Modeling Human Mind

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ABSTRACT

In this paper, we propose a computational model of personality (called *personality model*) for the purpose of implementing non-intellectual functions of human mind on computer systems. The personality model will be formulated based on psychoanalysis, assuming that defensive mechanism plays an essential role in a personality. Inductive probability will be employed for modeling defense mechanism. The personality model is useful for the expression of feelings, and will be used in virtual reality, computer game characters, agent secretaries, and robotics.

1. INTRODUCTION

This paper proposes a computational model of personality, called *personality model*, which is based on concepts, principles, and structures of human mind [1].

Human mind may be classified into *intellectual* activities, such as learning, reasoning, judging, estimating, memorizing and associating, and *non-intellectual* functions, such as emotion and unconsciousness. Various attempts have been made to implement the intelligence, such as studies on expert systems and neural networks[3], but non-intellectual activities have scarcely been investigated. This paper models non-intellectual functions of human mind. The personality model is formulated based on psychoanalysis, assuming that defensive mechanism plays an essential role in a personality. Inductive probability is employed for modeling defense mechanism.

2. THE PERSONALITY MODEL

In this section, we formulate a computational model of personality based on the knowledge of psychoanalysis.

2.1 Personality in psychoanalysis

This section describes briefly how human personality is understood in psychoanalysis. S. Freud proposed that it was possible to analyze personality in terms of topography, structure, economy, dynamics and development [4].

In terms of topography, Freud pointed out that most human activities were regulated by unconsciousness rather than conscious volition. Structurally, personality consists of *ego*, *super-ego* and *id*, which are associated with reality, morality, and pleasure principles, respectively. Id is associated with the drives of *want to do something*, and super-ego is associated with the drives of *must do something*. Ego adjusts between the drives of id and those of super-ego. The economic theory states that the mental process is a result of the quantitative distribution of energy. Mental activities involve a certain kind of energy, whose quantity and distribution determine which mental process occurs. The dynamic theory states that psychological phenomena are the result of conflicts among ego, super-ego and id. Such conflicts cause anxiety (feeling of the collapse of ego). Ego uses defensive mechanism to escape from the anxiety.

Defense is an adaptive mechanism, which maintains ego by avoiding danger, anxiety, or displeasure. The mechanism functions automatically when the energy of ego drops (or when ego becomes weak). Defense mechanism involves repression, denial, projection, and reaction formation, among which repression is the most important. Repression withholds from recall and encloses under unconsciousness the memories, ideas, feelings, or desires that are painful or dangerous to accept.

2.2 General framework of the personality model

The rest of this section formulates a personality as a computational model. The psychoanalytical structural, economic, and dynamic theories described in Section 2.1 are used for modeling personality. The model focuses on the defensive mechanism as the essentials of personality. That

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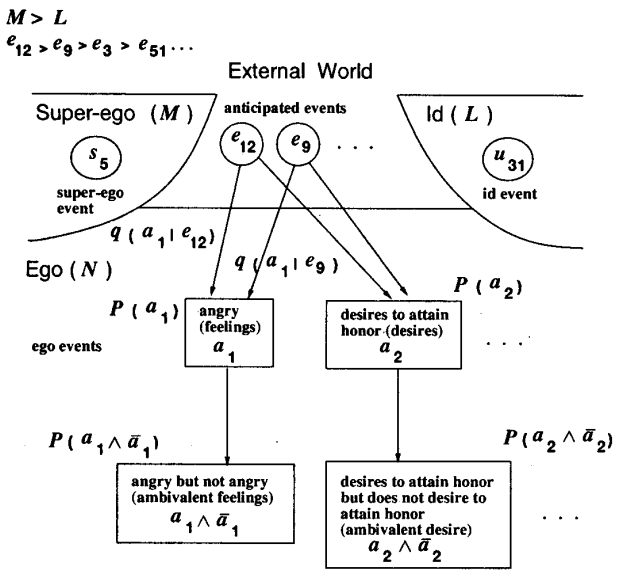

Figure 1: An image of the framework of the personality model

is, we model the following mechanism:
Trigger $\longrightarrow$ Conflict $\longrightarrow$ Anxiety $\longleftrightarrow$ Defense

For example, a person may have a conflicting feeling toward a subject he/she sees or hears: *I like it, but I hate it.* The person becomes anxious when such a conflict occurs. Usually, the defensive mechanism works to avoid anxiety, but there are cases in which the mechanism does not properly work, anxiety grows, and a vicious cycle is formed. This paper focuses on *repression*, which is a typical defensive mechanism.

This section gives the general framework of the personality model. An image of the framework is shown in Figure 1. Personality is constituted by three modules: ego, super-ego, and id, for each of which *events* occur.

(1) Actualization of super-ego events

A finite set is given in advance for the events of super-ego (hereinafter called *super-ego events*); $S \stackrel{\text{def}}{=} \{s_1, \cdots, s_l\}$. An event of these super-ego events is actualized according to a given probability distribution which depends on the person.

(2) Actualization of id events

Similarly, a finite set for the events of id (*id events*) is given in advance; $U \stackrel{\text{def}}{=} \{u_1, \cdots, u_m\}$. An event of these id events is actualized according to a given probability distribution which depends on the person.

(3) Ego events

A finite set is given in advance for the events of ego (*ego events*); $K \stackrel{\text{def}}{=} \{a_1, \cdots, a_p\}$. Ego events include feelings, memories, ideas, and desires. Feelings, for example, are further classified into fear, anger, sadness, and pleasure. Ego events are defined by the inductive probability (described later) that is calculated from the anticipated events.

(4) Anticipated events

We assume that a person anticipates in his/her mind what will occur next when he/she receives information of some kind from the external world. A finite set of the *anticipated events* is given in advance; $E \stackrel{\text{def}}{=} \{e_1, \cdots, e_n\}$. The person stochastically anticipates which of these events will occur (we assume that only one event will occur). Here, let Z be a random variable for expressing the actualized anticipated event, whose probability distribution is as follows:

$$\{P(Z = e_i) \mid i = 1, \cdots, n\}. \qquad (1)$$

This probability distribution depends on information given and the personality. Here, the order on strength is given for the set of the anticipated events $\{e_1, \cdots, e_n\}$ in advance. An event with a stronger value has a larger effect on super-ego events. For example, the order of strength may be $e_{12} > e_9 > e_3 > e_{51} > \cdots$.

(5) Law of energy of conservation

Energy is defined for each of these three modules of personality. The sum of the energy of super-ego M, the energy of ego N, and the energy of id L is always constant: $M + N + L = 1.0$, provided that $M, N, L \geq 0$.

(6) Conditions for the defensive mechanism to work

The energy of ego N determines the intensity of defense (for example, repression). A large N value signifies strong ego (reality principle) and that the person can solve a conflict by facing reality and not by using defensive mechanism. Such a person neglects the effect of the super-ego event that causes a conflict (e.g. s_5), and the corresponding id event (e.g. u_{31}) becomes dominant.

On the other hand, a small N value signifies that ego does not well function and thus the defensive mechanism works. Defense is an adaptive mechanism that works when ego is weak.

(7) Rules for determining conditional probability values

When a super-ego event s_5 and an id event u_{31} occur, the conditional probability $\{q(a_j \mid e_i)\}$ between anticipated events $\{e_1, \cdots, e_n\}$ and ego events $\{a_1, \cdots, a_p\}$ is determined in the following manner.

An arbitrary a_j $(j = 1, \cdots, p)$ is chosen. a_j is treated as follows.

The process described below is performed for anticipated events $\{e_1, \cdots, e_n\}$ one by one in the order of strength (from the strongest one to the weakest one). We assume that $e_1 > \cdots > e_n$ without losing generality. Let the target anticipated event be e_i. In this case, the conditional probability $\{q(a_j \mid e_1), \cdots, q(a_j \mid e_{i-1})\}$ for the anticipated events $\{e_1, \cdots, e_{i-1}\}$ is already determined. The conditional probability $q(a_j \mid e_i)$ is thus stochastically determined according to the following rules.

- The strengths of super-ego energy M and id energy L determine which of the super-ego event s_5 or the id event u_{31} has a stronger effect (the greater the energy is, the stronger the effect is).
- The strength of anticipated events $(e_1 > \cdots > e_n)$ determines the effect of the super-ego event s_5 on e_i. This effect is smaller than the effect of the super-ego event s_5 on $(e_1, \cdots, e_{i-1})$.

2.3 Conflict

This section defines *conflict* based on the inductive probability $P(a \cap \bar{a})$ of ego event a. Inductive probability was proposed by Otsu [2], which was a natural extension of the usual probability. The following characteristic, which is not seen in usual probability, is inherent in inductive probability.

Proposition 1

$$P(A \cap \bar{A}) \geq 0. \tag{2}$$

That is, law of contradiction does not hold. □

Equation (2) shows that the probability of "*A and not A*" can be a positive value.

We can easily find that inductive probability has the following characteristics:

Proposition 2 *The inductive probability* $P(A \cap \bar{A}) \stackrel{\text{def}}{=} E_n[q(A \cap \bar{A} \mid b_n)]$ *takes a value within the range of*

$$0 \leq P(A \cap \bar{A}) \leq \frac{1}{4}. \tag{3}$$

The maximum value $1/4$ *is realized when* $q(A \mid b_n) = 1/2$ *for any* $n \in \boldsymbol{N}$, *and the minimum value* 0 *is realized when* $q(A \mid b_n) = 0$ *or* $q(A \mid b_n) = 1$ *for any* $n \in \boldsymbol{N}$ *where* $\boldsymbol{N}$ *is the set of all natural numbers.* □

We then define *conflict* using the inductive probability.

Definition 1 (conflict) *Using the inductive probability, for any ego event "a", the degree of conflict is defined as*

$$P(a \cap \bar{a}). \tag{4}$$

The larger the value of equation (4) *is, the stronger the conflict is. As shown in Proposition 2, the values of equation* (4) *are 0 or larger but never larger than* $1/4$. *When this value is* 0, *there is no conflict, and the conflict is maximum when the value is* $1/4$. □

2.4 Anxiety

In this section, *anxiety* is formulated.

Definition 2 (anxiety) *Let* α *be a real number such that* $0 \leq \alpha \leq 1/4$, *which is called anxiety parameter. Then "feeling anxious" is defined as a state when there exists an ego event* $a \in K$ *which satisfies*

$$P(a \cap \bar{a}) \geq \alpha. \tag{5}$$

The degree of anxiety $UE(\alpha)$ *is defined by*

$$UE(\alpha) \stackrel{\text{def}}{=} \frac{4}{|K|} \sum_{\substack{a \in K \\ P(a \cap \bar{a}) \geq \alpha}} P(a \cap \bar{a}), \tag{6}$$

where $K = \{a_1, \cdots, a_p\}$ *is a finite set of ego events,* $|K|$ *is the cardinarity of* K, *and* $4/|K|$ *is a coefficient for normalization.* □

2.5 Repression

Repression does not work immediately after the person feels anxious. If the anxiety is not severe, the person can support himself/herself even under an anxious state. However, if the anxiety is very strong, the person cannot support it, and repression works to defend himself/herself. We call the anxiety limit over which repression works *critical anxiety*. This section formulates critical anxiety and repression using the degree of anxiety UE (equation (6)).

Definition 3 (critical anxiety) *Let β be a real number such that $0 \leq \beta \leq 1$, which is called critical anxiety parameter. Then, critical anxiety is defined as a state when*

$$UE(\alpha) \geq \beta. \tag{7}$$

□

Definition 4 (repression) *Repression occurs by the mechanism described below when the person confronts the critical anxiety.*
(1) *Ego produces an artificial anticipated event $\hat{e}_1$ which satisfies*

$$q(a \mid \hat{e}_1) = 0 \tag{8}$$

or

$$q(a \mid \hat{e}_1) = 1 \tag{9}$$

for any ego event $a \in K$ such that $P(a \cap \bar{a}) \geq \alpha$ (artificial anticipated events are expressed with $\hat{}$ on letters). That is, an artificial anticipated event $\hat{e}_1$ is added to the set of anticipated events $E = \{e_1, \cdots, e_n\}$.

Then, the number of anticipated events increases from n to $n+1$, and the probability distribution expressed by equation (1), which is

$$\{P(Z = e_1),\ \cdots,\ P(Z = e_n)\} \tag{10}$$

changes into

$$\{\gamma P(Z = e_1),\ \cdots,\ \gamma P(Z = e_n),\ P(Z = \hat{e}_1) = 1-\gamma\}. \tag{11}$$

Here, the real number $0 \leq \gamma < 1$ is called repression parameter.

Artificial anticipated events $\hat{e}_2, \hat{e}_3, \cdots$ are successively produced until the person escapes from the critical anxiety, in other words, $UE(\alpha) < \beta$.

(2) *For each artificial anticipated event $\hat{e}_k$, a self-acceptance degree AD_k is produced. The anxiety parameter α and the critical anxiety parameter β are updated based on the sum of self-acceptance degrees:*

$$AD \stackrel{\text{def}}{=} \sum_k AD_k. \tag{12}$$

□

The following two theorems can be easily proved (see [1] for the proofs).

Theorem 1 *The conflict $P(a \cap \bar{a})$ strictly monotonously decreases as artificial anticipated events occur according to Definition 4 (1).* □

Theorem 2 *Either $P(a)$ or $P(\bar{a})$ strictly monotonously decreases, and the other strictly monotonously increases as artificial anticipated events occur according to Definition 4 (1).* □

Definition 4 (1) signifies that a person *artificially* produces an anticipated event $\hat{e}_1$ for easing the anxiety caused by ego events satisfying $P(a \cap \bar{a}) \geq \alpha$, and reduces the conflict $P(a \cap \bar{a})$ (see Theorem 1). The person attempts to avoid the critical anxiety by reducing $P(a \cap \bar{a})$ below α.

The mechanism of Definition 4 is called *repression* due to the following reason. By Theorem 2, an artificial anticipated event $\hat{e}_1$ causes a drop in either $P(a)$ or $P(\bar{a})$ and an increase of the other. Therefore, one of the two is suppressed. This is *repression.*

Definition 4 (2) assumes that the self-acceptance degree AD_k takes a small negative value and that the resulting changes in anxiety parameter α and critical anxiety parameter β are also small negative values. In other words, α and β decrease. When α decreases, the number of ego events that satisfy $P(a \cap \bar{a}) \geq \alpha$ increases, thus the anxiety degree $UE(\alpha)$ becomes larger (generally, $UE(\alpha) \nearrow (\alpha \searrow 0)$). As a result, repression easily occurs. When the critical anxiety parameter drops further, repression occurs more easily. Repression takes place in order to ease anxiety, and the conflict seems to disappear. However, anxiety actually increases, and repression further advances (in other words, the person becomes unstable).

Definition 5 (behavior of a person when he/she is not at the critical anxiety) *When a person does not feel the critical anxiety, the following mechanism works:*

> *Self-acceptance degree AD is produced, which changes the anxiety parameter α and the critical anxiety parameter β.*

□

Definition 5 assumes that the self-acceptance degree is positive value (i.e., $AD > 0$) and that changes in α and β are small and positive values. In other words, α and β increase. This signifies that the person accepts himself/herself bacause repression does not take place, and the possibility that the person feels anxious, suffers critical anxiety, and uses repression, is somewhat reduced.

3. NUMERICAL EXAMPLE

A numerical example is given for the behavior of the personality model.

(1) Initial values of parameters
As initial values, super-ego energy $M = 0.5$, id energy $L = 0.4$, and ego energy $N = 0.1$ were used. Since $M > L$, super-ego has more energy than id. Since N is small ($= 0.1$), ego easily causes repression. Anxiety parameter $\alpha = 0.1$, critical anxiety parameter $\beta = 0.7$, and repression parameter $\gamma = 0.2$ were used.

(2) Actualization of a super-ego event and an id event
It was assumed that a super-ego event '*courtesy to seniors*' (s_{11}) and an id event '*desire for self approval*' (u_{25}) were actualized according to the given probability distributions, respectively.

(3) Anticipated events
The following four anticipated events were prepared in advance: e_1 (Father scolds me), e_2 (Father beats me without hesitation), e_3 (Father ignores me), e_4 (Father praises me). Let the strength order of these events be $e_3 > e_1 > e_2 > e_4$. The information "*I threw a ball and broke a window*" was provided from the external world and determined the probability distribution of the anticipated events as follows: $P(Z = e_1) = 0.5$ (Father scolds me), $P(Z = e_2) = 0.5$ (Father beats me without hesitation), $P(Z = e_3) = 0.0$ (Father ignores me), $P(Z = e_4) = 0.0$ (Father praises me). That is, the person anticipated that he/she would be either scolded or hit by Father with the same probability.

(4) Ego event
For the sake of simplicity, only one ego event, which was '*I feel anger*'(a_1), was considered.

(5) Determination of conditional probability $q(a_1 \mid e_1)$
For the anticipated event e_1 (Father scolds me), the conditional probability $q(a_1 \mid e_1) = 0.45$ was stochastically determined from the super-ego event s_{11} (Courtesy to seniors) and the id event u_{25} (Desire for self approval). Since s_{11} is stronger than u_{25}, this conditional probability value is small (0.45), which signifies '*not very angry*'. This strength was stochastically determined from the relationship between super-ego energy M (morality principle) and id energy L (pleasure principle) ($M > L$).

(6) Determination of conditional probability $q(a_1 \mid e_2)$
For the anticipated event e_2 (Father beats me without hesitation), the conditional probability $q(a_1 \mid e_2) = 0.55$ was stochastically determined from the super-ego event s_{11} and id event u_{25}. Although $M > L$, this probability value (0.55) is higher than that of $q(a_1 \mid e_1)$ because '*being hit*' is a more serious matter than '*being scolded*' for the person, and '*desire for self approval*' (u_{25}) is stronger than '*courtesy to seniors*'(s_{11}). This reflects the order of anticipated events: $e_1 > e_2$.

(7) Calculation of inductive probability
The inductive probability for an ambivalent feeling of '*angry but not angry*' was determined:

$$\begin{aligned} P(a_1) &= P(\textit{angry}) = 0.5, \\ P(\bar{a}_1) &= P(\textit{not angry}) = 0.5, \\ P(a_1 \cap \bar{a}_1) &= P(\textit{angry but not angry}) = 0.2475. \end{aligned}$$

Since the maximum value of $P(\textit{angry but not angry})$ is 0.25, the probability for conflict is very high.

(8) Detection of whether the person is at the critical anxiety ($UE(\alpha) \geq \beta$?)
Since $P(a_1 \cap \bar{a}_1) = P(\textit{angry but not angry}) = 0.2475 > 0.1 = \alpha$ (anxiety parameter), the person feels anxiety. Since $UE(\alpha) = 4 \cdot P(a_1 \cap \bar{a}_1) = 4 \times 0.2475 = 0.99 > 0.70 = \beta$ (critical anxiety parameter), the person is at the critical anxiety. The energy of ego N is small, 0.1. Therefore, repression works.

(9) Occurrence of artificial anticipated events and change in probability distribution
Repression works and produces an artificial anticipated event $\hat{e}_1$ (Father is kind). Assume that $q(a_1 \mid \hat{e}_1) = 0.0$. The artificial anticipated event produces an self-acceptance degree $AD_1 = -0.01$ and a change in probability distribution of anticipated events which we now state: $P(Z = e_1) = 0.1$, $P(Z = e_2) = 0.1$, $P(Z = e_3) = 0.0$, $P(Z = e_4) = 0.0$, $P(Z = \hat{e}_1) = 0.8$

(10) Re-calculation of inductive probability
The inductive probability for an ambivalent feeling of "*angry but not angry*" was again calculated:

$$\begin{aligned} P(a_1) &= P(\textit{angry}) = 0.1, \\ P(\bar{a}_1) &= P(\textit{not angry}) = 0.9, \\ P(a_1 \cap \bar{a}_1) &= P(\textit{angry but not angry}) = 0.0495. \end{aligned}$$

The inductive probability of "*angry*" decreased, that of "*not angry*" increased, and that of "*angry but not angry*" extremly decreased, which meant that the conflict was reduced. The person is no longer at the critical anxiety nor anxious. This is

a result of repression.

(11) Changes in parameters of various kinds Anxiety parameter $\alpha = 0.1$ and critical anxiety parameter $\beta = 0.7$ change according to the sum of self-acceptance degrees $AD = \sum_k AD_k$. Since $AD_1 = -0.01$ is the only self-acceptance degree produced in this case study, $AD = -0.01$. Assume that the magnitude of change in critical anxiety parameter ($\Delta\beta$) is determined by a hyperbolic tangent tanh and that the magnitude of change in anxiety parameter ($\Delta\alpha$) is determined by $(1/4)\tanh$. That is, $\Delta\alpha \stackrel{\text{def}}{=} (1/4)\tanh(AD), \Delta\beta \stackrel{\text{def}}{=} \tanh(AD)$. Since $AD = -0.01$, $\Delta\alpha = -0.0025$ and $\Delta\beta = -0.01$, which lead $\alpha = 0.0975$ and $\beta = 0.69$. Such changes in parameters cause repression to occur slightly more easily.

4. CONCLUSIONS

This paper proposed a computational model called *personality model* based on the psychoanalytical knowledge, whose purpose was to implement the non-intellectual activities of human mind on computer systems. Inductive probability played an important role in the formulation of the personality model. In the future, we will evaluate, analyze and improve the personality model via computer simulations.

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