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Intelligent Garbage Bin Classification System Based on Deep Learning

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Abstract

With the rapid development of science and technology, people's living standard has been greatly improved, and the garbage in urban life is also increasing rapidly. A large amount of garbage is transported to landfill or incineration outside the city, only part of the garbage is harmless treatment, garbage processing speed is slow and the intelligent level of garbage classification is low. How to realize the fast classification of garbage has become an unavoidable problem for the country and even the world. Therefore, this paper proposes the design of garbage bin intelligent classification based on deep learning. The specific method is as follows: The NB-IOT technology is used to build intelligent garbage bin monitoring network, and the convolution neural network is used to build garbage intelligent classification model and classification algorithm. The simulation results show that the classification algorithm has fast response speed and high accuracy.

Keywords

Garbage classification; Deep learning; NB-LOT; BP neural network; Convolutional neural network.

1. Introduction

The topic mainly analyzes the domestic and foreign waste classification, and discusses the research status of intelligent garbage can. A remote monitoring network of garbage cans based on NB-IOT was built, and the overall structure and hardware control system circuit of garbage cans were designed. In terms of software, garbage images are preprocessed and feature extraction of garbage images is completed. Texture, shape fusion feature and HSV color feature are respectively taken as input samples of BP neural network to complete BP neural network training. On the other hand, The network structure of the last three layers of Alexnet convolution neural network model is modified, and the garbage RGB image is taken as the input sample of Alexnet convolution neural network for transfer learning, so as to build the garbage intelligent classification model.

Matlab was used to conduct simulation experiments on intelligent garbage classification. The simulation results of intelligent garbage classification based on convolutional neural network were compared with BP neural network and other traditional intelligent classification methods. Classification and discrimination tests were conducted on 90 test samples.The results show that the accuracy of the migrated convolutional neural network for garbage image classification reaches 100%. Compared with the traditional BP neural network image classification (accuracy around 70% >), the migrated convolutional neural network has faster training speed and higher recognition rate.The results show that the transfer learning algorithm of convolutional neural network has potential application value in the intelligent classification of garbage images.

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2. Current Situation at Home and Abroad

In today's society of saving and environmental protection, it is necessary not only to deal with the increasing amount of garbage, but also to recycle the available resources in the garbage.Garbage classification is not only an efficient method of resource recovery, but also a social problem related to people's livelihood and sustainable development.However, at present, the sorting bins in China are only printed with the words "recyclable bins" on the box body, and there is no clear explanation on how to classify garbage. In addition, China's propaganda on environmental protection is not in place, and citizens' lack of environmental protection awareness, resulting in the placement of sorting bins on the street is practically empty.

At present, the academic circles of our country have made researches on the treatment of domestic garbage in multi-disciplinary fields.Some scholars have investigated and evaluated the economic value of garbage sorting in daily life. The survey shows that garbage recycling can not only protect the environment, but also bring considerable economic benefits. Most residents are supportive of garbage recycling when interviewed about whether they have the willingness to pay.In psychological research, Lu Xianfeng analyzed the influence of individual internal factors and objective factors such as law and education on urban residents in garbage classification. The results showed that a single factor was weak in improving urban residents' environmental awareness, and multiple mechanisms were needed to work together.There are also some invention patents on smart garbage cans, such as an automatic garbage can based on capacitive sensor principle, which can distinguish garbage by sensing its dielectric constant;There is also some research on intelligent control of trash cans, using speech recognition to control trash cans.For example, scholars put forward the use of pattern recognition technology to carry out automatic classification, and elaborated the technical support and implementation method of the conceptual design of automatic classification garbage can, and realized the source control.

Japan is among the best in the world when it comes to sorting waste. This is largely due to their propaganda and education on garbage classification. Japanese children receive education on environmental protection from an early age and use their own garbage bags to carry garbage in public places such as buses and subways. In terms of classification methods, Japanese garbage classification is more meticulous, which is divided into five categories: combustible, non-combustible, resource, coarse and harmful. The coarse category includes old larger electrical equipment, etc. Resources include plastic bottles, cans and other renewable resources.

As an economic power with a large population, the United States is also a large garbage producer. However, it is different from China in garbage treatment. American residents will participate in garbage classification in their daily life. The US government has even developed waste separation and recycling as an industry, which can not only provide jobs and reduce waste disposal capital, but also create billions of dollars of wealth from it. The U.S. government provides separate trash cans for neighborhoods and streets, and arranges for people to clean them up in a timely manner. The entire process is done jointly by the government and residents.

In the research of smart trash can, a lot of progress has been made in foreign countries, such as two-dimensional code printed on garbage bags, smart trash can scan to obtain garbage information and then automatically classify; There are also microcontroller applied to the garbage can control its automatic switch; For example, South Korea has designed a sorting bin from the entrance of the bin, so that only the rubbish of a specific shape can be thrown in. Although some progress has been made in the research on garbage cans both at home and abroad, the currently widely used classified garbage can is still the most common one, and the popularity of smart garbage cans has not been improved.

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3. The Overall Design of Intelligent Classification Trash Can

3.1. Overview of Intelligent Sorting Garbage Cans

Subject classification ash-bin intelligent monitoring system is described based on design and implementation of NB - IOT communication technology, installed in a trash can internal perception of data from the sensor node to the trashcan capacity and trash can switch information uploaded to the server through the NB - IOT communication, such as the server will then transfer the perception layer up data processing,Send command information to the terminal according to the obtained information.There will be an alarm when the garbage can is full or broken, and the sanitation department can obtain the information of the garbage can through the server and recycle the garbage in time.

3.2. Overall Structure of Intelligent Classification Garbage Bin

The intelligent classification garbage bin designed in this paper is mainly composed of image acquisition module, power module, perception module, microprocessor, communication module, motor and classification module.

1) Collection module: it is installed at the entrance of garbage bin to collect image data of garbage.

2) Classification module: a classifier trained by neural network for the classification of recyclable garbage, which is the focus of this paper.

3) Perception module: this module is mainly composed of basic sensors to obtain the storage information, switch information and positioning information inside the garbage can.

4) Power module: provides stable power supply for the whole system.

5) Microprocessor: used for data processing and sending commands to control the operation of the whole equipment.

6) Motor: installed at the bottom of the trash can to drive the rotation of the trash can cover. There is a groove on the trash can cover and a valve at the bottom.When the garbage classification result is battery, the control motor will rotate the groove with battery to the corresponding garbage classification sub-bucket position.

7) Communication module: used for information transmission and remote monitoring.

3.3. The Key Technology

Internet of Things technology is a technology that uses a variety of sensors to connect objects to the Internet according to specified communication protocols, so as to realize the connection between things.The core of this technology is still what we know as the Internet, which is an extension of Internet technology.The traditional Internet of Things is the Internet of Things based on RFID radio frequency technology. After a long time of evolution, the current Internet of Things integrates sensor technology, RFID technology and other technologies.In practical applications, sensors are embedded in physical objects such as air conditioners, power grids and trash cans, and integrated with the Internet to achieve remote management and control of life.

The Internet of Things is generally divided into three layers according to the functional layer, namely, the perception layer, the network layer and the application layer.

(1) As the basic level, the task of the perception layer is to collect the information of objects. In this project, it mainly collects the storage capacity of the garbage can and the switch status and positioning information of the intelligent garbage can equipment.

(2) As the middle layer, the network layer uses wireless transmission to complete the transmission and exchange of information between the perception layer and the application layer.

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(3) The application layer is the top layer of the whole network, and its main function is to store and analyze the data transmitted by the perception layer.Based on the results, issue instructions to the next two layers.In the smart trash can designed in this topic, the application layer has the following three functions:

① Analyze and store the data uploaded by the perception layer, such as the switch information of the smart garbage bin, the capacity information of the garbage bin and other work information.

② Alarm message will be sent if the garbage can is full or out of order, and the alarm can be set by SMS or APP to remind the staff.

③ After receiving the fault alarm, the staff can manually issue instructions to control the garbage can function module and verify whether there are false positives.

In Internet communication, communication modes are generally divided into wireless communication and wired communication [].Wired communication is through optical fiber, metal wire communication, its advantage is relatively stable in the process of data transmission, has a strong anti-interference ability.Disadvantages are due to the use of optical fiber or metal wire as a carrier, the cost is relatively high.Wireless communication mainly uses electromagnetic wave as the carrier to receive and send information, which is cheaper and more convenient, but has less anti-interference ability than wired transmission.This topic chooses the NB-iot wireless transmission mode.

At present, there are 2g, 3G, 4G telecommunication networks, wifi, ZigBee wireless network, and the NB-IOT communication developed in recent years.

(1) The advantages of 2G, 3G and 4G telecom networks are that their transmission speed is relatively fast, which can reach 1-10OMBps. Long-distance transmission costs are expensive, and they are generally used in mobile phones, laptops and other electronic devices.

(2) The transmission rate of WFI communication is 11-54Mbps, and the transmission distance is generally 10-100 meters. At present, this kind of communication method is relatively popular. Whether shopping malls, schools or companies, as long as there is a large flow of people, almost there will be wifi network coverage to meet people's wireless network life, but this kind of communication method has low security.

(3) Zigbee is a wireless sensor device with a transmission speed of 100KBps, low power consumption and cost, but a short transmission distance of only tens of meters. It is generally applicable to a large number of wireless sensor networks with small spacing.

Network architecture for NB-iot technology:

NB-IOT networks typically consist of terminals (UE), base stations, core networks, IOT platforms, and application servers.

The terminal device (UE) is connected to the base station eNodeB and the core network (EPC) through the air port.The core network interacts with the non-access layer of the terminal and forwards the collected data to the iot platform for processing.The IOT platform transmits data from the grassroots to the application server. The application server communicates with the IOT platform through HTTP or HTTPS and controls terminals through the IOT platform.

The intelligent classification garbage cans designed in this paper are characterized by a large number of garbage cans, less data to be transmitted and longer standby time. Compared with the traditional LTE network, the characteristics of high broadband and high response speed, low price and low power consumption of NB-iot meet the requirements of this design.

4. Intelligent Classification Algorithm of Garbage Image

The quality of dustbin intelligent classification module is the key factor to check the dustbin classification. An intelligent classification dustbin with low classification ability is worthless.

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How to improve the accuracy of garbage classification is the focus of this paper. In this paper, the transfer learning of Alexnet convolutional neural network is used to build an intelligent garbage image classification model, and it is compared with the traditional artificial neural network algorithm (BP neural network), indicating that convolutional neural network has greater advantages in garbage image classification.

The processing flow of the conventional BP neural network image classification algorithm is shown in Figure 1:

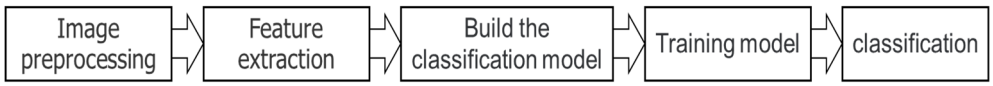

Figure 1. Classification flow of BP network

4.1. Advantages of Cloud Based Storage

1. Gray processing: In daily life, the images that people can see directly are generally color maps or RGB images. RGB images have R, G and B channels, and any color of the images we see is mixed by these three channels (red, green and blue) in a certain proportion. If we analyze a color photo and enlarge it to the extreme, we will find that the original color picture is composed of countless small square blocks of pigment points, each of which is formed by the proportion of R, G and B colors. We call this small square block of pig ment points as pixel points, which is the basic unit of an image.

Original Grayscale

Figure 2. Contrast image before and after gray processing

The RGB of general image is only the color distribution in optics, which reflects the morphological characteristics of the image. Grayscale image and HSV image are inferior to grayscale image and HSV image. Therefore, before image feature extraction, grayscale processing should be performed on RGB image to transform 3D image into grayscale image. Such grayscale image is a two-dimensional array composed of black pixels of different depths, which is a component of 3D RGB image.After the original color image is transformed into a grayscale image, the original three channels become one channel, where each pixel is represented by the magnitude of 0~255 to represent the grayscale image's grayscale value. Different from RGB image, each pixel of grayscale image has only one grayscale value. The calculation formula for transforming RGB images into grayscale images is as follows:

$$gray = 0.299 \times R + 0.587 \times G + 0.144 \times B \tag{1}$$

The comparison figure after gray processing is shown in 2.

2. Mean filter denoising: Filtering is defined as a technology that shields signals of other useless frequencies to retain useful information when receiving signals of a specific frequency in order to prevent interference from other frequencies. In the process of image shooting, due to the existence of external factors, the image will contain some error information, which is called image noise, and the function of the mean value filter 12L is to weaken the other useless noise of the image. It works by calculating the mean of pixels in a region other than the center and

replacing the center point with this mean. For example, in a 7×7 pixel area, which is composed of a central pixel point and a total of 48 pixels points around it, the average value of the 48 pixels points is calculated first, and the obtained mean value is used to replace the center value. The entire image is then replaced in this way so that the noise in the image is reduced. This method can remove some weak noises in the image and make the image smooth. Compared with other methods, this filtering method is easy to understand and fast in image processing. Mean filtering has a good effect on eliminating Gaussian noise. In addition, in the image sampling of intelligent classification garbage cans, gaussian noise is easily generated due to external light and other problems. Therefore, mean filtering is used in this paper to filter images, and the effect comparison is shown in Figure 3.

Original Gaussian noise Mean filtering

Figure 3. Comparison of filtered images

4.2. Feature Extraction of Garbage Images

1. Extraction of texture features: Texture feature is one of the most important visual features of images, which can reflect the structural features of images. It is mainly reflected in the distribution law of image pixels in gray space. This distribution law is a measure of the local area of the image and is the characteristic attribute of the image itself in gray space. Texture features have its advantages and disadvantages, its advantage is that it is the statistics of pixels in gray space, rotation invariance and hierarchy, has a certain anti-noise ability, the disadvantage is that the change of image resolution will affect the image texture features, even false features caused by external interference. Through the visual perception of the image, we can find that the roughness of the image and the direction of the arrangement are the two main factors to distinguish the texture of the image.

Texture is a measure of the distribution law of pixel gray value in local space, so there will also be spatial distribution relationship between two pixels separated by a certain distance in the neighborhood space of an image. Gray co-occurrence matrix (GLCM) is a method that can extract texture features by studying the spatial distribution characteristics of gray in images.

GLCM are two specific distance apart, through the statistical characteristics of the Angle of the same number of pixels, and then represented in the form of matrix, this new form of matrix became gray level co-occurrence matrix, such as the horizontal direction, the distance of 1 co-occurrence matrix GLCM (1, 1) the value of the figure is expressed as the original pixels horizontally adjacent pixels as the logarithm of 1, GLCM (1,2) represents the logarithm of the occurrence of (1,2) of adjacent pixel pairs in the horizontal direction [24], so it can be known that the gray level co-occurrence matrix is a symmetric matrix. The change speed of texture feature of an image is inversely proportional to the value on the diagonal of GLCM. When calculating the eigenvalue of GLCM, we generally calculate its gray level co-occurrence matrix from four directions: 0°, 45°, 90° and 135° respectively.

$$P_{0°d(a,b)} = |\{[(k,l),(m,n)] \in D: k-m=0, |l-m|=d, f(k,l)=a, f(m,n)=b\}| \quad (2)$$

$$P_{45°d(a,b)} = |\{[(k,l),(m,n)] \in D: (k-m=d, l-m=-d) \cup (k-m=-d, l-m=d), f(k,l)=a, f(m,n)=b\}| \quad (3)$$

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$$P_{90°d(a,b)} = |\{[(k,l),(m,n)] \in D: |k-m| = d, l-n = 0, f(k,l) = a, f(m,n) = b\}| \quad (4)$$

$$P_{135°d(a,b)} = |\{[(k,l),(m,n)] \in D: (k-m = d, l-n = d) \cup (k-m = -d, l-m = -d), f(k,l) = a, f(m,n) = b\}| \quad (5)$$

It can be seen from the above that the larger the pixel magnitude of an image is, the larger the gray level co-occurrence matrix will be. Therefore, the gray level co-occurrence matrix is a matrix with a large amount of data, which is generally not used as a feature to distinguish textures. Therefore, the dimension reduction of the feature matrix is required by statistical method. The features calculated based on the gray level co-occurrence matrix generally include energy, color, contrast, uniformity, correlation, variance, and average, and variance, color, difference variance, difference average, difference color, and correlation information, etc. The features extracted in this paper are energy, contrast, correlation, color mean and standard deviation.

(1) contrast

Contrast mainly describes the brightness contrast of a pixel in an image and its adjacent pixels, reflecting the clarity of the texture in the image. The higher the contrast, the clearer the visual effect of the texture in the image, and the lower the contrast, the more blurred the visual effect of the texture in the image. The calculation formula is as follows:

$$Con = \sum_i \sum_j (i-j)^2 P(i,j) \quad (6)$$

(2) energy

Energy reflects the uniformity of gray information distribution in the image. The larger the value is, the more uniform the gray distribution of the image is, and the smaller the change of gray value is. The smaller the value is, the more uneven the gray distribution of the image is and the greater the change of gray value is.

$$Asm = \sum_i \sum_j P(i-j)^2 \quad (7)$$

(3) entropy

As a method of measuring the amount of information contained in an image, the entropy of texture information in an image is described. The higher the value of the lineal state, the higher the non-uniformity of the image, and the lower the value of the lineal state, the lower the non-uniformity of the image.

$$Ent = \sum_i \sum_j P(i,j)\, logP(i,j) \quad (8)$$

2. HSV color feature extraction of garbage images:

(1) HSV color space

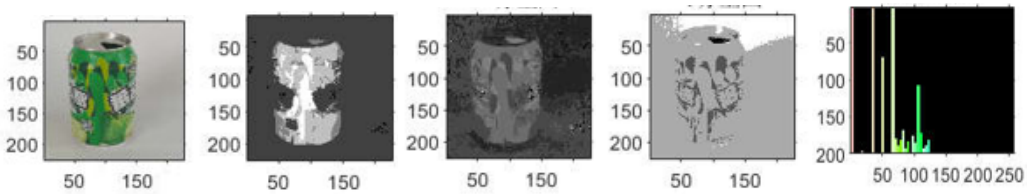
Last century, A.R. Smith proposed a new color space to replace the traditional RGB space, which is called HSV color space. HSV color space is three-dimensional, which is different from RGB space. HSV model is similar to a hexagonal cone shape with H, S and V components.

(2) Color features

Color features there are many commonly used color features are: color histogram, color moment, color set, color correlation graph, color aggregation vector.

① Color histogram

Color histogram is an intuitive description of the distribution of various colors in the image. It belongs to a statistical concept and has no necessary connection with the location of colors. This feature is widely used in image retrieval. Algorithm 2 in this paper mainly takes the color histogram of HSV as the image feature, and its effect is shown in Figure 4.



Original S component H component V component Color histogram

Figure 4. Color histogram

② the color set

The color set is similar to the color histogram. It quantifies the HSV color space to obtain several binary bits, then divides the image into several small regions, and uses indexes in each small region, finally obtains a color index set.

③ color moment

By calculating the first, second and third moments of color and nine low-order moments of three components as the features of the image, this method is relatively simple, but its resolution is not as good as other color features.

④ Color aggregation vector

The color aggregation vector is evolved from the histogram, which can represent the color position of the image by comparing the color moment with the histogram.

⑤ Color correlation diagram

Like histogram, color correlator can express the distribution of certain colors in the image, but it can also express the spatial correlation of different colors.

4.3. BP Neural Network

1. Artificial neural network

In the 1980s, artificial neural networks gradually became the focus of scientific research. Artificial neural network is a network model constructed by a large number of neurons and the connection mode between different neurons. It is designed to simulate the way of brain neural network processing and remembering information to process information. The connection mode of neuron to neuron is represented by weights, which are obtained after network training in the later stage and store how artificial neural network recognizes information. Each neuron is followed by activation function, whose function is to control the output of each neuron through nonlinear combination of weighted inputs. Therefore, the output result of neuron is jointly determined by neuron connection mode, activation function and trained weight. The artificial neural network model is shown in Figure 5.

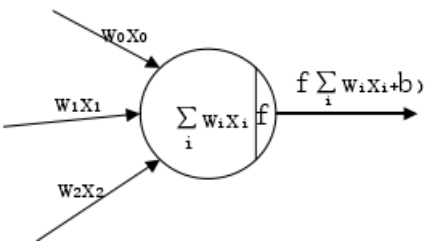


Figure 5. Arti ficial Neural Network Model

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In the figure, X0, X1 and X2 are neuron inputs, WO, W1 and W2 are weights, and F is activation function. Each set of input signals is multiplied by the weight before being output to the neuron at the next level to form the input of the neuron at the next level by the activation function.

Activation function is the condition that restricts the transmission from one neuron to the next layer. In artificial neural network, the output of neuron information to the next neuron needs activation function to determine whether the information is transmitted to the next layer. At present, the more common activation functions include sigmoID function, TANH function and ReLU function.

As mentioned above, the activation function plays a limiting role in determining whether or how a neuron outputs, which is similar to the output of biological neural network. Neurons need to reach a specific condition when transmitting information to the outside before they send out relevant signals. In an artificial neural network, this condition can be a threshold, and when the neuron input of the neural network reaches this threshold, it is allowed to pass on to the next neuron. The reason why artificial neural network is similar to biological neural network in processing information is largely due to the role of activation function. Here are a few common activation functions.

(1) SigmoID activation function

The function graph of activation function Sigmoid is shown in Figure 6:

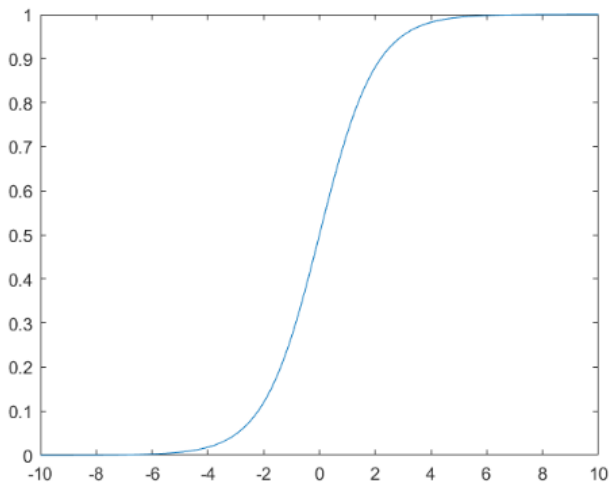

Figure 6. Simoid activati on function

$$\delta(x) = \frac{1}{1+e^{-x}} \tag{9}$$

As can be seen from the sigmod graph above, its output is in the interval of (0,1). In the past, sigmod was a relatively common activation function, often used for dichotomies. It can be seen from the graph that there are some defects in itself. If the input deviates slightly from the origin of coordinates, the gradient of the function will become very small, which is not conducive to the back propagation of the neural network. It may lead to almost no influence of the weight W on the loss function in the propagation process, which is not conducive to the optimization of the weight. This problem is also commonly referred to as gradient saturation.

(2) a tanh function

The graph of TANh function is shown in Figure 8:

As shown below, TANh is a hyperbolic tangent function, which is similar to the curve of sigmod function. It is obtained by translating the Sigmoid function through central symmetry. It solves

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the asymmetry problem of the center point of sigmoid function, and the output interval is (-1, 1).

$$f(x) = \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \tag{10}$$

Tanh function and Sigmoid function have the same disadvantages. When the input of the function is large or small, the output is almost smooth and the gradient is very small, which is not conducive to updating the weight. This function is commonly used in dichotomous problems, tanh for the hidden layer, and sigmoid for the output layer.

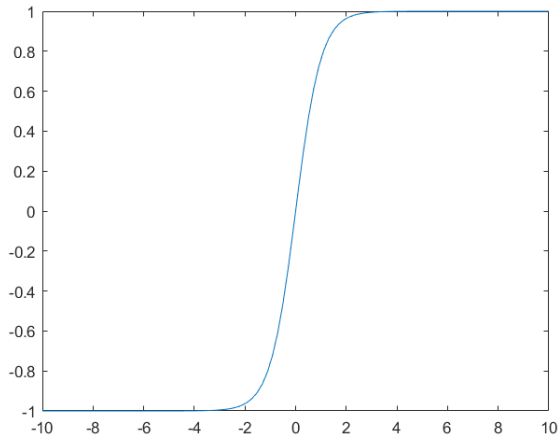

Figure 7. Activation function tanh

2. BP neural network algorithm

BP neural network is a kind of artificial neural network which is widely used at present. It is composed of forward and reverse propagation algorithms. Its structure is composed of input layer, hidden layer and output layer, and the connection between each layer is expressed by weight. When a group of input for the BP neural network, after dealing with the node will result and expectations do contrast, if the actual output and desired output error is not up to par, the BP neural network will enter the error back propagation phase, the neural network will be based on the forward propagation of error correction between the input layer, hidden layer and output layer weights, after repeated training, Stop training when the error is reached. These two propagation processes are called signal forward propagation process and error back propagation process. The whole process is the learning process of BP neural network. Its BP neural network model is shown in Figure 8:

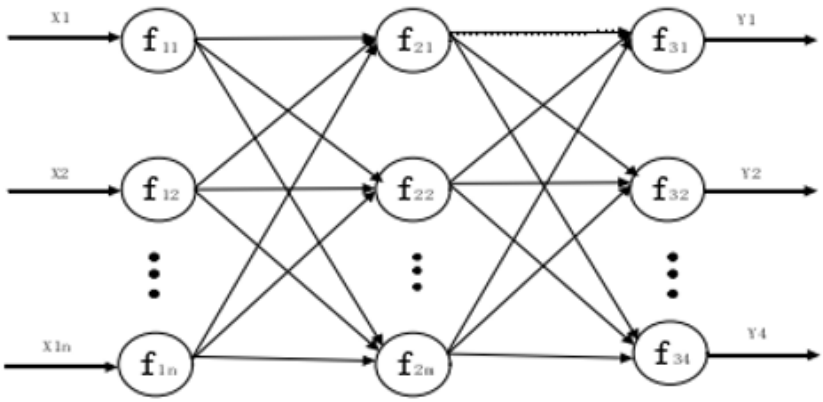

Figure 8. BP Neural Network Model

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In Figure 8, n and M respectively represent the number of neurons in the input layer and hidden layer. Since only four categories are selected for garbage classification in this paper, there are only four neurons in the output layer. Where [x1, X... 1n] is the input of BP network, and [Y14,Y2k, Y3k,Y4k] is the expected output. The connections between the layers are represented by weights.

3. BP neural network design

The structural design of BP neural network has a great influence on the performance of the whole algorithm, so how to determine the number of hidden layers, the number of neurons at each layer and the selection of network parameters in the design of BP neural network is crucial [37].

(1) Determination of hidden layers

The primary condition for the design of BP neural network is to determine the number of network layers, that is, the number of hidden layers. In the actual situation, we know that the three-layer network structure can achieve any nonlinear mapping. Increasing the number of network layers can improve the information processing ability of the whole BP neural network, but the disadvantage is that with the increase of the number of hidden layers, it will increase the difficulty of network training. Therefore, on the premise of meeting the requirements, the number of hidden layers should not be increased as much as possible, and the network performance should be improved in other ways.

(2) Determine the number of neurons at each layer

The number of neurons in the input layer of BP neural network is usually determined by the dimension of sample input, which should be able to describe the characteristics of things. In terms of image classification, we need to preprocess images before training to extract image features and minimize the dimension of sample input. The premise is that these features can accurately represent the image, if the extracted features can't represent the image then it can't achieve the expected results.

The number of neurons in the output layer is determined by the final output category. This paper studies four types of recyclable garbage classification, so the output layer is 4 neurons.

The number of neurons in the hidden layer is related to the number of neurons in the input and output layers. If the number of neurons in the hidden layer is too small, the whole network will lack the ability to process information; if the number of neurons in the hidden layer is too large, the training time will be prolonged and the generalization ability will be lacking. At present, some empirical formulas can be used to determine the number of hidden layer neurons

To determine the final number of neurons through appropriate adjustments during training.

(3) Setting network parameters

Set an appropriate initial weight, and the selection of the initial weight will affect the efficiency of the entire network training. If the initial weight is too large, the network will be saturated; if the initial weight is too small, the network will converge to the local minimum value. In general, the weight is between 0 and 1. The selection of the maximum training times can avoid too long training time. Other parameters, such as learning rate and learning algorithm, will affect the performance of the network.

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