Data denoise and application in event classification & Trigger parameters Optimization

International Scientific Event “GRAND” Collaboration Meeting, 2025, Warsaw Poland

Pengfei Zhang(XD)； Hanrui(XD). **2025.06.4**

（Xidian University， zhangpf@mail.xidian.edu.cn)

Contents

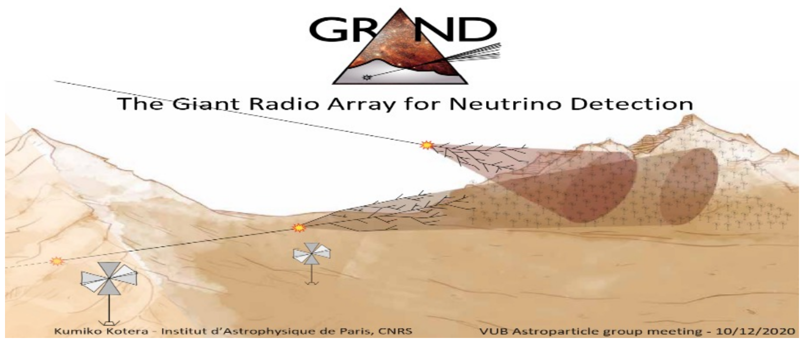
Not only for fun but also for application

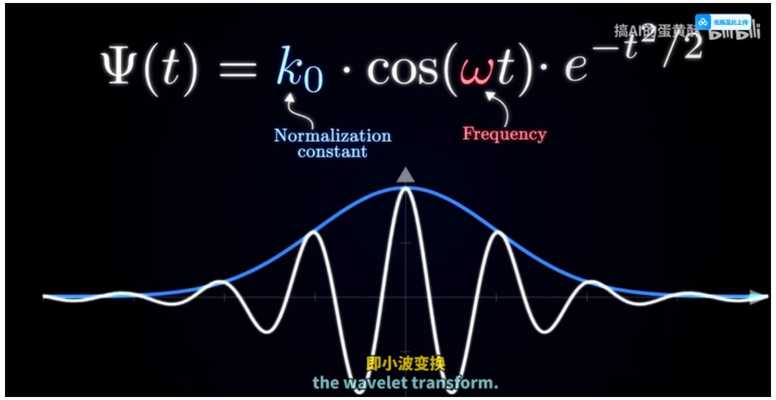
（1） Wavelet and Correlation based data preprocess.

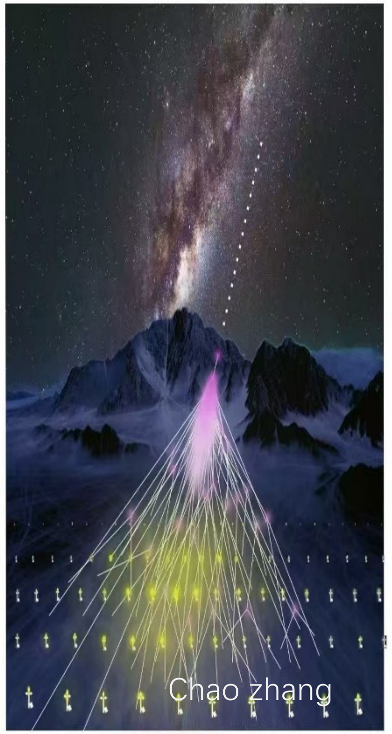
（2） Classification of event.

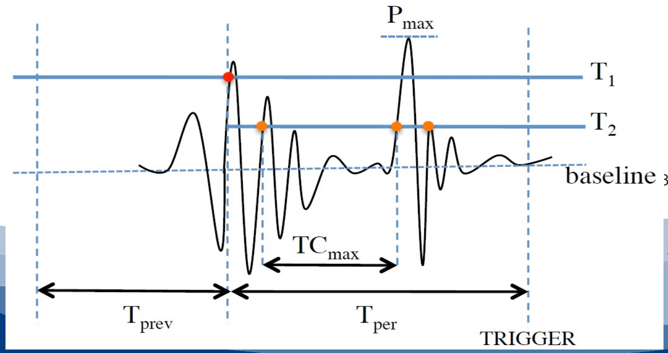
（3） Tigger algorithm.

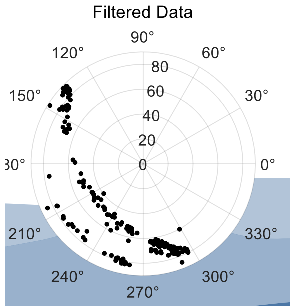
（4） Parameter's optimization

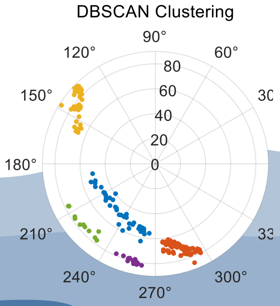




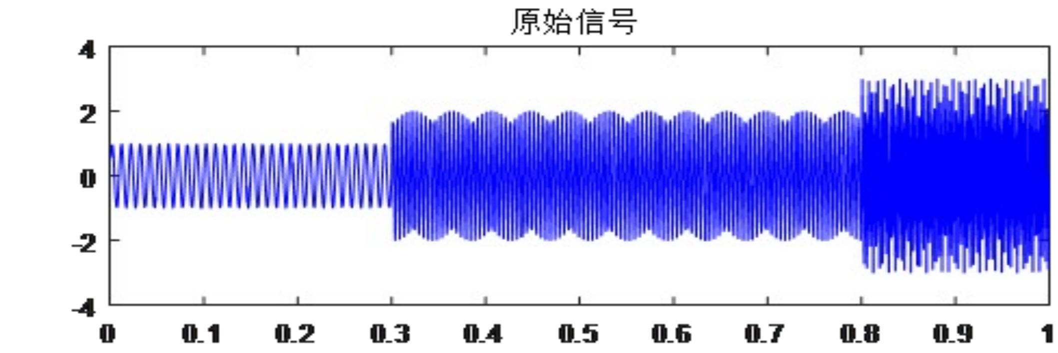


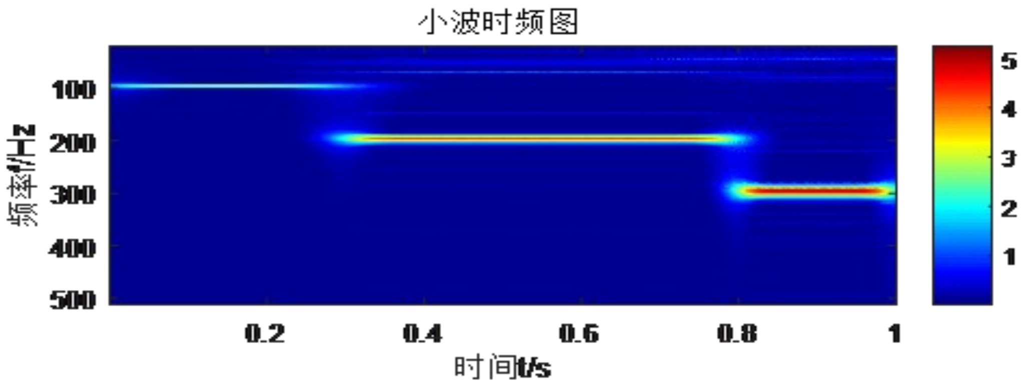


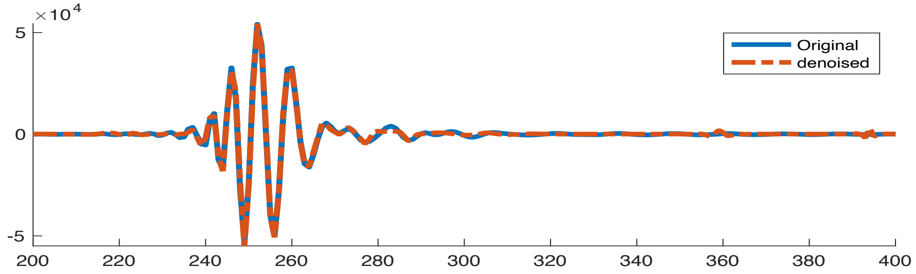


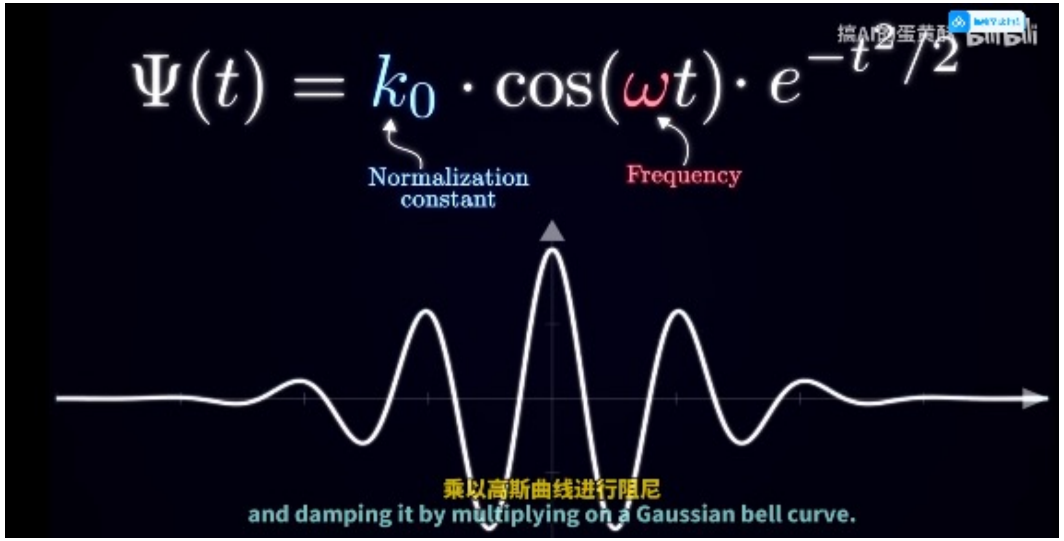


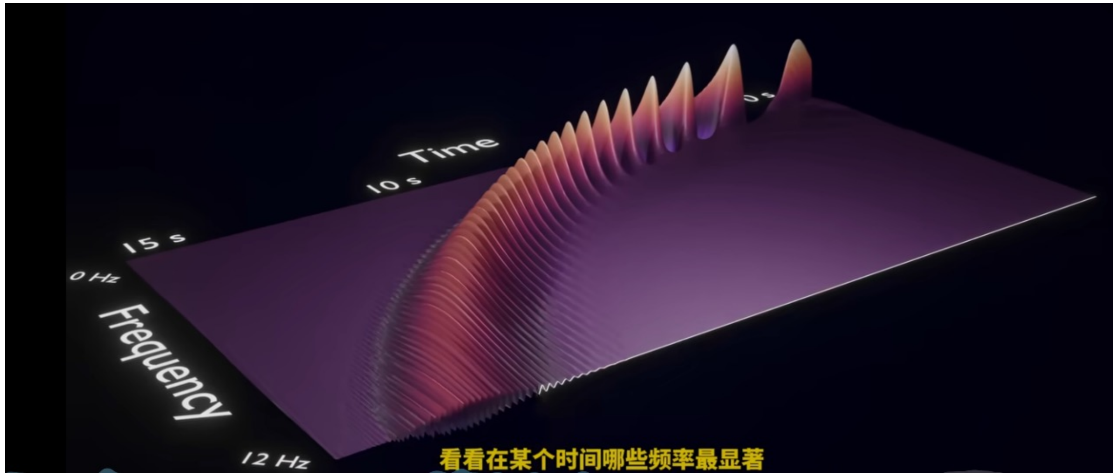
Wavelet


原始信号
4
2
0
-2
-4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

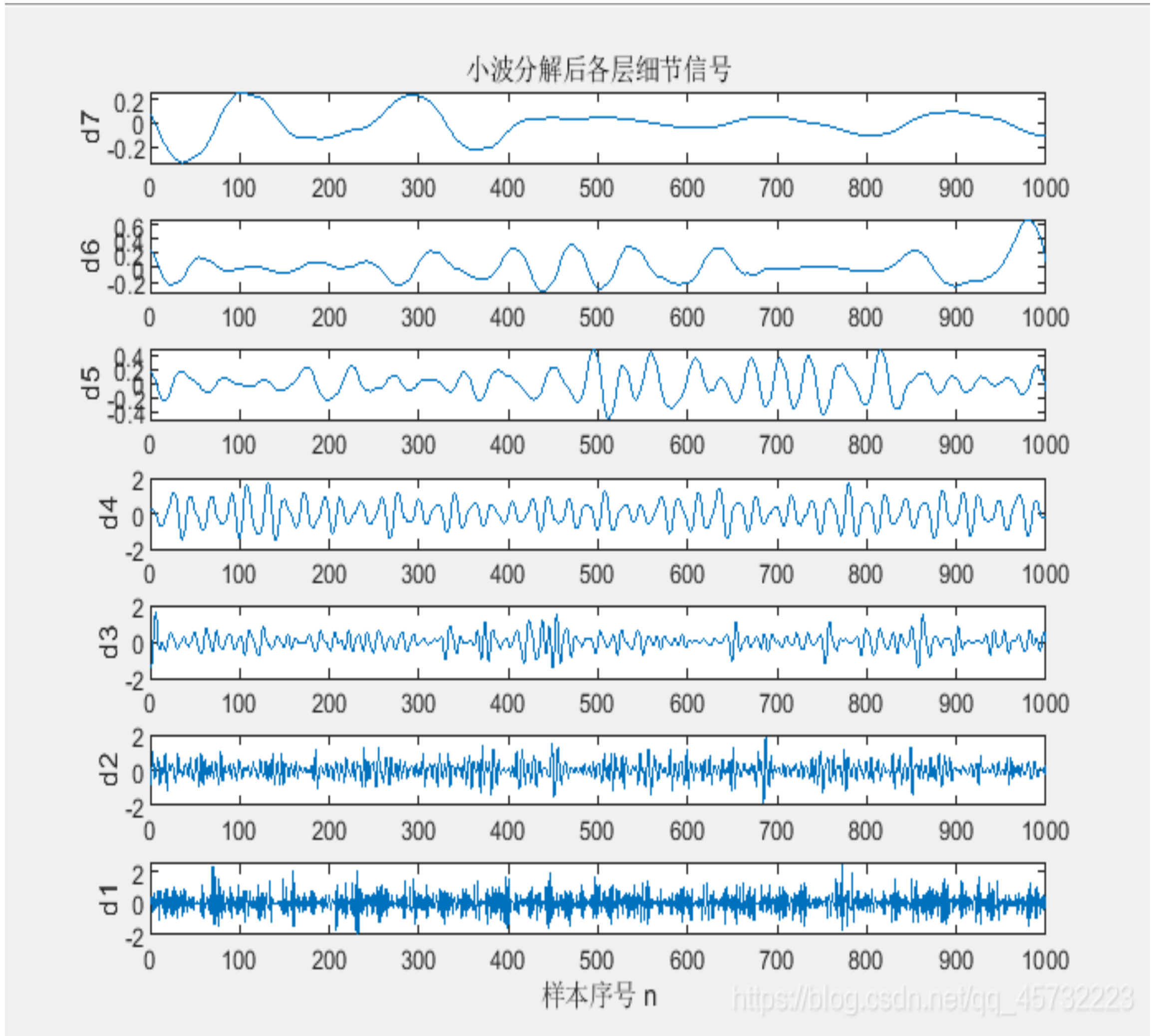

小波时频图
频率f/Hz
100
200
300
400
500
0.2
0.4
0.6
0.8
1
时间t/s
5
4
3
2
1


×10^4
5
0
-5
200
220
240
260
280
300
320
340
360
380
400
Original
denoised

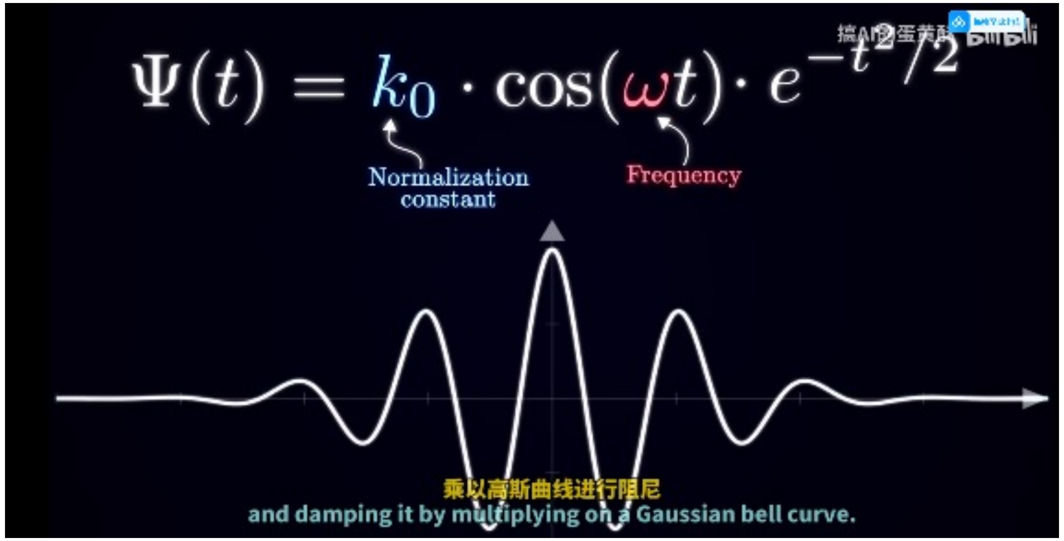

$\Psi(t) = k_0 \cdot \cos(\omega t) \cdot e^{-t^2/2}$
Normalization constant
Frequency
乘以高斯曲线进行阻尼
and damping it by multiplying on a Gaussian bell curve.


Time
10 s
15 s
0 Hz
Frequency
12 Hz
看看在某个时间哪些频率最显著

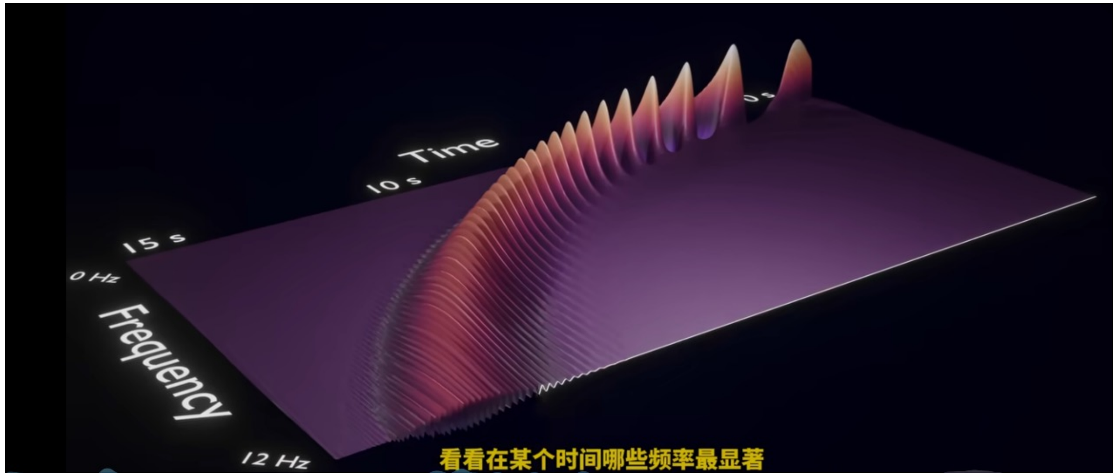
Wavelet



小波分解后各层细节信号
d7
d6
d5
d4
d3
d2
d1
0 100 200 300 400 500 600 700 800 900 1000
样本序号 n
https://blog.csdn.net/qq_45732223



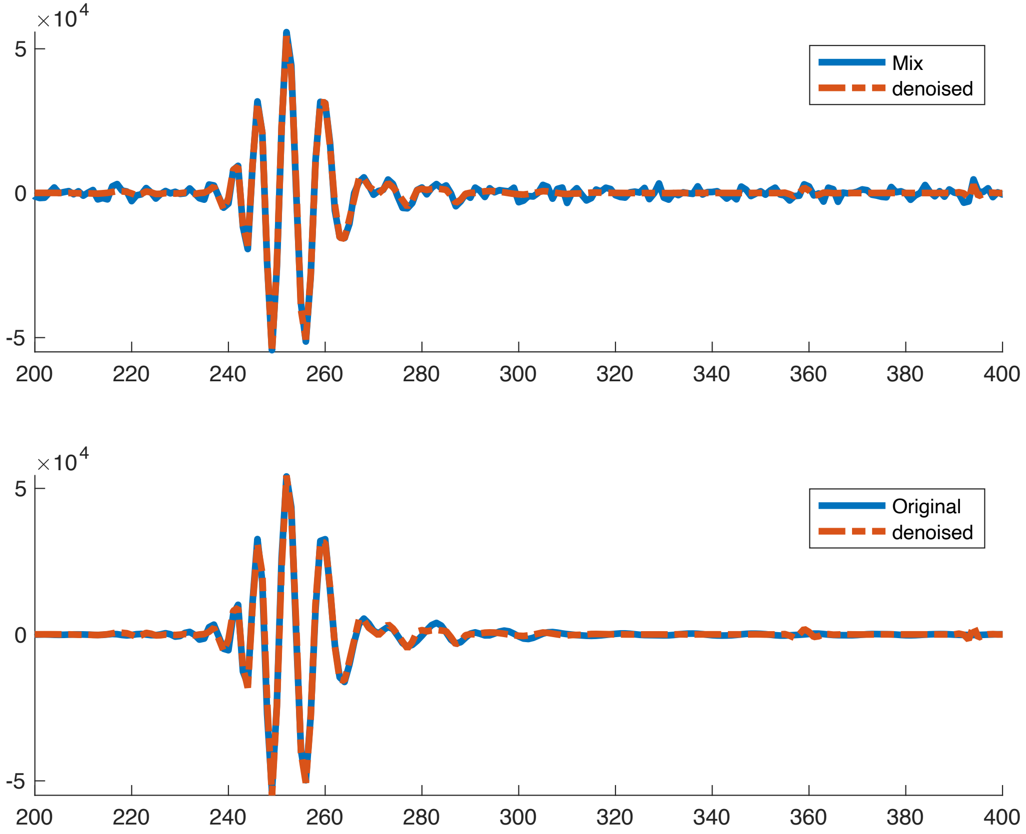
$\Psi(t) = k_0 \cdot \cos(\omega t) \cdot e^{-t^2/2}$
Normalization constant
Frequency
乘以高斯曲线进行阻尼
and damping it by multiplying on a Gaussian bell curve.



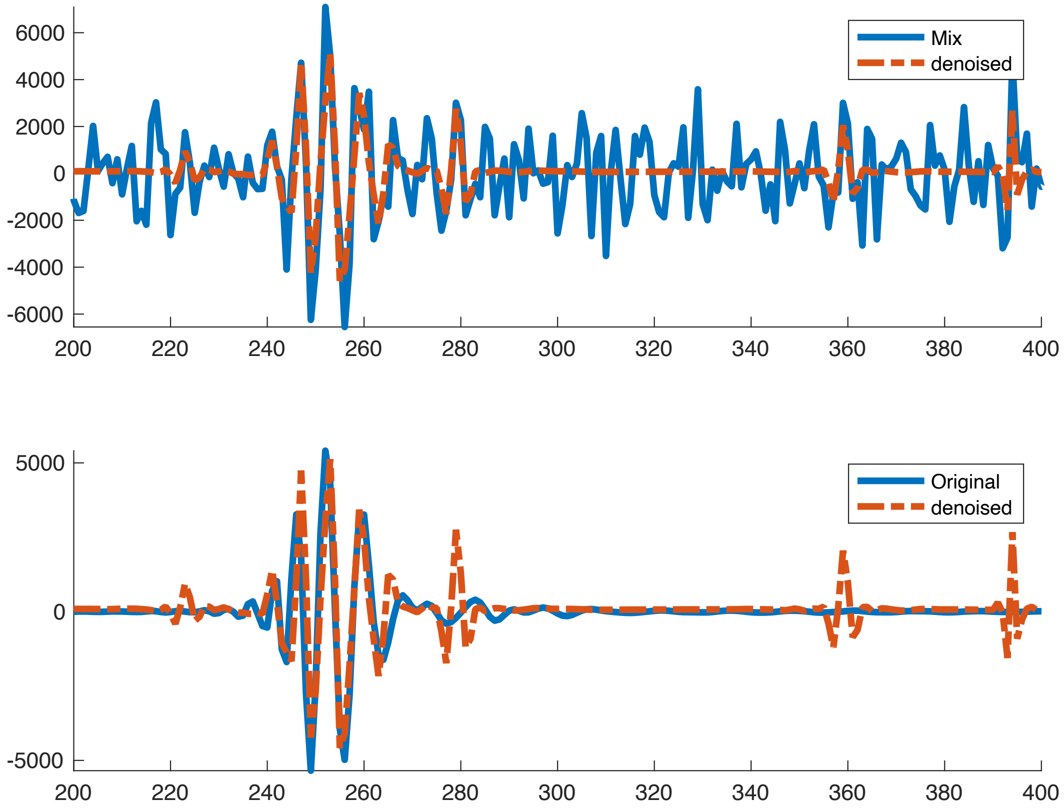
Time
10 s
15 s
0 Hz
Frequency
12 Hz
看看在某个时间哪些频率最显著

Wavelet based denoise:

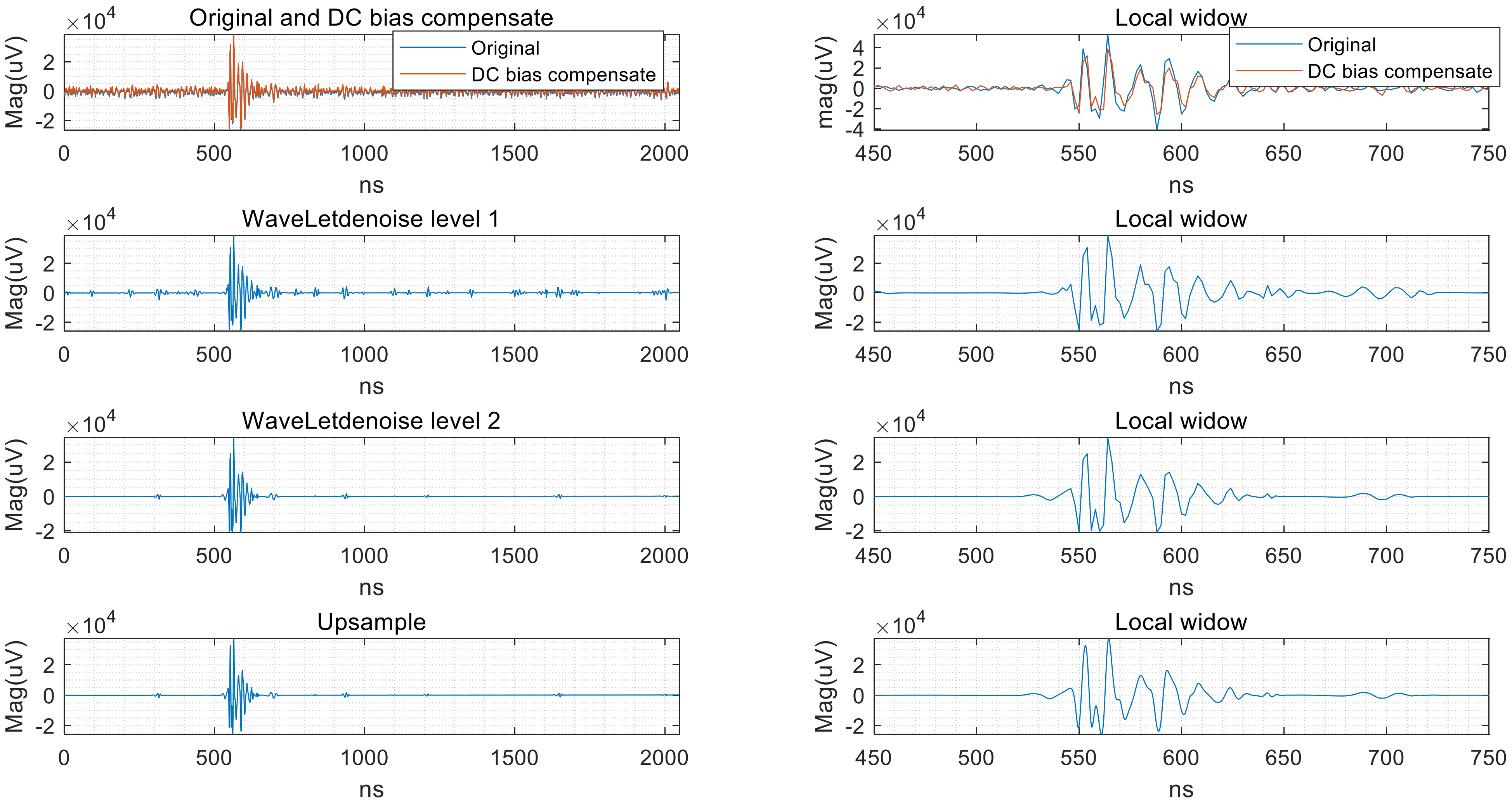
High SNR



Low SNR

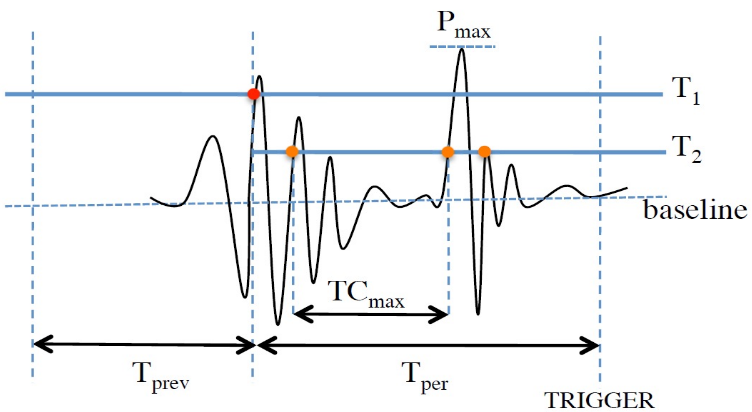


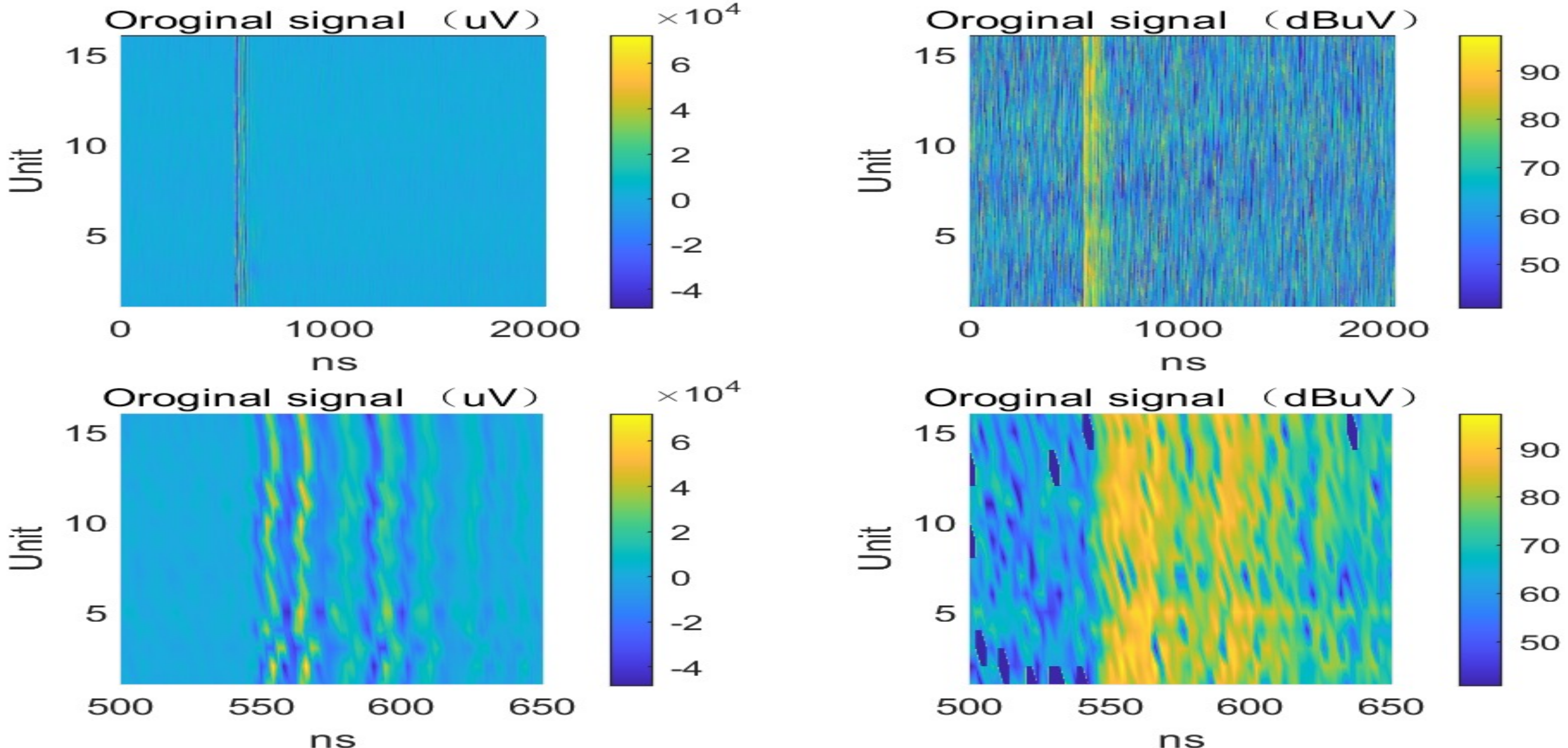
Wavelet based denoise:



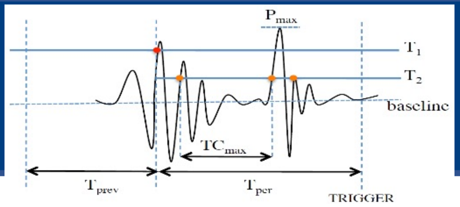
Do we need to transform 1024bit data？ Can we run this in FPGA

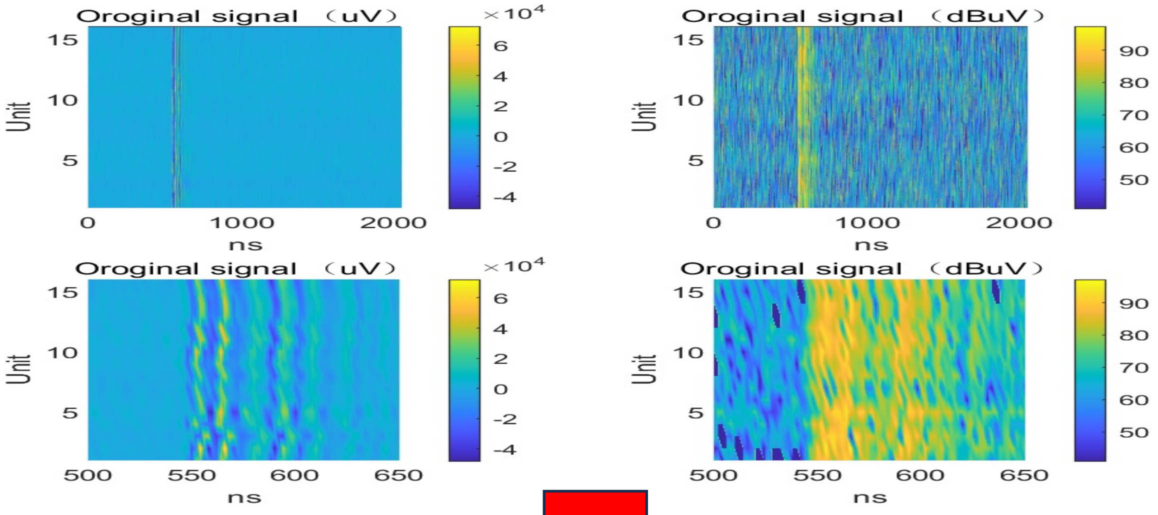
Up sample based correlations and T1 trigger time calibration:

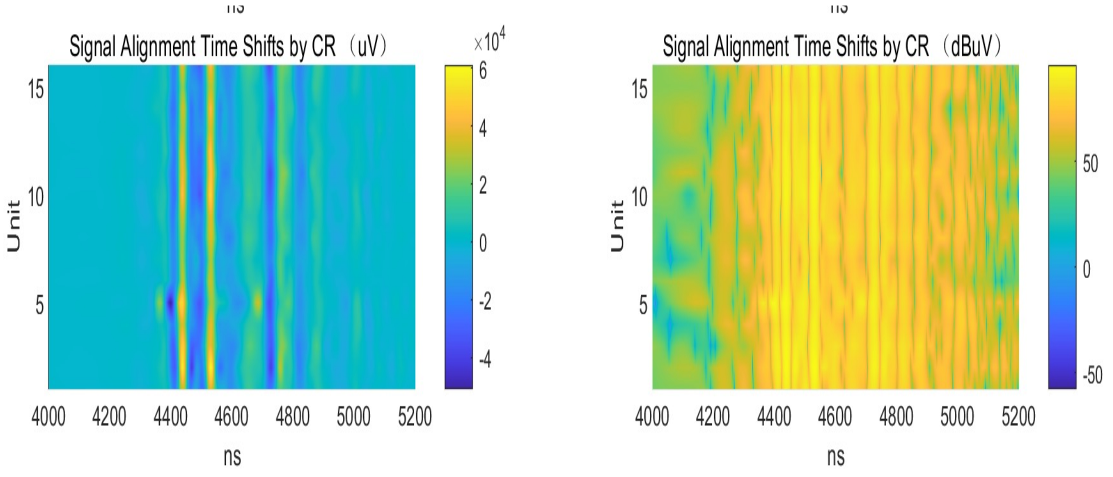


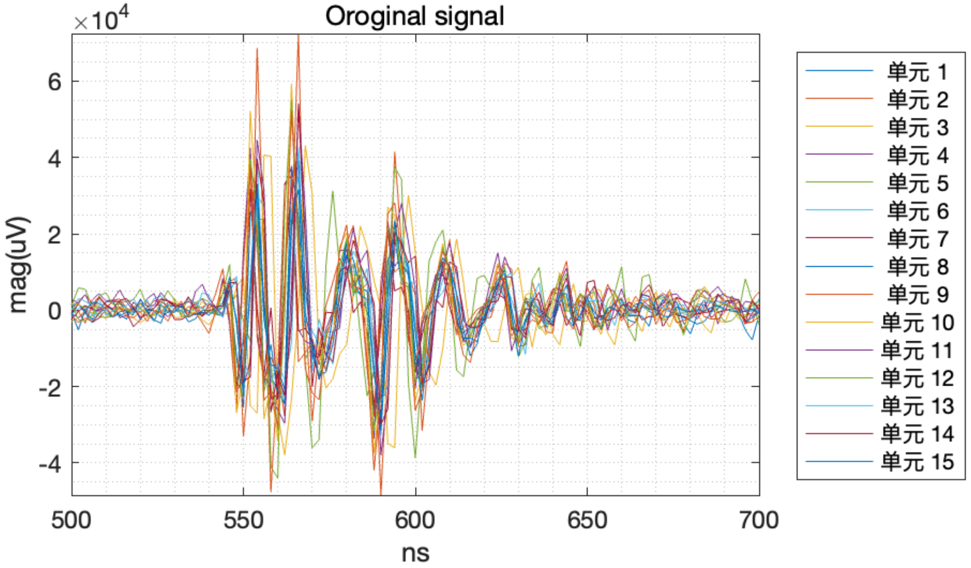


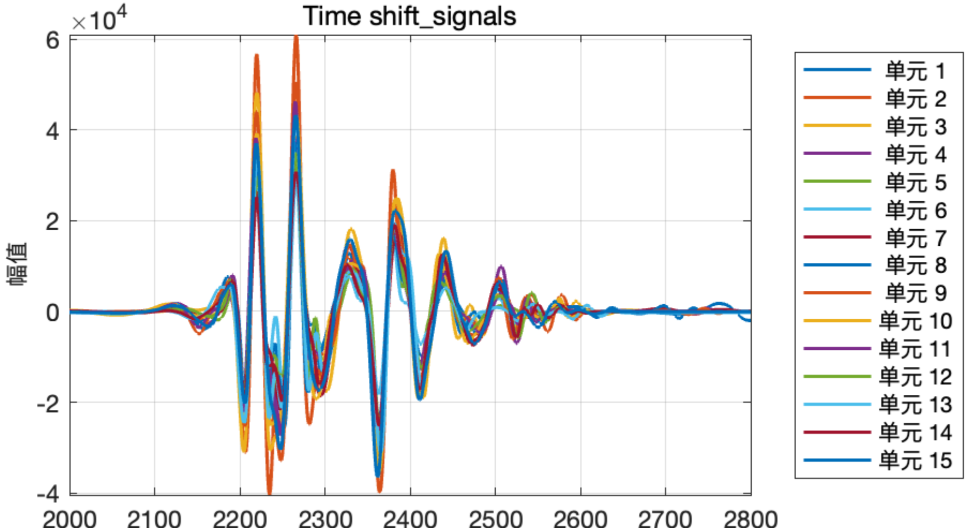
Up sample based correlations and T1 trigger time calibration：



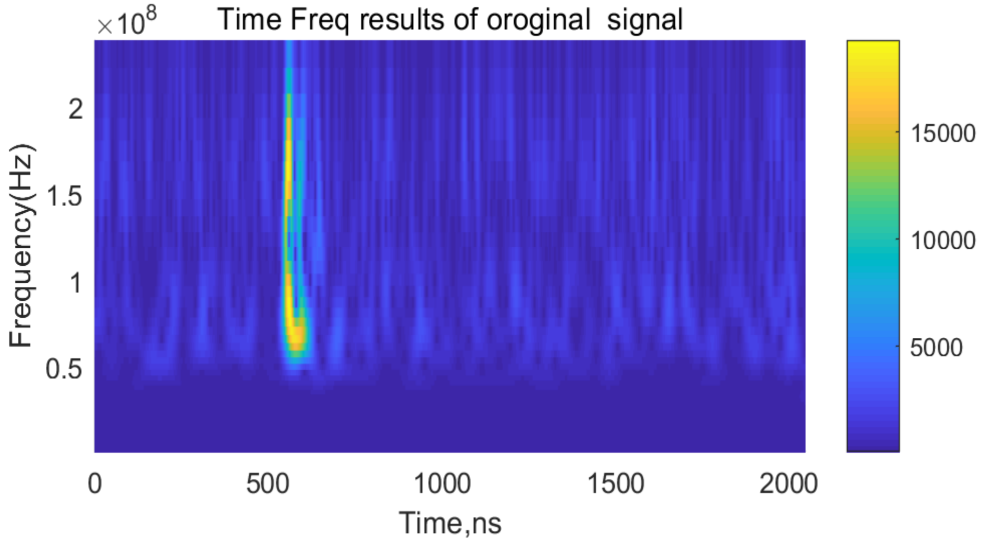


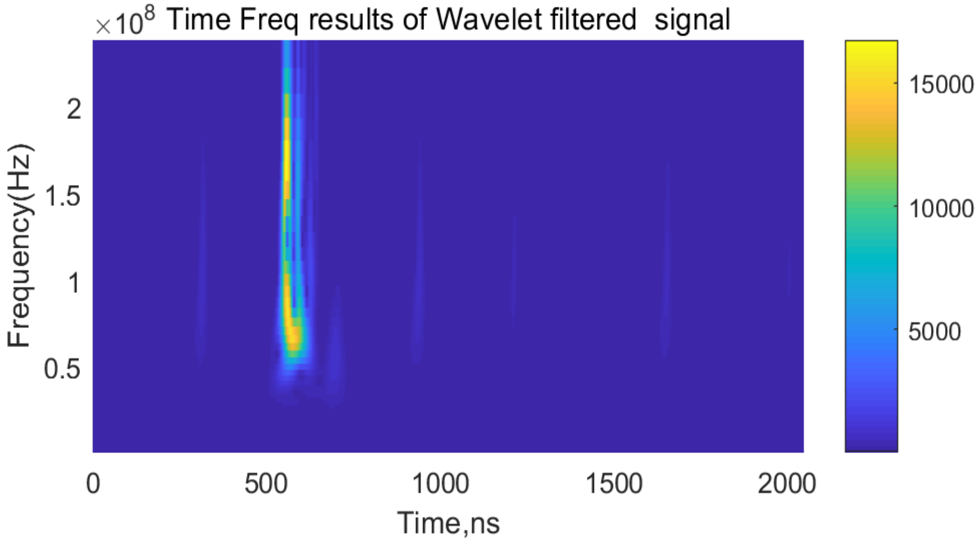


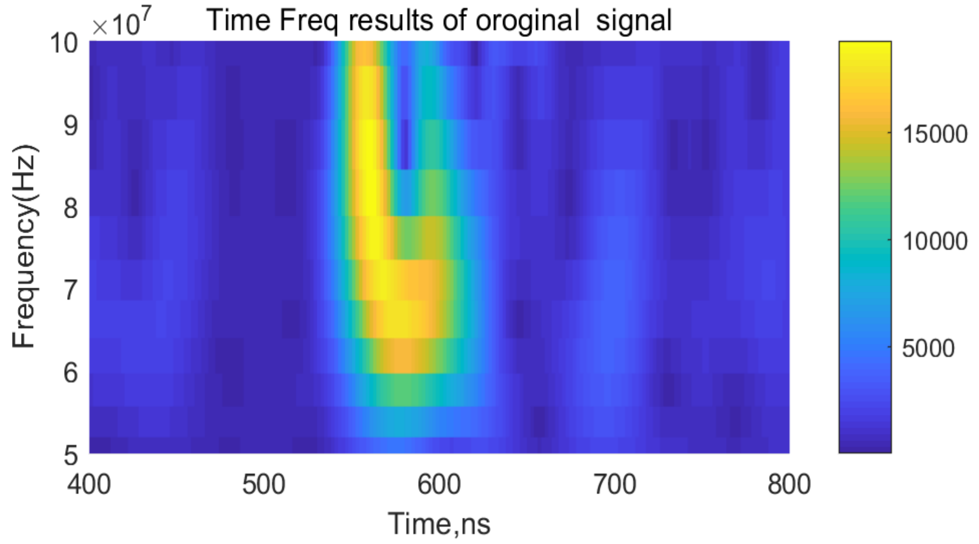


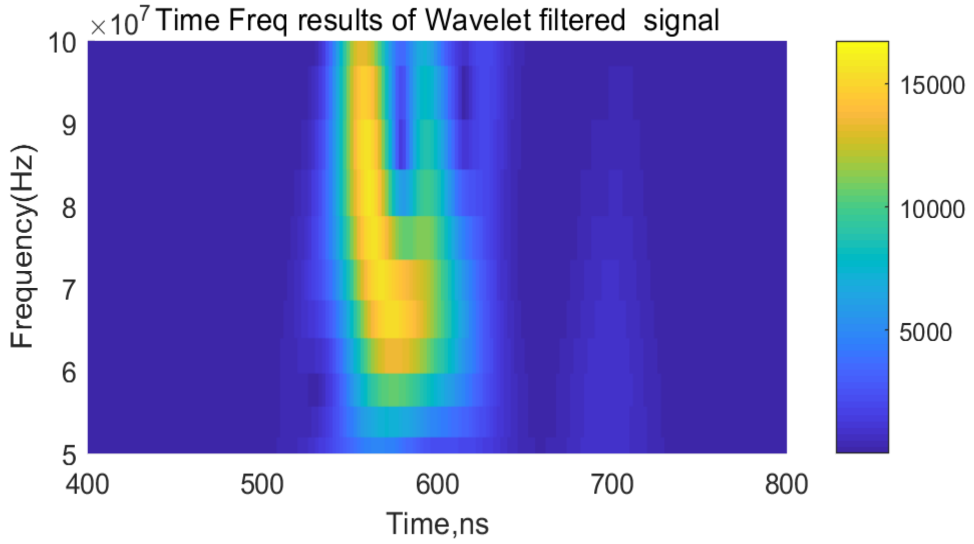


Time and frequency co-analyze from wavelet：

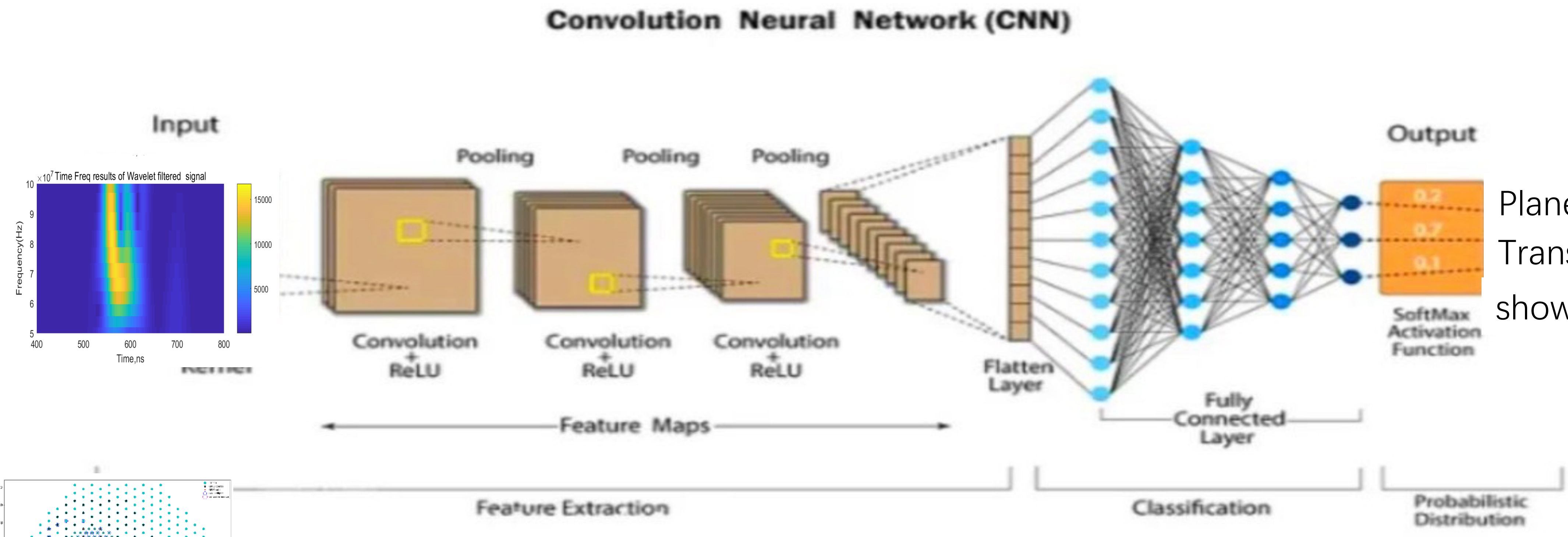








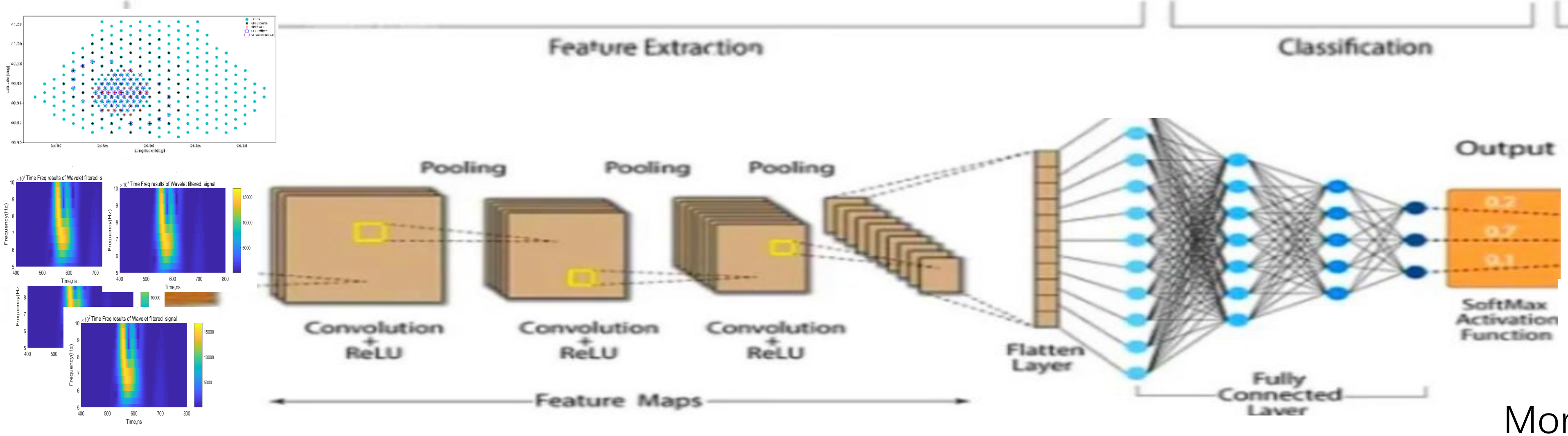
CNN based data process:



Plane

Transformer

shower



Core

Xmax/direction

Energy

More information!

Contents

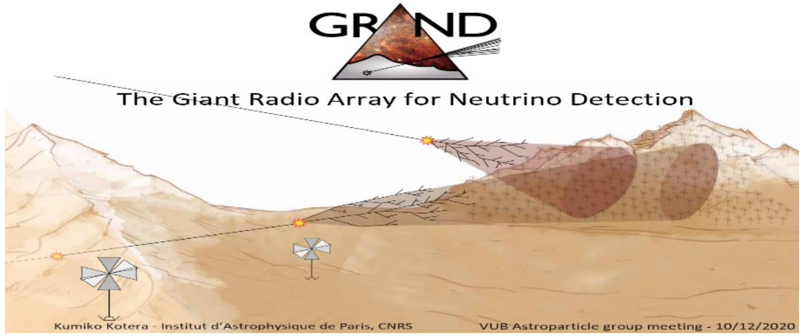
Not only for fun but also for application

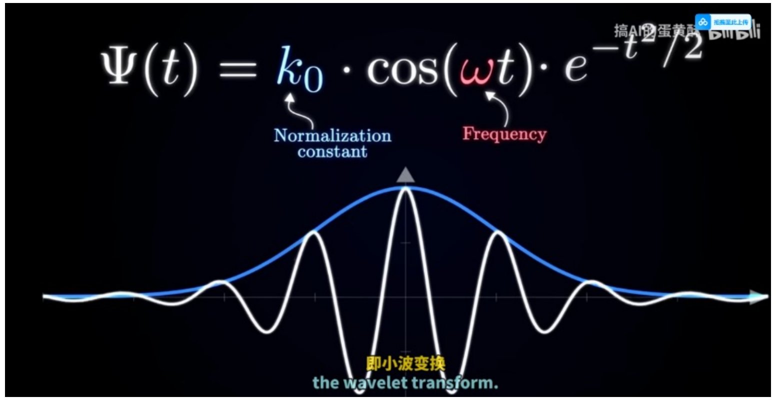
(1) Wavelet and correlation based data preprocess.

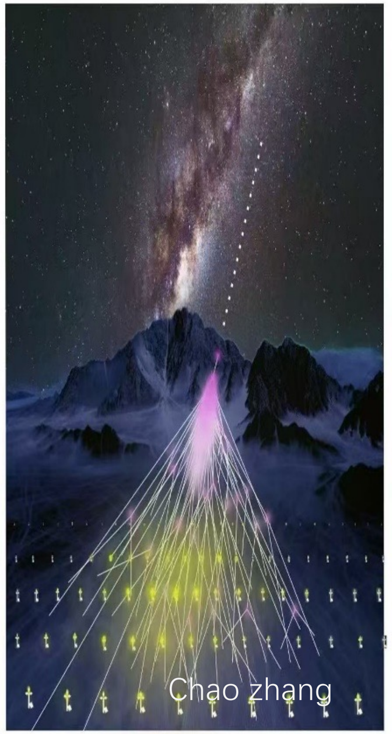
(2) Classification of event.

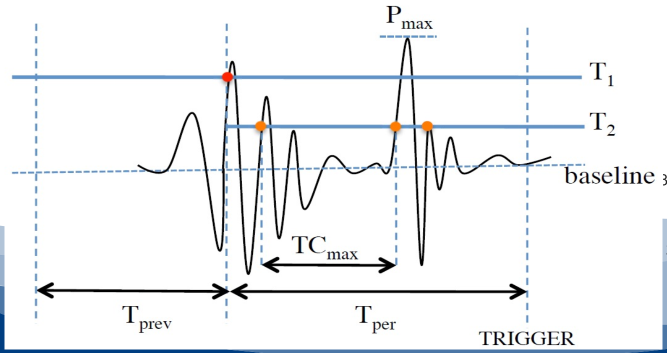
(3) Tigger algorithm.

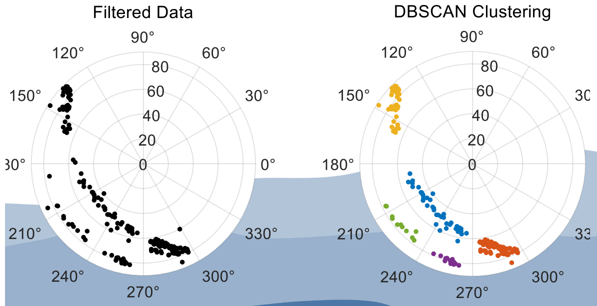
(4) Parameter's optimization



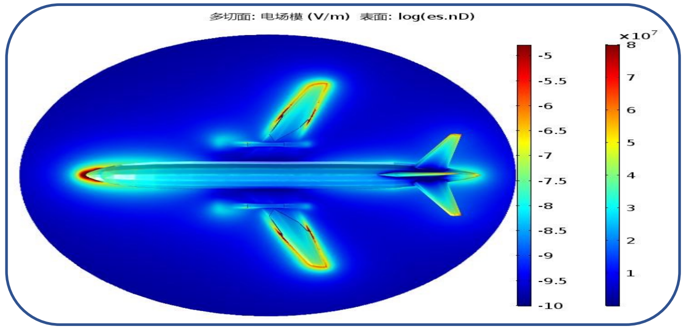


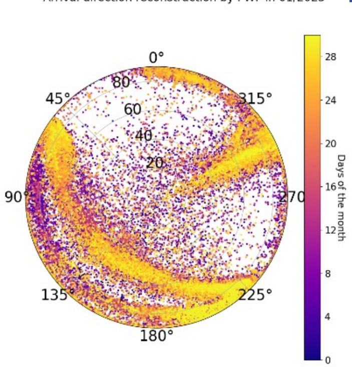


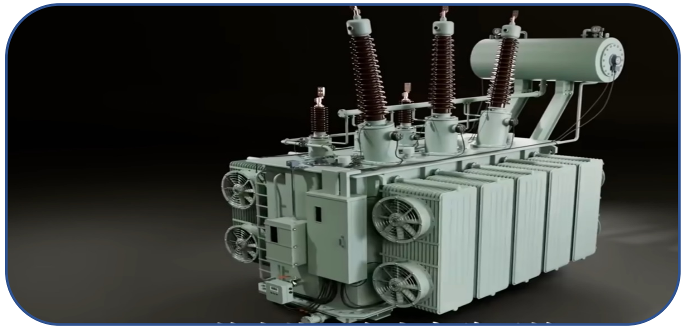


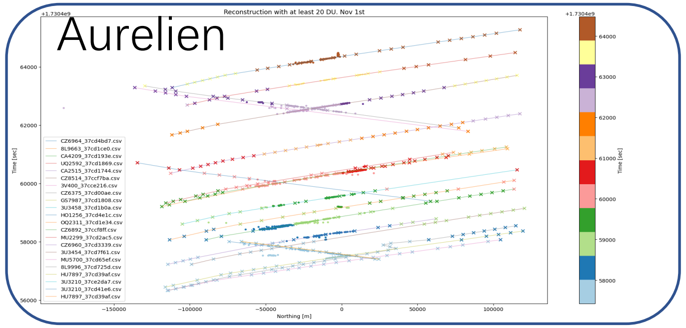


Interfere sources around us： electrostatic of plane and pulse from HPAC Transformer









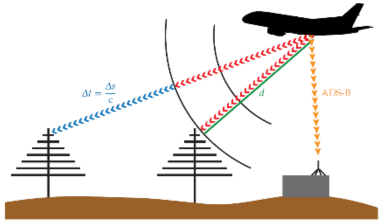
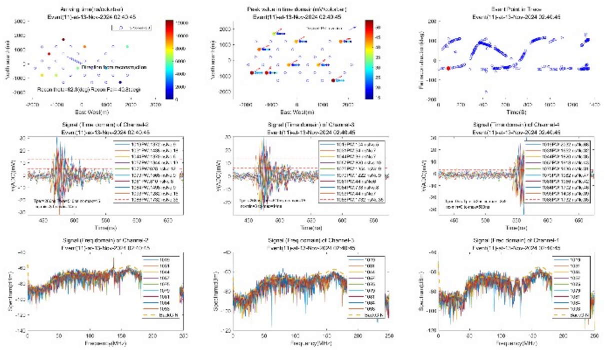


Figure 4. Concept of the time calibration using commercial airplanes. The airplane broadcasts its position via digital ADS-B packets at 1090 MHz. These signals are received and interpreted by a dedicated setup in the AERA field in real time. In addition, (some) commercial airplanes emit pulsed signals in the frequency range of 30–80 MHz recorded by the AERA detector stations.



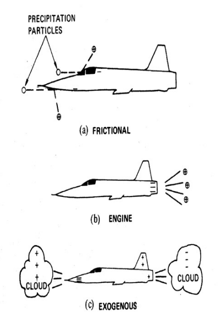


Fig. 1. Charging processes.

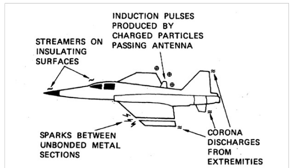


Fig. 4. Interference sources.

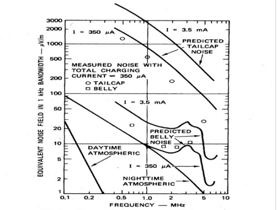
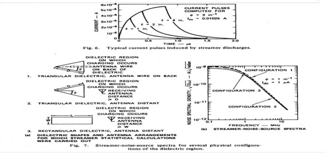


Fig. 5. Corona discharge noise in 707 antennas.



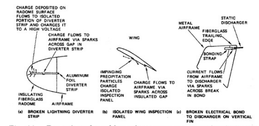
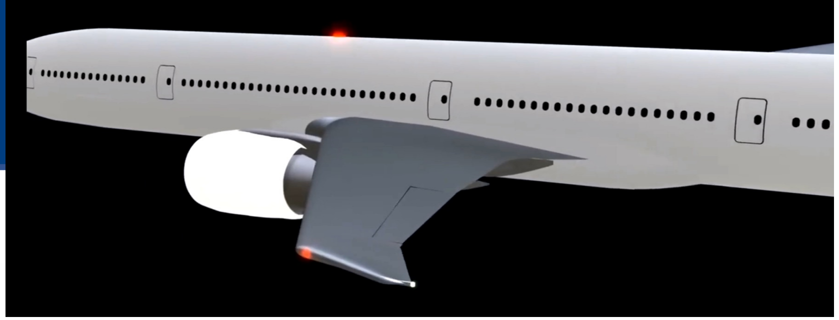


Fig. 11. Examples of sparking-noise sources on operational aircraft (after Moore).

Radiation (Xidian)



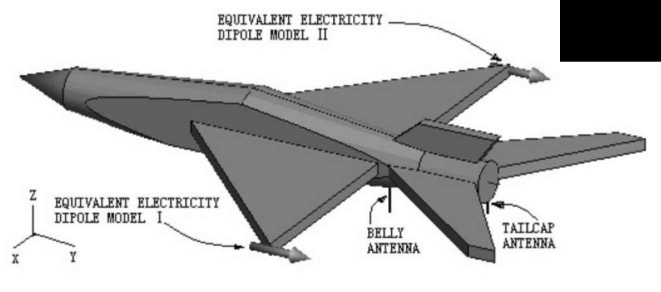


Fig. 3. Model of the composite airplane.

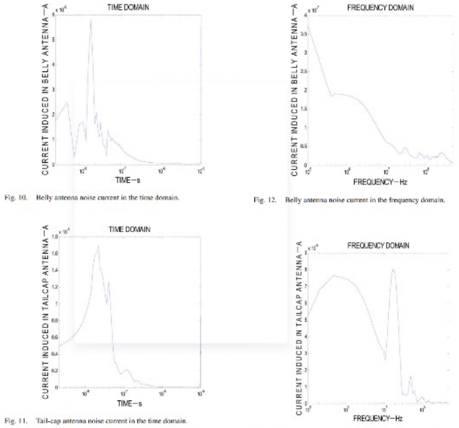


Fig. 10. Belly antenna noise current in the time domain.

Fig. 12. Belly antenna noise current in the frequency domain.

Fig. 11. Tail-cap antenna noise current in the time domain.

Fig. 13. Tail-cap antenna noise current in the frequency domain.

IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY, VOL. 50, NO. 4, NOVEMBER 2008

na
ory
aft
ent
to
ect
nd
ed

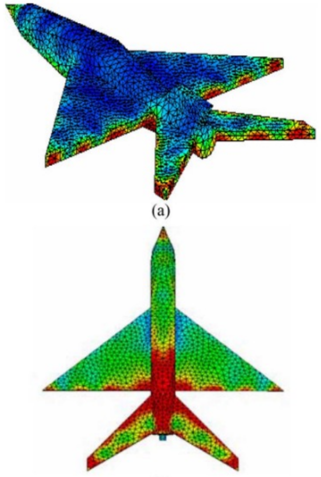


Fig. 4. Distribution of the induced current density on the surface of the airplane.

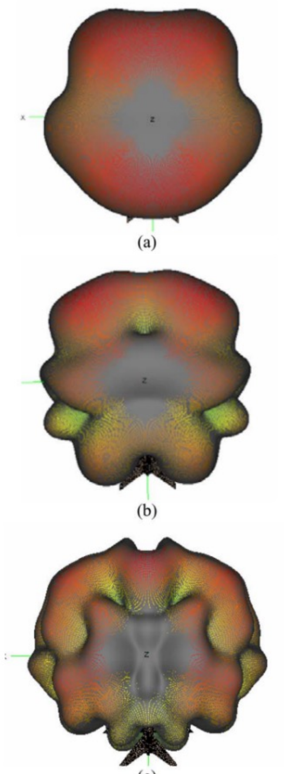


Fig. 5. Corona discharge far-field radiation patterns. (a) 30 MHz. (b) 6
(c) 100 MHz.

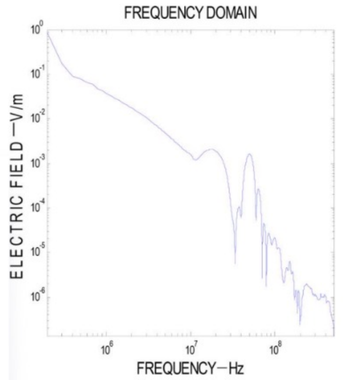


Fig. 8. Electric noise field at the tail-cap-antenna location in the frequency domain.

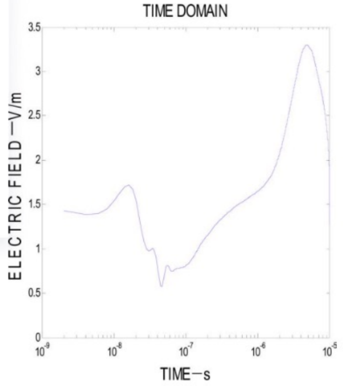


Fig. 9. Electric noise field at the tail-cap antenna location in the time domain.

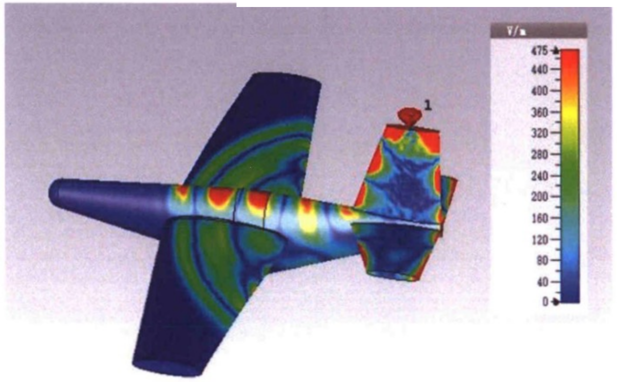


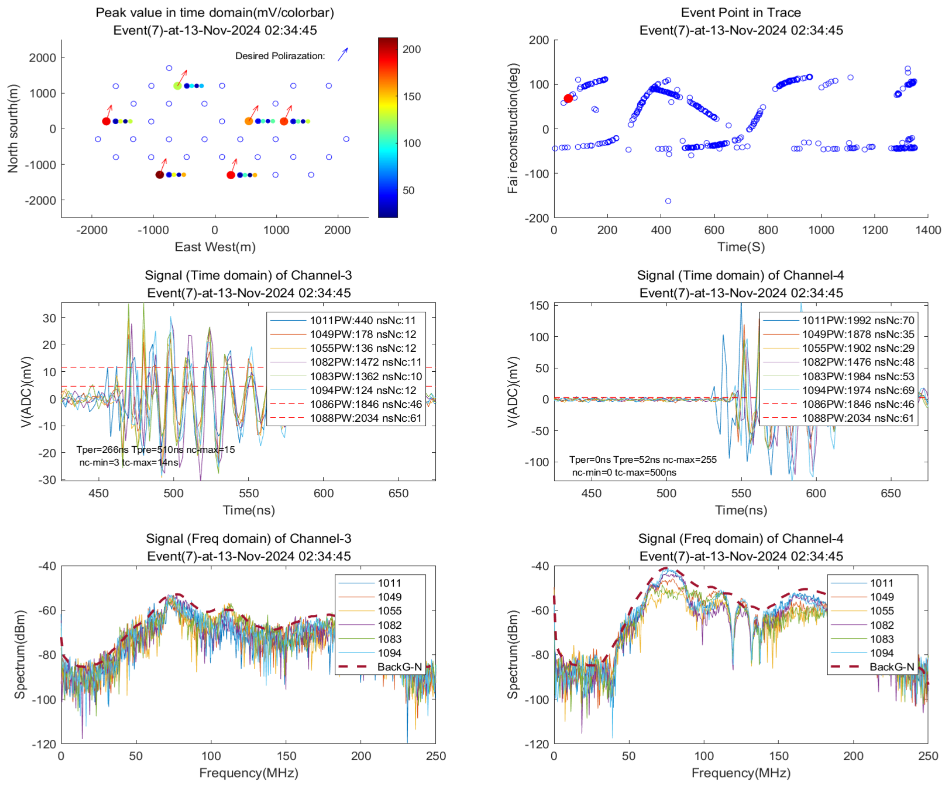
图 1-11 飞行器尾翼电晕放电的电场强度分布图

Figure1-11 Electric Field Intensity Distribution of Corona Discharge on Aircraft Tail Wings

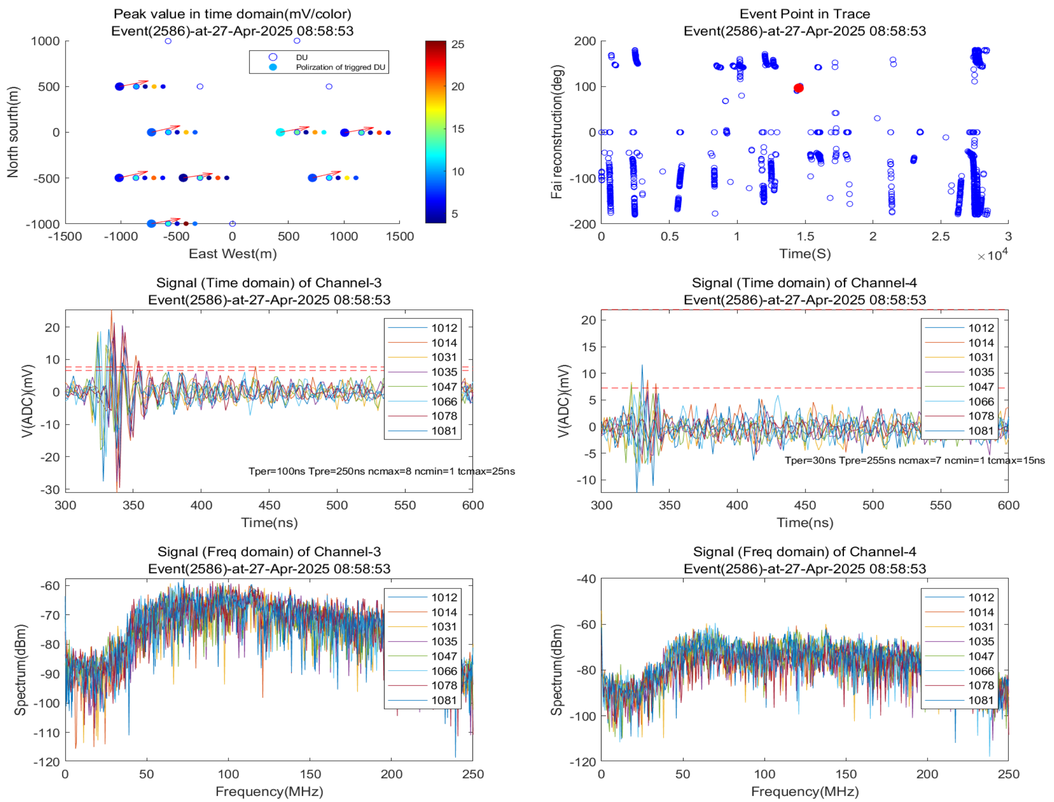
Analysis of Corona Discharge Interference on Antennas on Composite Airplanes

Huan-Zhan Fu, Yong-Jun Xie, and Jun Zhang, *Member, IEEE*

Compare



VS



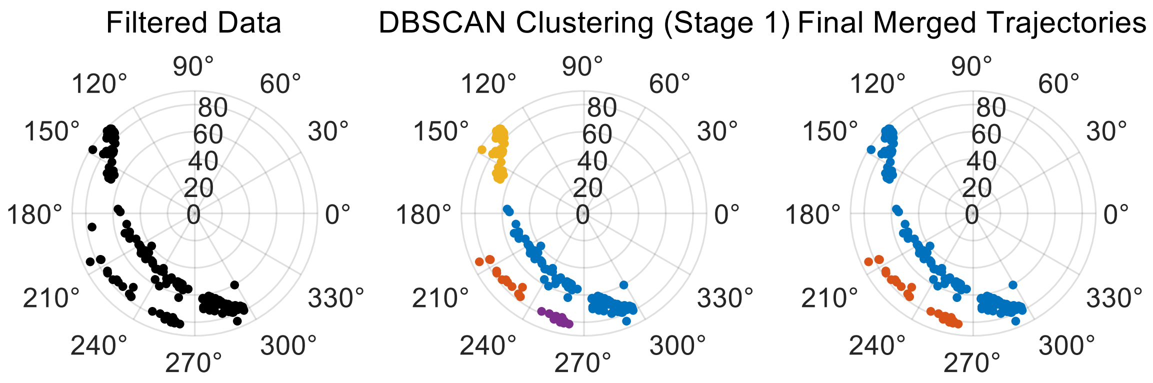
Airplane Event

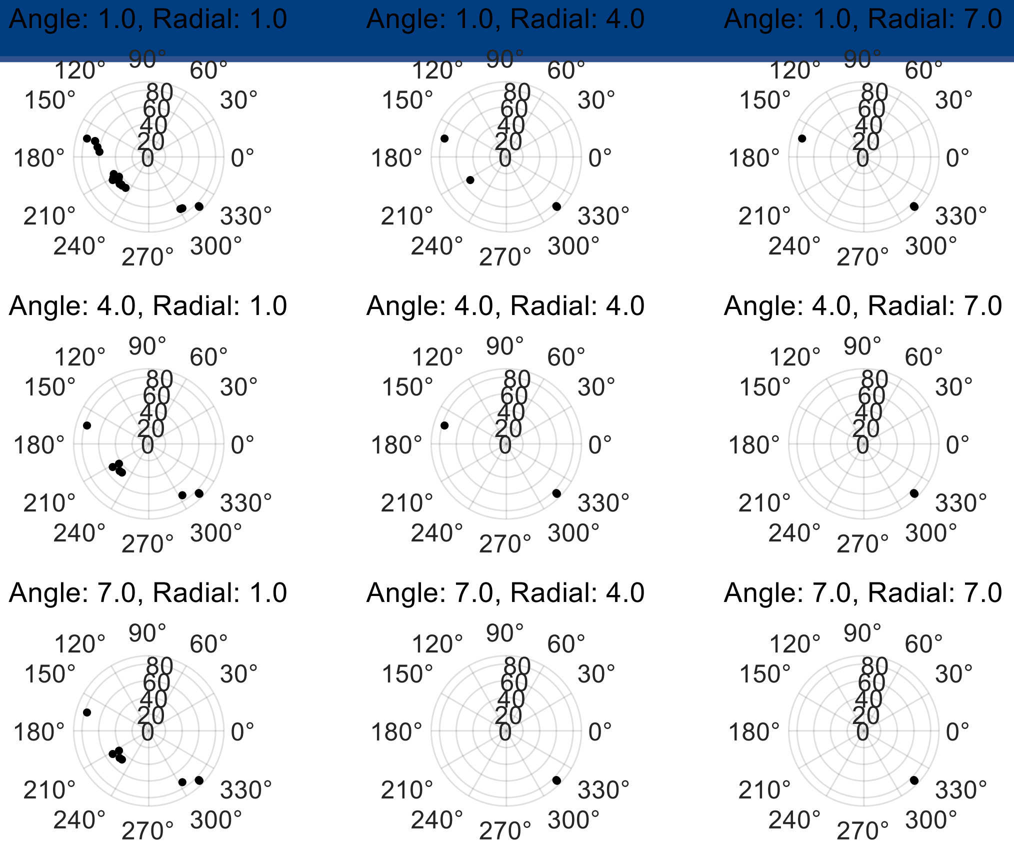
EAS candidate

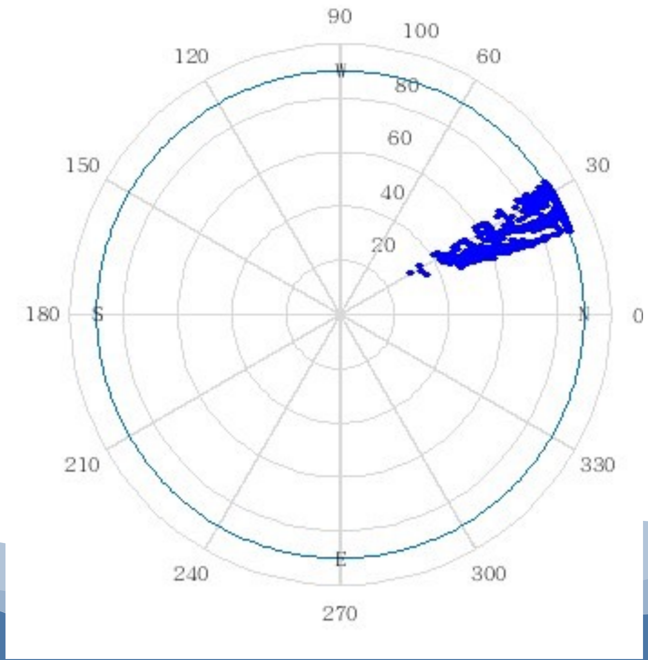
- Obvious increase in broadband spectrum.
- Wider pulse in time domain
- Location on the trajectory(track correlation)
- Polarization is unstable

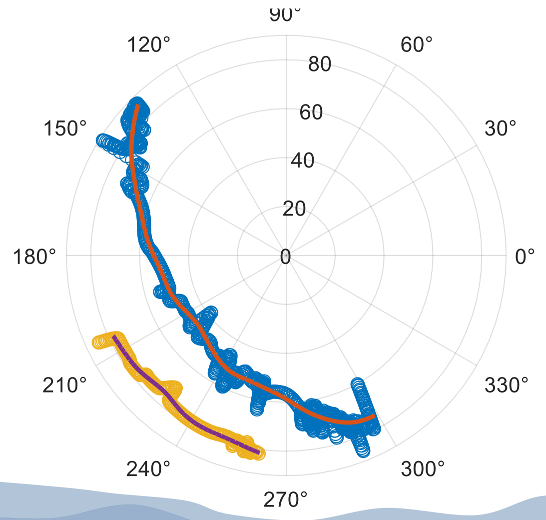
- Non-Obvious increase in broadband spectrum.
- Pulse—width is smaller than 100ns
- Separated from the trajectory(track correlation)
- Polarization is B*V

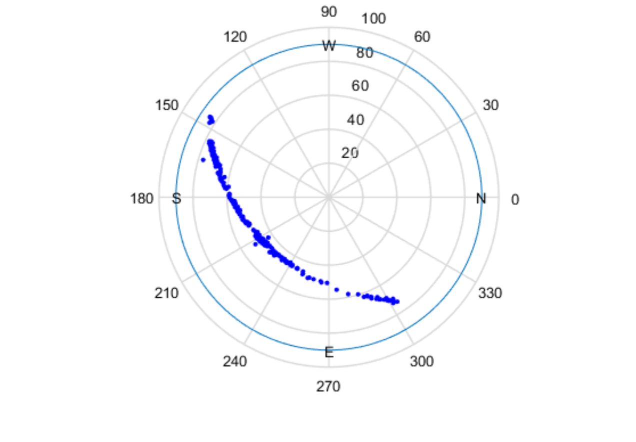
Tracing


Filtered Data
DBSCAN Clustering (Stage 1)
Final Merged Trajectories

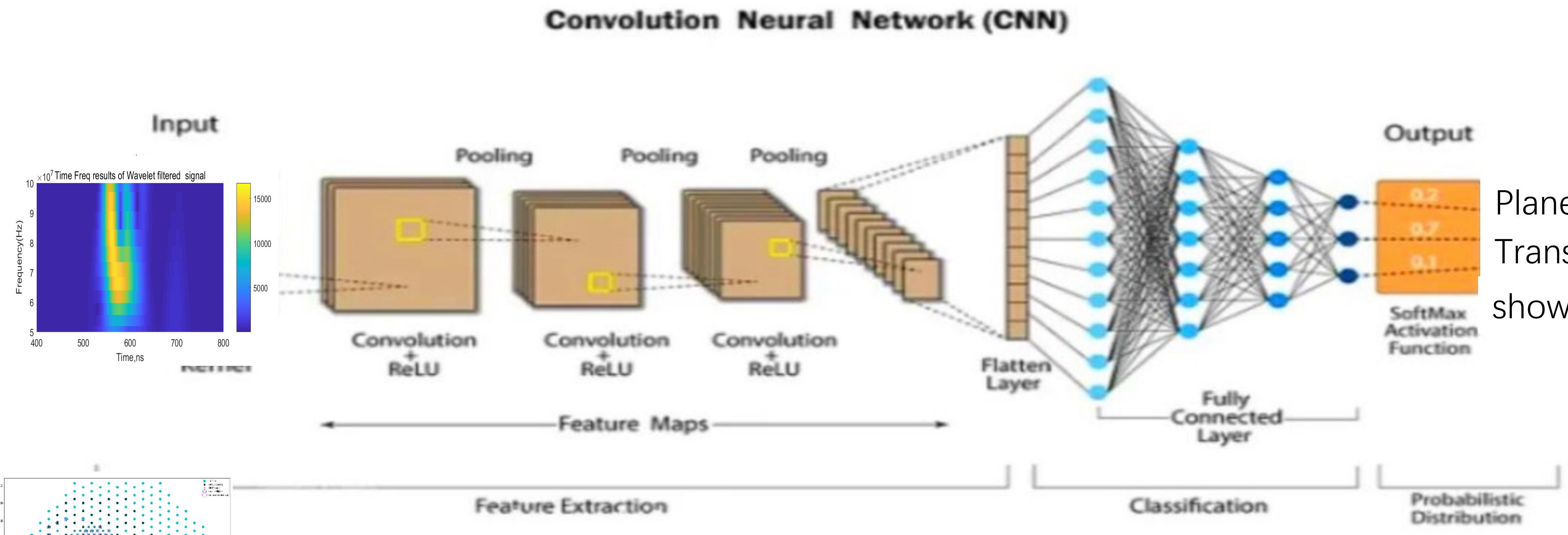

Angle: 1.0, Radial: 1.0
Angle: 1.0, Radial: 4.0
Angle: 1.0, Radial: 7.0
Angle: 4.0, Radial: 1.0
Angle: 4.0, Radial: 4.0
Angle: 4.0, Radial: 7.0
Angle: 7.0, Radial: 1.0
Angle: 7.0, Radial: 4.0
Angle: 7.0, Radial: 7.0







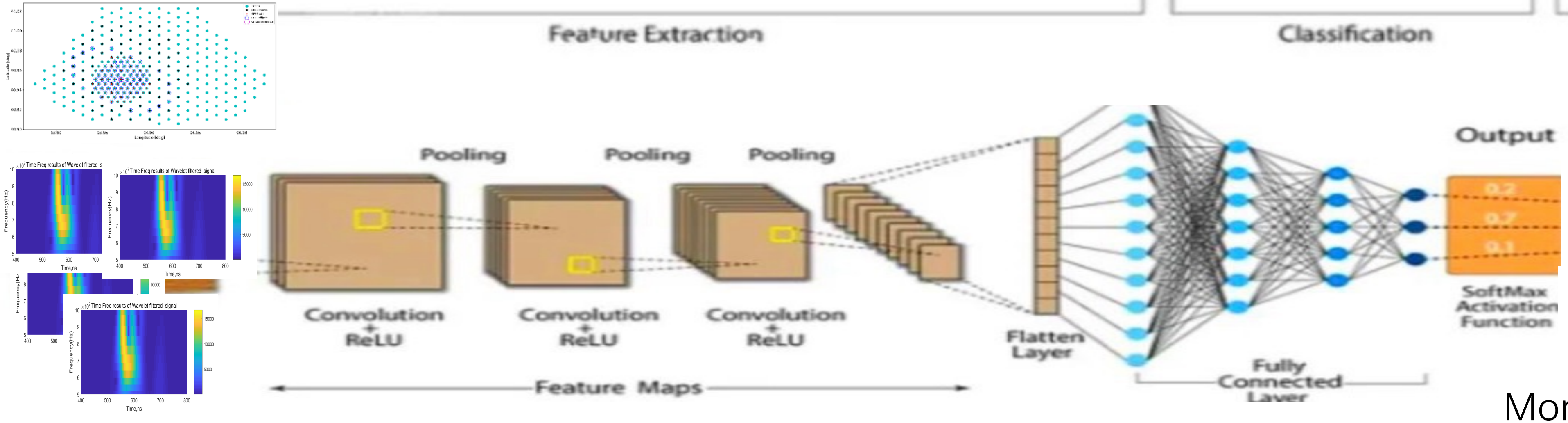
CNN based data process:



Plane

Transformer

shower



Core

Xmax/direction

Energy

More information!

Contents

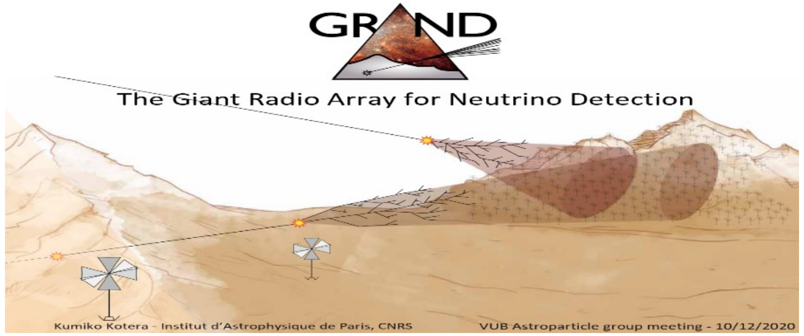
Not only for fun but also for application

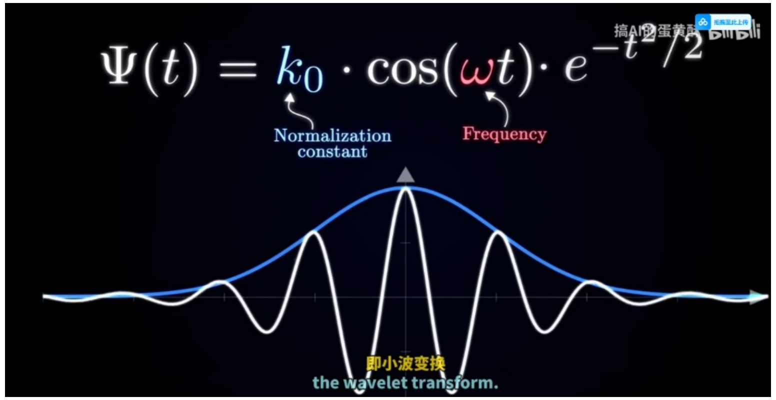
(1) Wavelet and correlation based data preprocess.

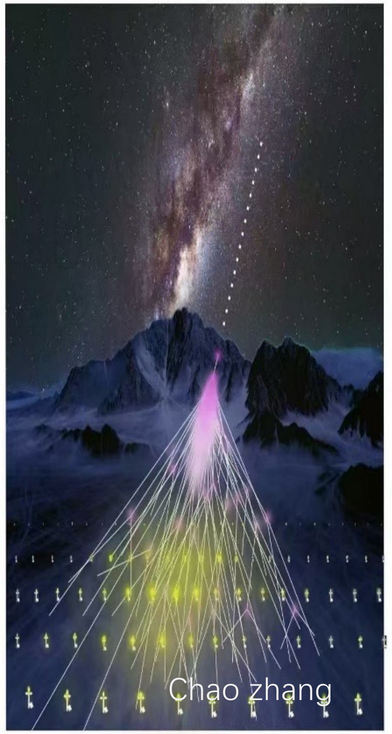
(2) Classification of event.

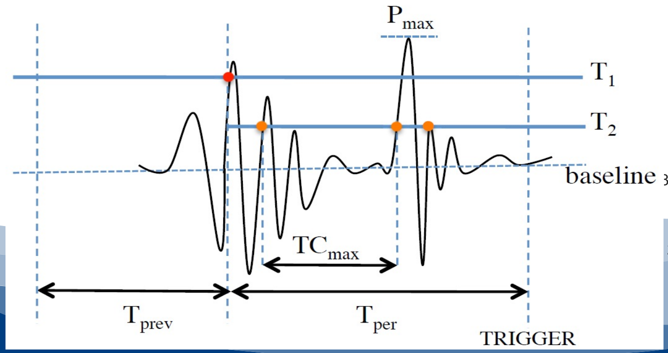
(3) Tigger algorithm.

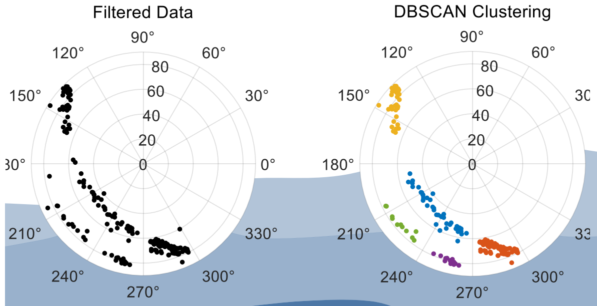
(4) Parameter's optimization



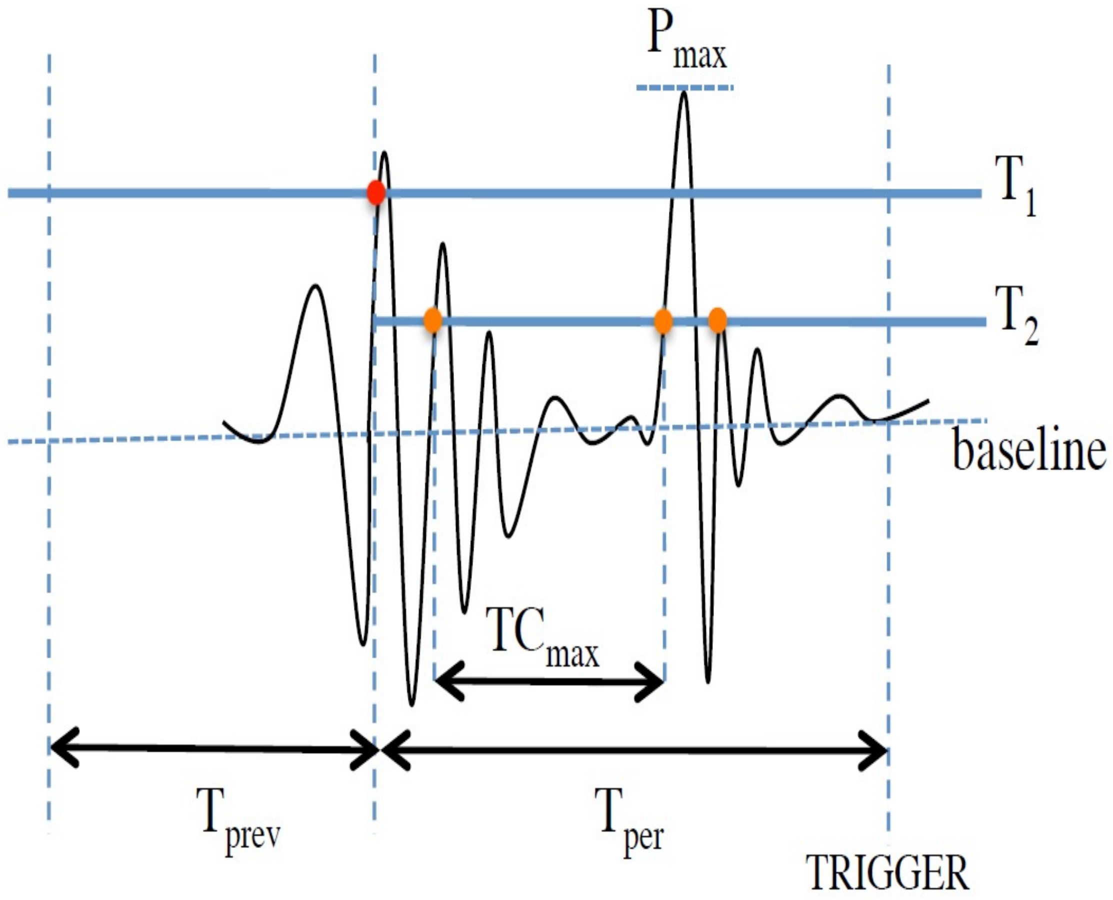






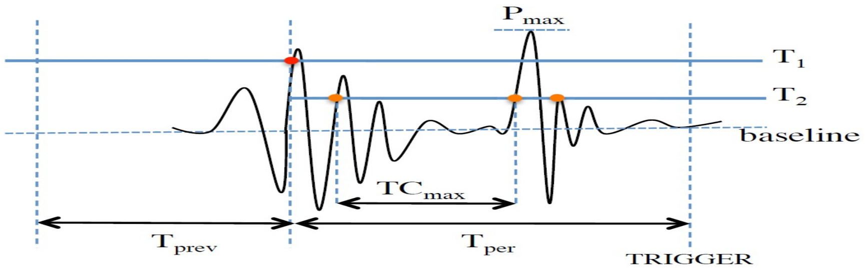


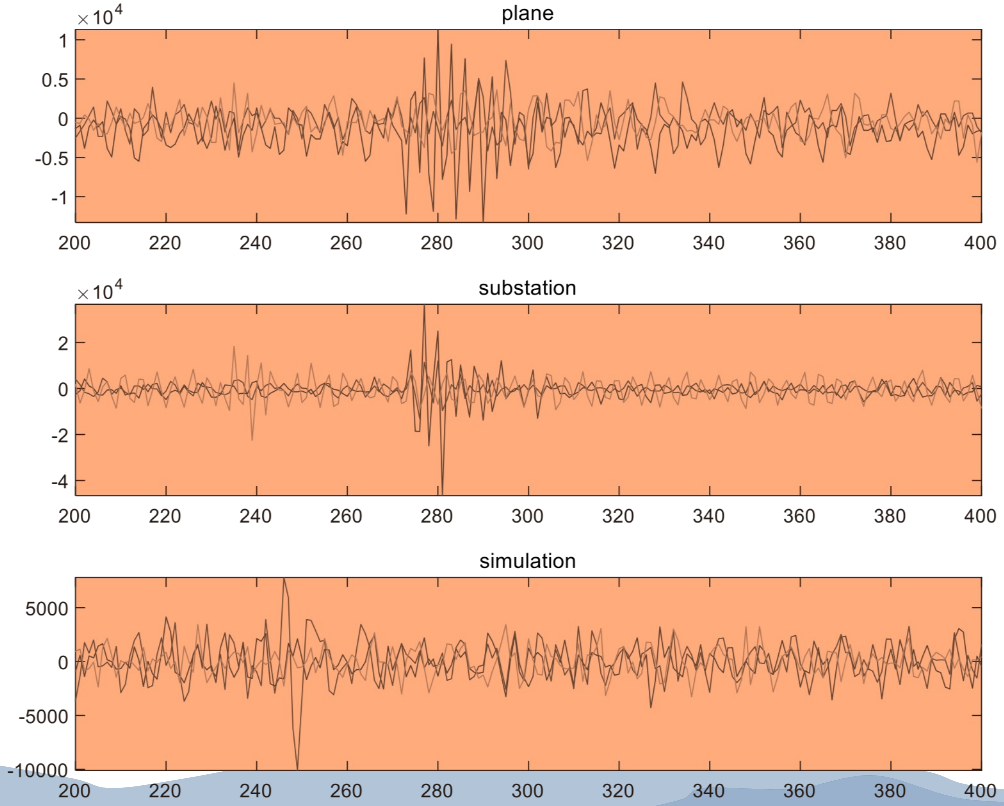
Trigger algorithm

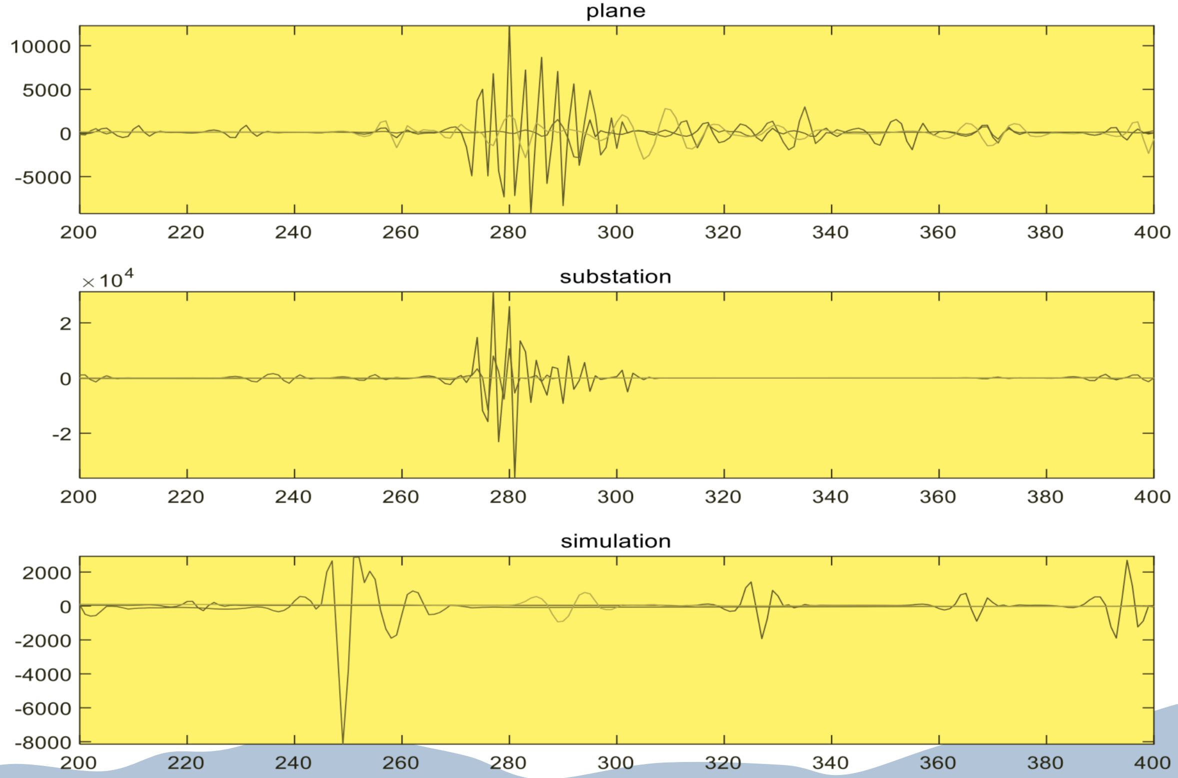


Parameters	Function	Related parameters
T1	The main threshold, which determines the detection sensitivity at the start of the pulse	T2、Tprev、Tper
T2	secondary thresholds to verify pulse persistence	T1、Tper、NCmin/NCmax
Tprev	Quiet period to ensure that there are no other triggers before T1 is triggered	T1、Tper
Tper	The trigger window limits the time range of T2 detection	T1、T2、TCmax
NCmin/NCmax	T2 triggers are limited to filter pulses that are too short or too long	Tper、TCmax
TCmax	Maximum T2 trigger interval ensures pulse continuity	Tper、NCmin/NCmax

Trigger algorithm



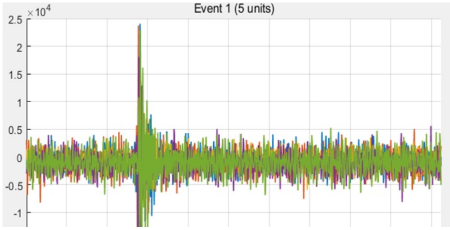




Algorithm implementation and parameter optimization

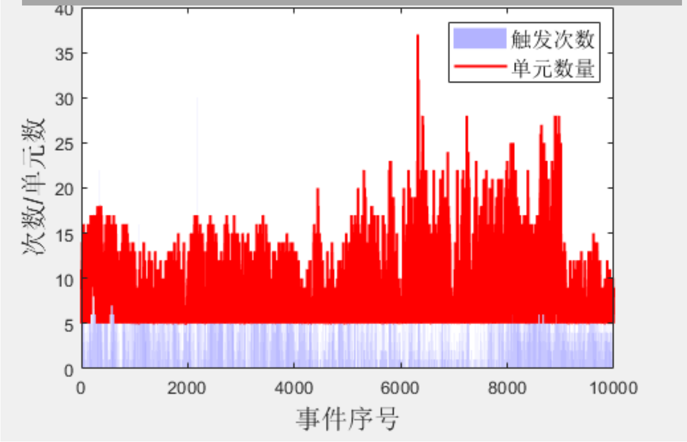
- First, the other parameters are relaxed to limit the T1 range

When T1 is 15000μv (the estimated high value), the correct event trigger rate is 54.77%

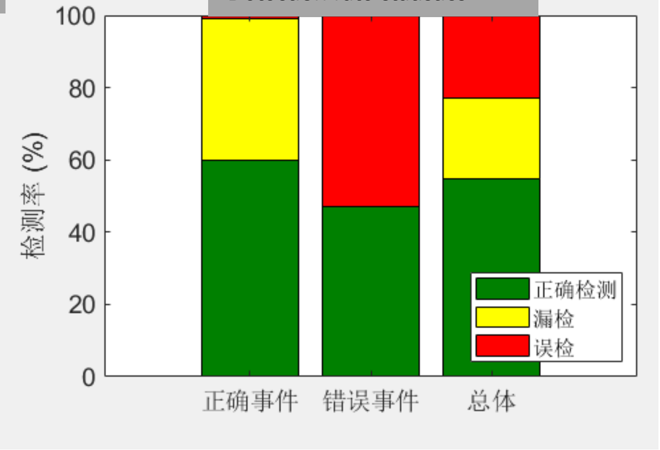



```
params = struct(...
    'T1', 15000,...
    'T2', 4000,...
    'Tprev', 400,...
    'Tper', 1000,...
    'NCmin', 1,...
    'NCmax', 1000,...
    'TCmax', 300);
```

Statistics on the number of times each event is triggered and the distribution of the number of units



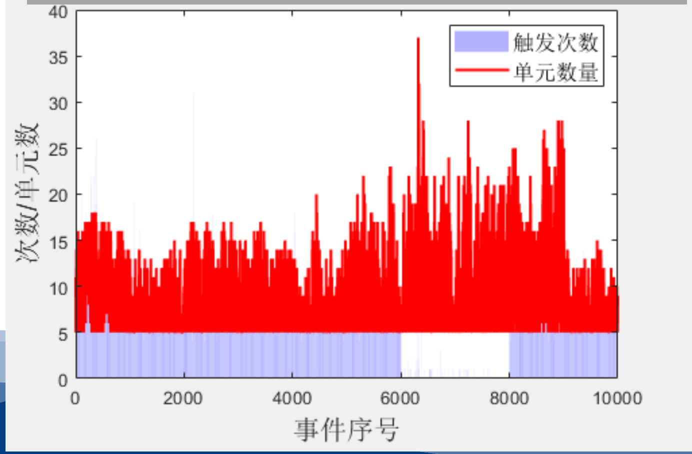
Detection rate statistics



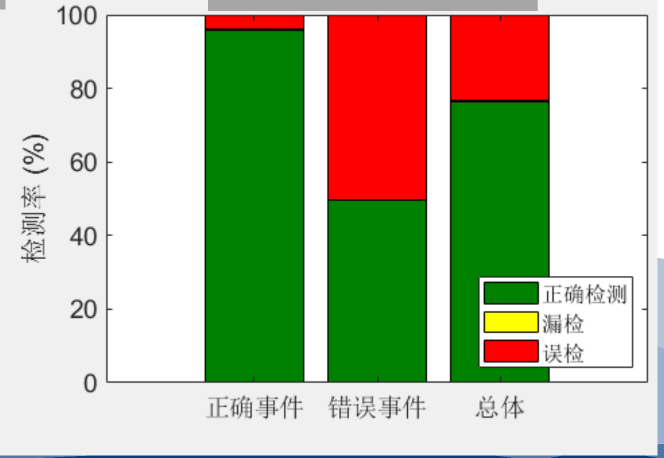
- Gradually lower T1 to 8000μV, and the correct event trigger rate rises to 95.84%

```
params = struct(...
    'T1', 8000,...
    'T2', 4000,...
    'Tprev', 400,...
    'Tper', 1000,...
    'NCmin', 1,...
    'NCmax', 1000,...
    'TCmax', 300);
```

Statistics on the number of times each event is triggered and the distribution of the number of units



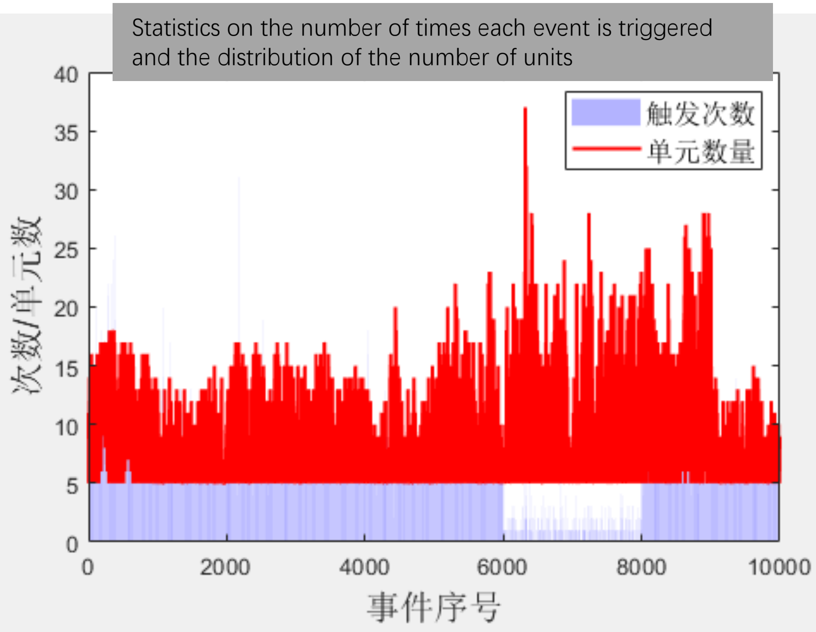
Detection rate statistics

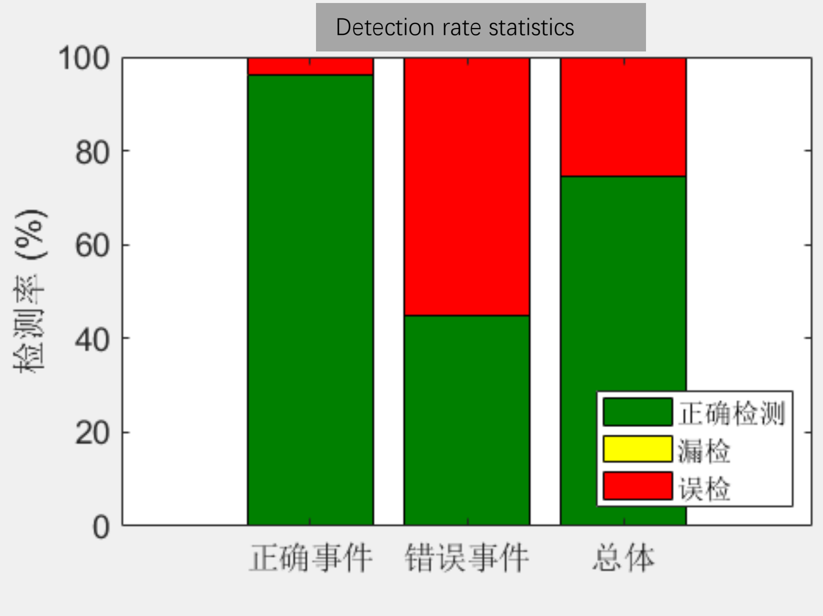


Algorithm implementation and parameter optimization

- At this time, changing the value of Tprev found that there was a large correlation with the accuracy of the first type of interference event, and when another pulse was added to the first type of interference phase event, Tprev could exclude the first type of error data, and the accuracy of the first type of interference event began to decrease when it was adjusted below 360ns, and the lower limit of Tprev was about 360ns. At this time, the correct event trigger rate is still 95%, and then the value of Tprev starts to increase from 400ns, and when the value of Tprev is greater than 500ns, the correct event recognition rate begins to decrease, so the upper limit is around 500ns

```
params = struct(...
    'T1', 8000,...
    'T2', 4000,...
    'Tprev', 360,...
    'Tper', 1000,...
    'NCmin', 1,...
    'NCmax', 1000,...
    'TCmax', 300);
```

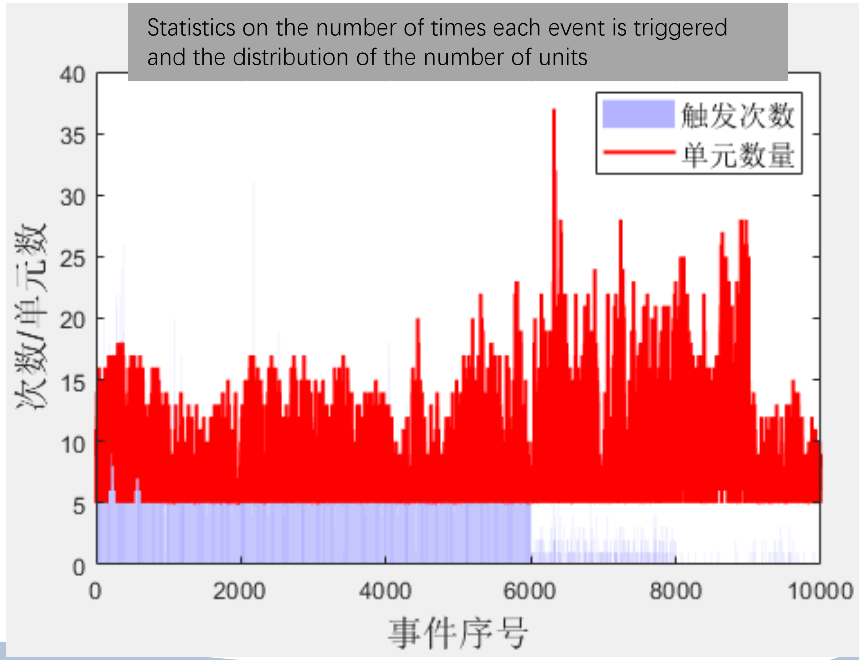


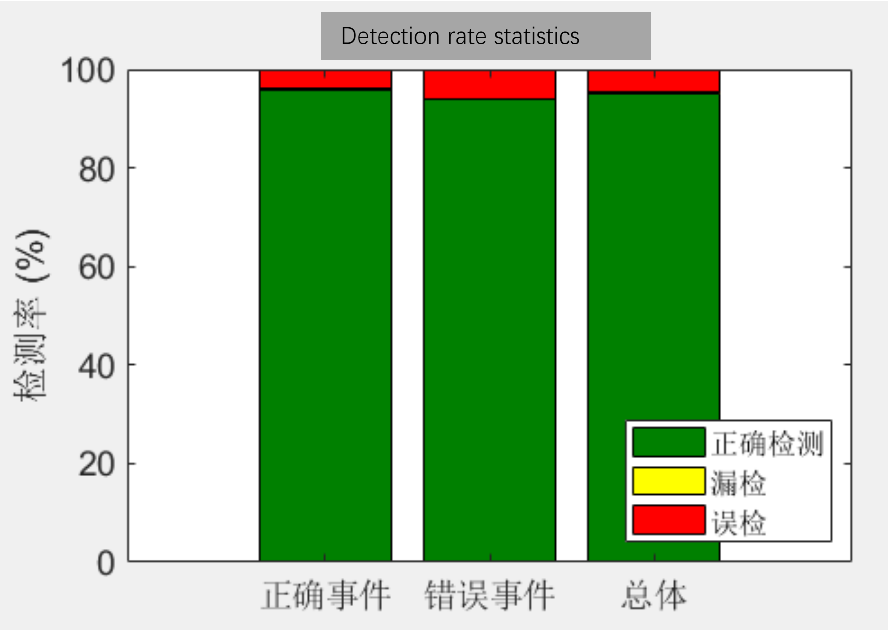


Algorithm implementation and parameter optimization

- Since T2 is closely related to NC, the two are jointly debugged during parameter tuning. Combined with the comprehensive detection accuracy to adjust the NC range, when T2 is 6000, NCmax is 19, and NCmin is 2, the highest comprehensive detection rate is 94.93%.

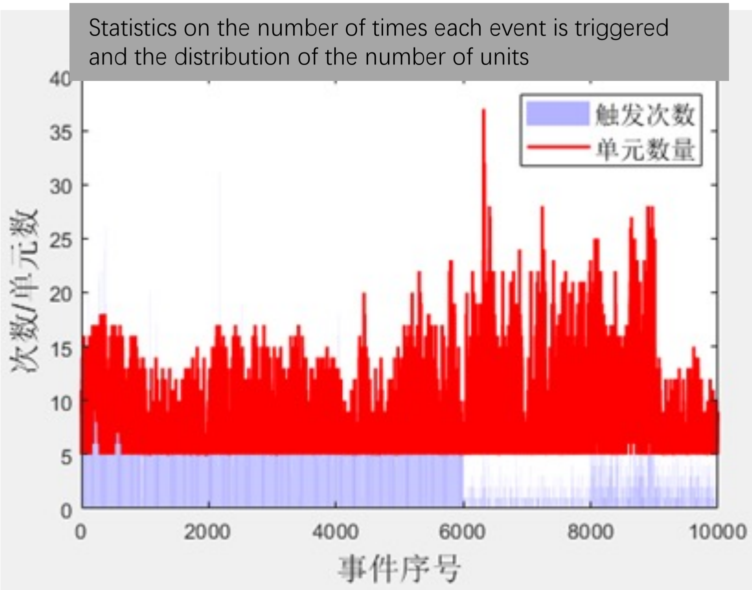
```
params = struct(...
    'T1', 8000,...
    'T2', 6000,...
    'Tprev', 400,...
    'Tper', 1000,...
    'NCmin', 2,...
    'NCmax', 19,...
    'TCmax', 300);
```





Algorithm implementation and parameter optimization

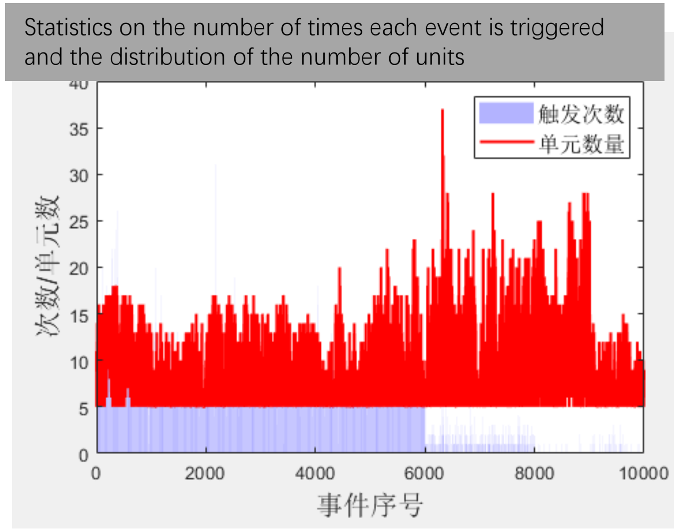
- The initial value of Tper in the time window is 1000ns, and when the Tper value is increased, the correct detection rate does not change significantly, and when the Tper value is decreased, the trigger rate decreases, for example, when the Tper is 300ns, the correct detection rate drops to 88.64% as shown in the figure below. Therefore, the value of Tper can be assumed to be around 1000ns.

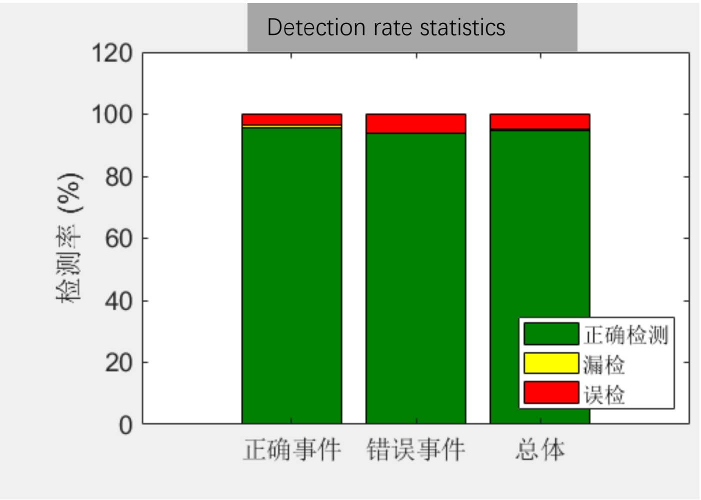


Algorithm implementation and parameter optimization

- Then the value of TCmax is changed, and when the TCmax is 200ns, the recognition rate is 94.97%

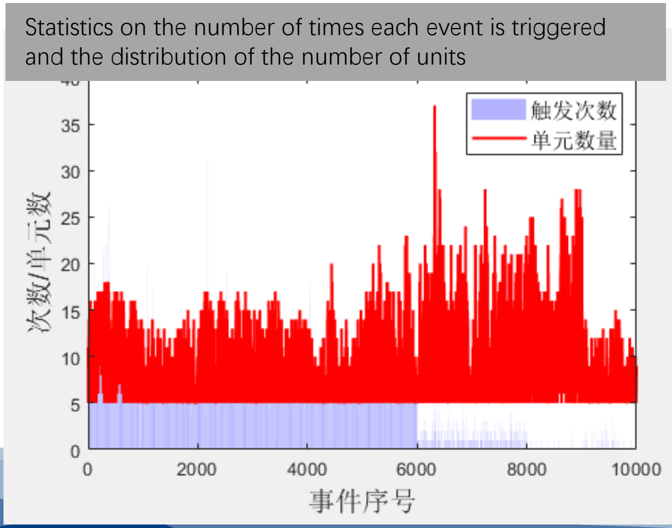
```
params = struct(...
    'T1', 8000,...
    'T2', 6000,...
    'Tprev', 400,...
    'Tper', 1000,...
    'NCmin', 2,...
    'NCmax', 19,...
    'TCmax', 200);
```

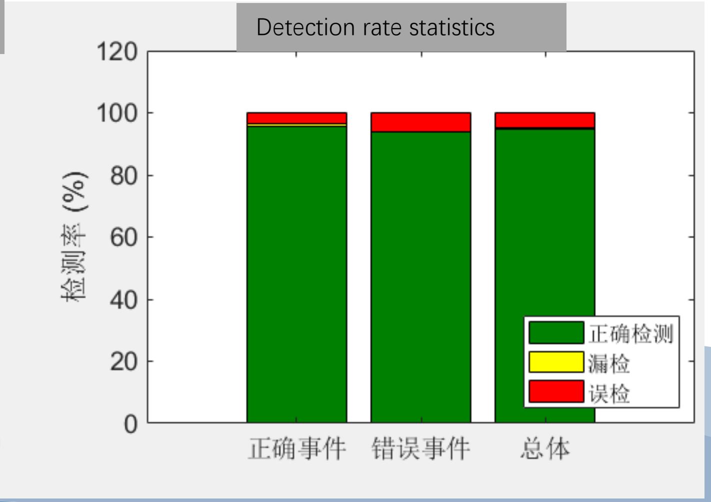




- When the Tcmax is reduced to 100ns, the recognition rate reaches a high value of 95.04%

```
params = struct(...
    'T1', 8000,...
    'T2', 6000,...
    'Tprev', 400,...
    'Tper', 1000,...
    'NCmin', 2,...
    'NCmax', 19,...
    'TCmax', 100);
```





Contents

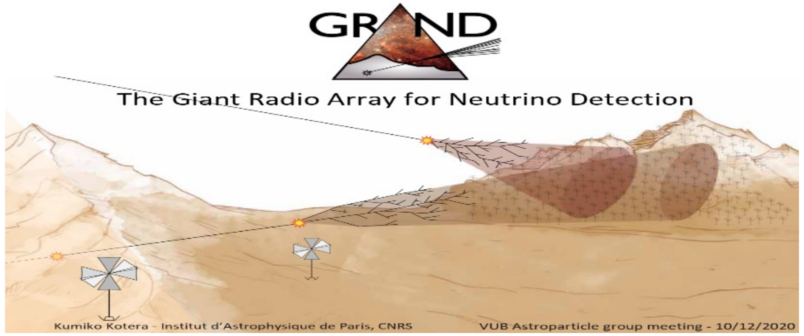
Not only for fun but also for application

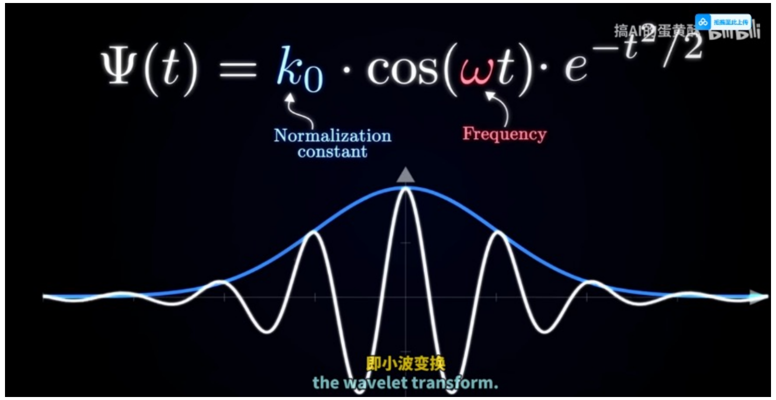
(1) Wavelet and correlation based data preprocess.

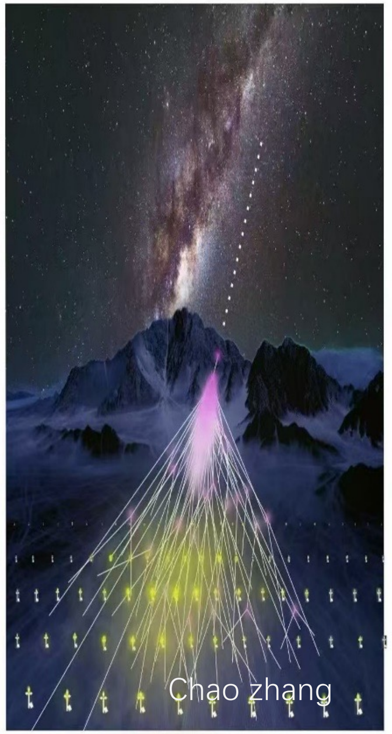
(2) Classification of event.

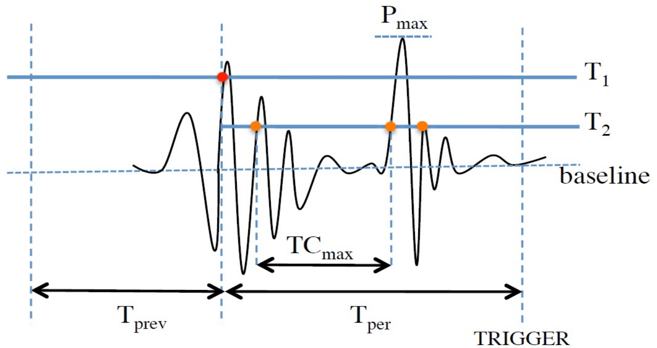
(3) Tigger algorithm.

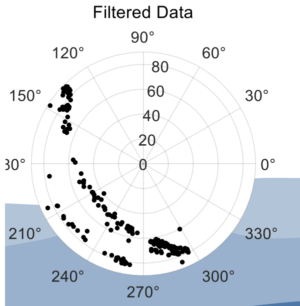
(4) Parameter's optimization

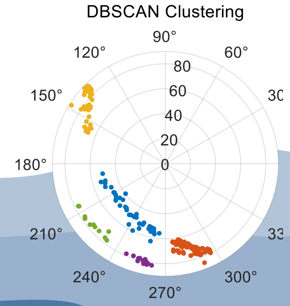




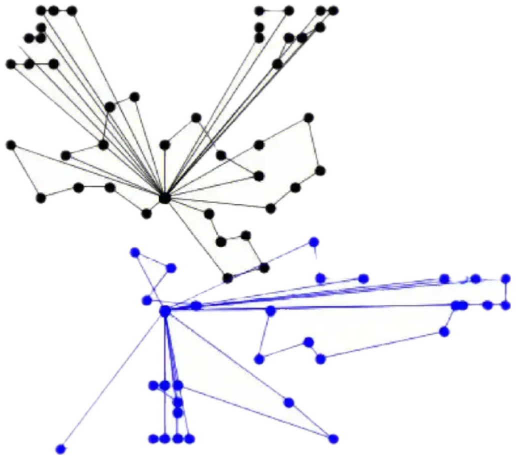


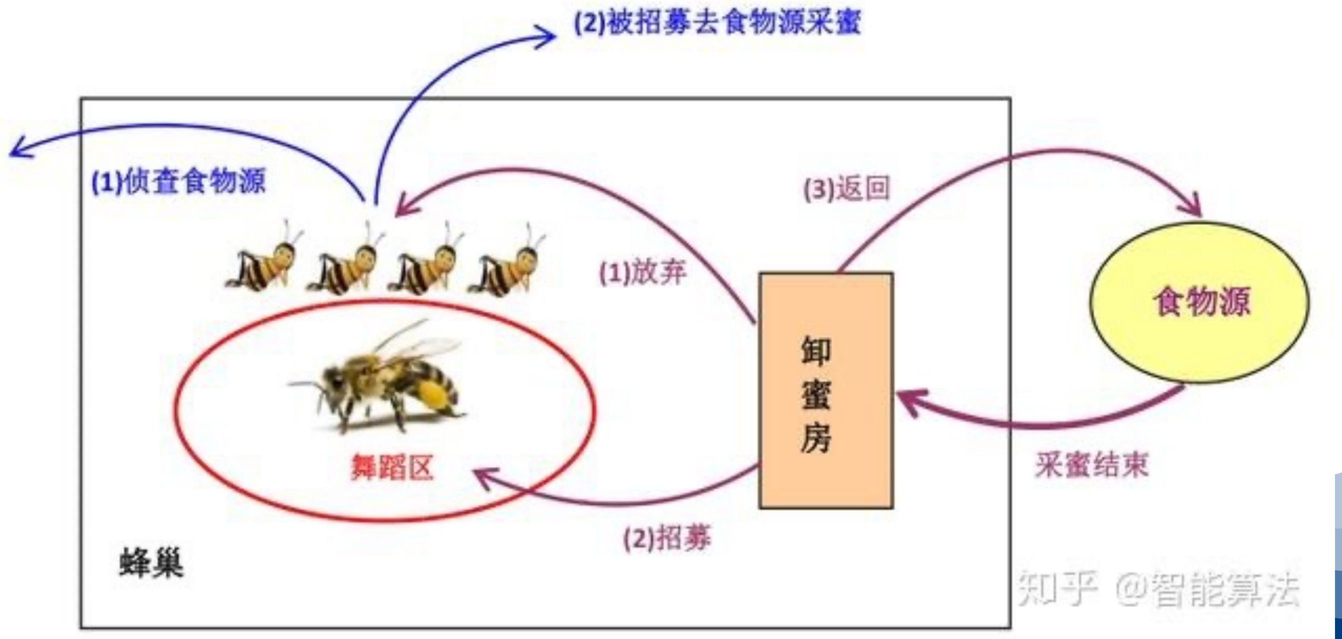




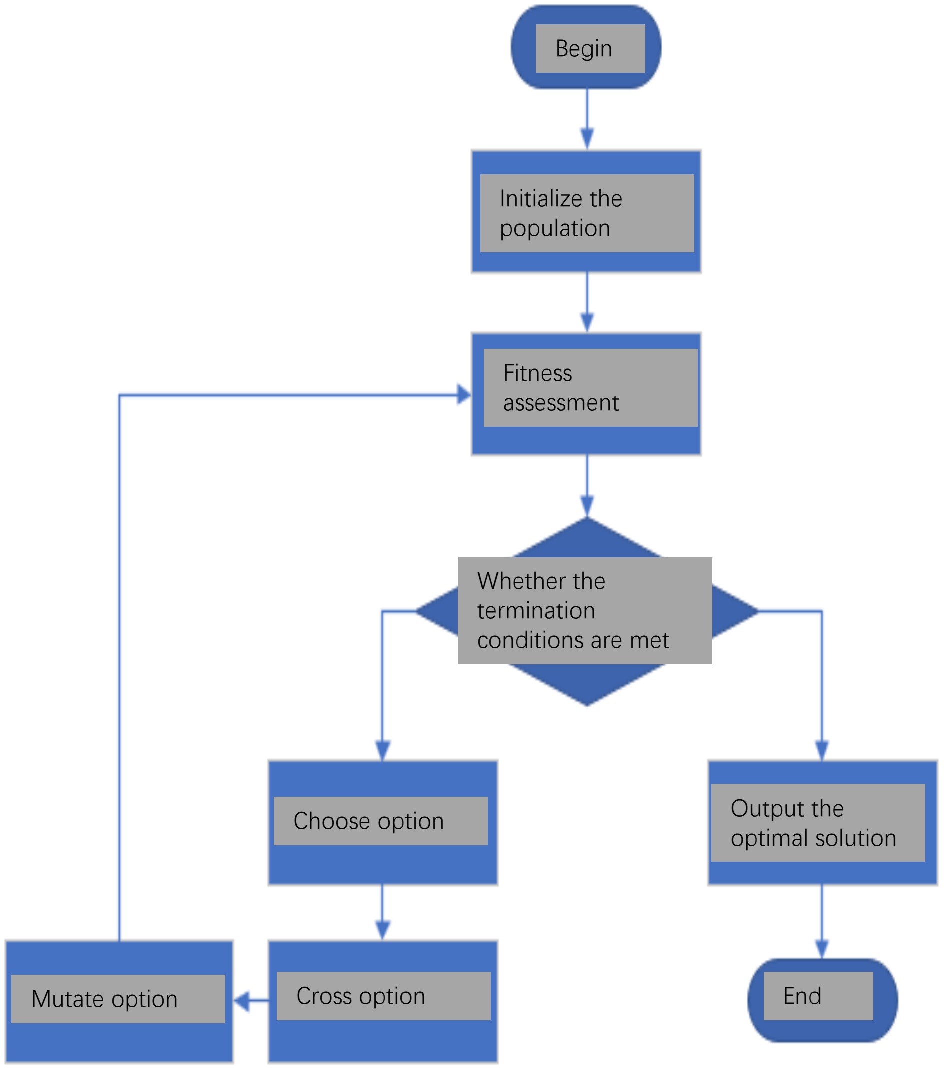


GA /PSO /DA





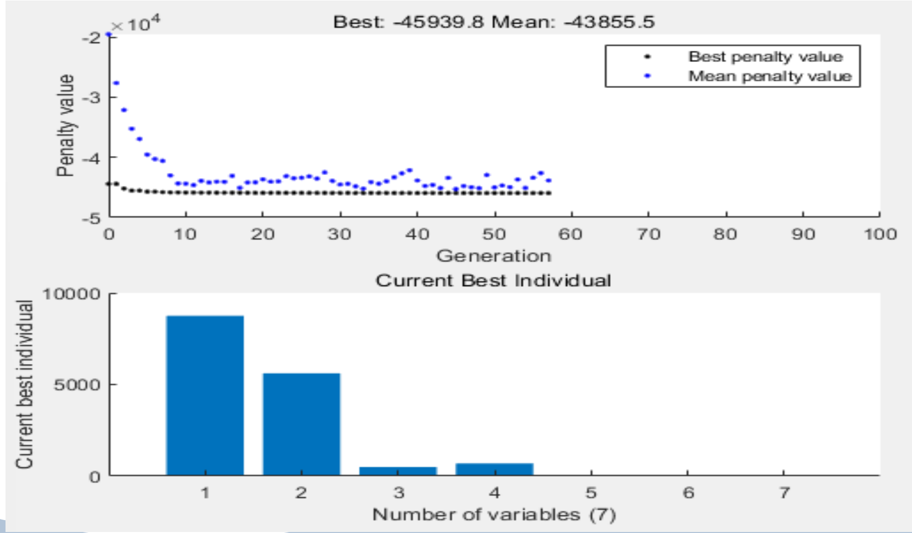
(2)被招募去食物源采蜜
(1)侦查食物源
(3)返回
(1)放弃
卸蜜房
食物源
舞蹈区
采蜜结束
(2)招募
蜂巢
知乎 @智能算法



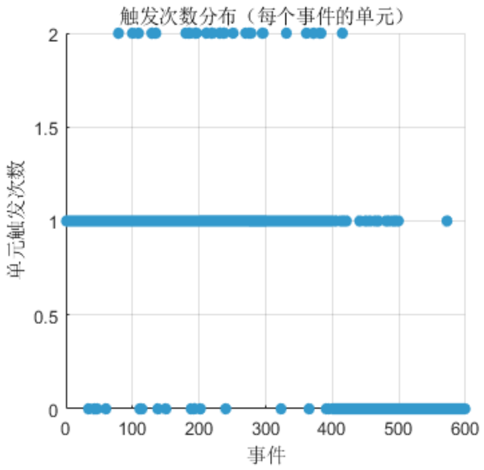
Begin
Initialize the population
Fitness assessment
Whether the termination conditions are met
Choose option
Output the optimal solution
Mutate option
Cross option
End

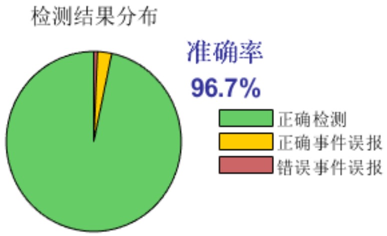
Genetic algorithm parameter optimization results

When the number of iterations is set to 100 and the population size is set to 50, the iteration effect is as shown in the following figure, and the iteration results achieve the expected effect in about 60 generations. The analysis shows that the parameters obtained by the genetic algorithm are more similar to those obtained by manual adjustment above, the parameter range is relatively close, and the accuracy of the parameters obtained by the genetic algorithm reaches 96.7%, which is higher than that of the traditional method.



T1: 8120.7
T2: 5829.3
前导时间: 403.1
周期时间: 881.6
最小触发数: 2
最大触发数: 20
最大间隔: 86.0





Conclusion：

1、A fast 、low cost denoise algorithm is employed to do the preprocess of data;
2、The time frequency domain picture of signal is generated to be used in ML based data process；
3、The event classification is done based on polarization、spectrum、tracing、direction；
4、The trigger parameters optimization is done based on GA