指先の触覚に対する局所振動の影響の定量化における Webアプリケーションを用いたカスプ面解析の応用

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Application of Cusp Surface Analysis Using Web Application to Quantification of Effect of Localized Vibration on Tactile Sense at Finger Tip

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This paper describes about the cusp surface analysis system and the effect of the localized vibration on the tactile sense at a finger tip. The personality of subjects, the localized vibration and the discrimination ability of subjects are employed as the factors in the cusp surface analysis. The discrimination ability of subjects is calculated by the magnitude estimation method. In the result of the cusp surface analysis, it is clarified that the catastrophe phenomenon (jumping phenomenon) is generated in the relationship among the emotional instability, the acceleration amplitude of the localized vibration and the discrimination ability. In the range of bifurcation set, increasing the acceleration amplitude of the localized vibration, probability of decrease of the discrimination ability increases and increasing the emotional instability, probability of decrease of the discrimination ability increases.

Key words: Cusp surface analysis, Tactile sense, Web application, Localized vibration, Personality of subjects

1 Introduction

The catastrophe theory is applied to many fields such as behavioral science, psychology, physics, biology etc. French mathematician Rene Thom classifies the elementary catastrophe of seven types in catastrophe theory [1]. The cusp model with two control factors is frequently applied to discontinuous phenomenon. Furthermore, Loren Cobb proposed the cusp surface analysis. The cusp surface analysis is based on the cusp model in the catastrophe theory[2-4]. The three dimensional geometric is feature of the stochastic cusp catastrophe model in the discontinuous phenomenon. The effectiveness of this analysis is verified. The geometric feature of the stochastic cusp catastrophe model in the discontinuous phenomenon, that is, data governed by irregular nature was clarified including the human factors, and the model was quantified by three-dimensional representation for the cusp surface analysis. In this paper, the system of three-dimensional representation for the cusp surface analysis is described and effectiveness of the cusp surface analysis for psychological data is verified. A cusp surface is a

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statistical response surface model, based on the cusp model of catastrophe theory. The conventional cusp surface analysis performed with a stand-alone computer. But, in this paper, the cusp surface analysis system is constructed to examine the effectiveness of the program by web server. According to operating on web server of cusp surface analysis, client can easily use a cusp surface analysis program without a preparing for an analysis program or the system environment etc.

In this paper, effect of the localized vibration on the tactile sense at a finger tip is taken up. The personality of subjects, the localized vibration and the ability of discrimination of subjects are employed as the factors in the cusp surface analysis.

2 Cusp surface analysis

In the cusp surface analysis, it is assumed that the variable expressed as X_1, X_2, ・・・, X_v is shown in relation to parameter $A(\underline{X})$, $B(\underline{X})$, $C(\underline{X})$. Then formula is changeable into the form of the following formula. In the cusp surface analysis, Cobb's cusp catastrophe model is used. Cobb's formula is as follows.

$$0 = A(\underline{X}) + B(\underline{X})[Y - C(\underline{X})] - D[Y - C(\underline{X})]^3$$
$$A(\underline{X}) = A_0 + A_1X_1 + A_2X_2 + \ldots\ldots + A_vX_v$$
$$B(\underline{X}) = B_0 + B_1X_1 + B_2X_2 + \ldots\ldots + B_vX_v$$
$$C(\underline{X}) = C_0 + C_1X_1 + C_2X_2 + \ldots\ldots + C_vX_v \qquad (1)$$

D is a constant $\underline{X}$ is independent variable vector, three control factors are scalar values, predicted value Y is number of independent variables. $A(\underline{X})$ is unsymmetrical factor, $B(\underline{X})$ is bifurcation factor and $C(\underline{X})$ is linear factor.

In parameter estimating, most likelihood method is used. Statistical testing which is satisfied criterion of the catastrophe model is not single. Then three criterions are proposed by Cobb. In three-dimensional representation for the cusp surface analysis, it became possible to treat quantitatively psychological data and physical data. Likelihood for the cusp model is compared with likelihood of the linear model. When ratio of logarithm likelihood is larger than χ^2 value by means of χ^2 testing, the condition of criterion is satisfied. In the equation, as the value of Y has one value to the value of X, this model does not form a catastrophe model. Also, it take place that unsymmetrical factor $A(\underline{X}) = A_0$, and bifurcation factor $B(\underline{X}) = B_0$. Then, when $D \neq 0$ and one at least for $A(\underline{X})$, $B(\underline{X})$ and $C(\underline{X})$ are not zero, this criterion is satisfied. When data point in estimated bimodal range do not include in the ratio of constant, bimodal type does not form. Then, when data point existed 10% of bimodal range at least, condition of criterion is satisfied. When these are satisfied condition of criterion, the cusp catastrophe model is formed. In this paper, the three dimensional geometric feature of the stochastic cusp catastrophe model in jumping phenomenon of physiological data is described. The effectiveness of this analysis is s verified in the discontinuous phenomenon of physiological data governed by irregular nature was clarified including the human factors. The model was quantified by three-dimensional representation for the cusp surface analysis. In this paper, A, B and C will be called the asymmetry, bifurcation, and linear factors, respectively. The cusp surface analysis offers three separate tests to assist the user in evaluating the overall acceptability of the cusp catastrophe model. To confirm a cusp model all three tests should be passed. The cusp catastrophe model may be said to describe the relationship between a dependent variables if all of these three conditions hold:

1) The chi-square test shows that the likelihood of the cusp model is significantly higher than that of the linear model.
2) The coefficient for cubic term and at least one of the coefficients of asymmetry and bifurcation factors are significantly different from zero.
3) At least 10% of the data points fall in the bimodal zone of the estimated model.

3 Cusp Surface Analysis System[5]

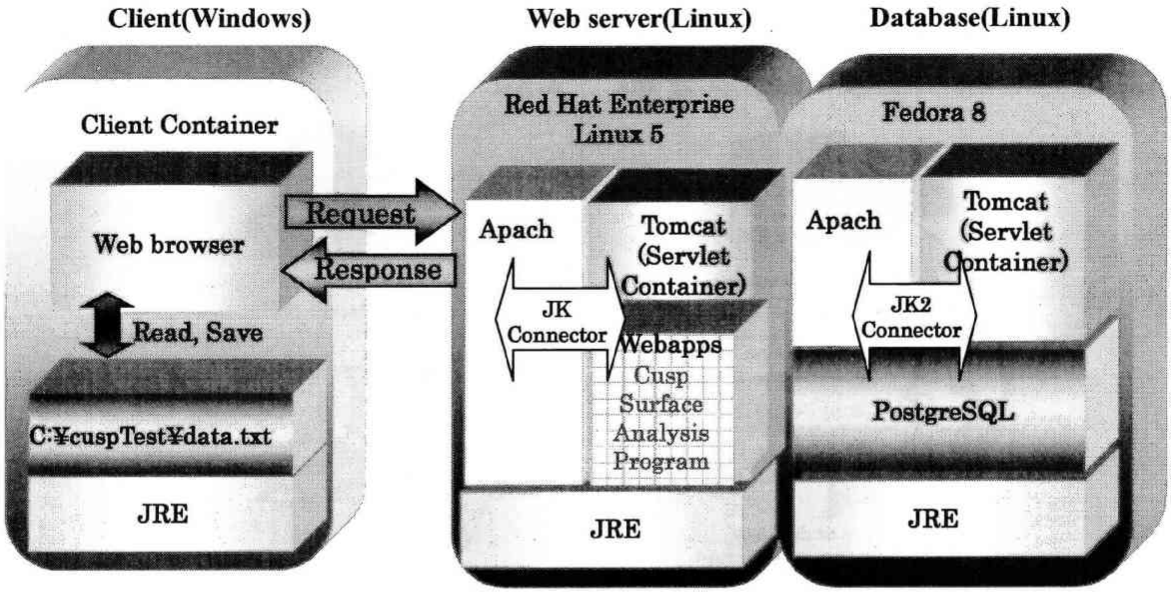

Fig.1 Structure of client, Web server and Database server.

The cusp surface analysis system is a system performing calculation in the cusp surface analysis on a web server from cooperation of Linux, Apache, Tomcat, PostgreSQL and Java. Apache of web server software is installed in the web server. In addition, Tomcat of the web server software is carried to treat Java servlet and Java Server Pages (JSP). Tomcat is done plug-in into Apache. Tomcat independently plays a role of the web server. But the reason of the plug-in is the improvement of the processing performance and the problem of security etc. If the client has web browser and Java, client can use the cusp surface analysis program on the web server. The giving and receiving of the web server is performed in protocol called the HTTP (Hyper Text Transfer Protocol). The client request "the cusp surface analysis program" as HTTP, and the web server response the service of "the cusp surface analysis program" as HTTP. Web browser on the client provides service for the client as HTML (Hyper Text Markup Language). Web browser plays a role to change HTTP gotten from web server into HTML. The cusp surface analysis system is available that the client can save data to both database and local directory. And saved data from both web server and local directory are also able to open. Internet Explorer (I.E) is started to start the cusp surface analysis program, and following URL is input.

https://163.51.55.140/cusp2008-DB/cuspmain.html

If the main screen of the cusp surface analysis program is executed by input URL, the system performs normally. If the main screen of the cusp surface analysis program is executed, the system performs normally.

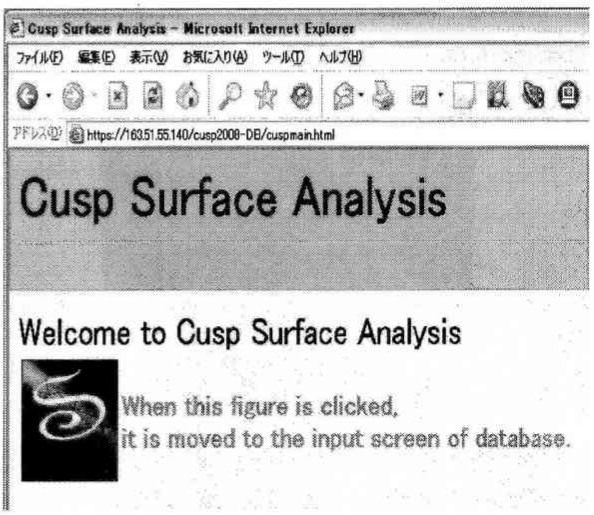

Fig.2 Cusp surface analysis main screen.

The cusp surface analysis system uses SSL (Secure Sockets Layer) of a cryptographic system that uses two keys to encrypt data. The client and the server use the public-key and secret-key to encrypt and decrypt the data they send to each other and to secure the safety of the data. URL requires an SSL connection start with 「https:」 instead of 「http:」. Fig.3 shows the structure of SSL.

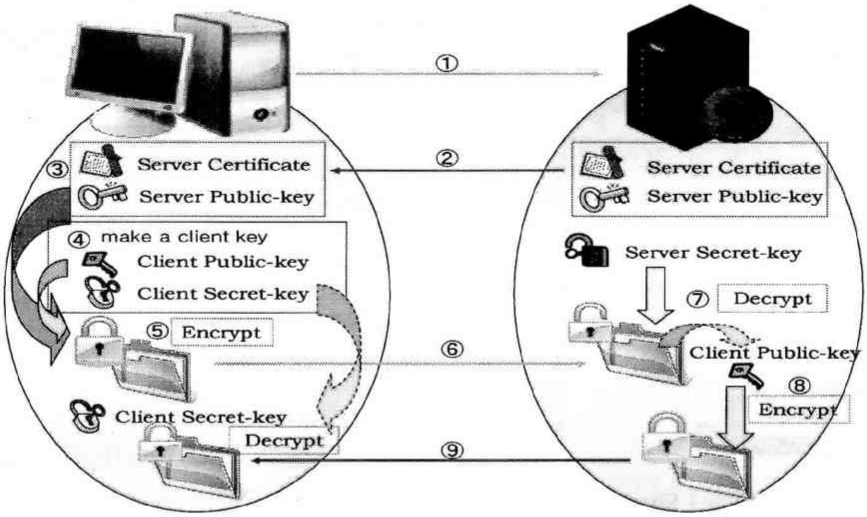

Fig.3 Structure of SSL.

4 Experiment

4.1 Experimental Specimen

As the experimental specimens, four kinds of the sandpaper with different roughness is used. These are 600 grit, 320 grit, 240 grit, 150 grit of Japan Industrial Standard. This experiment uses 16 pieces in steps of roughness of the sandpaper. The experimental specimen is devised in step of 4 pieces. These sandpapers are 1 group. This is generated 4 groups as shown in Fig.4.

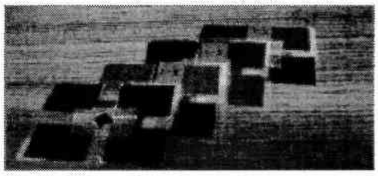

Fig.4 Experimental specimen (16 pieces of sandpaper)

This experiment uses the panel that sandpaper is lined up 16 pieces prepared by single row. Sandpaper is lined up at random. In this experiment, vibration generator is used to generate localized vibration. The frequency is fixed to 50Hz that is frequency feeling vibration at a finger tip[6]. The acceleration amplitude is changed at range to 0.0g – 1.1g by 0.1g interval, and 1.3g, 1.5g.

4.2 Experimental Method

Subjects touch the experimental specimen by a fore finger sequentially. Subjects evaluate roughness by numerical value at feeling. In range to numerical value, lower bound is 50 and upper bound is about 100. Final digit of numerical value must not be 0. The numerical value is large so as rough. Exposing vibration, subjects touch the sandpaper exposed by a vibration generator sequentially. Subjects are vibration time for fore finger per a piece of the sandpaper is 3 seconds and the roughness of the sandpaper is evaluated. Experimental specimen prepared on a vibration generator is shown in Fig.5.

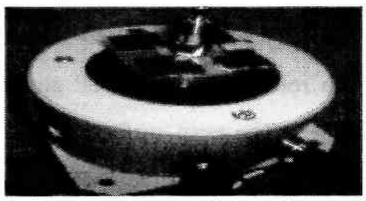

Fig.5 Vibration generator and experimental specimen

As an experimental procedure, the experiment expose in the vibration using a vibration generator. Subjects are exposed the vibration at fore finger for 3 seconds, and they evaluate roughness for nearest sandpaper attached marker. Subjects evaluate the other 3 pieces clockwise by same method when they finished evaluation of 1 piece. In this experiment, the next group is evaluated when the evaluation is finished all of 4 pieces. Subjects evaluate by same method. Subjects confirm the numerical value that they evaluated the sandpaper touched last to before a group. Subjects start new a group. Numbers of experiment finishes 1 time when 4 groups finish all. Subjects repeat the evaluation at 20 times for mention the above. An experiment used the panel with no vibration is included to numbers of experiment. The order of experiment is at random.

4.3 Discrimination Ability

This paper shows a method of finding of the discrimination ability to discriminate roughness. The logarithm exchange is performed to evaluate in feeling quantity and physical quantity. The relationship is linear. Slope of its relation is the discrimination ability. Feeling quantity is calculated by data of experiment. The data are devised in steps of numbers of experiment. The evaluation results of 16 are devised in steps of the sandpaper's roughness. The result of each roughness is calculated using geometric mean. The ratio evaluated for standardizing by 600 grit sandpaper in value of geometric mean. This ratio is defined as feeling quantity. The logarithm is evaluated using the proportion. The physical quantity is the defined value that calculated by 1000 times of inverse of number of roughness of sandpaper. The physical quantity is evaluated by the logarithm exchange. The discrimination ability is evaluated using the least squares by logarithm of feeling quantity and physical quantity.

4.4 Y-G Personality Inventory

Y-G (Yatabe-Gilford) personality inventory is used to evaluate personality of subjects. Y-G personality inventory is inquiry method. Questionnaire about personality of subjects are shown in inquiry paper. Subjects answer in terms of "Yes"," No" and "Yes/No" to evaluate the personality of subjects. The personality in this paper is evaluated by the emotional instability. Test 4 articles, that is, D (Depression), C(Cyclic Tendency), I(Inferiority Feelings), N (Nervousness) are picked up as factor of emotional instability from articles in Y-G personality inventory and the emotional instability is shown by the total of numerical values. Executing method is reading method.

5 Experimental results

5.1 Experiment (in the case of 6 subjects)

In this experiment, 6 subjects are undergraduate students from 21 to 23 years old. The results of experiment are the localized vibration, the discrimination ability and Y-G personality inventory. These are shown in Fig 6. From this figure, the effect of factors to structure of relationship is not clarified with dispersion[7]. Thus cusp surface analysis is carried out. As a group of 6 subjects, these results are analyzed by 3 dimensional model using the cusp surface analysis.

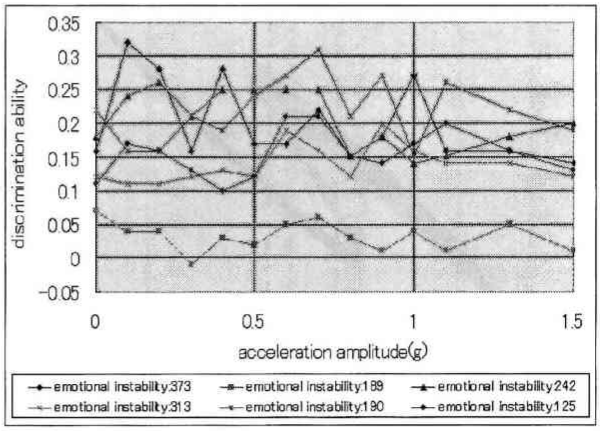

Fig.6 A total of experimental results

Table 1 Data (6 subjects)

number of data	X_1	X_2	Y
1	37.3	0	0.16
2	37.3	1	0.32
3	37.3	2	0.28
⋮			
82	12.5	11	0.2
83	12.5	13	0.16
84	12.5	15	0.13

Table 1 shows the part of total data for a group of 6 subjects. In cusp surface analysis, data of Table 1, that is, the emotional instability X_1, the acceleration amplitude of the localized vibration X_2 and the discrimination ability Y is used. For output of the cusp surface model, X_1 is shown 1/10 of real value and X_2 is shown 10 times of real value. A total data is inputted to applet of the cusp surface analysis system developed in our laboratory. From this result of analysis, formula of the cusp catastrophe model is obtained. And these results are shown in from Fig.7 to Fig.13. From Fig.7 of data of a group of 6 subjects, the catastrophic phenomenon generates in relationship among the emotional instability, the acceleration amplitude of the localized vibration and the discrimination ability.

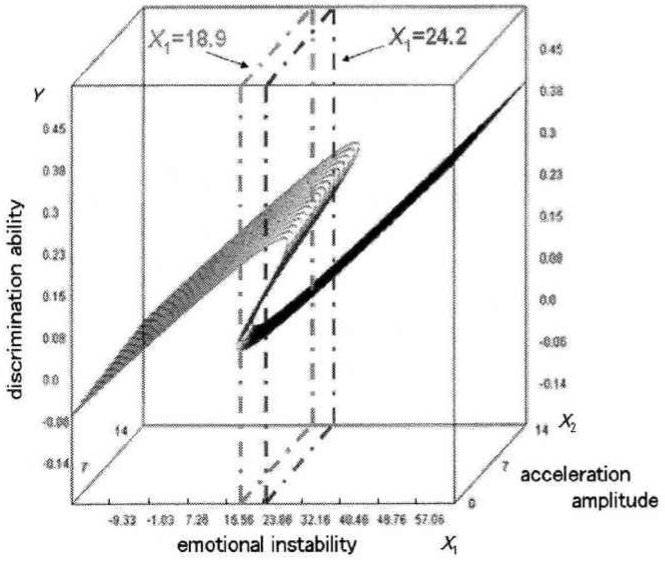

Fig.7 Effect of X_1 and X_2 on Y

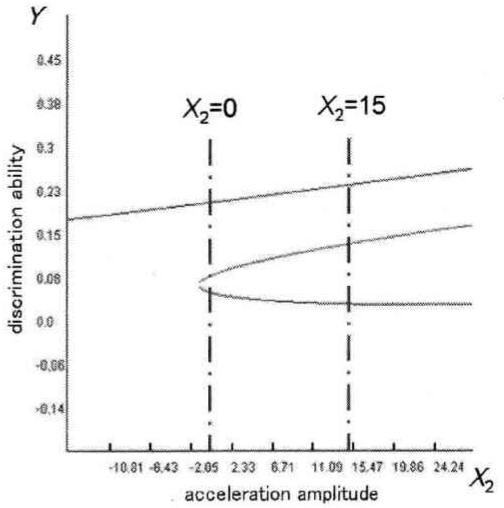

Fig.8 Effect of X_2 on Y at X_1=18.9

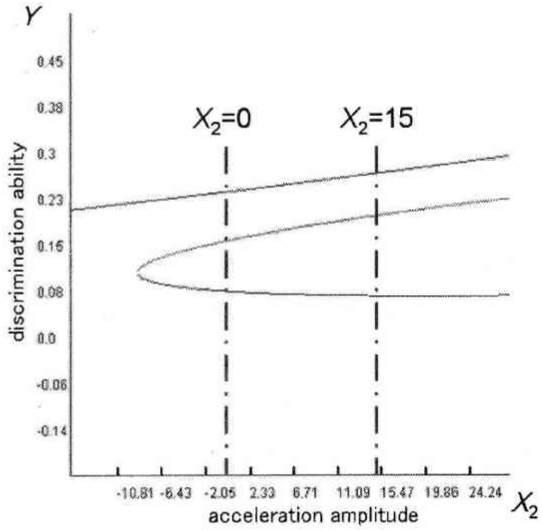

Fig.9 Effect of X_2 on Y at X_1=24.2

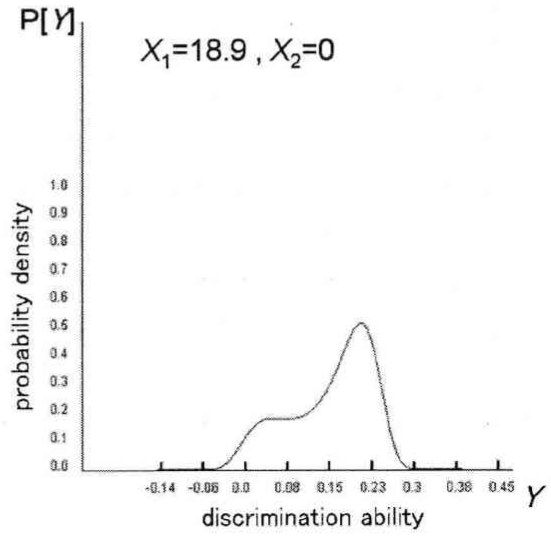

Fig.10 Probability density of Y at X_1=18.9 and X_2=0

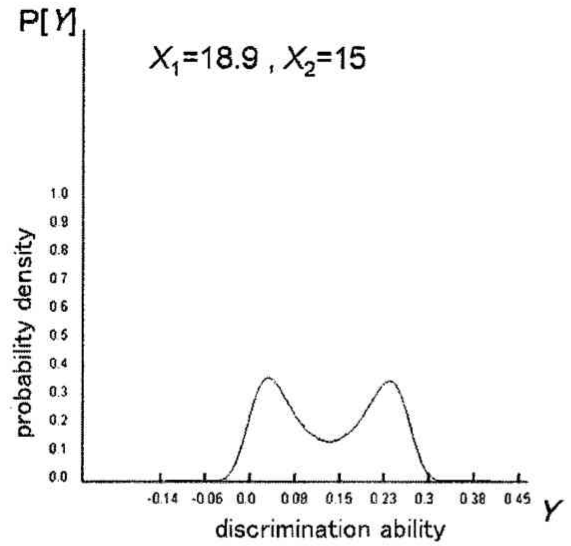

Fig.11 Probability density of Y at X_1=18.9 and X_2=15

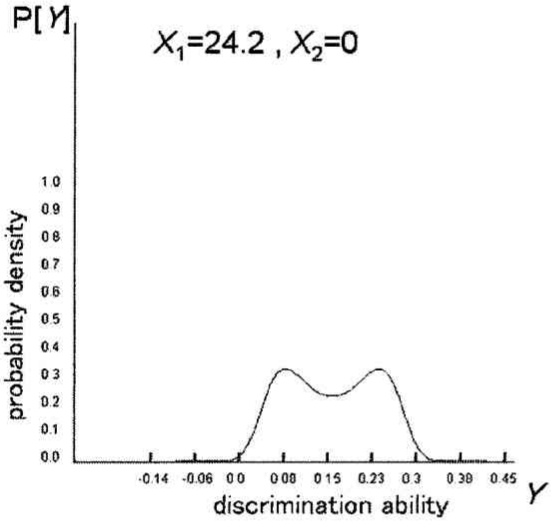

Fig.12 Probability density of Y at X_1=24.2 and X_2=0

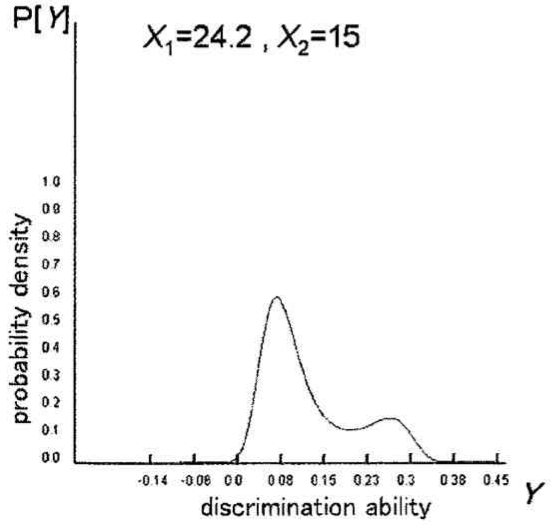

Fig.13 Probability density of Y at X_1=24.2 and X_2=15

Focusing on the catastrophic phenomenon, the emotional instability of 2 subjects 189 and 242 are used. Fig.7 shows relationship among the emotional instability, the acceleration amplitude of the localized vibration and the discrimination ability and Fig.8 and 9 show relationship between the discrimination ability and the acceleration amplitude of the localized vibration at constant the emotional instability. From Fig.8 to Fig.13, at constant the emotional instability 189, the acceleration amplitude of the localized vibration increase from 0g to 1.5g, probability density of the discrimination ability Y increases at mode of lower side of Y and decreases at mode of higher side of Y. On account of results, organic sense of finger tip is discriminated degree of roughness increasing the acceleration amplitude of the localized vibration. At constant the emotional instability 242 is compared with constant the emotional instability 189. In the case of the acceleration amplitude of the localized vibration 0g, probability density of the discrimination ability Y increases at mode of lower side of Y and decreases at mode of higher side of Y.

The case of the acceleration amplitude of the localized vibration 1.5g is same as 0g. Increasing the emotional instability, subject astray about numerical value of roughness discriminated, so reevaluate different numerical value of roughness. It guesses to be able to reevaluate accurate numerical value of roughness.

5.2 Experiment (15 subjects)

In next experiment, 15 subjects are undergraduate students from 21 to 23 years old. In the result of carrying out the cusp surface analysis using total data, the formula of the cusp catastrophe model is obtained and the result is shown in from Fig.14 to Fig.20.

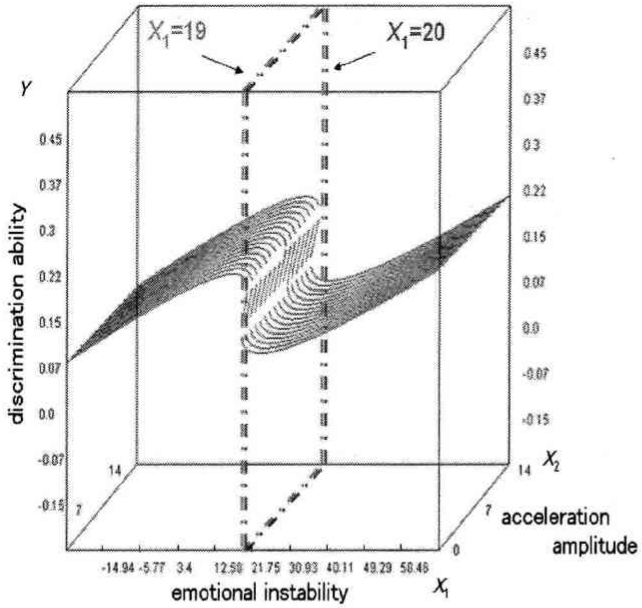

Fig.14 Effect of X_1 and X_2 on Y

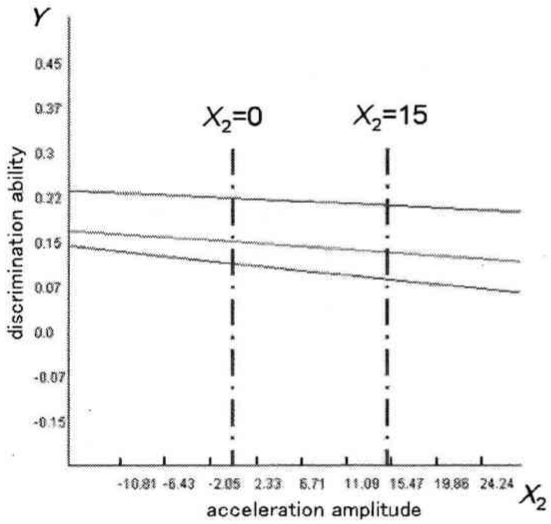

Fig.15 Effect of X_2 on Y at X_1=19

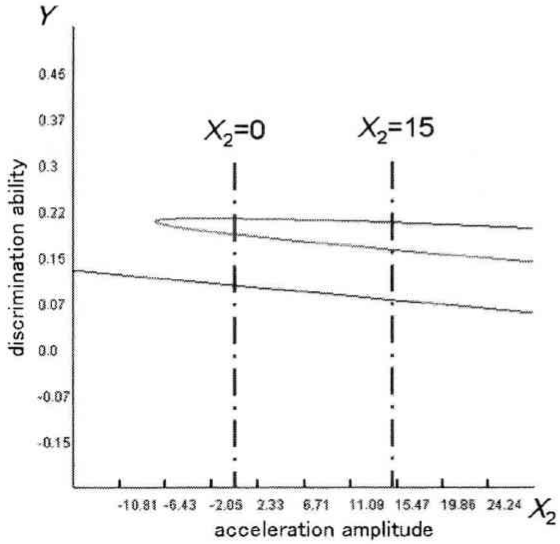

Fig.16 Effect of X_2 on Y at X_1=20

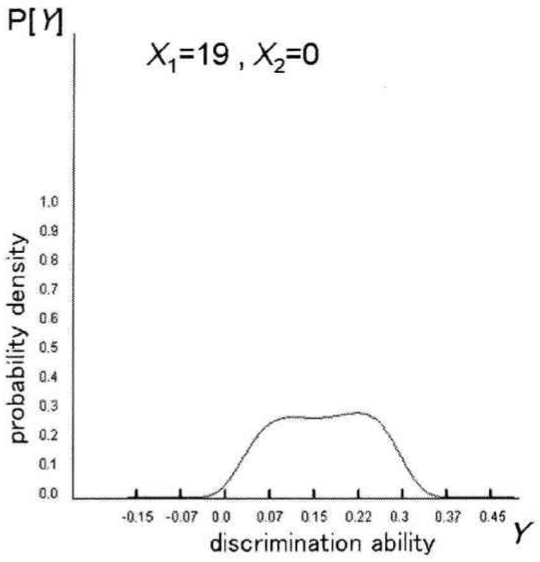

Fig.17 Probability density of Y at X_1=19 and X_2=0

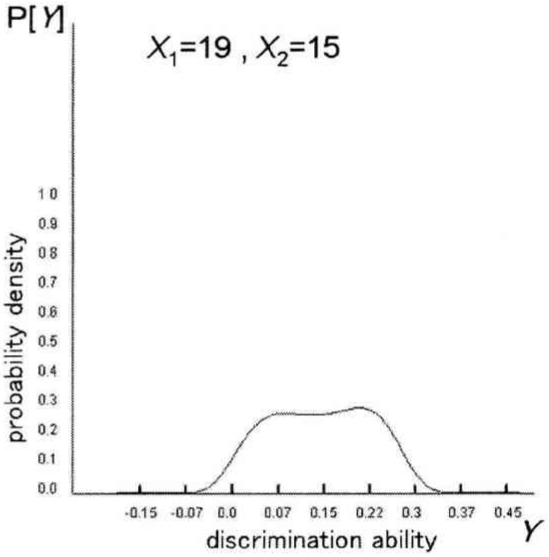

Fig.18 Probability density of Y at X_1=19 and X_2=15

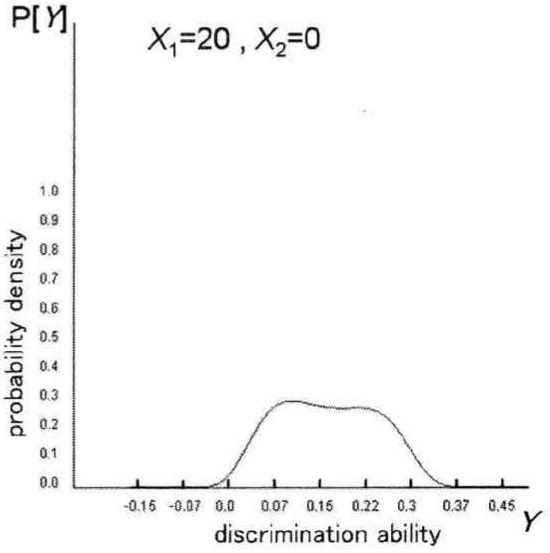

Fig.19 Probability density of Y at X_1=20 and X_2=0

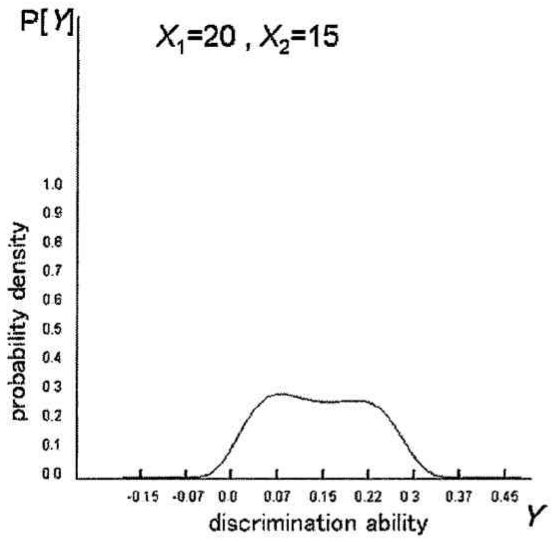

Fig.20 Probability density of Y at X_1=20 and X_2=15

In the case of a group of 15 subjects, it is clarified from Fig.14 that catastrophe phenomenon is generated in the relationship among the emotional instability, the acceleration amplitude of the localized vibration and the discrimination ability. Constant the emotional instability with 190 in the split set of the catastrophe phenomenon is used. Split set in the catastrophe phenomenon is narrow, so it compares with at constant the emotional instability 210. From Fig.15 to Fig.20, at constant the emotional instability 190, the acceleration amplitude of the localized vibration increase from 0g to 1.5g, difference of probability density of the discrimination ability is not obtained same as the result of a group of 6 subjects. At constant the emotional instability 200 compares with constant the emotional instability 190. In the case of the acceleration amplitude of the localized vibration 0g, probability density of the discrimination ability Y increases at mode of lower side of Y and decreases at mode of higher side of Y. This result is obtained same as the result of a group of 6 subjects.

6 Conclusions

1) The cusp surface analysis system is available that the client can save data to both database and local directory.

2) In the relationship among the emotional instability, the acceleration amplitude of the localized vibration and the discrimination ability, it is clarified that the catastrophe phenomenon (jumping phenomenon) is generated.

3) In the range of bifurcation set, increasing the acceleration amplitude of the localized vibration, probability of decrease of the discrimination ability increases and increasing the emotional instability, probability of decrease of the discrimination ability increases.

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