

On the Cognitive Processes of Human Perception with Emotions, Motivations, and Attitudes

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ABSTRACT

An interactive motivation-attitude theory is developed based on the Layered Reference Model of the Brain (LRMB) and the Object-Attribute-Relation (OAR) model. This paper presents a rigorous model of human perceptual processes such as emotions, motivations, and attitudes. A set of mathematical models and formal cognitive processes of perception is developed. Interactions and relationships between motivation and attitude are formally described in Real-Time Process Algebra (RTPA). Applications of the mathematical models of motivations and attitudes in software engineering are demonstrated. This work is a part of the formalization of LRMB, which provides a comprehensive model for explaining the fundamental cognitive processes of the brain and their interactions. This work demonstrates that the complicated human emotional and perceptual phenomena can be rigorously modeled and formally treated based on cognitive informatics theories and denotational mathematics.

Keywords: attitude; cognitive informatics; cognitive model; emotion; LRMB; mathematical model; motivation; PAR; perceptual processes; RTPA; the brain

INTRODUCTION

A variety of life functions and cognitive processes has been identified in cognitive informatics (Wang, 2002a, 2003a, 2007b) and cognitive psychology (Payne & Wenger, 1998; Pinel, 1997; Smith, 1993; Westen, 1999; Wilson & Keil, 1999). In order to formally and rigorously describe a comprehensive and coherent set of mental processes and their relationships, an LRMB has been developed (Wang & Wang,

2006; Wang, Wang, Patel, & Patel, 2006) that explains the functional mechanisms and cognitive processes of the brain and the natural intelligence. LRMB encompasses 39 cognitive processes at six layers known as the *sensation, memory, perception, action, meta* and *higher cognitive layers* from the bottom up.

Definition 1: Perception is a set of internal sensational cognitive processes of the brain at

the subconscious cognitive function layer that detects, relates, interprets, and searches internal cognitive information in the mind.

Perception may be considered as the sixth sense of human beings since almost all cognitive life functions rely on it. Perception is also an important cognitive function at the subconscious layers that determines personality. In other words, personality is a faculty of all subconscious life functions and experience cumulated via conscious life functions. It is recognized that a crucial component of the future generation computers known as the *cognitive computers* is the *perceptual engine* that mimic the natural intelligence (Wang, 2006, 2007c).

The main cognitive processes at the perception layer of LRMB are *emotion, motivation, and attitude* (Wang et al., 2006). This article presents a formal treatment of the three perceptual processes, their interrelationships, and interactions. It demonstrates that complicated psychological and cognitive mental processes may be formally modeled and rigorously described. Mathematical models of the psychological and cognitive processes of emotions, motivations, and attitudes are developed in the following three sections. Then, interactions and relationships between emotions, motivations, and attitudes are analyzed. Based on the integrated models of the three perception processes, the formal description of the cognitive processes of motivations and attitudes will be presented using RTPA (Wang, 2002b, 2003c, 2006b, 2007a). Applications of the formal models of emotions, motivations, and attitudes will be

demonstrated in a case study on maximizing strengths of individual motivations in software engineering.

THE HIERARCHICAL MODEL OF EMOTIONS

Emotions are a set of states or results of perception that interprets the feelings of human beings on external stimuli or events in the binary categories of pleasant or unpleasant.

Definition 2: An emotion is a personal feeling derived from one's current internal status, mood, circumstances, historical context, and external stimuli.

Emotions are closely related to desires and willingness. A *desire* is a personal feeling or willingness to possess an object, to conduct an interaction with the external world, or to prepare for an event to happen. A *willingness* is the faculty of conscious, deliberate, and voluntary choice of actions.

According to the study by Fischer, Shaver, and Carnochan (1990) and Wilson and Keil (1999), the taxonomy of emotions can be described at three levels known as the sub-category, basic, and super levels as shown in Table 1.

It is interesting that human emotions at the perceptual layer may be classified into only two opposite categories: *pleasant* and *unpleasant*. Various emotions in the two categories can be classified at five levels according to its strengths of subjective feelings as shown in Table 2 (Wang, 2005), where each level encompasses

Table 1. Taxonomy of emotions

Level	Description				
Super level	Positive (pleasant)		Negative (unpleasant)		
Basic level	Joy	Love	Anger	Sadness	Fear
Sub-category level	Bliss, pride, contentment	Fondness, infatuation	Annoyance, hostility, contempt, jealousy	Agony, grief, guilt, loneliness	Horror, worry

Table 2. The hierarchy of emotions

Level (Positive/Negative)		Description	
0	No emotion	-	
1	Weak emotion	Comfort	Safeness, contentment, fulfillment, trust
		Fear	Worry, horror, jealousy, frightening, threatening
2	Moderate emotion	Joy	Delight, fun, interest, pride
		Sadness	Anxiety, loneliness, regret, guilt, grief, sorrow, agony
3	Strong emotion	Pleasure	Happiness, bliss, excitement, ecstasy
		Anger	Annoyance, hostility, contempt, infuriated, enraged
4	Strongest emotion	Love	Intimacy, passion, amorousness, fondness, infatuation
		Hate	Disgust, detestation, abhorrence, bitterness

a pair of positive/negative or pleasant/unpleasant emotions.

Definition 3: The strength of emotion $|E_m|$ is a normalized measure of how strong a person's emotion on a five-level scale identified from 0 through 4, that is:

$$0 \leq |E_m| \leq 4 \tag{1}$$

where $|E_m|$ represents the absolute strength of an emotion regardless whether it is positive (pleasant) or negative (unpleasant), and the scope of $|E_m|$ is corresponding to the definitions of Table 2.

It is observed that an organ known as *hypothalamus* in the brain is supposed to interpret the properties or types of emotions in terms of pleasant or unpleasant (Payne & Wenger, 1998; Pinel, 1997; Smith, 1993; Wang et al., 2006; Westen, 1999).

Definition 4: Let T_e be a type of emotion, ES the external stimulus, IS the internal perceptual status, and BL the Boolean values true or false. The perceptual mechanism of the hypothalamus can be described as a function, that is:

$$T_e : ES \times IS \rightarrow BL \tag{2}$$

It is interesting that the same event or stimulus ES may be explained in different types, in terms of pleasant or unpleasant, due to the difference of the real-time context of the perceptual status IS of the brain. For instance, walking from home to the office may be interpreted as a pleasant activity for one who likes physical exercise, but the same walk due to car breakdown will be interpreted as unpleasant. This observation and the taxonomy provided in Tables 1 and 2 leads to the following Theorem.

Theorem 1: The human emotional system is a binary system that interprets or perceives an external stimulus and/or internal status as pleasant or unpleasant.

Although there are various emotional categories in different levels, the binary emotional system of the brain provides a set of pairwise universal solutions to express human feelings. For example, angry may be explained as a default solution or generic reaction for an emotional event when there is no better solution available; otherwise, delight will be the default emotional reaction.

THE MATHEMATICAL MODEL OF MOTIVATIONS

Motivation is an innate potential power of human beings that energizes behavior. It is motivation that triggers the transformation from thought (information) into action (energy). In other words, human behaviors are the embodiment of motivations. Therefore, any cognitive behavior is driven by an individual motivation.

Definition 5: A motivation is a willingness or desire triggered by an emotion or external stimulus to pursue a goal or a reason for triggering an action.

As described in LRMB (Wang et al., 2006), motivation is a cognitive process of the brain at the perception layer that explains the initiation, persistence, and intensity of personal emotions and desires, which are the faculty of conscious, deliberate, and voluntary choices of actions.

Motivation is a psychological and social modulating and coordinating influence on the direction, vigor, and composition of behavior. This influence arises from a wide variety of internal, environmental, and social sources, and is manifested at many levels of behavioral and neural organizations.

The taxonomy of motives can be classified into two categories known as learned and unlearned (Wittig, 2001). The latter is the primary motives such as the *survival motives* (hunger, thirst, breath, shelter, sleep, and eliminating pain). The former are the secondary motives such as the need for achievement, friendship, affiliation, dominance of power, and relief anxiety, which are acquired and extended based on the primary motives.

Definition 6: The strength of motivation M is a normalized measure of how strong a person's motivation on a scale of 0 through 100, that is:

$$0 \leq M \leq 100 \quad (3)$$

where $M = 100$ is the strongest motivation and $M = 0$ is the weakest motivation.

It is observed that the strength of a motivation is determined by multiple factors (Westen, 1999; Wilson & Keil, 1999) such as:

- a. The *absolute motivation* $|E_m|$: The strength of the emotion.
- b. The *relative motivation* $E - S$: A relative difference or inequity between the expectancy of a person E for an object or an action towards a certain goal and the current status S of the person.
- c. The *cost* to fulfill the motivation C : A subjective assessment of the effort needed to accomplish the expected goal.

Therefore, the strength of a motivation can be quantitatively analyzed and estimated by the subjective and objective motivations and their cost as described in the following theorem.

Theorem 2: The strength of a motivation M is proportional to both the strength of emotion $|E_m|$ and the difference between the expectancy of desire E and the current status S, of a person, and is inversely proportional to the cost to accomplish the expected motivation C, that is:

$$M = \frac{2.5 \cdot |E_m| \cdot (E-S)}{C} \quad (4)$$

where $0 \leq |E_m| \leq 4$, $0 \leq (E, S) \leq 10$, $1 \leq C \leq 10$, and the coefficient 2.5 makes the value of M normalized in the scope of [0 .. 100].

In Theorem 2, the strength of a motivation is measured in the scope $0 \leq M \leq 100$. When $M > 1$, the motivation is considered being a desired motivation, because it indicates both an existing emotion and a positive expectancy. The higher the value of M, the stronger the motivation.

According to Theorem 2, in a software engineering context, the rational action of a manager of a group is to encourage individual emotional desire, and the expectancy of each software engineer and to decrease the required effort for the employees by providing additional resources or adopting certain tools.

Corollary 1: There are super strong motivations toward a resolute goal by a determined expectancy of a person at any cost.

It is noteworthy that a motivation is only a potential mental power of human beings, and a strong motivation will not necessarily result in a behavior or action. The condition for transforming a motivation into a real behavior or action is dependent on multiple factors, such as values, social norms, expected difficulties, availability of resources, and the existence of alternative goals.

The motivation of a person is constrained by the attitude and decision-making strategies of the person. The former is the internal (subjective) judgment of the feasibility of the motivation, and the latter is the external (social) judgment of the feasibility of the motivation. Attitude and decision-making mechanisms will be analyzed in the following subsections.

THE MATHEMATICAL MODEL OF ATTITUDES

As described in the previous section, motivation is the potential power that may trigger an observable behavior or action. Before the behavior is performed, it is judged by an internal regulation system known as the attitude.

Psychologists perceive attitude in various ways. Fazio (1986) describes an *attitude* as an association between an act or object and an evaluation. Eagly and Chaiken (1992) define that an attitude is a tendency of a human to evaluate a person, concept, or group positively or negatively in a given context. More recently, Wittig (2001) describes attitude as a learned evaluative reaction to people, objects, events, and other stimuli. Attitudes may be formally defined as follows.

Definition 7: An attitude is a subjective tendency towards a motivation, an object, a goal, or an action based on an intuitive evaluation of its feasibility.

The modes of attitudes can be positive or negative, which can be quantitatively analyzed using the following model.

Definition 8. The mode of an attitude A is determined by both an objective judgment of its conformance to the social norm N and a subjective judgment of its empirical feasibility F, that is:

$$A = \begin{cases} 1, & N = \mathbf{T} \wedge F = \mathbf{T} \\ 0, & N = \mathbf{F} \vee F = \mathbf{F} \end{cases} \quad (5)$$

where $A = 1$ indicates a positive attitude; otherwise, it indicates a negative attitude.

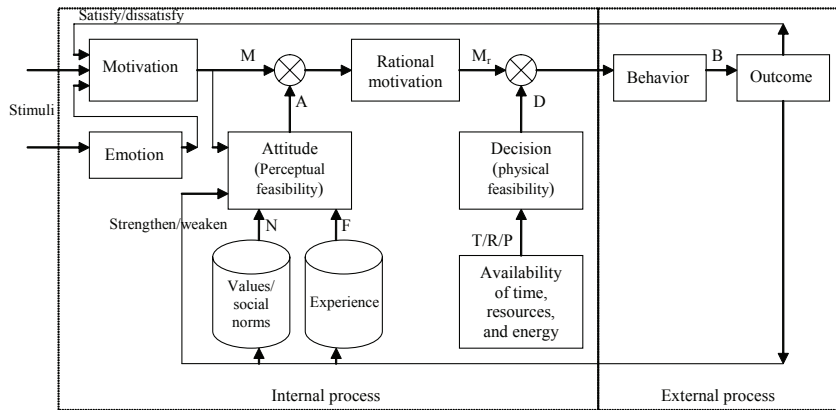
INTERACTIONS BETWEEN MOTIVATION AND ATTITUDE

This section discusses the relationship between the set of interlinked perceptual psychological processes such as emotions, motivations, attitudes, decisions, and behaviors as formally modeled in the preceding sections. A motivation/attitude-driven behavioral model will be developed for formally describing the cognitive processes of motivations and attitudes.

It is observed that motivation and attitude have considerable impact on behavior and influence the ways a person thinks and feels (Westen, 1999). A reasoned action model is proposed by Fishbein and Ajzen (1975) that suggests human behavior is directly generated by behavioral intentions, which are controlled by the attitude and social norms. An initial motivation before the judgment by an attitude is only a temporal idea; with the judgment of the attitude, it becomes a *rational* motivation (Wang et al., 2006), also known as the *behavioral intention*.

The relationship between an emotion, motivation, attitude, and behavior can be formally and quantitatively described by the Motivation/Attitude-Driven Behavior (MADB) model as illustrated in Figure 1. In the MADB model, motivation and attitude have been defined in

Figure 1. The motivation/attitude-driven behavior (MADB) model



Equations 4 and 5. The rational motivation, decision, and behavior can be quantitatively analyzed according to the following definitions. It is noteworthy that, as shown in Figure 1, a motivation is triggered by an emotion or desire.

Definition 9: A rational motivation M_r is a motivation regulated by an attitude A with a positive or negative judgment, that is:

$$M_r = M \cdot A = \frac{2.5 \cdot |E_m| \cdot (E-S)}{C} \cdot A \quad (6)$$

Definition 10: A decision D for confirming an attitude for executing a motivated behavior is a binary choice on the basis of the availability of time T , resources R , and energy P , that is:

$$D = \begin{cases} 1, & T \wedge R \wedge P = \mathbf{T} \\ 0, & T \vee R \vee P = \mathbf{F} \end{cases} \quad (7)$$

Definition 11. A behavior B driven by a motivation M_r and an attitude is a realized action initiated by a motivation M and supported by a positive attitude A and a positive decision D toward the action, that is:

$$B = \begin{cases} \mathbf{T}, & M_r \cdot D = \frac{2.5 \cdot |E_m| \cdot (E-S)}{C} \cdot A \cdot D > 1 \\ \mathbf{F}, & \text{otherwise} \end{cases} \quad (8)$$

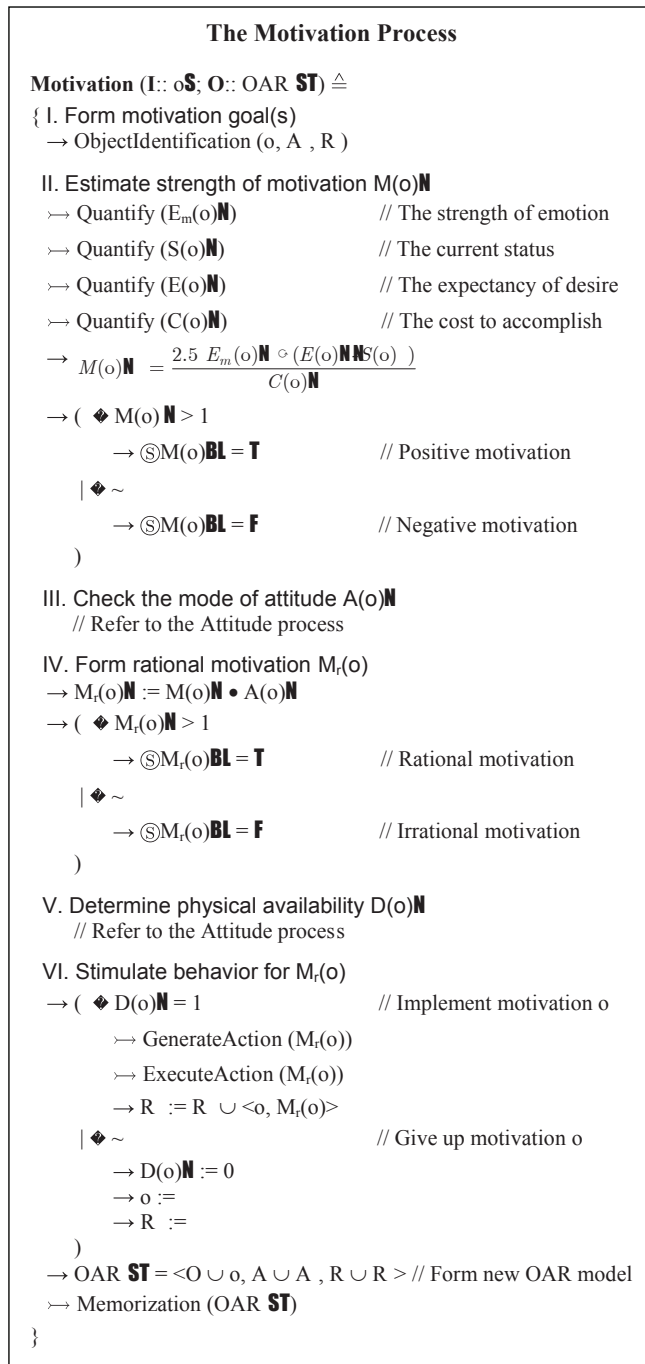
FORMAL DESCRIPTION OF COGNITIVE PROCESSES OF MOTIVATION AND ATTITUDE

The formal models of emotion, motivation, and attitude have been developed in previous sections. This section extends the models and their relationship into detailed cognitive processes based on the OAR model (Wang, 2007d) and using RTPA (Wang, 2002b, 2003c, 2006b, 2007a), which enable more rigorous treatment and computer simulations of the MADB model.

The Cognitive Process of Motivations

The mathematical model of rational motivation is described in Equation 6. Based on Equation 6, the cognitive process of motivation is presented in Figure 2. The motivation process is divided into four major sub-processes known as: (1) to form motivation goal; (2) to estimate strength of motivation; (3) to form rational motivation; and (4) to stimulate behavior for the motivation.

Figure 2. The cognitive process of motivation



The MADB model provides a formal explanation of the mechanism and relationship between motivation, attitude, and behavior. The model can be used to describe how the motivation process drives human behaviors and actions, and how the attitude as well as the decision-making process help to regulate the motivation and determines whether the motivation should be implemented.

The Cognitive Process of Attitudes

The mathematical model of attitude has been described in Equation 5. Based on Equation 5, the cognitive process of attitude is presented in Figure 3. The attitude process is divided into three major sub-processes known as: (1) to check the mode of attitude; (2) to determine physical availability; and (3) to stimulate behavior for the motivation.

The Integrated Process of Motivation and Attitudes

According to the MADB model and the formal description of the motivation and attitude processes as shown in Figures 1 through 3, the cognitive processes of motivation and attitude are interleaved. An integrated process that combines both motivation and attitude is given in Figure 4 via the following sub-processes: (1) to form motivation goals; (2) to estimate strength of motivation; (3) to check the mode of attitude; (4) to form rational motivation; (5) to determine physical availability; and (6) to stimulate behavior for the rational motivation.

MAXIMIZING STRENGTHS OF INDIVIDUAL MOTIVATIONS

Studies in sociopsychology provide a rich theoretical basis for perceiving new insights into the organization of software engineering. It is noteworthy that in a software organization, according to Theorem 2, the strength of a motivation of individuals M is proportional to both the strength of emotion and the difference between the expectancy and the current status of a person. At the same time, it is inversely proportional to the cost to accomplish the ex-

pected motivation C . The job of management at different levels of an organization tree is to encourage and improve E_m and E , and to help employees to reduce C .

Example 1: In software engineering project organization, the manager and programmers may be motivated to the improvement of software quality to a different extent. Assume the following factors as shown in Table 3 are collected from a project on the strengths of motivations to improve the quality of a software system, analyze how the factors influence the strengths of motivations of the manager and the programmers.

According to Theorem 2, the strengths of motivations of the manager M_1 and the programmers M_2 can be estimated using Equation 4, respectively:

$$\begin{aligned} M_1(\text{manager}) &= \frac{2.5 \cdot |E_m| \cdot (E-S)}{C} \\ &= \frac{2.5 \cdot 4 \cdot (8-5)}{3} \\ &= 10.0 \end{aligned}$$

and

$$\begin{aligned} M_2(\text{programmer}) &= \frac{2.5 \cdot 3.6 \cdot (8-6)}{8} \\ &= 2.3 \end{aligned}$$

The results show that the manager has much stronger motivation to improve the quality of the software system than that of the programmers in the given project. Therefore, the rational action for the manager is to encourage the expectancy of the programmers or to decrease the required effort for the programmers by providing additional resources or adopting certain tools.

According to sociopsychology (Wiggins, Eiggins, & Zanden, 1994), social environment, such as culture, ethical norms, and attitude greatly influences people's motivation, behavior, productivity, and quality towards collaborative work. The chain of individual motivation

Figure 3. The cognitive process of attitude

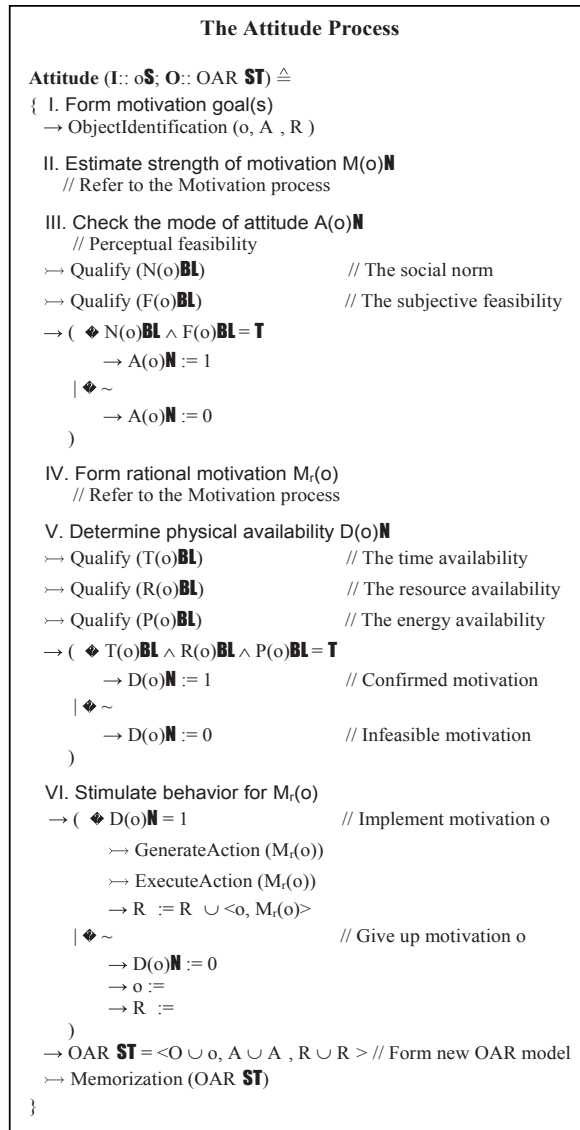


Table 3. Motivation factors of a project

Role	E _m	C	E	S
The manager	4	3	8	5
Programmers	3.6	8	8	6

Figure 4 The integrated process of motivation and attitude

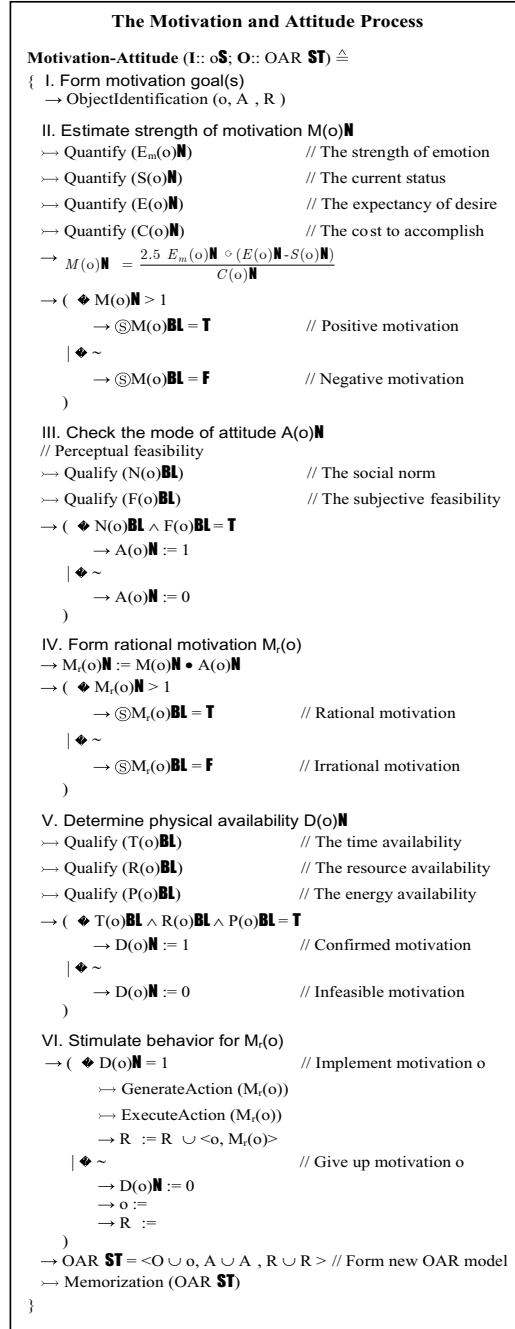
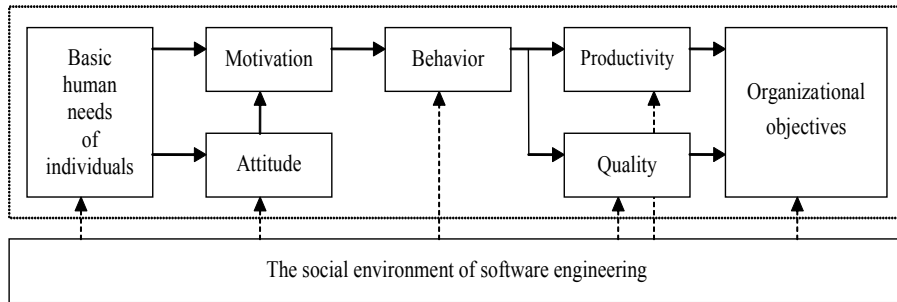


Figure 5 The chain of motivation in a software organization



in a software organization can be illustrated as shown in Figure 5.

Cultures and values of a software development organization helps to establish a set of ethical principles or standards shared by individuals of the organization for judging and normalizing social behaviors. The identification of a larger set of values and organizational policy towards social relations may be helpful to normalize individual and collective behaviors in a software development organization that produces information products for a global market.

Another condition for supporting creative work of individuals in a software development organization is to encourage diversity in both ways of thinking and work allocation. It is observed in social ecology that a great diversity of species and a complex and intricate pattern of interactions among the populations of a community may confer greater stability on an ecosystem.

Definition 12: Diversity refers to the social and technical differences of people in working organizations.

Diversity includes a wide range of differences between people such as those of race, ethnicity, age, gender, disability, skills, educations, experience, values, native language, and culture.

Theorem 3: The diversity principle states that the more diversity of the workforce in an organization, the higher the opportunity to form new relations and connections that leads to the gain of the system fusion effect.

Theorem 3 is particularly useful for software development organizations where creative work products are engineered. System theory indicates that if the number of components of a system reaches a certain level—the critical mass—then the functionality of the system may be dramatically increased (Wang, 2007a). That is, the increase of diversity in a system is the condition to realize the system fusion effect, which results in a more powerful system with newly created relations and behaviors that only belong to the system as a whole.

CONCLUSION

This article has described the perceptual processes of emotions, motivations, and attitudes based on which complicated psychological and mental processes may be formally modeled and rigorously explained. Relationships and interactions between motivation and attitude have been formally described in RTPA. It has been recognized that the human emotional system is a binary system that interprets or perceives an external stimulus and/or internal status as in the categories of pleasant or unpleasant. It has revealed that the strength of a motivation is

proportional to both the strength of the emotion and the difference between the expectancy of desire and the current status of a person and is inversely proportional to the cost to accomplish the expected motivation. Case studies on applications of the interactive motivation-attitude theory and cognitive processes of motivations and attitudes in software engineering have been presented.

This work has demonstrated that the complicated human emotional and perceptual phenomena, as well as their natural drives and constraints, can be rigorously modeled in denotational mathematics and be formally treated and described. This work has been based on two fundamental cognitive informatics models: the LRMB and the OAR model. The former has provided a blueprint to exploring the natural intelligence and its mechanisms. The latter has established a contextual foundation to reveal the logical representation of information, knowledge, and skills in the perceptual space of the brain.

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