

An Interaction Model to Analyze Dynamics of Human Performance

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Abstract—This paper proposes a human interaction model based on the findings in personality psychology, which provides useful information in analyzing the dynamics of human performance. The model was derived from scientific literature that deeply investigated the relations between important factors of personality. The proposed model can be considered one of the communication models although it does not treat information consisting of language, attitude, intention, or opinion explicitly. The paper first presents the modeling process that includes a hypothesis on dynamical change in the performance of a person as a result of interaction with other persons. Then the paper shows some simulation results with model verification using a questionnaire survey.

I. INTRODUCTION

In the research filed of group dynamics it is said that to understand groups is the key issue to understand our selves, other people, and the society [1]. Related to this, many important findings have been reported, such as the methods of group decision-making and interaction between group members, or the theory of leaderships. On the other hand, personality trait has been deeply studied in the field of psychology; one of the main results is summarized as the big five model [2-5]. Applications of this theory include the study of personal performances in daily life or on the job [6,7].

In this paper, we propose an interaction model to analyze the changes of human performance in a group by defining performance factors that correspond to the five factors of personality. This research is positioned between the fields of group dynamics and psychology, and aimed at connecting them based on the systems concepts. This paper, however, focuses only on the mathematical model that expresses the changes in performance due to interactions in a group. The model was derived from the investigation of literatures in

psychology and the final rules were selected by the genetic algorithm.

In our understanding, the study of communication is to understand the information between human and human (human communication) or human and computers (human interface) or humans from computers (media communication). Although the model presented in this paper does not explicitly include the style or method of communication, it could be considered one of the communication models that treat communication between personalities.

In the next section we define the performance variables that are used in the model. Then, in Section III, we present an interaction model that considers relations between those performance variables. In Section IV, we explain how we obtained the rules in the model. Section V is devoted to showing a simulation result, in which we used an actual dataset to select if-then rules to be used in the model. Finally, in Section VI, we summarize the paper and present some issues left for future study.

II. PERFORMANCE VARIABLES

Based on the factor traits in the big five theory (extroversion, agreeableness, conscientiousness, neuroticism, and intelligent or openness to experience), we here define the following performance variables:

- (1) Variable “activeness” from the personality “extroversion”: Typical words related to extroversion are “claim”, “talkative”, etc., which express activeness of a person. It is a criterion of the real action on his/her conscientiousness to the outside system.

- (2) Variable “tenderness” from the personality “cooperativeness”: Related words to cooperativeness are love, sociality, alignment nature, etc., that are indices of sympathizing with a partner.
- (3) Variable “endurance” from the personality “diligence”: Diligence is related to the terms such as intention to achievement, thinking introversion, etc, that express the endurance of action.
- (4) Variable “composure” from the personality “emotional stability”: Emotional stability is related to ups and downs of feeling, that is, composure or calmness.
- (5) Variable “mentality” from the personality “intellect”: There are intelligence, a cultured person, abundant experience, etc. as terms related to intellect, which associate the concept mentality.

Based on these definitions, we will propose an interaction model, and select the rules to be used in the model using the genetic algorithm.

III. RELATION BETWEEN PERFORMANCES

We assume that a performance variable of an agent is affected by the performance variables of other agents as well as by the changes in other variables of the same agent. Model 1 and 2 below correspond to the above changes respectively. Fig.1 shows the interaction model used in this paper. Here, we defined the agent having the communication with person behaviors as 5 performance factors.

Model 1: (pair-wise interaction) Let us consider two agents A and B , whose variables are denoted by a_i, b_i respectively; here, $i = 1, 2, 3, 4, 5$ correspond to variables (activeness, tenderness, endurance, composure, mentality). When these agents happen to meet (step (1) in Fig.1), one of the agents, say A , is affected by another according to the model that consists of a set of if-then rules such as

$$\text{If } b_2 - a_2 > 0 \text{ ,}$$

$$\text{then } a'_3 = a_3 + k\alpha |b_2 - a_2| \quad (1)$$

Here, a'_i is the tentative value of a_i just after the calculation of Model 1(step (2)).

Model 2: (self-innovation) After the interaction, the agent A has changed in some performance variables. It will justify its performance variables by the model consisting of a set of rules such as

$$\text{If } a'_1 - a_1 > 0 \text{ ,}$$

$$\text{then } a''_5 = a'_5 + k\beta |a'_1 - a_1| \quad (2)$$

After the calculation by Model 2, we set $a_i = a''_i$ (step (3) in Fig.1), and this process (1)-(3) is called 1 term in Fig.1

The values of performance variables of the agent B will also change in the same way, and same time with agent A .

IV. RULE EXTRACTION

The rules are derived from analyzing about 80 sentences that describe human personalities. These sentences are applied to Abridged Big Five Dimensional Circumplex model (AB5C model) [8] that researched relevance to Circumplex model [9] and Big-Five model, which referenced to adjective words [10][11] that are used in sentences. Among them the number of sentences that are used to develop if-then rules is 32. Table 1 shows the number of sentences used in Models 1 and 2 in this research where second and third columns indicate the correspondence between personal traits and performances. The signal of [+], [-] means positive or negative influences, for example, in the model 1, signal of [+] means higher than another person relatively, and in the model 2, [+] means higher than before changed oneself.

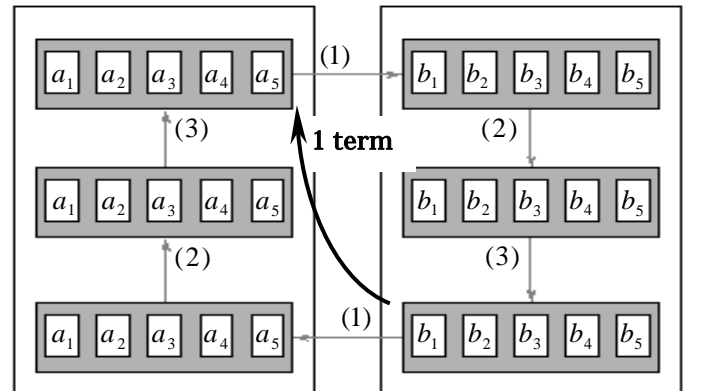


Fig. 1 Changes in performance by the interaction of two agents

To estimate the magnitudes of changes in performance variables, we give a score to each sentence considering the strength of influence, and negative or positive influence. In the simulation we assume the values of α, β in Equations (1) and (2) as positive real numbers, and the value of k is 1 or -1.

Table 1 Classification of sentences to describe human personalities.

(The numbers indicate the number of sentences.)

Model1

Sentences	personality traits		performances	
1	Agreeableness	-	Activeness	+
4	Agreeableness	-	Tenderness	-
5	Agreeableness	+	Tenderness	+
3	Conscientiousness	+	Tenderness	-
8	Extraversion	-	Tenderness	-
1	Extraversion	+	Tenderness	-
2	Extraversion	+	Tenderness	+
2	Neuroticism	-	Tenderness	-
2	Neuroticism	-	Composure	-

Model2

Sentences	personality traits		performances	
2	Agreeableness	+	Composure	-
3	Agreeableness	-	Composure	+
2	Conscientiousness	+	Endurance	+
1	Conscientiousness	+	Activeness	+
2	Conscientiousness	+	Composure	-
1	Conscientiousness	+	Composure	+
3	Conscientiousness	+	Mentality	+
2	Conscientiousness	-	Mentality	-
1	Extraversion	-	Endurance	+
2	Extraversion	+	Activeness	+
1	Extraversion	+	Tenderness	+
1	Extraversion	-	Mentality	-
1	Extraversion	+	Mentality	-
2	Intelligence	-	Activeness	-
1	Intelligence	-	Composure	-
2	Intelligence	-	Composure	+
6	Intelligence	+	Mentality	+
3	Intelligence	-	Mentality	-
1	Neuroticism	+	Endurance	+
1	Neuroticism	-	Activeness	-
4	Neuroticism	-	Composure	-
3	Neuroticism	+	Composure	+
1	Neuroticism	+	Mentality	+

V. SIMULATION RESULT

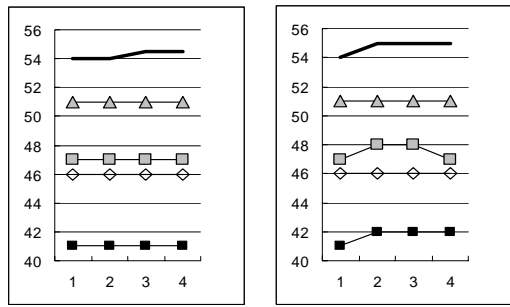
We carried out a questionnaire survey that we call the real data to determine model parameters. We asked seven graduate students in the same laboratory in our university to answer how performances of members changed every three months a year, at the same time we asked them to answer their personality traits using a standard check sheet; the latter was used to determine the initial values in the simulation.

A. Genetic algorithm

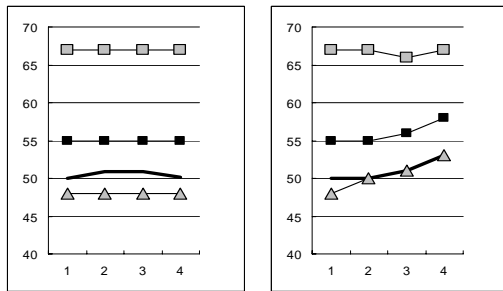
Because it is difficult to obtain absolute values of performance changes using a simple model, we tried to estimate relative values of performance changes. That is, we assumed the parameters arbitrary. We used the genetic algorithm to select if-then rules to be used in simulation. The number of codes in the genotype is 32 that correspond to the number of rules obtained from the literatures. If some rule is used then we set the corresponding entry is 1, otherwise 0. We set the initial values of genotypes randomly, and used the simple crossover to produce the next generation and set both α and β as 0.01.

B. Comparison with real data

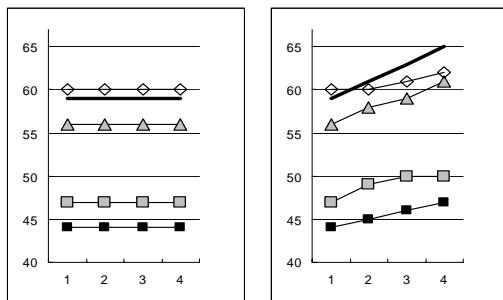
We selected the best rules that correspond to situation. Figure 2 shows the simulation results with the better if-then rules selected by the genetic algorithm and with the average after ten times simulations (left hand side) and real data form the members in the group (right hand side). In Fig. 2, the horizontal axis indicates the time (1, 2, 3 and 4 correspond to June, September, December, and March, respectively), while the vertical axis indicates performance level. In the fact, they don't have lived only seven members. Then, we asked them to think about only seven member situations about seminar, laboratory room, teamwork, without only the contacts with family members. We see from Fig. 2 the model behaves well to some extent. It should be noted that the simulation results are influenced by the initial condition and the chances of meeting of two agents.



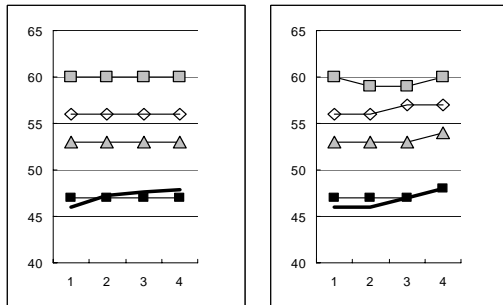
Person 1. Left: simulation result, Right: real data



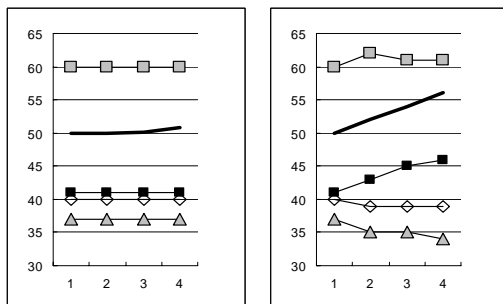
Person 2. Left: simulation result, Right: real data



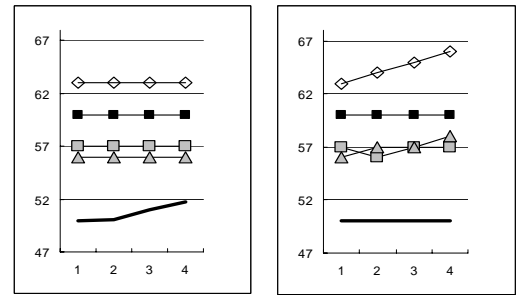
Person 3. Left: simulation result, Right: real data



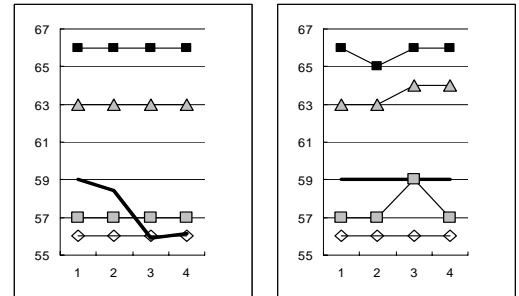
Person 4. Left: simulation result, Right: real data



Person 5. Left: simulation result, Right: real data



Person 6. Left: simulation result, Right: real data



Person 7. Left: simulation result, Right: real data

- : activeness
- : tenderness
- △— : endurance
- : composure
- ◇— : mentality

Fig. 2 Simulation results.

Table 2 Result of adopted rules for describe human personalities.

(The numbers indicate the number of sentences.)

Model1

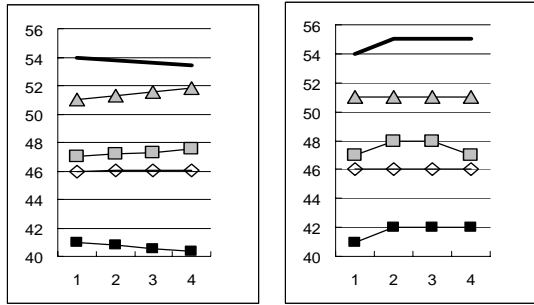
number	Sentences	personality traits	performance
1	4	Agreeableness -	tenderness -
2	5	Agreeableness +	tenderness +
3	3	Conscientiousness +	tenderness -
4	8	Extroversion -	tenderness -
5	2	Extroversion +	tenderness +
6	1	Extroversion +	tenderness -
7	2	Neuroticism -	tenderness -

Model2

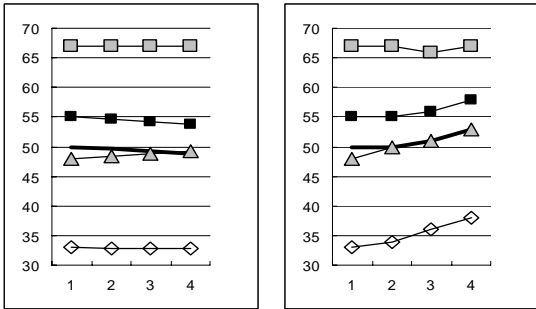
number	Sentences	personality traits	performance
8	1	Conscientiousness +	activeness +
9	2	Conscientiousness +	composure -
10	1	Conscientiousness +	composure +
11	3	Conscientiousness +	mentality +
12	2	Conscientiousness -	mentality -
13	2	Conscientiousness +	endurance +
14	2	Extroversion +	activeness +
15	1	Extroversion -	endurance +
16	1	Intelligence -	composure -
17	2	Intelligence -	composure +
18	3	Intelligence -	mentality -
19	3	Neuroticism +	composure +
11	1	Neuroticism +	endurance +

C. Consideration

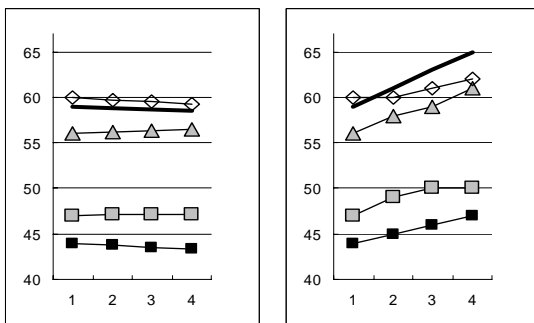
Table 2 shows the selected rules, which might be used in this group. The rules in Table 2, however, cannot explain the real data correctly, because only one rule is active. Therefore, we tried to select rules from among possible 200 rules and show the result in Fig.3 and Table 3.



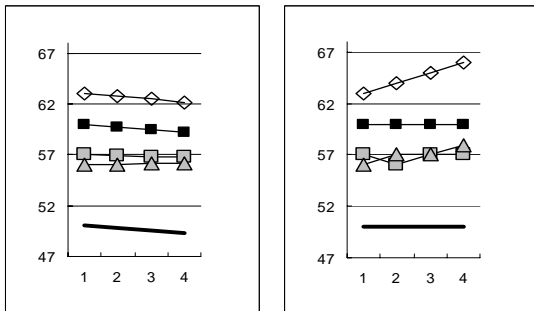
Person 1. Left: simulation result, Right: real data



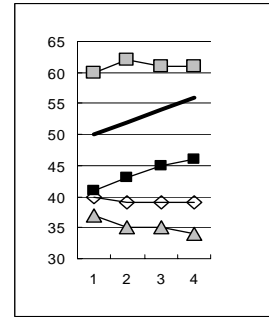
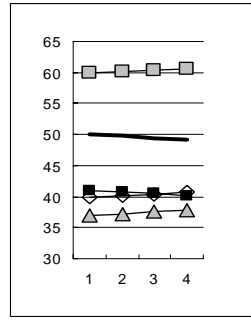
Person 2. Left: simulation result, Right: real data



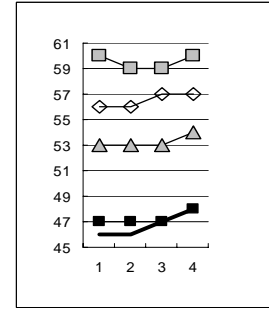
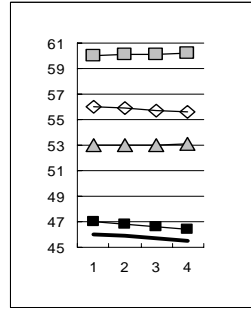
Person 3. Left: simulation result, Right: real data



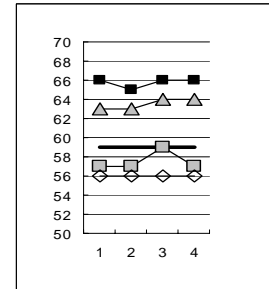
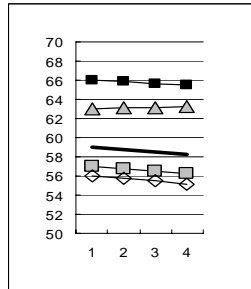
Person 3. Left: simulation result, Right: real data



Person 5. Left: simulation result, Right: real data



Person 6. Left: simulation result, Right: real data



Person 7. Left: simulation result, Right: real data

- : activeness
- : tenderness
- △— : endurance
- : composure
- ◇— : mentality

Fig. 3 Simulation results

VI. CONCLUDING REMARKS

This paper proposed an interaction model to express performance changes in a human group. The model consists of a number of if-then rules that were derived from the investigation of psychology. We finally selected if-then rules by the genetic algorithm using the real data. From the simulation result we realized that the model estimates the tendency of performance changes to some extent.

However, the model does not take into account the environment or situation around the group. Therefore, our future work includes the design of environment and its

influences on the performance change. In the field of knowledge management such an environment is often called “Ba”. We will extend this research to the design of suitable “Ba” for knowledge management in scientific research laboratories.

ACKNOWLEDGEMENTS

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Table 3 Result of adopted rules for describe human personalities.

(The numbers indicate the number of sentences.)

Model 1		Model 2	
personality trait	performance	personality trait	performance
Extroversion	- activeness +	Extroversion	+ activeness +
Extroversion	- activeness -	Extroversion	- tenderness -
Extroversion	+ tenderness +	Extroversion	+ tenderness +
Extroversion	+ endurance +	Extroversion	+ tenderness -
Extroversion	- composure -	Extroversion	- endurance +
Extroversion	+ composure +	Extroversion	- endurance -
Extroversion	- mentality -	Extroversion	+ endurance -
Extroversion	+ mentality -	Extroversion	- composure +
Agreeableness	- activeness -	Extroversion	- composure -
Agreeableness	- tenderness +	Extroversion	+ composure -
Agreeableness	+ tenderness +	Extroversion	- mentality +
Agreeableness	+ endurance +	Extroversion	- mentality -
Agreeableness	+ endurance -	Extroversion	+ mentality +
Agreeableness	- composure -	Agreeableness	+ activeness +
Agreeableness	+ composure -	Agreeableness	+ activeness -
Conscientiousness	- activeness -	Agreeableness	- tenderness -
Conscientiousness	+ activeness -	Agreeableness	+ tenderness +
Conscientiousness	- tenderness +	Agreeableness	+ tenderness -
Conscientiousness	- tenderness -	Agreeableness	- composure -
Conscientiousness	+ tenderness +	Agreeableness	+ composure +
Conscientiousness	+ endurance +	Agreeableness	+ mentality +
Conscientiousness	- composure +	Conscientiousness	- activeness +
Conscientiousness	- composure -	Conscientiousness	- activeness -
Conscientiousness	+ composure +	Conscientiousness	- tenderness +
Conscientiousness	+ mentality +	Conscientiousness	+ tenderness +
Neuroticism	+ activeness +	Conscientiousness	- endurance +
Neuroticism	- tenderness +	Conscientiousness	- endurance -
Neuroticism	- tenderness -	Conscientiousness	- composure +
Neuroticism	+ tenderness +	Conscientiousness	+ composure +
Neuroticism	+ tenderness -	Conscientiousness	- mentality +
Neuroticism	- composure +	Conscientiousness	- mentality -
Neuroticism	- composure -	Conscientiousness	+ mentality +
Neuroticism	- mentality -	Neuroticism	+ tenderness +
Intelligence	+ tenderness -	Neuroticism	- endurance +
Intelligence	+ endurance +	Neuroticism	- endurance -
Intelligence	- composure +	Neuroticism	+ composure +
Intelligence	- composure -	Neuroticism	+ composure -
Intelligence	+ composure +	Neuroticism	- mentality +
Intelligence	+ composure -	Neuroticism	+ mentality -
Intelligence	- mentality -	Intelligence	+ activeness +
		Intelligence	- endurance +
		Intelligence	+ endurance +
		Intelligence	+ endurance -
		Intelligence	+ mentality -

REFERENCES

- [1]. Donelson R. Forsyth. Group Dynamics, Brook / Cole Wadsworth, Belmont, California, 1999.
- [2]. Tupes, E. C. & Christal, R. E., Recurrent Personality factors based on trait ratings, Journal of Personality, Vol.60, pp.225-251, 1961.
- [3]. W. Mischel. Personality and Assessment, Mahwah, New Jersey, 1968.
- [4]. Digman., J. M. & Takemoto Chock, N. K., Factors in the natural language of personality: Re-Analysis, Comparison and Interpretation of Six Major studies, Multivariate behavioral research Vol.16, pp.149-170, 1981.
- [5]. Paul T. Costa Jr and Robert R. McCrae. Four ways five factors are basic, Personality and Individual differences, Vol.13, No.6, pp.653-665, 1992.
- [6]. Paul T. Costa, Jr. and Robert R. McCrae. Personality in Adulthood: A six-year longitudinal study of self-reports and spouse ratings on the NEO Personality Inventory. Journal of Personality and Social Psychology, Vol.54, No.5, pp.853-863, 1988.
- [7]. Rbert. P, Dawn. D. A, Personality trait-based interactionist model of job performance, Journal of Applied Psychology, Vol.88, No.3, pp.500-517, 2003.
- [8]. Hofstee, De Raad and Goldberg, integration of the big five and Circumplex approaches to trait structure, Journal of personality and social psychology, vol.63, pp.146-163, 1992.
- [9]. Wiggins, 1979; Wiggins and Trapnell, P. D. a dyadic-interactional perspective on the five-factor model. In Wiggins, J.S. (ED) the five factor model of personality: Theoretical perspectives. New York: The Guilford Press 1996
- [10]. Goldberg, L. the development of markers for the big-five factor structure. Psychological assessment, vol.4, pp.26-42, 1992.
- [11]. Jonson, J.A. and Ostendorf, F. Clarification of the five factor model with the abridged big five dimensional Circumplex. Journal of Personality and Social Psychology, vol.65, pp.563-576, 1993.