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A Study on Measurement of Characteristics of Handwriting Letters with the Mouse Device for Male and Female Dexterous Students

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Abstract: It may be the figure of the human handwriting as one of the most interesting outputs. By research on the figure of handwriting, characteristics or behaviors of the human are analyzed and cleared. The purpose of this paper is to report results on the comparison of data (the characteristics data by this measurement method) and the evaluation given by pattern differences of handwriting capital letters: B and D; U and V having constructive similarities. By using the divergence as one of statistics method, figures drawn by the dominant or non-dominant hand of examinees who are selected 40 persons of male and female dexterous students in total. Experiment for data collection is done based on the procedure of the author, and it is done by book-size personal computer display and the mouse device and by the recognition function of the computer.

The following results are obtained:

1) average vector on pattern elements of t= (t_1, t_2, …, t_7 or t_8)
2) variance and covariance matrix on pattern elements of t= (t_1, t_2, …, t_7 or t_8)
3) value of divergence: $D_{BD}(t)$, $D_{UV}(t)$ etc.

And, the conclusion of this paper on figures of handwring for male and female dexterous students analyzed by the statistics methods given in chapter 4 are shown.

1. INTRODUCTION

It is said that there is a typeface result on the characters of autograph as one of the interesting human action outputs. From a past, characteristics (features, quickness of the action and sportiveness etc.) of the said person are understood from the character typeface of handwriting. It is said that there are legal effectiveness of the human's demonstration and sign with the evidence in the character by the dominant hand of the said person, but there are no legal effectiveness in the handwritten character by the non-dominant hand. The change of the handwritten character is called even in our university of the authors recently, and matters such as cartoon character and fashionable character are called for female students. Nowadays, analytical research on handwritten characters is carried out in versatile.

In this paper, for the purpose of the measurement and analysis of the handwriting character pattern in capita l letters with the constructive similarity, 20 persons such as male and female dexterous student for each are selected by the author. Experiment is carried out using book-size personal computer and the mouse device with commonality and objectivity. And, the experimental method proposed by the author is used which has the function of the personal computer and which judges the recognition of the character described on the display of the computer. Then, results which examined by the divergence (the distance) on measurement of the pattern of the handwriting capital letters with the constructive similarity in 40 persons of student in total and their evaluation are reported.

Still, this paper is constructed by the method of approach and contents of both Munakata et.al.(2000) and Munakata (2002).

2. METHOD

2.1 Sample (Examinee)

It is selected 20 persons of dexterous male student in the university of the author and 20 persons of dexterous female as an examinee. And, there are male who belong to baseball, golf, basketball and soccer etc. sports club. A half of them is the member of those club. There are female who belong to tennis, basketball, land and swimming club. Though they may not belong to the sports club, some of female examinees do snow boards, beach volleyball, badminton etc. as the hobby. So, 18 of 20 persons have sports experience at present. However, both male and female examinees do not join the club of computer, and they have no special experience in operations of the computer and the mouse device. So, it is thought that all 40 examinees are equivalent in the level of computer operations..

2.2 Theory of the analysis and measurement item

Divergence of two different probability density functions, i.e. the distance of them had been defined by Kullback (1959). It can be possible that this divergence is used as a scale of the quality of measurement result on two patterns. Marill and Green (1963) applied divergence as one evaluation method of the pattern analysis of the handwriting alphabet capital letters. Sakai and Nishio(1967), Shimura (1977) and Nakata(1983) were studied about pattern analysis of the objects by the methods of divergence etc..

In this paper, it is presupposed by the authors that the observed value of symbol S_i of handwriting capital letter regards it as n dimensional probability density function: $P_i(x) = P_i(x_1, x_2, ..., x_n)$ and symbol S_j

of handwriting capital letter regards it as n dimensional probability density function: $P_j(x) = P_j(x_1, x_2, ..., x_n)$ with similarity in Munakata (1989). Then, divergence $D_{ij}(x)$ between two probability density functions $P_i(x), P_j(x)$ was defined,

$$D_{ij}(x) = \int_{-\infty}^{\infty} P_i(x) \log L(x) dx - \int_{-\infty}^{\infty} P_j(x) \log L(x) dx \quad \cdots (1)$$

Here, $L(x) = P_i(x) / P_j(x)$.

It is thought that $D_{ij}(x)$ of (1) is the distance quantity physically, so if it is large numerically, the difference between symbols S_i and S_j becomes large, and it is easy to distinguish pattern difference of them easily.

In the case that the distributions are normal, i.e. $Pi(x)$ and $Pj(x)$ are normal type and both average and variance are different (this is in usual case), that is,

$$P_i(x) = \frac{1}{\sqrt{2\pi |V_i|}} \exp\left\{ -\frac{1}{2} (x - u_i)^T V_i^{-1} (x - u_i) \right\} \quad \cdots (2)$$

$$P_j(x) = \frac{1}{\sqrt{2\pi |V_j|}} \exp\left\{ -\frac{1}{2} (x - u_j)^T V_j^{-1} (x - u_j) \right\} \quad \cdots (3)$$

divergence $D_{ij}(x)$:

$$D_{ij}(x) = \frac{1}{2} tr\left[(V_i - V_j)(V_j^{-1} - V_i^{-1}) \right] + \frac{1}{2} tr\left[(V_i^{-1} + V_j^{-1})(u_i - u_j)(u_i - u_j)^T \right] \quad \cdots (4)$$

is obtained from (2), (3) and (1).

Here,

$x : n$ dimensional observed value vector

$u : n$ dimensional mean value vector

$V : n$ dimensional variance, covariance matrix.

And,

V^{-1}: inverse matrix of V

x^T: transpose of vector x

$|V|$: determinant of matrix V

trA: sum of diagonal elements of matrix A.

The above analysis of the author, in short, intends to carry out the pattern evaluation of handwriting character using Kullback divergence $D_{ij}(x)$. It is said that the approach may be just like the computer version of Marill and Green(1963).

The numerical value difference of divergence stands for differences between two patterns of handwriting letters, because the piecewise comparison evaluation of pair is carried out by divergence which the character pattern with the multidimensional elements is estimated by one dimensional numerical value (the scalar value). But, if there is not beforehand sufficient information on difference of pattern in general, it seems to be difficult reversely that analysts can clear pattern differences in them from the numerical value difference of divergence.

2.3 Measurement method and statistical analysis

Using the book size personal computer display and the mouse device, the handwriting character is analyzed by the method and procedure which the author (Munakata(1989)) gave. In this analysis, capital letters in which the pattern has the elemental similarity (that is, the commonness) in $t_1, t_2, t_3, \ldots, t_8$ (at next giving) and in pixel like: letters B and D, and U and V are chosen in this paper.

Then, in filling up frame of one side 6cm and the center point + shown in **Fig.1**, it is made that capital letter is directly described by the examinee so that the handwriting letter may coincide center +. And it is a premise that the handwriting letter can be recognized by the personal computer as the letters of B and D, and U and V. Still, when it can not be recognized, it is eliminated and is redrawn again.

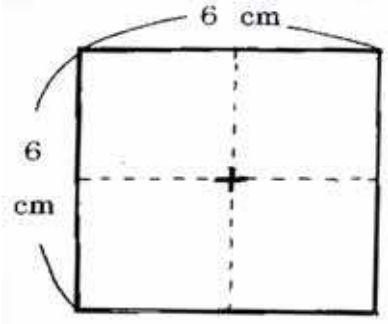

Fig.1 Filling up frame of the handwriting letter

Following the concrete analysis procedures, each examinee is writing letters B and D, and U and V with the mouse device first by the dominant hand, and next, written by the non-dominant hand similarly.

Still, in present examinee of male students, all 20 persons shown in **Photo 1** are the same as the dominant hand is a

Photo 1 Male student

right hand. On the other hand, **Photo 2**, 3 persons in 20 female students are left hands as the dominant ones. So, there are 17 persons whose dominant hand is a right hand.

Photo 2 Female student

By measurement, the distance of the character t_i ,i =1,2,…,8, (the unit is mm) in 8 directions is measured by the scale, as shown in **Fig. 2** and **Fig.3**. Then, t= (t_1,t_2,…,t_8) of letters B and D is thought of fulfilling 8 dimensional normal distribution. And, U and V are thought of fulfilling 7 dimensional normal distribution because of the lack of t_8 element. Based on these, divergence between handwriting capital letters with similarity is separately obtained by the dominant hand and the non-dominant hand.

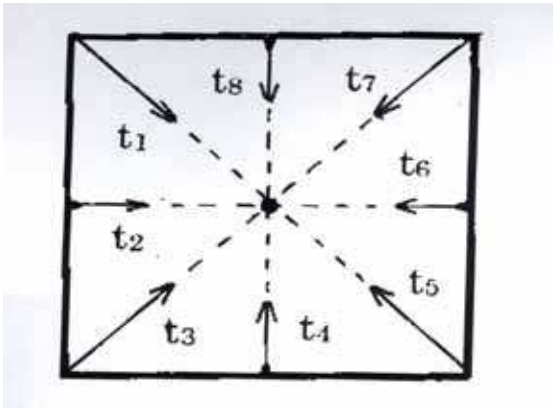

Fig.2, Measuring method of handwriting letter

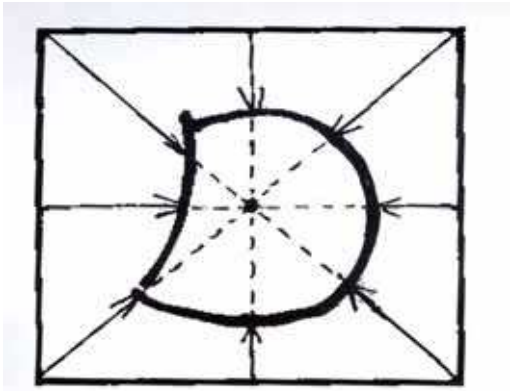

Fig.3 Measuring example of handwriting letter

3. RESULTS

Present experimental results (data and those treatment results and experimental situations) are the following **Table 1, Table 2** and **Table 3** and so on.

(1) Result of mean values
(2) Result of variance, covariance matrices
(3) Result of divergence numerical values.

Here, B, D, U and V by non-dominant are denoted by B', D', U' and V' attached the dash, respectively.

Table 1 Experimental results（Mean value vectors(cm)）
（20 participants of male student）
Dominant hand

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
B	2.19	1.57	1.91	1.33	2.76	2.71	2.82	1.23
D	1.99	1.40	1.99	1.45	2.61	1.69	2.77	1.28

	t_1	t_2	t_3	t_4	t_5	t_6	t_7
U	1.89	1.39	2.19	1.02	2.30	1.52	1.79
V	1.80	1.84	3.04	1.11	3.08	1.69	1.83

Non-dominant hand

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
B	1.97	1.46	2.03	0.92	2.65	2.00	2.54	0.80
D	2.06	1.56	2.04	1.16	2.66	1.62	2.55	1.04

	t_1	t_2	t_3	t_4	t_5	t_6	t_7
U	1.85	1.43	2.40	1.07	2.47	1.36	1.90
V	1.78	1.85	3.11	1.19	3.33	1.99	1.94

（20 participants of female student）
Dominant hand

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
B	2.29	1.65	2.22	1.26	2.70	2.34	2.78	1.33
D	2.27	1.65	2.29	1.37	2.67	1.54	2.77	1.36

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	t_1	t_2	t_3	t_4	t_5	t_6	t_7
U	1.90	1.41	2.47	1.30	2.47	1.63	2.09
V	1.91	1.78	2.89	1.16	3.06	1.89	1.92

Non-dominant hand

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
B	2.36	1.72	2.41	1.05	2.52	2.04	2.78	1.11
D	2.27	1.75	2.47	1.24	2.50	1.48	2.54	1.23

	t_1	t_2	t_3	t_4	t_5	t_6	t_7
U	2.08	1.57	2.48	1.33	2.75	1.82	2.48
V	1.97	1.84	2.91	1.15	3.31	2.27	2.71

Table 2 Experimental results（Variance and covariance matrices）

（20 participants of male student）

B Dominant hand

0.274	0.034	0.107	−0.013	0.324	0.266	0.165	0.096
0.034	0.071	0.079	0.007	0.014	0.016	0.030	0.031
0.107	0.079	0.211	0.008	0.093	0.042	0.077	0.067
−0.013	0.007	0.008	0.247	0.059	0.046	-0.022	-0.003
0.324	0.014	0.093	0.059	0.781	0.337	0.382	0.231
0.266	0.016	0.042	0.046	0.337	0.485	0.181	0.105
0.165	0.030	0.077	- 0.022	0.382	0.181	0.306	0.212
0.096	0.031	0.067	- 0.003	0.231	0.105	0.212	0.201

D Dominant hand

0.343	0.176	0.278	0.101	0.296	0.046	0.251	0.030
0.176	0.144	0.176	0.040	0.136	0.040	0.128	0.047
0.278	0.176	0.301	0.027	0.206	0.029	0.187	0.014
0.101	0.040	0.027	0.257	0.145	0.012	0.044	- 0.001
0.296	0.136	0.206	0.145	0.372	0.100	0.270	0.030
0.046	0.040	0.029	0.012	0.100	0.256	0.080	0.101
0.251	0.128	0.187	0.044	0.270	0.080	0.306	0.064
0.030	0.047	0.014	- 0.001	0.030	0.101	0.064	0.095

U Dominant hand

0.262	0.122	0.152	0.028	0.158	0.066	0.110
0.122	0.090	0.077	0.032	0.058	0.028	0.029
0.152	0.077	0.237	0.017	0.194	0.014	0.064
0.028	0.032	0.017	0.427	0.085	0.315	0.218
0.158	0.058	0.194	0.085	0.268	0.080	0.157
0.066	0.028	0.014	0.315	0.080	0.417	0.292
0.110	0.029	0.064	0.218	0.157	0.292	0.268

V Dominant hand

0.258	0.103	0.080	0.093	0.019	0.050	0.185
0.103	0.108	0.081	0.038	0.044	0.056	0.098
0.080	0.081	0.104	0.047	0.040	0.030	0.012
0.093	0.038	0.047	0.101	0.038	0.034	0.024
0.019	0.044	0.040	0.038	0.079	0.085	0.022
0.050	0.056	0.030	0.034	0.085	0.165	0.063
0.185	0.098	0.012	0.024	0.022	0.063	0.841

B Non-dominant hand

0.359	0.231	0.393	0.165	0.102	0.124	0.198	0.086
0.231	0.273	0.340	0.070	0.062	0.091	0.131	0.086
0.393	0.340	0.625	0.172	0.075	0.171	0.217	0.149
0.165	0.070	0.172	0.209	0.226	0.123	0.216	0.066
0.102	0.062	0.075	0.226	0.526	0.243	0.370	0.029
0.124	0.091	0.171	0.123	0.243	0.243	0.264	0.032
0.198	0.131	0.217	0.216	0.370	0.264	0.458	0.078
0.086	0.086	0.149	0.066	0.029	0.032	0.078	0.114

D Non-dominant hand

0.301	0.180	0.239	0.188	0.152	0.083	0.184	0.097
0.180	0.208	0.167	0.080	0.059	0.017	0.095	0.103
0.239	0.167	0.303	0.142	0.082	0.067	0.114	0.093
0.188	0.080	0.142	0.302	0.281	0.195	0.243	0.096
0.152	0.059	0.082	0.281	0.408	0.308	0.293	0.092
0.083	0.017	0.067	0.195	0.308	0.311	0.181	0.091
0.184	0.095	0.114	0.243	0.293	0.181	0.352	0.116
0.097	0.103	0.093	0.096	0.092	0.091	0.116	0.133

Results of U Non-dominant hand and V Non-dominant hand were omitted.

（20 participants of female student）

D Dominant hand

0.246	0.179	0.257	0.053	0.044	0.035	0.061	0.056
0.179	0.184	0.239	0.023	0.031	−0.006	0.039	0.038
0.257	0.239	0.379	0.067	0.078	0.020	0.094	0.084
0.053	0.023	0.067	0.250	0.204	0.145	0.216	0.180
0.044	0.031	0.078	0.204	0.393	0.299	0.311	0.131
0.035	−0.006	0.020	0.145	0.299	0.301	0.293	0.101
0.061	0.039	0.094	0.216	0.311	0.293	0.379	0.174
0.056	0.038	0.084	0.080	0.131	0.101	0.174	0.187

U Dominant hand

0.381	0.238	0.234	0.179	0.197	0.112	0.201
0.238	0.186	0.169	0.137	0.098	0.043	0.083
0.234	0.169	0.269	0.228	0.152	0.118	0.202
0.179	0.137	0.228	0.319	0.167	0.155	0.242
0.197	0.098	0.152	0.167	0.369	0.202	0.311
0.112	0.043	0.118	0.155	0.202	0.175	0.262
0.201	0.083	0.202	0.242	0.311	0.262	0.469

V Dominant hand

0.519	0.237	0.187	0.314	0.031	0.059	0.275
0.237	0.143	0.112	0.137	0.023	0.019	0.066
0.187	0.112	0.187	0.102	−0.017	−0.006	0.013
0.314	0.137	0.102	0.426	0.182	0.092	0.324
0.031	0.023	−0.017	0.182	0.247	0.119	0.263
0.059	0.019	−0.006	0.092	0.119	0.138	0.288
0.275	0.066	0.013	0.324	0.263	0.288	0.863

U Non-dominant hand

0.498	0.286	0.377	0.329	0.239	0.113	0.068
0.286	0.247	0.305	0.256	0.144	0.070	0.079
0.377	0.305	0.418	0.373	0.197	0.071	0.062
0.329	0.256	0.373	0.475	0.200	0.046	0.033
0.239	0.144	0.197	0.200	0.210	0.142	0.151
0.113	0.070	0.071	0.046	0.142	0.172	0.228
0.068	0.079	0.062	0.033	0.151	0.228	0.393

V Non-dominant hand

0.687	0.368	0.338	0.260	−0.223	−0.197	−0.199
0.368	0.287	0.288	0.145	−0.152	−0.127	−0.128
0.338	0.288	0.343	0.183	−0.155	−0.124	−0.122
0.260	0.145	0.183	0.332	−0.007	−0.011	−0.036
−0.223	−0.152	−0.155	−0.007	0.246	0.198	0.288
−0.197	−0.127	−0.124	−0.011	0.198	0.196	0.347
−0.199	−0.128	−0.122	−0.036	0.288	0.347	0.979

Results of B dominated hand, B Non-dominant hand and D Non-dominant hand were omitted.

Table 3 Experimental result of divergence numerical values

Divergence of Between two English letters	Values of divergence (20 participants of male student)	Values of divergence (20 participants of female student)
$D_{BD}(t)$	26.751	31.538
$D_{B'D'}(t)$	11.036	25.665
$D_{BB'}(t)$	24.687	21.129
$D_{DD'}(t)$	12.984	9.153
$D_{UV}(t)$	67.527	20.170
$D_{U'V'}(t)$	23.276	21.978
$D_{UU'}(t)$	21.390	11.583
$D_{VV'}(t)$	4.453	7.693

As experimental situations, the next facts are observed by an eye watching.

Male students:

For the considerably many examinees, first two letters B and D by dominant go to the top and bottom obliquely. It seems to be the inexperience. However, there are many results of writing at the center point + after the third trial.

In comparison with those by dominant or by non-dominant, there are many results of collapsing shape letter in the character by non-dominant. Also, it is abounding of the erasure rewriting which it is not recognized in the personal computer by non-dominant. But, it is impressive that the description by non-dominant, of examinees belonging to the sports club (baseball and basketball) is almost equal to the good(perfect) writing of letter by dominant.

Female students:

2 persons in examinees do the 3 times rewrite in B first by dominant. However, these examinees also write without the second trial because they are accustomed. It is generally said that the number of redrawing in both by dominant and by non-dominant is considerably less than the prior prediction.

In B and D, it seems to be oblique to bottom or right downward direction a little. In U and V, there are no obliqueness. Many examinees draw the smallish, compact, round character at the center point + because of some the habituation. However, there are many results which collapsed in the character by non-dominant. In examinees of female student here, rewriting of the non-recognition by the personal computer are less than the prior prediction, because the sports experienced examinees are abounding. And, the compact character is writing in many cases.

Still, the cartoon character or the fashionable character can not be seen in this writing.

4. Discussion and Consideration

It is elementally said that there is the characteristic of pattern differences in the letters: t_6 in B and D, and t_2, t_3 and t_5, t_6 in U and V.

(1) Results on the mean value vector

Male students:

Results on characteristic of pattern differences in the character are together coming out both in case of by dominant and non-dominant numerically.

Especially, it seems to be described that the mean values are smallish, namely the character textures are big by non-dominant in B and D, and big mean values, namely the smallish character textures by non-dominant in U and V.

Female students:

The same results as male students are coming out in trend.

Especially, it seems to be coming out the result on big mean values, namely the smallish, compact textures of described character by non-dominant both in B and D and in U and V.

(2) Results on variance and covariance matrices

Male students:

At the first, negative values are in those elements in B and D by dominant. Because it seems to be the reason that the writing characters may incline toward t_4 and t_8 directions (the heave direction) or t_4 and t_7 directions (the right oblique direction).

As for the dispersion values, namely the values of elements of variance and covariance matrices, it seems to be together equivalent on each capital letter both by dominant and by non-dominant.

Female students:

At the first, negative values are in those elements in B and D by dominant. Because it seems to be the reason that the writing characters may incline toward t_2 and t_6 directions (the horizontal direction) or t_2 and t_7 directions (the right oblique direction). And, there may incline t_3 and t_5 directions (the right downward direction and the left downward direction) or t_3 and t_6 directions (the right oblique direction).

As for the dispersion values, namely the values of elements of the variance and covariance matrices, it seems to be more generally big for both in B and D, and in U and V by non- dominant, and it is thought that this is a commonsense result.

(3) Results on divergence numerical value

Male students:

67.527 in U and V by dominant is the largest value in the result of these values. 26.751 in B and D by dominant is the next. There are the pattern differences of t_2, t_3 and t_5, t_6 in U and V and of t_2, t_6 in B and D, so it seems to appear in the difference of the divergence values between these characters by dominant.

In the characters by non-dominant, the difference of the described character pattern is a little. Even if these are the characters of collapsed to each other, it seems to be no rising numerical differences, and it seems to be also a little in the difference of the collapsed characters.

The results in B and B', and V and V' etc. should be originally the zero. It seems to come out the difference between by dominant and by non-dominant in drawing these characters.

Generally, it seems to be larger difference in U and V than in B and D as the described character pattern as a result.

Female students:

31.538 in B and D by dominant is the largest value in the result on these values. The value in U and V by dominant is 20.170. There are pattern differences of t_6 in B and D, and of t_3, t_5 and t_2, t_6 in U and V, so it seems to appear in the difference of the divergence value between these characters by dominant.

In the letters in B' and D' by non-dominant, it seems to be small numerical value evaluation of the difference as the writing character pattern in comparison with by dominant. Even if these are characters of collapsed to each other, it seems to be not so large numerical differences of the divergence value. In the meantime, though the value is small numerically, it is changed the converse in the value between in U' and V' and in U and V.

The results in B and B', and V and V' etc. should be originally the zero. It seems to come out the difference between by dominant and by non-dominant in writing these characters in female students, too..

Generally, in B and D and in U and V as the writing character pattern, it seems to be big difference in the

formers B and U of each set and the former set B and D of two sets as a result.

The consideration in this paper will be given the following.

The consideration of **male students**:

It is surely using the result which the personal computer recognized as the character. For the comparison of the characters by dominant with by non-dominant, there are much impression of the character which collapsed of shapes in the characters written by non-dominant. Though these are matters of mean value vector and its dispersion, it is unexpected a little that there is very much no difference dispersion of the characters between by dominant and non-dominant. mean value vector and cooperative of the dispersion, non-dominant is large a little in the dispersion, though examinees are writing the smallish, compact character in which anyway described at central + of the filling up frame both by dominant and non-dominant. This is a result of largely anticipating.

However, for the character pattern, even if the dispersion before it collapses in the character is equivalent to the dispersion after it collapsed, the interpretation is difficult, when it collapses. And, it is not indicated that there may be effects of the handwriting sign etc. by non-dominant.

The consideration of **female students**:

It is surely using the result which the personal computer recognized as the character, too. For the comparison of the characters by dominant with by non-dominant, the impression of the collapsed character is strong in the characters by non-dominant. Though these are matters shown through It is considered that the author want to utilize these results Kullback divergence, the evaluation and their consideration are reported.For the character pattern, after it collapsed in the character and more and more dispersion, it is difficult for the character interpretation, and it is queer as the character. It is also not realized that there may be effects of signature by non- dominant.

5. CONCLUSION

For statistical analysis of the typeface of characters which is one of the interesting human action outputs, the data are collected by the book-size personal computer display and the mouse device for each 20 examinees such as male and female dexterous students. And, the results on statistical analysis of average, variance and covariance matrices, Kullback divergence, the evaluation and their consideration are reported.

It is considered that the author want to utilize these results of Man-Machine system of human engineering and work analysis of production management in engineering fields. and experience in this paper for the research of construction

As future problems, there are the improvement of the accuracy on the experiment by the computer using the mouse device and the characteristic extract of human worker under computer operational environment.

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