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# *The Study on the Evaluation of the Visual Work Using the Logistic Curve*

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## SYNOPSIS

Display equipment has been used as communication media in the factory, office, and home. In order to communicate effectively, it is necessary to clarify the characteristics of eye movement in the case of looking at the display. The development of Eye Camera enables us to measure eye movement during work, so that we can collect the many data of eye movement during work.

In this study, we proposed a method to evaluate the visual work using the distribution of visual points in X and Y axis. The cumulative distribution is approximated by the logistic curve which shows the symmetry and kurtosis by the parameter. The proposed method was applied to the three typical display models, that is, the digital meter model, reading model, and game model.

In the digital meter model, the visual points were distributed symmetrically along the meters, and the symmetry and kurtosis of the distribution varied by the arranged direction of the meter.

In the reading model, the visual points were distributed nearly symmetrically and uniformly in each axis and they were moved around the character and line from the period of spectrum analysis.

In the game model, the visual points moved according to the target and were distributed symmetrically in the Y axis. And whether the target moved vertically or horizontally, the kurtosis of the distribution became equal in each axis.


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## 1. INTRODUCTION

In the factory, office and home, the visual media, that is, TV, CRT, LED screen, and so on, enable to communicate various types of informations (1). For the progress of such media concerning to the communication, it is important to know the way of looking at the display from eye movement. Recently, owing to the development of Eye Camera, we can measure eye movement directly during the work. Heiden V.D.(2) studied eye movements during the design work using the CAD workstation. Yurbus.A.L.(3) investigated eye movement in the case of looking at pictures.
The distribution of visual points is closely related to the visual work, but there is no method to evaluate the visual work using the distribution of visual points.

In this study, we propose a method to evaluate visual work by using the parameters of the logistic curve which approximates the cumulative distribution of the visual points in X and Y axis. In order to evaluate the effectiveness of the proposed method, it is applied to three display models which are used in the factory, office and home.

## 2. EXPERIMENTAL EQUIPMENT

The experimental equipment is composed of the Eye Camera, VTR, Data-Output-Unit, and micro computer. The eye movement is measured by the Eye Camera and recorded on VTR at the intervals of 33ms. The eye movement recorded on VTR is transformed into the coordinates$(X_i, Y_i)$ of the visual points and transfered to the micro computer by the Data-Output-Unit.

## 3. ANALYTICAL METHOD

The characteristics of the visual work are made clear from the distribution of the visual points in the X and Y axis.

### 3.1 The class interval of the histogram

First, the data$(X_j, Y_j)$,(j=1,2,,N) are shown in the histogram in each axis. The class interval is determined to 0.2cm which is the accuracy of the equipment.

$P_i = f_i/N$ $(i=1,2,\cdots,k)$ is put as the relative frequency of X axis or Y axis in the class i, where $\sum_{i=1}^{k} f_i = N$.

Secondly, the period of $P_i$ is calculated from the spectrum analysis. And the class interval of histogram is determined from the period.
If the relative frequency does not show the period, the class interval of the histogram is set at 0.2cm.

### 3.3 The logistic curve

As the cumulative distribution of the visual points reveals S shape in each model, the logistic curve approximates to the cumulative distribution. The logistic curve is expressed as follows.

$$f(X)=\frac{K}{1+b\cdot\exp(-a\cdot X)}-C \qquad (1)$$

$$F(X)=\frac{f(X)+C}{K}=\frac{1}{1+b\cdot\exp(-a\cdot X)} \qquad (2)$$

Where, it is assumed that X is the median of the class of histogram in each axis, and F(X) is the approximated cumulative relative frequency. The parameters(a,b) in the equation(2) are varied by the difference of the mean value and the standard deviation in the X axis. Then each parameter is normalized as follows.

$$F'(z)=\frac{f'(z)+C}{K}=\frac{1}{1+b'\cdot\exp(-a'\cdot z)} \qquad (3)$$

Where, $z=(X-\bar{X})/s,$ (4)

$a'=a\cdot s,$ (5)

$b'=b\cdot\exp(-a\cdot\bar{X}),$ (6)

$\bar{X}=\sum_{i=1}^{k}X_i/N,$ (7)

$s^2=\sum_{i=1}^{k}(X_i-\bar{X})^2/(N-1)$ (8)

Here, the symmetry of the normarized distribution is defined by the probability which the visual points exists in the area of $z<0$. Then the symmetry is expressed by $F'(0)=1/(1+b')$ containing the parameter(b').
If the distribution is symmetric, the value of F'(0) becomes 0.5. And the inclination of the cummulative distribution which is determined by the parameter(a') expresses the kurtosis of the distribution. Further the parameter C shows the shape in the region of $z<0$ and K shows that of $z>0$. As the value of K and C become large, the distribution is approximated by the straight part of the logistic curve, and the distribution resembles to the uniform distribution. The parameters (a',b') are estimated by the least square method under the conditions that parameters (C and K) are given. The value C is given from 0 to 0.3 at every 0.02, and K is given from 1 to 1.8 at every 0.04. And the logistic curve which has the highest correlation

coefficient is selected among all combinations of C and K. Further the parameters (a',b',K,C) are calculated for the normal distribution and uniform distribution to compare the distribution of each model.

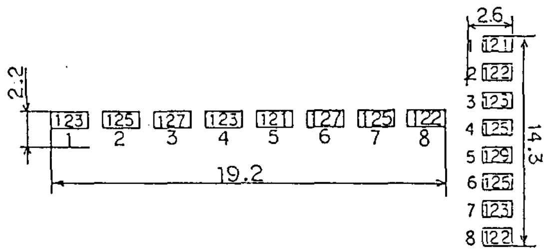
## 4. THE EXPERIMENTAL CONDITION

The following models are selected as the display model, which is used in the factory, office, and home. The characteristics of each model are shown in Table.1, and the example of the digital meter model and reading model are shown in Fig.1.

(i) The digital meter model

This model is the digital meter which is used in the factory as the monitor of the system. The 8 digital meters are arranged along the horizontal line (model SA) or vertical line(model SB) on the CRT. Each meter is composed of 3 digital figures. The value of each meter increases from 100 one by one at the same time, and stops randomly after 10～15sec. The subject searches the meter which shows the maximum value among them.

As the subject has a tendency to watch the changing value of meter, the visual point moves basically along the line of displayed meters in each model.




(a) SA (b) SB

(i) The digital meter model (cm)

夜。この部屋の中には、闇が静かにこもっていた。新しい、真っ黒な、ビロードを張りめぐらしたような闇が。大きなガラス窓の前には、カーテンがかけられていなかったが、闇は戸外まで同じようにつづいていた。空には厚い雲が広がっているのだろう。今夜は月影はもちろん、星のまたたきさえなかった。この家は都会から遠くはなれた林の中なので、ネオンの輝きも、ヘッドライトのきらめきも、この部屋までは訪れてこなかった。物音といえば、林の木の葉がかすかに風にそよぐ音。それに、部屋の中で、時どき思い出したようにおこる深いため息。
「あなた。テレビでもつけましょうか。少しは気をまぎらわせなくてはいけないわ」闇の静けさのなかで、それにたえられないような、いらだった女の声がした。「いや、いいんだ。俺はこの暗い中で、ぼんやりしているほうが好きなんだ。だが、おまえが見たいのなら、つけて

(ii) The reading model (cm)

Fig.1 Example of the model

Table.1 The charactristics of each model

| | | Display figure | | | | | |
|---|---|---|---|---|---|---|---|
| Model | | Shape | Width(cm) | Arranged Direction | Moved Direction | Visual Distance | Number of Subjects |
| Digital meter | SA | Digital figure | 2.2×19.2 | Horizontal | | 50cm | 5 |
| | SB | 〃 | 14.3× 2.6 | Vertical | | 50cm | 5 |
| Reading | R | Character | 11.0×14.8 | Horizontal | | 40cm | 3 |
| Game | GA | Mark | 21.0×28.0 | | Horizontal | 60cm | 5 |
| | GB | 〃 | 〃 | | Vertical | 60cm | 5 |

(ii) The reading model

This model(R) is for reading work which is the fundamental work in the office. The Japanese text is shown on CRT. The text has 15 lines in 1 page laterally, and each line is composed of 25 characters. The subject reads the text along the line.

(iii) The game model

This model is the TV game which is widely played in homes. The targets move randomly from horizontal direction (model GA) or vertical one (model GB) . The subject operates the mark to shoot the target by the operation board.

## 5. EXPERIMENTAL METHOD

First the subject puts on the Eye Camera and his head is secured in a stationary position.

The visual model is displayed on CRT and eye movement is recorded on VTR during the work. The coodinates($X_i$,$Y_i$) of the visual point on CRT is obtained from Data-Output-Unit. The visual model is displayed about 60sec in the GA, GB and R model, and 15～20sec in the SA and SB model. As the visual point is measured at the interval of 33ms, the number of data is about 1800 in the GA,GB and R model, and 450～600 in the SA and SB model. There were 5 subjects(male) in each model. They are 22-27 years old and their uncorrected vision is 0.5-1.5.

## 6 RESULTS

The example of histogram of each model were shown in Fig.2.

### 6.1 The spectrum of the distribution of the visual points

As the meter was arranged horizontally in the digital meter model(SA), the visual points did not show a period in each axis. As the meter was arranged vertically(SB), the distribution showed a period of 0.5±0.1cm in the Y axis and none period in the X axis.

In the reading model, the distribution in the X axis showed the period of 0.5cm±0.1cm which was nearly equal to the space between the characters (0.5cm). In the Y axis, the period of the distribution was 0.5cm±0.1cm, which was nearly equal to the space between the lines(0.7cm). It became clear that the visual point distributed periodically around the characters

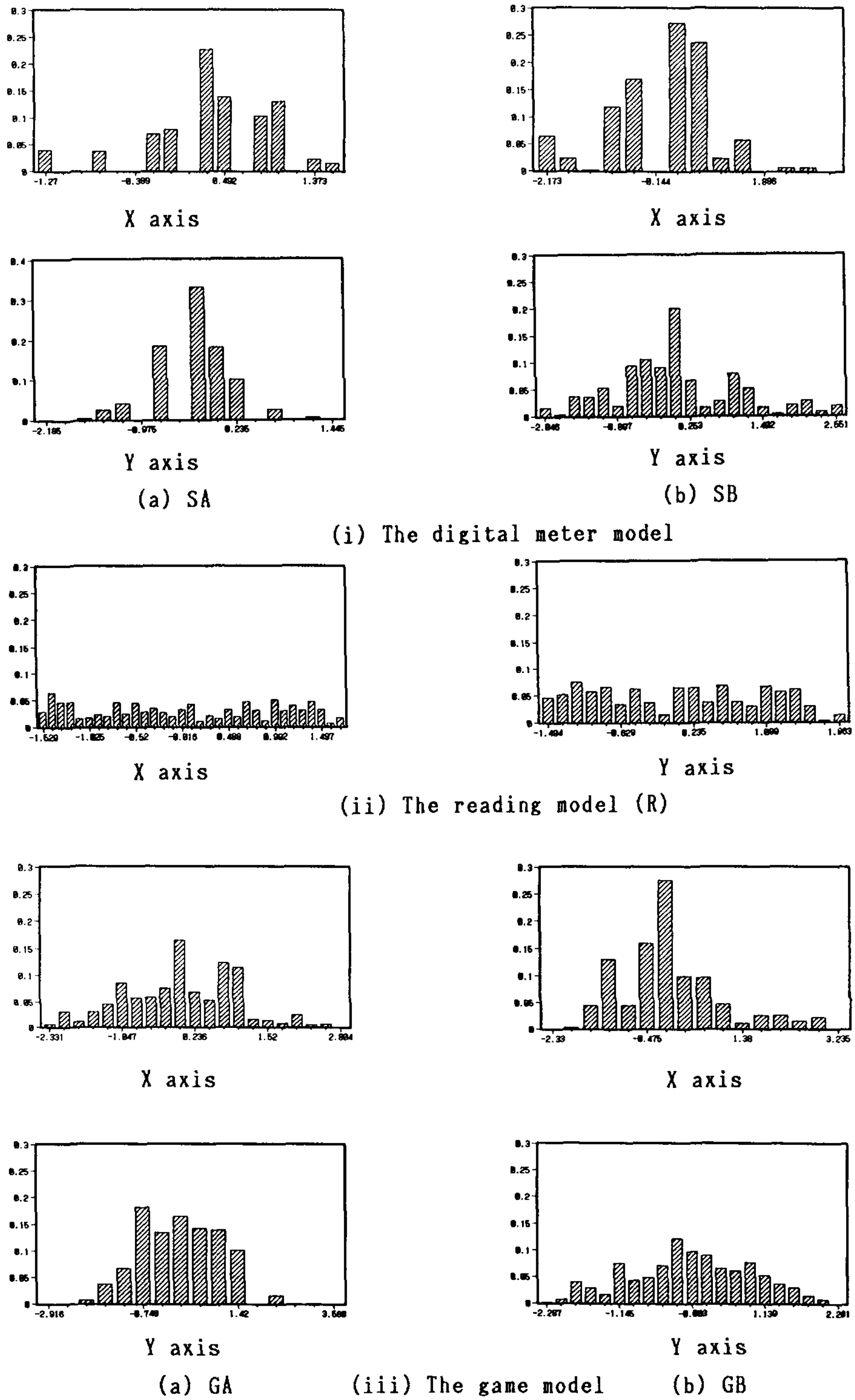



Fig.2. Example of the histogram

and the line, as the subject read laterally the Japanese text.

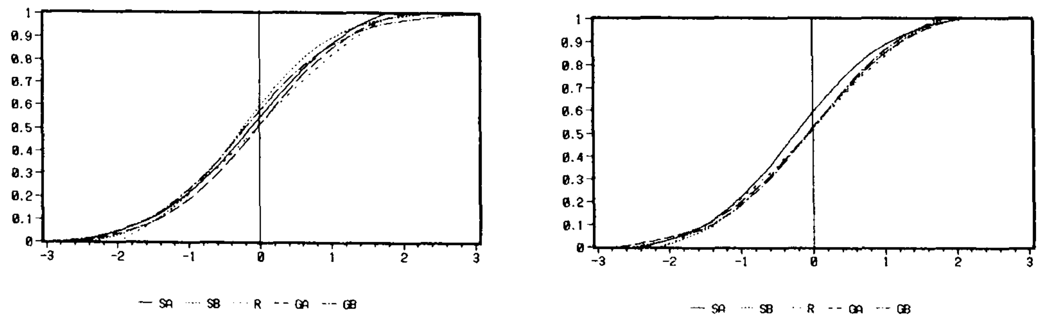
As the target moved horizontally in the game model(GA), the distribution in the X axis showed a period of 0.7cm±0.1cm. In the Y axis, there were differences among the subjects. As the target moved vertically in the game model(GB), the distribution showed a period of 0.8cm±0.1cm in the X axis and 0.6cm±0.2cm in the Y axis. From these results, it was shown that the period of distribution was 0.7±0.1cm in the X axis whether the target moved horizontally or vertically. And as the target moved vertically, the period was 0.6cm in the Y axis.

### 6.2 The logistic curve

It was shown that the cumulative distribution of each model was able to be approximated by the logistic curve because of the high correlation coefficient(0.96～0.98). The logistic curve of each model was shown in Fig.3.

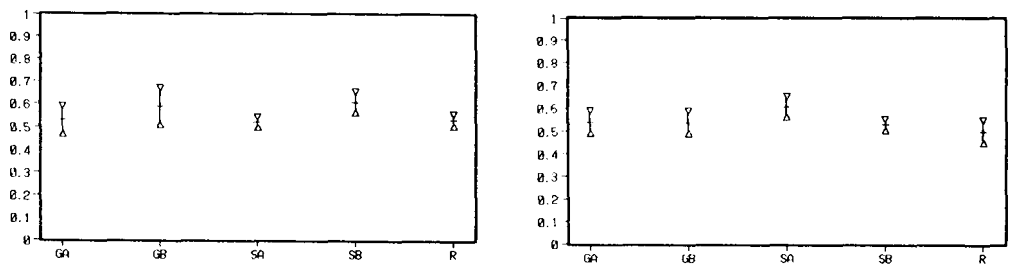
#### 6.2.1 The symmetry of the distribution

The value of f(0) for the symmetry was shown in Fig.4 in each model.




(i) X axis (ii) Y axis

Fig.3. The logistic curve




(i) X axis (ii) Y axis

Fig.4. The symmetry(Average±Standarddeviation)

In the digital meter model, the value of f(0) was 0.52±0.02 in SA and 0.61±0.05 in SB in the X axis, and 0.61±0.04 in SA and 0.51±0.02 in SB in the Y axis. The parameter(b') was 0.93±0.39 in SA and 0.65±0.17 in SB in the X axis, and 0.68±0.24 in SA and 0.98±0.22 in SB in the Y axis. A significant difference was shown between SA and SB in each axis. From these results, the distribution was not symmetric in the axis along which the meters were arranged.

In the reading model, the visual points distributed nearly symmetrically in each axis, as the value of f(0) was 0.53±0.03 in the X axis and 0.50±0.05 in the Y axis, and b was 0.89±0.10 in the X axis and 1.03±0.21 in the Y axis.

In the game model, the value f(0) was 0.53±0.06 in GA and 0.59±0.08 in GB in the X axis, and 0.54±0.05 in GA and 0.54±0.05 in GB in the Y axis. The parameter(b') was 0.65±0.17 in GA and 0.89±0.10 in GB in the X axis, and 0.95±0.44 in GA and 0.99±0.35 in GB in the Y axis. The distribution was not symmetric, as the target moved vertically in the X axis. The distribution was nearly symmetric whether the target moved horizontally or vertically in the Y axis, as the significant difference between GA and GB was not shown by one way ANOVA.

6.2.2 The kurtosis

The parameter (a') for the kurtosis was shown in Fig.5 in each model, the standard normal distribution, and uniform distribution.

The parameter(a') was 2.25 in the normal distribution and 0.77 in the uniform distribution.

In the digital meter model, the parameter (a') was 1.32±0.11 in SA and 1.68±0.11 in SB in the X axis, and 1.50±0.09 in SA and 1.32±0.15 in SB in the Y axis. A significant difference was shown between SA and SB in

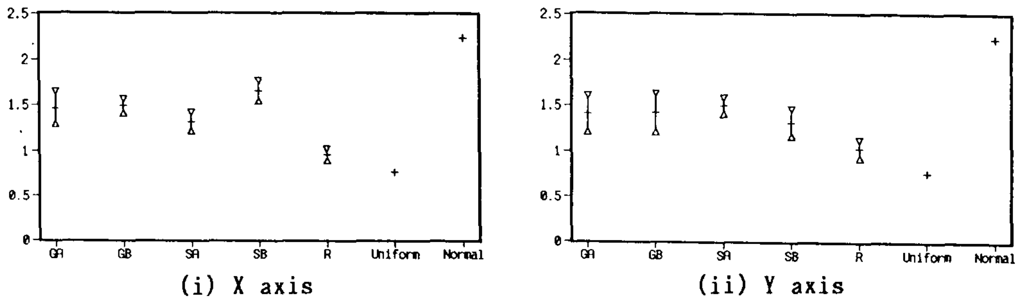



Fig.5. The kurtosis(Average±Standarddeviation)

each axis by one way ANOVA. Therefore, as the subject looked at the information horizontally(SA) or vertically(SB), the distribution resembled to the normal distribution

In the reading model, the parameter (a') was 0.97±0.03 in the X axis and 1.08±0.11 in Y axis. The visual points were distributed uniformly in each axis, as the parameter (a') was nearly equal to 1.

In the game model, the parameter (a') became equal, that is, 1.47±0.18 in GA and 1.49±0.08 in GB in the X axis, and 1.41±0.20 in GA and 1.42±0.21 in GB in the Y axis. There was no significant difference between GA and GB model by one way ANOVA. Therefore, it was made clear that the kurtosis of the distribution became equal in each axis whether the target moved horizontally or vertically.

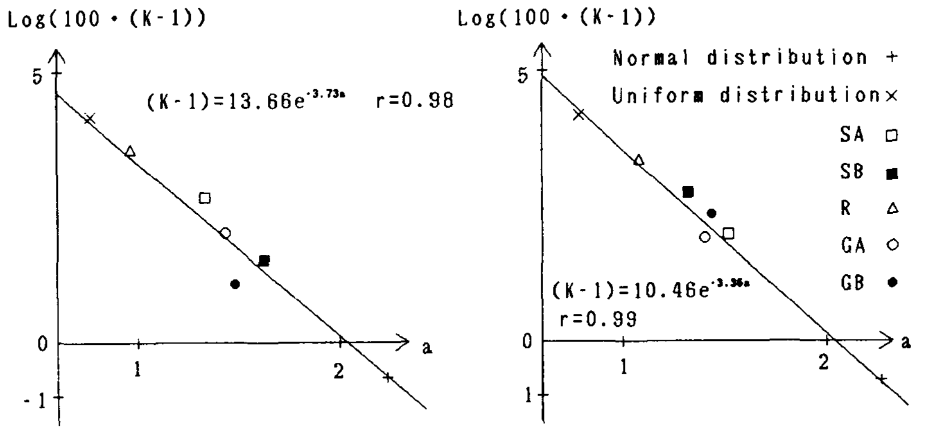
### 6.2.3 The relationship between the parameter (a') and K

Fig.6 showed the relationship between the parameter (a') and K. The parameter K was transformed into logarithm in each model, the normal distribution, and uniform distribution.

In the standard normal distribution, K=1.0 and (a')=2.25, and K=1.64 and (a')=0.77 in the uniform distribution.

In the digital meter model and game model, the parameter (a') lay middle of the normal distribution and uniform distribution in each axis.

In the reading model, as the visual points distributed uniformly in each axis, the parameter (a') became nearly equal to the uniform distribution.




(i) X axis (ii) Y axis

Fig.6. The relationship between the parameter (a') and K

There was a logarithmical linear relationship between the value of (a') and K in each axis. They were approximated by the following equation.

$(K-1)=13.66 \cdot e^{-3.73a}$ r=0.980 (9)

$(K-1)=10.46 \cdot e^{-3.35a}$ r=0.993 (10)

6.2.4 The value of K

The value of K in each model was shown in Table.2.

The value of K was 1.0 in the normal distribution, and 1.64 in the uniform distribution.

In the digital meter model, K was 1.13±0.08 in SA and 1.05±0.04 in SB in the X axis, and 1.07±0.03 in SA and 1.16±0.09 in SB in the Y axis. The edge shape of the distribution in the region that z>0 resembled to the normal distribution in the axis along which the meters were arranged, because of the value of K became nearly equal to 1.0.

In the reading model, K was 1.35±0.03 in the X axis and 1.29±0.08 in the Y axis. And K became largest among five models in each axis. Then, the edge shape of the distribution resembled to uniform distribution.

In the game model, K was 1.08±0.08 in GA and 1.03±0.02 in GB in the X axis, and 1.07±0.09 in GA and 1.10±0.10 in GB in the Y axis. K was nearly equal to 1.0 whether the target moved horizontally or vertically, and K was nearly equal to those in GA and GB in each axis by one way ANOVA. Then it was made clear that the edge shape of the distribution in the region that z>0 resembled to the normal distribution.

6.2.5 The value of C

The value of C in each model was shown in Table.2.

C was 0 in the normal distribution, and 0.3 in the uniform distribution.

In the digital meter model, the value of C was 0.03±0.04 in both models in the X axis, and 0.04±0.03 in SA and 0.07±0.04 in SB in the Y axis. Whether the meters were arranged horizontally or vertically, C was and

Table.2 The value of K and C (Average±Standard Deviation)

| | | X axis | | Y axis | |
|---|---|---|---|---|---|
| Model | | K | C | K | C |
| Normal distribution | | 1.00 | 0 | 1.00 | 0 |
| Uniform distribution | | 1.64 | 0.3 | 1.64 | 0.3 |
| Digital meter model | SA | 1.13±0.08 | 0.03±0.04 | 1.07±0.03 | 0.04±0.03 |
| | SB | 1.05±0.04 | 0.03±0.04 | 1.16±0.09 | 0.07±0.04 |
| Reading model | R | 1.35±0.03 | 0.19±0.03 | 1.29±0.08 | 0.12±0.06 |
| Game model | GA | 1.08±0.08 | 0.03±0.04 | 1.08±0.09 | 0.02±0.02 |
| | GB | 1.03±0.02 | 0.02±0.02 | 1.11±0.10 | 0.02±0.01 |

nearly equal to 0 in each axis. Then it was made clear that the edge shape of the distribution in the region that $z<0$ was nearly equal to the normal distribution.

In the reading model, the value of C was $0.19\pm0.03$ in the X axis and $0.12\pm0.06$ in the Y axis. As the value of C was the largest among five models in each axis, the edge shape of the distribution in the region that $z<0$ resembled to the uniform distribution in the five models.

In the game model, C was $0.03\pm0.04$ in GA and $0.02\pm0.02$ in GB in the X axis,and $0.02\pm0.02$ in GA and $0.03\pm0.04$ in GB in the Y axis.
Whether the target moved horizontally or vertically, the value of C became equal in GA and GB in each axis by one way ANOVA. And the edge shape of the distribution in the region that $z<0$ was nearly equal to the normal distribution.

6.2.6 The relation between K and C

The relation between K and C was shown Fig.7 in each model and two typical distributions.

There was the linear relationship between K and C in each axis, and it was approximated by the following equation.

In X axis : $K=2.09\cdot C+0.99$ $r=0.995$ (11)

In Y axis : $K=2.09\cdot C+1.02$ $r=0.995$ (12)

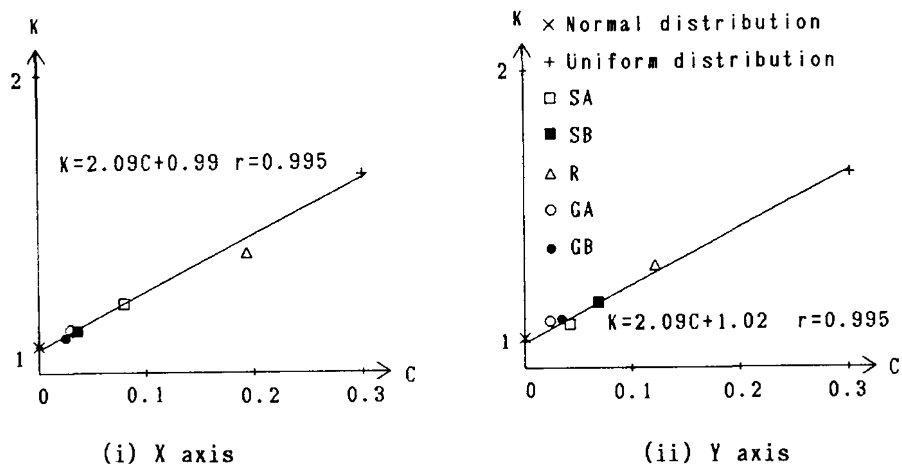



Fig.7. The relationship between K and C

## 7. CONCLUSIONS

In this study, we proposed a method to evaluate the visual work by using the logistic curve which was approximated to the cumulative distribution of visual points. Three typical displays prevailing in the factory, office, and home were analyzed by the proposed logistic curve.
(1) As the subject looked at the digital meter arranged horizontally or vertically, the visual points distributed symmetrically along the meter. And the kurtosis of the distribution became large in the perpendicular axis to the axis which was arranged the meter.
(2) As the subject read the Japanese text written laterally, the distribution became uniformly in each axis. And the visual points were distributed around the character and line by spectrum analysis.
(3) Whether the target moved horizontally or vertically in the TV game, the visual points were distributed symmetrically in the Y axis, and the kurtosis of the distribution became equal in each axis.

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