ADASS XXVIII

A METHOD TO DETECT RADIO FREQUENCY INTERFERENCE BASED ON CONVOLUTIONAL NEURAL NETWORKS

- Dai Cong[1], Zuo Shifan[2], Liu Wei[1], Li Jixia[2] , Zhu Meng[1], Wu Fengquan[2], Chen Xuelei[2], Yu Xianchuan[1]

1 College of Information Science and Technology, Beijing Normal University, Beijing, China

2 Cosmology Group, National Astronomical Observatory, Beijing, China

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- Background
- Proposed method
- Experiment
- Conclusion

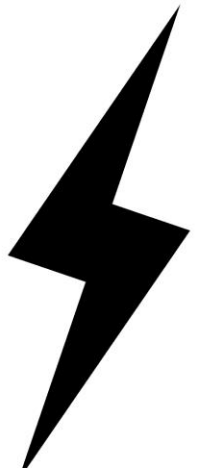
BACKGROUND

PART ONE

RADIO FREQUENCY INTERFERENCE

- Man-made interference

Global positioning system (GPS), mobile phones, aircraft navigation communications and artificial noise sources and etc.



- Natural interference

Lightning noise, solar reflection and etc.

PROBLEMS

With the significant improvement of resolution and sensitivity of radio telescopes, they become more and more sensitive to the interference noise, and the influence of the interference on the observation results is intensified.

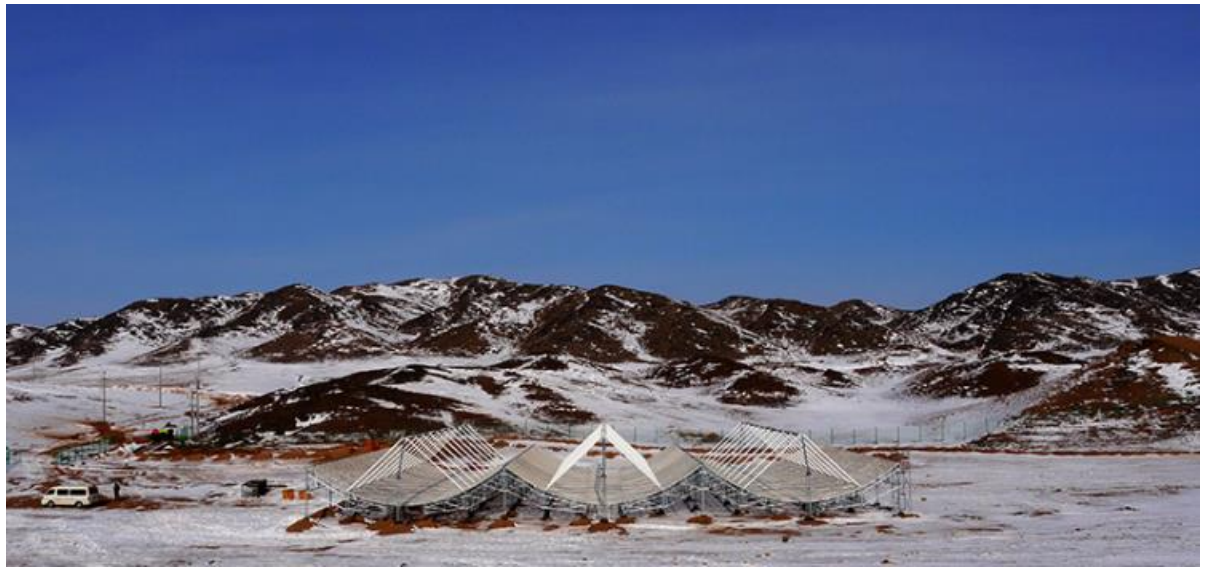
- *Loss of data and reduction of data quality*

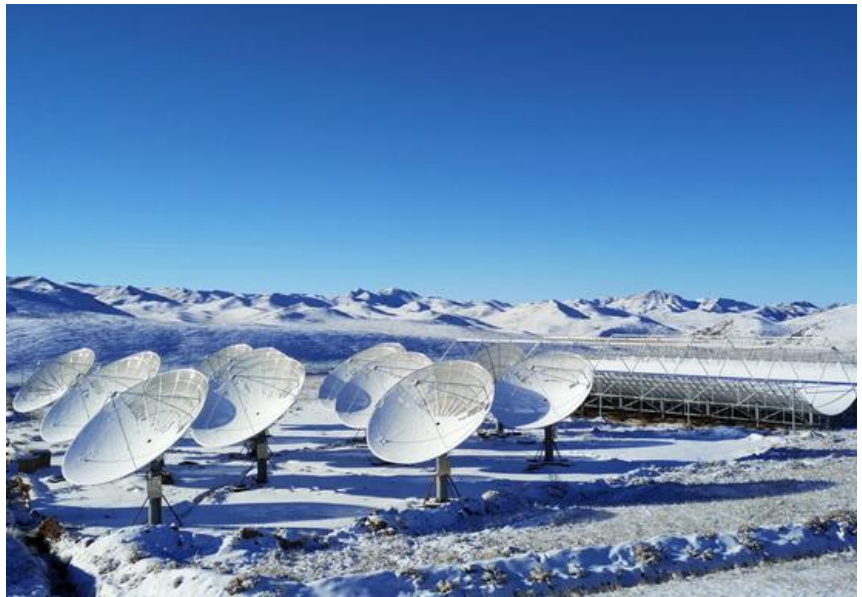
- *Influence of searching for objects such as pulsar fast radio bursts and radio transient sources*

”TIANLAI” PLAN

A radio telescope-array, aims to observe the large-scale structure of the universe, that is to explore the distribution of matter in space.

http://tianlai.bao.ac.cn/index.html





TASK

- *The rule of RFI is difficult to figure out*.
- *The telescope array of "Tianlai plan" produces terabytes of data*, which challenges the traditional data processing methods.

How to detect RFI in massive observing radio data automatically and efficiently?

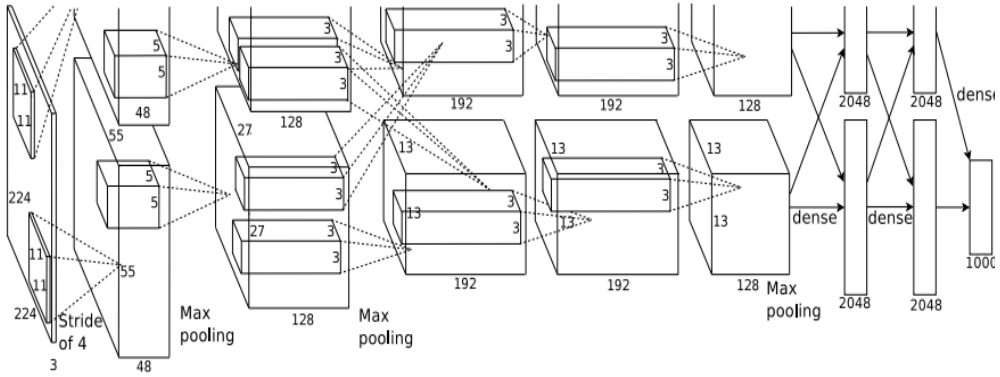
DEEP LEARNING

Caffe

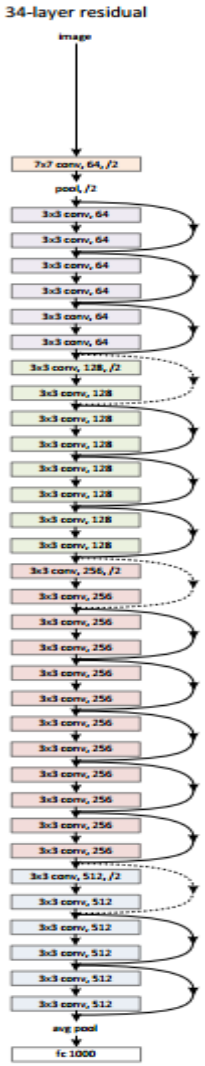
Keras

TensorFlow

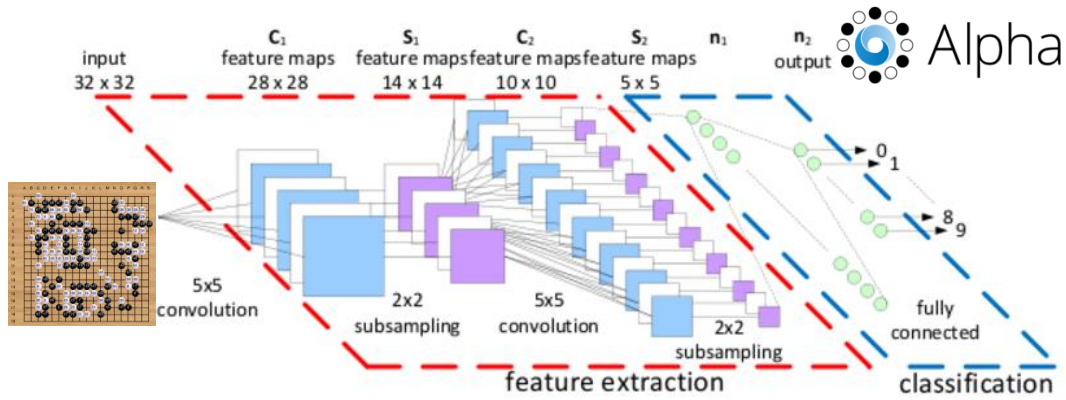
AlexNet



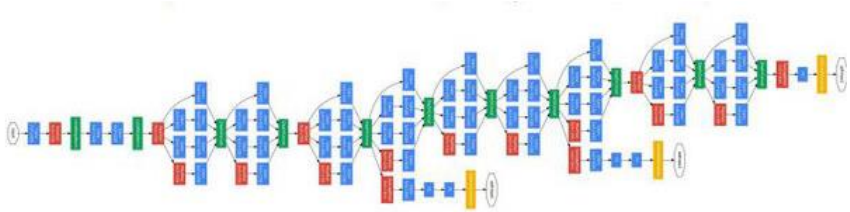
ResNet



AlphaGo



GoogLeNet

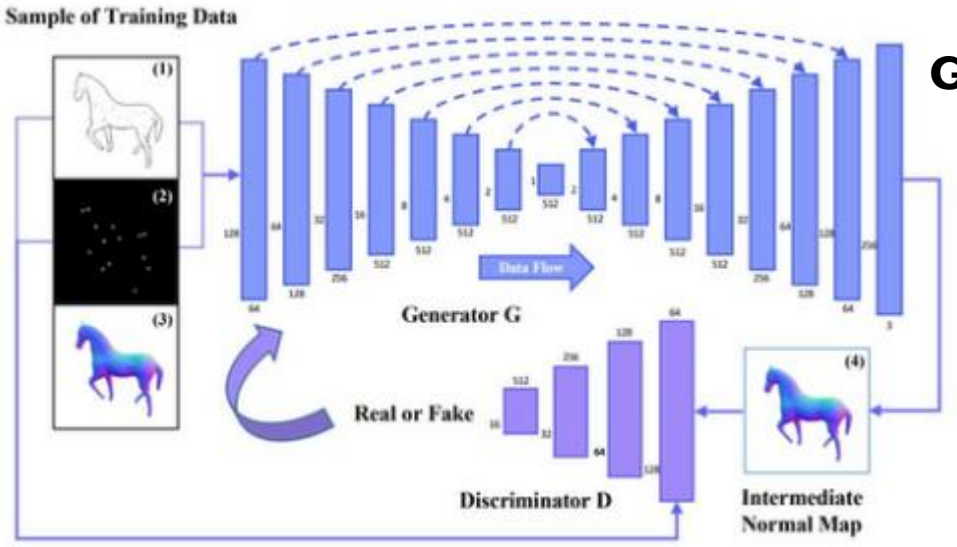


Going Deeper with Convolutions

Christian Szegedy, Wei Liu, Yangqing Jia, Pierre Sermanet, Scott Reed, Dragomir Anguelov, Dumitru Erhan, Vincent Vanhoucke, Andrew Rabinovich

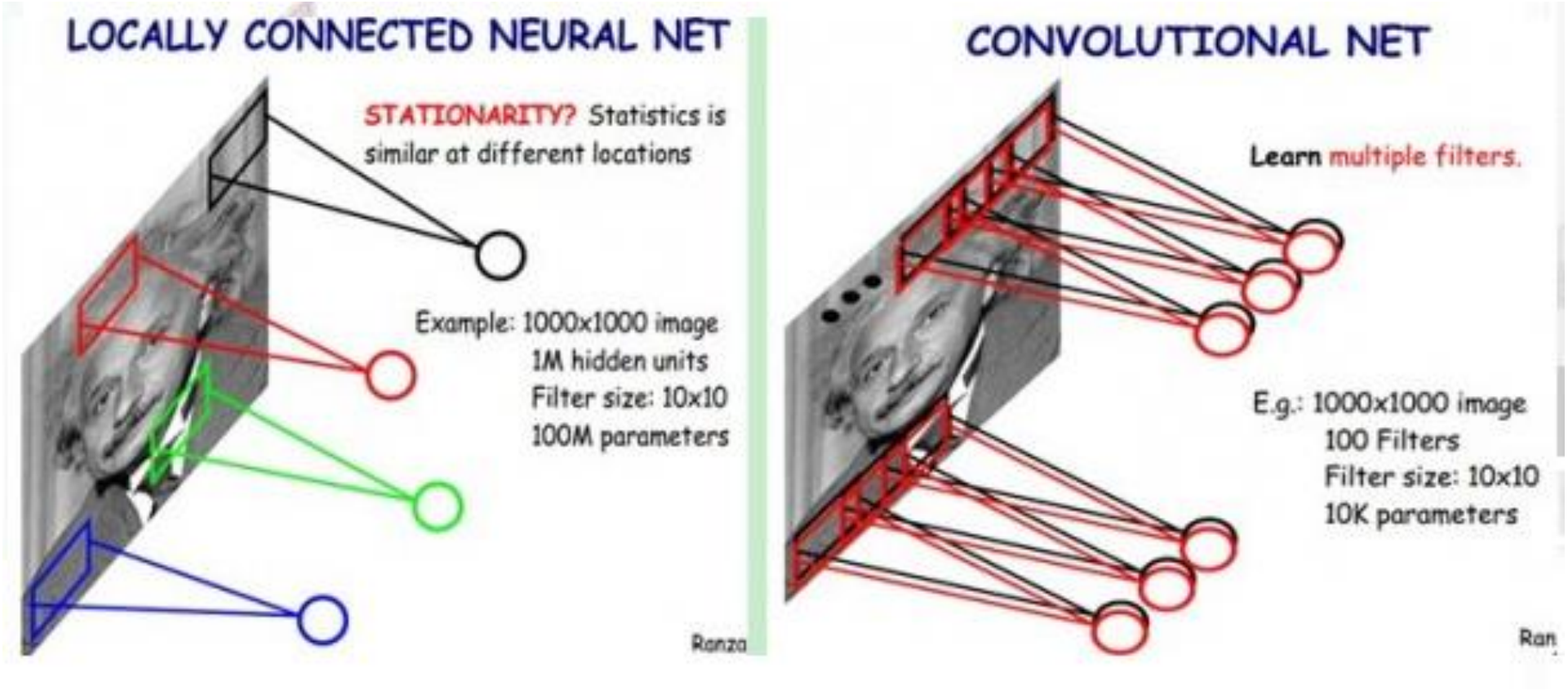
ArXiv 2014, CVPR 2015

GAN



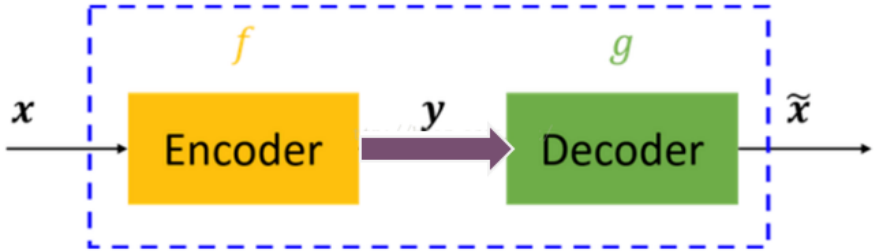
CONVOLUTIONAL NEURAL NETWORK,CNN

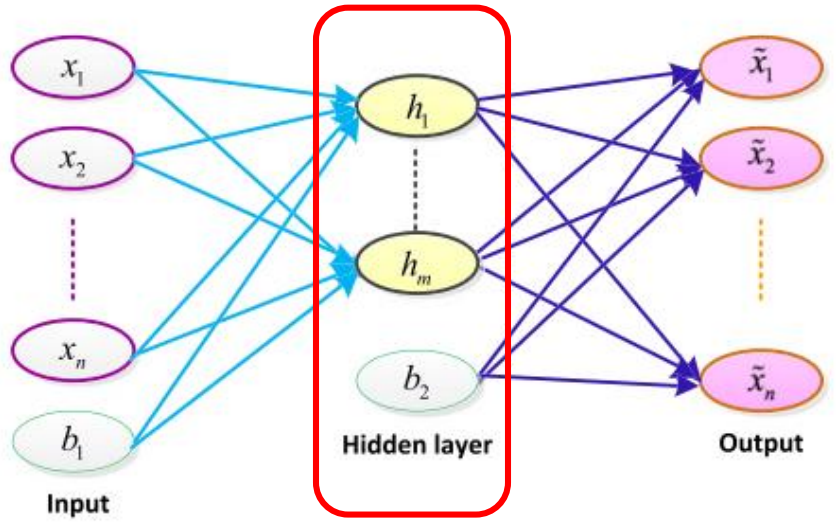
Deeper layers extract concrete features, shallower layers extract abstract features.



AUTO-ENCODER

Through self expression, the feature of the data is extracted



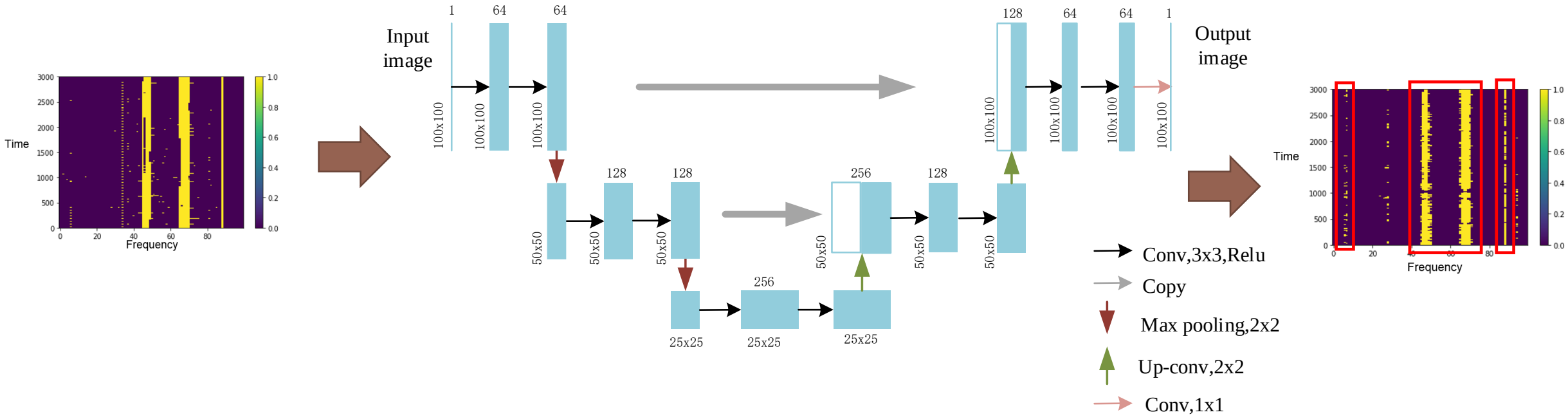


PROPOSED METHOD

PART Two

UNET

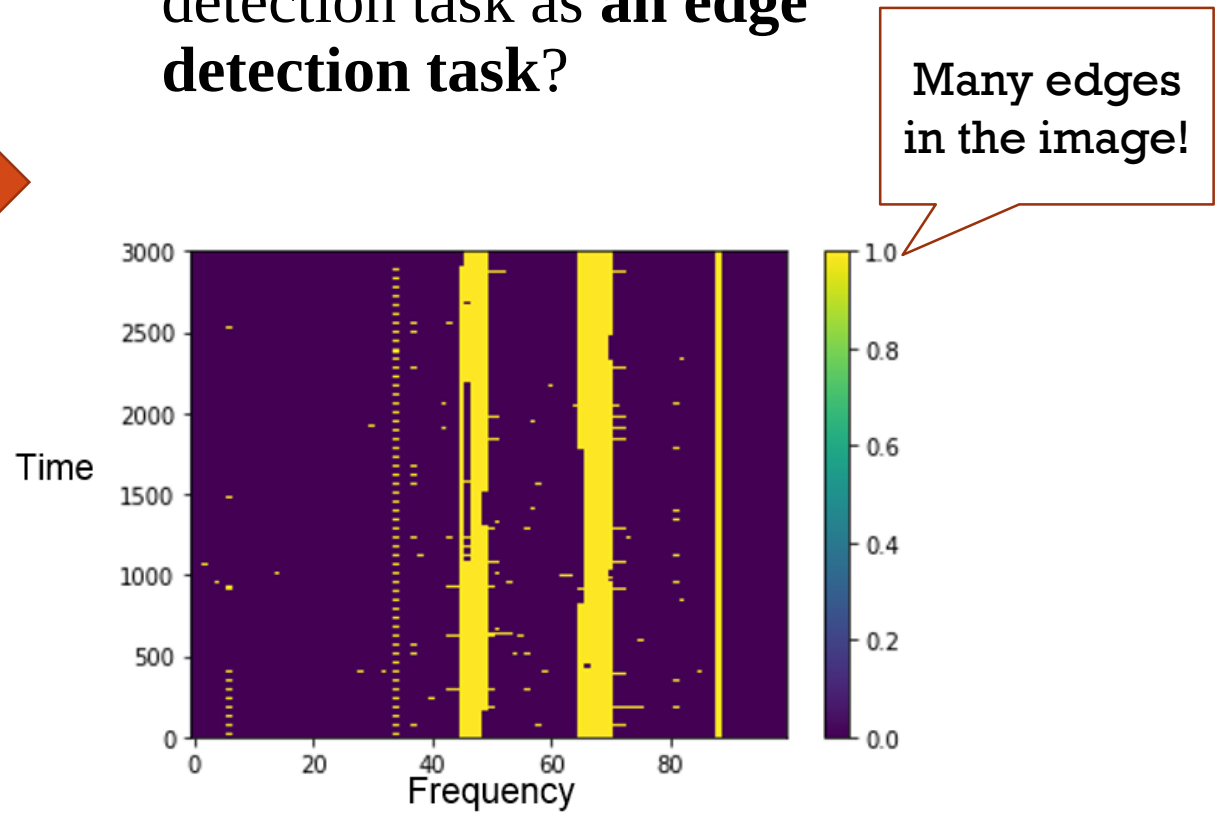
- We trained a UNET on Tianlai data.



UNET

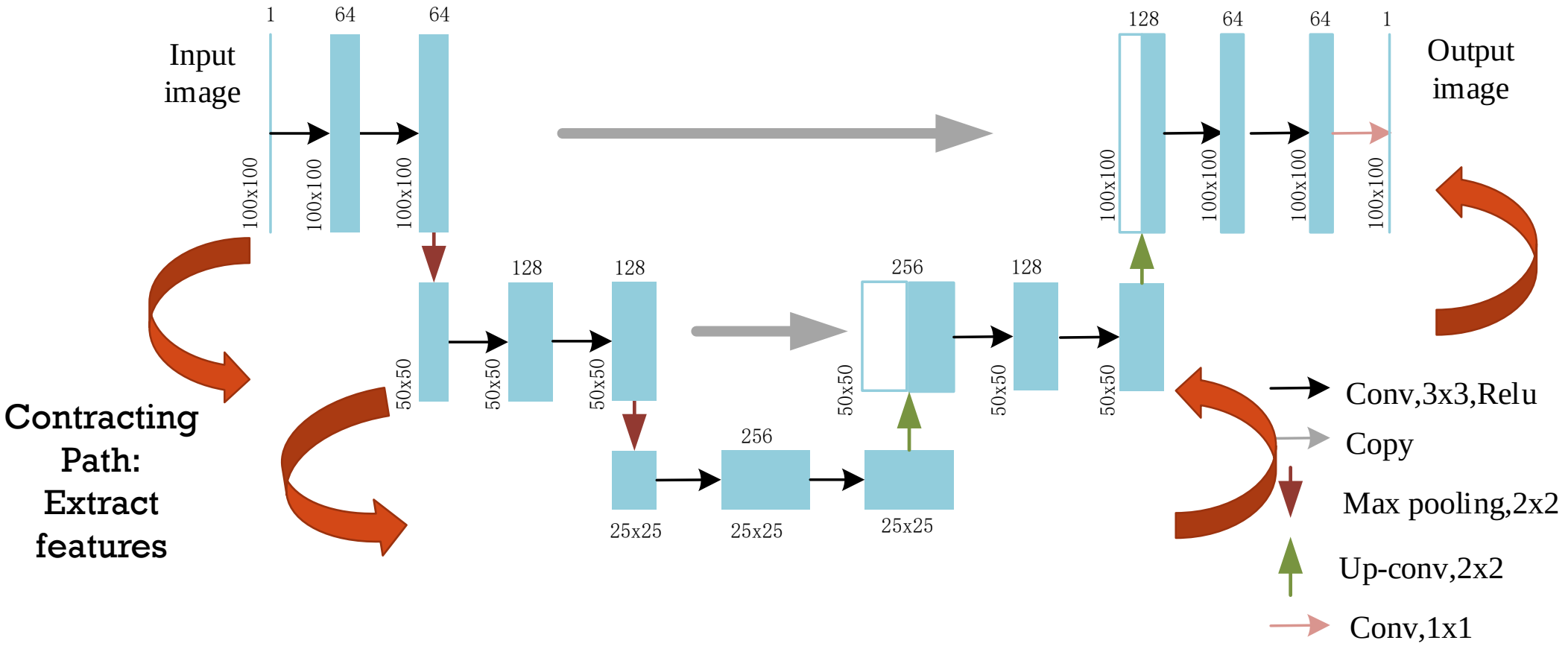
- UNET was firstly originated and proposed for medical image processing.
- A use for edge detection of objects in images.

How about regarding the RFI detection task as **an edge detection task**?



UNET

- A UNET that we designed and achieved .



SOME DETAILS OF UNET

- Loss function: log loss function

$$L(Y, P(Y|X)) = -\log P(Y|X) = -\frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{M} y_{ij}\log(p_{ij})$$

Y is output variable

X is input variable

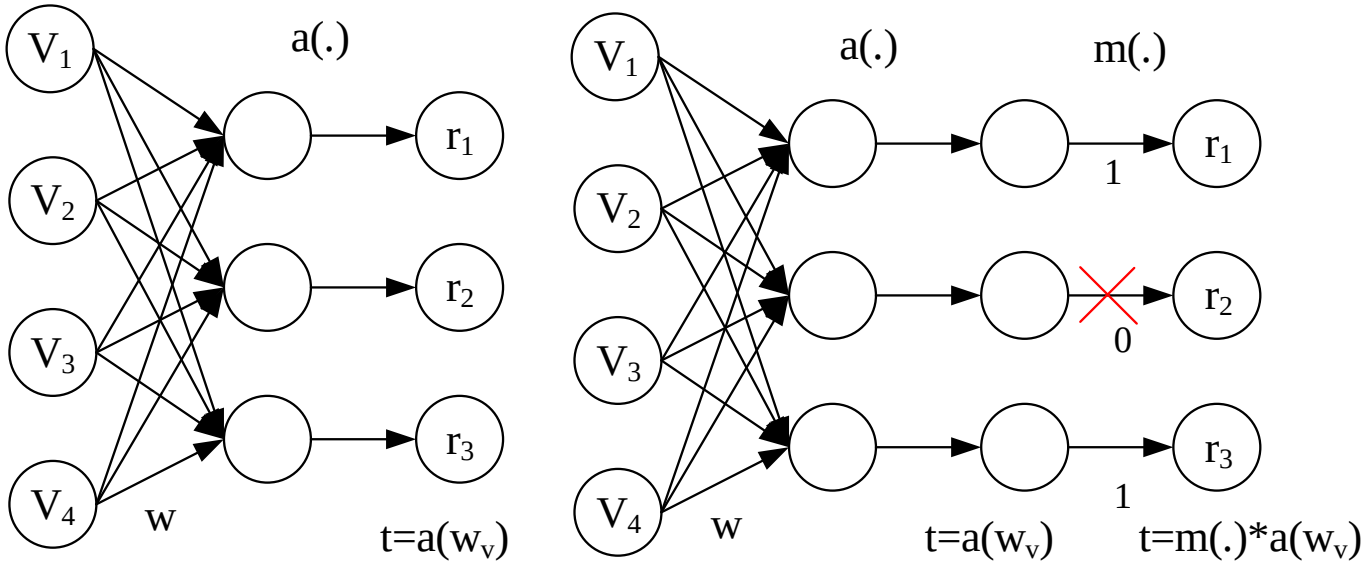
N is the number of input samples

M is the number of classes

p_{ij} is the possibility of xi belonging to class

SOME DETAILS OF UNET

- To prevent over fitting: dropout layer



No-Drop Network

No-Drop Network

- The left figure doesn't contains a dropout layer. The right figure contains the dropout layer after the fully connected layer, which randomly suppress some nodes to stop working by setting their outputs as value 0.
- a(.) is an active function.

ADVANTAGES OF UNET

- It can calculate each pixel's **possibility** of being a RFI signal.

--we set a threshold of 0.5

If the **possibility** value >0.5 true

If the **possibility** value <0.5 false

- It can learn the distribution of RFI better.

--With its improved symmetrical structure, it combines the features of corresponding layers(from shallower to deeper layers) during the up-sampling process.

ADVANTAGES OF UNET

- It can learn more spatial information, the relationship between different baselines.

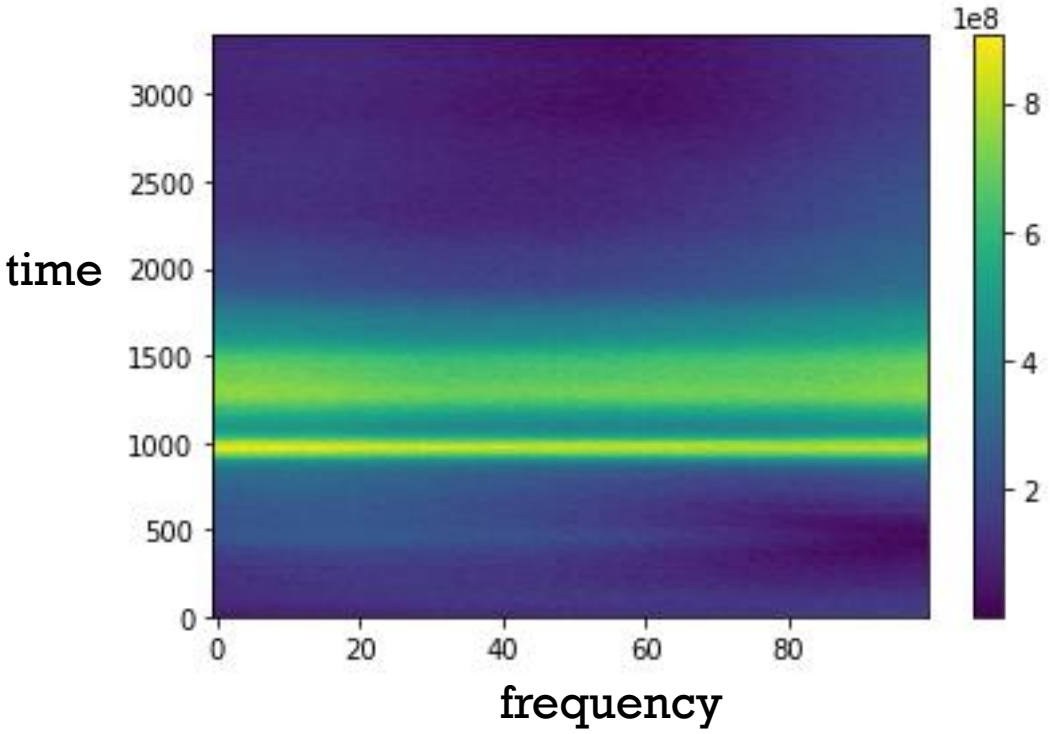
- It can automatically and efficiently detect RFI in massive radio data.

EXPERIMENT

PART Three

DATA I

Tianlai dataI	Time points number	Frequency points number	Baseline number
original	3340	100	18528
After preprocessing	3000	100	18528



Original image

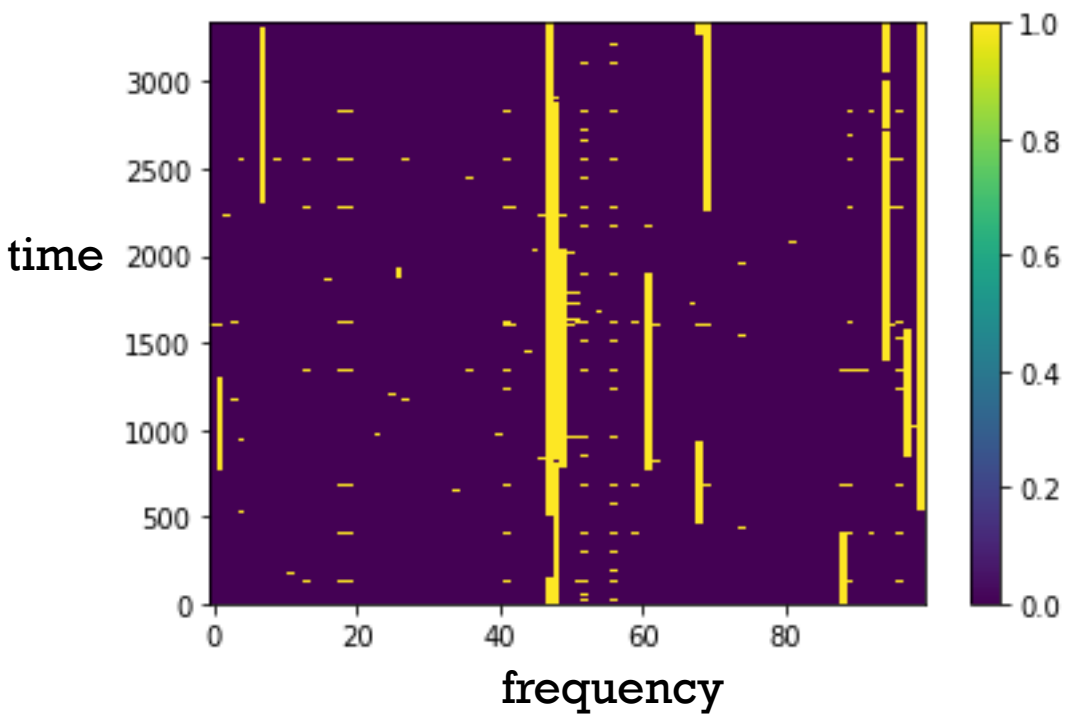
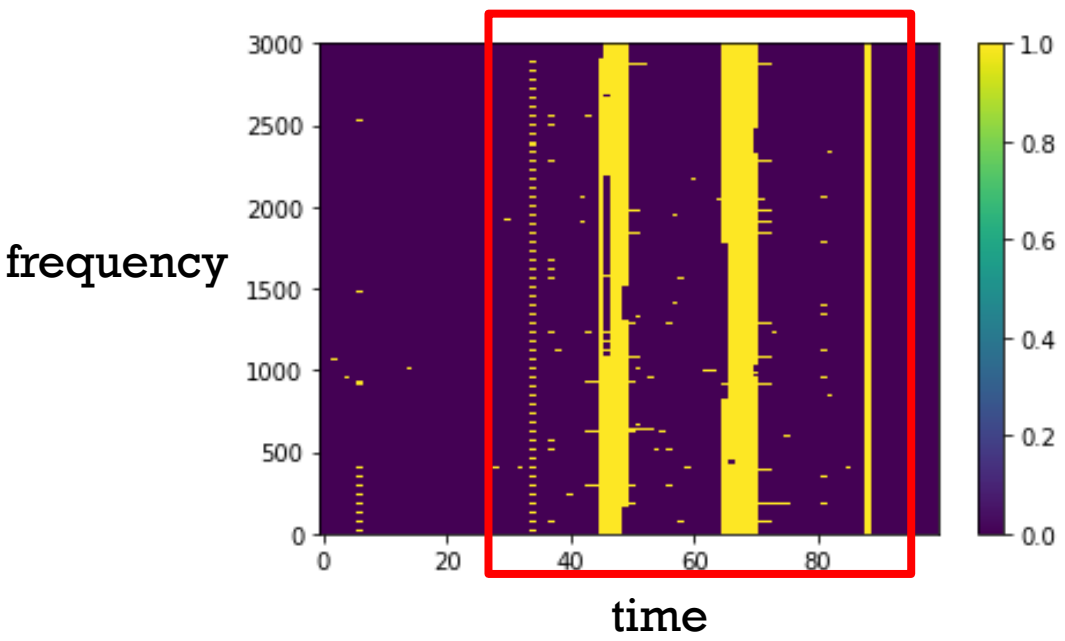


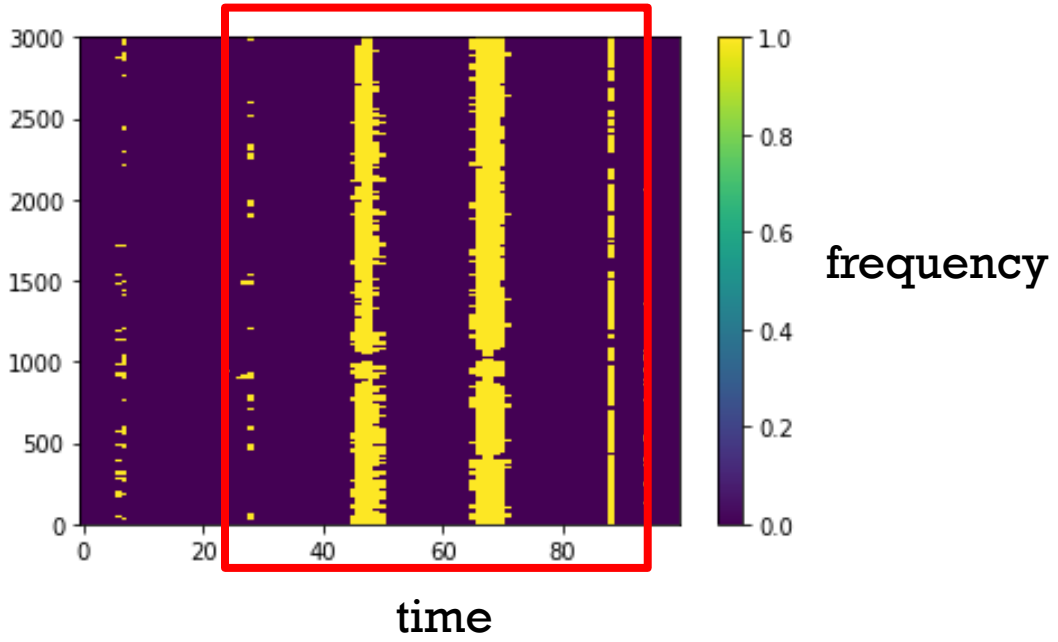
Image with RFI flagged

EXPERIMENT RESULT

For Tianlai data I, 14-layer UNET



Ground truth



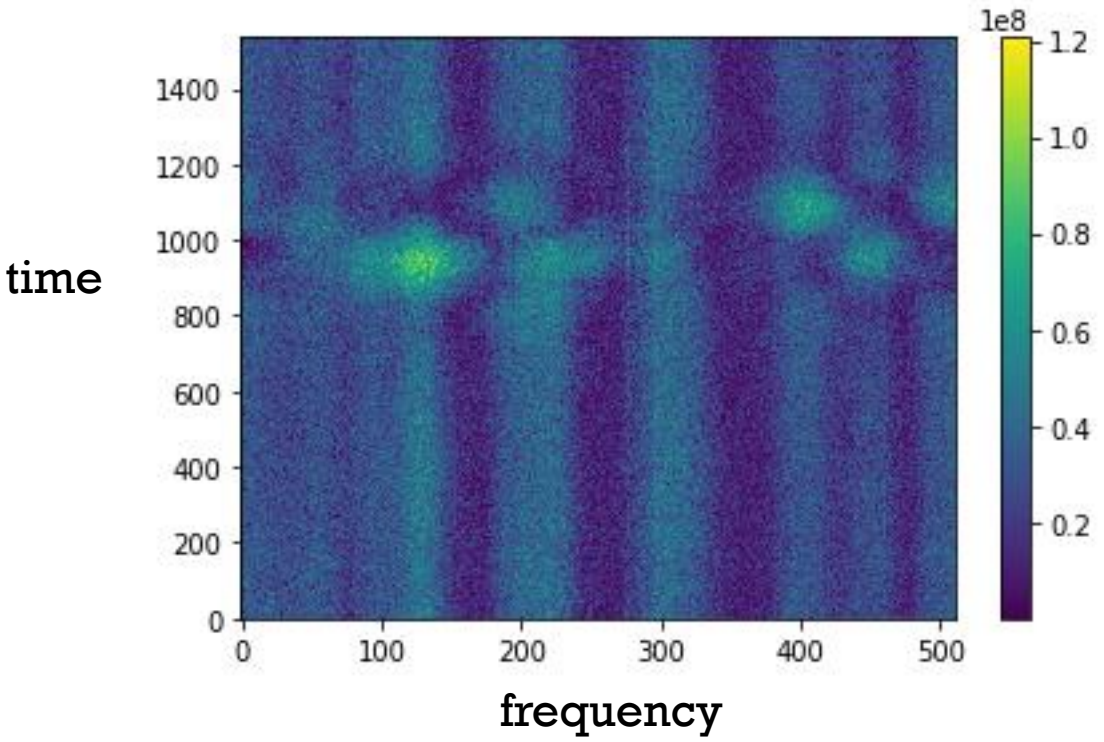
Detecting RFI with 14-layer UNET

Evaluation

Tianlai data I	Precision rate	Recall rate	F-1score
False	0.97	0.98	0.98
True	0.87	0.77	0.83
Avg/Total	0.96	0.96	0.96

DATA II

Tianlai dataII	Time points number	Frequency points number	Baseline number
original	1650	576	18528
After preprocessing	1536	512	18528



Original image

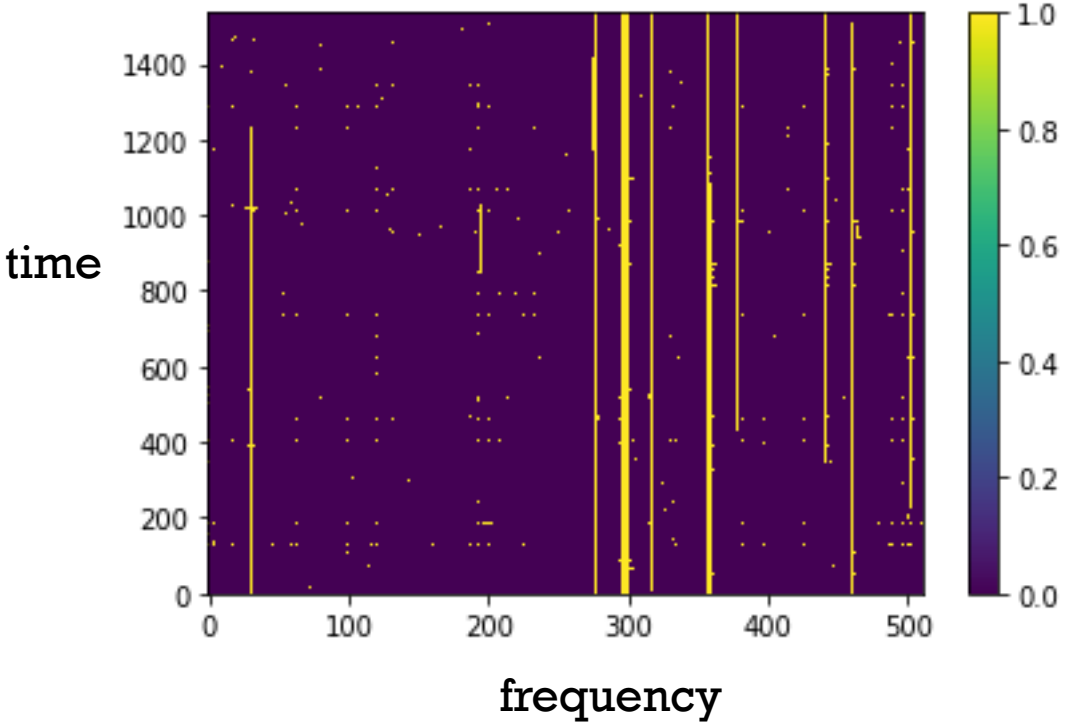
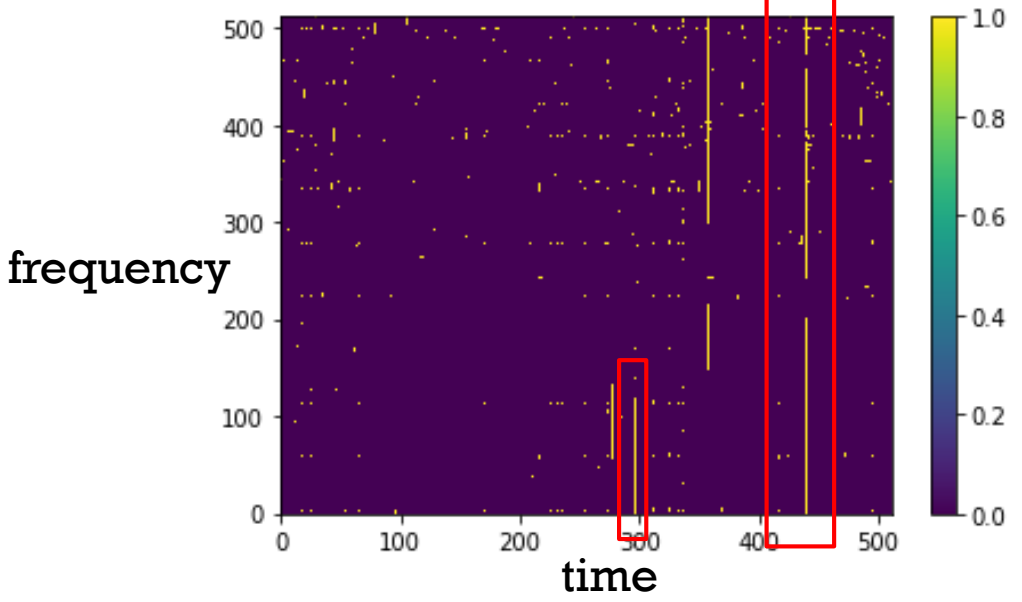


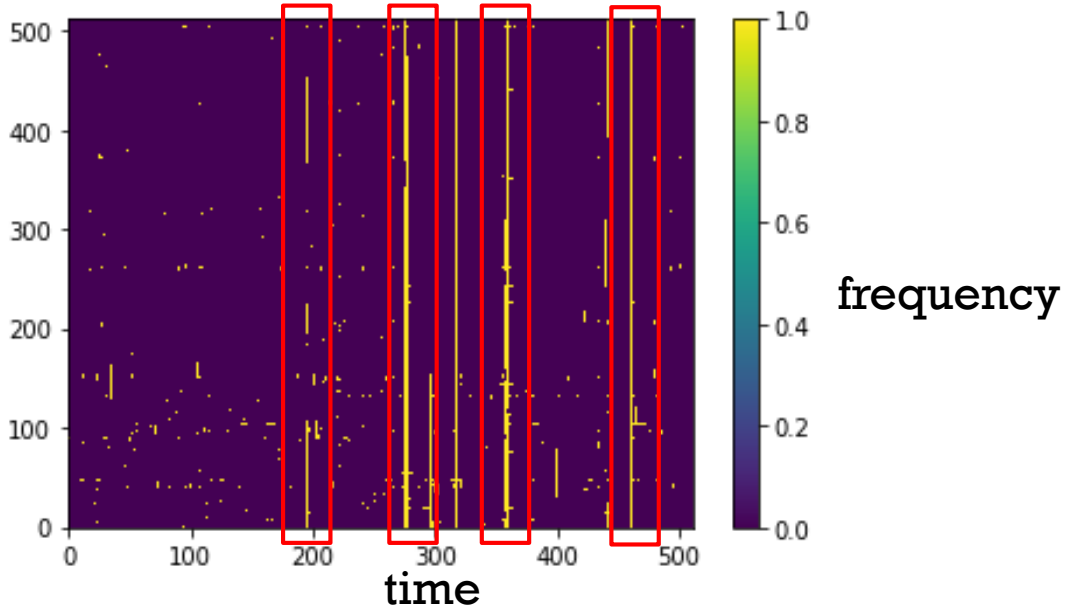
Image with RFI flagged

EXPERIMENT RESULT

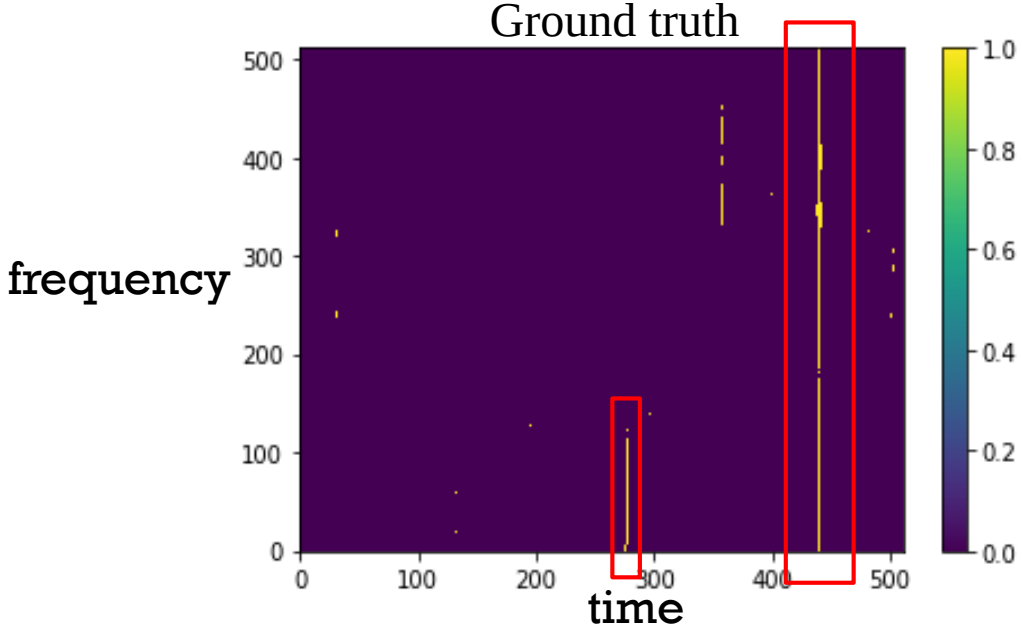
For Tianlai data II, 30-layer UNET



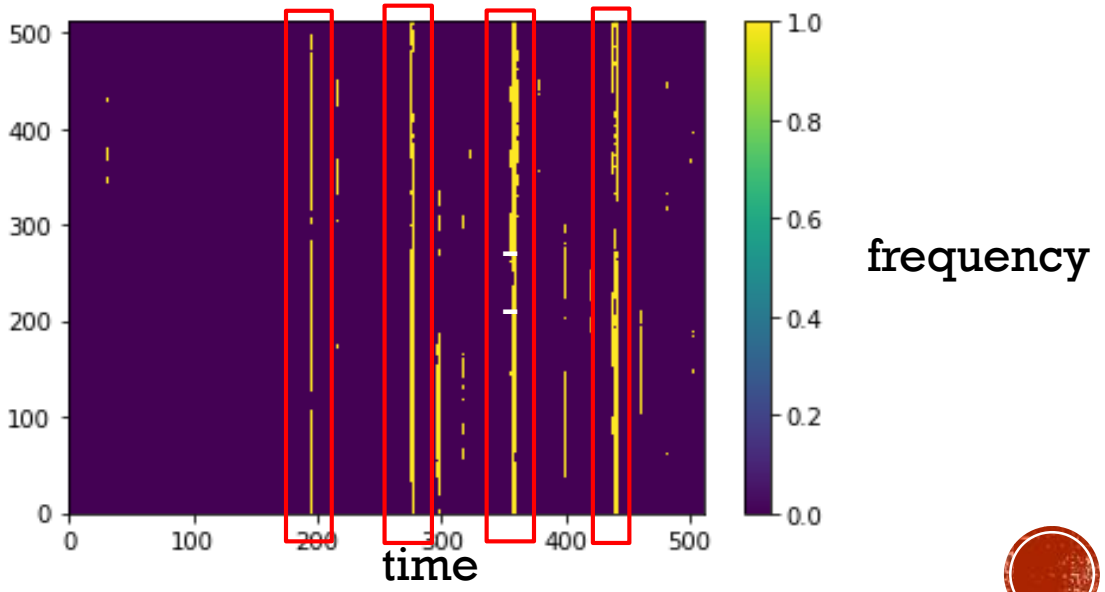
Ground truth



Ground truth



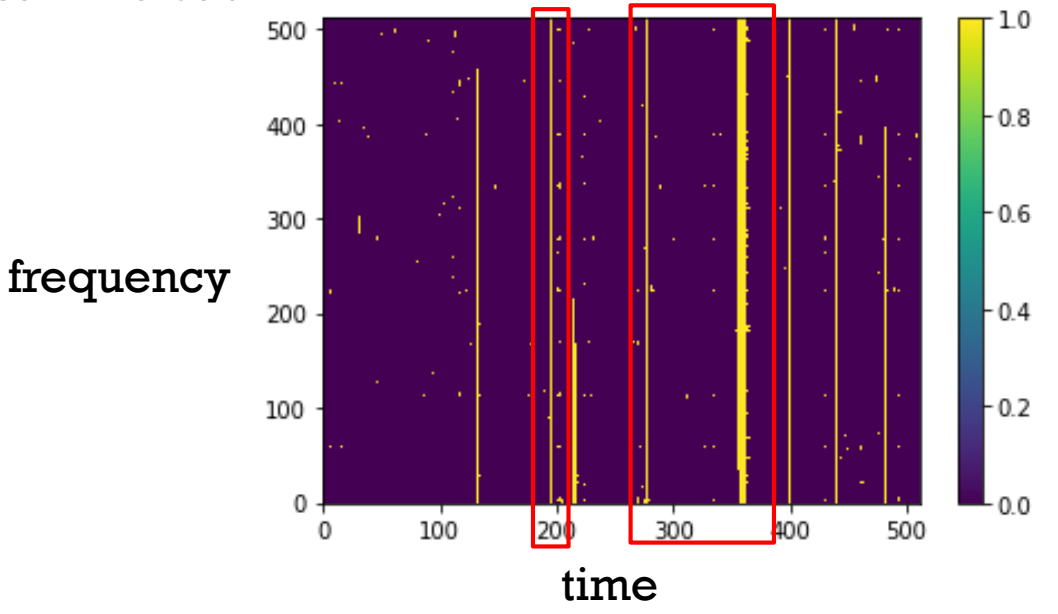
Detecting RFI with 30-layer UNET



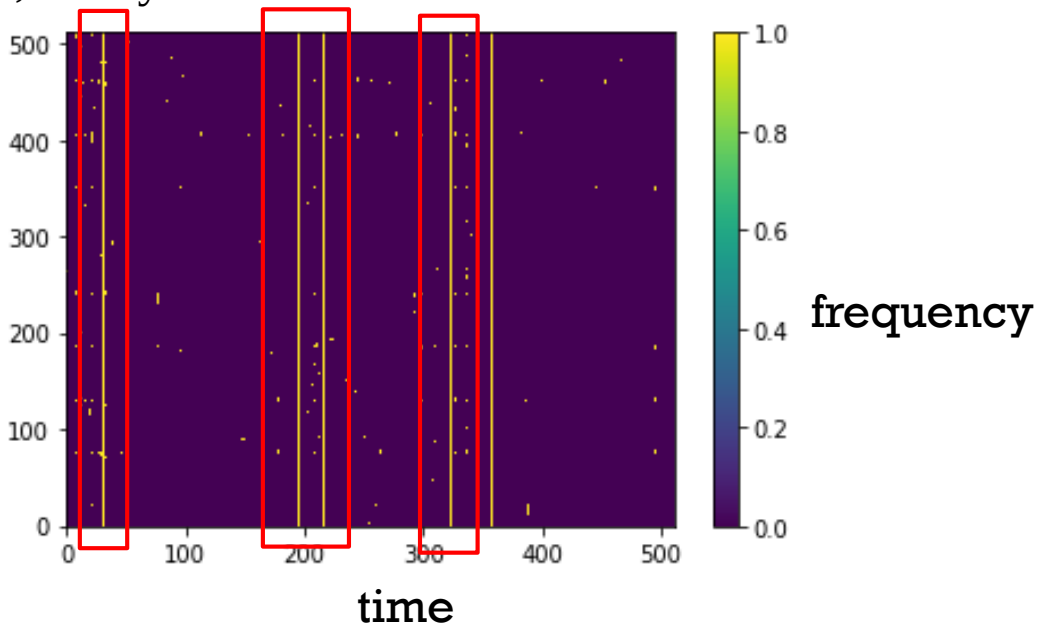
Detecting RFI with 30-layer UNET

EXPERIMENT RESULT

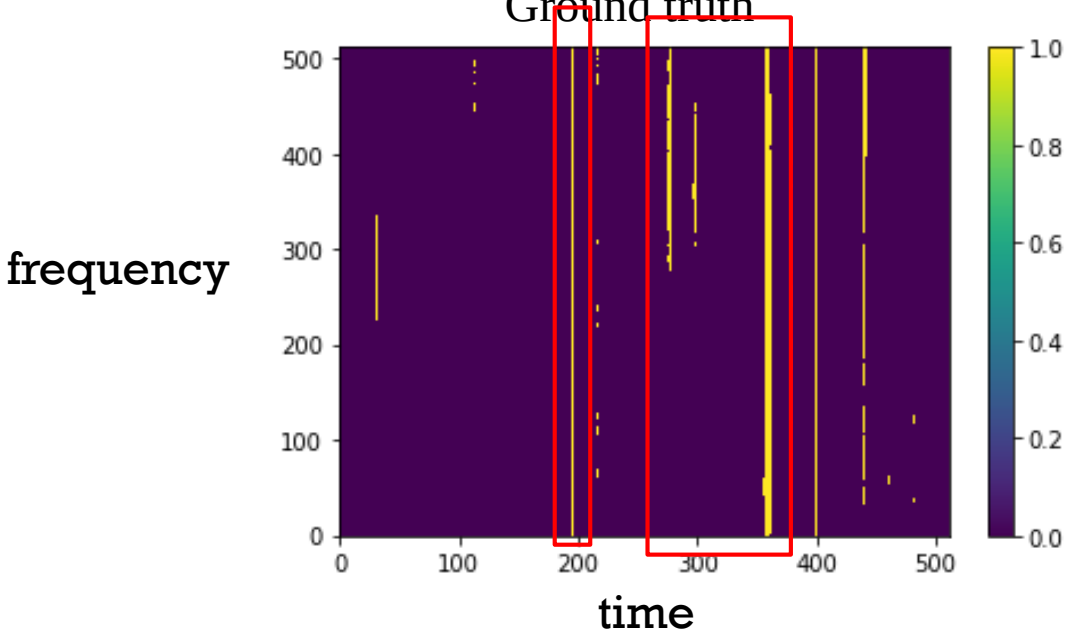
For Tianlai data II, 30-layer UNET



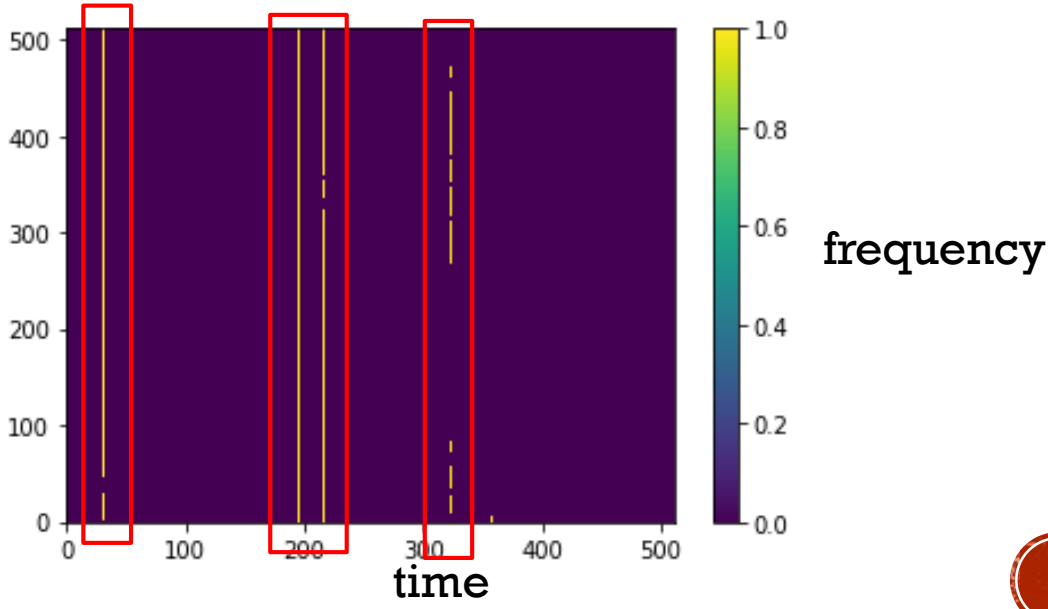
Ground truth



Ground truth



Detecting RFI with 30-layer UNET



Detecting RFI with 30-layer UNET

CONCLUSION

PART Four

CONCLUSION

We used a improved method based on UNET to automatically and efficiently detect RFI in massive radio data.

- First, we preprocess the data to suit the network,
- Secondly, We train the improved with Adam(Adaptive Moment Estimation) to optimize the loss function on GTX1080ti.
- Finally, we detect RFI signals with the trained U-Net and obtain results with RFI flagging. We firstly use the U-Net on “Tianlai” data and obtain satisfying results.

ACKNOWLEDGEMENTS

- Thanks to gravitational wave interdisciplinary project of Beijing Normal University
- Thanks to College of Information Science and Technology of Beijing Normal University
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THANKS FOR LISTENING

Q&A