APPLICATION OF CUSP SURFACE ANALYSIS USING WEB APPLICATION TO VISUAL PERCEPTION

Yasufumi Kume
Department of Mechanical Engineerng, Kinki University, Japan

Keywords: Catastrophe theory, Server and client, Cusp surface analysis, Web application.

Abstract: Cusp surface analysis system is constructed to examine the effectiveness of the program of cusp surface analysis by web server. According to operating on web server of cusp surface analysis, client can easily use a cusp surface analysis program without preparing for an analysis program or system environment etc. This paper examines the relationship of 'kinds of ambiguous figures', 'levels of detail figures ' and ' human visual perception ' using 315 kinds of fisher's ambiguous figures. Fisher introduced ambiguous man/girl figure. An array of 315 ambiguous man/girl figures has 21 steps of column from a man's face to girl's shape and has 15 row levels of detail. The experimental data are applied to cusp surface analysis. Summing up this paper, (1) as the cusp surface analysis can be opened to the public on the web server, the clients input URL he or she can perform the cusp surface analysis. (2) As the results of the experiments, the cusp catastrophe phenomenon occurs as kinds of the ambiguous figures and the levels of detail figures in human visual perception.

1 INTROUCTION

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 (Thom, 1975). The cusp model with two control factors is frequently applied to discontinuous phenomenon. Furthermore, Loren Cobb proposed the cusp surface analysis. A cusp surface is a statistical response surface model, based on the cusp model of catastrophe theory (Cobb,1998). Conventional cusp surface analysis performed with a stand-alone computer. But, in this paper, cusp surface analysis system is constructed to examine the effectiveness of the program by webserver (Kume, Morita,2006). Figure1 shows transition of research for cusp model. Figure 2and Figure 3shows 3D cusp catastrophe model and cusp surface.

According to operating on web server of cusp surface analysis, client can easily use a cusp surface analysis program without preparing for an analysis program or the system environment etc. This paper examines the relationship of 'kinds of ambiguous figures', 'levels of detail figures' and 'human visual perception' using 315 kinds of ambiguous figures. Fisher introduced ambiguous man/girl figure, and Attneave made 8 figures by embedding the figure in the sequence, and Tim Poston and Ian Stewart made 32 figures. 315 kinds of ambiguous figures by interpolation of figure of Tim Poston and Ian Stewart figure are made by Atsuo Murata etc (Murata, Kume and Hashimoto, 1984). An array of 315 ambiguous man/girl figures has 21 steps of column from a man's face to girl's shape, and has 15 row levels of detail. The experimental data are applied to cusp surface analysis

2 CATASTROPHE THEORY AND CUSP SURFACE ANALYSIS

In cusp surface analysis(Cobb,1998), it is assumed that the variable expressed with $X_1, X_2, \cdots, X_v$ exists in relation to parameter $A(\underline{X}),B(\underline{X}),C(\underline{X})$. The formula is changeable into the cusp catastrophe model is used. Catastrophe theory is proposed by Rene Thom in French mathematician as mathematical method described development of configuration in nature (Thom, 1975). Figure 3 and Figure 4 show 3D cusp catastrophe model and cusp surface. In cusp surface analysis, it is assumed that

Kume Y. (2009).
APPLICATION OF CUSP SURFACE ANALYSIS USING WEB APPLICATION TO VISUAL PERCEPTION.
In *Proceedings of the International Conference on Knowledge Management and Information Sharing*, pages 251-257
DOI: 10.5220/0002267602510257

the independent variable expressed with X_1, X_2, ・・・, X_v exists in relation to parameter $A(\underline{X}),B(\underline{X}),C(\underline{X})$. Then formula is changeable into the form of the following formula.

$$0 = A(\underline{X}) + B(\underline{X})[Y - C(\underline{X})] - D[Y - C(\underline{X})]^3$$

$$A(\underline{X}) = A_0 + A_1X_1 + A_2X_2 + \ldots\ldots + A_vX_v \quad (1)$$

$$B(\underline{X}) = B_0 + B_1X_1 + B_2X_2 + \ldots\ldots + B_vX_v$$

$$C(\underline{X}) = C_0 + C_1X_1 + C_2X_2 + \ldots\ldots + C_vX_v$$

,where D is a constant, and $\underline{X}$ is independent variable vector, three control factors are scalar values and predicted value Y is decided, then v 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 catastrophe model is not single. Three criterions are proposed by Cobb. This prediction equation is a cubic polynomial in ***Y*** which means that for each values of ***X*** there are either one or three predicted values of ***Y***.

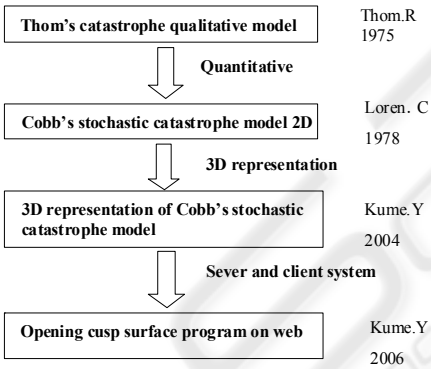

Figure 1: Transition of research for cusp mode.

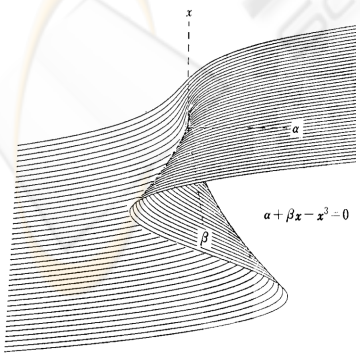

Figure 2: Thom's cusp model.

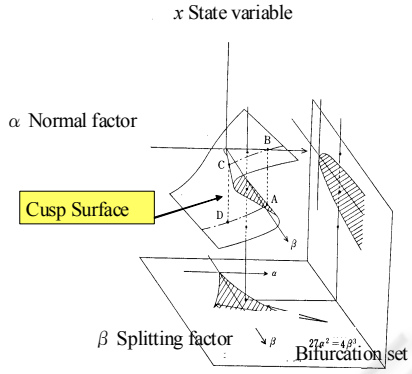

Figure 3: 3D cusp models.

3 CUSP SURFACE ANALYSIS SYSETM

The cusp surface analysis system as shown in Figure 4 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 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

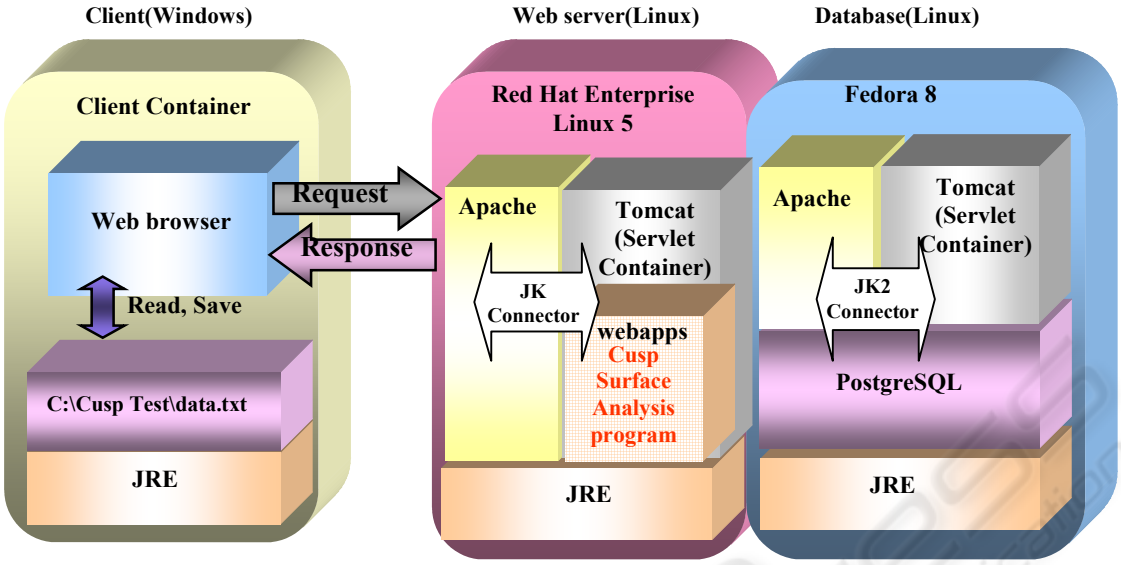

Figure 4: Structure of client, Web server and Database server.

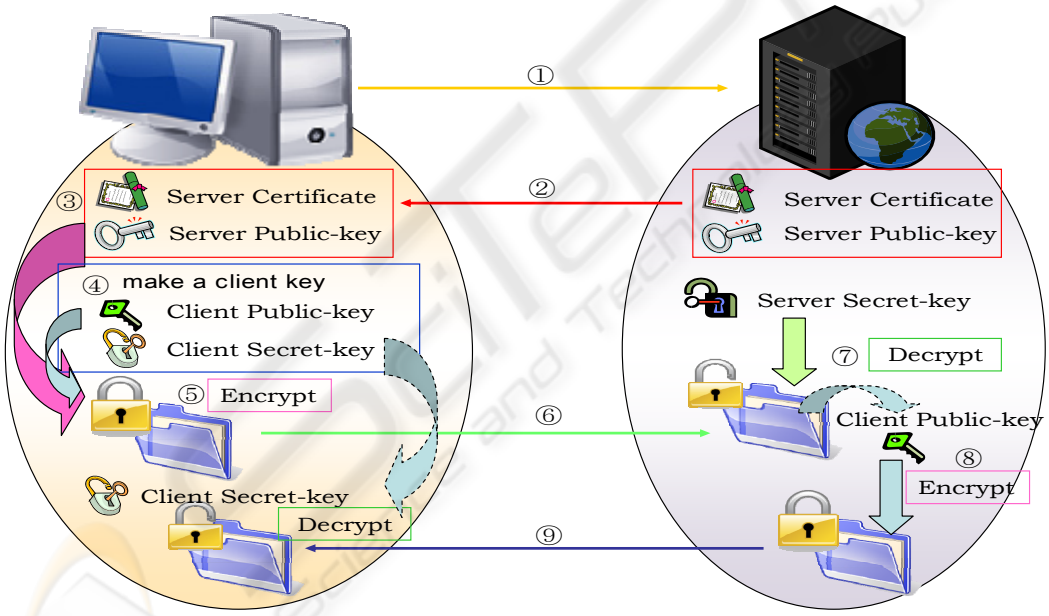

Figure 5: Structure of SSL.

performs normally.Cusp surface analysis system uses SSL (Secure Sockets Layer) of a cryptographic system as shown in Figure 5 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.

4 APPLICATION OF CUSP SURFACE ANALYSIS SYSTEM TO EXPERIMENT RESULT

This experiment shows the relationship among 21 kinds ambiguous figures which changes from man's face to woman's shape, 15 levels detail figures, and visual Figures size used in this experiment is 2.2×4.0cm. In the kind of the ambiguous figures, man's face is A① and woman's shape is U①. Among 15

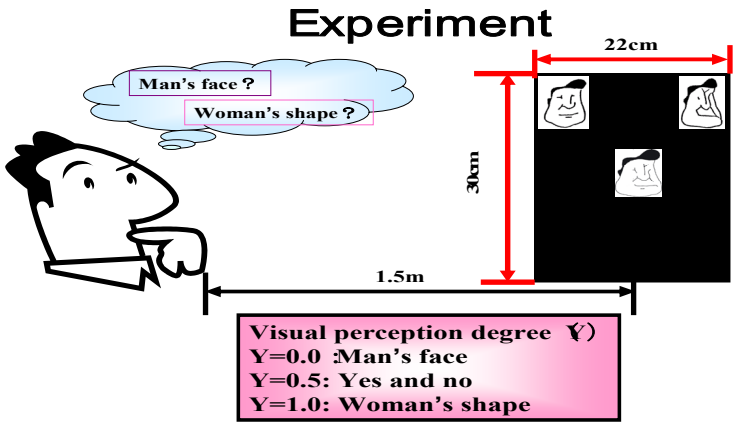

Figure 6: Experimental methods.

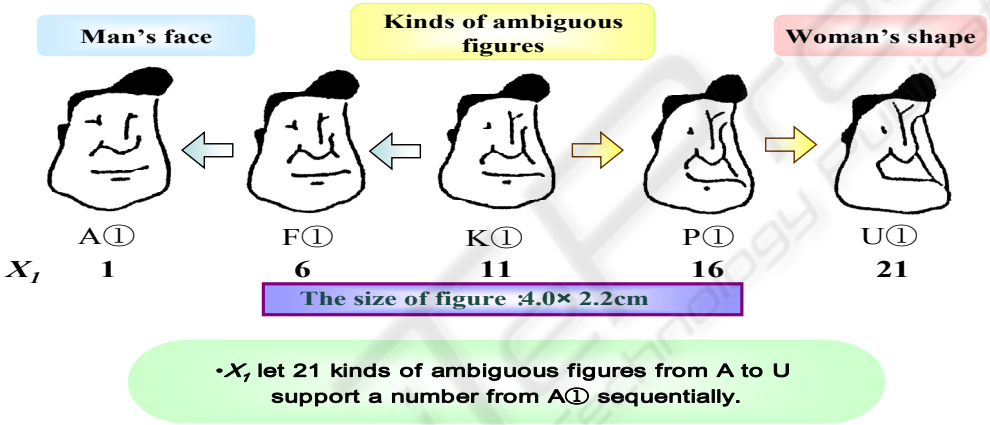

Figure 7: In the case of level ①of detail figures, 21 kinds of ambiguous figures.

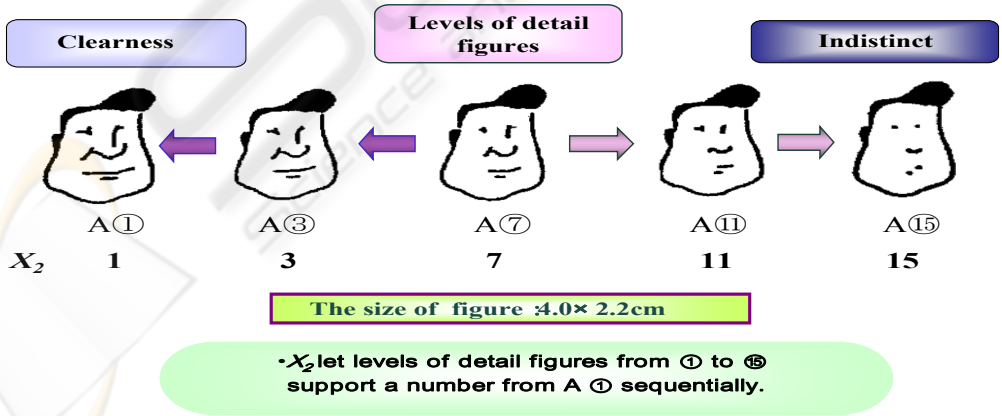

Figure 8: In the case of the kind A of ambiguous figures, ⑮ levels of detail figures.

levels of detail figure, level① is most detail figure and most indistinct figure is level⑮. Two figures past on the upper section of a black board so that the subject can judge easily. Two figures are the highest probability to be seen by man's face and woman's shape.

In this experiment as shown in Figure 4, subjects are shown at random 21 figures per one subject. And the 315 data are taken from 15 subjects of 20's. Visual perception change points are set as following:

Table 1: The results of 21 kinds ambiguous figures, 15 levels detail figures, and visual perception (Case1~Case315) Experimental data (21×15=315).

X_1: Kinds of the ambiguous figures, X_2: Levels of detail figures, Y : Visual perception.

Case	X_1	X_2	Y	Case	X_1	X_2	Y	Case	X_1	X_2	Y
1	6	4	1	106	8	10	1	211	16	9	1
2	2	4	0	107	17	8	1	212	11	3	0
3	3	4	0	108	9	14	1	213	19	9	1
4	13	8	0.5	109	7	15	0.5	214	9	9	0
5	2	10	0.5	110	14	10	0.5	215	16	3	1
6	8	12	0	111	7	8	1	216	5	5	0
7	14	4	1	112	20	8	0	217	3	5	0
8	19	6	1	113	14	12	0.5	218	3	3	0
9	7	4	1	114	10	14	0.5	219	2	1	0
10	1	13	0.5	115	17	10	1	220	14	5	1
11	21	4	1	116	10	10	0.5	221	4	3	0
⋮				⋮				⋮			
96	18	12	1	201	15	7	0	306	8	7	0
97	9	13	1	202	4	9	0	307	10	9	1
98	1	2	0	203	6	9	0	308	9	1	1
99	5	8	0.5	204	21	9	0.5	309	17	9	1
100	13	4	1	205	3	1	0	310	17	3	1
101	14	2	1	206	20	7	0.5	311	20	11	1
102	1	10	0.5	207	9	5	0	312	13	1	1
103	7	6	0	208	7	11	0	313	2	11	0
104	7	14	0.5	209	1	11	0	314	2	9	0
105	2	13	0.5	210	20	1	0.5	315	19	3	1

subject answers Man's face－ (0.0), Yes and no－ (0.5), and subject answers woman's shape－ (1.0). The subjects are shown 1.5 meter far from figure. Since back ground colors may influence subject's judgment, 22×30cm black board is pasted on the back of each figure. This getting data are used for a cusp surface analysis.

In analysis, linear regression model's parameter is presumed. Linear model's is estimated by the least squqre method. The correlation coefficient is obtained from data. In the result, correlation matrix is obtained. And square multiple correlation coefficient is obtained. Log liklihoooood of linear regression model can be obtained from linear square multiple correlation coefficien .This is the initial values used by the maximum likelihood method when it begins its iterative search for the best f itting coefficient for the catastrophe model.

5 ANALYTICAL RESULT

This is the initial values used by the maximum likelihood method when it begins its iterative search for the best fitting coefficients for the catastrophe model. The maximum of log likelihood can be obtained by the Newton-Raphson method . In the result of estimating parameter from data of experiment results, it is shown in Table 2 as follows.

Table 2: Standard partial regression coefficient.

Var	A_ν	B_ν	C_ν	D
Const	-0.11	7.113	0.097	6.591
1	0.673	-0.753	-0.014	
2	-0.105	-3.006	-0.018	

X_1: Kinds of the ambiguous figures, X_2: Levels of detail figures, Y : Visual perception

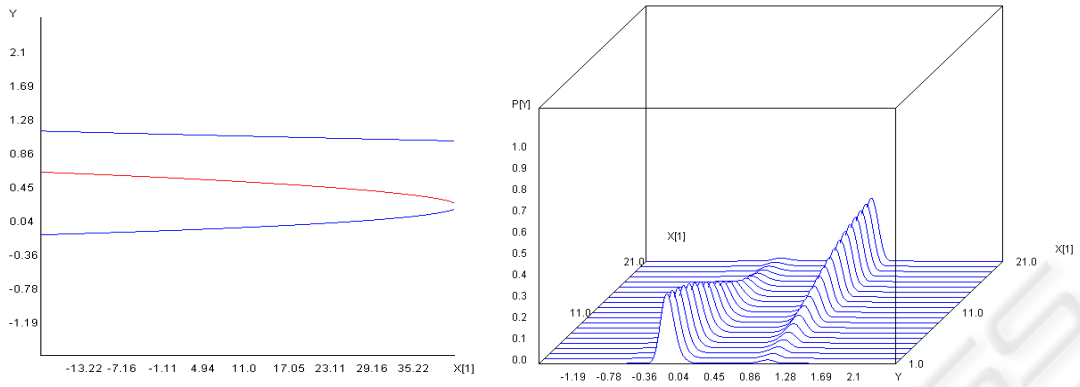

Figure 9: Visual perception by kinds of ambiguous figures in the case of the level ① of detail figures. And the probability density function 3D figure according to kinds of ambiguous figures and visual perception in the case of the level ① of detail figures.

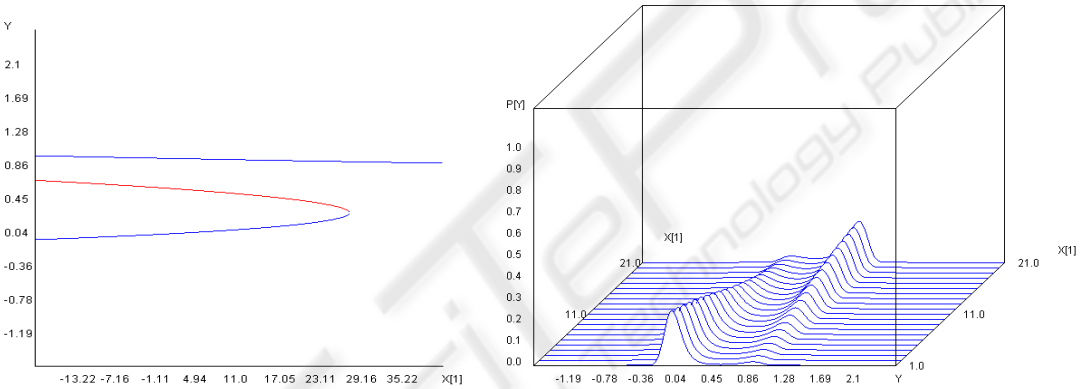

Figure 10: Visual perception by kinds of ambiguous figures in the case of the level ⑧ of detail figures. And the probability density function 3D figure according to kinds of ambiguous figures and visual perception in the case of the level ⑧ of detail figures.

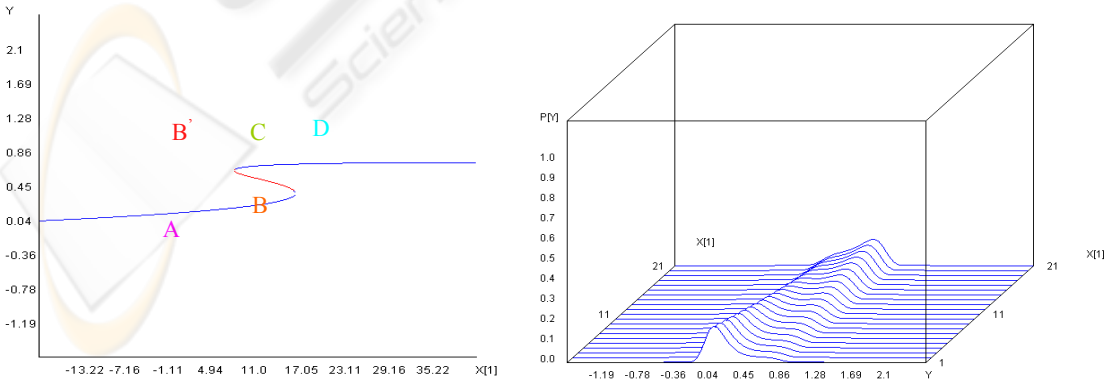

Figure 11: Visual perception by kind of the ambiguous figure in the case of the level □ of detail figures. And the probability density function 3D figure according to kinds of ambiguous figures and visual perception in the case of the level□ of detail.

$$0 = A(\underline{X}) + B(\underline{X})[Y - C(\underline{X})] - 6.591[Y - C(\underline{X})]^3$$
$$A(\underline{X}) = -0.11 + 0.673X_1 - 0.105X_2$$
$$B(\underline{X}) = 7.113 - 0.753X_1 - 3.006X_2$$
$$C(\underline{X}) = 0.097 - 0.014X_1 - 0.018X_2$$

In figure 11 visual perception dramatically changes A→B→C→D from man's face to woman's shape. Thus, when the level of detail figures is ⑮, visual perception is suddenly changed at near Q⑮ (X_1=17) of ambiguous figures. The cusp catastrophe phenomenon occurs as kinds of ambiguous figures and levels of detail figures in human visual perception.

The figure of equal probability is Fisher's figure of K①. But the experiment test result shows that the ambiguous figure to have equal probability exist between J① and K① in this case.

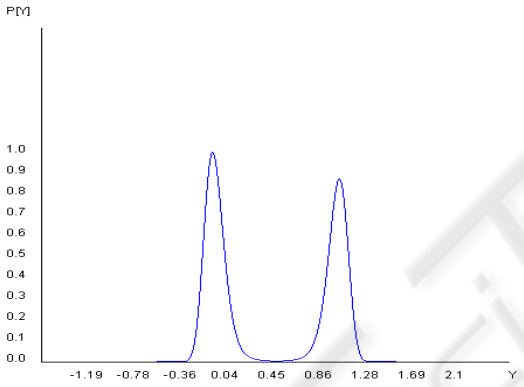

Figure 12: Probability density function of ambiguous figure J in level① of detail figures. Figure 10 and 11 show the probability density function that the variety of ambiguous figures at the level ① of detail figures.

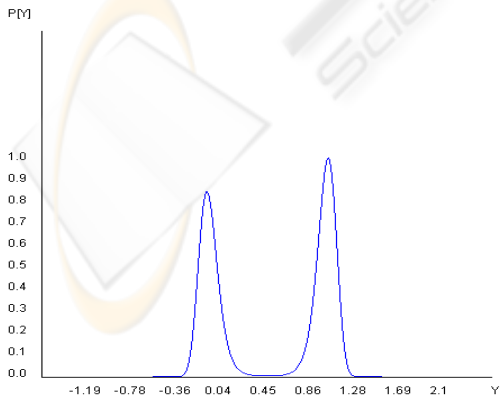

Figure 13: Probability density function of ambiguous figure K in level ① of detail figures.

6 CONCLUSIONS

(1) As the cusp surface analysis can be opened to the public on the web server, the clients input URL he or she can perform the cusp surface analysis.
(2) It is clarified that the data in local PC and database server are loaded and saved by cusp surface analysis program. However, when the client transfers data of 73 rows or more from database server to local PC, the cusp surface analysis system cannot be executed normally. Also, when the data saved into the database server are 365 rows or more, 'S.Read' button cannot be executed.
(3) The data transmission of the cusp surface analysis program is encrypted for security by SSL and communicates with web server.
(4) As the results of the experiments, the cusp catastrophe phenomenon occurs as kinds of the ambiguous figures and the levels of detail figures in human visual perception.

REFERENCES

Cobb, L., 1998. An Introduction to Cusp Surface Analysis. http://www.aetheling.com/models/cusp/Intro.htm

Kume, Y., Morita,Y., 2006.Construction of Web Application for Cusp Surface Analysis, J. school Sci. Eng. Kinki Univ.42 , pp.45-51(in Japanese).

Murata, A., Kume, Y. and Hashimoto,F., 1984. Cusp Catastrophe Phenomenon in Visual Organic Functions, Japan Industrial Management Association ,Vol. 35, No.3, pp.150-155(in Japan).

Thom, R., 1975. Structural stability and morphogenesis, New York:Benjamin-Addison Wesley.