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A Design Creation Method for Ship Configuration based on the Aesthetic Cognitive Theory

Takeshi Shinoda[1] and Nobuyoshi Fukuchi[1]

[1]Kyushu University, Japan; E-mail: shinoda@nams.kyushu-u.ac.jp

Abstract

The shape of an industrial product has to be determined within the constrained conditions of keeping firmly many kinds of functional and performance requirements. On the other hand, the configuration of artistic work would be created desirably using the sense of aesthetics, even if conflicting slightly with these requirements. The development of a methodology for an aesthetic design founded on human sensitivity is becoming highly desirable in recent years. In this paper, a method of measuring beauty quantitatively for an artistic evaluation is proposed using the aesthetic cognitive theory and the optimum configuration could be found by a search using the genetic algorithm. Furthermore, an expression of optimum ship appearance can be gained as graphics.

Keywords: aesthetic cognitive theory, aesthetic shape design, optimum design of ship by beauty

1 Introduction

It is difficult to generalize the design methodology for an aesthetic design, because the results of an artistic design may be vague as the ill-defined problem in which solution can be decided depending upon the designer's recognition against his objects. Another problem that is called the ill-structured problem; like a knotty problem also introduces vagueness in the design process because of the difficulty to find an algorithm for the process of solution.

In this paper, a method of measuring beauty as a quantity for artistic evaluation is proposed using the aesthetic cognitive theory that formative beauty is created by associating with visual characteristics. The composed elements of external form may be transformed into various genetic codes and the optimum configuration could be found by the search using genetic algorithm. Furthermore, an expression of optimum ship appearance can be gained as drawings of profile and three dimensional computer graphics by decoding the obtained solution. From the results of this attempt, the proposed method is clarified to be useful for ship configuration design.

2 Concept of aesthetic shape design

A flow of the concept of aesthetic shape design is shown in Figure 1. This is divided roughly into the following two streams, one of these is based on the statistical analysis model, by which

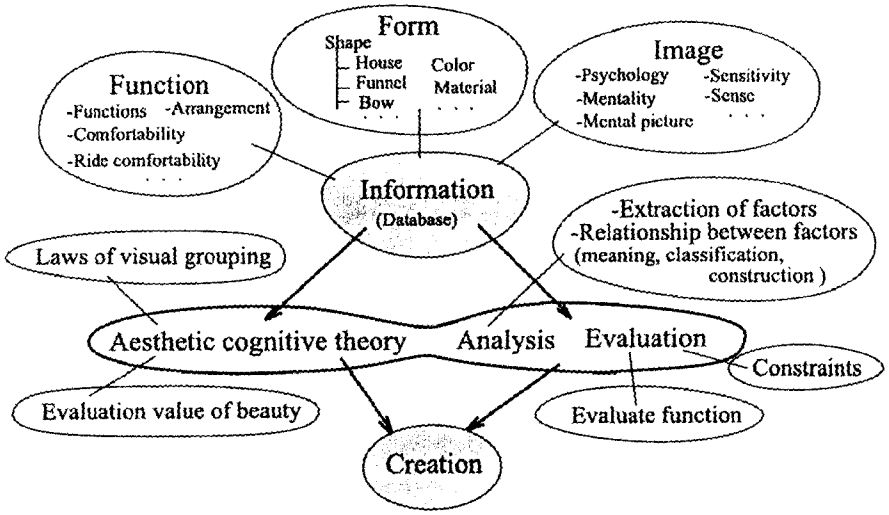


Figure 1: A conceptual flow chart of aesthetic shape design

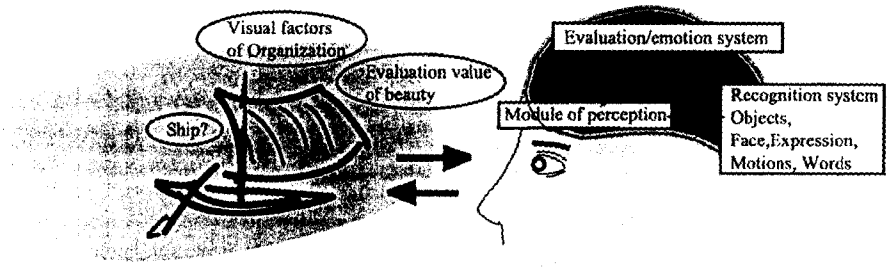


Figure 2: A model for the visual system of human

the degree of relationship between the design characteristics and an impression of a person who watch the ship shape is obtained(Shinoda et al 1995, Shinoda et al 1996) . The other stream is based on the cognitive psychology which assumes the model of characteristics of the visual system of humans, by which the evaluation value of beauty is obtained(Shinoda et a 1997).

In this paper, a design method aimed at the external form of ships using the latter stream is expressed mainly.

3 Evaluation of the external form of ships based on cognitive psychology

Behaviorism, which is a part of psychology, is based on the model of relationships between stimuli and reactions to that stimulating called S-R theory.

On the other hand, cognitive psychology is based on the model that is supplemented upon S-R model with the organization of function of human mind. It is also called S-O-R theory abbre-

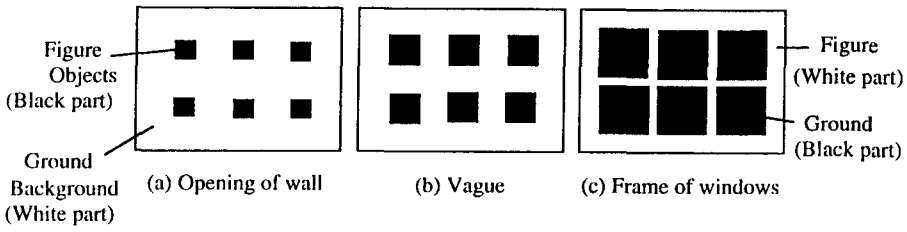


Figure 3: Figure-ground segregation

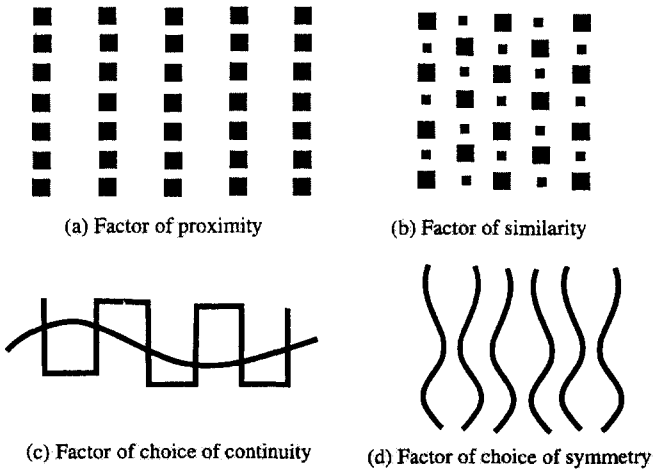


Figure 4: Laws of visual grouping

viately. In the field of aesthetic cognitive psychology, the evaluation value of beauty is destined using a model for the visual system of human as shown in Figure 2, and it is based on the visual factors of organization as expressed in the following chapter.

3.1 Visual factors of organization

To understand the process of creation of shape, it is needed to recognize that there are the following visual factors of organization in the Gestalt psychology(Mitchell 1991).

(a) Figure-ground segregation
Figure-ground segregation that is a concept of preprocessing of perception of pattern, is the distinction of the figure of objects from the background as shown in Figure 3. More light, smaller, regular and closed area is more easy to recognize as the figure of objects.

(b) Laws of Visual Grouping
In the process of recognizing as the objects, there are the following three laws of visual grouping mainly.

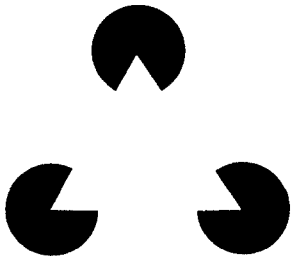


Figure 5: Subjective contours

1) Factor of proximity
Factor of proximity is one of the laws of visual grouping that proximity enhances recognition of objects. For example, in Figure 4(a), some proxy black squares are grouped together in the visual field and are recognized as lines in a lengthwise arrangements.

2) Factor of similarity
Factor of similarity is one of the laws that the similarity of color, shape, size are recognized each other as the objects. For example, in Figure 4(b), the same black squares is grouped together in the visual field and are recognized as inclined lines.

3) Factor of choice of shape
Factor of choice of shape is one of the laws to recognize the objects which has characteristics such as continuity (Figure 4(c)) and symmetry (Figure 4(d)).

(c) Subjective contours
Subjective contours is one of the laws to recognize the contours complimentarily. For example, in Figure 5, the shape of white triangle is recognized in relation to rule (a) and (b).

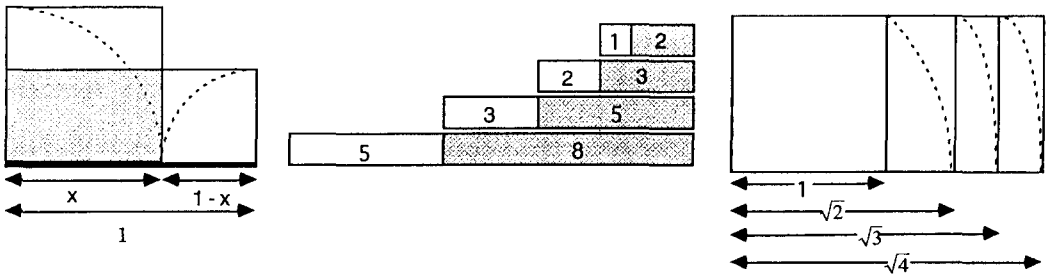
The above visual factors of organization are explained inclusively as the expansion of the Law of Pregnancy, and in the field of aesthetic cognitive psychology, a combination with the above factors has close relations with the beauty of shape.

3.2 Evaluation value of beauty based on aesthetic cognitive psychology

In the field of experimental psychology, the following formula is proposed as a method of measuring beauty quantitatively for artistic evaluations(Murayama 1995):

$$M = (1 + R)/P \tag{1}$$

where M is the evaluation value of beauty, P is summations of geometrical parameters of characteristic shape, and R is number of constraint conditions of the geometrical parameter that is inherent in P. It is psychologically established by the experimental result of Boselic and Leeuwenberg that the constraint condition R increases as the evaluation value of beauty in the case of similar topologies.



(a) Golden section (b) Fibonacci series (c) Dynamic symmetry

Figure 6: Laws of the proportion of beauty in harmony

But the pictorial feeling of the author, experience for arts and so on, are pointed out as an exception of formula (1).

3.3 Value of harmony

Golden section, Fibonacci series and Dynamic symmetry are famous as rules of harmony in the theory of art. When the value of beauty are calculated, these are taken as the constraint conditions of geometrical parameter of formula (1) in this paper.

(a) Golden Section
Golden section is the ratio of beautiful partitions of space as shown as Figure 6(a), and is expressed through the following rule:

$$(1 - x) : x = x : 1 \tag{2}$$

and that satisfies (2) is given the following value:

$$x = (-1 + \sqrt{5})/2 = 0.618 \tag{3}$$

The rectangle of the shadowed portion in figure has the ratio of Golden section. This ratio is found usually within the architecture in ancient Greece because of additivity for space that is easily combined with the square which has this ratio.

(b) Fibonacci Series
Fibonacci Series by A.Giraldi is expressed as the following recurrence formula:

$$F_n + F_{n+1} = F_{n+2} \tag{4}$$

when initial value $F_1 = F_2 = 1$ is chosen, following series is obtained:

$$1, 1, 2, 3, 5, 8, 13 \cdots \tag{5}$$

and more the ratios of two numbers adjacent to each other as shown Figure 6(b) take following series:

$$\frac{1}{1}, \frac{1}{2}, \frac{2}{3}, \frac{3}{5}, \frac{5}{8}, \cdots, \frac{377}{610}, \cdots \tag{6}$$

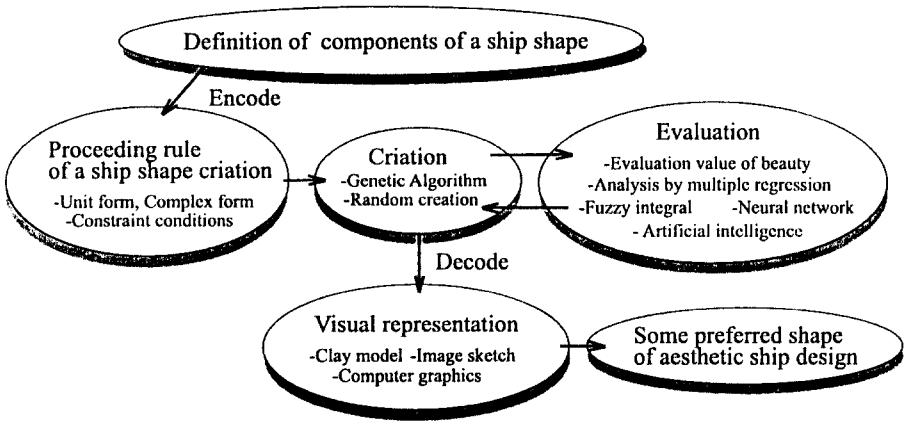


Figure 7: A concept of the flowchart of a shape creation

This series will gradually approach the ratio of Golden section as follows:

$$1, 0.5, 0.666, 0.6, 0.625, \cdots, 0.618, \cdots \tag{7}$$

Fibonacci series is seen widely in the nature such as the branch of a tree, the distance of a nebulous star, a musical scale of sound, and so on.

(c) Dynamic Symmetry
The following series of the square root of natural numbers are called Dynamic symmetry:

$$\sqrt{1}, \sqrt{2}, \sqrt{3}, \sqrt{4}, \sqrt{5}, \cdots \tag{8}$$

Dynamic symmetry of 2 is got by drawing the diagonal of a square as shown Figure 6(c), and the Dynamic symmetry of 3 is got through drawing a rectangle with aspect ratio of 1 by root 3.

To get Dynamic symmetry through such easy drawing process, it is explained as just one of the reasons that Dynamic symmetry are found out frequently in artificial design such as architecture, handicrafts; industrial products, and so on. According to J. Hambidge's research, Dynamic symmetry of 5 are found in about 85% of ancient Greek design which is existing in the world, and Dynamic symmetry of 2 are about 10%, and the Dynamic symmetry of 3 are 1 or 2%.

4 A creative attempt for ship shape design

4.1 The process of shape creation

A concept of the flow of a ship creation is shown as Figure 7 and take steps as follows.

(a) Components of a Ship Shape
In the first step of the flow of a ship creation, components of a ship shape are defined by a hierarchy model as in Figure 8. In this figure, a higher level of hierarchy shows more major parts of the ship shape such as house and hull of ship. On the other hand, a lower level of hierarchy shows details of ship components such as windows and doorways. In this paper, details of ship components

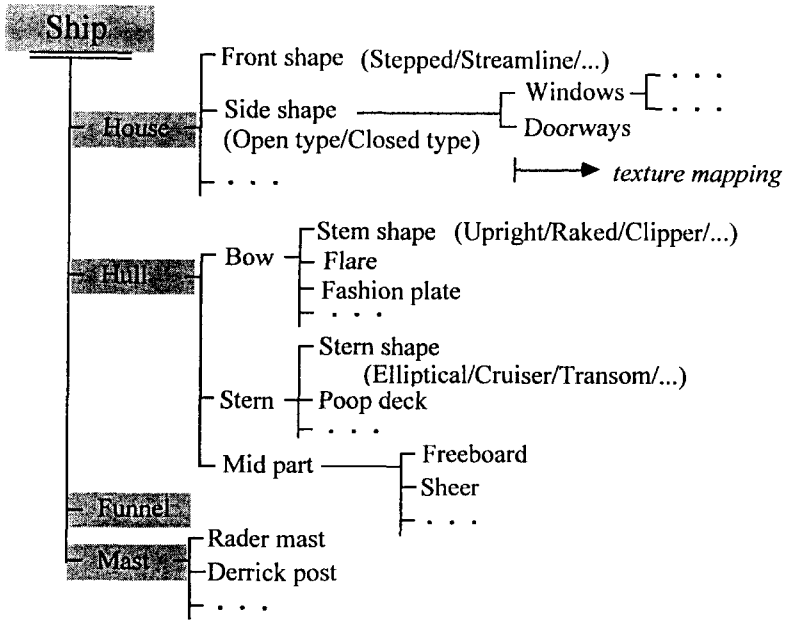


Figure 8: Definition of the components of a shape

are not considered and only the higher levels of hierarchy are taken as design components mainly because of attempts to obtain as overall general view of the ship.

Next, the parameter of design components are encoded as chromosomes of genetic algorithm (see Appendix) as in Figure 9. These chromosomes comprise of 164 bits that treat 48 geometrical parameters of the ship shape.

(b) Proceeding Rule of a Ship Shape Creation

Proceeding rule of a ship shape creation is shown as Figure 10.

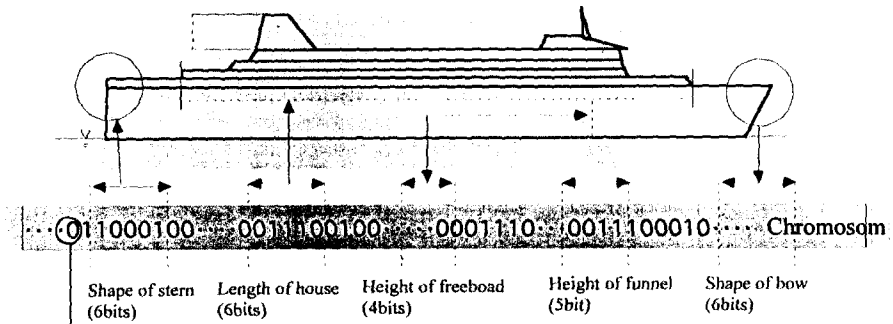
Unit form is defined as rectangles that are divided into three units such as the fore part, mid part and aft part in each deck. Aspect ratio(a : b) of each unit are considered as calculated unit.

And unit forms are combined into complex forms and the upper part, the lower part and the side parts are added to this, after which process the closed space in three dimensions is made. All parts of deck, hull and funnel are produced by similar steps.

Furthermore after synthesizing the complex form with the constraint conditions such as an incongruent shape satisfied, a ship form is obtained.

(c) Evaluation Value of Beauty

Next, unity, harmony, balance and rhythm of a created ship form are evaluated using the value of beauty based on formula (1). At each creative process such as the stage of unit form, complex form and ship form, the proportion of beauty in harmony are summed up using membership functions shown in Figure 11 for the reason that a fussiness of the aspect ratio for pleasing rectangle are proved through syntheses is of the results of some psychological experiments which is explained as the impression survey in appendix 1.



Components of a ship shape		Variables
Shape of bow		Angle, ...
House	1st deck	Length, Height, Angle of the front part,...
	2nd deck	Length, Height, Angle of the front part,...
	. . .	. . .
Funnel		Height, Arrangement, Number
Hull		Length of Deck, Height of frrboard, ...
. . .		. . .

(Total 48 geometrical parameters)

Figure 9: Coding model for a ship shape creation

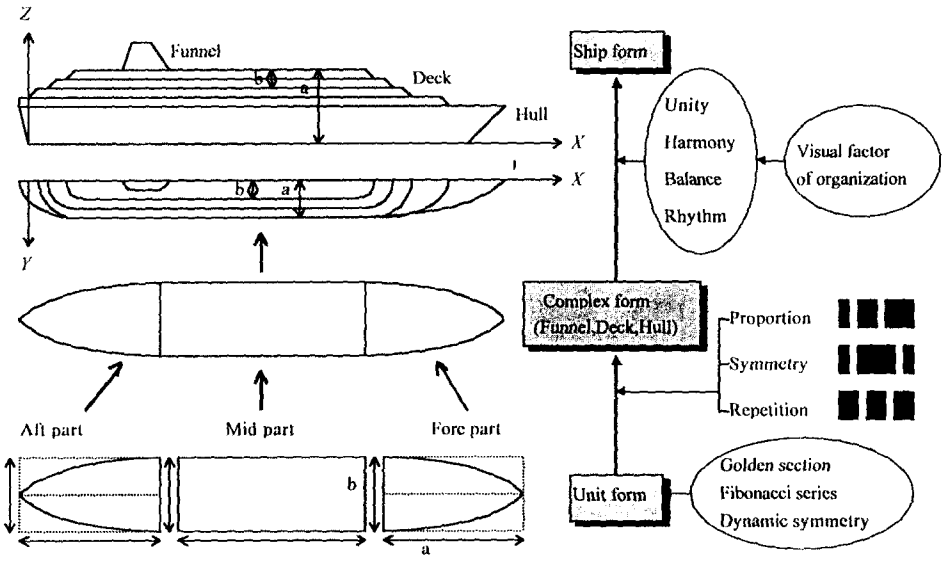


Figure 10: A proceeding rule for a ship shape creation

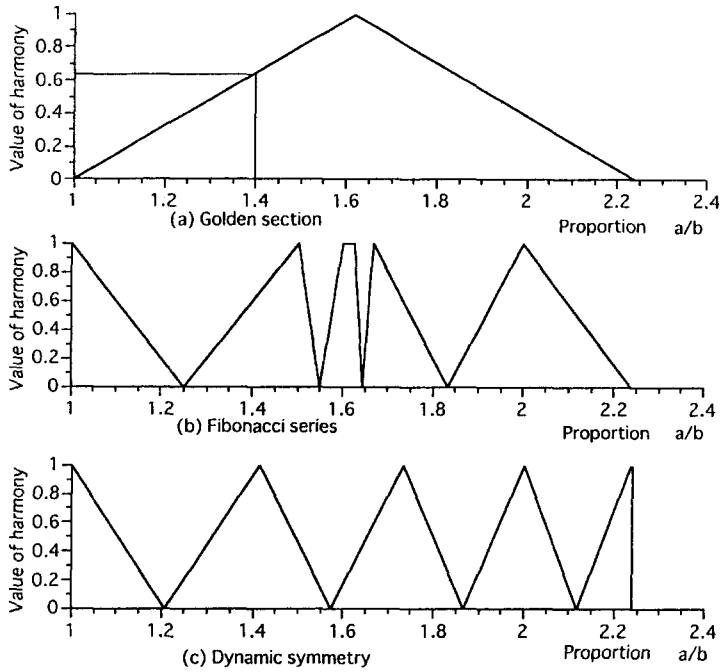


Figure 11: Membership function of the proportion of beauty in harmony

(d) Creation and Optimization

As the form of a ship is encoded as chromosomes, the form can be changed easily by the gene recombination such as inversion of bit. Besides it is easy to make some optimized ship shape by an optimization method such as genetic algorithm.

After these processing, ship shape can be reconstructed by decoding of ship shape code, thus some preferred shape of aesthetic ship design are obtained by the visual representation such as clay model, image sketch or computer graphics.

4.2 Some creative example of ship form

A new ship form is obtained after changing the gene code such as inversion of a bit. The change of ship shape under the random creation is shown in Figure 12 as the figures of profiles. This profile is represented using 29 out of 48 geometrical parameters of ship form, and with only such few parameters various ship shapes are generated. Here, evaluation value by fuzzy integration in this figure express the likeness of ship shape for a person as obtained according to the result of statistical investigations of the students of Kyushu University in 1995(Shinoda et al 1995, Shinoda et al 1996).

Next, by the choice of an initial ship shape and using genetic algorithm (GA) which is explained in appendix 2, the genetic code which maximize the evaluation value of beauty are obtained. The changes of evaluation value under the generation by GA is shown in Figure 13. The value of beauty rise rapidly in early generation, after that in 30th generation reaches a maximum. On the other hand, the evaluation value by fuzzy integration fluctuated under each generation and the relation with the value of beauty is not clarified in this research.

Figure 14 shows the ship shape as computer graphics (CG) under generation by the search

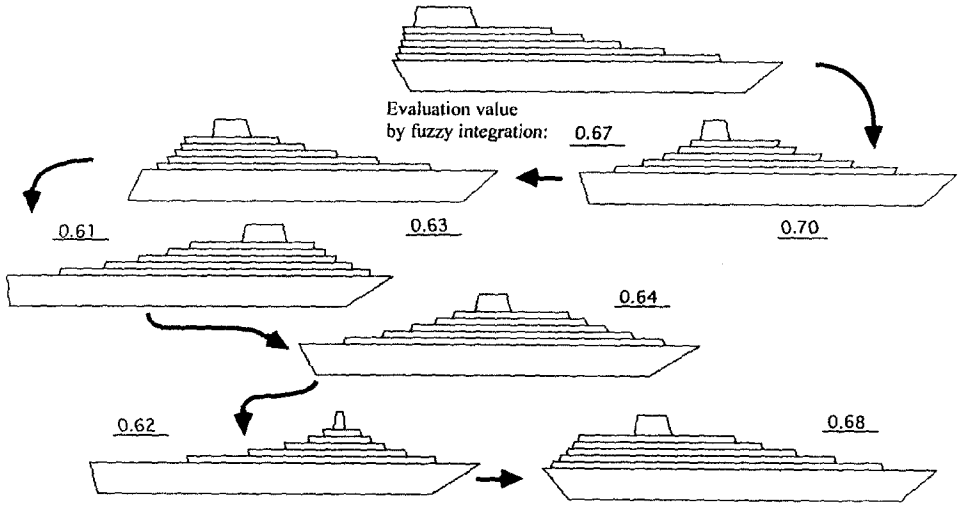


Figure 12: A change in ship shape under the random creation

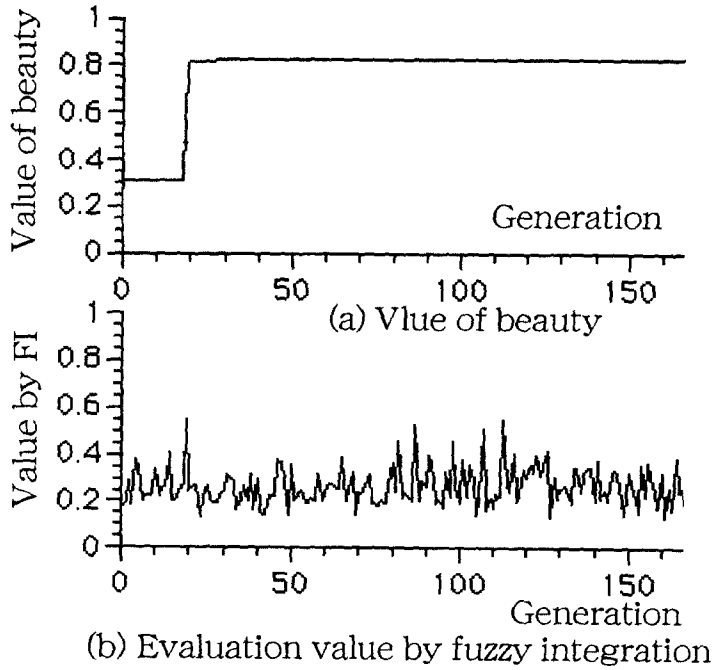


Figure 13: A variation of evaluation value under the generation by the analysis of the genetic algorithm

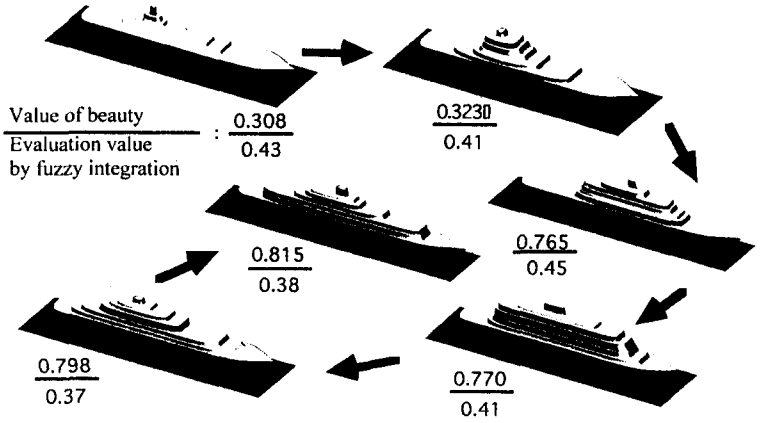


Figure 14: A change in ship shape under the generation by the analysis of the genetic algorithm

using GA. The ship shape changes uniform convergence with alternation of generations. Here, the method of NURBS (Non-uniform rational B-spline) and OpenGL(1993) as graphic library are used as the representation of 3D-CG for ship shape.

Figure 15 shows a concept for the ship shape designing model by CG and the value in this figure indicates the information such as the value of beauty and statistical result about beauty for ship shape.

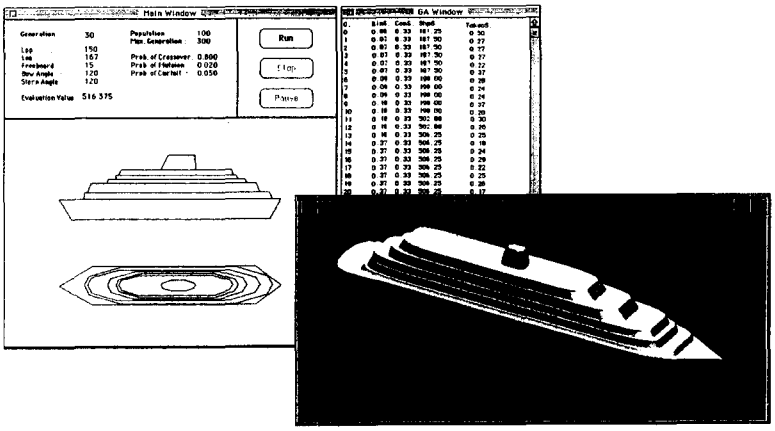


Figure 15: Ship shape designing model by computer graphics

5 Conclusions

A method of measuring the quantity of beauty for artistic evaluation is proposed through aesthetic cognitive theory. The composed elements of external form are encoded as various genetic codes and the optimum configuration could be found by the search using genetic algorithm.

Furthermore, an expression of optimum ship appearance can be gained as drawings of profile and three dimensional computer graphics by decoding the obtained solution, but it can't be concluded that the creative shape satisfy perfectly the likeness of ship shapes.

From the results of this attempt, the proposed method is clarified to be useful for ship configuration design in which ill-defined problems and ill-structured problems are inherent.

Appendix 1

The impression survey for the aspect ratio for the pleasing rectangle are taken by following step. The 81 rectangle samples which the breadth is fixed as the base length of 90 mm and the height is increase by 1 mm from 10 mm to 90 mm, are scattered on the table, and then a testee for the impression survey chose 16 pieces of the samples as the pleasing rectangle. Next the pleasing rectangles are narrowed down to 8 pieces, and the same process is continued. At last a piece of rectangle is decided as the most pleasing rectangle.

A part of results of the impression survey on the students of Kyushu University in 1998 is shown as example in Figure 16. This figure shows the frequency of the choice of 16 pieces for the pleasing rectangle which is normalized by maximum number (15 persons) and a similarity between the out line of this figures and the proportion of beauty in harmony are appeared approximately.

Appendix 2

Genetic algorithm (GA), is the optimizing method for the discrete evaluation function that is discretized as genetic codes. Figure 17 shows the models of GA, and the optimum value is got by the imitation of the struggle for existence.

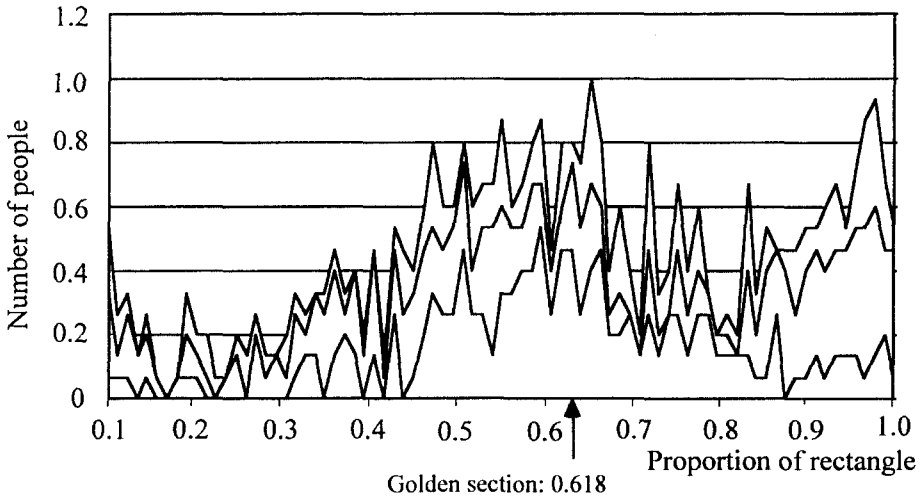


Figure 16: The frequency of the choice of 16 pieces for the pleasing rectangle

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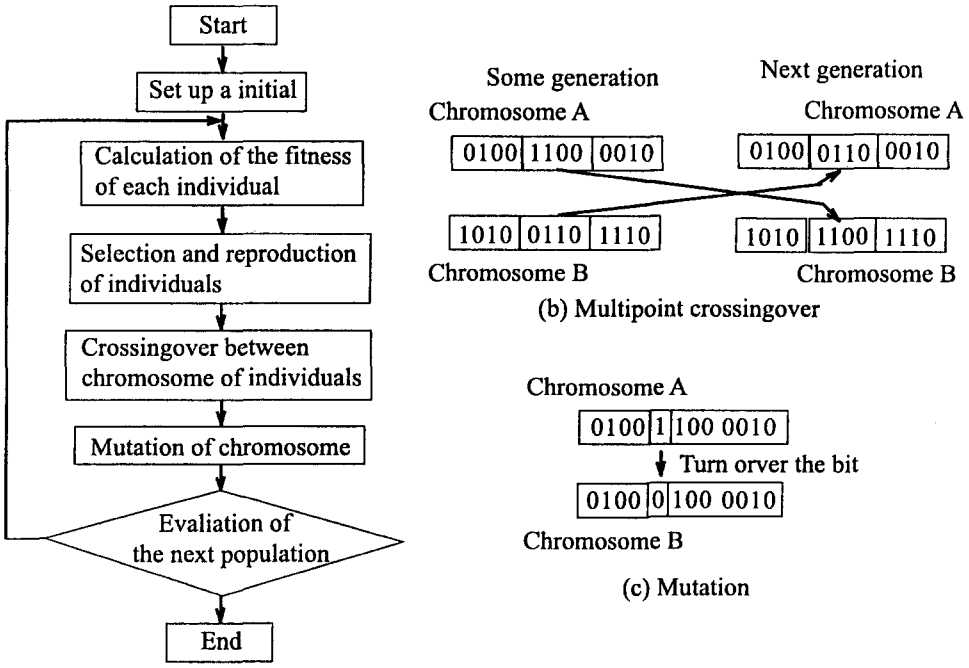

(a) Flow chart of genetic algorithm

(b) Multipoint crossingover

(c) Mutation

Figure 17: Models of genetic algorithm(GA)

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