Analysis of anti-interference detection ability of wave net network signal based on convolution neural

Tao Chen¹, *, Yaxuan Sun², Yulin Ding³

¹Leeds Joint School, Southwest Jiaotong University, Chengdu, Sichuan, 611756, China
²School of Mathematics and Statistics, Wuhan University, Wuhan, Hubei, 430072, China
³School of Electronic Science and Engineering, Xiamen University, Xiamen, Fujian, 361001, China

*Corresponding author email: taochen@swjtu.edu.cn

Abstract. Deep learning has been widely used in image, speech, natural language, and robot and so on. However, how to use these technologies in radar detection is still very few. There are a lot of artificial design elements in the traditional radar processing, its application range must be considered practically, while the intelligent radar relies more on the self-learning and improvement ability of the algorithm itself. In this paper, a method of target detection based on convolution neural network is proposed. By matching the received signal with the transmitted waveform, the matching feature of the sliding window is extracted. Moreover, the feature information processed by convolution network is connected into a network, and the anti-jamming target detection under any transmitted waveform and given form of interference is completed. As a creative way, this paper compares the signal anti-interference detection and processing ability of convolution network and full connection network on independent distance unit, and finds that convolution network has the best effect.

Keywords: Convolutional neural network, wave net network, signal, anti-interference.

1. Research background and significance

1.1. Background
The traditional radar has some problems, such as inflexible working mode, insufficient adaptability to environment and target [1]. As an intelligent radar, cognitive radar can automatically adjust the working mode and signal processing mode according to the prior information such as target, environment and jamming, which is the development direction of radar in the future [2]. On the one hand, radar can learn and adjust the signal processing mode automatically according to the information of target, environment and jamming. On the other hand, it can automatically adjust the working mode of radar according to its own signal processing process and environmental information, and realize the closed-loop system from transmitting waveform to target detection [3].

There are a lot of artificial design elements in the traditional radar processing, its application range...
must be considered practically, while the intelligent radar relies more on the self-learning and improvement ability of the algorithm itself. The intelligent radar realizes the closed-loop processing from the transmitting waveform to the target detection result, and improves the working mode and processing process of the radar end-to-end depending on the final detection result, which has a wider range of use and more integrated optimization. In the stable environment, it will be updated iteratively; in the unknown or changing environment, the intelligent radar can also adapt to the interaction with the environment quickly.

The jamming measures to radar include: radar signal detection, radar direction positioning, suppression jamming and deception jamming. Among them, deceptive jamming includes: distance deception, range gate traction; Doppler deception, velocity gate traction; angle deception; large range false target deception, etc. Most of these methods use manual design algorithm, which needs to be analyzed for specific problems. Now deep learning has solved the automatic design of the algorithm. This general scheme can be generalized to various anti-interference measures, and finally unified coordination of various measures to improve performance. In this paper, we will mainly discuss how to use deep learning to deal with echo data under large-scale false target deception.

1.2. Significance
Electromagnetic warfare includes radar, electronic warfare, communication, navigation and many other aspects, involving more research content [4]. This paper focuses on the anti-jamming detection of radar. There are many similarities between the problem of radar signal detection and the problem of image and speech detection. The data itself has a certain spatial or temporal structure, which satisfies certain translation and other deformations. This structural feature is exactly what the convolution network is good at, that is, it can match the same features in different positions through the sliding convolution kernel. Therefore, by constructing a reasonable convolution structure and convolution network, we can use depth learning to deal with the signal anti-jamming detection in the radar field.

2. Convolutional neural wave net network
In terms of data structure and form, radar echo signal in time dimension is very similar to acoustic signal (especially voice signal), so we use wave net for reference to process radar signal. In the multi-layer wave net network, each layer network contains gate activation unit, convolution with convolution kernel size of 1, residual connection and jump connection. The output of each layer network will be directly connected with the input of that layer, and the final output will also be directly connected with each layer network.

The application of gate structure in every layer of extended convolutional network can improve the ability of information flow in the network layer and make the network learn useful information more quickly. Gate activation unit can complete autocorrelation processing of output information, which is impossible for general convolution network. The matching filtering process in radar target detection can be regarded as an autocorrelation process. After the gate activation unit, a convolution layer with a convolution kernel size of 1 is connected to integrate the features of different channels on the same distance unit extracted in the gate activation unit. We use two identical convolution structures to integrate the features of these different channels. One of the features extracted from the convolution structure is used for the input of the next layer network, and the other is directly connected to the last layer of the whole network. The information extracted from this layer network is directly applied to the final target detection.

In the problem of signal interference detection, the input of the network is the sampling echo data at each time, and the output is the target detection result on the corresponding distance unit at each sampling time. Input and output are almost one-to-one correspondence, which requires the network structure itself to keep such correspondence; at the same time, considering that the input information contains some transient points. Because the transmitting waveform is a long pulse signal with phase code, the echo signal of the terminal distance unit will not receive completely because of the delay and become a transient point. This makes the output dimension smaller than the input dimension. We can
directly retain the output of the corresponding part as the distance unit of real concern, and directly discard the other parts.

3. Anti-interference detection of wave net network signal based on convolutional neural network
We can't solve the problem of multiple transmitting waveforms with the method of fixed transmitting waveforms. This is because when the network processes the fixed transmitting waveforms, it actually stores the matching coefficient of the target waveforms in the parameters of the network, and matches the echo signal with the network parameters, so as to achieve the effect of target detection. In the non-fixed transmitting waveforms, the echo form of the target is based on the radar the matching coefficient of the target waveform is also changed, which cannot be saved in the parameters of the network. We must find a new model structure to solve this problem.

3.1. Extract matching feature of sliding window
When we input the echo signal to the network, we also input the radar transmitting waveform corresponding to the echo, so that the network can match the echo according to the input radar waveform. In order to approximately eliminate the change of target signal structure caused by the change of radar transmitting waveform, and at the same time to retain the characteristics of intermittent sampling of jamming in time domain, we do the following operations: multiply the echo and pulse compression coefficient by sliding window, not sum the result of point multiplication (this is to retain the intermittent sampling characteristics of jamming in time domain), which is more Dimension we call sliding window matching dimension, as shown in the figure below.

![Figure 1. Extract matching feature of sliding window](image)

3.2. Set up wave net network
The information in the sliding window matching dimension is regarded as the characteristic information of echo signal in the current distance unit. When the transmitting waveform is fixed, the information of real part and virtual part is input, but the number of feature information is not 2 at this time, but the length of window matched with sliding window is equal. Then, we apply the target detection network under the fixed transmit waveform, only change the characteristic dimension of the input data from 2 to the length of the window, to do the anti-jamming target detection under the arbitrary transmit waveform. We call this processing structure the wave net network under the arbitrary transmit waveform, as shown in the figure below.
3.3. Convolution structure in sliding window matching dimension

We can only rely on the information on the sliding window matching dimension to complete the target detection task. When we judge whether there is a target on the current distance cell, we do not consider the neighbor distance cell. I call such detection independent detection and such network structure independent detection network. The network can automatically extract the sliding window matching feature of the echo signal through the gate activation unit and other convolution connections. If the network can make good use of these original information to complete the sliding window matching process, it can discard the manually extracted sliding window matching feature, and only use the echo signal and the transmitted waveform.

According to the detection theory, we can solve the optimal detection performance of independent detection, and compare it with the simulation results of independent convolutional networks (independent conv) and independent full connected networks (independent FC) of similar scale. The green line represents the independent convolution network, and the red line represents the independent full connection network. As shown in the figure below. The false alarm rate is $10^{-4}$. It can be found that the performance of the convolution network is very close to the optimal detection result under the condition of no interference, which shows that the independence assumption is approximately true under the condition of no interference. On the other hand, the performance of the all connected network is worse, which shows that the all connected network is not suitable for target detection, convolution operation has its role in the sliding window matching dimension. In the later experiments, we will see that its role will be more obvious in the presence of interference.

4. Experimental results

In order to ensure the matching of data dimensions and extract the features in the fast time dimension, we spliced the data after the initial feature extraction of the original data in the fast time dimension. In this way, the features extracted by independent convolution and independent convolution can be preserved simultaneously. When the feature splicing is completed, the wave net network is used to integrate the features extracted from two different directions, and finally the target detection results are obtained.

It is assumed that the carrier frequency of the pulse radar with random phase code is 3GHz, the bandwidth of the transmitting waveform is 2MHz, and the code length of the random phase code is 256, sampling is conducted with one time of the bandwidth. The experimental data is the mixed signal of the interference of any position target and intermittent sampling convolutional modulation. The target is a single point target, and the interference is transmitted by intermittent sampling convolutional modulation. The detection performance of different networks is compared with the change of interference signal strength under given SNR and with the change of SNR under given dry SNR.
The optimal value of independent unit represents the detection performance of single value given by the detection theory under the condition of no interference, and the signal interception method represents the detection performance of single value given by the detection theory under the condition that half of the signal-to-noise ratio is lost due to intermittent sampling interference. Through the simulation experiment, it is found that the convolutional neural network achieves the best detection effect under various conditions.

5. Conclusion
In fact, deep learning is a kind of improvement and complexity of neural network, which is mainly reflected in the increase of network layers, structure improvement and training volume. In recent years, it has made very good achievements in the fields of image and voice. Deep learning represented by convolutional neural network has the unique advantages of sparse connection, weight sharing and translation equivariant. When the data itself satisfies or approximately satisfies such translation equivariant, convolutional network can produce more excellent performance than full connection network.

The function of convolution in sliding window matching dimension is to use fully connected network in wave net network, which actually has IFC and dconv structure. It has good performance when the interference is very strong, which shows that convolutional neural network can effectively distinguish the interference in the sliding window matching dimension. Therefore, convolution in the sliding window matching dimension does play a certain role that is to identify interference. When the waveform is fixed, wave net can also identify the interference. Obviously, because the time dimension of wave net is N+L(s), which is not the same as that of wave net when randomly transmitting waveforms. It is equivalent to removing the information of L(s) length, and has a strong signal anti-jamming detection and processing ability in the radar field.

References
[1] Zhao Zhijian, Yu Ke, Ma Yuehua, Pan Jun, Yang Gewen. Radar anti-jamming performance evaluation based on AHP cloud model [J]. Aerospace defense, 2020, 3 (01): 65 – 72.
[2] Zhang guobing, Yang Liyong. Radar anti-jamming technology analysis system based on open source [J]. Electronic measurement technology, 2020, 43 (01): 18 – 22.
[3] Huang Yan, Zhao Bo, Tao Mingliang, Chen zhan ye, Hong Wei. Synthetic aperture radar anti-jamming technology review [J]. Journal of radar, 2020, 9 (01): 86 – 106.
[4] Yang Yabo. Design of radar jamming signal acquisition and analysis system [J]. Radar and countermeasures, 2019, 39 (04): 18 - 20.