Emotional Intelligence System for Ubiquitous Smart Foreign Language Education Based on Neural Mechanism

Weihui Dai* · Shuang Huang** · Xuan Zhou*** · Xueer Yu**** · Mirjana Ivanovi***** · Dongrong Xu******

Abstract

Ubiquitous learning has aroused great interest and is becoming a new way for foreign language education in today's society. However, how to increase the learners' initiative and their community cohesion is still an issue that deserves more profound research and studies. Emotional intelligence can help to detect the learner's emotional reactions online, and therefore stimulate his interest and the willingness to participate by adjusting teaching skills and creating fun experiences in learning. This is, actually the new concept of smart education. Based on the previous research, this paper concluded a neural mechanism model for analyzing the learners' emotional characteristics in ubiquitous environment, and discussed the intelligent monitoring and automatic recognition of emotions from the learners' speech signals as well as their behavior data by multi-agent system. Finally, a framework of emotional intelligence system was proposed concerning the smart foreign language education in ubiquitous learning.

Keywords : Foreign Language Education, Smart Education, Ubiquitous Learning, Neural Mechanism, Emotional Intelligence, Multi-Agent System

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1. Introduction

With the rapid development of the Internet, mobile communications and the increasing popularity of cloud computing, ubiquitous learning (U-Learning) has become a new way of foreign language learning and an excellent complement to classroom teaching, which is making great changes in traditional theories and methods of language education. Under this circumstance, the learners can access online educational resources anytime, anywhere and through any multimedia terminal. Exposed to all kinds of scenarios and cases enabled by the virtual reality technology, they can communicate and interact in an open learning community.

However, there are still problems in ubiquitous learning. For example, the major problem is how to increase learners' initiative and their community cohesion, and help them search for and locate suitable learning resources among a massive amount available on the Internet [Wei, Zhang, and Wei, 2012; Sa and Liu, 2008; Xing, 2003]. Therefore, a possible solution is to use intelligent technology to recognize and analyze the learners' emotional reactions online, and explore their interest and needs so as to provide accurate, efficient resource organization model, retrieval technology and demand-based teaching strategies.

In 1990, Salovey and Mayer introduced the concept of "Emotional Intelligence" [Salovery and Mayer, 1990]. In 1997, Picard from Massachusetts Institute of Technology held that computer can capture, process and reproduce human emotions in his book "*Affective Computing*" [Picard, 1997]. The developing technology of affective computing and emotional intelligence enables ubiquitous learning into a new stage of smart education, where the concept of "smart" was defined by Dai in 2012 as that machine can perceive and respond to human emotional needs and provide the full humanized services combining both rational and emotional intelligence [Dai, 2012]. This concept has been applied in wide areas such as smart city, smart healthcare, smart service, etc. [Dai, 2013; Zhou, 2012].

Research findings in cognitive neuroscience show that human's emotion arises from the external stimulus, and is the result of a series of neural activities dominated by the brain mechanism [Damasio, 1994; Davidson, Jackson, and Kalin, 2000]. The stimulus signals are transmitted by the peripheral sensory organs via the internal sensory paths to the limbic system of brain where the rapid first emotion is produced, and then form a relatively slow secondary emotion through the interaction of the limbic system and higher cognitive cerebral cortex [Damasio, 1994]. The process is controlled by emotional circuits of human brain and will lead to activated responses in the corresponding brain regions. Emotional changes not only generate activated responses in the brain of human beings, but also trigger a series of reactions through the neural regulation mechanism, and result in the corresponding variation of physiological signals (e.g. EEG, ECG, EDR, respiration, skin temperature, etc.) as well as external performances (e.g. speeches, facial expressions, gestures, movements, etc.) and the possible subsequent behaviors [Davidson, Jackson, and Kalin, 2000; Ververidis and Kotrropoulos, 2006; Horlings, 2008; Wang, 2014; Wang, Hu, Dai, Zhou, and Kuo,

2014]. Therefore, the recognition of emotions in a real environment can be processed by analyzing the expression patterns on the reactions of physiological signals, external performances and subsequent behaviors [Dai, 2012].

The intelligent monitoring and automatic recognition of the learners' emotional information in ubiquitous learning is the issue to be firstly considered in the emotional intelligence system., Although technology of emotion recognition has made great progress during the past decades, there are still barriers to satisfy the requirements in a real application. After a comprehensive analysis, we proposed that the recognition would be based on the fusion features from a series of intrinsically related performances dominated by the brain mechanism in the real environment. This paper will conduct a neural analysis of the learners' emotional characteristics in ubiquitous environment based on our previous research by fMRI (functional Magnetic Resonance Imaging) experiment, and then discusses how to introduce the emotional intelligence system into ubiquitous smart foreign language.

2. Neural Mechanism And Emotion Expression

2.1 Neural Mechanism of Emotions

Recent studies of human emotion and its neural mechanism has been well supported with the developing technology of fMRI (functional Magnetic Resonance Imaging), ERPs, (Event-related Potentials) and DTI (Diffusion Tensor Imaging). In particular, the blood oxygenation level dependent on functional magnetic resonance imaging (Bold-fMRI), with such advantages as being non-invasive, non-traumatic and capable of locating accurately the activated brain areas, has been applied to the studies of neural mechanism on language and emotion, and made a number of significant achievements [Horlings, 2008; Wang, 2014].

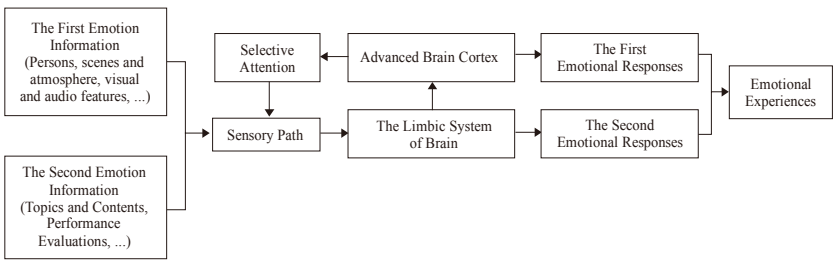
In ubiquitous learning environment, learners log into the Internet via a PC, a smart phone, an i-Pad or other multimedia terminal equipment, and participate in learning and teaching activities in an online virtual classroom. In our previous research [Wang, 2014; Wang, Hu, Dai, Zhou, and Kuo, 2014; Dai, Huang, Zhou,Yu, Ivanovi´, and Xu, 2014], we took the typical scenarios from the above environment as stimulus signals to observe the learner's brain activated responses in Bold-fMRI experiment. It was found that a series of brain regions which include precentral gyrus primary motor cortex (BA4), frontal premotor cortex (BA6), the medial prefrontal cortex (BA10), medial occipital primary visual cortex (BA17), occipital visual association cortex (BA18, BA19), temporal lobe Wernicke area (BA22), temporal lobe of the primary auditory cortex (BA41), temporal lobe of the auditory association cortex (BA42) and posterior part of inferior frontal gyrus Broca area (BA44, BA45) are the main functional brain areas involved in foreign language learning.

By observing brain responses and analyzing the testee's subjective descriptions, we found that the learner's emotions may be affected by a such factors as the topic, scene, vision, voice of the online courseware, the particular teacher or learning partner, and even the evaluation

feedbacks from the teacher, which were correlated with the activated patterns of such brain regions as the frontal lobe, anterior cingulate cortex, amygdala, and temporal lobe and the brain functional networks they formed. When emotion occurred, human body underwent physiological changes produced by the nervous system, which were later captured by brain and turned into particular emotional experience. Based on the testee's subjective descriptions, we acquired the parameters of the brain functional network related to some specific emotional experiences, which can be applied to the emotion recognition.

During the learning process, the emotional information contained in the stimuli signals from the outside are transmitted through the sensory paths of the learner's body to his limbic system where the first emotional responses are produced and then the secondary ones, generated through the cognitive activities of the advanced brain cortex. These emotions will cause some physiological changes to the body which can be captured and recognized by the brain and form particular emotional experience. At the same time, the advanced brain cortex will regulate the learner's attention selectively to the external emotional information and the sensory paths, depending on such advanced mental activities as motivating, knowledge, memorizing, cognition and decision making. The external emotional information associated with persons, scenes and atmosphere, and audio visual features usually produce the rapid first emotional responses, so we called the above information as the first emotion information. Those concerning topics and contents or performance evaluation have to be subject to the cognition of advanced brain cortex before forming the secondary emotional responses which are relatively slow but lasting longer. They are called the secondary emotion information.

Based on the experiment observations and analyses, we found that familiar partners, a desirable learning atmosphere, good visual effects, pleasant voices, suitable topics and materials, and positive evaluation feedbacks were the most important factors that aroused the learners' interest in ubiquitous learning and contributed to the pleasant emotional experiences. However, these factors play a different role in the first and the second emotional responses. According to the theories of cognitive neuroscience as well as the findings in our fMRI experiment, we concluded an emotional neural mechanism model as shown in <Figure 1>.



〈Figure 1〉 Emotional Neural Mechanism in Foreign Language

For the foreign language instruction in ubiquitous learning, the implications of this proposed model may be as follows: (1) attracting the most selective attention from learners based on their motivation, knowledge, memory, cognition and decision-making habits in teaching plans; (2) delivering the symbolic information such as famous teachers, familiar learning partners, and creating desirable atmosphere, special audio visual effects to stimulate the learners' intuitive first emotional responses; (3) selecting suitable topics and contents, conducting the teaching based on the learners' individual motivation, demand and capability and giving positive feedback on their performance evaluations.

2.2 Emotion Expression Pattern

Emotional changes not only generate activated responses in specific brain areas of human beings, but also trigger a series of physiological effects through the neural regulation mechanism, and result in the variation of related peripheral physiological signals (e.g. EEG, ECG, EDR, respiration, skin temperature, etc.) as well as external performances (e.g. speeches, facial expressions, gestures, movements, etc.), and may cause subsequent behaviors. Therefore, the intelligent monitoring and automatic recognition of emotions can be conducted by analyzing the expression patterns on the aspects of physiological signals, external performances or subsequent behaviors. In the ubiquitous learning environment, foreign language learners' emotional information may be obtained mainly through the audio and visual signals as well as the behavior data produced by their online activities. Among which, the audio signals and behavior data are more easily and precisely processed by the computer, so we consider this two types of data in our solution.

Many researchers have found that human voice contains rich emotion information, and even different languages may share the similar emotion expression patterns which have become the important "information textures" to identify the explicit and implicit emotions of human beings [Ververidis and Kotrropoulos, 2006; Jin, 2007]. Vocal emotions are mainly reflected in such parameters as speech speed, voice intensity, pitch frequency, LPCC (Linear Prediction Cepstrum Coefficient), MFCC (Mel Frequency Cepstrum Coefficient) [Jin, 2007; Wang, Hu, Dai, Zhou, and Kuo, 2014]. The average recognition rate of vocal emotions can come up to about 80% by the algorithms of hidden Markov model (HMM), artificial neural network (ANN), Gauss mixture model (GMM) and the support vector machine (SVM), etc [Ververidis and Kotrropoulos, 2006].

The behavior data are mainly acquired from the server's log files or by some online tracking tools. The switching frequency and retention time of web pages, the locations and movements of the mouse, and the keyboard operations are all the important parameters as the features to reflect the learners' emotions. For example, if the learner has strong interest in something and is in a fairly good mood, he tends to stay with the interested web page longer, use his mouse and keyboard at a higher frequency, answer questions more quickly, and be more willing to make positive comments. On the contrary, if he

is anxious and fretful, he will switch from one webpage to another frequently, move the mouse in a wide range quickly, and will be more likely to give negative responses. Through the behavior data mining of foreign learners, we can detect their emotional state and the interested points.

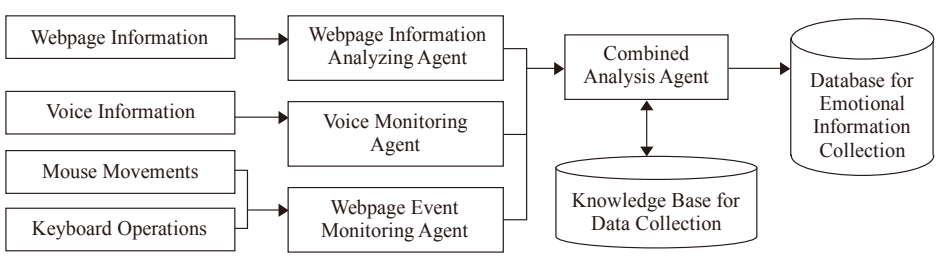
As to the foreign language learning in ubiquitous environment, usually the interactive behaviors of learners become more frequent and their emotional expressions are more apparent, so we can monitor and recognize the learner's emotional state better by their voice analysis and behavior data mining.

3. Intelligent Monitoring and Automatic Recognition of Emotions

3.1 Intelligent Monitoring

Intelligent monitoring of learner's emotions can be achieved through the webpage analysis, speech information collection, and the online data acquisition of mouse action and keyboard operation. Webpage analysis is realized by the web spider program based on Java technology. It starts with the URL of a webpage, links with the server through URL, sends requests and obtains the log files and webpage information, then extracts its layout structure, information type, plate position and operation records for bookmarking. Every change of the elements on the webpage, such as the appearing of voice, moving, clicking and scrolling of the mouse or the operation of the keyboard, will all trigger the corresponding JavaScript function. In order to meet the requirements of real-time data collection, we adopted the PHP language to program the above JavaScript function, and process the voice information collection and the mouse and keyboard data acquisition. The multi-agent technology was applied to our solution to realize the intelligent monitoring as shown in <Figure 2>.

In <Figure 2>, the Webpage Information Analyzing Agent (WIA Agent) is responsible for the retrieval and analysis of the webpage information such as its layout structure, information type, and plate position. The Voice Monitoring Agent (VM Agent) is responsible for the real-time monitoring and recording of learners' voices. The Webpage Event Monitoring Agent (WEM Agent) captures the mouse positions, actions, movements and the keyboard operations. Since the data obtained by the WIA, VM, and WEM agents are correlated and required be analyzed by multimodal fusion, a Combined Analysis Agent (CA Agent) was conducted to fulfill this function. The CA



〈Figure 2〉 Intelligent Monitoring of Emotions by Multi Agents

Agent analyzes the above data supported by the Knowledge Base for Data Collection (KBDC), which has acquired the data collection strategies and rules on the basis of sample training in typical scenarios and a large number of case studies in order to offer the accurate guidance about how to find the emotional information. That information will be detected and analyzed by CA Agent, and then stored in the Database for Emotional Information Collection (DBEIC) for further recognition.

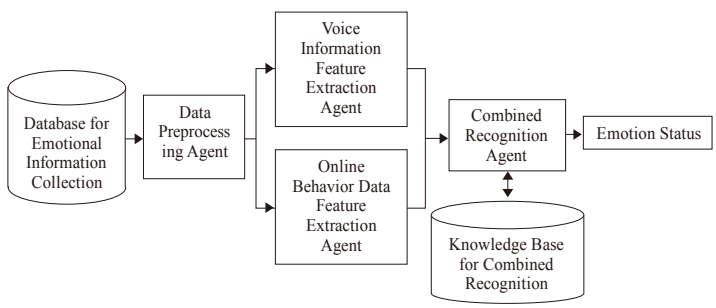
3.2 Automatic Recognition

The automatic recognition of emotions is also a matter of pattern recognition by multi agents, which includes three steps: data preprocessing, feature extraction and emotion recognition as shown in <Figure 3>.

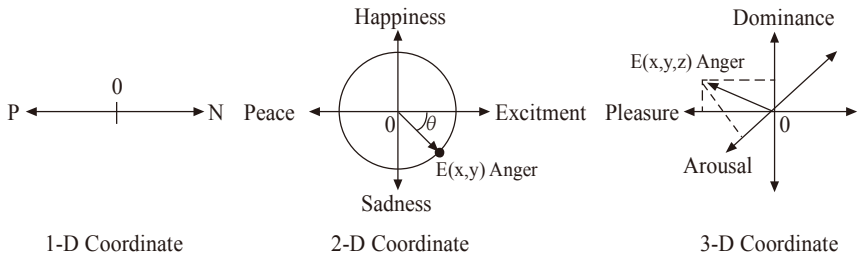
In <Figure 3>, the Data Preprocessing Agent (DP Agent) is responsible for the pre-processing of the data from Database for Emotional Information Collection (DBEIC) so as to meet the requirements of feature extraction. The Voice Information Feature Extraction Agent (VIFE Agent) processes the voice data and extracts emotional features for further combined recognition. The online Behavior Data Feature Extraction Agent (BDFE Agent) processes the data about webpage's information as well as the mouse and keyboard operations, and also extracts the related emotional features for further combined recognition. The Combined Recognition Agent (CR Agent) can analyze the correlated relationship between the above features, and identifies the learner's emotion status by the combined multimodal recognition algorithm. It is supported by the strategies and rules from the Knowledge Base for Combined Recognition (KBCR), which is built based on the sample training in typical scenarios and the experiences obtained by machine learning.

3.3 Emotion Classification and Description

How to classify and describe human's emotions has remained a controversial issue. Emotions fall into two categories: the discrete form and the continuous form. The discrete form is also known as the Six Big: Anger, Disgust, Fear, Joy, Sadness, and Surprise [Ekman and Power, 1999]. The continuous form describes the emotional state in a continuous space with different dimensions. Among them, the one-dimensional coordinate describes only positive and negative emotions with their



〈Figure 3〉 Automatic Recognition of Emotions by Multi Agents

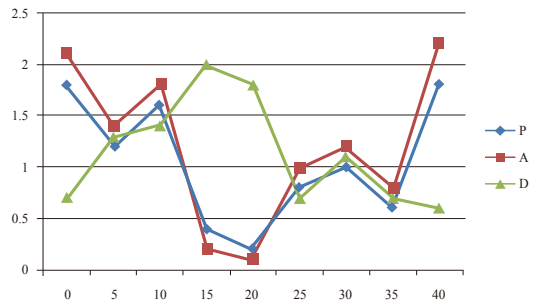


〈Figure 4〉 Continuous form of Emotions in Different Dimensions

strengths. The two dimensional coordinates are based on the Hidenori H. and Fukuda T.'s unit circle of Emotional Space (Hidenori and Fukuda 2001) where the emotion state is represented in a unit circle with two opposite coordinates: Peace vs. Excitement, Happiness vs. Sadness; The 3-D space has different models presented by Wundt [Wundt, 1897], Schlosberg [Schlosberg, 1954], Izard [Izard, 1991], and Osgood [Osgood, 1996] respectively.

Based on a comprehensive psychological research work, A. Mehrabian demonstrated that any kind of an emotion state can be well described by the three nearly independent continuous dimensions: Pleasure-Displeasure (P), Arousal-Nonarousal (A), Dominance-Submissiveness (D), and therefore proposed the famous PAD model [Mehrabian, 1995; Mehrabian, 1996]. This model provides an effective means to evaluate the complex emotions, and has been successfully applied to the subjective measurement by manual manner in a variety of areas [Tao, Liu, Fu, and Cai, 2008; Lu, Fu, and Tao, 2010; Jia, Zhang, Meng, Wang, and Cai, 2011]. Fig.4. shows the continuous form of emotions in different dimensions.

The emotions of foreign language learners may be in complicated and mixed status, which will dynamically change in the learning process. Therefore, we describe their emotions in the PAD 3-D emotional space and convert the issue of emotion recognition into the problem of estimating the P, A, D values of the learners' speech signals as well as their behavior data by multi-agent system. <Figure 5> shows the dynamic changes of the learner's emotions in a 45min course of foreign language education.



〈Figure 5〉 Dynamic changes of the Learner's Emotions in PAD Values

By analyzing foreign language learners' emotion status and its varying characteristics in the learning process, we can discover the statistical distribution and the changing rhythms of their emotion status in different periods and scenarios, and find the learners' ROI (Region of Interest). This has significant implications in emotional intelligence design.

4. Emotional Intelligence System for Smart Education

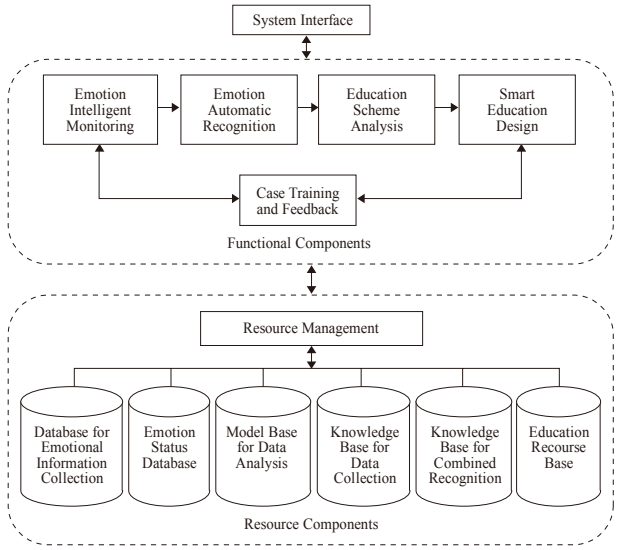
With intelligence monitoring and automatic recognition of foreign language learners' emotions, we can find their ROIs and the characteristics of their emotional changes in the learning process, based on which we have designed an education scheme and teaching plans that are on-demand and more appealing and enjoyable to learners in order to provide state of the art teaching models, skills and technologies for smart foreign language education in the ubiquitous environment. The proposed framework of emotional intelligence system is shown as in <Figure 6>:

This system includes three parts: system interface, functional components and resource components. Among them, system interface offers the access and control for its users. Functional components are composed of five modules: Emotion Intelligent Monitoring, Emotion Automatic Recognition, Education Scheme Analysis, Smart Education Design, and Case Training and Feedback. Based on the multi agent technology, this system provides the intelligent monitoring and automatic recognition of foreign language learners' emotions so as to adjust the online teaching according to the learners' emotional changes and. It also supports the case training and gives the emotional feedback on each teaching.

The system resource components include two databases, one model base, two knowledge bases, and one hypermedia education resource base, which provide the resources for the operation of each functional component in this system.

5. Conclusion and Discussion

With the development of modern information network and mobile communication technology, personalized learning in ubiquitous learning envi-



〈Figure 6〉 Framework of Emotional Intelligence System for Smart Education

ronment has been made possible in web space accessible by a variety of multimedia terminals at anytime and anywhere. It has brought new changes to the theories, means and patterns of traditional foreign language teaching. In the U-learning environment, learners' emotional experiences have significant impacts on stimulating their learning interest and improving the teaching efficiency. Therefore, how to apply emotional intelligence to foreign language teaching and learning on the new concept of smart education has been the issue worthy of our think. That means we should perceive and respond to the learner's emotional needs on computer and provide the fully customized services with not only the rational intelligence but also the emotional intelligence.

According to the emotional neural mechanism model proposed in this paper, the stimuli signals from the outside contain the first emotion information and the second emotion information, which produce different emotional responses and may be considered in the design of teaching strategies and skills. Emotional changes will not only result in the brain responses, but also trigger a series of physiological effects which may be reflected in the peripheral physiological signals, external performances, and subsequent behaviors. In ubiquitous learning environment, the voice signals and behavior data are more easily and precisely processed based on which the intelligent monitoring and automatic recognition of foreign language learners' emotions can be realized by multi-agent system. Therefore, this paper presented a framework of emotional intelligence system for smart foreign language education in the ubiquitous learning environment.

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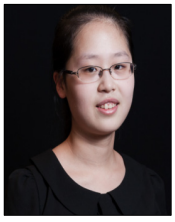

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