EGMC:Explainability using Gradient based methods for Modulation Classification

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SECTION 1:

Problem Definition & Literature Survey

The Problem

Explainability methods for the **deep learning models** to **understand and visualise** the learned parameters and predictions reasoning.

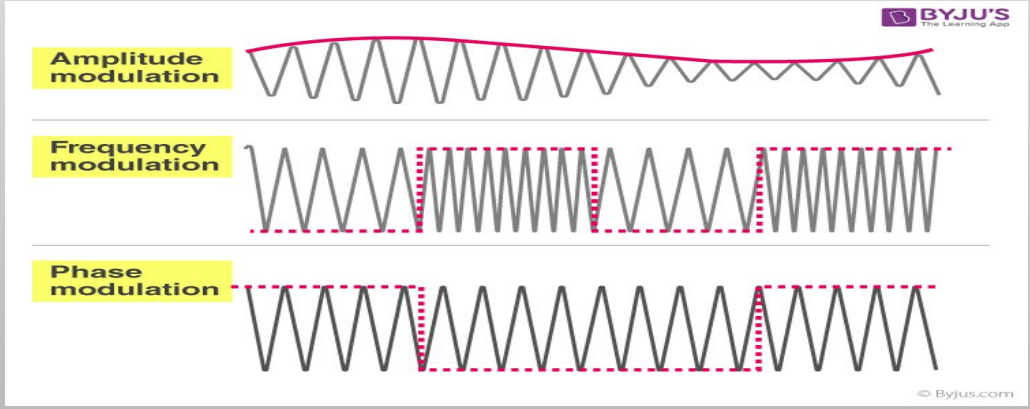
Literature Survey

These have been following researches done which are related to this project.

1. Modulation Schemes
2. Constellation Diagram and Modulation Classification using constellation Diagram
3. DL methods for Modulation Classification
- Automatic Modulation Classification
- Modulation Classification Based on Signal Constellation Diagrams and Deep Learning
- Automatic Modulation Classification Exploiting Hybrid Machine Learning Network
4. Visualisation using gradient based methods[GradCAM and GradCAM ++]

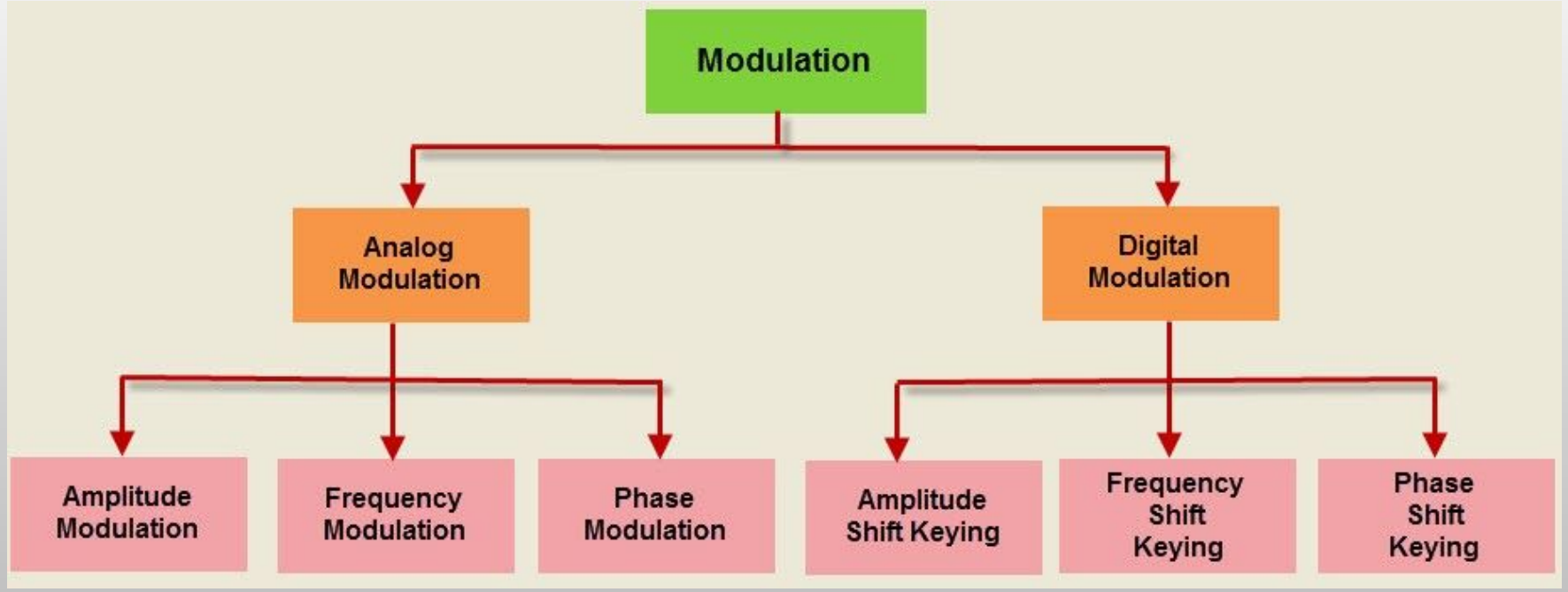
Modulation

Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted.



Source : www.byjus.com

Modulation Schemes

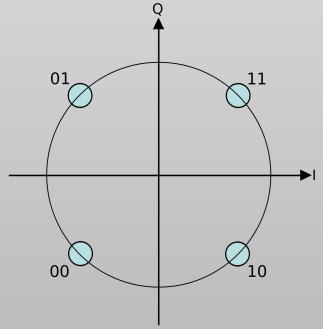


Source : www.watelectronics.com

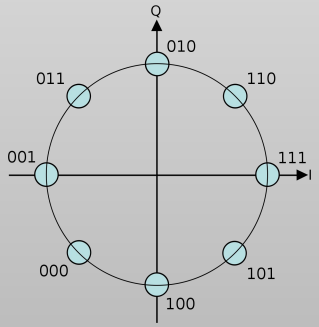
Constellation Diagram

A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying. It displays the signal as a two-dimensional xy-plane scatter diagram in the complex plane at symbol sampling instants

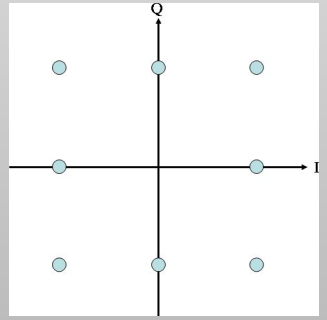
Source : commons.wikimedia.org



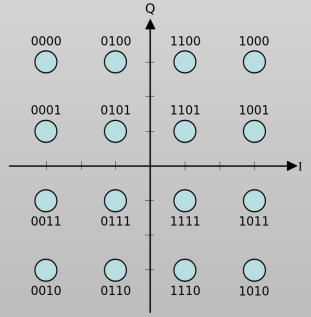
4-PSK



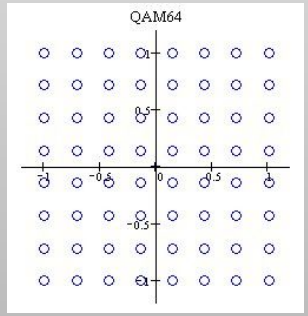
8-PSK



8-QAM



16-QAM



64-QAM

DL Methods for Modulation Classification :

Automatic Modulation Classification

- Proposed a **convolutional neural network (CNN)-based** cooperative AMC (Co-AMC) method for the MIMO systems.
- The r**eceiver equipped with multiple antennas cooperatively recognizes the modulation types.**
- Each received antenna gives their recognition sub-results via the CNN, respectively.
- With recognition sub results and some rules it classifies the modulation class.

DL Methods for Modulation Classification :

Modulation Classification Based on Signal Constellation Diagrams and Deep Learning

- They have used **two convolutional neural network (CNN)-based DL models, AlexNet and GoogLeNet.**
- They developed several methods to represent modulated signals in data formats with gridlike topologies for the CNN.
- Results demonstrate the significant performance advantage and application feasibility results demonstrate the

DL Methods for Modulation Classification :

Automatic Modulation Classification Exploiting Hybrid Machine Learning Network

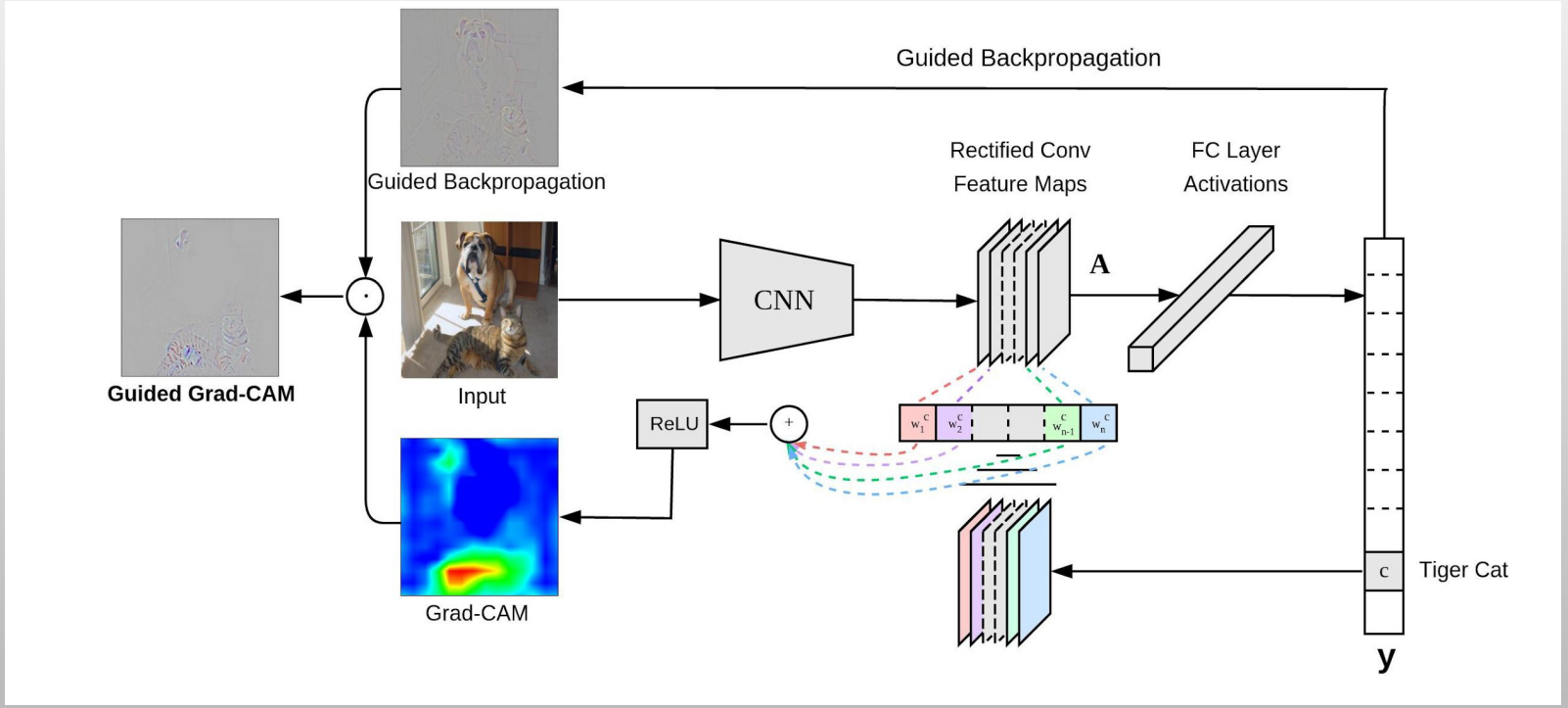
- They have **constructed a multilayer hybrid machine learning network** for the classification of **seven types of signals in different modulation.**
- They extracted the signal modulation features by making full use of a set of algorithms such as time-frequency analysis, discrete Fourier transform, and instantaneous autocorrelation and accomplish automatic modulation classification using **naive Bayesian and support vector machine in a hybrid manner.**
- The parameters in the network for classification were determined automatically in the training process.

Visualisation using gradient based methods :

- **GradCAM - Base Method**
- **GradCAM ++ (Used Method)**

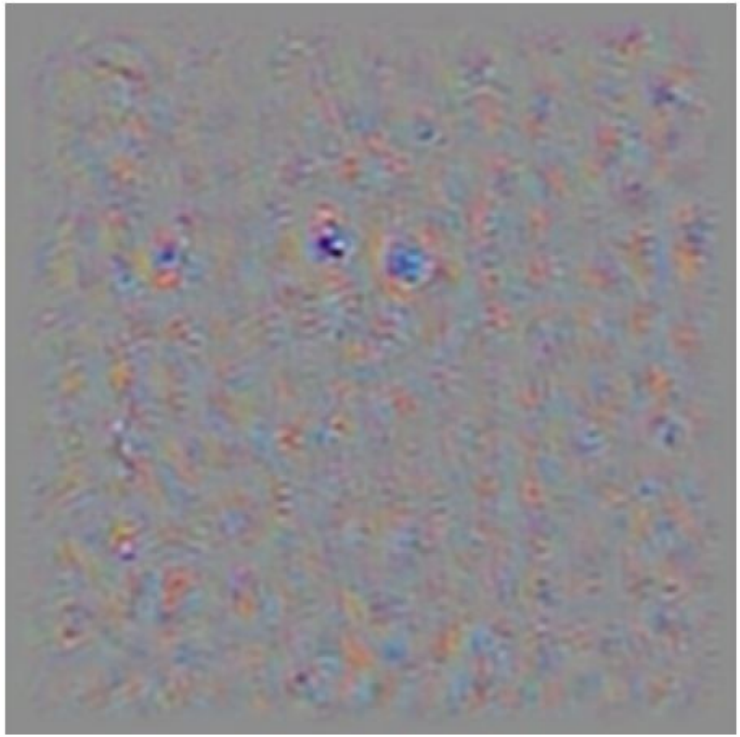
A technique for making Convolutional Neural Network (CNN)-based models more transparent by visualizing the regions of input that are “important” for predictions from these models — or visual explanations

Visualisation using gradient based methods(contd.) :
GradCAM (Gradient-weighted Class Activation Mapping)



Source : medium.com

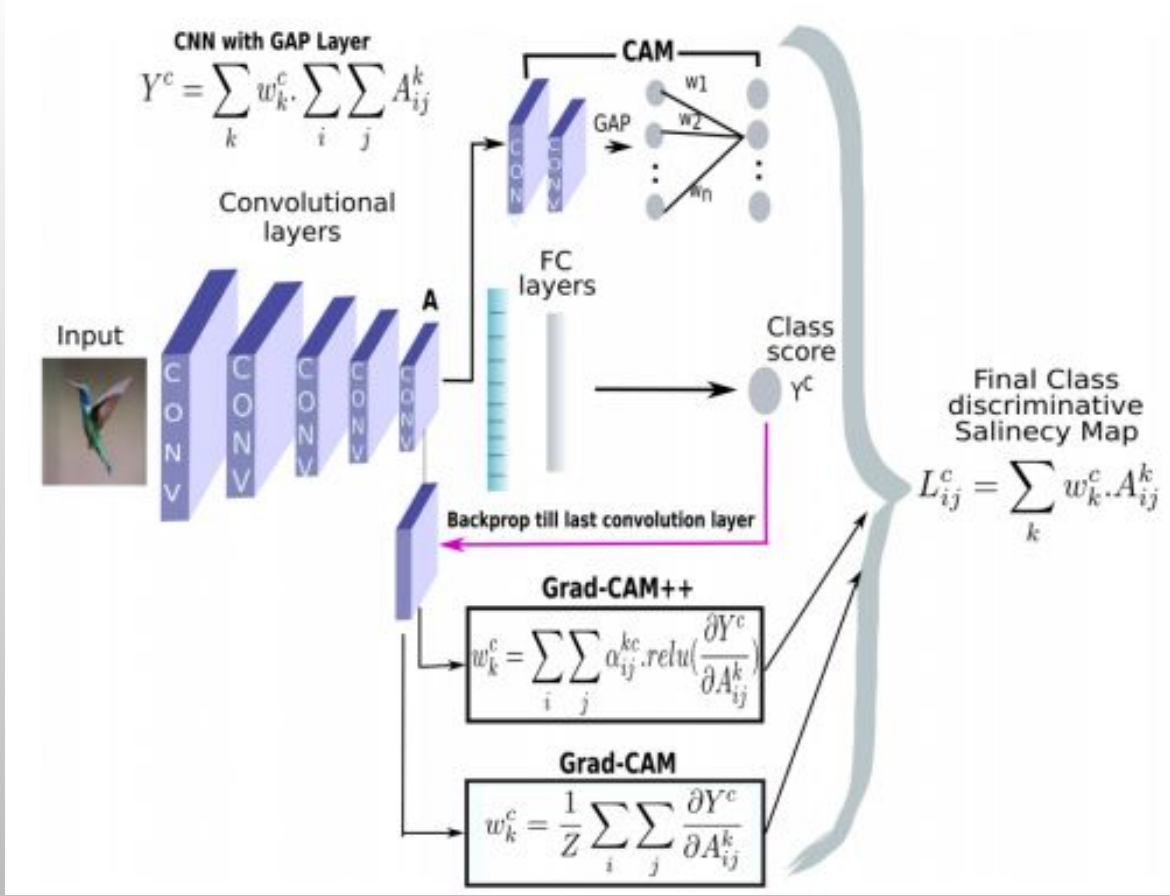
Deconvolution



Guided Backprop

Source : medium.com

GradCAM ++
Block DIagram



Source : medium.com

SECTION 2:

Different Solution Proposed (Nationally and/or Internationally)

Kürşat Tekbıyık, Ali Rıza Ekti, Ali Görçin, Güneş Karabulut Kurt, Cihat Keçeci **Analysis and Visualization of Deep Neural Networks in Device-Free Wi-Fi Indoor Localization**

Method Used : t-SNE

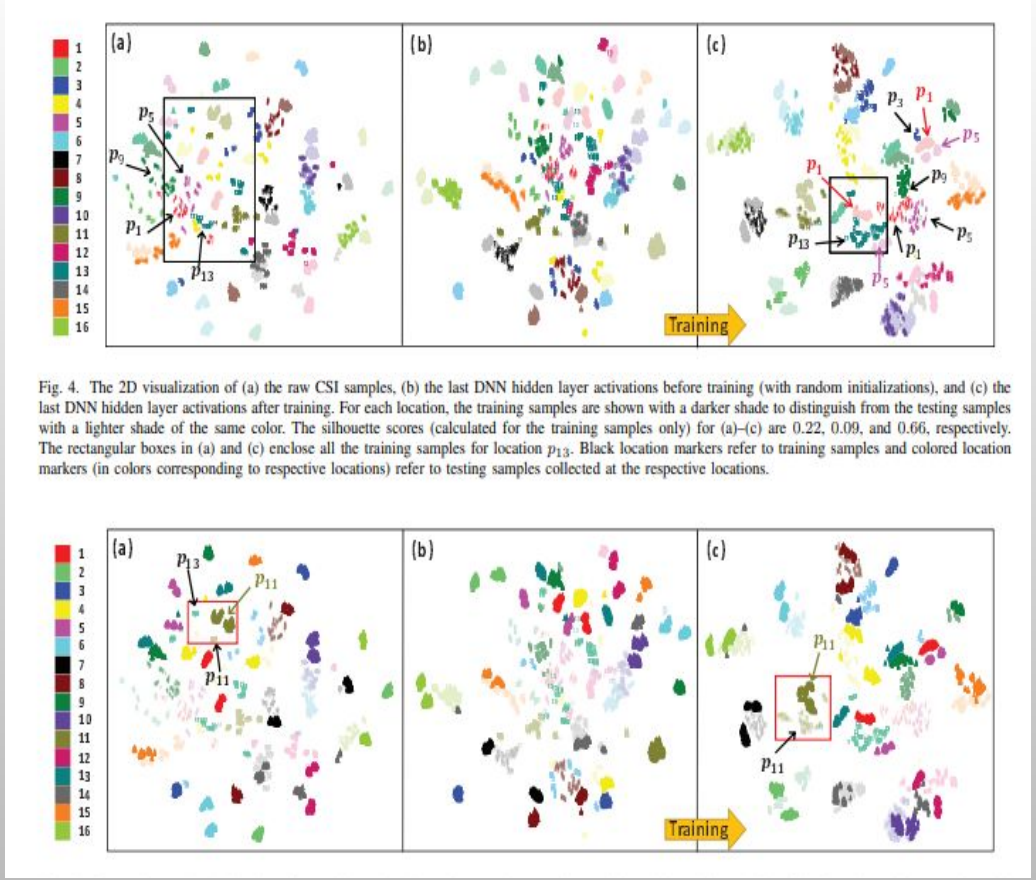
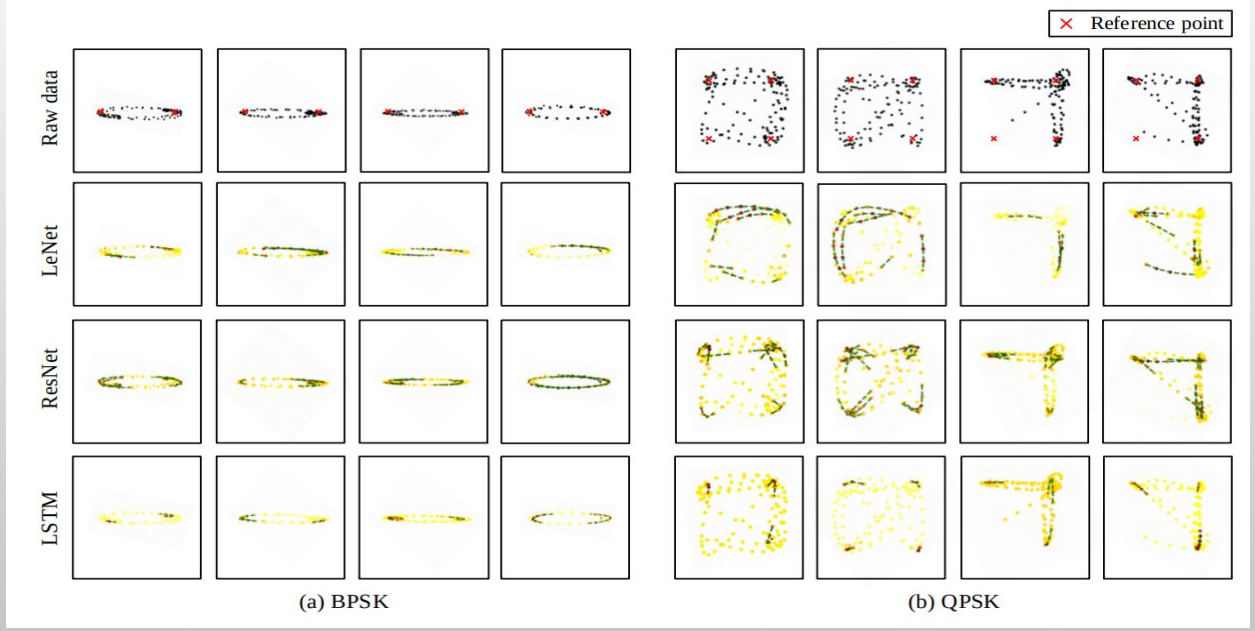
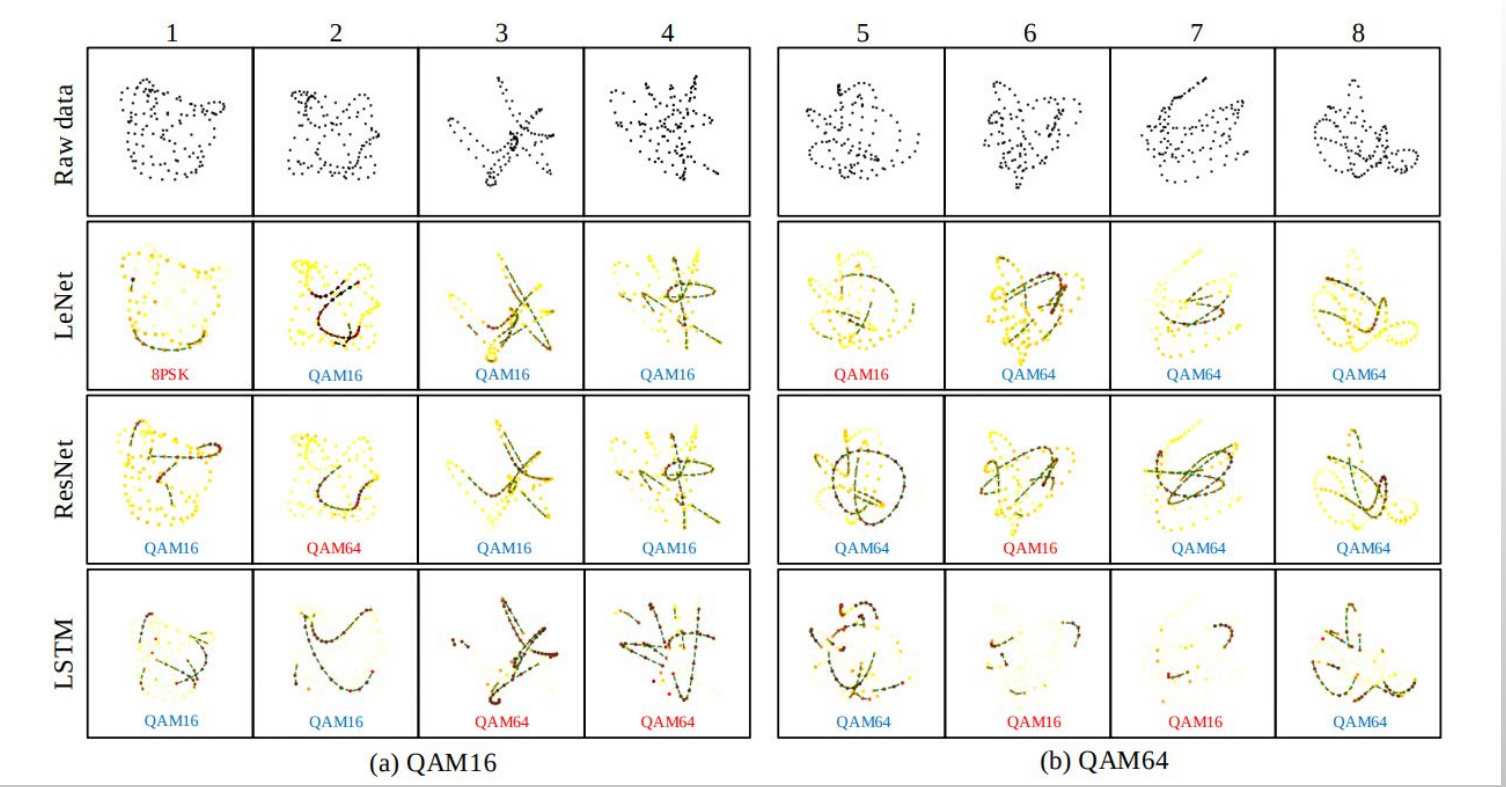


Fig. 4. The 2D visualization of (a) the raw CSI samples, (b) the last DNN hidden layer activations before training (with random initializations), and (c) the last DNN hidden layer activations after training. For each location, the training samples are shown with a darker shade to distinguish from the testing samples with a lighter shade of the same color. The silhouette scores (calculated for the training samples only) for (a)–(c) are 0.22, 0.09, and 0.66, respectively. The rectangular boxes in (a) and (c) enclose all the training samples for location p_{13}. Black location markers refer to training samples and colored location markers (in colors corresponding to respective locations) refer to testing samples collected at the respective locations.

Huang, Liang & Zhang, You & Pan, Weijian & Jinyin, Chen & Qian, Li & Wu, Yuan. (2020). **Visualizing Deep Learning-based Radio Modulation Classifier.**

Method Used : Grad-CAM

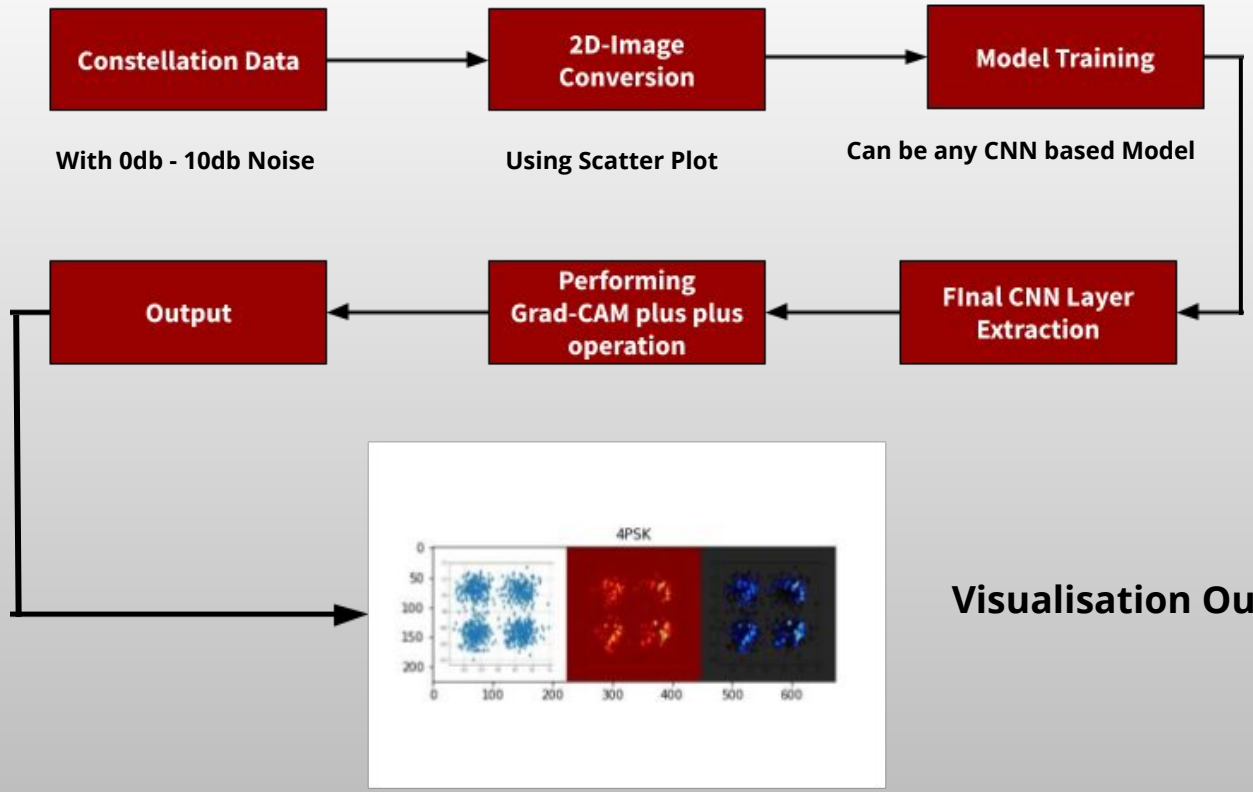




Huang, Liang & Zhang, You & Pan, Weijian & Jinyin, Chen & Qian, Li & Wu, Yuan. (2020). Visualizing Deep Learning-based Radio Modulation Classifier.

SECTION 3:

Idea to solve the problem & Implementation



Visualisation Output

SECTION 4:

Results after implementation

Intersection with Standard Constellation Diagram

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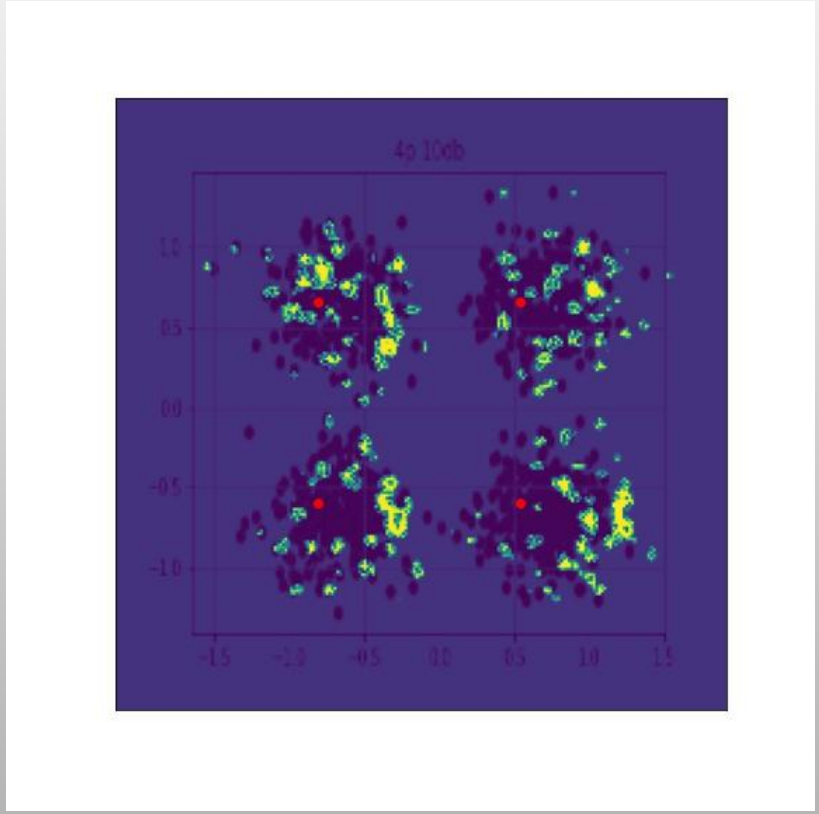

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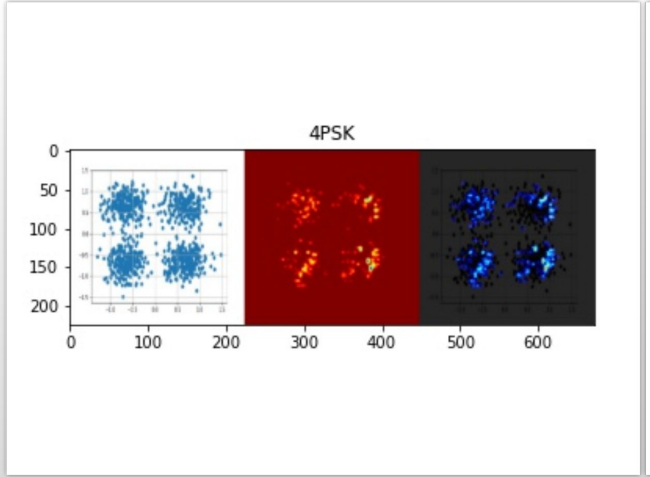
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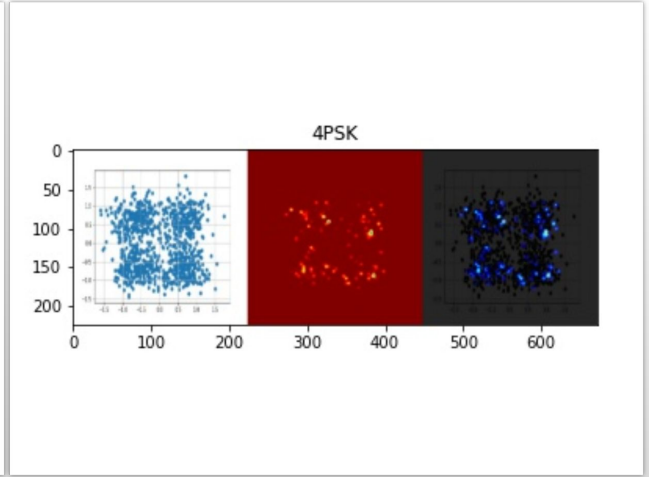
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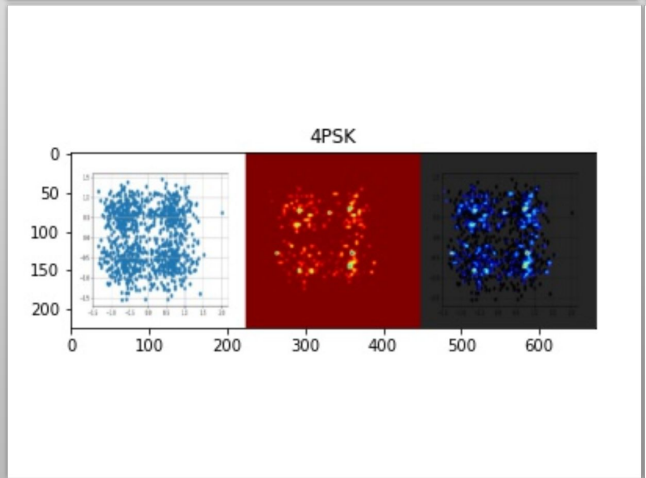
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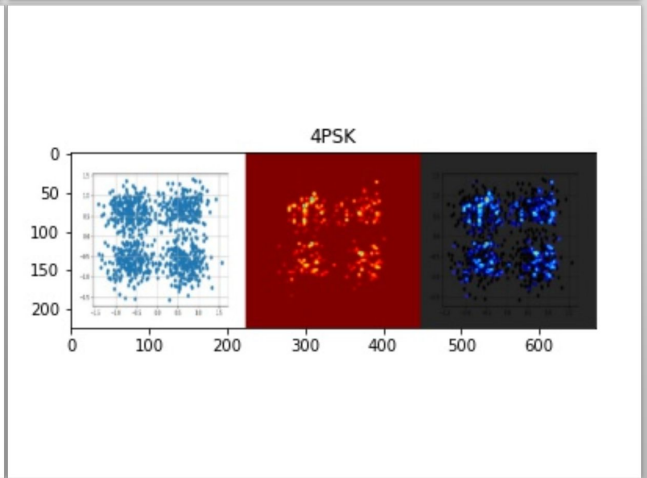
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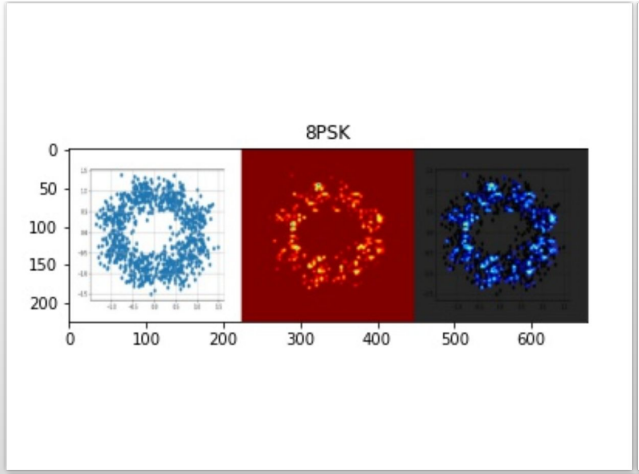
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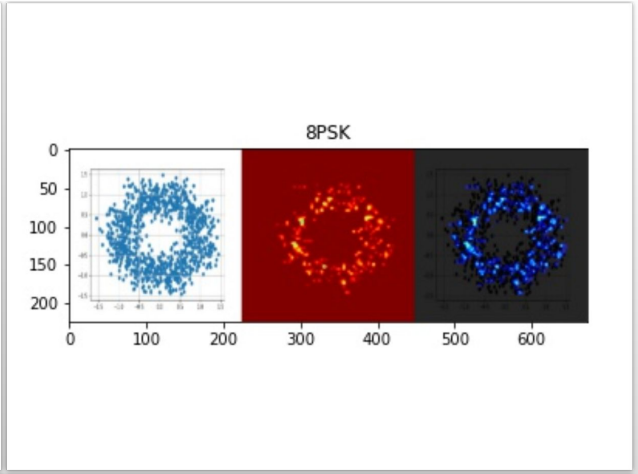
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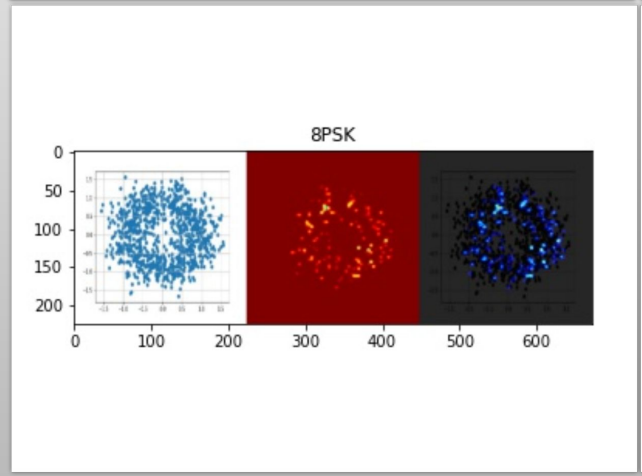
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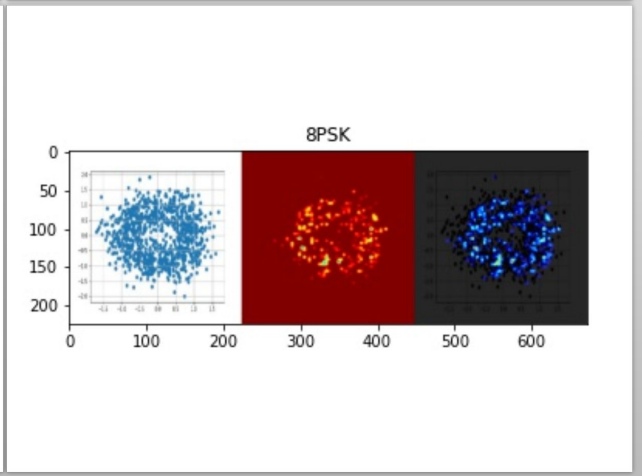
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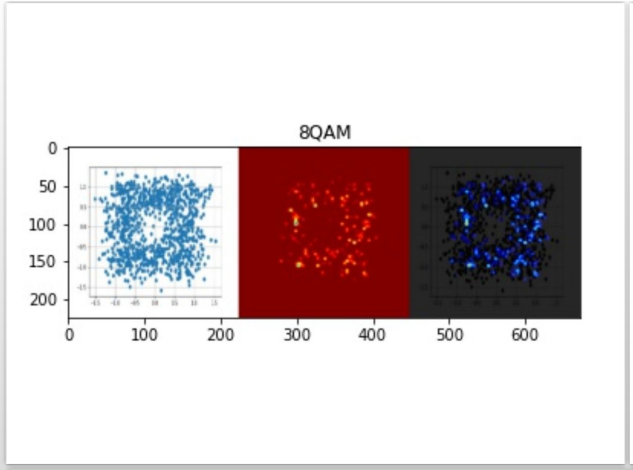
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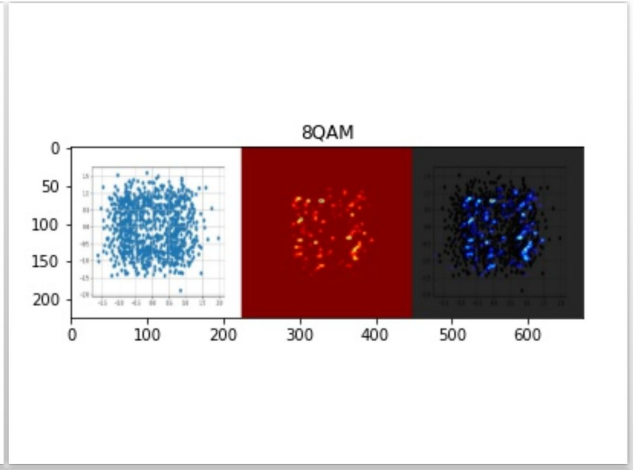
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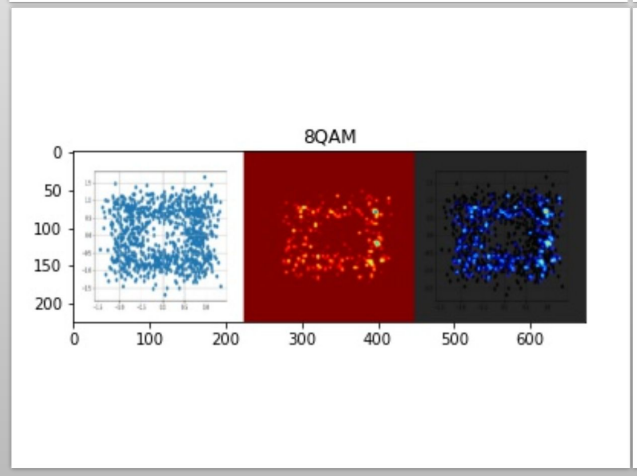
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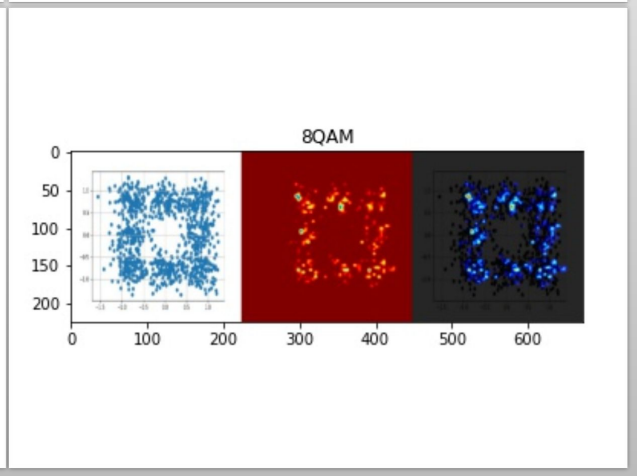
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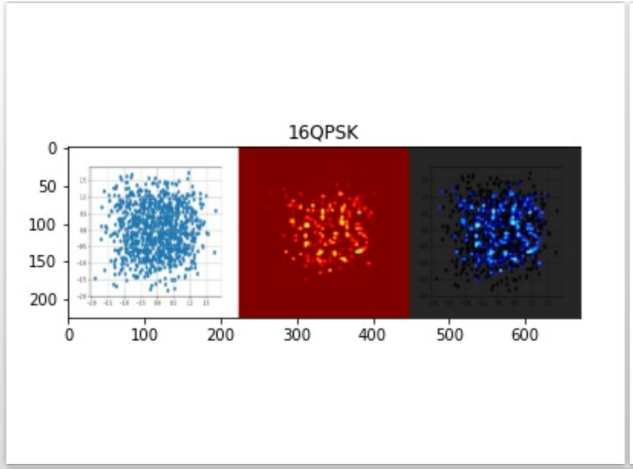
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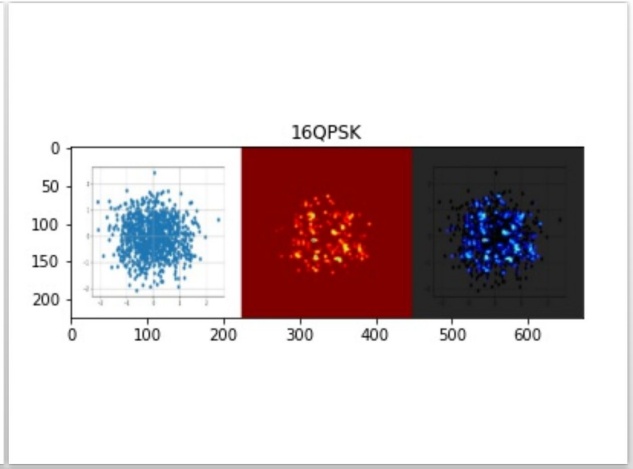
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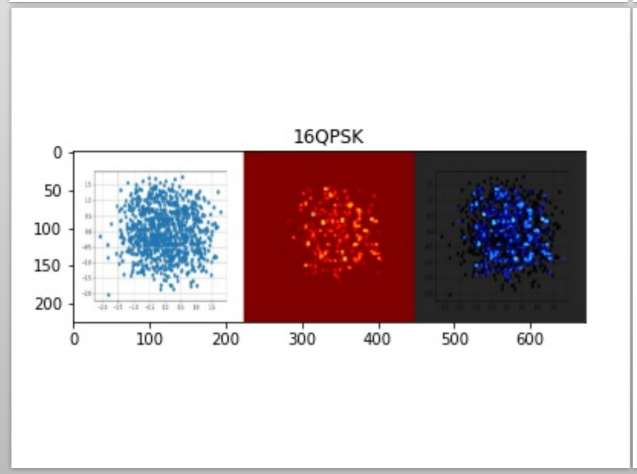
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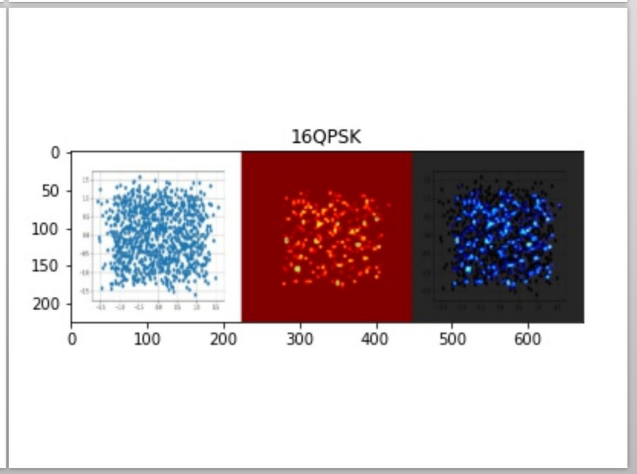
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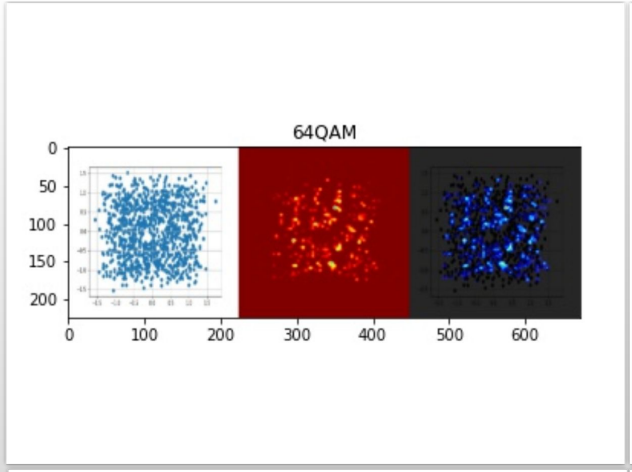
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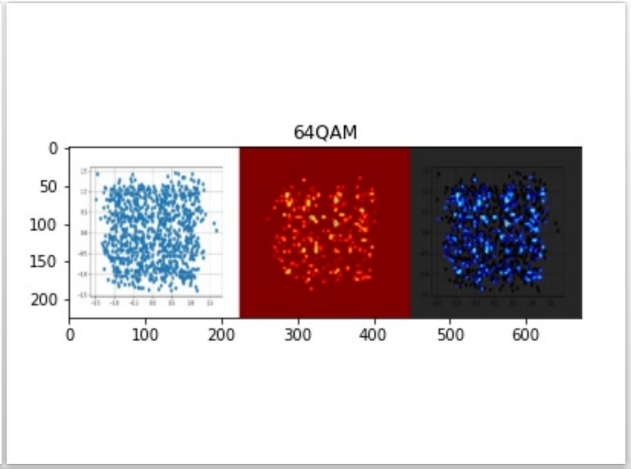
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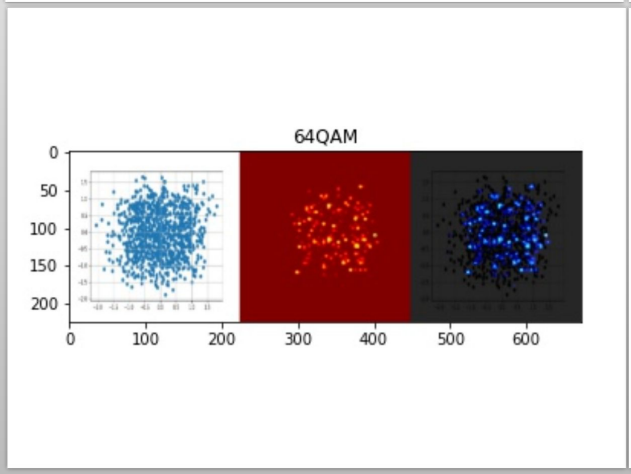
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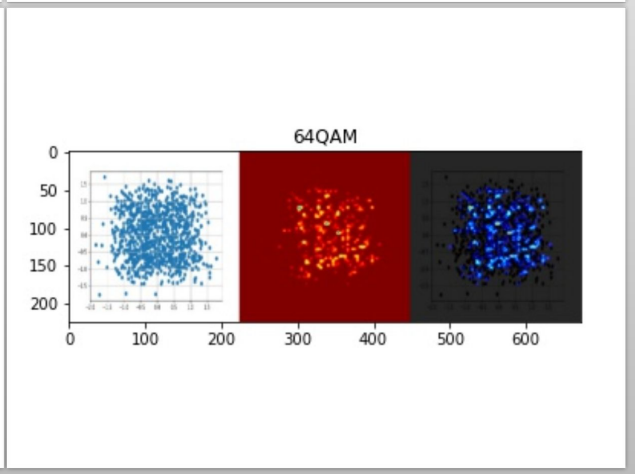
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