An Advanced Mental State Transition Network and Psychological Experiments

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Abstract. The study of human-computer interaction is now the most popular research domain overall computer science and psychology science. The most of essential issues recently focus on not only the information about the physical computing but also the affective computing. The emotion states of human being can dramatically affect their actions. It is important for a computer to understand what the people feel at the time. In this paper, we propose a novel method to predict the future emotion state of person depending on the current emotion state and affective factors by an advanced mental state transition network[1] . The psychological experiment with about 100 participants has been done to obtain the structure and the coefficients of the model. The test experiment also has been done to certificate the prediction validity of this model.

1 Introduction

In research of modern information science and human computer interface, the non-verbal information has caused more attention. The latest scientific research indicate that emotion of human being play a core role in decision making, perception, learning, and moreover they influence the very mechanisms of rational thinking [2]. The automatic emotion state recognition has gained more attention because of the desire to develop natural and effective interfaces for human-computer communication application [3]. The myriad of theories on emotion can be largely examined in terms of two components: emotions are cognitive, emphasizing their mental component, and emotions are physical, emphasizing their bodily component [2]. Numerous physical experiments have been done (Ekaman, Frijda, [4] [5] [6] etc.) but external information such as language and facial expressions are not enough to model human emotion [1]. Though, various emotional models have been proposed in previous studies (the Plutchik's Multidimensional Model [7], the Circumplex Model of Affect [8] etc.), there is no mental model that can be described appropriately in a numerical way.

In this paper, we present an advanced mental state transition network in order to predict the future emotion state. This network model is improved from the original mental state transition network model[10] by considering the whole priori conditional probability under the various affective environments. The network structure and coefficients are acquired from the psychological experiment designed on the basis of the conditional propability table and be testified by 50 random data. It hypothesizes that the human emotions are simplified to seven basic categories and transfer among these discrete states. The state is defined as a mental state. However, there existed some certain expectation value with some external causes. By means of experimentation of a large set of psychological questionnaires, the conditional transition probabilities among mental states can be calculated.

The proposed advanced mental state transition network can be used in prediction of the emotion state of human on engineering science. Also the model which gathered from a large amount of raw psychological data can reflect the common aspect of human emotion transitions. The test experiment also verifies the model reliable and pragmatic.

2 Emotion State Transition Network Model

The research of human mental state firstly started on the psychological field and many definitions of emotion have been defined and psychological tradition has probed that nature of emotions systematically are shaped by major figures in several discipline-philosophy, biology and psychology [11].The two main theories in this domain have indicated that definitely some cross-culture emotions widely existed in each nationality and there exists a separation between positive and negative affective emotions [12]. Now the improvement of research on human-machine interaction makes it necessary to find out a describable definition of emotion and a practical method to recognize and predict emotions.

2.1 Prototype of Six Basic Emotions

After studying a vast amount of literature on the signs that indicate emotion, both within the psychological tradition and beyond it [3], we have found six archetypal emotions (happy, sad, angry, surprise, fear and disgust) as presented by Ekman. They are widely accepted among different areas and are easier to capture and describe than other complex emotions [11]. In our research, we presume that human mental movements can be divided into six archetypal emotional states. Besides these, we add another neutral state-calm (quiet / serene).

2.2 Mental State Transition Network

Emotion in its narrowest sense is full-blown emotion and is generally short lived and intense [13]. To simplify the study, our experiment only takes account of the full-blown emotion. Then, the seven discrete mental states we proposed can construct a closed mental space. In that case, we can create a mental state transition network model of human being as the Fig 1 shows. In the Fig 1 the circle in center indicates a calm mental state. The circles around represent the other six mental states. The arrows denote direction from one state to the other.

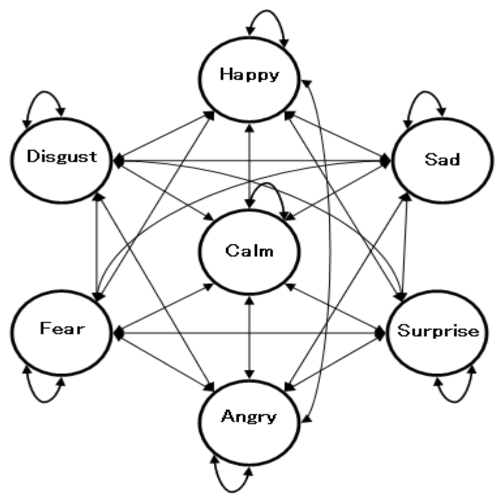

Fig. 1. Mental State Transition Network Model

2.3 Improvement of the Mental State Transition Network

The original mental state transition network is set up to describe the foundation of the emotion transition. Theoretically, the model can predict the situations of emotion transition. But it can not support the complicated situations containing certain affective stimulation which happened in common. However, it is necessary to sophisticate the model for both in theory and in practical.

We propose the model with the condition probability tables (CPTs) which consider the external affective stimulations. In the following Fig 2, the model is somewhat like the original one. The arcs represent the transitional probability from one emotion state to another one while the difference is that each circle was replaced by a circle with a inward arrow standing for external affective factors from emotion situation $P(E_k)$.

Since what we are dealing with are in a closed emotion space composed by only seven emotion states, it hypothesizes that state in model is independent from each other. the probability of each emotion situation E_k is $P(E_k)$ and we have $\sum_k P(E_k) = 1 \ i = 1 \ldots 7$. The probability of transition from state a_j to state a_i is $P(a_i|a_j, E_k)$.

The CPTs(Conditional Probability Tables) proposed in model indicate the transition probability between two emotions independently. This is actually a

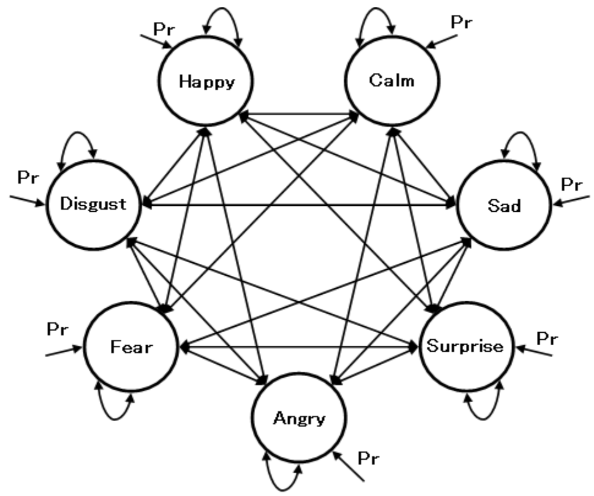

Fig. 2. Advanced Mental State Transition Network Model Considering the External Affective Factors

Bayesian network model that can be used to infer the emotion in the next period. According to this model, we can learn the probabilities of mental state transition for a person in a particular emotional situation by means of the psychological questionnaire.

3 Model Psychological Experiment

3.1 Psychological Experiment Based on the Mental State Transition Network

The conditional probability table is the foundation of the advanced mental state transition network model. In our experiment, CPT is obtained through psychological survey experiment. Over 100 individuals have attended our psychological experiment in the first phase. The participants are recruited primarily from the different high schools and universities in China and Japan. They are from 18 to 30 years old. About 60 percent of them are males and 40 percent are females. All of them were required to fill the questionnaires about emotion state transitions with different clues.

The psychological experiment basically required participants to fill out tables which were designed to describe transitions among seven emotion states following certain clues. The content of the questionnaire is described in the following three parts. First, individual information of the participant, including gender, age, educational level, nationality, occupation, and self-character assess were asked; Second, tables were designed depending on seven discrete mental states and third, an example was presented to show the participants how to fill out the table.

Table 1. Sample of Psychological Questionnaire

	Happy	Calm	Sad	Surprise	Angry	Fear	Disgust
Happy	10						
Calm	8						
Sad	5						
Surprise	3						
Angry	0						
Fear	2						
Disgust	1						

Table 1 is an example of original investigation data we collected. In the table, the header row represents current emotion (mental) state, and the first column represents the emotion (mental) state at next period of time. The digital number in each lattice means the possibility of that situation.

The experiment firstly appealed to the participants to imagine a certain emotional situation under the proposed clues and select what the next emotional state will be with some effect (including internal and external effect). Then we compared each items to calculate the probabilities.

The clues included seven different standard types corresponding to seven prototype emotions. For example, we gave the participants the clue that their wishes suddenly achieved to simulate the happiness situation.

In the questionnaire, the degree of possibility takes an integer value from 0 to 10. The maximum 10 means that the likelihood to transfer from the current state to next state is 100% and the minimum 0 means the possibility of transition is 0%. In table 1, transitional probabilities from the current happy state into happy/ calm/ sad/ surprise /angry/ fear/ disgust states are 10/8/5/3/0/2/1 respectively. In order to allow the participants to fill out the table more easily, the sums of all items in each column are not equal and we must normalize the original data before collecting statistics.

3.2 Model Experiment Result Analysis

Normalization The original items in the table are designed to be easily filled out and cannot be directly calculated as the probability distribution. Before we collect statistics on the data, we have to normalize the raw data[14].

Model Data Analysis After data normalization, the unbiased estimated means are calculated to obtain the CTPTs(conditional transitional probability tables) of the model. With these CTPTs we can predict the transition procedure of mental states in various situations.

Table 2. Sample of Transitional Probability in Happy Situation

	Happy	Calm	Sad	Surprise	Angry	Fear	Disgust
Happy	0.443	0.471	0.369	0.426	0.355	0.324	0.383
Calm	0.274	0.259	0.296	0.238	0.276	0.288	0.290
Sad	0.042	0.047	0.099	0.058	0.058	0.058	0.054
Surprise	0.121	0.150	0.147	0.186	0.158	0.145	0.135
Angry	0.029	0.035	0.045	0.048	0.093	0.047	0.049
Fear	0.017	0.021	0.027	0.021	0.038	0.094	0.035
Disgust	0.073	0.018	0.015	0.023	0.022	0.044	0.055

Table 2 includes the unbiased mean of each transition among mental states in the network model. The conditional probability table have been computed in a happiness situation.

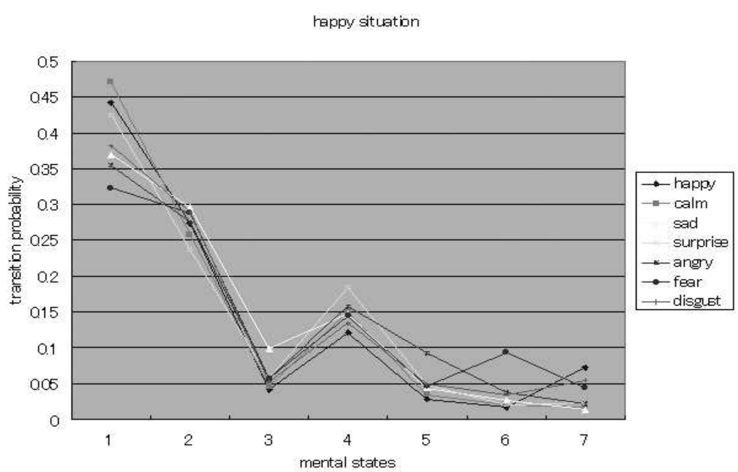

Fig. 3. Conditional Transitional Probability in Happy Situation

Fig 3 indicates the tendency of transitions from different start mental states in the happy situation. From analysis of six emotional situations, it denotes that under external effect:

- The probabilities of all transitions among mental states are all lower than 0.5 in all of six basic emotional situations.
- The mental states are likely to transfer to the states that are similar to the external emotion situations.
- The tendencies of transitions from different states are primarily analogous under a same external environment.

In this way we obtained average of mental state transitional probabilities under conditions of all six prototype emotions that showed in Fig 4.

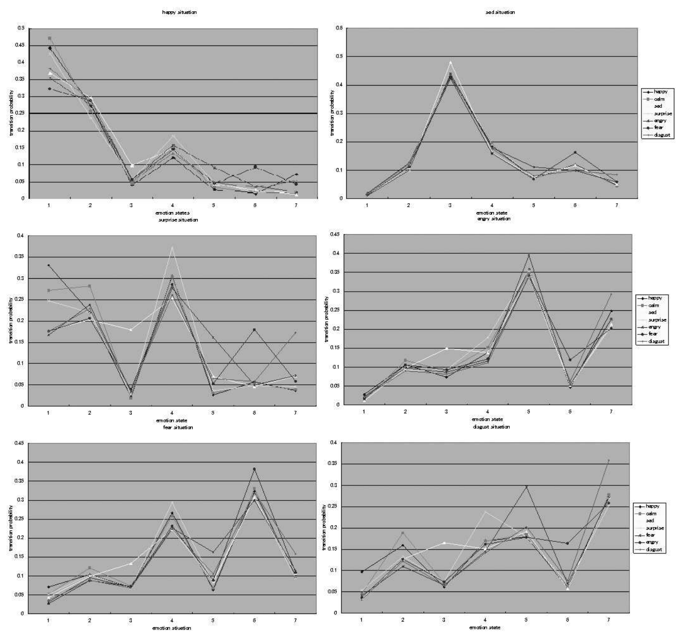

Fig. 4. Conditional Transitional Probabilities in Six Situations

4 Model Test Experiment

From the previous section a practical transition network model has been built up depending on about 100 pieces of questionnaires. In order to test the validity of this advanced mental state network model, we used another set of 50 random survey results as the test data.

The advanced mental state transition network is used to predict the future emotion state from a previous state with its stationary transitional probability distribution and external condition. Comparison mental states transitions according to the transition network model and test data will certify the validity of the model.

Firstly, in an intuitive viewpoint, we can verify the validity qualitatively. Comparing the top two states transfered from each state between the test data and corresponding probability distribution from the model, the model can be proved to be useful when the states are matching.

Then, we test the model by comparing the transitional probability distribution of all the states. This will finally present a determinate probability that describes the degree of validity of the model.

In the first case, from the model the top two states with largest probabilities are selected to compare with the top two from the test data directly. Table 3 has shown one example result of Comparison in happy situation. The results that the top twp states from the model and test data are matched have indicated that the model is valid qualitatively.

Table 3. Sample of Qualitatively Test Result of Mental State Transitional Network

	Happy	Calm	Sad	Surprise	Angry	Fear	Disgust
Happy	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Calm	2	2	2	2	2	2	2
Sad							
Surprise							
Angry							
Fear							
Disgust							

In the second case, the two kinds of transitional probabilities, $P_m\left(a_i|a_j\right)$ and $P_t\left(a_i|a_j\right)$ are considered. $P_m\left(a_i|a_j\right)$ indicates the transitional probability from state a_j to state a_i in model and $P_t\left(a_i|a_j\right)$ is the probability computed from the test data.

$$\sum_i P_m(a_i|a_j) = 1 \tag{1}$$

$$\sum_i P_t(a_i|a_j) = 1 \tag{2}$$

In our model, there are seven possible states to be transfered into from the start state. In an ideal case, the distribution of the transitional probability of the test data must match the model. We use the difference between distributions of the model and the test data to evaluate the validity. The following equation is used to calculate the related difference between the states:

$$P_j = \sum_i P_m(a_i|a_j)(1 - |P_m(a_i|a_j) - P_t(a_i|a_j)|) \tag{3}$$

The equation describes the difference between the probability distributions, $P_m(a_i|a_j)$ and $P_t(a_i|a_j)$. As the difference increases, the degree of validity P_j decreases. If the distributions of the probability are analogous, the result becomes one. For the whole model, we use the mean value of all states to evaluate the model validity P. The equation is as following:

$$P = \frac{1}{N}\sum_{j}\sum_{i} P_m(a_i|a_j)(1 - |P_m(a_i|a_j) - P_t(a_i|a_j)|) \tag{4}$$

N is the total number of the states. P is closer to 1, the model is more valid.

Compared with the 50 random test data, the probabilities of the model validity distributing on the six external emotion situations are indicated in the Tabl 4:

Table 4. Probabilities of the Model Validity

	Happy	Sad	Surprise	Angry	Fear	Disgust
P	0.87	0.85	0.82	0.84	0.85	0.83

The results mean that the model is close to the actual situation of human mental state transition.

5 Conclusion

In paper we proposed an advanced mental state transition network model that can be applied to predict the transition situation of emotion states in the next period under several affective stimulating environments. We implemented these thoughts by the psychological experiments to obtain the conditional transition probability tables in different emotional situations and the validity of the model was tested. The validity test experiment achieved a relatively high precision rate of 0.843 with the set of 50 random test data.

In advanced research, we will expand the range of the psychological experiments and make the model much more accurate and practical through considering more complex emotion states and situations.

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