2005－MPS－55（10）
2005／6／28

Construction and Evaluation of *Kansei* Information Processing Systems based on *K*-Model

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Abstract *Recently, the report which reflects Kansei of the user in the multi-modal interface has been made. With this, we propose a K-Model which realizes efficient treatment and Kansei information processing by the dynamic system. In a K-Model, the Kansei Information processing is carried out by Multi-Agent Systems. We have applied this GM to as a Kansei information processing algorithm. In this paper, Kansei information processing systems(KIPS) have been constructed and based on the K-Model. Here, the system which calculates in real-time Kansei information from the voice as examples of the KIPS to be constructed. As an evaluation, the following were investigated : model accuracy, processing time and Kansei element discrimination rates of constructed systems. As a result, the effectiveness of a K-Model has been discussed.*

1 Introduction

In the multi-modal human interface, the technique was proposed that reflects a human *Kansei*[1]. For example, software robot "Stellar[2]" has interface systems that decides the *Kansei* condition of the robot from the user's action. The method which distinguishes the *Kansei* condition of the user from the voice is also reported[3]. The systems that reflect such user's *Kansei* is called the *Kansei* information processing systems(KIPS). In this paper, it's as examples, human interface system that extracts the *Kansei* information from the voice is constructed. In such systems, not only discrimination accuracy but also real-time operation should be regarded seriously.

It is necessary, however, to analyze using multiple factors in order to extract *Kansei* Information, from the input system of voice. Therefore, it is complicated to carry out the treatment, and it tends to become enormous in calculations. Therefore, the following are required : optimization of the treatment and efficiency improvement by parallel processing, etc.. It is to be added that the continuity of the time variation is in human *Kansei*. That is to say, it is necessary to express by the dynamic system. However, the algorithm of the dynamic system becomes complicated. And the processing algorithm changes depending on the system with a given purpose. It is nonproductive that the human brain mounts the complicated dynamic system one by one. Moreover, internal processing model of human *Kansei* information processing is sad to be a black box, and the clear elucidation has not still been made.

Therefore, the expression of the systems with the use of input-output relation is widely used. For example, the method that decides *Kansei* information by discriminant analysis of multivariate analysis, etc. has already been reported. It created discriminant function using the already clearified input-output relationship. This does not consider the internal processing structure. However, the human *Kansei* condition does not remain only in discrete information. Because, for example, the change of human kansei is smooth in the time-region, even if it changes from angly to disgust. It is not easy to analyze it only in the discriminant function by distance calculation and discretion information. Because, it is impossible that to clarify all input-output information with human *Kansei*. In other words, input-output relation of *Kansei* information is grey information. Then, we propose *Kansei* Information Processing Model by Multi-Agent Systems(MAS) based on Grey Theory[4, 5]. This is defined as a *K*-Model[6].

In a *K*-Model, Grey Model(GM) was adapted as a *Kansei* information processing algorithm. It is the model of differential equation in Grey Theory. It is possible that a GM takes continuous function, if a discretion point of some input and output is given in mathematical approximation. In this paper, we mount MAS that autonomously constitute the KIPS from relation data of input-output. As an evaluation, it experiments real-time *Kansei* information processing from the voice, and the discrimination rates and processing time are measured.

2 *K*-Model

In this paper, the *K*-Model shown as a *Kansei* Information Processing Model in figure 1 is proposed. This proposed model is the multi-input and multi-output. Human *Kansei* must be analysed by multi-

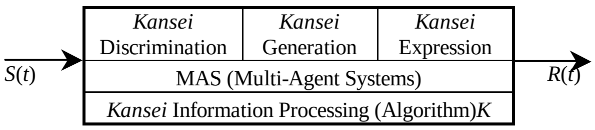

Figure 1: K-Model

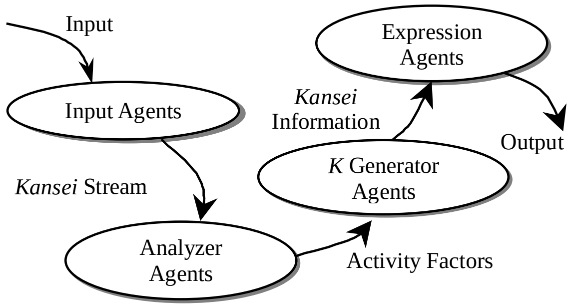

Figure 2: basic configuration of MAS based on K-Model

ple factors. That is to say, as it was shown earlier that, multiple factors of tone qualities and fundamental frequency, etc. were increasingly input as the time passes in case of the extraction of *Kansei* information in the voice in the continual sequence. Such input system is defined as *Kansei* stream $S(t)$. When $S(t)$ was input, the MAS autonomously analyzes it. The MAS carries out *Kansei* Discrimination, *Kansei* Generation and then *Kansei* Expression by the *Kansei* information processing algorithm. As a result, $R(t)$ is output. This process is expressed in the following equation.

$$R = [K]S \tag{1}$$

where, $[K]$ is the *Kansei* Information Processing Algorithm.

Based on the above-mentioned K-Model, the MAS as a *Kansei* Information Processing Model is considered. Here, the process of calculating *Kansei* information from data such as the voice is defined. It becomes the next 4 arithmetic steps.

- The system accepts input data (voice, facial expression, etc.).
- The system analyzes parameters of the kansei Stream (frequency analysis, etc.).
- The system calculates *Kansei* information according to analyzed parameters.
- The system decides the output value based on caluclated *Kansei* information.

If the system based on the K-Model is constructed, Agent which realizes the process of the superscription will have to be prepared in each. These Agents are classified into the group of the every role. Here, it is divided into separated Agent group which consists of 4 kinds following $n = 4$, namely figure 2. And, each becomes the MAS composition for these 4 kinds of Agents. These Agents output *Kansei* information by the connection of the work of the mutuality.

Table 1: *Kansei* Elements Standard

x_1	0	0.1333	0.6666	0.7777	1.0
x_2	0	0	1	0.5	1
x_3	0.25	0	0.5	1	0.875
x_4	0.125	0	0.875	1	1
x_5	0.5	0.875	0.25	0.5	1
x_6	0.25	0.75	1	1	1

3 Construction

3.1 Setting of the *Kansei* Elements Standard

Kansei Elements Standard is defined as discretely showing the feature quantity of input signal for the optional *Kansei* element. In this paper, feature quantity of the voice which corresponds to the each *Kansei* element as example is shown at table 1. Here, five *Kansei* elements are defined. It is terror, angry, sadness, happy and disgust. In proportion to this, five parameters of strength(x_2), talk speed(x_3), pitch average(x_4), tone quality(x_5), pitch range(x_6) on the voice have be made to be the *Kansei* discrimination element. The value which table 1 gave is an initial value normalized, and again, it is made to be a relative value which is proportional for the *Kansei* element for the input. And it is necessary to also define numerical solution on the output value.

By this equation, $x_1(t) = \sum_{m=2}^{6} x_m(t)$, the output value is set. Where, x_1 is supposed to be normalized in $[0, 1]$.

The numerical solution x_1 correspond to five *Kansei* elements. The correspondence range is shown at table 2. Here, the arithmetic mean of x_1 between each *Kansei* elements is used on range setting of table 2.

Analyzer Agents has function that extracts peculiar feature quantity from input signals. Extracted value becomes the basic condition factor of Analyzer Agent. This factor has been defined as "Activity Factor". It normalizes the Activity Factor in the range of [0,1]. The minimally the number of necessary Analyzer Agents is five agents. Because, five parameters are shown in *Kansei* Elements Standerd, and those parameters are necessary to analyse *Kansei* information.

3.2 *Kansei* Information Processing Algorithm by GM(n, m)

MAS based on the K-Model autonomously constructs the processing systems. K Generator Agent

Table 2: *Kansei* Information output value

Kansei	range of x_1
sadness	$x_1 < 0.0666$
disgust	$0.0666 \leq x_1 < 0.3999$
happy	$0.3999 \leq x_1 < 0.7222$
terror	$0.7222 \leq x_1 < 0.8886$
angry	$0.8886 < x_1$

choose necessary Analyzer Agent using the abovementioned *Kansei* Elements Standerd. Based on GM(n, m) described later further, the relation is constructed.

GM(n, m) is a mathematical model of differential equation type in the grey theory. It is possible that therefore, it approximately gets the continuous function. Got function becomes m factors n order differential equation.

The model of GM is constructed by using the *Kansei* Elements Standard(table 1). In this paper, the model of GM is 6 factors of 5 input through 1 output. And this model is 1st order grey differential equation. Therefore, it becomes $n = 1$ and $m = 6$, then GM$(1, 6)$ is formed. The general equation of GM$(1, 6)$ is shown in following equation(2).

$$\frac{dx_1^{(1)}(t)}{dt} + ax_1^{(1)}(t) = b_1x_2^{(1)}(t) + b_2x_3^{(1)}(t) + \cdots + b_5x_6^{(1)}(t) \quad (2)$$

Equation(2) is a continuous difference equation. Therefore, this is developed in the difference equation. The solution of GM$(1, 6)$ is expressed according to following equations(3) and (4). Equation (5) is called IAGO. It is final output of GM.

$$\hat{x}_1^{(1)}(k) = \left\{x_1^{(1)}(1) - \frac{s(k)}{a}\right\} e^{-a(k-1)} + \frac{s(k)}{a} \quad (3)$$

$$s(k) = \sum_{m=2}^{6} b_{m-1}x_m^{(1)}(k) \quad (4)$$

$$\hat{x}_1^{(0)}(k) = \hat{x}_1^{(1)}(k) - \hat{x}_1^{(1)}(k-1) \quad (5)$$

Here, the coefficient in equations(2) and (3) is obtained by the least squares method according to following equation(6). The coefficient is made to be $\hat{a}$.

$$\hat{a} = [a, b_1, \cdots, b_{m-1}]^T = (B^TB)^{-1}B^TX_N \quad (6)$$

where, B and X_N in equation(6) are as follows.

$$B = \begin{bmatrix} -z^{(1)}(2) & x_2^{(1)}(2) & \cdots & x_6^{(1)}(2) \\ -z^{(1)}(3) & x_2^{(1)}(3) & \cdots & x_6^{(1)}(3) \\ \vdots & \vdots & \ddots & \vdots \\ -z^{(1)}(N) & x_2^{(1)}(N) & \cdots & x_6^{(1)}(N) \end{bmatrix} \quad (7)$$

$$z^{(1)}(k) = 0.5\left(x_1^{(1)}(k) + x_1^{(1)}(k-1)\right) \quad (8)$$

$$X_N = \begin{bmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(3) \\ \vdots \\ x_1^{(0)}(N) \end{bmatrix} \quad (9)$$

The coefficient $\hat{a}$ is obtained by above procedure. It is possible to obtain the output value of $\hat{x}_1^{(1)}(k), (k = 1, 2, \cdots, N)$ by substituting the equation(3).

However, there is a case in which the model does not satisfy a precision which is prescribed, even if the coefficient is substituted mechanically. The systems will not take sufficient analysis accuracy, when the GM is adopted and that does not satisfy a precision which is prescribed. The mathematical test is carried out in order to verify accuracy of GM. In this paper, that successor difference test which is included for the grey theory as accuracy verified methodology is carried out. The output value of $\hat{x}_1^{(0)}(k)$ got by GM, when output value which is required to be $x_1^{(0)}(k)$. The error analysis is applied between $x_1^{(0)}(k)$ and $\hat{x}_1^{(0)}(k)$.

$$q(k) \equiv x_1^{(0)}(k) - \hat{x}_1^{(0)}(k) \quad (10)$$

As a result of the error analysis, the value of equation(10) is made to be a residual. The average value of output value is to be $\bar{x}$, and residual is to be $\bar{q}$, in order to the requiring of equations(11) and (12). In this case, successor difference ratio C and small error probability P are got in the following equations.

$$C = \frac{\sqrt{\frac{1}{N}\sum_{k=1}^{N}(q(k) - \bar{q})^2}}{\sqrt{\frac{1}{N}\sum_{k=1}^{N}(x_1^{(0)}(k) - \bar{x})^2}} \quad (11)$$

$$P = p\left\{|q(k) - \bar{q}| \leq 0.6745S_i\right\} \quad (12)$$

As this result, it is the accuracy sufficient, when the value of C and P is $(0.65 < C \wedge P < 0.7)$ with the regulation[5] for GM. In short, formed model is adopted.

Formed model fell below the regulation, and it would become the accuracy inadequate. In this case, it is necessary to improve the model accuracy in whether it discards the model and some forms. Then, we proposed the modeling accuracy improvement method for GM using cubic spline function and Taylor sequential approximation. This model is called T-3spGM[7]. In case of this paper, the MAS attempts accuracy improvement using T-3spGM, if the model accuracy is insufficient for the accuracy. Coefficients of GM are approximated by Taylor sequential approximation in n iterations. Therefore, it is possible that the successive approximation is done, until the accuracy is obtained.

4 Evaluation

Mounted the KIPS is evaluated. An action example of the systems is shown in the figure 3. Following

Table 3: *Kansei* element discrimination accuracy

Kansei	discrimination accuracy(%)
sadness	45.8
disgust	62.0
happy	74.2
terror	46.7
angry	63.5

three items is used to the evaluation. (1)Comparison verification of the self-organization accuracy of MAS. (2)Processing time. (3)*Kansei* elements discrimination accuracy. These items are verified, and the effectiveness of the this proposal systems is evaluated. And, the packaging of the Agent uses Aglets-2.0.2[8].

First, the self-organization accuracy of the MAS is described. Comparison result between usual GM(1,6) and T-3spGM(1,6) is 0.129(GM) and 0.005(T-3spGM). The value of the error uses $\frac{1}{N}\sum_{k=1}^{N}|q(k)|$. From this result, it can be said that a precision prescribed has sufficiently been satisfied by applying T-3spGM. Final coefficient $\hat{a}$ by T-3spGM is $a = 2.165, b_1 = -0.006, b_2 = -0.753, b_3 = 3.012, b_4 = 0.859, b_5 = -1.025$.

Next, the processing time is described. The processing time is made to be the time until it outputs the *Kansei* element, after the voice is spoken. Here,1[sec] voice is input. It was about 1.7[sec] in the time which depended on the treatment. It was measured using CPU:Pentium3-1GHz and Mem:1024MB computer environment. From this result, the real time can be called being sufficient.

Finally, the *Kansei* element discrimination accuracy is described. For the voice which spoke the feeling with the optional examinee by concentrating, the experiment investigates the fidelity with the result of outputting. This result is shown in the table 3. The result over 60% has been obtained on happy, disgust and angry. However, it consisted under 50% on sadness and terror. From this result, the whole discrimination accuracy remained 58.4%. What is considered as this reason is the output value shown at the table 2. There is the dispersion in the range of each *Kansei* element. The following are seen : elements with the wide range, elements the narrow range, etc.. Therefore, the setting of the output value will have to be reexamined.

Additionally it is also considered that the noise component is included for the input voice. It is considered that the solution is possible by introducing the noise rejection algorithm[9] into the input system, for this.

5 Conclusion

In this paper, example of the KIPS was constructed based on *K*-Model. In addition, the system was evaluated. As a result of the evaluation, it was proven

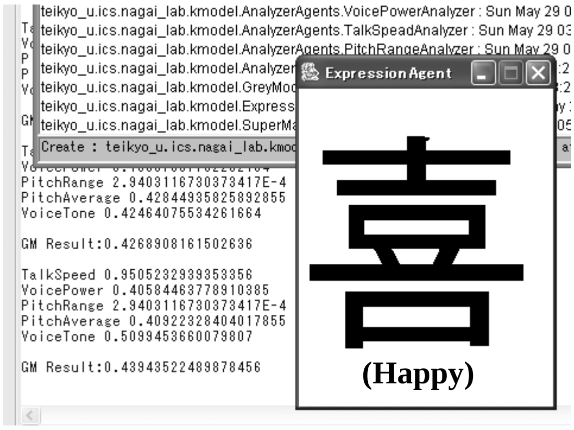

Figure 3: Example of the KIPS based on *K*-Model

that the accuracy of the *Kansei* information processing algorithm was drastically improved by introducing T-3spGM. And, it was shown that the *Kansei* element discrimination rates from the voice was about 58%. On the processing time, it was reported that the sufficient effect was also raised for real-time processing.

As future problem, the setting method of output value will have to be reexamined. By adding, it wants to also do the accuracy improvement of Analyzer Agents.

References

[1] Rosalind W. Picard. *Affective Computing*. The MIT Press, London, 1997.

[2] H. Ushida, Y. Hirayama, H. Nakajima. An Interface Agent Based on an Autonomous Behavior Decision Model. *The IEICE Transactions on Information and Systems*, J82-D-II(10):1655–1665, Dec. 1999.

[3] Y. Kinjou, Y. Tsuchimoto, I. Nagayama. Feeling recognition of spoken words for advanced communication with emotional information processing. *Technical Report of IEICE.*, HIP2001-86:49–54, Jan. 2002.

[4] J. L. Deng. The control problems of grey systems. *Systems & Control letters*, North-Holland(5):288–294, 1982.

[5] M. Nagai and D. Yamaguchi. *Elements on Grey System Theory and Applications.* Kyoritsu Publishing, Tokyo (in Japanese), 2004.

[6] T. Akabane, D. Yamaguchi, G. D. Li, K. Mizutani and M. Nagai. Kansei Information Processing Model Applied Multi-Agent Systems Based on Grey Theory. *Journal of Japan Society of Kansei Engineering*, Aug. 2005.

[7] G. D. Li, D. Yamaguchi, K. Mizutani and M. Nagai. New Proposal and Evaluation Based on Grey Theory GM. *IPSJ SIG Technical of Japan Resarch Report*, Vol.2004(93):177–184, Sept. 2004.

[8] Danny B. Lange, Mitsuru Oshima. *Programming and Deploying Java Mobile Agents with Aglets*, Addison-Wensley, 1998.

[9] C. H. Hsieh. Speech Enhancement Based on GM(1,1) Model. *Journal of Grey System*, Vol.6(2):141–146, 2003.