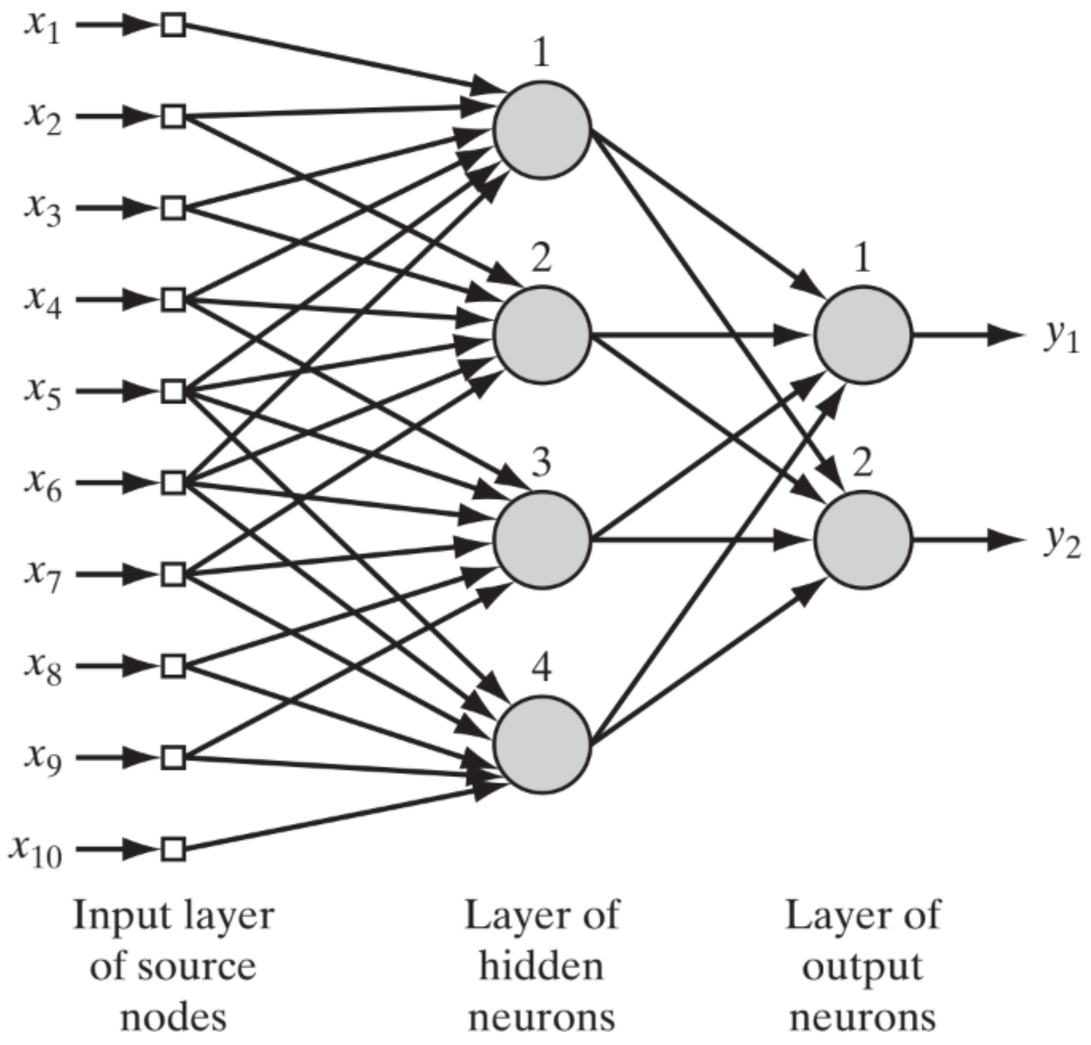


Decision making

Data handling

Mathematical

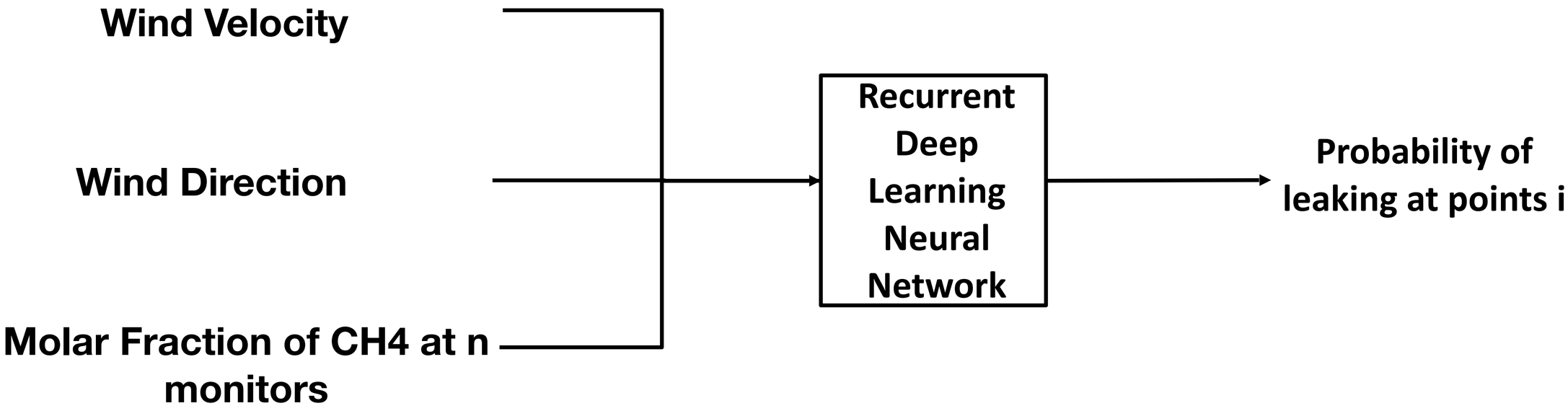
Neural network - basics



$$L = \frac{1}{N} \sum_{i=1}^{N} (Y_P - Y_R)^2$$

Methodology

Flowchart for neural network



Methodology

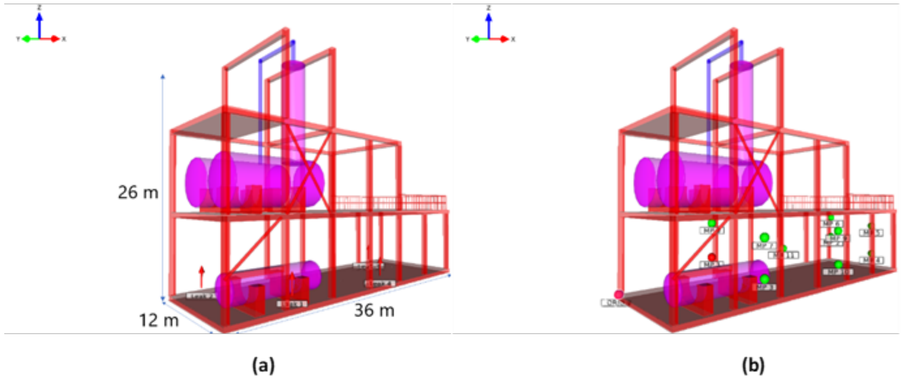


Figure: (a) Leak locations and (b) Monitoring points (MP) and origin coordinate at module geometry. (c) x-y View

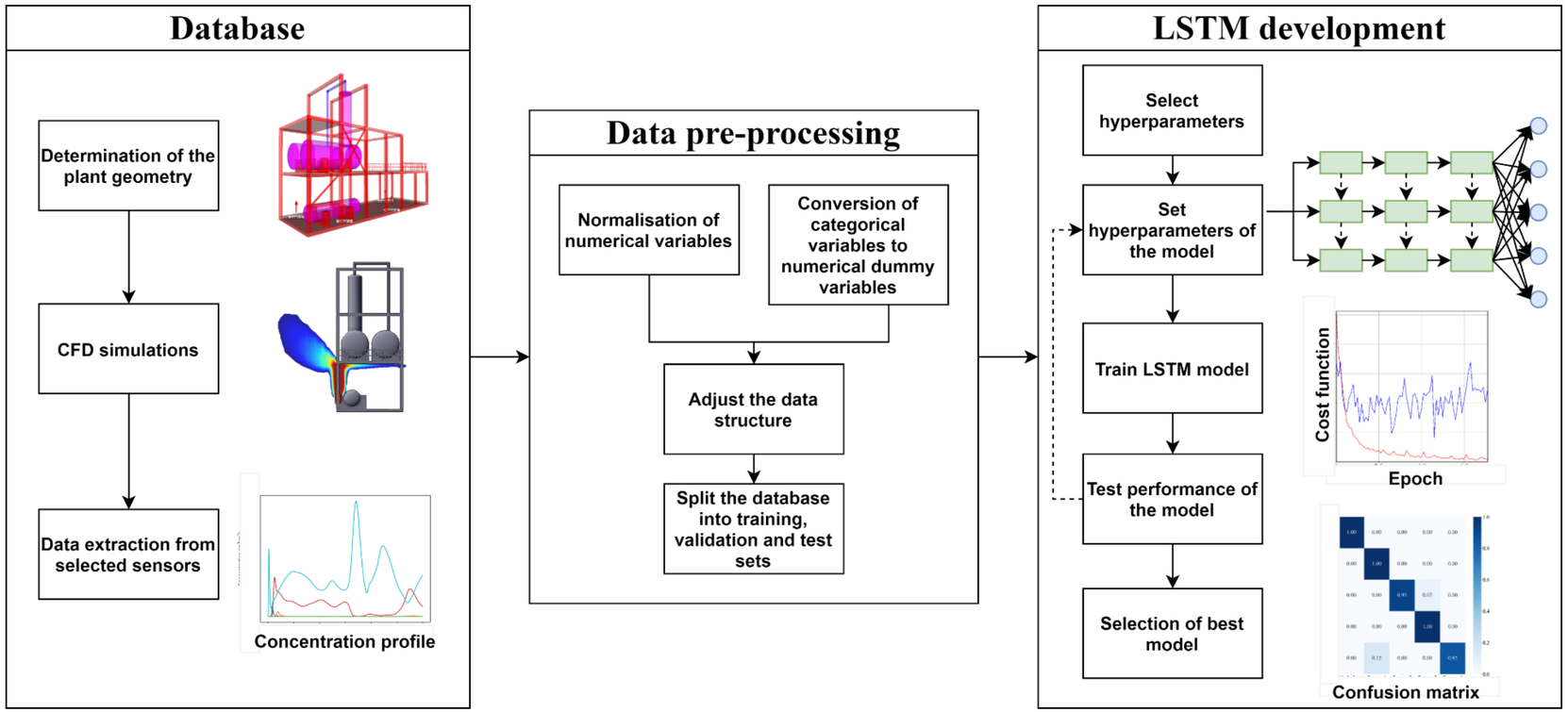
Table: Gas leak locations, wind directions and

	Leak Location			Wind Direction	Wind Velocity (m/s)
	x (m)	y (m)	z (m)		
L1	7	-11	1	N, S, E, W, NE, SE, SW and NW	2, 4, 6 and 8
L2	2	-3	1		
L3	28	-3	1		
L4	20	-11	1		

- 4 Leak Locations x 8 wind directions x 4 wind velocities = 128 simulations for ventilation and dispersion
- 8 wind directions x 4 wind velocities = 32 simulations for ventilation

Methodology

- Use of Python programming language and libraries from TensorFlow and Keras
- Regularization tool: early-stopping
- Used during optimisation phase to avoid overfitting
- Hyperparameters



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Results

- **The dataset included 128 cases for four leakage sources and 32 cases without leakage**
- **Eight wind directions and four wind velocities**
- **The data acquisition rate was set at 5 s**
- **Each dataset was 3 min long**

LSTM-RNN	Stacked LSTM	Neurons	Timesteps	Training accuracy	Test accuracy	Number of weights	Epochs
1	**2**	**75**	**12**	**0.994**	**0.963**	**74,480**	**53**
2	3	100	8	0.987	0.960	209,705	69
3	3	125	12	0.993	0.958	324,630	55
4	3	100	6	0.985	0.956	209,705	71
5	3	100	12	0.993	0.956	209,705	47
6	3	75	10	0.989	0.954	119,780	34
7	3	150	12	0.992	0.954	464,555	47
8	2	150	12	0.986	0.953	283,955	43
9	3	100	12	0.990	0.953	209,705	33
10	3	100	12	0.990	0.953	209,705	69

Table: Results of LSTM-RNN models

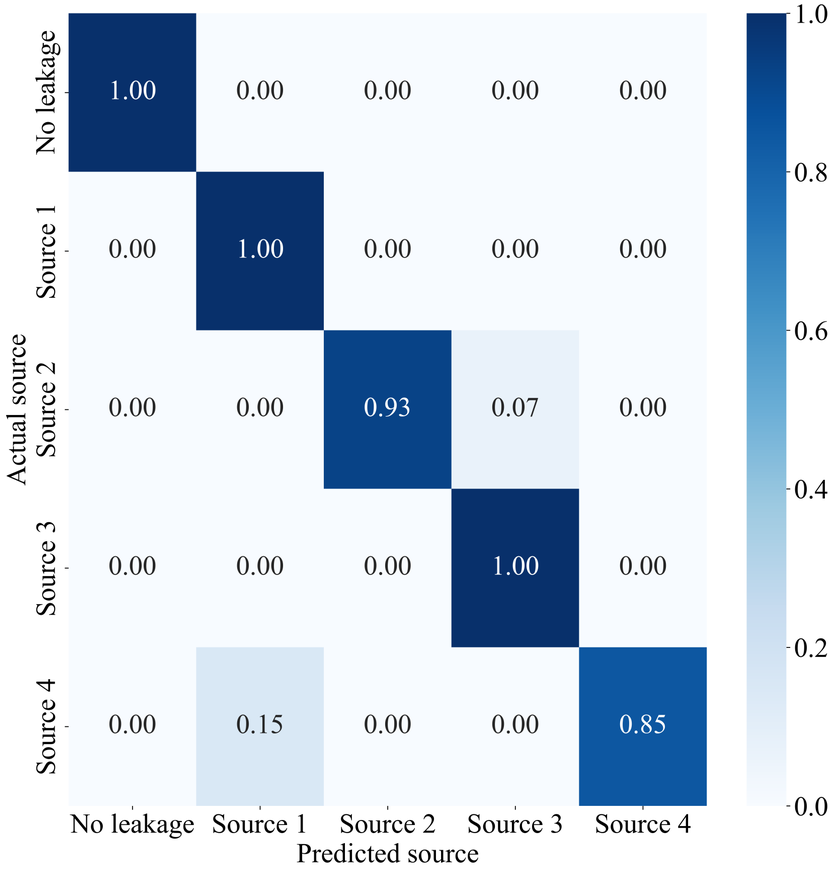


Figure: Confusion matrix of LSTM-RNN model 1 for the test data base

Results

Neurons	Time-steps	Weight initialization	Training accuracy	Test accuracy	Number of weights
20	11	Random normal	0.985	0.962	2565
30	12	Random normal	0.989	0.959	4745
40	10	Random normal	0.983	0.947	7525
20	12	Random normal	0.986	0.943	2565
45	12	Random normal	0.984	0.943	9140
10	10	Random uniform	0.980	0.943	985
40	9	Random uniform	0.984	0.942	7525
30	12	Random uniform	0.986	0.941	4745
30	12	Identity	0.974	0.941	4745
50	7	Identity	0.972	0.939	10905

Table : Results of GRU models

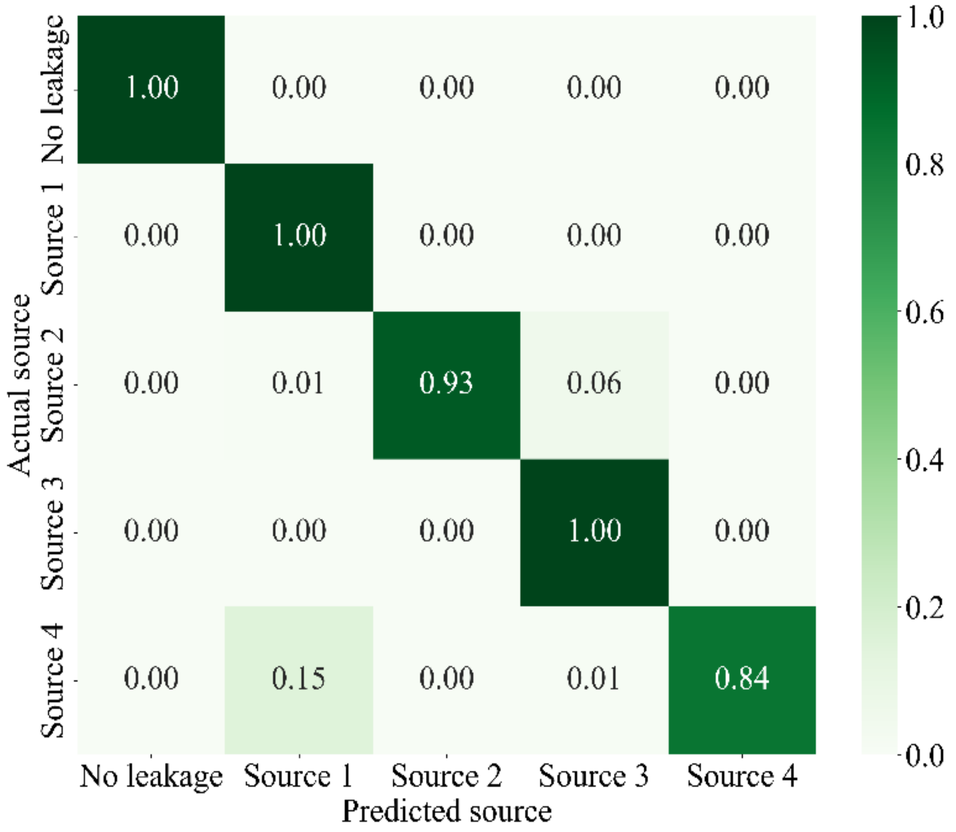
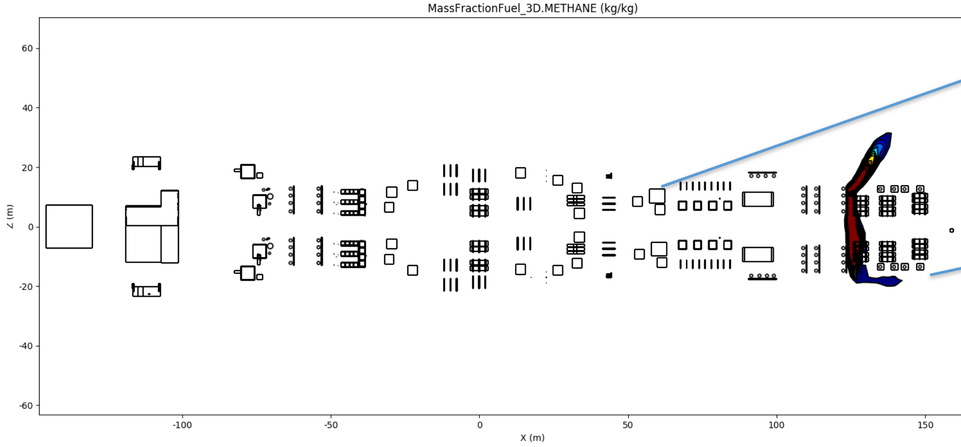
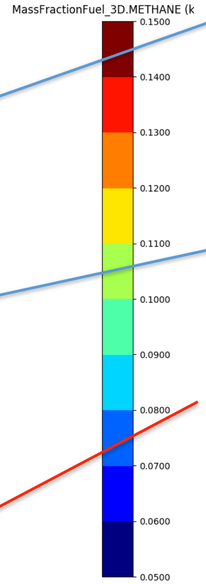
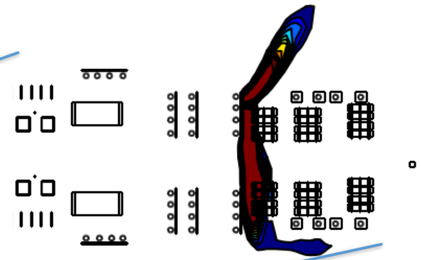


Figure: Confusion matrix of the best GRU model for the test data base.

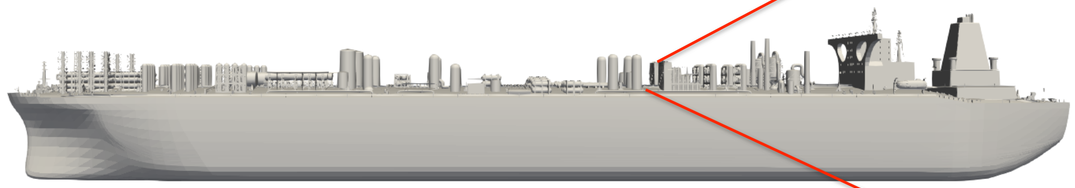
Case study

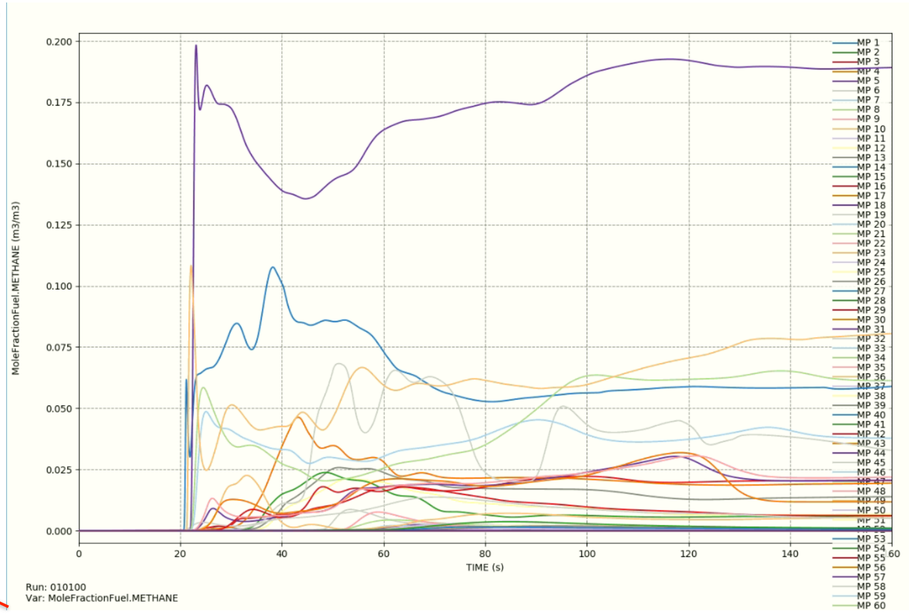




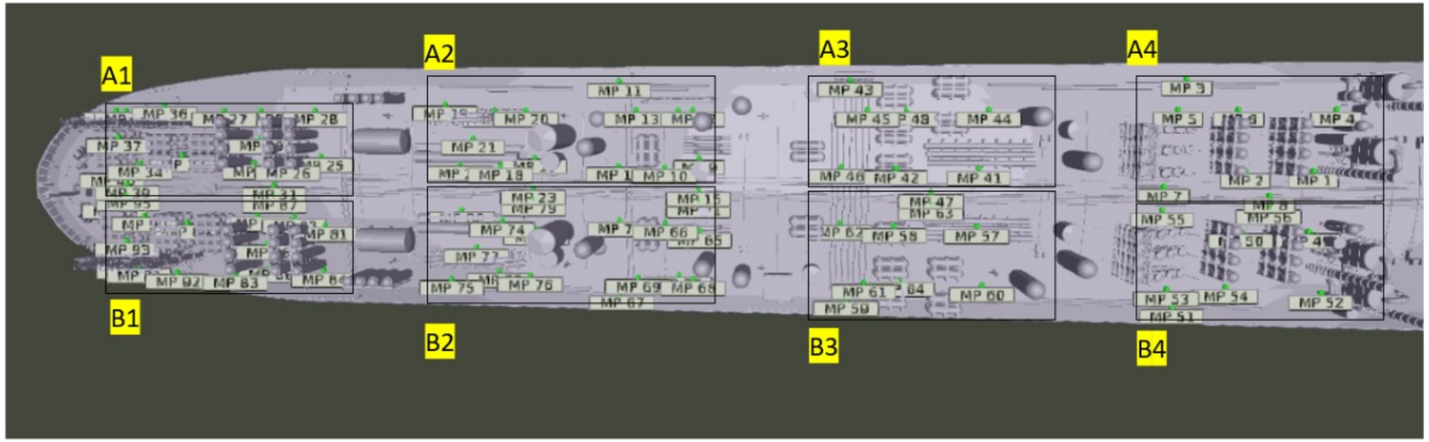


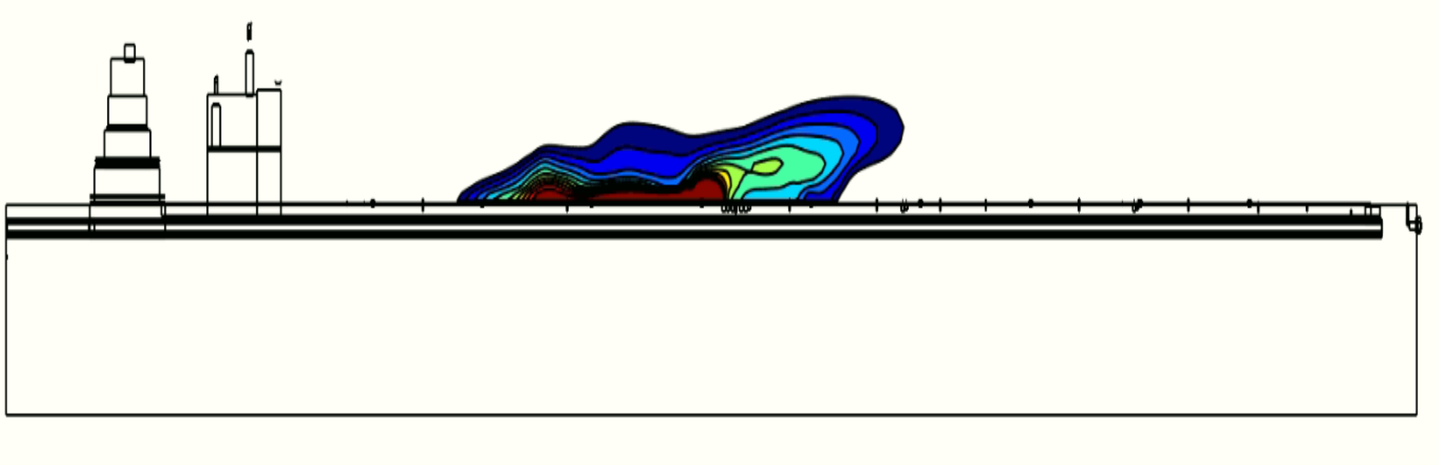
Upper view

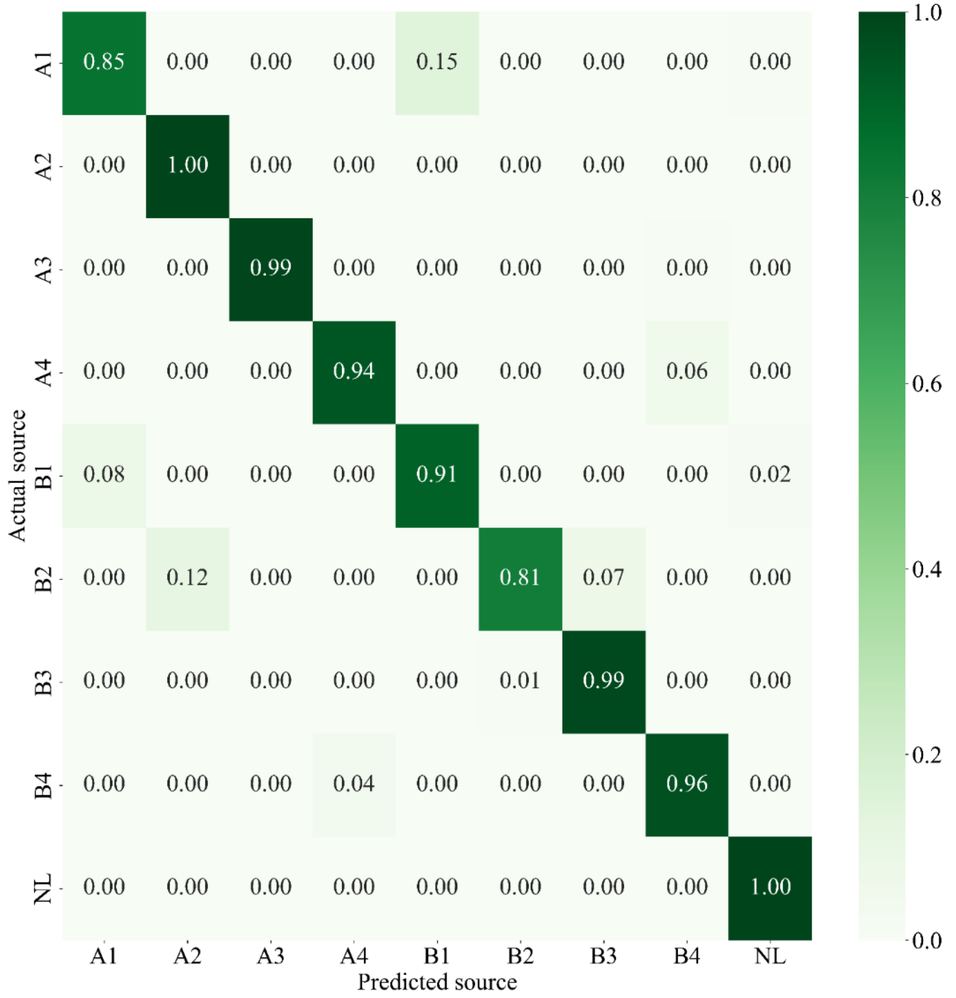




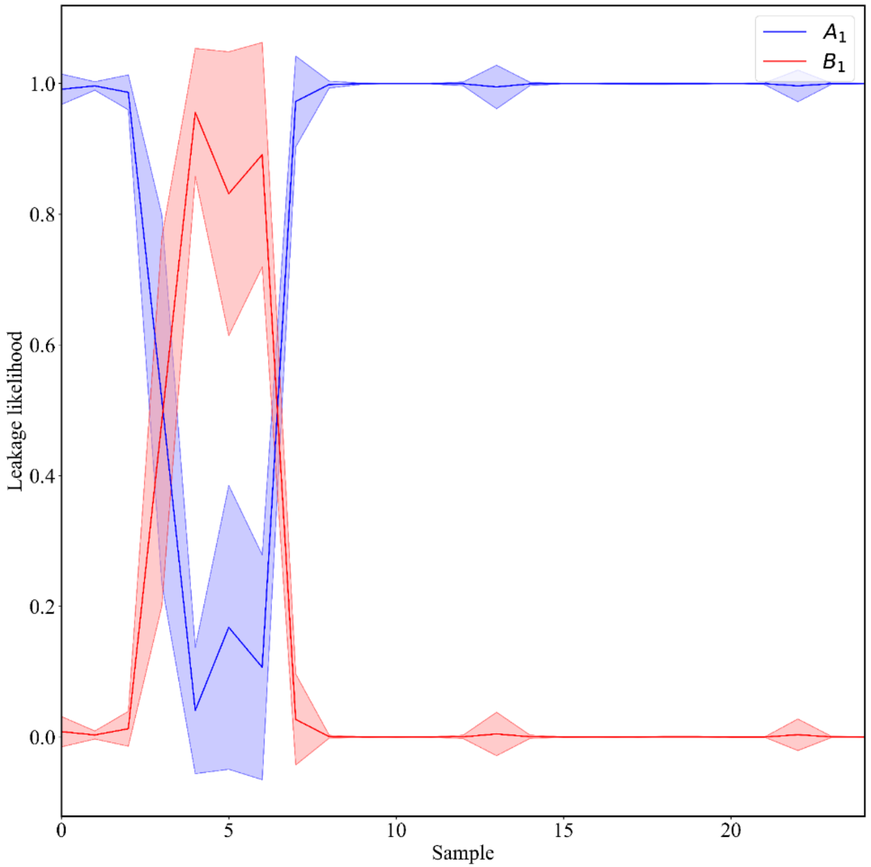
Case study

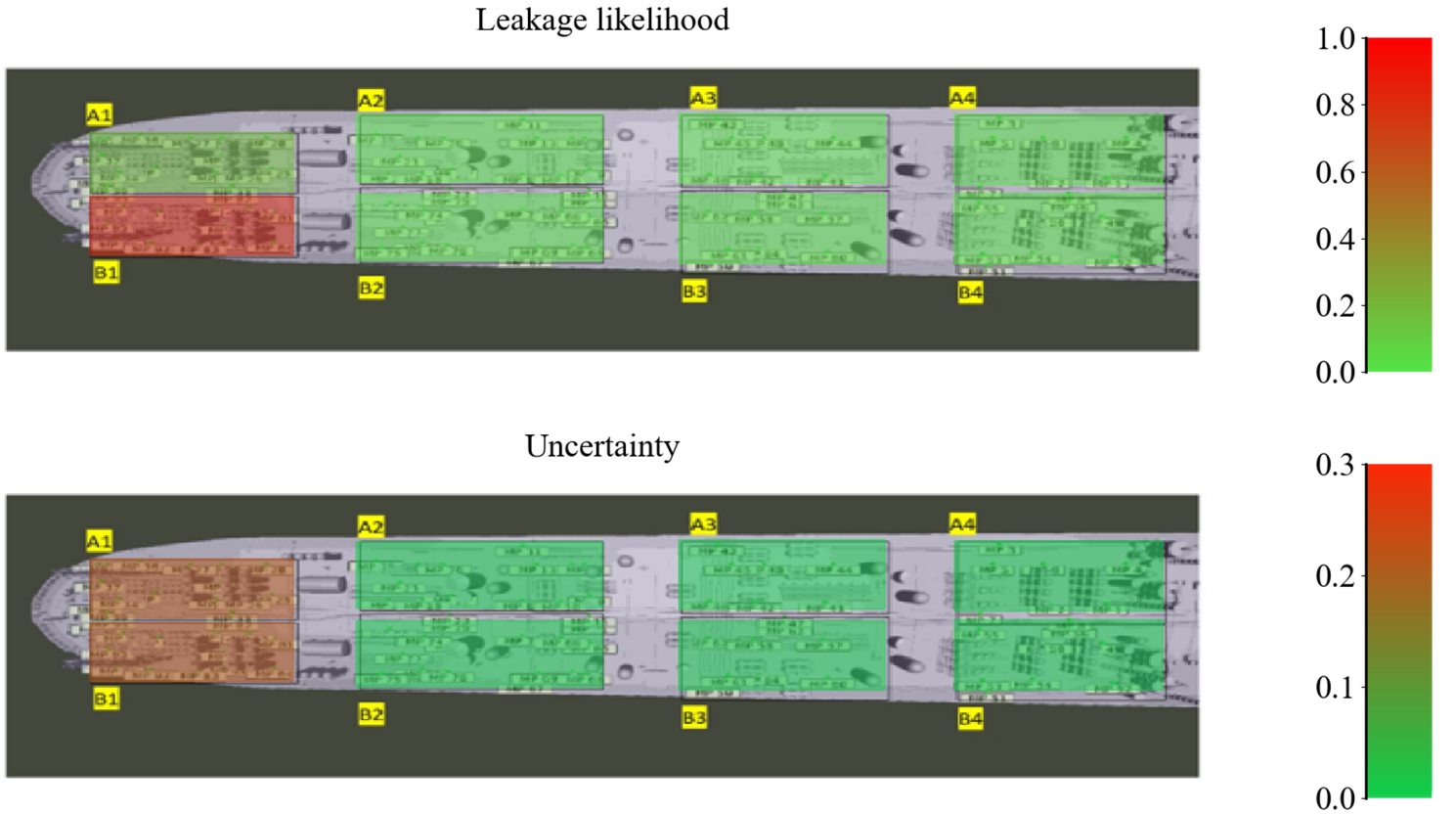

A1
A2
A3
A4
B1
B2
B3
B4



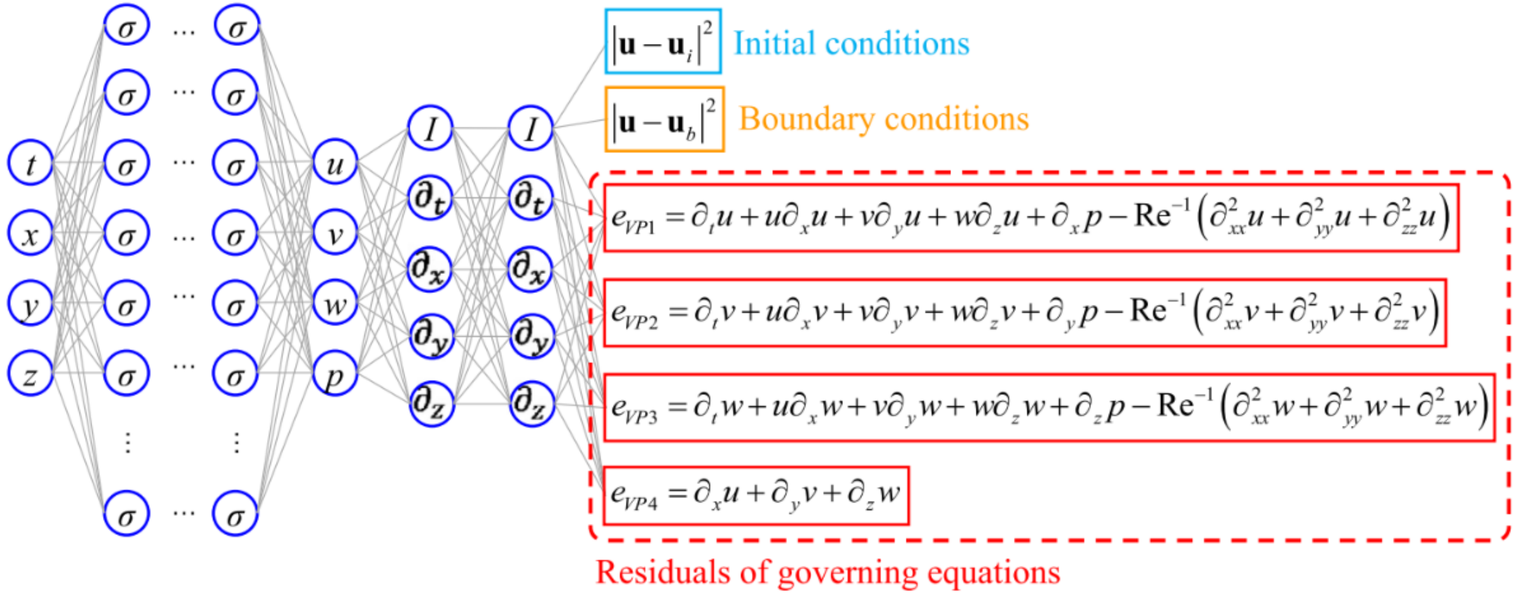

A1 0.85 0.00 0.00 0.00 0.15 0.00 0.00 0.00 0.00
A2 0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
A3 0.00 0.00 0.99 0.00 0.00 0.00 0.00 0.00 0.00
A4 0.00 0.00 0.00 0.94 0.00 0.00 0.00 0.06 0.00
B1 0.08 0.00 0.00 0.00 0.91 0.00 0.00 0.00 0.02
B2 0.00 0.12 0.00 0.00 0.00 0.81 0.07 0.00 0.00
B3 0.00 0.00 0.00 0.00 0.00 0.01 0.99 0.00 0.00
B4 0.00 0.00 0.00 0.04 0.00 0.00 0.00 0.96 0.00
NL 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00
Actual source
A1 A2 A3 A4 B1 B2 B3 B4 NL
Predicted source
1.0
0.8
0.6
0.4
0.2
0.0

Closing remarks

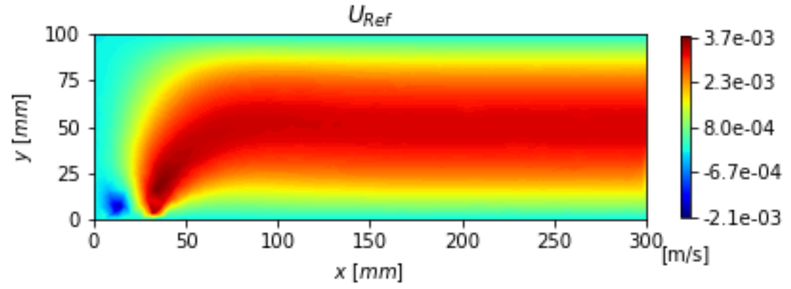


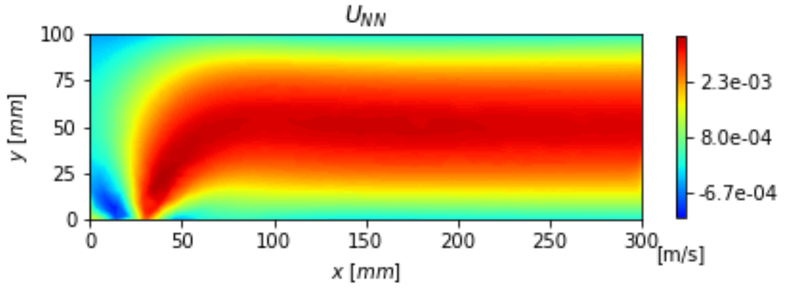


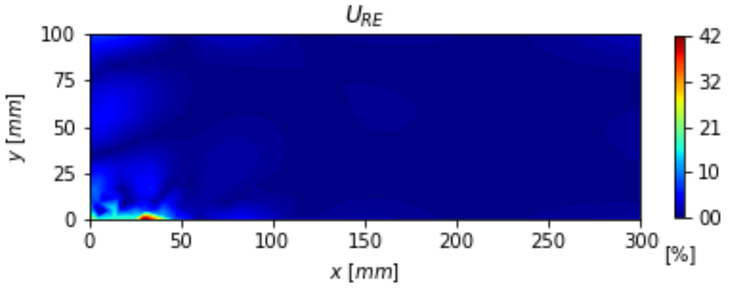
Physics informed neural network



$$L = \frac{1}{N}\sum_{i=1}^{N}\left[f(x,y) - f_P(x,y)\right]^2$$







Acknowledgments