WHAT DOES A CORRELATION BETWEEN HUMAN RESPONSES TO DIFFERENT ATTRIBUTES MEAN?

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Abstract

In order to evaluate the human responses to visual stimulus that change in different attributes such as size, shape and degree of grayscale of objects in the inspection image, a procedure for measuring them is proposed in the paper. By the experiment of paired comparison for dual attributes of objects generated artificially, a correlation between two kinds of attributes is examined on the basis of sensory inspection. From the results, an interesting measure of evaluating the relationship among relevant attributes such as size, shape and density of grayscale of objects was obtained. A hypothesis on correlation among them is also discussed on the meaning of correlation between one attribute and the other attribute of modality.

Several kinds of image processing method have been applying to the automated visual inspection system for defects on the product surface (Chin & Harlow 1982, Huang, Cheng, & Chen, 1992). One of the aims of this research is in the development of the heuristic and simple method that is used in the judgment process in the automated visual inspection system instead of inspector. A sort capacity by human vision is so delicate, therefore such information processing to a sort of images has been regarded unfit on the computer. On the other hand, a visual inspection process has a problem in productivity, since a precision and a speed of the performance will be degraded by fatigue of the inspector. In order to meet these problems, some studies were tried for the standardization of an operation time of visual inspection (Morawski, 1992, Drury, 1972), though they did not reach to propose a good evaluation measure, and research of productivity of the production system which consists of a process including such a human being has left lots of problems unresolved. In the practical situation of quality control on visual inspection, a panel must decide the judgement of the quality by using one's sensitivities for multiple attributes whether the quality of an object is good or not. It is an important viewpoint to obtain the skill of the professional sense that has the knowledge or skill. In order to meet these problems, a new method is proposed for the

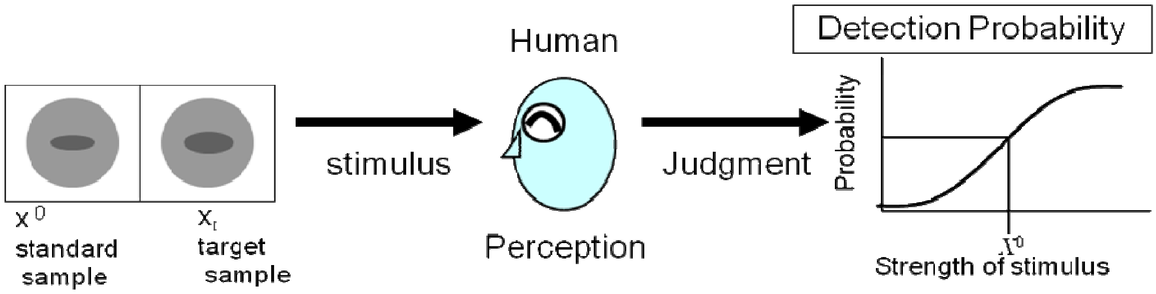


Fig. 1. Psychometric function obtained by the relashon between stimulus and response.

Table 1. Values of strength of stimulus used as standard and target sample for pared comparison test..

i	x_i^0	x_{i1}	x_{i2}	x_{i3}	x_{i4}	x_{i5}	x_{i6}	x_{i7}
1	19.23	17.78	18.36	18.93	19.53	20.11	20.68	21.26
2	0.672	0.644	0.655	0.666	0.677	0.688	0.699	0.71
3	0.583	0.553	0.565	0.577	0.589	0.601	0.613	0.625

evaluation of human ability on psychometric function. The standard sample was designed by means of paired comparison and constant stimuli. In order to evaluate the visual sensory properties of a panel in the practical inspection task, the psychophysical experiment was performed by Nakagawa, Nakayasu, Miyoshi, and Yamanaka (2005) to obtain the psychometric curves to evaluate the distinction probability of target object under the situation of various combinations of mixed attributes. This analysis is a trial to improve detection probability of defects in visual inspection task by using the results of dual attributes sensory testing. In the paper, it is examined to define the correlation among the attributes of figure and to improve the detection probabilities when the decision was made under the situation of multiple attributes.

Method

It is well known that the psychometric curve is a function that shows the correspondence relationship between stimulus strength and human response. In this paper, the detection probability in an inspection task is determined by the relation of a response corresponding to the difference between the strengths of a standard sample and target sample as shown in Fig. 1. This relation is similar to that between the cognition probability of threshold that is dependent on the degree of difference of strengths of standard and target stimuli. Therefore, the probability becomes to zero or unity when there is large difference between them.

In this study, the task and human perceptual ability to FRP (fiber reinforced plastics) product defect inspection image data as shown in Fig. 2 is taken into account in order to evaluate the human sensitivities on each attribute and the correlation among attributes. Three attributes (i.e., size, aspect ratio, and grayscale of an inspection object) were manipulated by the artificial values produced for sensory test. As to the amount of the feature, the first attribute x_1 means the size whose value is dependent on the length of the long axis of an ellipse. The second attribute x_2 is the shape defined by aspect ratio of the length of the long axis to short axis. Finally, the third attribute x_3 is quantified by the degree of grayscale (or color density). In this way, the strength of the stimuli for each attribute x_{ij} (i=1,2,3, j=1,2,…) was determined by the values in Table 1 as a set for the paired comparison. In Fig. 3, the shematic aspect is drawn, but the values of attributes used for Fig. 3 are acssented for typical replica for the explanation. The details of data treatment and numeric conversion of stimulus

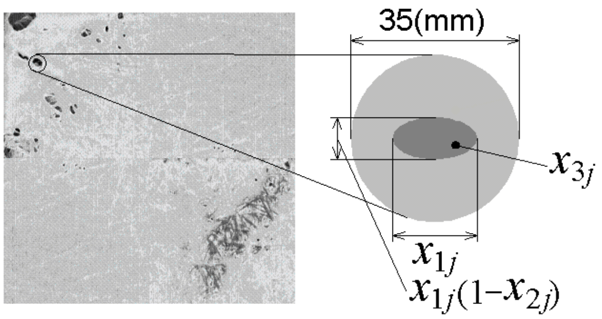
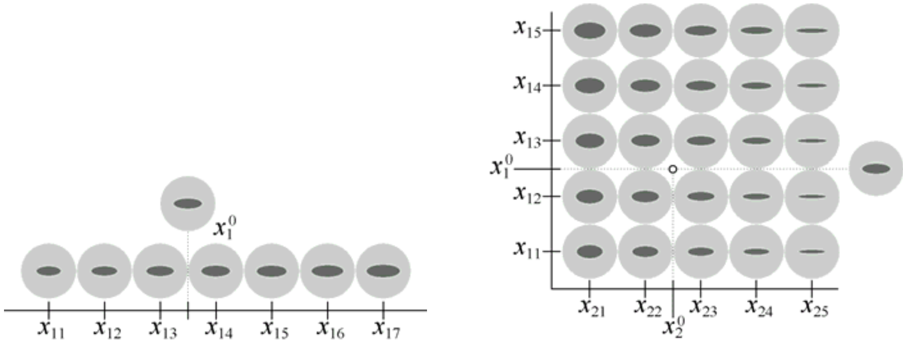
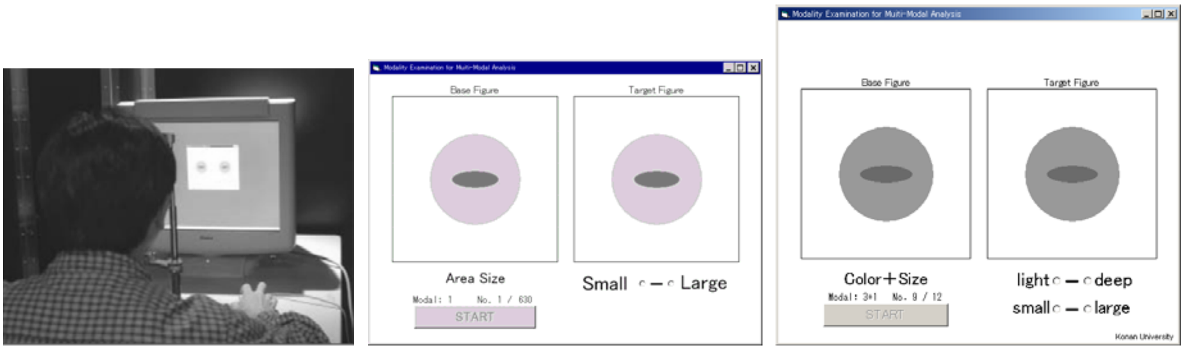


Fig. 2. Artificial replica for three kinds of attributes created from FRP inspection image data.



(a) single attribute (x_1) (b) dual attributes (x_2 and x_3)

Fig. 3. Examples of degree of stimuli for single and dual attribute sensory test.



(a) photo of experiment (b) single attribute test (c) dual attributes test

Fig. 4. Schematic aspect of sensory test and Stimulaus used in the test.

strength of these three attributes can be referred by Nakayasu et al. (2007).

31 participants of 20-26 years old joined to the experiments of single and dual attributes sensory tests with informed consent. In the experiments, the head of participant is fixed shown in Fig. 4(a) and the stimulus of sensory test appeared in the display located with the distance of 60cm from the participant's eyes. There are two kinds of stimulus used in sensory test as shown in Fig. 4 (b) and (c) that was generated by the PC with the programming code developed by Visual Studio 6.0 (Visual Basic language) on Windows OS. As for visual stimulus of the test, the target sample is located on the center of a background figure that is within a circle with light density as shown in Fig. 4 (b) and (c). The degree of visual field is about 1 degree from fixation point to a target figure and 2 degree to the background circle. The paired comparison method is used for standard sample where the constant and target figures are located on left and right side respectively.

The strength of the visual stimulus is divided into several categories that are dependent on the strength of the stimulus. The answer of participant is performed by selection from two kinds of candidates as:

1. The strength of the target sample is stronger than that of the standard sample, or
2. The strength of the target sample is not stronger than that of the standard figure.

The participant must select one of the two answers for the single and dual attributes respectively.

Results and Discussions

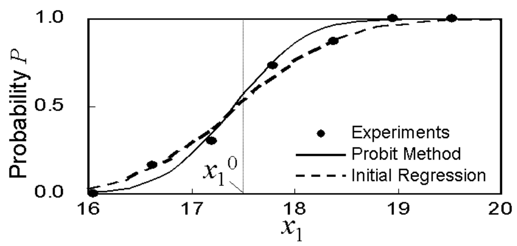
Experimental results of single attribute sensory test

Table 2. Mean values and coefficients of variation of PSE.

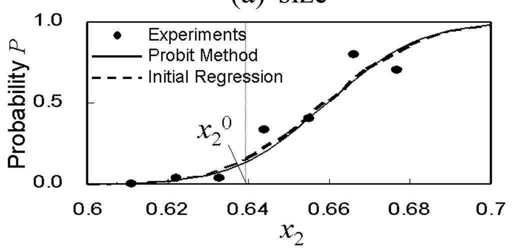
attribute	mean	*CV*
x_1	17.44	0.043
x_2	0.651	0.016
x_3	0.546	0.035

As a typical example of the results of single attribute sensory test, the psychometric curves for each attribute of perticipant B are shown in Fig. 5, where the parameters of the distribution were estimated by the iteration calculation based on probit method whose estimators are ML estimators. The details of estimation procedure can be refered in Nakagawa et al. (2005). It is seen from monotonically increasing functions of paticipant A in Fig. 5 that the pshycometric curves obtained by probit method are almost fitting in initial regression curves in the case of attributes x_2 and x_3 while the curve by probit method is not fitting in initial regression curve in the case of attribute x_1. The reason for the discrepancy in the attribute x_1 dues to the experimental data of attribute x_1. From the obtained psychometric curves, it will be forecasted that the sensitivities for the size and aspect ratio are slightly higher than that of grayscale in the case of participant A, since the slope of the curves are larger than that of grayscale.

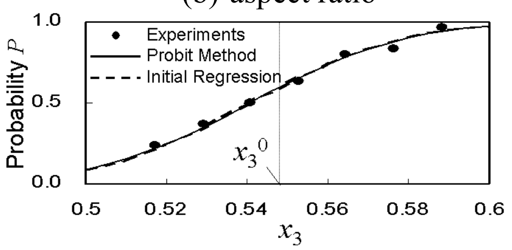
For the evaluation of the tendencies on three kinds of attributes, in order to avoid the influence by individualities of participants, distributions of PSE that means 50% percentile are investigated for x_1, x_2 and x_3 for all participants. The results are shown on the relationshp between normal variate Y and stimulus strength in Fig. 6. This distribution of PSE can be obtained by method of mean rank in due small order of PSE. From this figure, it is seen that the distribution of PSE fits in Normal distribution with the parametres listed in Table



(a) size

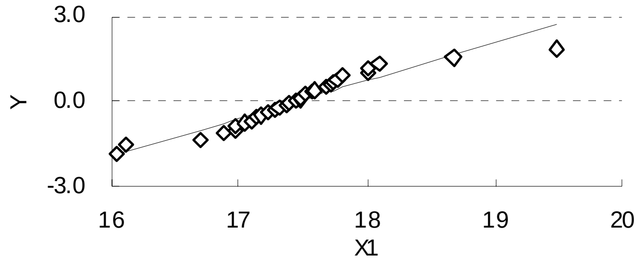


(b) aspect ratio

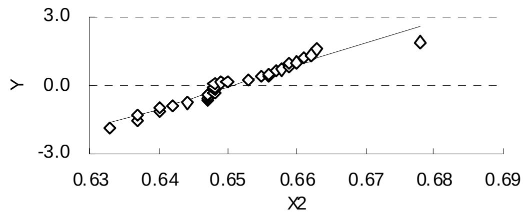


(c) grayscale

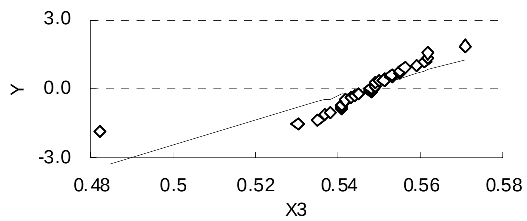
Fig. 5. Psychometric curves (paticipant A).



(a) size

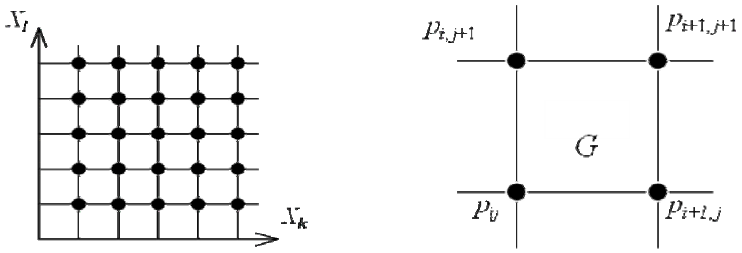


(b) aspect ratio



(c) grayscale

Fig. 6. Distribution of PSE of all participants



(a) definition of axis of dual attributes (b) element and center of gravity

Fig. 7. Discrete observation probability and definition of axis.

2. It is also noted that the mean values of PSE become close to the strenguth of the standard stimuli of x_1^0, x_2^0 and x_3^0.

Estimation of coefficient of correlation between i and j attributes from discrete observation probability

Correlation of coefficient of *k* and *l* attributes can be estimated by the results of dual attributes sensory test. From the results of dual attributes, observation probability p_{ij} ($i = 1,2, \ldots, n,\ j = 1,2, \ldots, m$) is a discrete probability p_{gij}($i = 1,2, \ldots, n\text{-}1,\ j = 1,2, \ldots, m\text{-}1$) for each discrete zone of combination *i* variable and *j* variable.

$$p_{g_{ij}} = \max\left(p_{ij} - p_{i+1,j} - p_{i,j+1} + p_{i+1,j+1},\ 0\right) \tag{1}$$

where $g_{ki}=(x_{k,i}+x_{k,i+1})/2$, $g_{lj}=(x_{l,j}+x_{l,j+1})/2$. Discrete probabilities p_{gij}($i = 1,2, \ldots, n\text{-}1,\ j = 1,2, \ldots, m\text{-}1$) is normalized and G(g_{ki}, g_{lj}) is a gravity point as shown in Fig. 7. From these formulations, the parameters μ_k, μ_l, σ_k^2, σ_l^2, σ_{kl} are calculated using the following equation.

$$\mu_k \doteqdot \sum_{i=1}^{n-1}\sum_{j=1}^{m-1} g_{ki}\, p_{g_{ij}} \qquad \mu_l \doteqdot \sum_{i=1}^{n-1}\sum_{j=1}^{m-1} g_{lj}\, p_{g_{ij}}$$

$$\sigma_k^2 \doteqdot \sum_{i=1}^{n-1}\sum_{j=1}^{m-1} (g_{ki} - \mu_k)^2\, p_{g_{ij}} \qquad \sigma_l^2 \doteqdot \sum_{i=1}^{n-1}\sum_{j=1}^{m-1} (g_{lj} - \mu_l)^2\, p_{g_{ij}}$$

$$\sigma_{kl} \doteqdot \sum_{i=1}^{n-1}\sum_{j=1}^{m-1} (g_{ki} - \mu_k)(g_{lj} - \mu_l)\, p_{g_{ij}} \tag{2}$$

Estimation of detection probability using three kinds of attributes

Now suppose that the detection probability *P* under the situation of multiple attributes are defined by

$$P = P(E_1 \cup E_2 \cdots \cup E_n) \tag{3}$$

In this condition of $P_1 \leq P_2 \leq \cdots \leq P_n$, the lower bound probability P_L under multiple attributes can be estimated by the equations. (Madsen, Krenk, & Lind, 1986; Nakagawa et al., 2005)

$$P_L = P_1 + (P_2 - P_{12}) + \sum_{k=3}^{n} \max\left\{ P_k - \sum_{l=1}^{k-1} P_{lk}\ ,\ 0 \right\}, \qquad P_{lk} = P(E_l \cap E_k) \tag{4}$$

Table 3 Correlation of coefficient

Subject	ρ_{12}	ρ_{23}	ρ_{31}
A	-0.406	-0.426	0.397
B	0.072	0.173	0.1
C	0.545	-0.522	-0.718
D	0.423	-0.042	0.528
E	0.532	-0.249	-0.315
F	0.573	-0.18	0
G	0.177	-0.373	-0.104
H	0.342	0.224	-0.272
I	0.528	0.548	0.048
J	-0.1	0.031	-0.02
K	-0.038	-0.095	0.329
L	-0.062	-0.09	0.346
M	0.144	-0.05	0.539

Table 4. Improving ratio of detectability

Subject	P_{12} (%)	P_{23} (%)	P_{31} (%)	P_L (%)
A	31.65	32.01	18.5	32.15
B	23.85	22.23	23.41	23.85
C	15.83	33.74	37.76	37.76
D	18.06	25.67	16.14	25.67
E	16.07	29.01	30.11	30.11
F	15.29	27.88	25	27.88
G	22.17	31.08	26.65	31.08
H	19.45	21.41	29.38	29.38
I	16.14	15.78	24.23	24.23
J	26.59	24.51	25.32	26.59
K	25.61	26.51	19.66	26.51
L	25.98	26.43	19.38	26.43
M	22.7	25.8	15.94	25.8

From the results in the experiments, the probabilities for dual and multiple attributes are larger than those of single attribute. This tendency is same in all experimental conditions. Increasing amount of detection probability, however, is not same in different ways with the variation of correlation coefficient. In fact, the variation is seen from the correlation coefficient ρ_{12} , ρ_{23} and ρ_{31} for combinations of attributes x_1 , x_2 and x_3 in Table 3. Table 4 shows improving ratio of detection probabilities for dual attributes: P12, P23, P31 respectively rise approximately 21%, 26% and 24% for mean in the case of dual attribute experiments. That is to say improving ratio of detection probabilities have a pronounced tendency to depend correlation coefficient.

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