

# Construction of the Data Save System of the Cusp Surface Analysis Using Web Application

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**Abstract.** This paper describes cusp surface analysis system constructed to examine the effectiveness of the program on a web server. According to operating on the 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. And the paper also examine characteristic of the human visual perception using 315 kinds of ambiguous figures. 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.

**Keywords:** cusp surface analysis, web server, kinds of ambiguous figures, levels of detail figures, visual perception.

## 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. A cusp surface is a statistical response surface model, based on the cusp model of catastrophe theory [2]. 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 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.

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 [3]. 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 experiment data apply to cusp surface analysis.

## 2 Construction of Cusp Surface Analysis System

Fig.1. above shows interchange information between Web application server and the client. Web browser indicates the web application to client on Fig.1. A system developed cusp surface analysis program is deployed on web server. The cusp surface analysis program is opened and performed by the URL like a web page. When registered URL on web server is appointed, a cusp surface analysis program is corresponding to it and carrying out as HTML in a web browser via a web server.

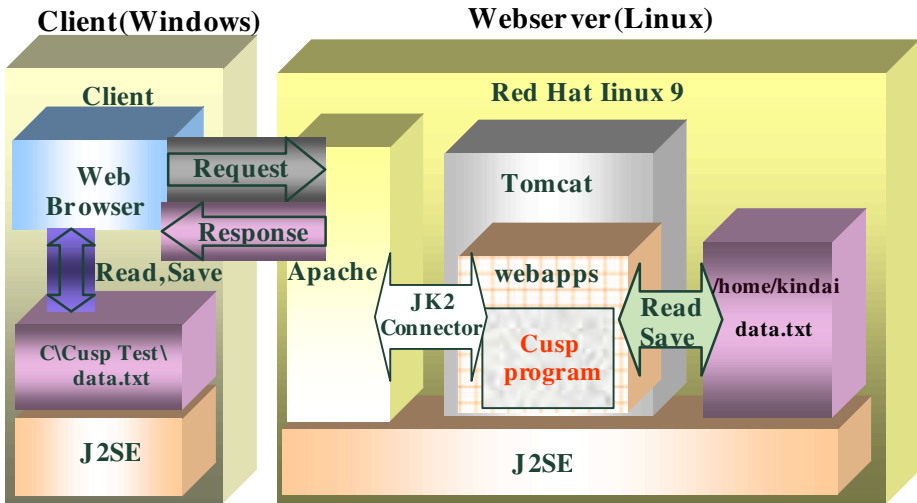


Fig. 1. Structure of client and Web server

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 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 requests “the cusp surface analysis program” as HTTP, and the web server responses 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 web server 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: <http://163.51.55.136/cusp2008/cusp.html>.

### 3 Limitation in Applet

The cusp surface analysis program is built with Java applet, and Java isolate applet in a frame called Send Box in order not for applet to damage in every new performance. Thus, applet has basic limitations as following [4];

1. An applet cannot ordinarily read or write files on the host that is executing it.
2. An applet cannot make network connections except to the host that it came from.
3. An applet cannot start any program on the host that is executing it.
4. An applet cannot read certain system properties.

Cusp surface analysis program has loading and saving function of data. But client can not use the functions.

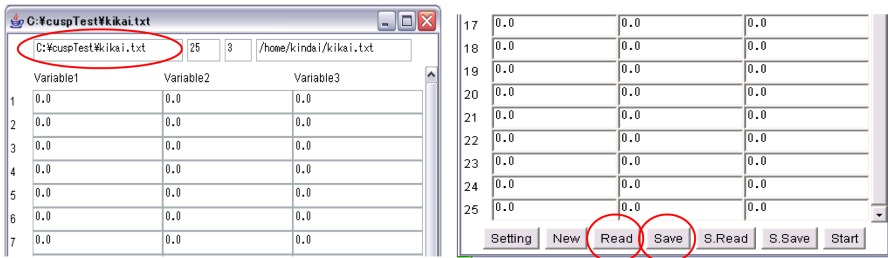


Fig. 2. Reading function of Data

Because reading and writing the file of performing Host is prohibited according to 1) limitation above. However, the Policy File [5] (.java.policy) makes it possible in spite of applet limitation. That is, the set up of Policy file is necessary for opening saved data to program. Clients have to set up the Policy file and then 'Read', 'Save' buttons would be available.

### 4 Experimental of Ambiguous Figures

This experiment is to examines that a characteristic of the human visual perception. The result of 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 perception. 315 kinds of ambiguous figures are composed of 'kinds of ambiguous figures' and 'levels of detail figures'. 315 kinds of ambiguous figures are used to examine the visual perception by 'kinds of ambiguous figures' and 'levels of detail figures'. Figures size used in this experiment is 2.2×4.0cm. In the kinds of ambiguous figures, man's face is A and woman's shape is U. Among 15 levels of detail figure, level① is most detail figure and most indistinct figure is level⑮. This experiment ①, ③, ⑤, ⑦, ⑨, ⑪ level of detail figures are only used. ⑫-⑮ level of detail figures are barely recognized so that ①-⑪ level of detail figures are selected for experiment. In this experiment, A subject of 20's man is shown at random 126 figures and 3 times. Visual perception change points are set as following: subject answers Man's face - (0.0), Yes and no - (0.5), and subject answers woman's shape - (1.0).

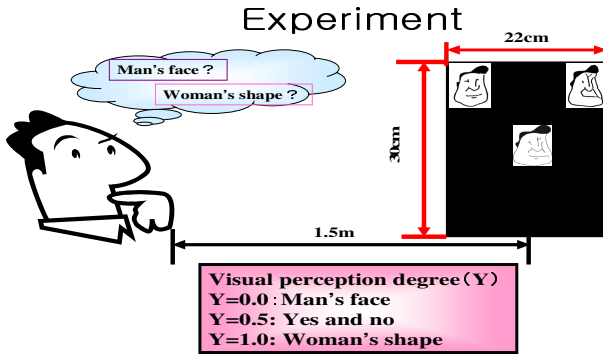


Fig. 3. Experimental method

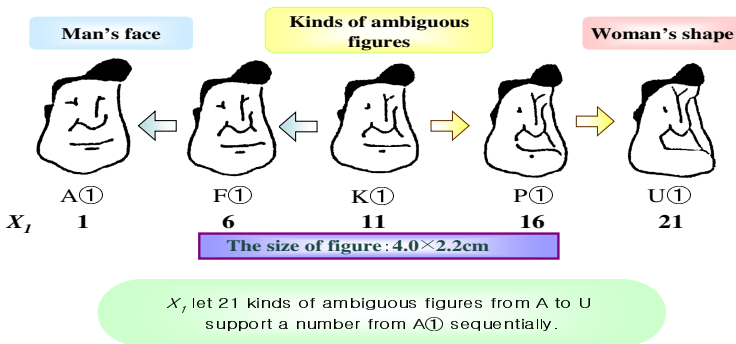


Fig. 4. In the case of level ① of detail figures, 21 kinds of ambiguous figures

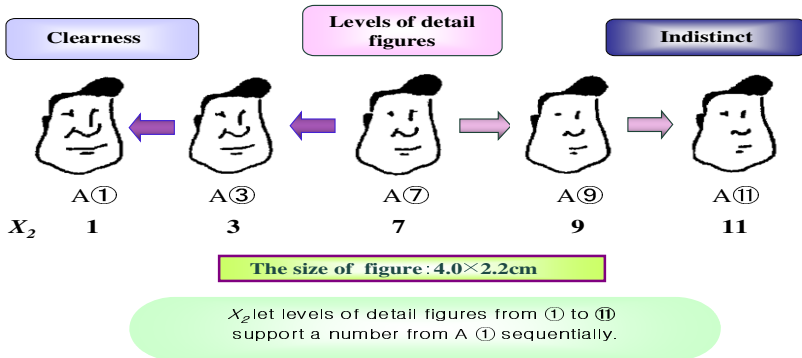


Fig. 5. In the case of the kind A of ambiguous figures, 11 levels of detail figures

Two figures past on the upper side 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.

A subject is shown 1.5 meter far from figure. Since back ground colors may influence subject's judgment, 22x30cm black board is pasted on the back of each figure. This getting data are used for a cusp surface analysis.

**Table 1.**The results of 21 kinds ambiguous figures, 15 levels detail figures, and visual perception (Case1~Case378) Experimental data (126x3=378)

Case	X <sub>1</sub>	X <sub>2</sub>	Y	
1	1	20	9	1
2	2	7	9	0.5
3	3	10	11	1
4	4	21	11	1
5	5	15	3	1
6	6	19	9	0.5
7	7	10	5	1
8	8	10	1	1
9	9	16	3	0.5
10	10	20	11	0.5
11	11	13	3	1
12	12	18	1	1
⋮				
119	119	8	3	0
120	120	16	11	0.5
121	121	6	7	0.5
122	122	7	5	0.5
123	123	3	3	0
124	124	13	5	1
125	125	9	1	0
126	126	1	11	0

Case	X <sub>1</sub>	X <sub>2</sub>	Y	
127	1	12	1	1
128	2	16	11	0.5
129	3	19	1	1
130	4	20	9	0.5
131	5	4	1	0
132	6	20	1	1
133	7	8	11	0.5
134	8	15	7	0.5
135	9	12	3	1
136	10	11	11	0.5
137	11	20	7	0.5
138	12	11	7	0.5
⋮				
245	119	11	3	1
246	120	4	11	0.5
247	121	7	9	0
248	122	18	11	0.5
249	123	9	11	0
250	124	2	3	0
251	125	21	9	0.5
252	126	15	11	0.5

Case	X <sub>1</sub>	X <sub>2</sub>	Y	
253	1	5	5	0
254	2	21	3	1
255	3	5	1	0
256	4	15	3	1
257	5	20	7	0.5
258	6	21	5	1
259	7	7	9	0.5
260	8	15	11	0.5
261	9	10	7	0.5
262	10	21	7	1
263	11	17	1	1
264	12	10	11	0.5
⋮				
371	119	18	5	1
372	120	12	11	0.5
373	121	12	1	1
374	122	21	11	0.5
375	123	9	1	0.5
376	124	16	11	0.5
377	125	9	3	0.5
378	126	17	5	1

X<sub>1</sub>: Kinds of the ambiguous figures, X<sub>2</sub>: Levels of detail figures, Y : Visual perception

### 5 Application of Cusp Surface Analysis System to Experimental Result

Linear regression model's parameter is presumed.

The linear regression model's parameter is as follows:

$$A(\underline{X})=0, B(\underline{X})=B_0, C(\underline{X})=C_1 X_1 + \dots + C_v X_v, D=0 . \tag{1}$$

Linear regression model's parameter is substituted for the expression.

$$0=B_0[Y-(C_1 X_1 + \dots + C_v X_v)] . \tag{2}$$

Linear model's parameter is estimated by using the least square method.

The correlation coefficient ( $\gamma$ ) is obtained from the data of Table1 by the next expression. ( $S_{xy}$  : covariance  $S_x, S_y$  : sum of squares)

$$\gamma = \frac{S_{xy}}{\sqrt{S_x} \cdot \sqrt{S_y}}$$

$$= \frac{\sum_{i=1}^n (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \times \sum_{i=1}^n (y_i - \bar{y})^2}} \tag{3}$$

**Table 2.** Sum, Mean, and Sum of squares of the experimental data

	$X_1$	$X_2$	$Y$
Sum $(\sum x_i)$	4172	2268	181
Mean $(\bar{x} = \frac{\sum x_i}{n})$	11.037	6	0.479
Sum of squares $(S_x = \sum (x_i - \bar{x})^2)$	13803.48	4410	58.331

**Table 3.** Covariance and Correlation coefficient of the experimental data

	$X_1 \cdot X_2$	$X_1 \cdot Y$	$X_2 \cdot Y$
Covariance $(S_{xy} = \sum (x_i - \bar{x}) \cdot (y_i - \bar{y}))$	-14	671.796	-131
Correlation coefficient $(\gamma = \frac{S_{xy}}{\sqrt{S_x} \cdot \sqrt{S_y}})$	-0.00179	0.74868	-0.25829

As a result, the following correlation matrix was obtained.

**Table 4.** Correlation matrix of the experimental data

	$X_1$	$X_2$	$Y$
$X_1$	1.000	-0.00179	0.74868
$X_2$	-0.00179	1.000	-0.25829
$Y$	0.74868	-0.25829	1.000

The inverse matrix of the correlation matrix is as follows.

**Table 5.** Inverse matrix of table 4

2.499	-0.513	-2.003
-0.513	1.177	0.688
-2.003	0.688	2.677

Linear  $r^2$  value is obtained that is squared multiple correlation coefficient  $r$ .

When assume the element of the inverse matrix of multiple correlation coefficient  $r$  to be  $r^{22}$ .

$$r^2 = 1 - \frac{1}{r^{22}} = 0.626 \tag{4}$$

Log likelihood  $L1$  of the linear regression model can be obtained from linear  $r^2$  value.  
 ( $N$  : Number of data)

$$\begin{aligned} L_1 &= -\frac{N}{2} \times (1.0 + \ln(2\pi \times (1 - r^2))) \\ &= -\frac{378}{2} \times (1.0 + \ln(2\pi \times (1 - 0.626))) \\ &= -350.48 \end{aligned} \tag{5}$$

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.

$$\begin{aligned} L_2 &= \ln \prod_{i=1}^N f[Y|X] \\ &= \ln \prod_{i=1}^N \exp \left[ \psi + A(\underline{X}) \times Z + \frac{1}{2} B(\underline{X}) \times Z^2 - \frac{1}{4} D \times Z^4 \right] \\ &= \sum_{i=1}^N \ln \exp \left[ \psi + A(\underline{X}) \times Z + \frac{1}{2} B(\underline{X}) \times Z^2 - \frac{1}{4} D \times Z^4 \right] \\ &= \sum_{i=1}^N \left[ \psi + A(\underline{X}) \times Z + \frac{1}{2} B(\underline{X}) \times Z^2 - \frac{1}{4} D \times Z^4 \right] \end{aligned} \tag{6}$$

The maximum value of log likelihood  $L_2$  can be obtained by the Newton-Raphson method, it becomes  $L_2=-235.983$ . When log likelihood  $L_2$  convergence with Newton-Raphson method, a standard partial regression coefficient is shown in Table 6.

**Table 6.** Standard partial regression coefficient

Var	$A_v$	$B_v$	$C_v$	$D$
Const	0.026	1.941	0.047	3.572
1	1.883	-0.983	0.03	
2	-0.56	-1.728	-0.088	

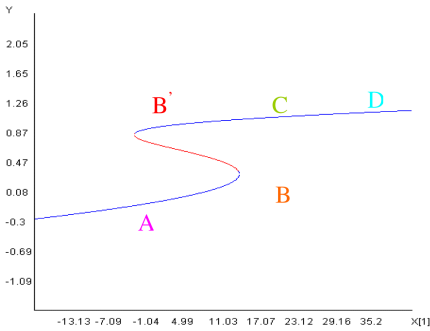
$$0 = A(\underline{X}) + B(\underline{X})[Y - C(\underline{X})] - 3.572[Y - C(\underline{X})]^3 \tag{7}$$

$$\begin{aligned} A(\underline{X}) &= 0.026 + 1.883X_1 - 0.56X_2 \\ B(\underline{X}) &= 1.941 - 0.983X_1 - 1.728X_2 \\ C(\underline{X}) &= 0.047 + 0.03X_1 - 0.088X_2 \end{aligned} \tag{8}$$

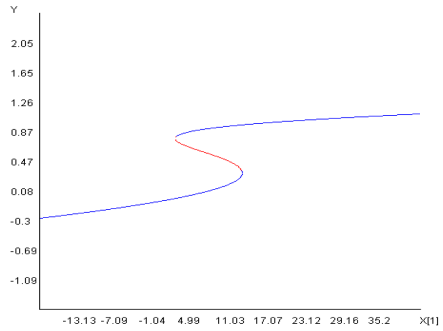
$X_1$ : Kinds of the ambiguous figures,  $X_2$ : Levels of detail figures,  $Y$  : Visual perception.

When the level of detail is ① ( $X_2=1$ ) , human visual perception changes according to kinds of ambiguous figures from Man's face ( $X_1=1$ ) to woman's shape ( $X_1=21$ ). Thus, jump phenomenon is appeared. However, increasing the level of detail makes jump phenomenon decreasing and finally it disappears when level is ⑩ ( $X_2=11$ ) . Especially, on Fig. 6, visual perception dramatically changes

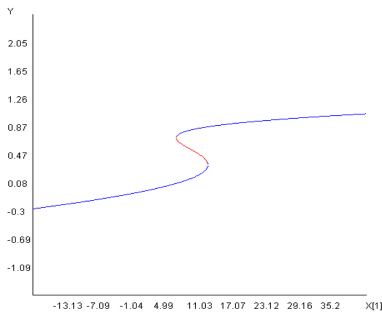
A→B→C→D from man's face to woman's shape. Thus, when the level of detail is ① (X2=1) , we can see visual perception is suddenly changed at near 11 of ambiguous figure. In other words, the human visual perception makes a change near to the figure of Fisher. As levels of detail figures are not clear, the subject recognize that the inside line becomes faint and makes the point. The change of the visual perception regards the point as man's face. And that time as the unclear degree increase, the subject doesn't know the figure which outside shape is changed. The cusp catastrophe phenomenon occurs as kinds of ambiguous figures and levels of detail figures in human visual perception.



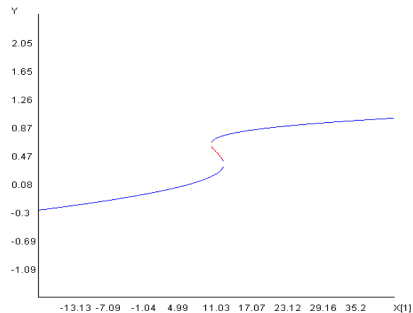
**Fig. 6.** Visual perception by kinds of ambiguous figures in the case of level① of detail figures



**Fig. 7.** Visual perception by kinds of ambiguous figures in the case of level③ of detail figures



**Fig. 8.** Visual perception by kinds of ambiguous figures in the case of level⑤ of detail figures

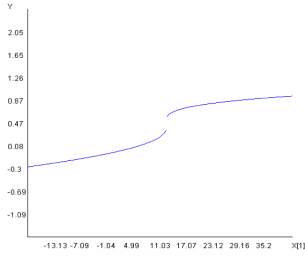


**Fig. 9.** Visual perception by kinds of ambiguous figures in the case of level⑦ of detail figures

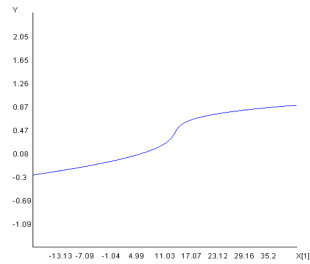
Fig. 12. shows that the visual perception expresses the 3D graph according to kinds of ambiguous figures and levels of detail figures.



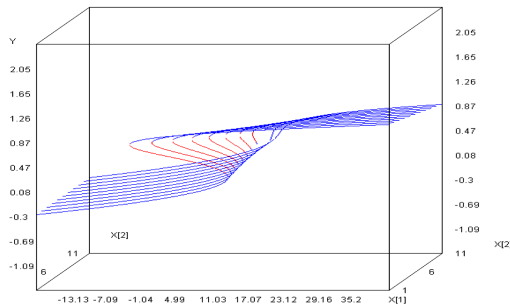
Fig. 13, 14 show the probability density function that the variety of ambiguous figures at the levels of detail is ① ( $X_2=1$ ). The figure of equal probability is Fisher's figure of K. But the experiment test result shows that the ambiguous figure to have equal probability exist between H and I in this case. Fig. 15 shows the probability density function 3D graph according to the kinds of ambiguous figures and the visual perception.



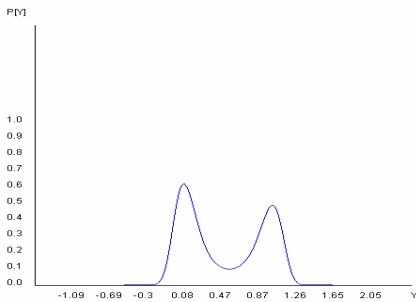
**Fig. 10.** Visual perception by kinds of ambiguous figures in the case of level ⑩ of detail figures



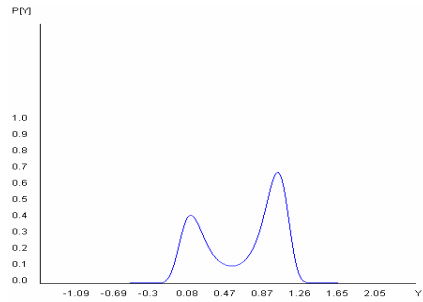
**Fig. 11.** Visual perception by kinds of ambiguous figures in the case of level ⑪ of detail figures



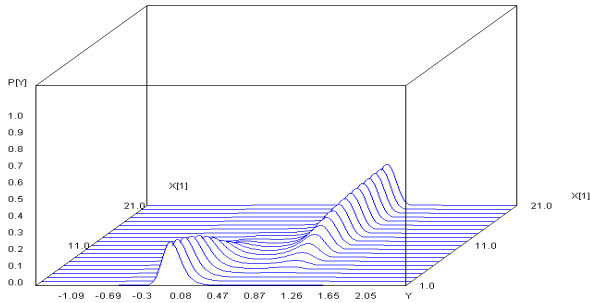
**Fig. 12.** Effect of Kinds and Detail in Ambiguous Figures to Visual Perception



**Fig. 13.** Probability density function of ambiguous figure H in level ① of detail figures



**Fig. 14.** Probability density function of ambiguous figure I in level ① of detail figures



**Fig. 15.** 3D Probability Density Function

## 6 Conclusions

The results can be summarized in this case as follows.

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 possible that the cusp surface analysis data's loading and saving in local directory and web server directory.
3. 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.

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