A Novel Approach for Classification and Forecasting of Time Series in Particle Accelerators

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Incentive

The Interlock system makes up $\sim 20\%$ of the total beam time loss

If beam interruptions (interlocks) can be predicted, we can prevent them

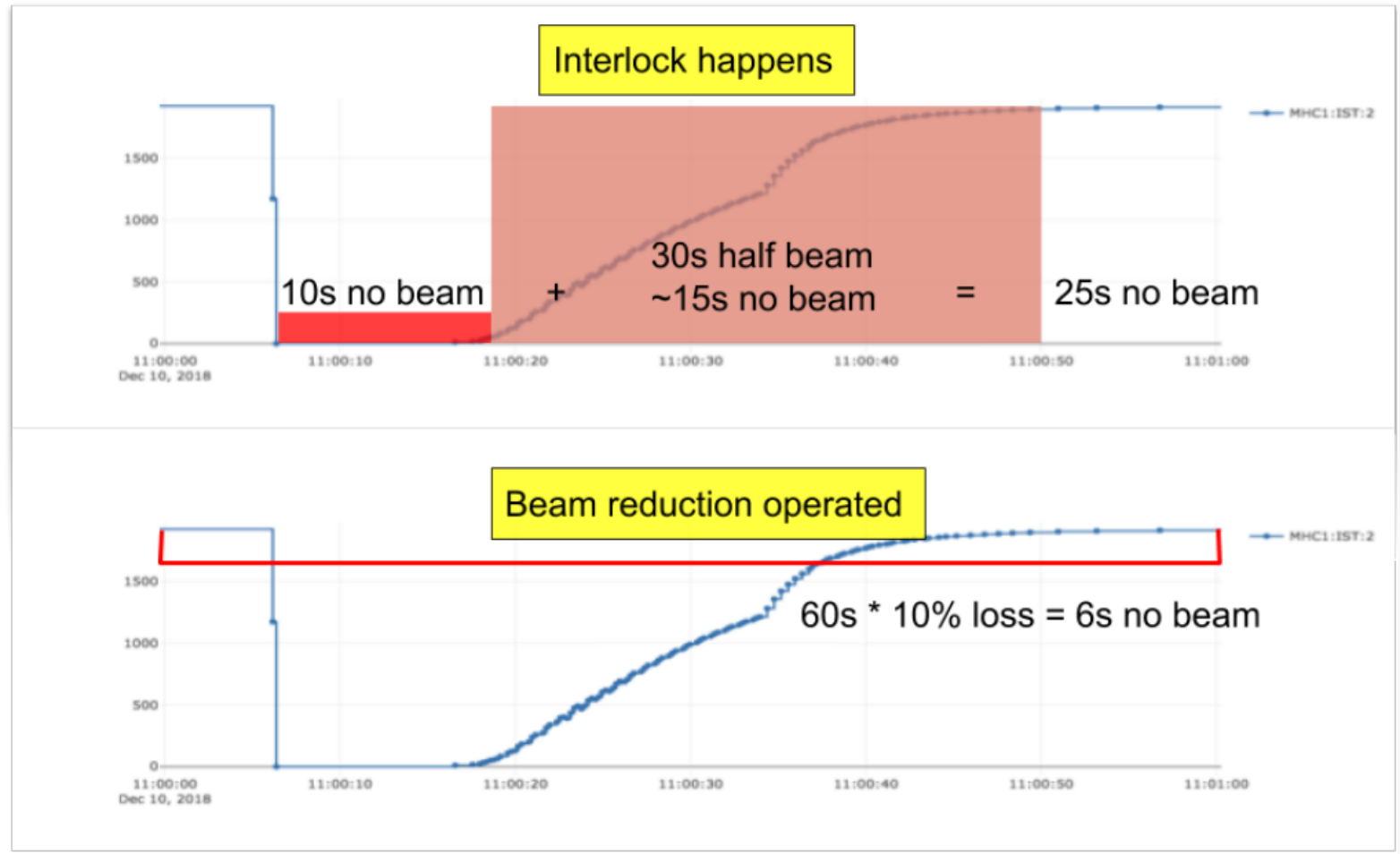
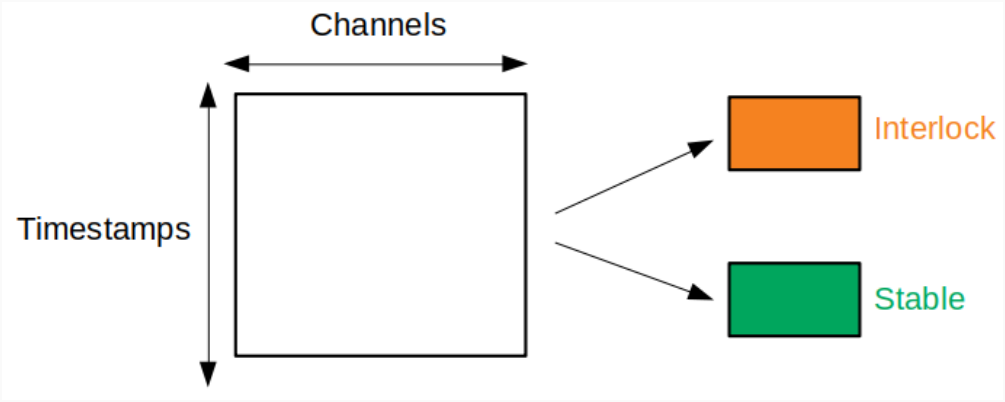


Figure by Sichen Li

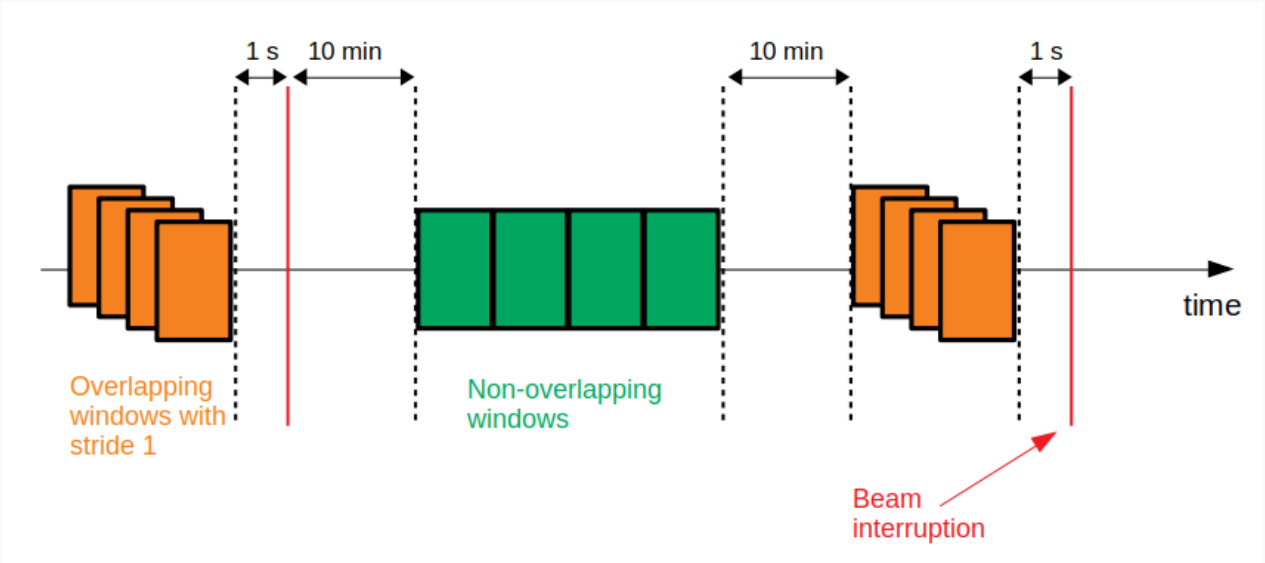
Formulating the problem

Classification approach: what gets classified?

"windows" of a multivariate timeseries

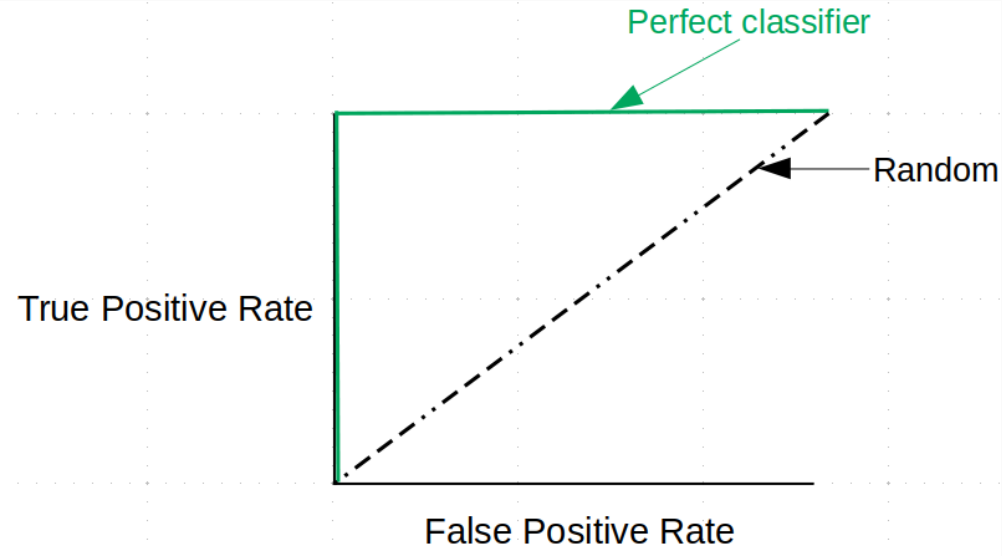


what are stable and interlock windows?



Receiver operating characteristic (ROC) plots

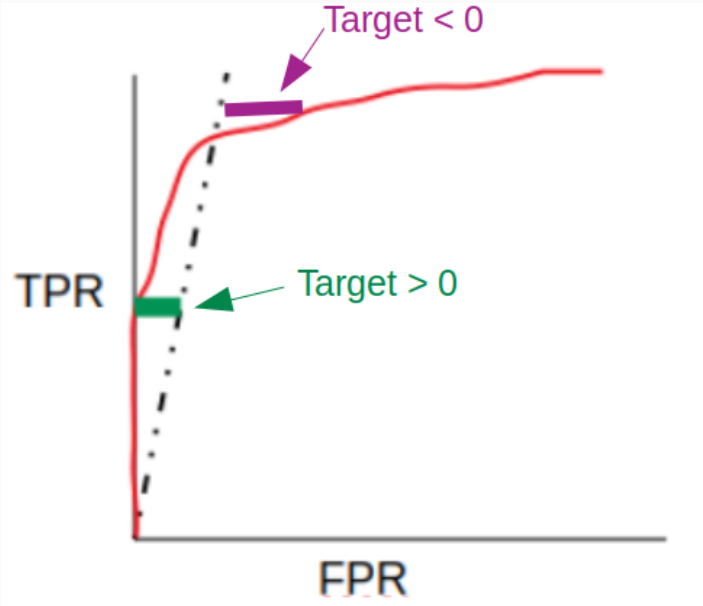
True positive rate (TPR) against the false positive rate (FPR) of the model predictions as a function of the discrimination threshold



Evaluation metrics

How many false positives can we tolerate?

$$\text{Target} = \max(TPR - 10 * FPR)$$



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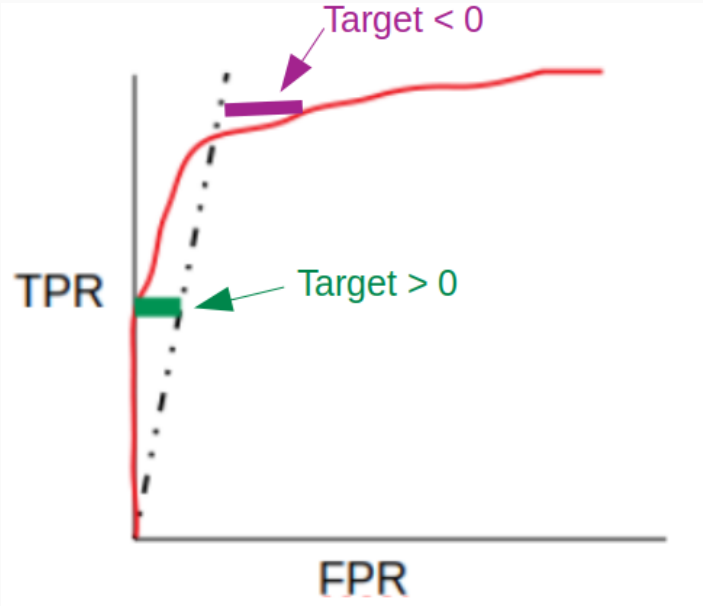


Beam time lost w.r.t the non-intervention baseline of 25 seconds per interlock:

$$(1 - TPR) * 25 + TPR * 6 + FPR * 45 * 6$$

Highly imbalanced classes:

- take 5 samples per interlock event
- bootstrapping of the interlock class

Different types of interlocks with varying sample numbers:

- only consider interlock events related to losses

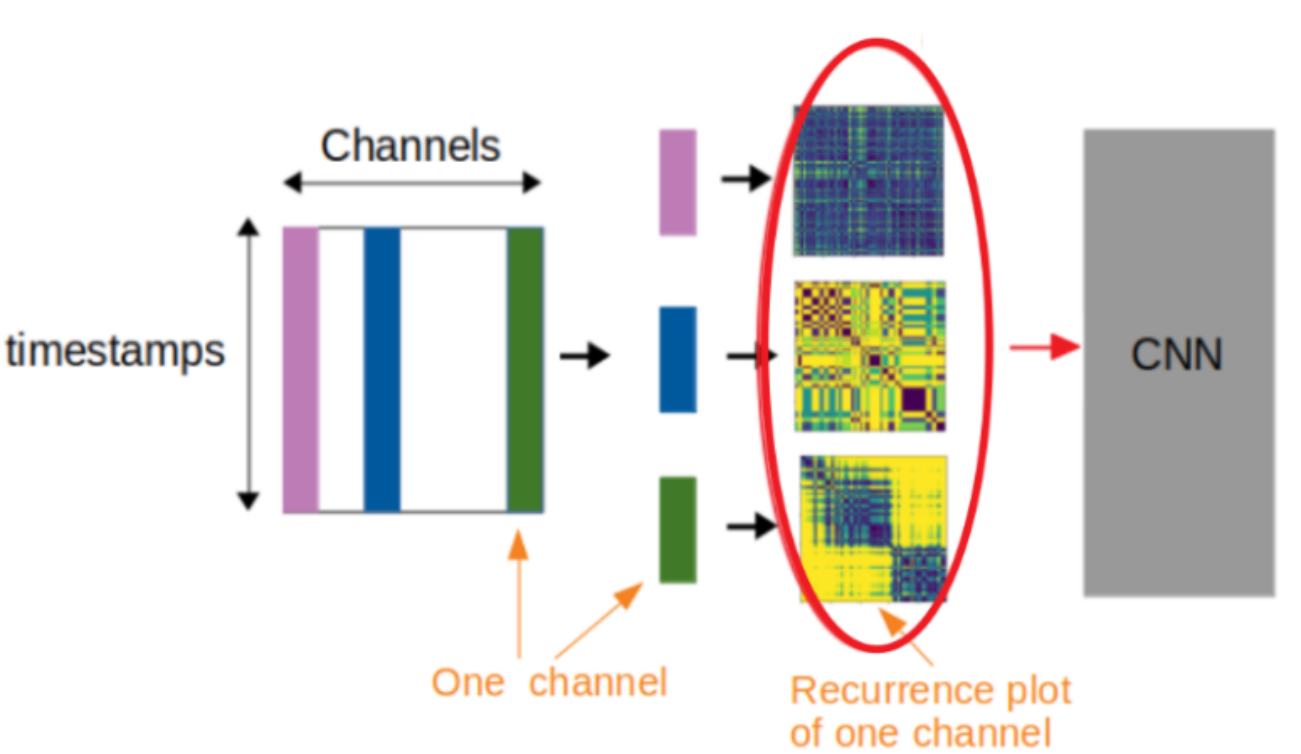
Standardize the signals to mean 0 and standard deviation 1

Window length of 12 s

RPCNN

Input

Recurrence Plots of the data windows

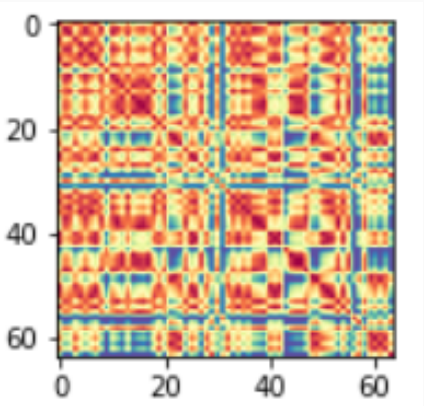


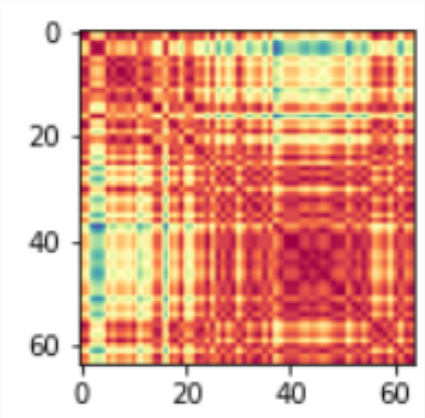
Time series classification $\rightarrow$ Image classification

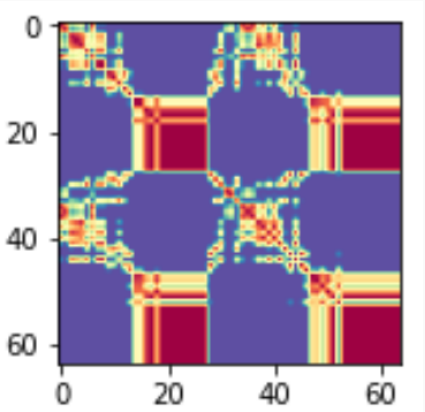
Recurrence Plots

What is a recurrence plot(RP)?

Tool to analyze dynamical systems and detect hidden dynamical patterns and nonlinearities

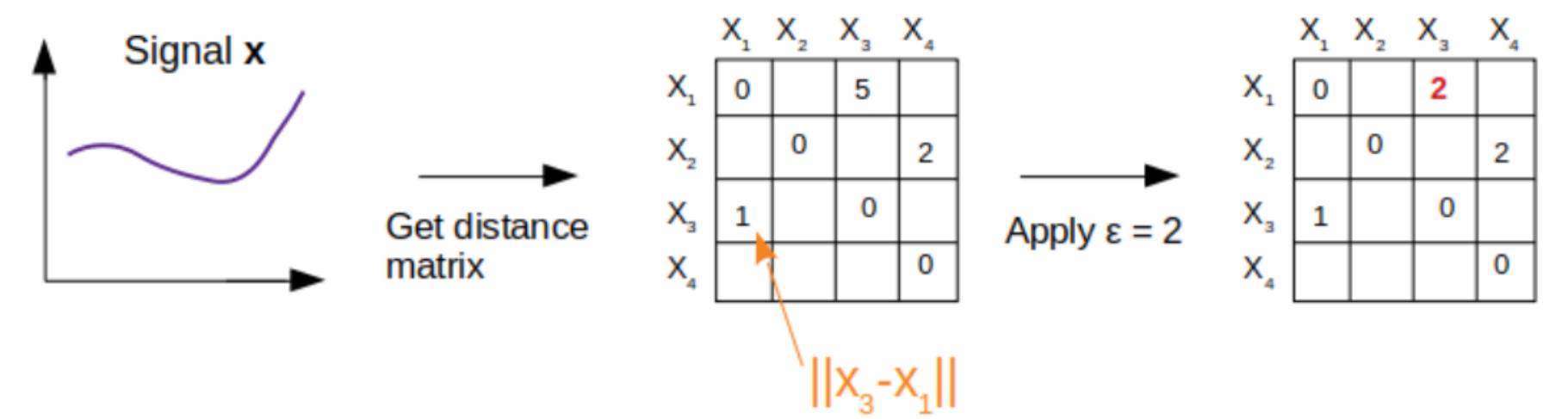




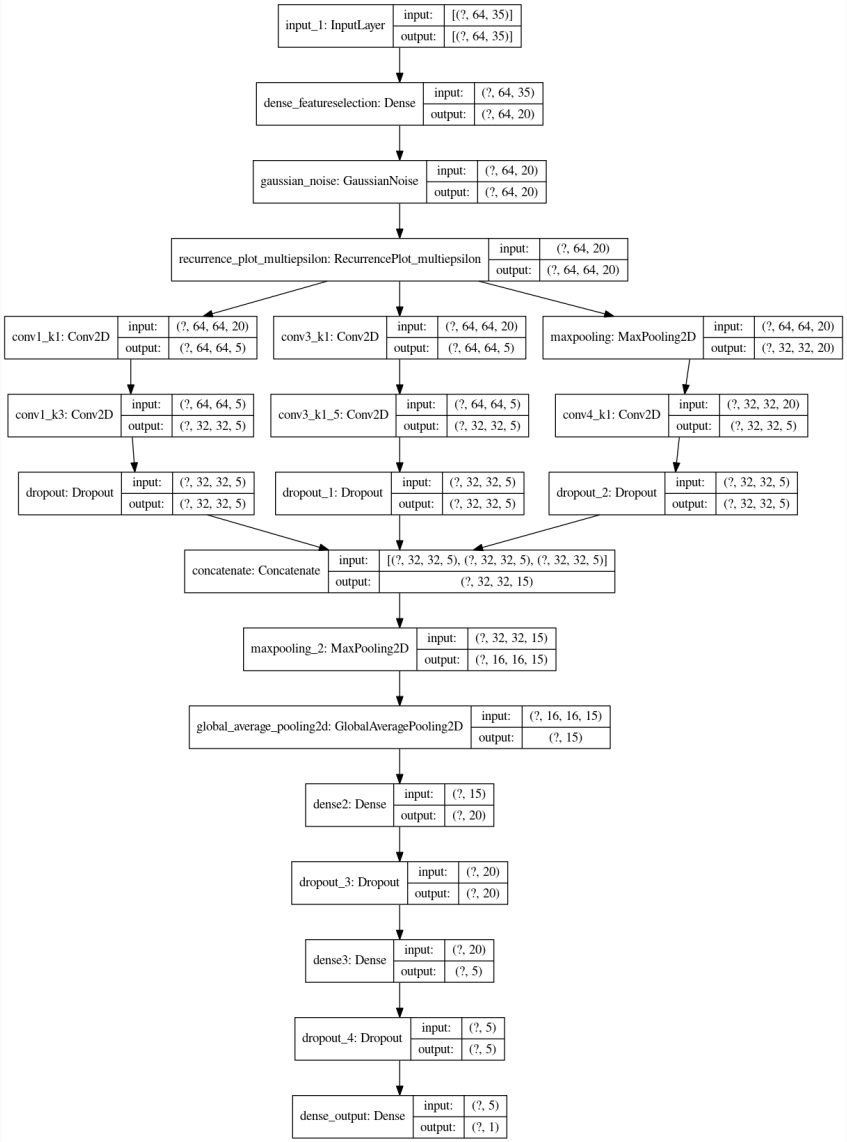


Global Recurrence Plots

$$D_{i,j} = \begin{cases} ||x_i - x_j||, & ||x_i - x_j|| \leq \epsilon \\ \epsilon, & ||x_i - x_j|| > \epsilon \end{cases}$$



Architecture



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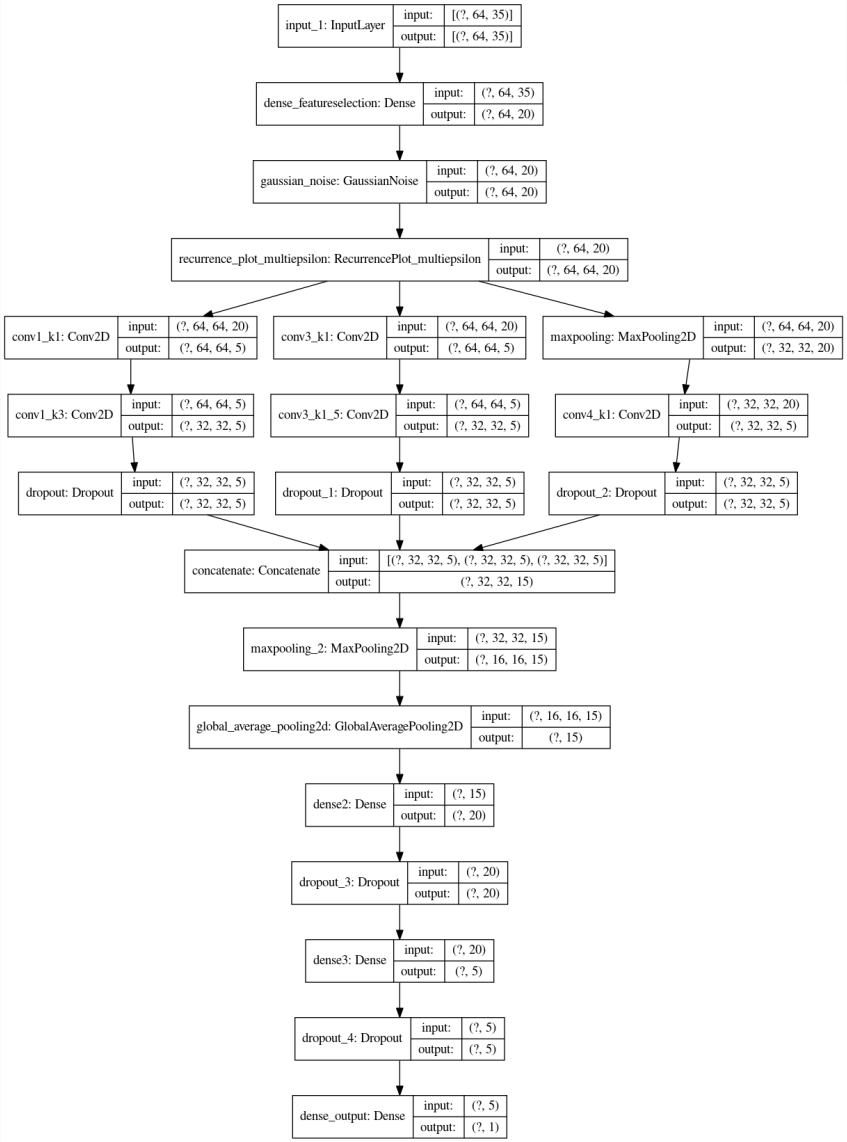

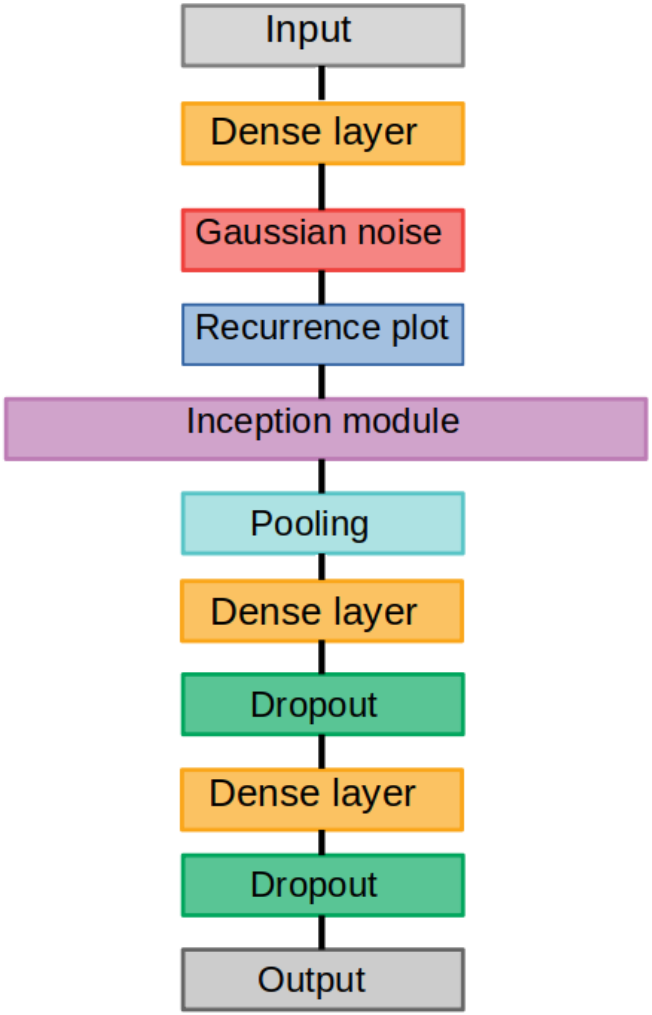

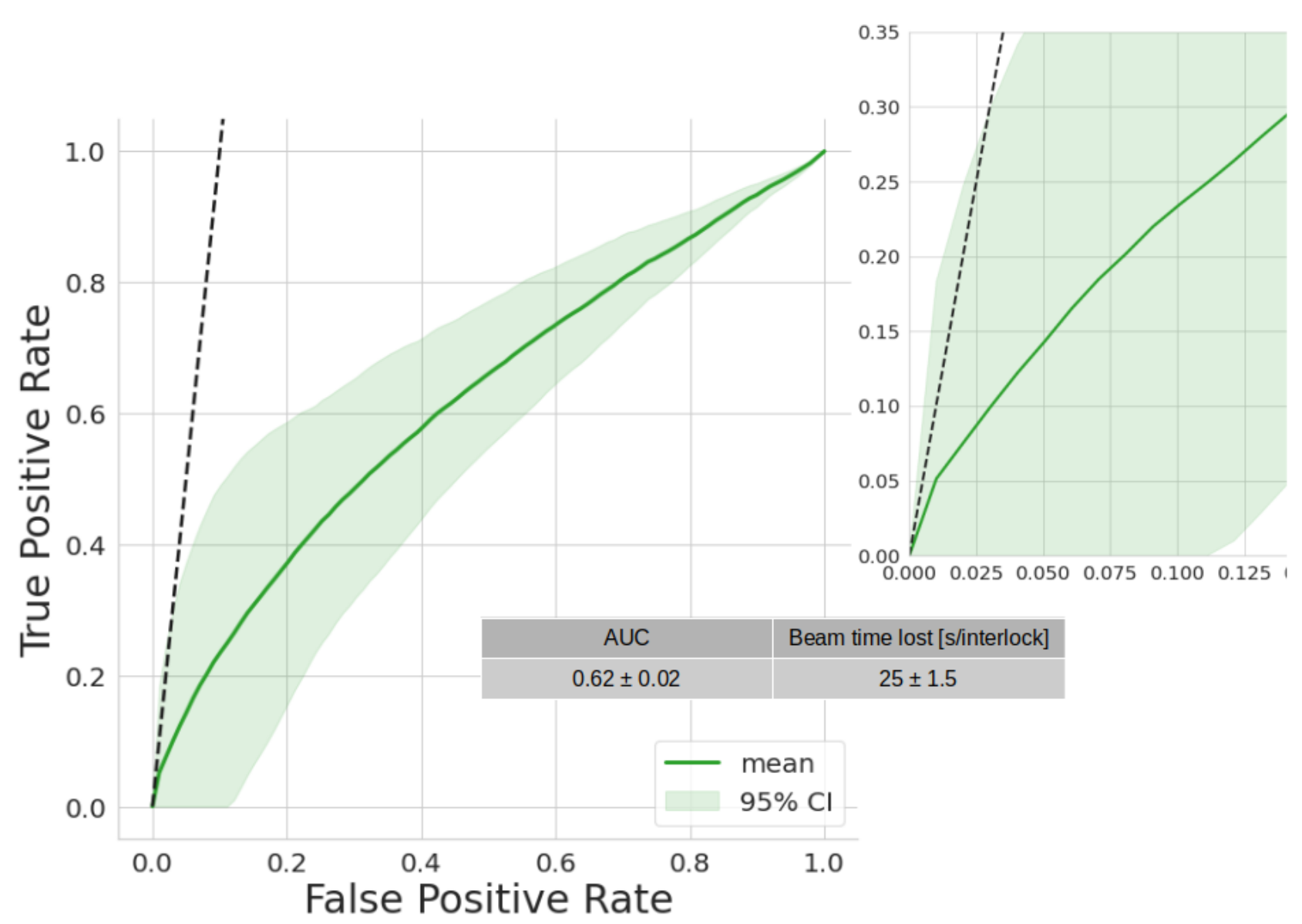
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.000
0.025
0.050
0.075
0.100
0.125
AUC
Beam time lost [s/interlock]
0.62 ± 0.02
25 ± 1.5
mean
95% CI

Conclusion

- Performance highly depends on the initialization
- Best models would save 1.5 s/interlock

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There are still many knobs left to turn

Thank you to

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Dr. Perez Cruz Fernando (SDSC)