Research on emotion recognition algorithm based on improved BP neural network

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Abstract. The application of small robots in the production of freeze frame animation can speed up the production progress and improve the quality of production. Small robots will play the role of intelligent agents. It is necessary to recognize their emotions for the promotion of animation films. With the development of intelligent technology, BP neural network has been applied to the field of emotion recognition because of its advantages of self-learning, self-adaptive and self-organization. In this paper, the parameters of BP neural network are adjusted and improved to avoid the defects of BP neural network in emotion recognition. Then, the parameters and structure of the network are designed according to the emotion category. Then a three-layer BP neural network with 4 input nodes, 13 hidden layer nodes and 4 output nodes is constructed. Finally, it is applied to emotion recognition, and 10 groups of data are selected from the training samples for detection, and the diagnostic accuracy is 80%.

1. Introduction
Stop-motion animation is one of the three main animation forms. Compared with the mainstream three-digital animation, stop-motion animation has the characteristics of simple process and operation[1]. However, in the process of production, manual operation requires frame by frame shooting, manual adjustment of actions and expressions, which leads to the irreversibility of the character's expressions and actions. The finished stop-motion animation works makes it impossible to realize the rich changes of the overall facial dynamic and facial expression dynamic and the delicate and coherent actions.

Therefore, The small robot is applied to the character making of stop-motion animation. The intelligent character can simulate human sensory feeling in the environment and feel various stimuli from the environment, including light, sound, smell, temperature and so on. These auditory, visual, taste, tactile and other sensory information stimulate different emotions[2]. In this paper, BP neural network is used for emotion recognition of small robot. This is because the neural network has the ability of non-linear relationship data processing, self-organization, self-learning and self adaptation[3]. Moreover, BP neural network has the advantages of parallel distributed processing, memory and fault tolerance, which can map the non-linear relationship of emotion system.

2. Related research
At present, emotion modeling and emotion recognition have been studied for decades. In terms of emotion modeling, Ortony et al.[4] proposed the emotion derivation model OCC model based on
cognitive evaluation theory. Based on the OCC model, Elliott implements an emotion inference engine system. Reilly and Bates [5] constructed a trustworthy agent system through emotion. Based on the study of the five factor personality model FFM, Ekman six basic expression theory and OCC model in psychology, Kshirsagar et al. [6] proposed using Bayesian trusted network to construct the personality model of virtual agent. Cathexis model developed by Velasquez of MIT artificial intelligence laboratory is the first complete computable emotion model [7]. The distributed and computable model could control the dynamic changes of various emotion phenomena (such as emotion, emotion, temperament, etc.), and provides a flexible method for emotion to affect the behavior changes of agents. Some researchers construct autonomous agents by simulating motivation and stimulation mechanism, as well as the physiological process of emotion. "Saya", which is an emotional robot developed by Kobayashi Research Laboratory of Tokyo University of science, Japan, could recognize six basic expressions of happiness, anger, disgust, sadness, fear and surprise. Park et al. put forward the emotional system of service robot based on neurocognitive science. The system draws on the research results of neurocognitive science and builds on the basis of OCC model, which can make the robot have a variety of emotions at the same time. The emotional knowledge model developed by Zhang Donglei and others [8] supported the intelligent emotional subject, whose internal emotional generation module adopts a hierarchical structure: reflective emotional generation module and subject cognitive emotional generation module.

3. Improved BP neural network and its improvement

In the BP neural network data processing, the sample data through the input layer, hidden layer, output layer. When the output of the output layer can not meet the user's expected output, the error is adjusted reversely, that is, through the output layer, hidden layer and input layer. The process of adjustment is mainly through the weight, until the system error can be within the allowable range. The essence of error adjustment of BP neural network is unconstrained nonlinear optimization problem. If the network structure of BP neural network is too complex, the calculation time of the whole system will increase, and it is easy to fall into the local optimal situation, which is not conducive to the optimal result. In order to improve the performance of BP neural network from the aspects of calculation accuracy and training speed, this paper improves it from the following two aspects.

(1) Add momentum term

By increasing the momentum term, the BP neural network is also prevented from falling into local optimum during training. Through the momentum term, we can adjust the change of the weight, so that the weight always changes at a certain speed, and there is no shock, so we can improve the training speed.

(2) BP neural network in data processing is through the first derivative of the weight and threshold to guide the next step of weight adjustment, which can get smaller system error. When the network converges, it usually considers the learning rate, which must be (0, 1). The smaller the error is, the slower the convergence rate would be. In order to improve the learning efficiency, this paper adopts the self-adjusting method of learning efficiency, that is, when the weight of the network makes the error information tend to be smaller, the learning rate of the next process will increase, on the contrary, the learning rate would decrease, which is a self-adjusting process.

On the basis of the above improvements, the BP neural network is described: set the number of nodes in the input layer, hidden layer and output layer is \( m \), \( n \) and \( k \) respectively, the BP neural network model can be expressed as follows:

\[
\begin{align*}
    y &= g \left( \sum_{j=1}^{k} v_j \left[ g \left( \sum_{i=1}^{n} w_{ij} x_i \right) + b \right] + b \right) \\
    e &= y - t
\end{align*}
\]

(1)

Rewrite formula (1) into vector form, that is:
Where: $X$ and $Y$ are input vector and output vector respectively. $W$ is weight vector between input layer and hidden layer, and $E < E_{\text{min}}$. $V$ is the weight vector between the hidden layer and the output layer. $B_1$ and $B_2$ are the offset weights of the hidden layer and the output layer respectively. The excitation function between the hidden layer and the output layer is sigmoid function, which is 

$$f(x) = \frac{1}{1 + \exp(-x)}.$$ 

In the $q$-th iteration, the output error of the $p$-th ($p = 1, 2, ..., k$) node is $e_p(q)$: which is expressed as:

$$e_p(q) = t_p(q) - y_p(q), (p = 1, 2, ..., k)$$  \hspace{1cm} (3)

where: $t_p(q)$ and $y_p(q)$ are the expected output value and the actual output value, respectively

$$\xi_p(q) = \frac{1}{M} \sum_k \left( \frac{1}{K} \sum_j e_j(q)^2 \right) - \frac{1}{M} \sum_k \left( t_k(q) - y_k(q) \right)^2$$  \hspace{1cm} (4)

The formula (4) is expressed as a vector

$$\xi_p(q) = \frac{1}{M} \sum_k \left( \frac{1}{K} \sum_j (T_k(q) - Y_k(q))^2 \right)$$  \hspace{1cm} (5)

Then, $\xi(q)$ is derived from $\nu(q)$, we can get:

$$U(q) = V(q) \left[ g(W(q)^T X + B_1(q)^T) + B_2(q) \right]$$  \hspace{1cm} (7)

**4. Analysis of experimental results of emotion recognition based on BP neural network**

Matlab is a very good simulation software, which provides a neural network toolbox, and can intuitively analyze and calculate the results of neural network. Therefore, this paper used the functions and algorithms provided by MATLAB for emotion recognition based on BP neural network.

In this paper, when using BP neural network for emotion recognition, the transfer function was sigmoid function, the number of hidden layer nodes was 13, and the training function was trainrp. 120
groups of collected data were diagnosed. The first 110 groups of data constituted the training set, and the last 10 groups of data constituted the detection. The recognition results of happy ($S_1$), sad ($S_2$), surprised ($S_3$) and disgusted ($S_4$) emotional states were shown in Table 1.

**Table 1. Results of emotion recognition based on BP neural network.**

| Sequence number | Actual output ($S_1, S_2, S_3, S_4$) | Emotional meaning of actual output | Expected output ($S_1, S_2, S_3, S_4$) | Emotional meaning of actual output | Correct identification (Yes/No) |
|----------------|--------------------------------------|----------------------------------|-----------------------------------|----------------------------------|-------------------------------|
| 1              | (0,1,0,0)                            | Sad                              | (0,1,0,0)                         | Sad                              | Yes                           |
| 2              | (0,0,1,0)                            | Surprised                        | (0,0,1,0)                         | Surprised                        | Yes                           |
| 3              | (0,0,0,1)                            | Disgusted                        | (0,0,0,1)                         | Disgusted                        | Yes                           |
| 4              | (1,0,1,0)                            | Happy + Surprised                | (0,1,1,0)                         | Sad + Surprised                  | No                            |
| 5              | (1,0,0,0)                            | Happy                            | (1,0,0,0)                         | Happy                            | Yes                           |
| 6              | (0,0,1,0)                            | Surprised                        | (0,0,1,0)                         | Surprised                        | Yes                           |
| 7              | (0,0,0,1)                            | Disgusted                        | (0,0,0,1)                         | Disgusted                        | Yes                           |
| 8              | (0,1,0,0)                            | Sad                              | (1,0,0,0)                         | Happy                            | No                            |
| 9              | (0,0,0,1)                            | Disgusted                        | (0,0,0,1)                         | Disgusted                        | Yes                           |
| 10             | (0,0,1,0)                            | Surprised                        | (0,0,1,0)                         | Surprised                        | Yes                           |

It could be seen from the diagnosis results in the above table that there were three groups of data with wrong identification, among which the fourth group identified happiness + surprise as sadness + surprise; the eighth group identified sadness + disgust as sadness. It could be seen that two of the 10 groups of data were wrong. The recognition accuracy was 80%.

5. Summary
In this paper, the parameters and network of BP neural network used in emotion recognition were designed in detail. At the same time, different training algorithms were simulated. The training function is *trainrp*. Finally, this paper used BP neural network with 3 input nodes, 9 output nodes and 13 hidden nodes to recognize the collected emotional data. The final recognition accuracy was 80%.

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