Embedded Systems for Analyzing Digital Art Aesthetics in Piano Performances using Emotional Recognition

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Abstract. Aesthetics is an innate ability. It is a meaningful study to make computers perceive "beauty", discover "beauty" and generate "beauty". With the deepening of intelligent optimization algorithm research, artificial intelligence technology "aesthetic" has penetrated into photos, paintings, web pages, ICONS, men and other aspects. However, there are very few studies on the evaluation of piano performance aesthetics. The study of piano performance aesthetics has certain research significance. First of all, limited by personal time and energy, people cannot select high-quality piano repertoire quickly. Secondly, limited by personal aesthetic consciousness and aesthetic ability, people cannot improve the aesthetic quality of piano music just like professional piano players. In the face of such problems, the aesthetic quality evaluation and improvement technology with artificial intelligence as the core provides economically feasible solutions for people to obtain high-quality tracks. Meanwhile, this technology promotes the development of simulated human aesthetic and thinking technology in the field of artificial intelligence. Since the key to aesthetics lies in the perception and classification of piano music score, timbre, audio and emotion, the emotion recognition of piano performance is crucial for the research of artificial intelligence "aesthetics". Piano performance emotion recognition is realized by using the computer to analyze performance characteristics and according to the mapping relationship between performance characteristics and emotion. The study of automatic emotion recognition of piano performance is of great significance to improve the human-computer emotional interaction ability of computer. Based on the above analysis, the main work and innovations of this paper are as follows:This paper first with MIDI music file as a research sample, follow the research method of classical music theory, combined with music psychology, cognitive psychology, music aesthetics and other related research results, the characteristics of the piano performance of a comprehensive and detailed description, and established a set of suitable for computer understanding and expression of the piano performance characteristics system. In the process of feature extraction of piano performance features, high-level features such as rhythm, speed and melody are mathematically defined. In this paper, we realize the computer recognition of the piano playing emotion by using the BP neural network. Finally, the research in this paper can realize the emotional classification of piano performance from the

perspective of artificial intelligence, which can use the above research content to quickly and automatically select high-quality piano performance tracks, saving a lot of time for manual screening.

Keywords: Emotional Recognition, Piano Playing, Aesthetic Research, BP neural network; Digital Art, Embedded Systems.
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1 INTRODUCTION

Piano performance is an art form with sound as the means of communication, and then produce emotional experience, which is also a kind of aesthetic embodiment. It can be said that the essence of piano performance is emotion, and the specific form of acoustic wave vibration of music is directly related to human emotion. Whether it is the emotional catharsis of the creators and players or the audience's acceptance of the emotional connotation of the music, all musical activities obey and reflect the fluctuations of people's inner world. Nowadays, the public's artistic aesthetic is constantly improving, which has brought great changes to the traditional and classical emotional recognition way of piano performance [1][2].

As mentioned above, this paper starts from the aesthetic research of piano performance art based on emotion recognition, finds out the music characteristics that have a great influence on the emotion classification of music, and establishes the corresponding knowledge system. Taking MIDI music file as the research sample, the mature recognition technology is used to solve the intelligent information analysis processing method of emotion recognition. Finally, the quantification of musical characteristics is classified and quantified according to the mapping relationship of musical characteristics and emotion. The purpose of the study is to hope that the computer can describe and express the emotional response caused by people listening to the piano repertoire in an appropriate model.

2 EMOTION RECOGNITION OF PIANO PERFORMANCE BASED ON THE BP NEURAL NETWORK

BP network is a multi-level feedforward neural network structurally similar to multi-layer perceptron with unidirectional propagation of information. Due to the advantages of simple structure, many adjustable parameters, many training algorithms, and good controllability, BP network has been widely used in pattern recognition, function approximation, and engineering control. On the basis of extracting the music feature space, using the BP neural network as a classifier to identify the emotion types of MIDI music fragments, as shown in the figure below.

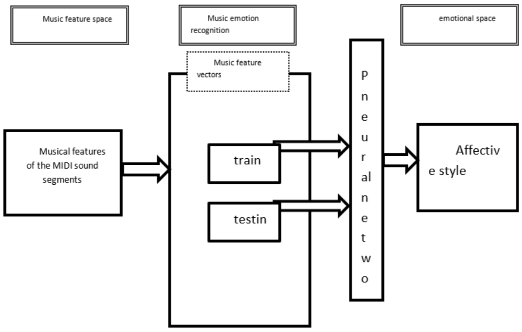

Figure 1: Block Diagram of Emotion Recognition Mapping Based on BP Neural Network.

2.1. Extraction of the Emotional Characteristics of the Piano Performance

The sample of MIDI music files are used as the data source for piano performance emotion research. However, the MIDI file in the However, it contains the pitch, value, strength, speed and other information needed by the experiment, but the form of these information and the experiment Requests do not match. Therefore, we need to output the MIDI instructions related to the emotional characteristics of the piano performance to another file in the form of experimental requirements. The information on the emotion characteristics of piano performance obtained in this chapter will provide a variety of parameter sources for the emotion recognition expert system established in subsequent experiments and the BP neural network used for emotion recognition and classification [3].

2.1.1 Relevant data structure of the piano performance information

1. Note: Note information is the most basic information during MIDI file resolution. We define notes as a structure with five properties as shown in Figure 1:

Category	***Definition***
Pitch	*1.The pitch is the high and low voice, determined by the frequency 2. In music, pitch represent different pitch, rhythm and tone, can represent the mood, rhythm and style 3.On the piano, the pitch is often referred to as key, different keys corresponding to different degree and the strength of vibration*
Intensity	*1. The strength of the sound intensity represents the sound 2. In music, the sound intensity can be used to show the strength of the music, the music of each size and strength 3.Sound intensity can also be used to represent the music rhythm and speed*
Duration	*1.The value represents the strength of the music 2.In music, the duration value can be used to represent each sound in the music, the music of the length of every minute of the day 3.Duration can also be used to represent the music rhythm and speed*
Start time andThe end of time	*Start time and end time refers to the notes in the entire music clips of absolute time*

Table 1: Note Structure.

2. Note queue for the track: The track note queue is a specific note queue created for the Track Chunk. The notes in the queue are arranged from small to large by their Start-Time. At the beginning of the analysis of the track, the corresponding team of notes is empty. When an instruction to open the note is encountered, the system parses the instruction to get the pitch, intensity, duration, and start time of the note, and adds the note to the queue. When an instruction to close a note is encountered, find this note from the note queue and fill in its end time. In this way, after the analysis of the track, the queue contains information about the pitch, intensity, duration, and start and ending time of all the notes in the track, preparing for the following section division of the music.

3. Section note queue: In order to facilitate various statistics in sections, you need to establish a section note queue for each section in the section. The section queue notes contain note information for all the notes in the track that belong to the section.

2.1.2 MIDI file parse

The MIDI music file contains all of the musical features, and the information about each note in the MIDI file can be read out. Decoded files that respond to music-related information and events can be generated by resolving the MIDI files. In this way, we can directly extract the music features from the decoding files, and design the corresponding data structures to model them, which is an important step in the realization of the music emotion recognition model. The MIDI file analysis of this experiment mainly includes the header file analysis, the global track analysis, the pronunciation track analysis, and the establishment of the section note queue [4]. Among them, the global track contains the speed and rhythm information for the entire MIDI music file. In the analysis of global audio tracks, the process of global audio track analysis is shown in Figure 2:

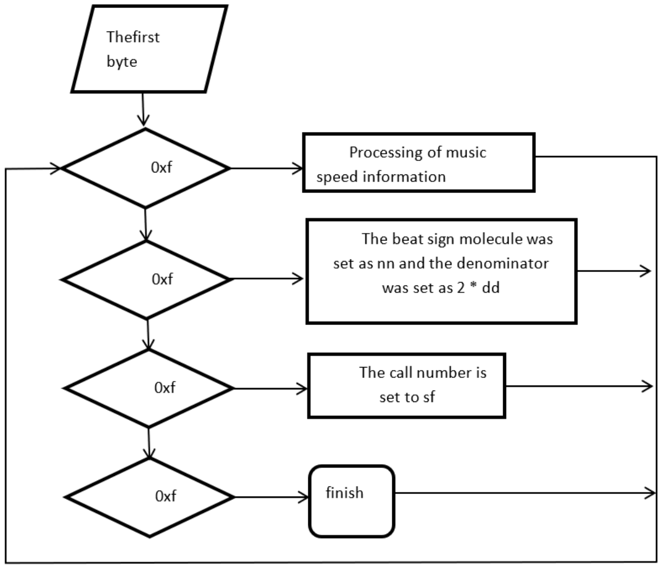

Figure 2: Global Audio Track Analysis Process.

To establish a section note queue, you first need to determine which bar a given note is in. This requires us to divide the subsections. Section is the smallest rhythm cycle in musical music, which has an important significance for the extraction of musical rhythm characteristics of the later text. Section division requires the use of the tick numbers of 1 / 4 notes as well as the beat number of the entire piece derived from the global track analysis. The section length of any beat piece can be obtained according to the tick number of 1 / 4 notes. The denominator of the beat sign is M, the molecule is N, the length of section is L, the tick number of 1 / 4 notes is S, and the length of section is calculated as shown in Figure 3.

The start and end times of each section can be determined by the section length L. To determine if a note belongs to the No In a section, only determine the start and end time of the note to the start and end time of the section. If the start and end times of the note meet the following three conditions, the note belongs to this section.

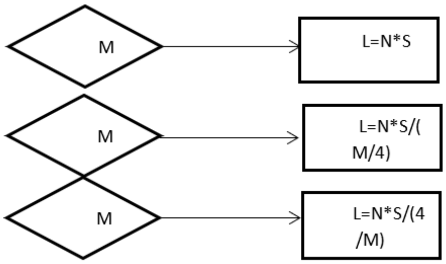

Figure 3: Subsection Length Calculation Method.

These three conditions are: the start time of the note is equal to the start time of the section; the start time of the note is greater than the section and less than or equal to the end time of the section; the start time of the note is less than the start time of the section and the end time of the note is greater than or equal to the start time of the section.

2.2. Extraction of Piano Performance Characteristics

The characteristics of piano performance can be divided into acoustic characteristics containing the basic information of notes such as pitch, duration and timbre, spatial and temporal characteristics containing rhythm, melody, speed, strength and other characteristics, and semantic characteristics of intonation. From the above analysis, it can be seen that the emotion of piano performance can not be expressed through the basic information of notes, and the analysis of the characteristics of piano performance should be considered from the organization form and the change law of notes. Therefore, considering the composition form of the piano performance characteristics and the hierarchical cognitive process of the audience's musical characteristics, we divided the piano performance characteristics into two levels as shown in Figure 4 (the arrow direction indicates the perceptual order of the music information in the cognitive process of the piano performance).

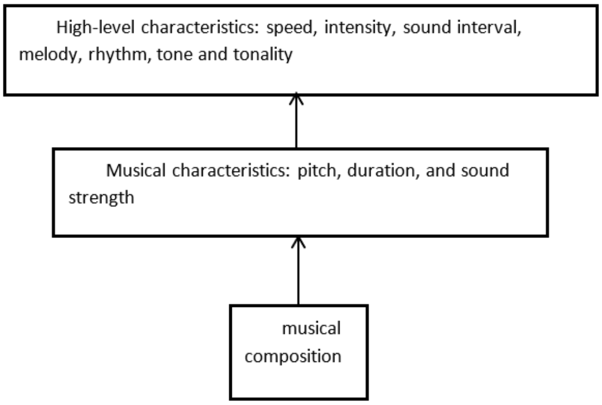

Figure 4: Music Feature Perception Process.

1. Extraction of the basic features Pitch pitch, time value and sound strength are the most basic elements of piano performance characteristics, and also the lowest characteristics of people's perception of the emotion of music. These characteristics act directly on the auditory system of listeners and are acoustic cues of emotional cognition of music. About the base The feature is defined as follows: The average pitch: indicates the pitch level of the music. The formula is defined as:

$$\overline{P} = \frac{\sum_{i=1}^{n} pi}{n} \tag{1}$$

Where, Pi indicates the pitch of the i th note and n indicates the number of notes of the piece. Pitch change: indicates the amplitude of the pitch change of the music. Here, we examine the sound of the music in terms of bars High change. The formula is defined as:

$$Var\_P = \frac{\sum_{i=1}^{n-1} Bar\ i{+}1^{-Bar\ i}}{N\overline{P}} \tag{2}$$

Where, $Bar_{\ i}$ indicates the average pitch of bar 1, and N indicates the number of bars of the piece. P indicates the average musical tone tall. We can also represent pitch changes by pitch mean variance:

$$Var\_P = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[p_i - \frac{\sum_{n=1}^{n} Pi}{n}\right]^2} \tag{3}$$

Sound range: Sound range describes the breadth of music pitch, which is an important indicator to measure the expression of music.The definition formula is as follows:

$$Range = Max(P_1, P_2, \cdots P_n) - Min(P_1, P_2, \cdots P_n) \tag{4}$$

Where, P1,P2,...Pn represents the pitch value of Pitch.

Time value: The time value is the duration of a note. The use of a large number of long time notes will slow the rhythm of the music, thus reducing the tension of the music. The concentrated use of short time notes will make the music become urgent and increase the tension of the music.

The representation of the time value is as follows:

$$Duration == EndTime - StartTime \tag{5}$$

Sound strength: Sound strength is the strength of the notes. This can be read directly in the MIDI file. The read analysis of note strength creates conditions for the extraction of the strength features of the following music.

2. tone colour

Tone is people's feeling of sound quality, is a subjective quantity of music. Music presents the timbre of music through the distribution of frequency components, and then stimulates people's senses and emotions. We note that people use semantic adjectives (e. g., rough and smooth, bright and gray, plump and thin, sweet and thin, sweet and bitter, soft and stiff, etc.) in order to describe the timbre. This is isomorphic to the description of the piano-playing emotion. Therefore, we believe that the timbre characteristics of the piano performance indirectly reflect the subject emotion of the music. The relationship between timbre and emotion mapping is shown in Table 2.

Music and emotion	***Sound color characteristics***
Hate	*Sonic sharp thorns，coarse，light*

Depression class	*The tone is low，pureness，simple，dismal The bass is monotonous，flat，cavity*
Calm meditation	*The tone is soft，pureness，simple*
Desire class	*The tone is low，flat，cavity，pureness，simple*
Pastoral style	*The tone is soft，pureness，simple*
Emotional class	*The tone is soft，Sweet and soft，abundant Magnificent，joyful，nasal sound*
Active class	*light，abundant，magnificent*
Give force class	*The tone is bright，sharp-pointed，brilliance*

Table 2: Tonic Color and Emotional Mapping Relationship.

We read the instrumental information used in the piano-playing piece by analyzing the MIDI files. Then the instrumental information can be linked to the timbre and emotion according to the musical terms, the appropriate emotions and the relevant connection of the instrument spectrum. Table 3 describes the connection between the spectrum distribution of piano playing signals and appropriate emotions or scenes.

Spectrum distribution map	***nomenclature of music***	***Suitable emotion / scene for expression***
The base frequency is the main	*Pureness simple*	*Pure lively*
Low harmonic is the main	*Soft，aloof Fluency，sweet*	*Intension，magnificent，stand alone*
The odd harmonic is the main	*Cavity，nasal sound ，open*	*Romantic，cold and detached ，calm*
It has significantly higher order harmonics	*Warm，light Dark，solemn*	*hold high，Rich feelings*

Table 3: The Connection Between Piano Performance Spectrum Distribution and Emotion Expression.

3. Strength extraction

Strength is one of the important means for music to express emotion, which can be strengthened and enriched to a certain extent. Through the change of strength, it can express the strong emotions such as anger cry and courage, and also express the subtle inner feelings such as low talk and sweet happiness. In addition, playing the same song with different strengths is enough to bring a different emotional experience to the audience. Strength is closely related to the emotional intensity of the music [4][5]. We describe the intensity information of music according to two characteristics. The formula is as follows:

$$Dyn = \frac{1}{n}\sum_{i=1}^{n} I_i \tag{6}$$

$$Var\_Dyn = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(I_i - \frac{\sum_{i=1}^{m} I_i}{m}\right)^2} \tag{7}$$

Equation 6 is the average intensity calculation method, and 7 indicates the degree of intensity change. Where, n and m indicate the number of notes of the music. The degree of intensity change can also be expressed by the following formula:

$$Var\_Dyn = \frac{\sum_{i-1}^{n-1} D_{i+1} - D_i}{N \cdot Dyn} \tag{8}$$

The description of intensity variation in Equation 8 is in units of musical bars rather than single notes, which excludes beats The influence of the rule of light and severity on the change of intensity is that we can describe the change of intensity more purely and macroscopically. However, the change in strength described in this way is not as precise as Equation 7.

3 BP NETWORK LEARNING PROCESS

The foothold of the BP network model is the BP algorithm, which means that the error is transmitted from back to forward, layer by layer. This method of error transmission is called the back-propagation of the error. The training process of BP algorithm is a learning process that requires a tutor, which can be divided into the following four parts:

1. The process from the input layer to the implied layer to the output layer, namely the process of forward propagation.
2. The error between the output value and the output layer node value is expected to be passed from the output layer to the hidden layer and again The process of passing by the hidden layer to the input layer and simultaneously correcting the connection weights, i. e., the process of error backpropagation.
3. Memory training process, repeated 1) and 2) part of the network training
4. In learning the convergence process, the network gradually tends to converge, and the global error gradually tends to be the most The process of small values.

The learning process of the BP algorithm is shown in Figure 5.

3.1. Construct BP Neural Network for Piano Performance

1. Design of input and output layers: The input layer inputs an 8-dimensional music feature vector. Thus, the number of nodes of the input layer is set to 8. The output layer outputs the emotional type of the music. Emotion is classified according to Juslin's hierarchical emotion model, including joy, tenderness, sadness, anger and fear, so the number of nodes of output neurons is set to 30 5 emotion types can be expressed as joy (0,0,1), tenderness (0,0,0}, sadness (0,1,1), anger (1,0,0), and fear (1,1,1).
2. Design of hidden layer: According to Kolmogorov theorem, the number of hidden layer nodes is 17.
3. Network Structure Design This paper adopts a network structure of 8 X 17X3. The input layer has 8 nodes, the hidden layer has 17 nodes, and the output layer has 3 nodes. The activation function of both hidden and output layers we choose $f(x) = \frac{1}{1+e^x}$ to ensure that the output falls between (0,1).

Setting of the network training parameters.The maximum number of cycles is set as 2500, the error expected-value is 0.001, the training function is the traingdx function, and the performance function takes the mean square error performance function.

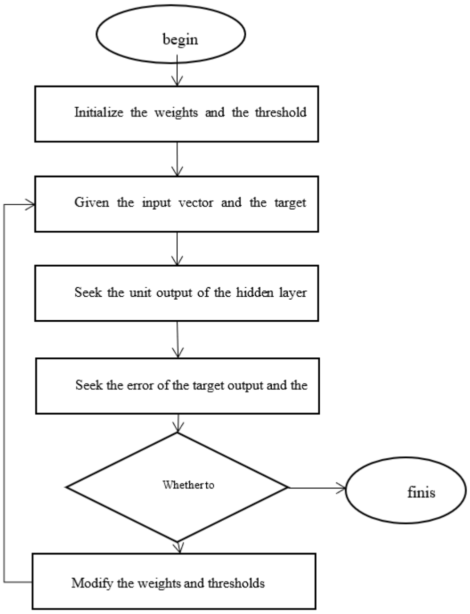

Figure 5: Learning Process of the Bp Algorithm.

Music segment name	***affective style***	***The sample set***
Carmen fragments	*happy*	*training set*
To Alice Fragments	*gentle*	*training set*
dream wedding	*gentle*	*training set*
Dream of love	*sad*	*test set*
starry	*happy*	*training set*
Confessions	*fear*	*test set*

Table 4: Some Sample Information Table.

This paper tests the network using multiple MIDI piano playing fragments meeting the experimental demanding format as test samples. It is found that the classification accuracy of BP neural network is higher than the reasoning-based expert system of music emotion cognition described above, especially in the ability to identify tenderness and sadness emotions. At the same time, we also found that the identification success rate of BP neural network is low in the identification of music fragments containing fear emotion, while the expert system based on reasoning rules can identify them all correctly [6][7][8][9][10]. This may be due to the small number of training samples for MIDI music segments containing fear emotion. We intercept a fraction of the test samples and their discriminant results are shown in Table 5. Table 5 indicates differences in the identification results of the expert system and BP neural networks on the same test samples.

Peng Qiong from Shanghai Jiao Tong University was used to identify the music fragments in the test set with an accuracy rate of about 73%. The BP neural network built in this chapter can improve the accuracy to 80%. Experiments have proved that rhythmic and melodic characteristics have a large influence on the recognition of musical emotions. Under the premise of the BP neural network structure is unchanged, selecting the appropriate music feature input vector will improve the classification accuracy of BP neural network to some extent.

This chapter divides the samples required for the experiment into the training and test sets. The appropriate training set is filtered as an input to the BP neural network, and the network connection weights and thresholds are constantly corrected to make the network converge. Finally, the emotion recognition model is used to identify the emotion of the test set and test the accuracy of the present algorithm [11[12][13][14][15][16][17].

Experimental results show that the proposed characteristic input vector of piano performance better reflects the feature information of the music, and improves the performance of the system to some extent. BP neural networks have higher classification accuracy compared to inference-based expert systems. However, the BP neural network is highly dependent on the training samples and has insufficient generalization ability. In the experiment, the change of the training sample will have a great influence on its classification accuracy.

Music segment name	***affective style***	***Expert judgment***	***BP neural network determination***
Carmen fragments	*happy*	*sad*	*happy*
To Alice Fragments	*gentle*	*sad*	*gentle*
dream wedding	*gentle*	*gentle*	*gentle*
Dream of love	*sad*	*gentle*	*sad*
starry	*happy*	*happy*	*gentle*
Confessions	*fear*	*fear*	*fear*

Table 5: Results for the Identification of Partial Music Segments.

4 CONCLUSION

Emotional computing is a breakthrough in the field of artificial intelligence, and it has become an emerging research feature of interdisciplinary research in computer science, cognitive science, neuroscience, brain science, psychology, behavioral science and other fields. Aesthetic study of emotion recognition is an important branch of emotional calculation and has a broad development prospect. On the basis of referring to a large number of research results of related theories, this paper selects the piano performance fragments expressing emotional feeling, adopts the empirical method to obtain the mapping model of music characteristics and emotion, describes the music characteristics in the form of knowledge and gives their expression in the form of knowledge. Using the research results of music psychology theory and using the rule-based expert system and BP neural network. The main research contents are as follows:

The architecture of piano playing emotion recognition is proposed. This paper combines the basic principle of piano performance emotion recognition, the basic process of emotion cognition, and the system structure and concrete work of the music emotion recognition system for the music characteristic space defined above The work process was analyzed in detail. A system based on reasoning rules is developed using generative rules to analyze piano emotions. This paper describes the characteristics of piano performance in the form of knowledge and expresses them in the computer, extracts the corresponding rules according to the theory of music psychology, and classifies the emotions of piano performance by using the generative system.

Choosing the music features with great emotional influence on piano performance, the music film was realized by using BP neural network classification technology Identification of segment emotion types. This paper selects 6 piano performance characteristics, and 60 sample pairs were selected under the guidance of music experts The network is trained. After experiment and testing, the classification accuracy has basically met the requirements. Embedded systems play a vital role in capturing and processing real-time data from piano performances, including audio and possibly video inputs. By integrating emotional recognition technology, the system can identify and analyze the emotional content of the performance, which may have implications for understanding the artistic expression, audience engagement, and the overall impact of the music played. This research aims to explore the intersection of embedded systems and emotional recognition in the context of piano performances to gain deeper insights into the artistry and aesthetics of digital music.

Despite some achievements of the work presented in this paper, many aspects of the work need to be refined and further studied due to the limitations of many conditions. Future research will focus on the following three areas:

Further research is needed to investigate the expression of piano performance characteristics. Because the extraction method of piano performance characteristics is not unified, especially the musical expression of complex piano performance characteristics involves music professional knowledge, which affects the related work of piano performance characteristics extraction. Secondly, some compositions are highly subjective and difficult to describe and extract quantitatively, which poses difficulties for the implementation of an expert system of rule-based emotion classification of compositions. Further work to express the characteristics of piano performance may bring breakthrough results.

Adopt a variety of knowledge methods to express the expert knowledge. Knowledge of piano performance is characterized by subjectivity, complexity and structure. This paper only expresses the knowledge of music. The application of multiple knowledge expression will help to improve the performance of the expert system.

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