A study of emotional motion description by motion modification rules using adjectival expressions

Atsushi Yamaguchi, Yoshikazu Yano, Shinji Doki, and Shigeru Okuma

Abstract— **Emotion expression through behavior is meaningful for communication processes between robots and humans. Automatic emotion expression generation is needed for those robots in order to stimulate communication with humans. Proposed technique generate emotional motions by modifying base motion patterns using the combination of the adjectival expressions. In order to generate emotional motions, emotional motion modifications should be based on rules which represents the relationship between emotion expressions and the combination of the adjectival expressions. Emotion modification rules are obtained by organoleptic tests. This paper, in particular, shows the relationship between the degree of adjectival modification and emotion expressions. Thus proposed technique generates the suitable emotional motion patterns from base motion pattern.**

Index Terms— **emotion entertainment robot, motion modification, emotional motion, organoleptic test**

I. INTRODUCTION

In recent years, the robot that aims at coexistence with humans, for example mechanical pets and humanoid type robots, have attracted attention and been widely developed. The purpose of this kind of robot is to let users interested in itself, to make pleasure and relax, and to live among them for their comfort life. These robots have to behave like real creatures, and communicate users more naturally according to need.

In the communication scene between humans, they communicate with various gestures corresponding to their emotions and situations, as these gestures are necessary for smooth communications. Gestures for emotion expression are meaningful for communication processes. Robot products also express their emotions with some gestures. However, these gestures are expressed just as output signals to display their inner status. They are prepared by motion designers in advance. At the point to send certain messages or to report their condition correctly, well-designed motions are desirable. On the other hand, the number of well-designed motions is limited. As limited variation of motions have been expressed, robots don't have an enough ability of emotion expression, therefore users used to be tired of robots. In order to make variations, it is desired to generate new motions, especially emotional motions for smooth communications.

As one of solutions to obtain new motions, mimic system is developed[1][2][3]. These systems observe the motion partners and extract significant motion patterns. This motion pattern is generated according to the common characteristic among the several variation of motions which are considered as a same kind of motion. These systems can extract new gestures. These systems, however, cannot derive suitable motion representation for several situations.

As another approach, motion modification technique is also developed[4][5][6]. These techniques generate new motion patterns from base motion patterns and motions modification parameters. Emotional motion generate using motion modification technique needs modification rules which represents the relationship between modification parameters and human sensitivities.

In order to determine the relationships between modification parameters and human sensitivities, several researches are implemented[7][8][9][10]. In[7], Nakata et al. applied Laban system to robots' motion description for the dance lesson. They obtained the relationships between Laban features and dance expressiveness, which is instructor's sensitivity, using statistical methods. However, as Laban features are hard-to-understand ones, it is hard to analyze each parameters. So the obtained relationship can't be applied to other motions. Also another expression of same emotion cannot be generated.

In order to acquire modification rules which are easy to understand and applicable widely, base features should be defined as familiar to designers. In this paper, we propose the emotional motion generation technique according to motion modification technique, whose modification parameters are familiar to designers and are easy to analyze. The relationship between modification parameters and corresponding emotion is determined by organoleptic tests.

II. PROPOSED TECHNIQUE

Emotional motion is generated by the base motion and motion modification parameters in order to generate various emotional motions under proposed technique . The motion which does not associate any emotions is used as a base motion.

Modification rules are described as follows. A motion expressed widely evokes a positive emotion. Oppositely that expressed narrowly evokes a negative emotion. These relations can denote as emotion representation rules. These rules can be applied to various base motions. It can be assumed that reversed rules are also applicable. When positive emotion should be expressed, to express widely is one of the suitable representation rules. So adjectival expression is regarded as base feature.

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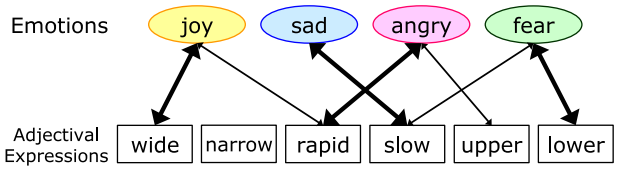

Fig. 1. The Concept of the Emotion model. The thick line indicate the relation is strong, and the fine line indicate the relation is weak.

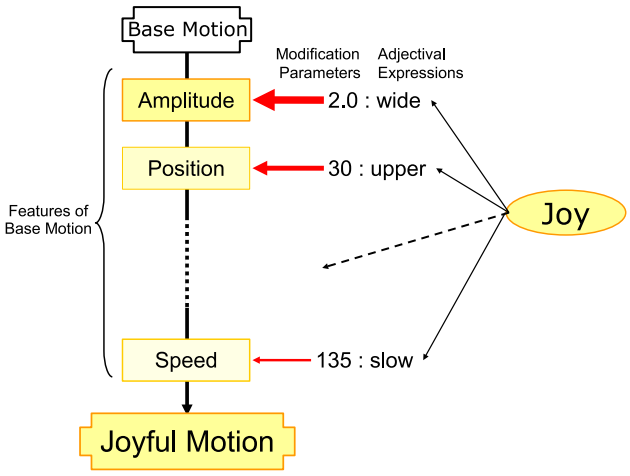

Fig. 2. The Diagram of Proposed Technique. Every adjectival expression operates one modification parameter. Modification parameter represents the intensity of adjectival expression. Modification parameters modify features of base motion, for example amplitude, position, speed.

Fig. 1 indicates the concept of emotion representation model. This figure shows the relationships between emotions and adjectival expressions. For instance, *waving a hand widely* evokes joy emotion and *raise a hand rapidly* evokes aggressive emotion. On the other hand, *waving a hand with joy* may show themselves widely.

It is safe to assume that certain emotional motion is generated by the motion modification using adjectival expressions. Therefore emotional modification rules are described using some adjectival expressions. Moreover, modification parameter represents the intensity of adjectival expressions as expressing with line width in Fig. 1. According to the definitions of the correspondence between the emotion and modification rule, corresponding adjectival expressions are applied to base motion. The relationship between adjectival expressions and emotion is determined by organoleptic tests.

A. Motion Generation

An emotional motion is generated as a modified motion by adjectival expressions. Fig. 2 shows the diagram of an emotional motion generation using adjectival expressions.

In order to apply adjectival expressions to base motions, adjectival expressions for this system should be described with easy rules for motion agent. Complex expressions, those expression are hard to implement such as “glorious”, “rough” and so on, are not suitable for this system.

In this paper, 9 adjectival expressions, 4 pairs of modification parameters and 1 N/A, are prepared shown in Table I, those are available to modify base motion. Each adjectival expression works as a filter to motion patterns. The detail of each filter is mentioned below. We apply single adjectival expression to base motion in this paper.

TABLE I
ADJECTIVAL EXPRESSIONS USED IN EXPERIMENT.

Adjectival Expressions		Modification Parameter	
A1	no change	N/A	
A2	wide	×2.0	amplitude
A3	narrow	×0.5	amplitude
A4	upper	+30	position
A5	lower	-30	position
A6	rapid	×1.5 (90/60)	speed
A7	slow	×0.5 (90/180)	speed
A8	accelerated	×1.3 (90/65)	acceleration
A9	decelerated	×0.7 (90/135)	acceleration

Each adjectival expression is defined as follows. A2, A3, A4 and A5 are used for the time-series data transformed from joint angle into polar coordinate system. A2 and A3 change amplitude to change the ’width’ of the motion. Corresponding modification parameter is used as a multiplying parameter. A4 and A5 to change ’display position’ of the motion. Corresponding modification parameter is used as a bias of display position. A6, A7, A8, and A9 change the ’speed’ of the motion. According to modification parameter, this filter resamples time-series joint angle data to modify whole sample number.

III. EXPERIMENTAL CONDITIONS

The purpose of this paper to clarify the relationship between emotion expression and adjectival expressions. The relationship is clarified by organoleptic tests. The target emotion is joy, sad, angry, and fear. The procedure of organoleptic tests is shown below.

1) Preference for adjectival expressions to modify base motions.
2) Evaluation the relationship between modification parameters and the power of emotions expression.

In this paper, motion patterns are expressed on right arm of human model made by CG soft DOGA[11]. It has 3 degrees of freedom for motion expression. Fig. 3 - 5 show the distribution of joint angles on human model.

A. Preference for Adjectival Expressions to Modify Base Motions

In this experiment, some adjectival expressions to modify base motions are selected from 9 adjectival expressions which are listed in Table I. In order to select applicable adjectival expressions for motion modification, we apply only single adjectival expression to the base motion, and modification parameter is fixed for the sake of reducing test patterns. That is, the modification parameter which means the major factor for motion modification denotes is applied and the rests are not applied.

4 base motions are prepared, ‘waving a hand 1’, ‘greeting’, ‘handing over’ and ‘waving a hand 2’. Modified motion patterns are generated by proposed system using 4 base

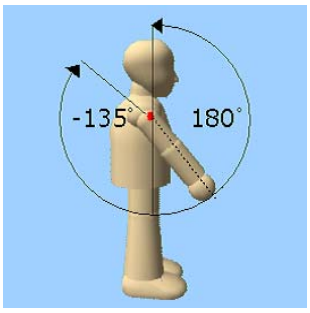

Fig. 3. Human Model's Shoulder Joint.1

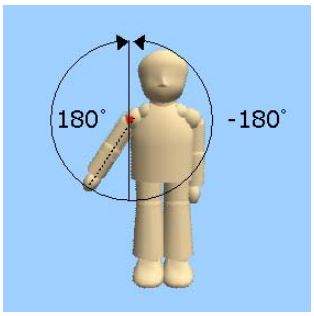

Fig. 4. Human Model's Shoulder Joint.2

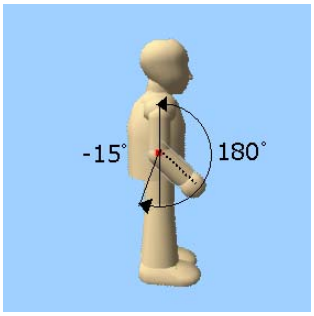

Fig. 5. Human Model's Elbow Joint.

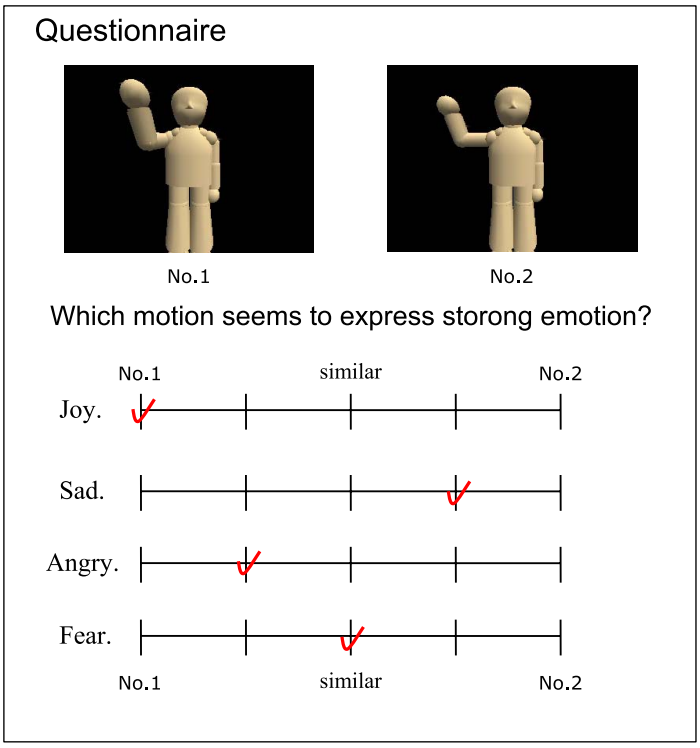

Fig. 6. Shown Motions in Option Experiment

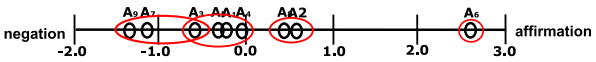

Fig. 7. Example of Result of the Analysis

motions and 9 adjectival expressions listed in Table I. So 9 modified variations are prepared for each base motion.

To select adjectival expressions for emotion expression is implemented in 2 stages. First, generated motions are evaluated by method of paired comparison. Second, the result of paired comparison method is analyzed using analysis of variance.

In this experiment, we use Scheffe's method of paired comparison with Nakaya's variation. Method of paired comparison is performed as below. The questionnaire is shown in Fig. 6. Examinees watch two motion movies, one modified motion and another modified motion. On each emotion, they choose the one which represents stronger emotion. 36 ($= {}_9C_2$) pairs of motion movie are evaluated.

Analysis of variance table is obtained from the results of analysis of variance. The relation figure is also obtained, the example is shown in Fig. 7. As the figure indicates, the adjectival expressions are ranked based on degree of emotion expressions and grouped with circle based on confidence interval test.

B. Evaluation the relationship between modification parameters and the power of emotions expression

In this experiment, adjectival expressions chosen in option experiment in III-A are used to modify base motions. And variation of modification parameter is considered. We apply single adjectival expression to the base motion, and modification parameter has several values. In order to choose the modification parameter, this system choose adjectival expressions from A1 to A7, and after that, choose available modification value at the corresponding adjectival expression.

3 base motions are prepared, 'waving a hand 1', 'handing over' and 'waving a hand 2'. We are going to apply several adjectival expressions which have influence on emotion expression in option experiment.

Experiment is implemented as below. The questionnaire is shown in Fig. 8.

Examinees watch the two motion movies, one is the base motion and another is the modified motion. After watching the movies, they select the impression from five choices, joy, sad, angry fear, and no impressed. When any of 4 emotions are chosen, they evaluate the strength of impression in 5 levels from 1 to 5. The strength 1 means that examinees are impressed weakly and the strength 5 means they are impressed strongly.

IV. Experimental Results

We experiment in organoleptic test involving the motion generated by proposed technique.

First, adjectival expressions are selected, which have influence on emotion expression using method of paired comparison and analysis of variance.

Second, the relationship between modification parameters and the power of emotions expression are evaluated using questionnaire.

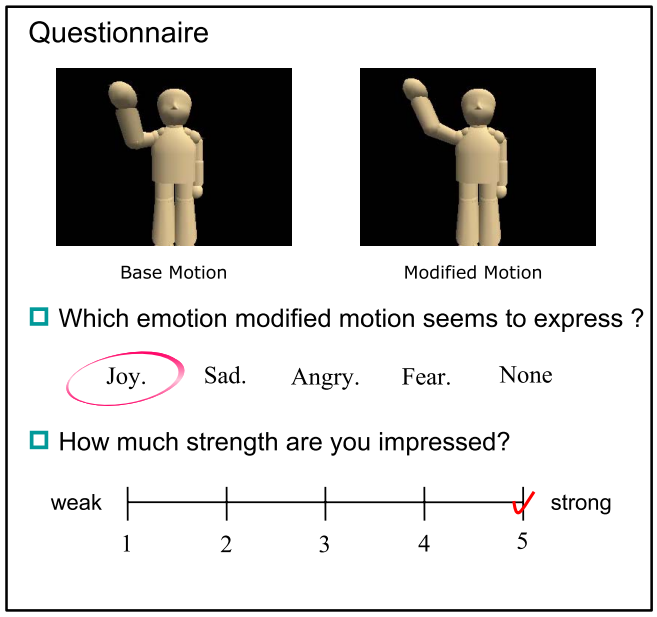

Fig. 8. Shown Motions in Experiment of the Power of Emotion Expression

A. Preference for Adjectival Expressions to Modify Base Motions

In this experiment, emotional motions which are presented to examinees are generated by the proposed technique. These motions are represented on its right arm, and are modified by only one adjectival expression denoted in Table I The number of examinees is 6, men in their 20's. The quoted emotion word denotes the corresponding emotion expression based on the base motion, for instance, "joy" denote the modified base motion which represents joy.

Fig. 9 shows the degree of each emotion expression by each adjectival expression. Adjectival expressions ranked and grouped using confidence interval test. The results of analysis of variance on each emotion are shown in Fig. 10 - 13. Table II summarized adjectival expressions grouped into representing each emotion effectively. If the group has some adjectival expressions, adjectival expressions are ranked in the group.

Table II shows both "joy" and "angry" are represented by the modified motion using adjectival expression "A6 : rapid". Although prime adjectival expression was different between "sad" and "fear", similar adjectival expression were selected to represent them. These results indicate that the subjective orders of human's sensitivity are acquired. Additionally we found that a pair of $A8$ and $A9$ is not effective to express emotional motion.

B. Evaluation the relationship between modification parameters and the power of emotions expression

In this experiment, we prepared emotional motions, which are generated with proposed technique using 3 base motions and 7 adjectival expressions shown in Table III. They are selected in IV-A, which have an influence on emotion expression. The number of examinees is 7, men in their 20's.

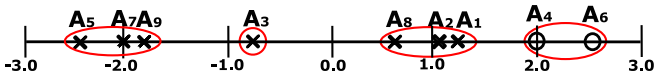

Fig. 10. Result of the Analysis : Joy

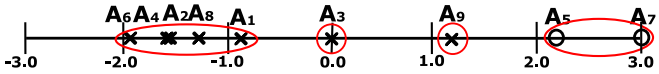

Fig. 11. Result of the Analysis : Sad

Fig. 12. Result of the Analysis : Angry

Fig. 13. Result of the Analysis : Fear

TABLE II
ADJECTIVAL EXPRESSIONS REPRESENTING EMOTIONS BEST.

Emotion	1st	2nd
Joy	upper	rapid
Sad	slow	
Angry	wide	rapid
Fear	lower	slow

Fig. 14 shows the relationship between emotion expression and width of motion. In Fig. 14, the horizontal axis indicates the amplitude magnification. The amplitude of the base motion was changed based on transverse value. The vertical axis indicates obtained score which examinees scored for modified motions. The vertical value is total amount of 3 base motions, 'waving a hand 1', 'handing over' and 'waving a hand 2'. The marked points, such as 0.25, 0.50, 0.90, 1.5, 2.0 and 3.0, in Fig. 14 indicate evaluated points. Transverse value 1.0 means the base motion. Irregular values, such as more than 3 or less than 0.25, are not dealt with, because modified motions should be treated as a same kind of motions. Fig. 14 shows "angry" is represented by the modified motion using adjectival expression "A2 : wide" as in the case shown in Fig. 12. "Joy" is represented widely as well as "angry". "Fear" is represented narrowly. We discuss the details of the relationship between emotion expression and amplitude magnification. As the base motion is modified with narrower

TABLE III
ADJECTIVAL EXPRESSIONS USED IN EXPERIMENT.

Adjectival Expressions		Modification Parameter	
A1	no change	N/A	
A2	wide	×1.5, ×2.0, *times*3.0	amplitude
A3	narrow	×0.25,×0.5,×0.9	amplitude
A4	upper	+15, +30, +90	position
A5	lower	-40, -30, -15	position
A6	rapid	×3.0,×2.0,×1.5	speed
A7	slow	×0.7,×0.5,×0.2	speed

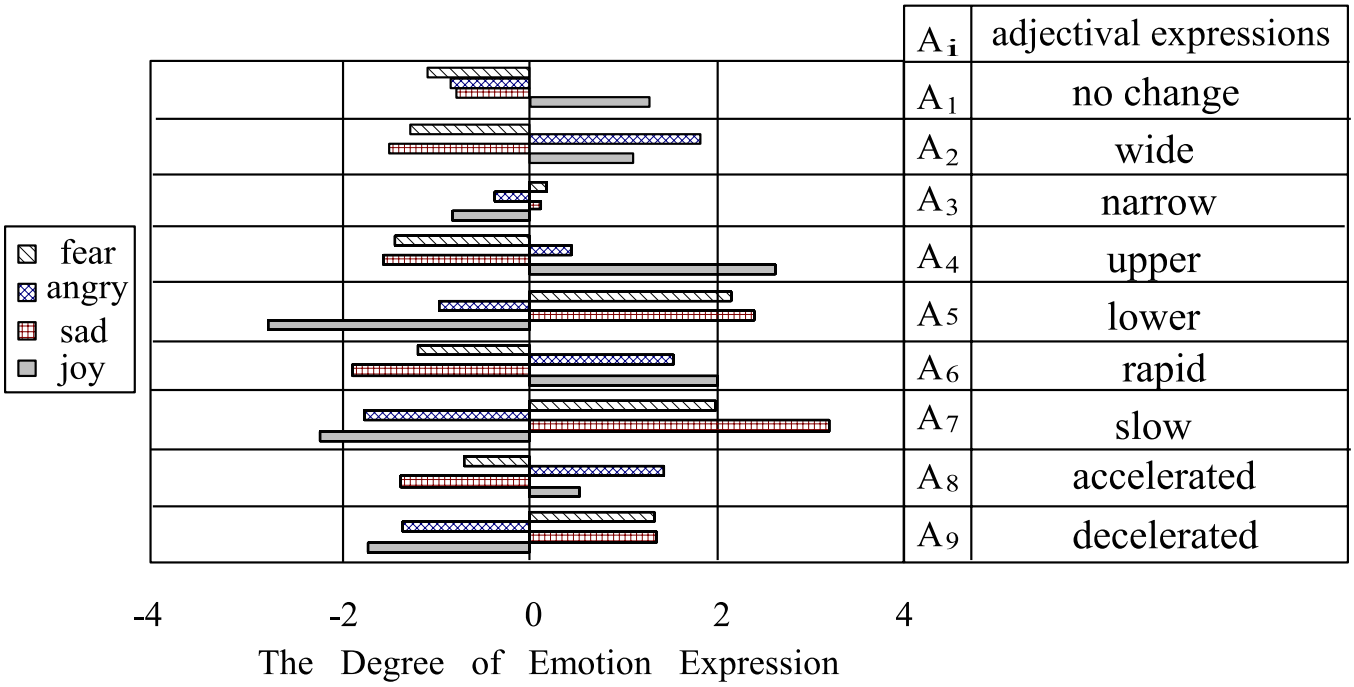

Fig. 9. The Result of Selection of Adjectival Expressions

expression, the modified motion expresses fear effectively. On the other hand, “joy” and “angry” show the saturation of impressed emotions as base motions are modified wider. In joy expression, it takes a maximum value at 1.5, that is to say the saturated point for “joy”. And from here to 2.0, it decreases. In “angry” expression, it reaches the saturation at 2.0. After that, it seems we cannot distinguish each “angry” expression after the magnification of 2.0. Both “joy” and “angry” are represented by the motion modified widely. The wider base motions are modified, the better modified motions express “angry”. When base motion is expressed wider, we can recognize the “joy” from the expression. However, when base motion is expressed more wider, it seems not to be “joy” expression, but rather to be “angry” expression. The modified rule to express more wider is not suitable for expressing “joy”. “Joy” and “angry” are sharply differentiated in this regard. Additionally, this figure shows the motion modified widely let us impress “angry”. These results accord with the results of single adjectival modification denoted in Table II

Fig. 15 shows the relationship between the emotion expression and the display position of the motion. In Fig. 15, the horizontal axis indicates the display position. Transverse value is considered as a variation of the display position,such as -40, -30, -15, 0 , 15, 30 and 90, that is modification parameter is used as a bias of vertical display position. The vertical axis indicates obtained score. We assumed the value of outer range is not suitable as a modification parameter for the sake of expressing the same kind of motion.

In the Fig. 15 shows “joy”, “sad” and “fear” are influenced by position modification parameter. These results are the same as the results mentioned in Fig. 9. Moreover, “angry” is represented upper as well as “joy”. We discuss the details of the relationship between emotion expression and display position. Both “joy” and “angry” are represented by modifying the base motions using adjectival expressions “upper”. In “angry” expression, even though the display position is rising, this modification feature influences “joy” majorly. Therefore when it is desired to generate “angry” expression using display position feature, other modification features should be also applied. “Sad” is represented by modified base motions using adjectival expressions “lower”. Here, “fear” has characteristic appearance. It takes a maximum value at -30, and neighbor test points, such as -40 and -15, show lower impression score significantly. That is to say, around -30 is particular point to express “fear”. Furthermore, fear expressions using any other modification parameters have a weak impression on examinee. That is to say, display position of the motion has a singular point of emotion expression.

Fig. 16 shows the relationship between emotion expression and the speed of the motion. In Fig. 16, the horizontal axis indicates the speed of motion, that is to say sum of flames. Transverse value is considered as amount of change of the speed of motion. That is to say, ‘the speed of motion’ changes as modification parameter sum of frames changes based on transverse value. The vertical axis indicates obtained score. Transverse value 90 means the base motion. Transverse value 30, 45, 60, 135, 180 and 450 are picked for modification parameters. Because modified motions are treated as same motions as far as base motions are modified using these parameters.

Fig. 16 shows both “joy” and “angry” are represented by the modified motion “rapidly” as in the case shown in table. II. “Sad” and “fear” are represented by modifying slowly as in the case in table. II. We discuss the details of the

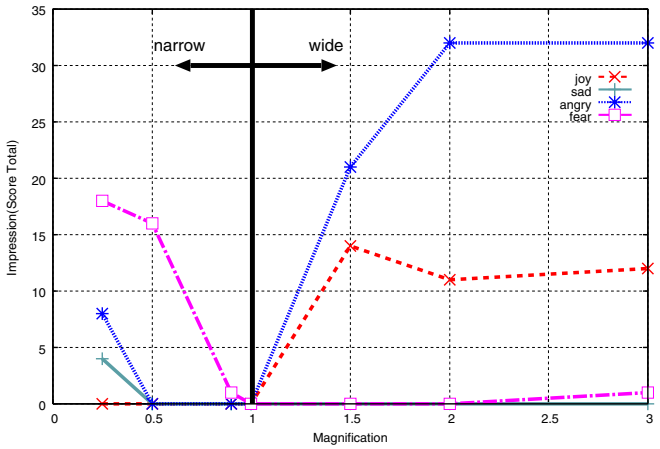

Fig. 14. The Relation between motion width and Emotions Expressions

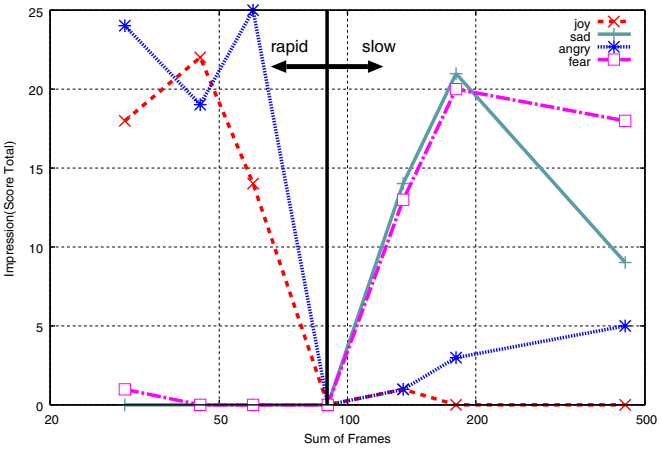

Fig. 16. The Relation between Motion Speed and Emotions Expressions

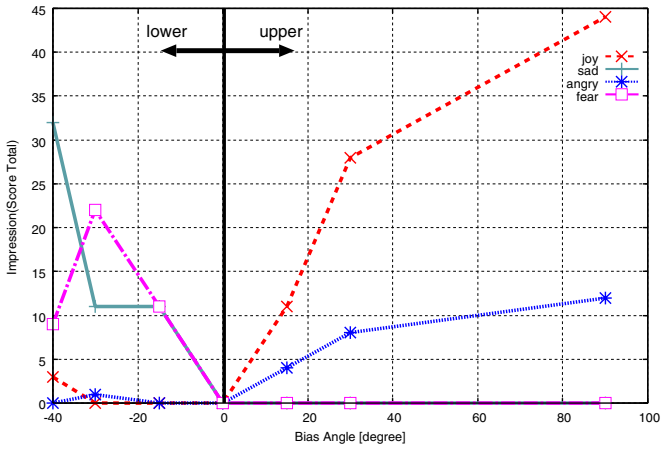

Fig. 15. The Relation between Motion Position and Emotions Expressions

relationship between emotion expression and speed of the motion. Speed of the motion also has a maximum point of emotion expression as well as width of the motion and display position. Speed of the motion has a maximum point of each emotion expression. For instance, "joy" is expressed the best using rapid motion with modification parameter 45. "Fear" and "angry" are expressed the best using rapid motion with modification parameter 60. Leveraging this difference make it possible to express similar emotions separately.

For the results mentioned above, each emotion has singular point of adjectival expressions with expression itself. Some of adjectival expressions have a strong influence on emotion expression in the limited modification parameter range. In addition, they have saturation of emotion expression. These results show human feelings and sensibilities well.

V. Conclusions

We made a technique to generate emotional motion using base motion and adjectival expressions, and clarify the relationship between emotion expressions and adjectival expressions.

This paper shows that motion modification using adjectival expressions can express emotions on the base motion, and useful adjectival expressions for each emotion are selected. Varying modification parameters can represent emotion stronger and weaker.

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