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MACHINE LEARNING IMAGE PROCESSING TECHNOLOGY APPLICATION IN BUNCH LONGITUDINAL PHASE DATA INFORMATION EXTRACTION

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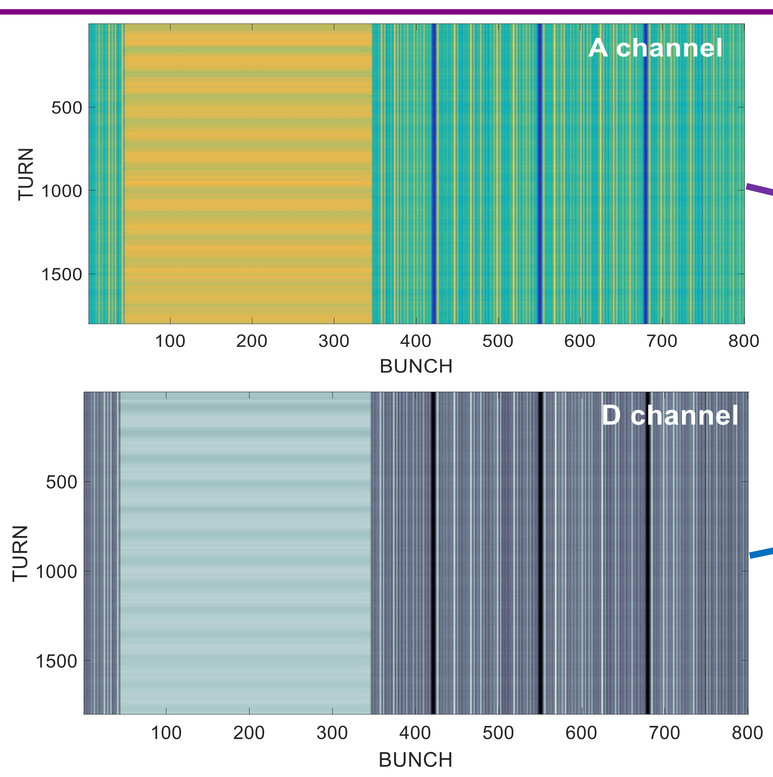
Introduction

In order to achieve the bunch-by-bunch longitudinal phase measurement, Shanghai Synchrotron Radiation Facility (SSRF) has developed a high resolution measurement system. We used this measurement system to study the injection transient process, and obtained the longitudinal phase of the refilled bunch and the longitudinal phase of the original stored bunch. A large number of parameters of the synchronous damping oscillation are included in this large amount of longitudinal phase data, which are important for the evaluation of machine state and bunch stability. The multi-turn phase data of a multi-bunch is a large two-dimensional array that can be converted into an image. The convolutional neural network (CNN) is a machine learning model with strong capabilities in image processing. We hope to use the convolutional neural network to process the longitudinal phase two-dimensional array data, and extract important parameters such as the oscillation amplitude and the synchrotron damping time.

Motivation

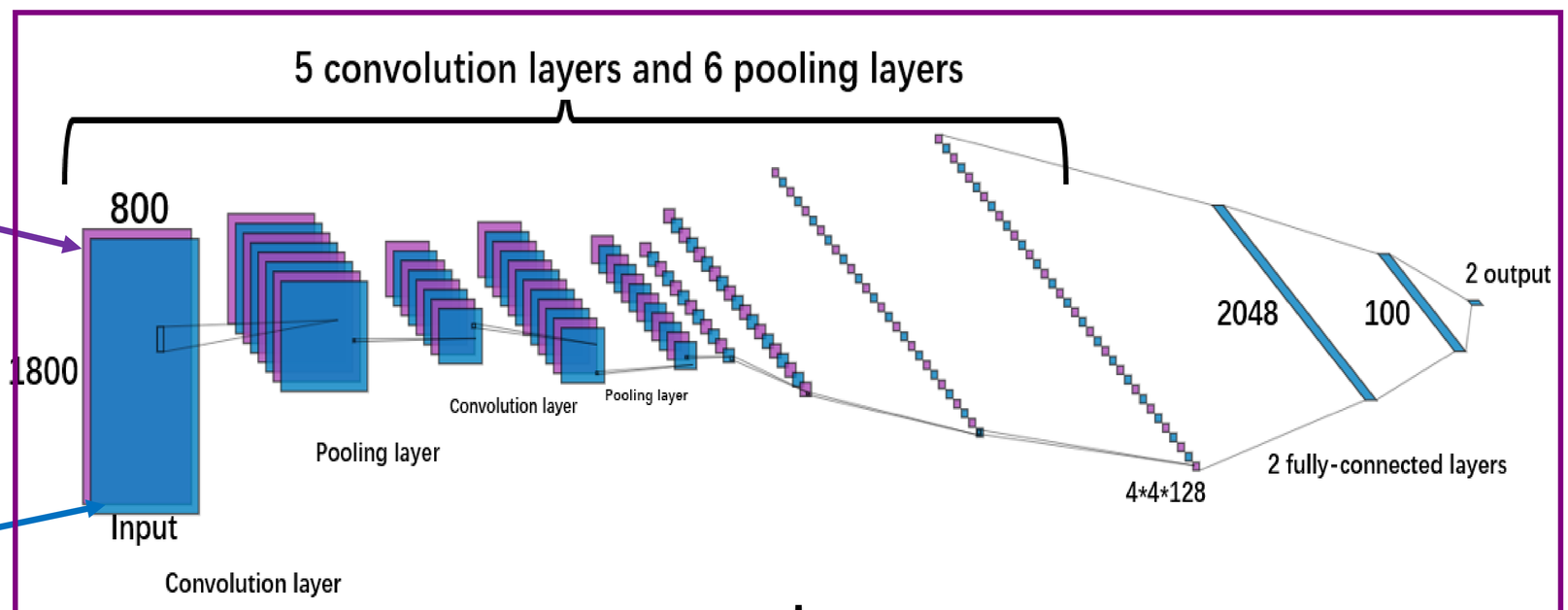
In our field of beam measurement, we collect huge amounts of data every day. These data are often stored in two-dimensional or even multi-dimensional arrays. If the two-dimensional array is restored according to the storage method of the greyscale image, it can be drawn into a greyscale image. **So can we use deep learning image processing techniques such as multi-layer convolutional neural networks to process such data in the form of multi-dimensional arrays and extract the information we need from it?**

a color picture with two primary colors(A channel and D channel)



A group data drawn into two images. D channel is similar to A channel. The difference between them is caused by the delay(100ps). With both of them, we can remove the influence of different charge quantities to get the phase oscillation parameters.

ML model(CNN)

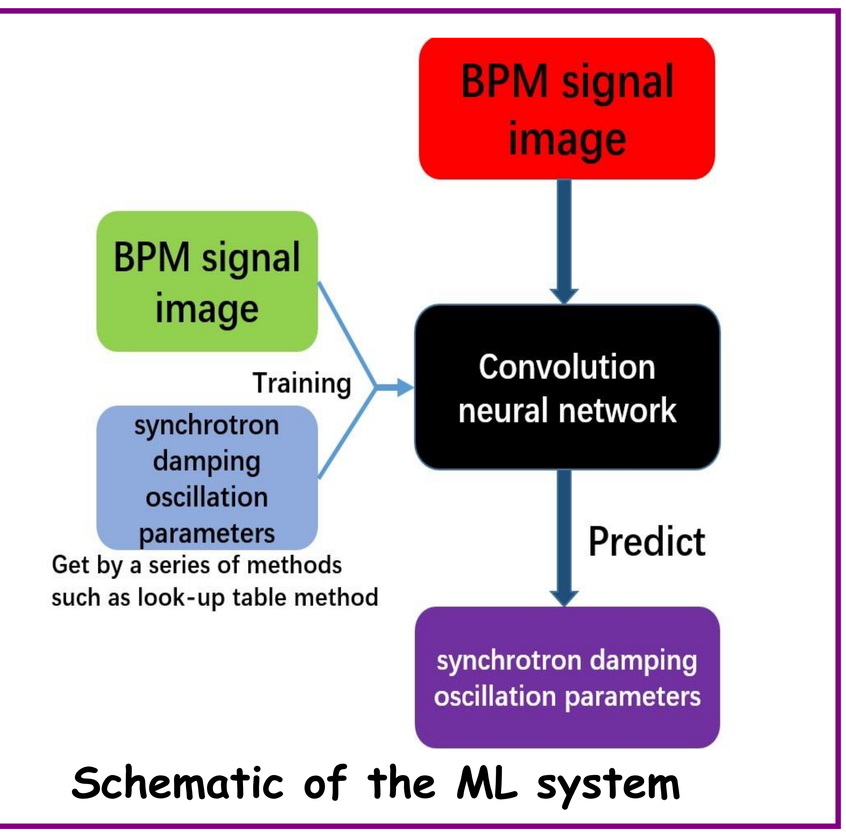


Convolution neural network

- representative algorithms of deep learning
- strong capabilities in image processing
- Huge data
- Spatial correlation in the data
- Information Position uncertainty

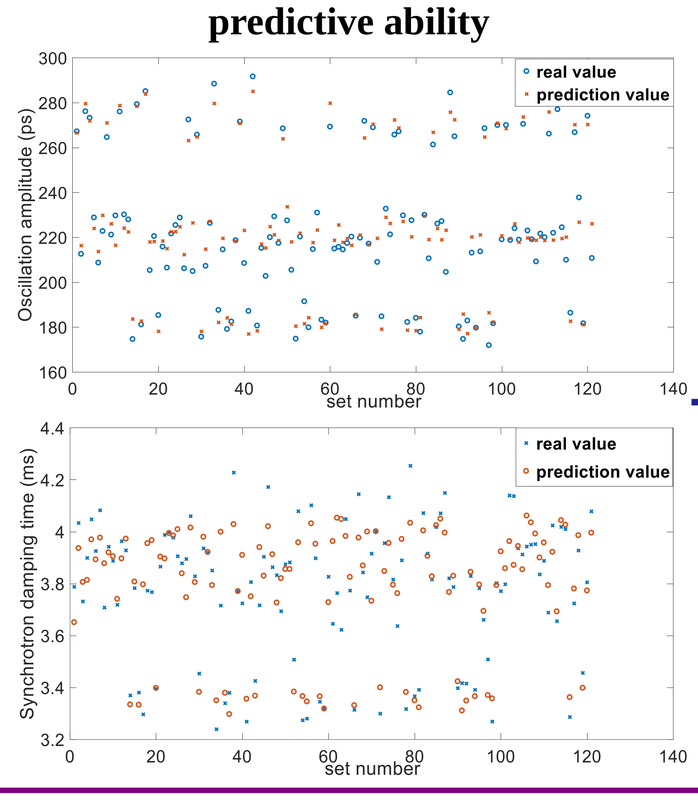
My CNN model in this program

- 1 input layer (two greyscale image)
- 5 convolution layers
- 6 pooling layers
- 2 fully-connected layers
- 1 output layer (regression-oscillation amplitude and the synchrotron damping time



Schematic of the ML system

predictive ability



- Prediction error of amplitude is 5ps
- Prediction error of damping time is 0.08ms

error analysis

- Too little training data(only 300 sets for training,100 sets for test)
- Error from so-called real value is large(obtained by a series of processes such as look-up table method)

Conclusion

- Technique tools based on ML image processing
- Processing the most primitive data(BPM electrical signal) like processing image
- Predict oscillation amplitude and the synchrotron damping time

Postscript

- The model is built based on Google's tensorflow and python SCIKIT-learn. THANKS.
- Our future goal is building a model to extract a series of beam state parameters(the more the better) we need , such as position, bunch size, and charge, from a multi-dimensional BPM primitive data

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