DEEP LEARNING FRAMEWORK FOR FAULT DETECTION IN ACCELERATORS

M.Piekarski

SOLARIS National Synchrotron Radiation Centre, Jagiellonian University, Kraków, Poland, www.synchrotron.pl

IN A NUTSHELL

This poster presents **an in-depth analysis of multi-modal, deep learning-based frameworks for fault detection** within big research infrastructures, with a specific focus on accelerator facilities. The study explores **multi-input approaches** (multiple data sources of different modalities) and architectures for identifying anomalies indicating potential faults in operation.

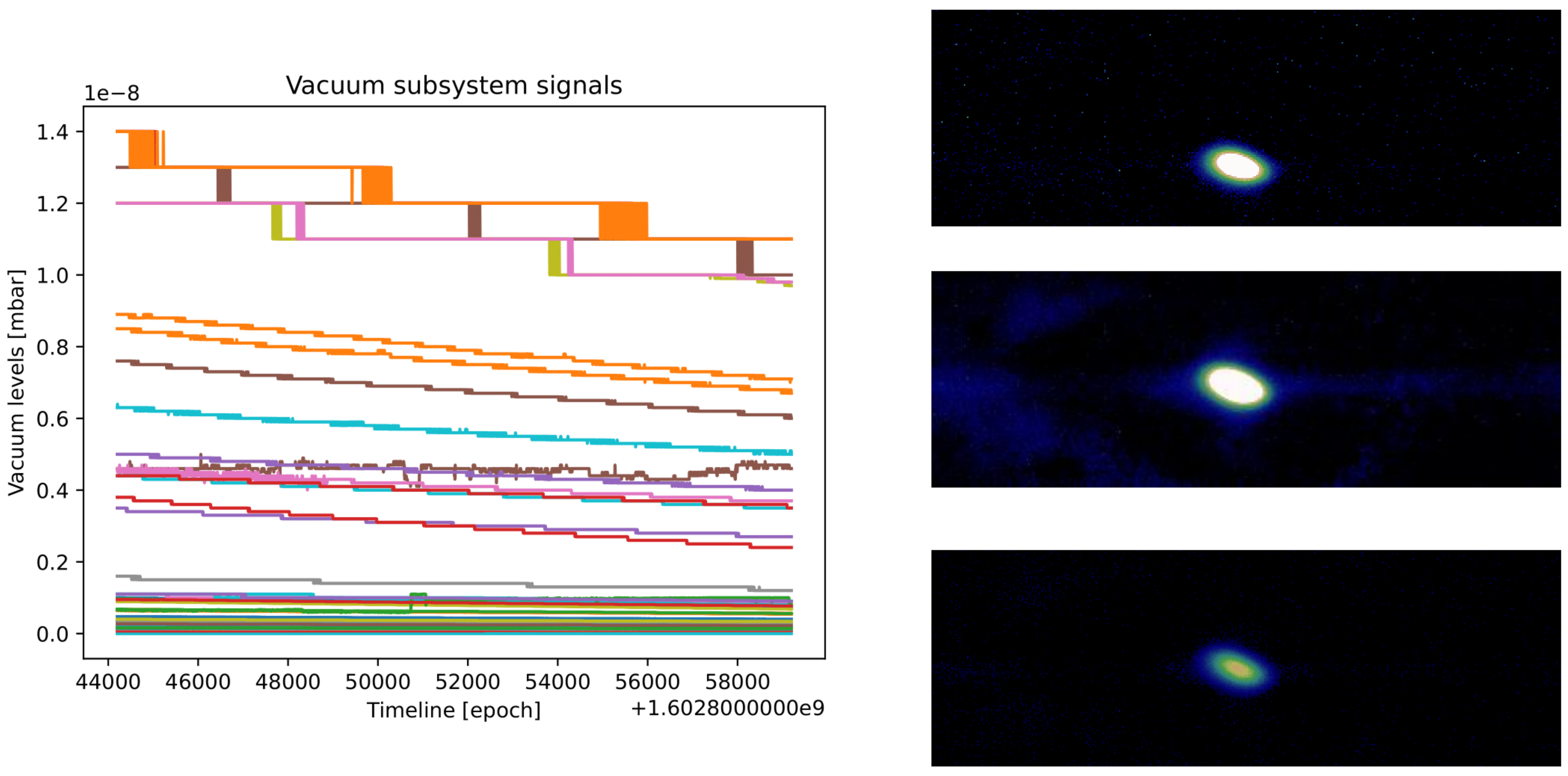
At the present stage, a **binary assignment is performed**: stable beam operation or unstable beam operation / no beam. Architecture is based on convolutional neural networks (CNN) and the **system reaches accuracy at the level of 94.1%.**

WHY DEEP LEARNING?

- Accelerators rely on precise control to achieve cutting-edge experimental results
- Fault and anomaly detection is vital to ensure stability, safety and high performance
- It is **not enough to rely only on low-level machine protection systems**
- Deep learning frameworks **proved their performance** in various fields

DATA

- Database created from scratch
- First modality: **390x134 pixels Pinhole transverse beam profile** images
- Second modality: **10x64 ultra high vacuum scalar time windows**
- For each image, 10 last UHV samples generated
- Labelled based on emmitance levels (in X and Y planes)
- 78 days of data collected, resulting in around 1M data samples



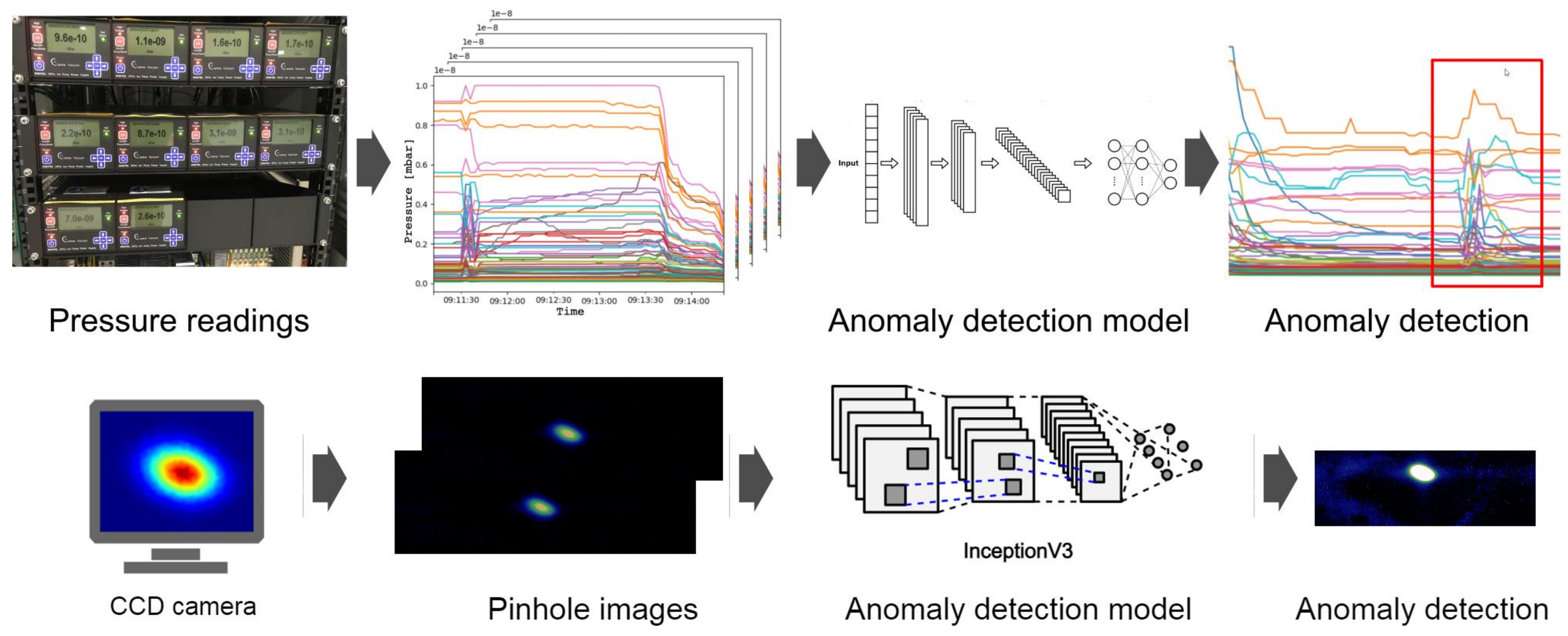
Examples of data samples from created dataset: around 5k vaccum signals + Pinhole transverse beam profiles captured during different stages of operation.

SOLARIS SYNCHROTRON

SOLARIS is a third generation light source operating at the Jagiellonian University in **Krakow, Poland**. Currently at SOLARIS **six experimental beamlines** offering various techniques, e.g.: photoemission electron microscopy, X-ray absorption spectroscopy, ultra angle-resolved photoemission spectroscopy or multi-scale X-ray and multimodal imaging, are available to the scientific community whereas **another three are already at advanced level of construction or commissioning**. Moreover, SOLARIS is also a **National Cryo-EM Centre**, with two latest generation cryo-electron microscopes enabling life science researchers to unravel life at the molecular level

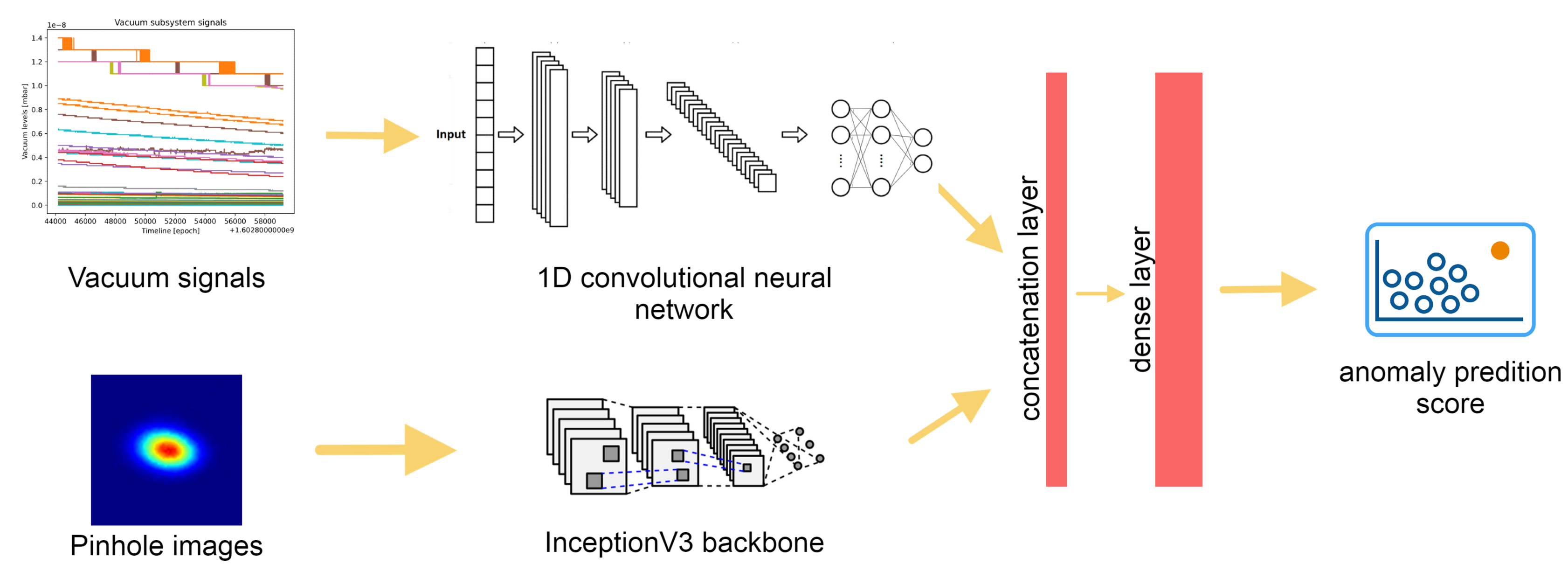
PROPOSED SYSTEM

- Two branch architecture (two input) based on deep neural networks
- Scalar part (UHV windows) based on **1D convolutional layers**
- Image (Pinhole) part utilizes **InceptionV3 fine-tuned** base model



Flowchart of both parts of the proposed framework.

- Both models connected through concatenation layer
- Added classifier on top with sigmoid binary output (**probability scores for anomaly and non-anomaly**)



Overview of the proposed fault detection system.

Architecture	Training [%]	Validation [%]	Testing [%]
Scalar only	84.3	81.0	81.1
Pinhole only	93.1	94.4	**91.4**
Multi-input	92.5	88.0	**91.4**

Results obtained both by separate models and one joint multi-input architecture.

CONCLUSIONS

- It has been proven that deep neural network-based systems **can achieve high accuracy in anomaly detection task**
- It can be concluded that **most of the information to the system brings Pinhole image**
- Still, there is a knowledge gain coming from data fusion
- Such systems could certainly serve as a support for the Operators giving valuable information on the current machine performance

ACKNOWLEDGEMENTS

The presented work has been achieved in collaboration with AGH University of Science and Technology in Kraków as a part of a PhD thesis.

This project is executed under the provision of the Polish Ministry and Higher Education project "Support for research and development with the use of research infrastructure of the National Synchrotron Radiation Centre SOLARIS" under contract nr 1/SOL/2021/2.