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Study on Game Theory and Model of ERP based on EEG

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Abstract

Decision-making process refers in a particular situation, and choosing from several existing optional strategy evaluation process of certain strategy, however, in a complex environment, individual decisions tend to be affected by other individuals and random change of strategy, thus it is difficult to make a best decision. Although game theory provides a variety of decision-making plan, but it is not clear how the decision is influenced by the experience. The best decision-making behaviors need flexible adjustment strategy accord to the recent gains. In order to explore the nature of the human decision-making process USES the zero-sum game COINS of the positive and negative game, assuming that flexibility was produced in the process of reinforcement learning and a reinforcement learning model is established. In addition, the entire record the event related potential in the process of the subjects in the experiment. Analysis of ERP (Event Related Potential) data mainly focus on feedback related negative wave, which was considered to reflect the error signal and benefit related to the brain potential. Results show that after the loss to the other party of the event related potential amplitude suggested that participants would change the policy of pushing in the subsequent regulations, and the result was satisfied.

Keywords: *EEG (electroencephalogram), Game Theory, Computer Model*

1. Introduction

Decision-making [1-3] was the core of human activities to individual, group, organization, and social life, which was crucial to explore people how to make decisions; this was the hot spot of research at home and abroad. Game theory studies how decision-making under a given information structure decision, to obtain maximum utility, and the equilibrium of different decisions between the main bodies. Most of the game theory research, from the perspective of the mathematical model and the behavior experiment, and the neural mechanism is still unclear. Decision-making game of neuroscience research at home and abroad for most of the animals such as monkeys was the research object, some studies had found that the lateral inside groove area neurons might encoding expected utility, the ministry of the lateral prefrontal cortex neuron coding had experienced in the past decisions, and the utility of gains was in the past, there had been reports of decision-making game behavior associated with mirror neurons. In order to study the decision-making game neuroscience research mostly from the man-machine game (that is, people playing with a computer game) behavior and mathematical model of the Angle of the game for everyone (namely people game) study were less, which mostly were from the perspective of behavioral science, verified the relevant mathematical model and hypothesis. This project adopted the double EEG

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(electroencephalogram, EEG)/event related potentials (event related potentials, ERP) synchronous recording method, time-frequency signal analysis method and the method of computer model of man-machine game and everyone's game with a variety of game decision-making operation more in-depth research, and constantly changing affect game decision of important parameters, such as information, utility, strategy, *etc.*, at the same time explored the similarities and differences between everyone game decision-making with man-machine game. ERP statistics analysis was adopted in the experimental results, the EEG signal time-frequency processing, feature extraction, pattern recognition and EEG in the brain area tracing method such as analysis of experimental data, combined with the literature of various decision model, put forward a new or revised decision model, and then feedback to the experiment, the validation improved constantly, finally formed a computer model, to reveal the neural mechanisms of all game. This study aimed to, through the game everyone's cognitive neuroscience research and computer model, clarify all game decision-making dynamics characteristics of EEG/ERP, reveal its change rule and produce brain areas, simulate with the computer model, and discover accurate decisions of the brain activity regularity and mechanism to provide more experimental evidence. The innovation of this study was to use the double EEG/ERP synchronous recording, analyzing the similarities and differences between every game and man-machine game, combining with computer model analysis to explore the neural mechanism of human social decision.

Domestic research mostly from the psychology Angle to explore, the psychology of Chinese academy of sciences by li shu and others carried out fruitful research. They have been trying from behavioral level revealed the risk decision-making process of people, "don't" qi when choice model, it is considered that the real mechanism of risk decision about not maximize the pursuit of some form with expectations, but somehow bian examine the existence of advantage of sexual relations between options. With the help of a characterization system (best and worst possible outcome dimension) to describe the state of the involved risk option, the model described human choice behavior as a search for a particular option in the process of subjective was superior to the other options. To test their hypothesis, they use the Asian disease problems; choose inversion problem and preference reversal alignment when the inspections don’t model, and extending the inspection to repeatedly, game situation. Preference reversal problem prove that human behavior, or in violation of the principle of metastatic expected utility theory. Li shu with the help of a "matching" task and a "bid" task, inspection perceptual differences between each pair of possible outcome could predict people's preferred choice. The overall result supported "qi when don't" explanation of the model. The data show that the so-called preference reversal of vision didn’t come from favored by people, but from the preferred mechanism not known to us. In 2005, Lishu chose reverse analysis also shows that in every time with the choice, if you don't think the biggest difference come from the same dimensions, would lead to reverse choice. Experimental design for a "matching" task, and took this test, in the condition of three kinds of decision, whether two options of the differences in each dimension could predict people's repeated selection mutation. The results supported the overall test - retest "qi when don't choose the interpretation of the way." Their findings showed that repeated selection may was consistent, it was not because of that every time the chosen option had a maximum value, but because each choice had the biggest difference from a fixed dimension. Their research found also that many game used by a one-off game mechanism were different. In a one-off game was not make choice according to the

expectations theory, but to follow the "qi when don't" decision rules for choice; When multiple simple sex game expectation theory to predict the participants choices, expected utility theory was redundant.

Study on game decision-making tend to behavioral decision and direction of brain development, using FMRI, EEG/ERP technology, to explore the decisions people brain activity, try on the physical level of people's decision-making process. From the perspective of individuals and groups, interactive cases, people how to choose the interactive strategy as well as the factors that affect people to choose.

To sum up the neural mechanism study of multiplayer game, was the basis of accurate understanding of decision-making work, also a weak link of modern decision-making theory to fill, and thus had important academic value. Therefore, this project use modern EEG/ERP record and analysis technology, from the perspective of neurobiology, game theory and signal analysis, the key choice everyone game, in a typical game of EEG/ERP research, clarify the neural basis of human game, reveal its brain regions and the strategy process, contribute to improve the decision-making theory and cognitive neuroscience.

2. Game Theory

Game with the development of the neural mechanism research, not only benefited from the progress of the development of neuroscience and cognitive science, and more depend on the observation of brain activity measurement instruments and the development of measurement technology. In more advanced, noninvasive brain activity measurement instruments and technology, studies of brain function and working mechanism, mostly in the form of destructive or traumatic, for example, based on the research of surgical operation was traumatic, and based on a certain area or certain connection of living brain damage, to see what kind of function loss research, was destructive. As a result, most research was in vivo animal brain, brain dead, or patients with severe brain. At present, the research of brain activity equipment without damage basically had two kinds: one kind is record the change of the activity of the brain magnetic induction imaging equipment. This kind of device has good spatial resolution, but the whole brain scanning speed is slow, low temporal resolution. At present there were mainly positron emission tomography (PET) equipment, magneto encephalography (MEG) records, single photon emission computed tomography (SPECT) equipment, optical imaging and magnetic resonance (MRI) and functional magnetic resonance imaging (MFRI) equipment, etc. Another kind record brain was brain voltage changes in time dimension measuring equipment. This kind of equipment time resolution was very high, but due to the effect of skull, scalp impedance, low spatial resolution. At present there were mainly record electroencephalogram (EEG) and deal with the EEG data of equipment. Deal with electrical data and record brain electrical equipment was based on the time related potential (Event-Related Potential, ERP) analysis technique.

2.1. Reinforcement Learning Model

Experimental economists to individual learning process in the repeated game extensively study, and the research method was generally by making electrodes implanted monkeys and computer game.

Daeyeo Lee used the monkey to the nature of learning process were studied, experiments for the monkey stone scissors - cloth games to play, and record the monkey

selection and win every time. In order to figure out how the monkey was affected by pushing and record in the past, build the reinforcement learning model respectively, faith, learning model and ordinary learning model to fitting the data. In three models assume that t period for each of the given target x (x = S, G, or C, S, G, C respectively, on behalf of stone, scissor and cloth) the value of the function of n (x), which is updated after each game value function for:

$$V_{t+1}(x) = aV_t(x) + \Delta_t(x) \quad (1)$$

Thus, a was the attenuation coefficient, $\Delta_t(x)$ was the target x changes the value of the function.

(1)Reinforcement Learning Model: In reinforcement learning model, if selecting target x and losing,

$$V_t(x) = \Delta_L(2)$$

If selecting target x and not losing not wining,

$$V_t(x) = \Delta_T(3)$$

If selecting target x and wining,

$$V_t(x) = \Delta_W(4)$$

If not selecting target x,

$$V_t(x) = 0(5)$$

Therefore, the probability of a particular target is

$$P_t(x) = \frac{\exp V_t(x)}{\sum_{u=\{S,G,C\}} \exp V_t(u)}(6)$$

(2)Belief Learning Model: Similar to this model and the reinforcement learning model, in addition to the renewal of the value function completely released according to computer the opponent, which was different from the reinforcement learning model is: $\Delta_t(x) = \Delta_L$ referred to defeat by computer the choice of target, $\Delta_t(x) = \Delta_T$ referred to equalize the selected target, $\Delta_t(x) = \Delta_w$ refers to beat the computer selected target. Do need to point out that these adjustments were applicable to the entire target and the choice of the monkey. Because of different target selection probability was obtained by the value function and so on each target on the value of the function with a fixed parameters, didn't change the probability value. Make Δ_L model, therefore, according to the maximum likelihood method was by choosing the rest of the three parameters (Δ_T , Δ_W and a) to match the data.

(3) Common Learning Model: Reinforcement learning model and brief learning model could be used to represent a more general model, if the change of the value function depends on the selection of both monkeys and computer. In one experiment, for example, the monkeys lose, so similar to the belief that learning model, representing three target value functions will

be adjusted at the same time. In other words, $\Delta_t(x) = \Delta_{CL}$ said of the test were monkeys at a lose target, $\Delta_t(x) = \Delta_{CT}$ was played a draw of the selected target, and $\Delta_t(x) = \Delta_{CW}$ refers to win when monkeys selected target. But, in the common learning model, in a lost after the test, the value function changes different from after a draw or win the changes. As a result, corresponding to the bureau after the change of the value function could be respectively Δ_{CL} , Δ_{CT} and Δ_{CW} , and to estimate, respectively, and corresponding to a winning change can remember Δ_{CL} , Δ_{CT} and Δ_{CW} . Like in brief learning model, can from three targets at the same time the corresponding correction parameters value minus the without affecting the selection probability function. Therefore, the value of Δ_{CL} , Δ_{CT} and Δ_{CW} are 0, then estimate the rest of the parameters.

Released in a state of the benchmark, the computer random selection, at this time the monkey would tend to certain regulations. Monkeys in the past when the computer analysis of regulations before deciding strategy, at this time the monkey will still be based on the previous measures and strategies of computers. But the computer at the same time analysis the monkey past regulations was as well as the record again after pushing at this time. The monkey's pushing strategy would change too. Through validation, and a simple reinforcement learning and brief learning model, compared to normal learning model could explain the obtained experimental data. This shows that monkeys learning process was affected by itself and competitors, and random decision strategies in social contacts might also be affected by the real and imaginary benefits adjustment.

3. Feature Extraction [4-10]

Fisher, the size of the distance, said the data segment size to distinguish between the two types of degrees. Feature extraction to extract in the STFT matrix can distinguish between sample types of data. Is different to different people, the following data set K3b, for example, has 93 samples, the experimental data to test the results, we put the total sample is divided into two sets, learning sample set L) (60 sample and testing sample set T (33 samples). Feature extraction steps as follows:

1) As learning sample set L as an example calculation Fisher distance matrix;

2) The Fisher distance matrix according to descending order;

3) According to the sort of Fisher distance matrix, before ordering Fisher distance matrix of k, the composition characteristics of the alternative collections Ch1 {};

4) For Fisher distance learning sample set classification line;

Computation formula is as follows:

$$y = \frac{\sum_{j=1}^{k} P_{ia} - \sum_{j=1}^{k} Q_{ib}}{2} \qquad (7)$$

Y is the classification of thread, Pia is 1 type (movement to the left to imagine), Qib is 2 types (movement to the right imagine) characteristic collection; K number was characterized.

5) Select Ch1 {}, the first element in the Ch {} to join feature set, and delete the elements in the Ch1, through the classification line calculation test sample set classification recognition rate;

6) Repeat the above steps, and recognition rate/biggest characteristic values.

4. Results

Behavior data and model suggests that the subjects in the game using the reinforcement learning, through the entire record of scalp when subjects and computer game in the process of event related potential to explore the neural mechanisms, cranial nerve to benefit from then was how to reflect the influence of the game decision-making. In the process of decision-making task feedback, expectations of reward evaluation did not match the actual results, between 200-400 ms after feedback was issued before middle cerebral cortex would induce the negative direction of the event related potential ingredients, or feedback related negative wave (FRNS). According to the analysis of the event related potential are mainly concentrated in the study of feedback related negative wave. Middle cerebral cortex FCZ electrode area before the adoption of the data from the result of the feedback: won (win) - lose (loss) for one dimensional repetitive measure analysis of variance, the results showed that former middle cerebral cortex, the day after the feedback related negative wave compared to win after the bureau of event related potential was more negative trend. If the estimated error could give necessary adjustment signal behavior in the future, from the feedback related negative wave amplitude should be able to predict the participants in the game would adjustment. To test this hypothesis, this paper according to the result of decisions and subsequent game of pushing the data was divided into four categories: lost and in the next game change regulations (win - lose); Lost and pushing in the same in the next game (win - lose); To win the next game and changes in the regulations (win - opposite); To win the next game and pushing in the same (win - lose). Results show that the two cases have in common was changed in the game of pushing event related potential amplitude was obvious released to constant amplitude. By frequency domain and time domain analysis of the win, lose, it can be seen that EEG signals of different events, have different characteristics, to a variety of EEG, in order to reflect the characteristics of the brain, which caused by the collected EEG signals, after superimposed on the time domain average projected onto a 2 d, taking a sample every 220 seconds, imagine right brain topographic map, as shown in 0~1760 ms, brain, no obvious change on the topographic map in 1980 ms time, begin to imagine, right brain topographic map as shown on the left side began to appear is evident in the brain waves move, begin from 1980 ms, volatile C3 as the center areas of the brain, brain strong volatility continued until 2640 ms, started in 3080 ms time, to the 3520 ms, reappear and phenomenon during 1980 ~ 2640, after a period of time to recover, EEG during the period of 4180 ~ 4840 ms, is once again a C3 sharp fluctuations in brain regions that figure, according to the results of imagine when the subjects of right as areas of the brain for the center with C3 reflect strong, according to the moving imagination pattern as shown in figure, every movement think time between 880ms,the figure is as show in Figure 1.

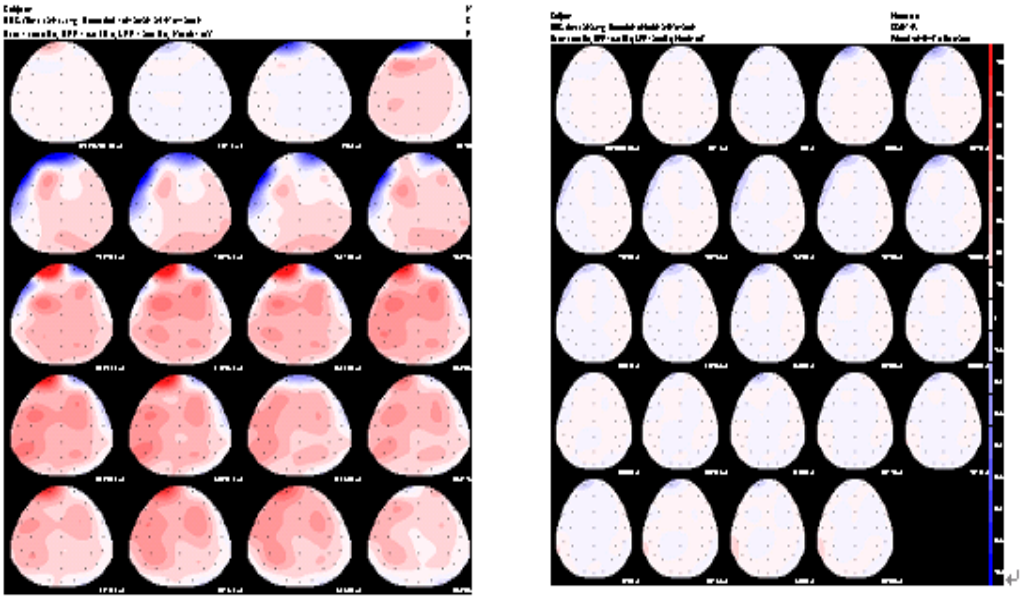

Figure 1. Brain Electrical Activity Mapping

The time-domain EEG signals for many times, and the average can achieve outstanding characteristics, the effect of noise, to the left and right two sports imagine stack, respectively, and comparison, through enhanced signal superposition, in the time domain signal shows certain characteristics, among them with FC3, C3, CP3, FCZ, CZ, CPZ, FC4, C4 and CP4 is most obvious and stable, as shown in figure, heavy color to left to imagine movement in light color for right imagine movement, compared to imagine movement, around more than nine with electrode EEG showed that figure showed that the subjects to lose to win game, electrical strength is bigger, which is as show in Figure 2.

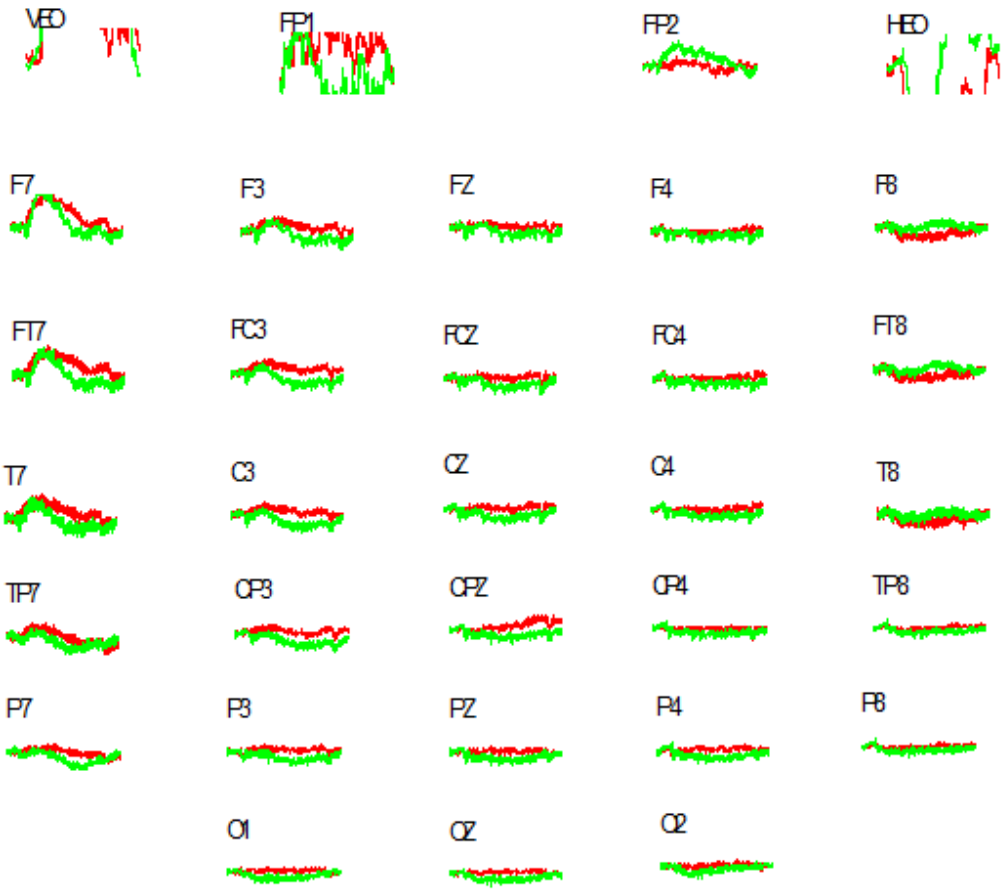

Figure 2. Electrode of EEG

Electrode compared to win - lose events respectively, Figure shows the contrast of C3 and C4 superposition of two electrodes of the time-domain signal, in the figure could discern between 2000 ~ 3000 ms, EEG appeared larger characteristics, which is as show in Figure 3.

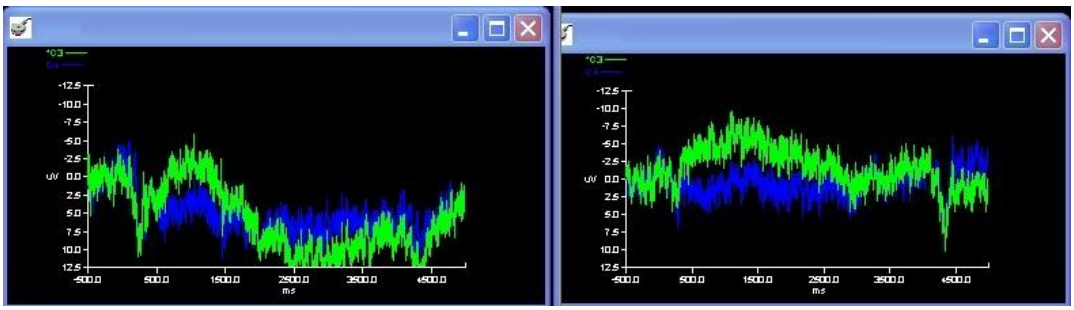

Figure 3. Characteristics of EEG

By using Feature Extraction , converts the signal time domain to frequency domain, the Figure shows the two movement around the C3 and C4 electrode on frequency domain signal contrast, figure display movement imagine EEG features was focused on the 2 ~ 8Hz, 12 ~ 15 Hz and 35 ~ 39 Hz three frequency domain, which is show in Figure 4.

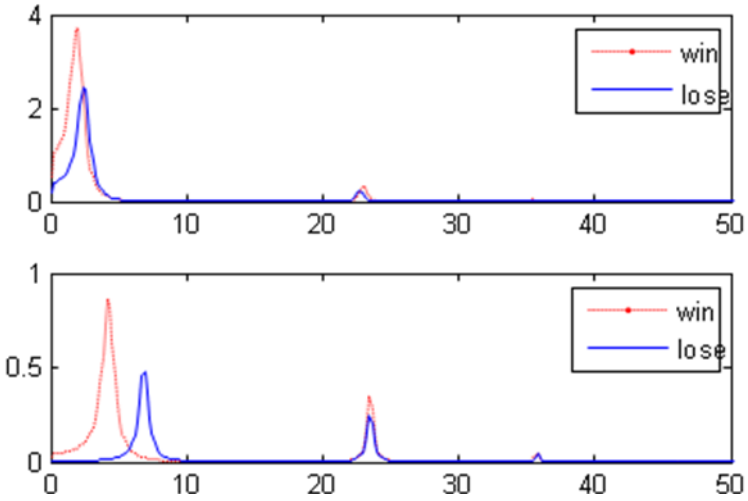

Figure 4. Feature Extraction of EEG

5. Discussion

For humans in a zero-sum game, the question of whether or not to follow the game theory are pushing strategy has a lot of related research, these studies have shown that individuals when making decisions tend to be influenced by other factors such as environment and deviating from the equilibrium strategies. There are many studies have found that people adopt in the process of decision-making is reinforcement learning model. In this article, through the experiment found that someone was a simple zero sum game, estimate the best decision possible using the reinforcement learning algorithm, this will make the authorities gradually tend to take some equilibrium strategies. When faced with a master a lot of personal information, after every game decision of value function should do some small updates, as well as the algorithm in this experiment, because the value function to do big predictable update it's easy to give in to his opponent exposure game decision-making. In this experiment, with the accumulation of experience, the subjects of value function of the change of amplitude will adjust according to rival the computer strategy accordingly. In addition, in this paper, the subjects after the result feedback induced event related potential was studied, and found that after the decision-making errors induced by negative wave ratio decision feedback related victory after induced feedback related negative wave is more obvious, regardless of winning or losing, decision-making in the following game is going to change strategy, which induced by the negative wave amplitude feedback related significantly higher than without changing strategy change. And this is just and strengthening cost function value is consistent in the model, the range of the changes in the value of the lost function than winning range is big, and then a game change strategy than changing policy changes in the value of the function. This means that the feedback related negative wave amplitude suggested that participants will change the policy of pushing in the subsequent regulations. With the deepening of the study subjects in this experiment, and the accumulation of experience, in reinforcement learning model, can see the value of the function change amplitude will be more and more not obvious, so that the opponent is more and more difficult to predict subsequent pushing on feedback related negative wave but this is not very well, for the neural mechanism of decision-making research remains to be further research.

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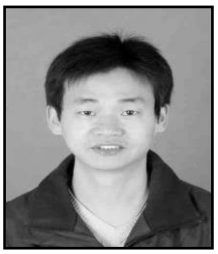

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