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The Algorithm of CFNN Image Data Fusion in Multi-sensor Data Fusion

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Abstract: CFNN hybrid system in Multi-sensor data fusion introduced fuzzy logic reasoning and neural network adaptive, self-learning ability, and using fuzzy neurons, so networking skills appropriate to adjust the input and output fuzzy membership function, and can dynamically optimize fuzzy reasoning in global by means of compensated logic algorithm, to make the network more fault tolerance, stability and speed up training. This paper introduces a mathematical model of the image data fusion, and elaborates CFNN image data fusion algorithms, simulation results show that this method can significantly improve the quality of the image data fusion, data fusion with other existing algorithms have a very significant effect.

Keywords: Multiple sensor, CFNN, Image data fusion, Image filtering, Simulation experiment.

1. Introduction

Multi-sensor technology is used for the detection object with different sensors and the different processing methods, in order to obtain more comprehensive detection information, and to improve detection accuracy and reliability. In the multi-sensor data fusion system, the sensor management includes two aspects, one is how to optimize existing sensors to better achieve the integration task, the second is how to eliminate the external environment changes or fails to bring some sensors effects [1]. Multi-sensor system, the information is indicative of the diversity, complexity and large capacity, information processing is different from the single sensor processing technology, the current, multi-sensor data fusion technology has become an important area of research. With the traditional multi-sensor data fusion method, artificial neural network technology has a good fault tolerance, self-organization and self-adaptability, while fuzzy theory in the field in itself a cause of great concern, fuzzy logic mimics human brain for processing model unknown or imprecise control problems, artificial neural network and fuzzy theory is actually a combination of structure and function of the human brain simulation.

2. Compensation Fuzzy Neural Network (CFNN)

2.1. The Principle of CFNN

Fuzzy system is composed by fuzzy generator, knowledge base, fuzzy inference engine, anti-blur components. Generator will blur the domain U maps each point on the fuzzy set on 'U'; fuzzy inference engine based on fuzzy rule base and fuzzy inference

knowledge generated by the fuzzy sets based on fuzzy logic inference and implication relations rules inferred fuzzy set theory on the domain, and then by anti-fuzzy controller to each point on the map is 'V'. Shown in Fig. 1.

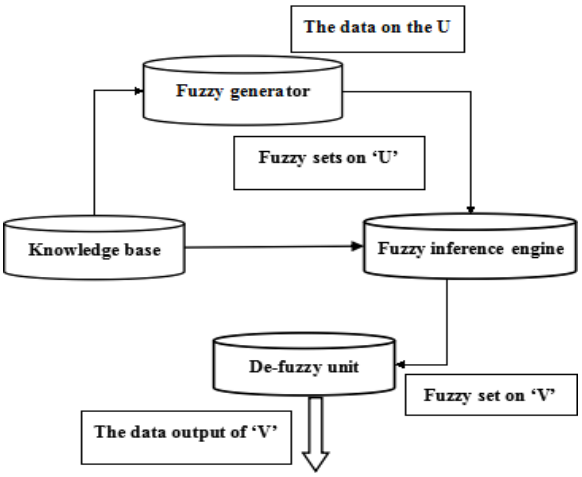


Fig. 1. Fuzzy logic system.

CFNN combination of fuzzy logic system and neural network features in the fuzzy neural network based on the introduction of a variety of fuzzy neurons, including neurons fuzzy, fuzzy reasoning neurons, anti-fuzzy neurons, compensatory fuzzy neurons. Among them, the compensatory fuzzy neuron has negative and positive, so the training data for computing operations to include passive and active operations. Negative fuzzy neural input xi can be mapped to the worst output for the development of a conservative worst-case decisions, such as taking the entered minimum; positive fuzzy neuron input xi can be mapped to the best output for the best case develop an optimistic decisions, such as taking the maximum input; compensatory fuzzy neural mapping the worst and the best input x2 x1 input to compensate for the output y, and is bounded in the worst case input and the best input to develop a relatively compromise measures [2], such as:

$$y = x1^{1-y} x2 , \quad (1)$$

which $y \in [0, 1]$, is the degree of compensation. Appropriate degree of compensation can accelerate learning speed and efficiency.

CFNN five-story structure, including input layer, fuzzy layer, fuzzy reasoning layer, compensation calculation layer, de-fuzzy layer. The first layer is directly connected to the input nodes, each node in the second layer represents a language variable value is calculated for each input vector of the linguistic values of the membership function of the fuzzy sets, the third layer of each node represents a fuzzy rule, and its role fuzzy rules are matched and calculate the degree of application of each rule, the fourth layer neurons through compensation calculation, the fifth layer Ambiguity and output. Between the layers is mainly based on the fuzzy logic system linguistic variables, fuzzy IF-THEN rules, the worst – the best computing, fuzzy reasoning methods, and build up the anti-blur function [3].

2.2. The Advantages of CFNN Applied to Multi-sensor Data Fusion

Compensatory fuzzy neural network technology applied to multi-sensor data fusion has significant advantages. First, the information CFNN unified storage in the network connection weights and coupling structure, which makes the sensor information and data representation with a unified form, it is easy for the information and data management, but also facilitates the establishment of a knowledge base. Secondly, CFNN effective artificial neural networks and fuzzy logic technology combines the information processing has a strong fault tolerance, if a sensor is faulty or the detection failure, CFNN strong fault tolerance can ensure detection system to work properly, and the system output and reliable information. Again, the compensation fuzzy neural network has a strong self-learning, adaptive and self-organizing feature enables the system to adapt to the ever changing environment and uncertainty detection information. Finally, the compensation fuzzy neural network parallel architecture and parallel processing mechanism makes information processing speed is very fast, able to meet the requirements of real-time processing information.

3. CFNN and Multi-sensor Data Fusion

The multi-sensor information fusion, with information redundancy, complementarity, real-time, low-cost sexual characteristics. In the multi-sensor system, each sensor information provided to some extent with some uncertainty, for this uncertain information fusion process is actually an uncertain process of reasoning. Multi-sensor information fusion can be more comprehensive and more accurate information. Based on different reasoning methods, multi-sensor information fusion are Bayesian estimation, Kalman filtering, DS evidence reasoning, fuzzy reasoning and neural network technology and other methods [4]. Using fuzzy sets and fuzzy reasoning membership functions to represent uncertainty reasoning. Multi-sensor data fusion technology with traditional, single sensor information processing technology the most significant difference is the multi-sensor information with a more complex form, the information can be fused at different levels, and integration.

Mapping data fusion model contains world space, measure space, pre-integration space, target space, described by W, M, M ', O. They linked together by three kinds of maps which can be expressed by S, P,

F. Among them, the mapping S is the use of multi-sensor external world space W to obtain the original data object to be recognized component test space M, P is the mapping of these raw data preprocessing constitute pre-fusion space M', while the pre-integration of spatial data through the complete integration task mapping F, and then get the target space.

$$W=\left[\begin{array}{cccc|cccc} W_{11} & W_{13} & \ldots & W_{1n} & E_{1(n+1)} & E_{1(n+2)} & \ldots & E_{1N} \\ W_{21} & W_{22} & \ldots & W_{2n} & E_{2(n+1)} & E_{2(n+2)} & \ldots & E_{2N} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ W_{m1} & W_{m2} & \ldots & W_{mn} & E_{M(n+1)} & E_{M(n+2)} & \ldots & E_{MN} \end{array}\right], \quad (2)$$

where W_{ij} represents No.'j'character of No.i target in external world of space, n represents the number of targets, m means that for a single target, E_{ij} means that we are concerned with an environment variable. We are most concerned about is the maximum number of features, so the matrix will have a lot of elements are zero.

The following matrix is measured space matrix at time't'.

$$M_t=\left[\begin{array}{cccc|cccc} D_{11} & D_{12} & \ldots & D_{1K} & S_{1(k+1)} & S_{1(k+2)} & \ldots & S_{1K} \\ D_{11} & D_{11} & \ldots & D_{2K} & S_{2(k+1)} & S_{2(k+2)} & \ldots & S_{2k)} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ D_{L1} & D_{L2} & \ldots & D_{LK} & S_{L(k+1)} & S_{L(k+2)} & \ldots & S_{Lk} \end{array}\right], \quad (3)$$

where D_{ij} represents the 'i' type of sensor in the j-th sensor raw data obtained, the number 1 indicates the type of sensor, k represents a type of sensor in the largest number of sensors, S_{ij} represents the amount of the external environment for the sensors in the raw data these raw data may be temperature, humidity and other data, it could be intelligence, situational and other semantic content. Matrix will also have a lot of elements are zero. And there is:

$$Mt=S(W), \quad (4)$$

After mapping M_t to P:

$$M_t=\left[\begin{array}{cccc|cccc} P_{11} & P_{12} & \ldots & P_{y} & S_{1(y+1)} & S_{1(y+2)} & \ldots & S_{y} \\ P_{21} & P_{22} & \ldots & P_{2y} & S_{2(y+1)} & S_{2(y+2)} & \ldots & S_{2y} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ P_{x1} & P_{x2} & \ldots & P_{xy} & S_{x(y+1)} & S_{x(y+2)} & \ldots & S_{xy} \end{array}\right], \quad (5)$$

The fact is that M'_t is the original measurement data after the formation of the pre processed data.

$$M'_t=P(M_t), \quad (6)$$

Data fusion at the pixel scale, P mapping into one-one mapping, target space is:

$$O=(C1\ \ C2\ldots\ldots Cc)T, \quad (7)$$

The target space is composed of the fusion result, as:

$$O=F\left[\sum_{t=0}^{NT} M'\right]t, \quad (8)$$

where T is the observation interval.

According to the problem of sensors management in data fusion, this paper presents a method of sensor management based on compensatory fuzzy neural network [5], as shown in Fig. 2.

The figure shows, first obtained by the external world space sensor array and environmental sensor data, and information obtained under environmental sensors, combined with the knowledge base of storing data, using the model developed in this logic sensor data fusion groups, including sensor selection, configuration and performance of the sensor between them in space and time coordinated. This eliminates the environmental changes on the negative impact of data fusion, and then the sensor array data were fuzzy inference layer, anti-fuzzy layer parameters for data selection. The method of image fusion evaluation information to the fusion rule selection and parameter selection process, we can more fully utilize the information provided by the information source, the fusion effect than other image fusion method has more advantages.

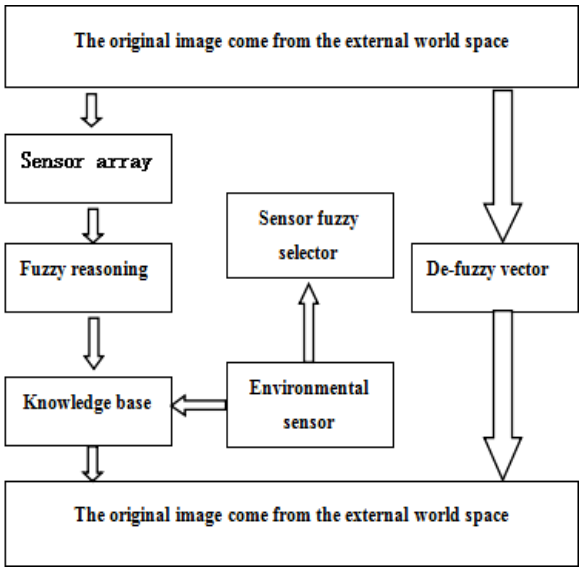


Fig. 2. Methods of sensor management based on CFNN.

4. Image Fusion at Pixel Level in Multi-sensor Fuzzy Neural Network

In the multi-sensor information fusion system, the multi-sensor image fusion system is an important component of its mainly for image information multi-sensor information fusion system. For the image fusion process generally includes the following aspects: the image pre-processing, such as noise

removal, image align etc.; determine image fusion algorithm; selected characteristics, recognition, image understanding and so on. Currently, multi-sensor image fusion process fusion algorithm commonly used in the weighted average method, multi-resolution tower algorithm, wavelet transform, Kalman filtering algorithm, image display technology, including gray-scale display, true color display, false color display, some scholars will be displayed the same way as fusion algorithms are combined in the further course of the displayed image complete fusion, so there have been false color space law and law.

4.1. The Characteristic of Image Fusion at Pixel Level in Multi-sensor Fuzzy Neural Network

Pixel-level multi-sensor image fusion fuzzy neural network is characterized by: the use of its inherent parallel architecture and parallel processing; knowledge distributed storage; have a strong fault tolerance, adaptability and self-organization. Network knowledge representation and network knowledge acquisition process will be completed concurrently, so the execution can be speeded up. In the process of logical reasoning, but also according to the actual needs of the network parameters through learning and training adaptive adjustment, so pixel-level multi-sensor fusion is a kind of fuzzy neural network has a strong adaptive ability of reasoning; in the real world, the image is inevitable presence of noise, the noise may even cause loss of information, in this case, the fuzzy neural network convergence in a reasonable manner to be reasoning. Image fusion, fuzzy neural network trained to treat every pixel of an image become separated several categories, so since, each image pixel has a membership function vector group, feature extraction and feature as inputs to participate fusion [6]. Currently, most of the fuzzy neural network is implemented using digital simulation, which uses software and digital signal processing chip to simulate and calculate.

Image fusion technology can be used from different sensors gray scale image synthesizing a fused image, the new image contains most of the information of the original image two. The basic idea of this algorithm is: When the corresponding pixels of two images are similar, the pixels of the composite image on the use of the average of two pixels, if the corresponding pixels of two images, there were significant differences, then select one of the most notable pixel points as synthetic image pixels [7]. In order to significantly pixel comparison of the image usually requires a significant defined matrix. Often using the weighted average method for image fusion, eclectic method is simple and intuitive for the real-time processing, but the short answer will reduce the composite image superimposed signal to noise ratio, when fused image gray difference is large, there will be significant splicing traces, is not conducive to the human eye recognition and subsequent target identification process. Taking into account the SNR of the image fusion can be used to define the compensatory fuzzy neural network algorithm in some weights.

4.2. Structure of Image Filter

Noise image filtering image processing is the most challenging problem [8]. The traditional filtering methods are mainly median filter, since the introduction of filtering, these methods remain on the filter effect and details are not ideal, and even unable to meet the actual demand, the following binding principles CFNN 2.1 and 4.1 pixel level multi-sensor fuzzy neural network algorithm for image fusion characteristics and the basic idea of the design is based on CFNN image filter.

In many images, the neighboring pixel highly correlated, and the correlation between the pixel distances is relatively weak, based on this, to create in the target pixel as the center of the filter window, the window of the target pixel outside the ignored. Filtering window can be created as a 3×3 or 5×5 pixel window, Fig. 3 shows the 3×3 pixel window. In general, the larger the pixel window, the filter more abundant information available, the higher the accuracy. But with the increase of network nodes, it will grow exponentially parameters to be optimized, the system will also dramatically increase the size and complexity of network learning and training levels will also increase rapidly.

X1	X2	X3
X4	X5	X6
X7	X8	X9

Fig. 3. 3×3 filtering window.

If the gray-scale image of 256 gray levels, can be used to filter CFNN, is to filter window non-center pixel gray value as input via the network fuzzy reasoning and self-organization, self-learning, to achieve each input fuzzy Weighted and compensation calculation, and then get the window after de-fuzzy center pixel gray value and as an output.

In this image filter structure, the first layer is the input layer, and each node is directly connected to the input, where the center pixel of the filter window African gray value as input.

The second layer is fuzzy layer. Fuzzy input vector is the process by the gray value of its space to the fuzzy space, directly affects the fuzzy image filtering effect. Here, the signal can be obtained through membership functions membership. For the membership function selection, you can have a variety of ways, there will be a Gaussian function as the membership function, the function formula is the following:

$$Ui = f(xi) = \exp[-(\frac{xi - \alpha}{\beta})^2], \quad (9)$$

where xi is the input pixel gray value, α is the membership function center, β membership function width. α, β determines the value of membership function in the form, but also determines the blur effect. α, β for the need to learn the parameters in the fuzzy neural network training to get its optimum value.

The third layer is a layer of fuzzy inference, and fuzzy rules as follows:

R_k: if x_1 is A_{1k} and ...and x_n is A_{nk}

$$y=B_k^{[3]}, \quad (10)$$

where A_{ik} is the fuzzy sets on input domain U, B_k is the output fuzzy sets on the domain V, k represents No. k rule, k is 1,2,3, ..., m, of which m is the total number of rules.

The degree of application of fuzzy inference rules expressed by w, then the degree of application for the No. k rules is:

$$W_k = \prod_{i=1}^{n} u_{ik}, k = 1,2,...m, \quad (11)$$

The fourth layer is a compensation layer, by compensating the negative neurons, positive compensation calculation, the fuzzy inference input and output membership functions to compensate, to quickly reach the optimal value. In the fuzzy filter design, definition negative computation of No.k fuzzy rules is:

$$u_k = \prod_{i=1}^{n} uA_{ik}(x_i), \quad (12)$$

Active computation is:

$$u_k = \prod_{i=1}^{n} uA_{ik}(x_i)]^{1/n}, \quad (13)$$

Compensate computation is:

$$uA_{ux}..xn_k = u_k^{1-y} v_k^{y} = [\prod_{i=1}^{n} uA_{ik}(x_i)]^{1-y+y/n}, \quad (14)$$

where y is the degree of compensation, this system uses a single-valued fuzzy, so

$$u_{bk}(y) = [\prod_{i=1}^{n} uA_{ik}(x_i)]^{1+y+y/n}, \quad (15)$$

The fifth layer is the de-fuzzy sets, in which the main center is gravity de-fuzzy method, de-fuzzy function is:

$$y = \frac{\sum_{k=1}^{m} \xi_k \delta_k [\prod_{i=1}^{n} u_{Aik}(x_i)]^{1\ y+y/n}}{\sum_{k=1}^{m} \xi_k [\prod_{i=1}^{n} u_{Aik}(x_i)]^{1\ y+y/n}}, \quad (16)$$

The fuzzy neural network filter from the input and output data collection system to generate fuzzy rules and fuzzy reasoning, fuzzy, fuzzy set parameters such solution is the use of neural networks self-learning and memory function to store, learning and optimization. Therefore, the image filter is single-valued fuzzy generator, Gaussian membership function, product inference rule, negative-positive as well as the center of gravity de-fuzzy compensation calculation is constituted compensation fuzzy neural network image filter [9].

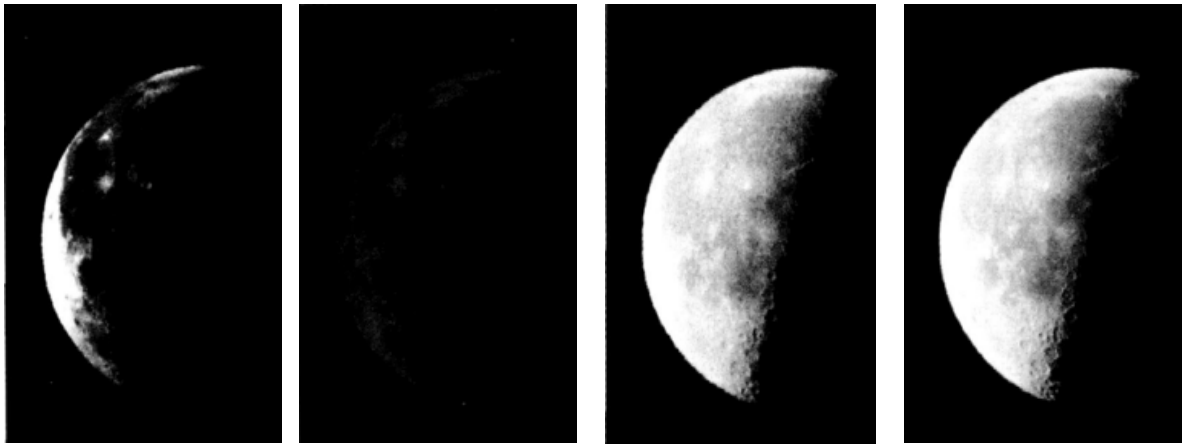
5. Simulation

In order to verify the effectiveness of the filter based CFNN image , can be simulated MATLAB [10], used with a 256 gray level standard 256×256 pixel image A and image B standard as training images. We know that in the original image data fusion alone can not clear the noise points and image data points, but also did not identify the presence of the noise signal, where the signal to noise ratio is only one measure of image quality indicators. During the experiment , the choice of 3×3 filter window, so the neural network input node 8, in order to calculate the signal to noise ratio. This will signal to noise ratio as CFNN image filter based on fuzzy neural network that is pixel-level image fusion algorithm in image fusion process control indicators, but also as a comparison of different data fusion methods of image quality of the merits of quantitative indicators. In the experiment used the original image A and image B simulate the original image data obtained from different sensors, respectively, using the weighted average method and fuzzy neural network for pixel-level multi-sensor image fusion, can be seen from the Fig. 4, based on fuzzy neural network pixel-level multi-sensor image fusion, or both in the visual effects on the signal to noise ratio than the weighted average method has more advantages, which can be based on the CFNN pixel-level multi-sensor image fusion with high feasibility and effectiveness.

6. Conclusions

Any system can be seen as a mapping process from one space to another, data fusion system is also like this, data fusion system can be seen as a space for the outside world to the target space mapping process. Multi-sensor data fusion technology is the result of the development of sensor technology and information processing technology, not only is the

information fusion and integration, also integrate lots of information processing methods and techniques together, and comprehensive analysis. This paper focuses on the shortage of the traditional image filtering method in the filtering results, designed a new image filters based CFNN, and applied CFNN to multi-sensor data fusion, has obtained the good simulation effect for the multi-sensor data fusion provides a new development ideas.



(a) Original image A (b) Original image B (c) By weighted average method (d) Fuzzy neural network fusion image

Fig. 4. The simulation illustration.

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