Study on the Gene Design of Yacht Side View Shape Based on Shipowners' Expectation Images

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Abstract

Considering the design of yacht shape, this paper puts forward a design method of yacht lateral shape gene. This paper chooses the characteristic line of the side view of the yacht as the research object, uses the Bezier curve to quantify it, extracts and expresses the characteristic line of the yacht, and studies the preference degree of the yacht shape from different shipowners. The aims of the paper are to calculate the characteristic line of the yacht side view structure with different styles, construct the mapping model between the owner's inner demand and the characteristic line of the yacht, convert it into evolution function and use genetic algorithm to show the ship evolutionary relationship of the desired characteristic line and the shipowners' expected yacht side view. Based on the Matlab algorithm, a series of characteristic line design methods of yacht side view with both family continuity and personality difference are deduced, which proves the feasibility of the method and provides a reference for enterprises of yacht as well as individual designers.


1. INTRODUCTION

Currently, Most of the yacht enterprises shape the family heritage of the visual image by increasing the personalized shape design of the yacht so that to deeply impress the expected buyers in order to enhance brand identification and its competitiveness. Such as superstructure side view of the porthole fin shape of Ferretti yacht and the ship side portholes of Sunbird yacht. They are all inherited down as the family design in the process of several generations of products, even if the signs are removed, they can be identified through different yacht brands with the family characteristics.

Shipowners' personalized demand of the yacht is becoming increasingly strong, and the first visual experience of the owners has a more intuitive impact on their purchase decision. If the yacht designer can predict the differences of expected image of the owner, and carry out targeted program design according to different buyers, they will occupy an important advantage in the future market competition. How to form a design method that can not only inherit the characteristics of the family brand image, but also can carry out creative design according to the owner's expectations is both the opportunity and challenge that current yacht enterprises are facing.

Based on the design point of view, this paper puts forward a design method of the yacht lateral appearance gene of the owner's expectation image, and takes the yacht side view characteristic line as the research object. By extracting the characteristic line of the yacht side view and studying the individual demand of the ship owner, the evolution function of the yacht gene of shipowners' expectation is established, and the genetic system is used to establish the evolutionary system of the family gene describing the evolutionary goals that meet the expectations of the shipowners.

2. THE DESIGN OF YACHT SHAPE GENE OF SHIP OWNERS' EXPECTATION IMAGE

In the gene design of yacht family, Heredity and Variation of the family gene are mainly driven by the owner's expectations. The dominant genes can be inherited to the next generation, and recessive genes are implied; Offspring yacht and the parent yacht held a certain contact so they are easy to be identified, and in this way the
genetic gene are formed, such as the car head design of Audi, superstructure side view of the porthole fin shape of Ferretti yacht and the ship side portholes of Sunbird yacht. They are all inherited down as the family design in several generations of products, even if the signs are removed, they can be identified through the family characteristics of different yacht brand.

2.1 Preference of Shipowner

When the owner chooses a yacht, the outside stimulus is sensed by the senses to the sensation, resulting in sensory sensation such as visual, tactile, auditory, olfactory, and other sensual sensation, and then the owner arranges the alternative yachts according to his own wishes. This wish arrangement is called the owner's preference. It is not intuitive and is a feeling and tendency hidden in the hearts of people. Preferences reflect the individual needs of consumers, preferences and interests, and have a great impact on the consumer's purchasing tendencies (Marvin, 1987). Therefore, the depth of excavation of the owner's expected preference, has a very important significance for better fitting the owner's expectation image

The shape of the product design has become an important factor affecting consumer preferences and purchasing decisions (Kreuzbauer and Malter, 2005; Charlie et al., 2012), and many experts have confirmed this phenomenon. For example, Chuang (2001) Sun Jianning (2004), through the study of the shape of the product design respectively confirmed that the mobile phone design and bike shape design are important factors affecting the willing of consumers to buy. Moreover, the emotional engineering mapping model was established, which enables the designers to design a more reasonable solution fitting consumer's expectation. As a practitioner in this area, Jobs paid attention to the appearance of Apple products design, and gradually occupy the global market.

When consumers come into contact with new products, there are always many different cognitive behaviors that draw them to take interest to the product, including some abstract adjectives, such as "gorgeous", "beautiful", "conceptual" and other adjectives to describe their own inner preference for cognition. These adjectives are basically distributed in three levels: evaluation factor, potential factor and activity factor (Lichtenstein and Slovic, 2006). Therefore, how to capture the expectations of consumers, transform these expectations into a product suitable for consumer, and express the consumers preferences through the product, has become the most important thing that needed to be considered by designers.

2.2 The Mapping between the Owner's Expectation and the Yacht Family Shape Gene

The mapping between shipowners' expectation image and yacht family design is basically based on semantic difference method and perceptual engineering method, and the computer aided technology and various mathematical modeling methods are integrated to realize the mapping. Soddu (2002) Janssen (2006) Liu Hong et al. (2006) studied and developed computer-aided product concept design system to help designers to design based on evolutionary computation; Hu Weifeng (2011) proposed the theory of car modeling gene evolution, and generated a series of designs.

Through the study of the expected images of the owner and subdivision of them, while researching the characteristics of the yacht family shape gene and the construction order, the association between family gene and personalized gene and mapping association between the expected image of the ship owner and yacht family shape gene are established, which will then be transformed into the genetic function of the expected image of the owner. The genetic algorithm was used to optimize the gene (Luo et al., 2016). On the basis of the optimal progeny, and according to the inherited gene, a family series with intrinsic correlation will be formed, which integrates the yacht designer's coding process and the decoding process of the owner together.

3. EXTRACTION AND EXPRESSION OF YACHT LATERAL APPEARANCE GENE

Generally speaking, designers often use line analysis method to extract a key line in the yacht design, which is regarded as a “characteristic line” to study the structural characteristics of the yacht. By extracting the key characteristic line of the yacht, designers can not only accurately refine the core of yacht shape, but also can strengthen the shape of the yacht. The extraction of the key characteristic lines of the yacht should keep the basic form of the yacht prototype line, the momentum and the degree of smoothness of the type line, etc. The extraction steps mainly include the determination, extraction and contrast analysis of the key characteristic lines. The extraction of key characteristic lines is a very important part. Accurate extraction of key lines is the key to further analysis of later period.
Figure 1. The "familiarization" and "differentiation" of the Azimut, Ferretti and Sunbird

Each yacht brand is composed of a number of characteristic lines. For example, Yachts of Ferretti, due to the different functions, length and speed of the yacht, have been differentiated into various product lines such as open bridge flying yacht, sports yacht, flying bridge leisure yacht, and many other product lines. In the construction of a series of yacht designs, yacht builders often maintain the shape characteristics of the family while keep the difference, the purpose of which is to adapt to a wide range of markets.

Three yacht designers with more than 5 years' experience in yacht design from the Ferretti, Azimut, Sunbird and other series of brands were invited to conduct horizontally and vertically comparative study on yacht among different series of the same brand and among the same series. The aims is to combine different features of the characteristic line of yacht side view and the personalized gene, to uniform the design style of the bow, stern and porthole. Family genes like radar receivers, deck rails and so on are regarded as parts of the fixed style of the entire product group. According to the relevant empirical study (Hu et al., 2009; Tovey et al., 2003; Zhao, 2007; Zhang, 2007), the extracted abstract yacht lateral shape genes were described and expressed in the form of key characteristic lines.

3.1 Personalized Genes

Individualized genes are used to describe the parametric decision on the variables of genetic evolution problems by means of morphological calculations (Stiny, 1980; McCormack et al., 2004).

The outer contour of the yacht is a typical Bezier curve, on the expression of personalized genes through the combination of the hard point and curvature control points of the curve. Take the 45ft Ferretti yacht as an example, its side view outline structure consists of three smooth quadratic Bessel curves. Curve 1 consists of two hard points and two control points, which begins with the outer side of the contour line to where the contour slope mutates; Curve 2 consists of two hard points and two control points, from the first transition point to the second transition point; Curve 3 consists of three hard points and five control points, from the second transition point to the outermost end of the stern, as shown in Figure 2. HP (Hard point) is used to represent the hard point and CP (Control point) to the curvature control point. Bezier curve is used to describe the positive side of the picture structure line of 12 Ferretti yacht samples, and the hard points and control points are marked. Defining the hard point HP01 as the origin (0,0), the horizontal line is set to the x-axis, and the vertical line to the y-axis to establish the two-dimensional coordinate system. Variables that are represented by capital letters represent the coordinate value corresponding to all hard points and control points. Thus, the individualized genes are identified by 26 variables represented by A ~ Z to complete gene expression. The coordinate value of each point in the coordinate system is shown in Table 1.
3.2 Expression of Family Gene

Compared with the individualized genes, the shape of the family gene is more complicated, which is usually a collection of multiple characteristic lines, and the parameterization difficulty coefficient is larger. Moreover, to keep the family sense of the yacht without evolution the family gene can be expressed directly through the characteristic line, conducting overall use by collection form. The expression of the family gene requires the yacht designers to use the vector mapping software to summarize and describe the overall shape and detail of each inherited gene, and a concise feature line is needed for the final description.

While describing the yacht structure line, the first step is to describe the individual gene of the yacht outline with Bezier curve; details are then added to describe the family gene according to other inherent location. Finally, a more complete yacht overall characteristic line map is finished. Figure 3 shows the gene expression of the lateral characteristic line of the Ferretti yacht.

### Table 1: The yacht side contours hard points and control points variable tables

<table>
<thead>
<tr>
<th>Point</th>
<th>Variable</th>
<th>X-axis</th>
<th>Y-axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP01</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CP01</td>
<td>A</td>
<td></td>
<td>B</td>
</tr>
<tr>
<td>CP02</td>
<td>C</td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>HP02</td>
<td>E</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>CP03</td>
<td>G</td>
<td></td>
<td>H</td>
</tr>
<tr>
<td>CP04</td>
<td>I</td>
<td></td>
<td>J</td>
</tr>
<tr>
<td>HP03</td>
<td>K</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>CP05</td>
<td>M</td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>CP06</td>
<td>O</td>
<td></td>
<td>P</td>
</tr>
<tr>
<td>CP07</td>
<td>Q</td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>CP08</td>
<td>S</td>
<td></td>
<td>T</td>
</tr>
<tr>
<td>HP04</td>
<td>U</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>CP09</td>
<td>W</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>HP05</td>
<td>Y</td>
<td></td>
<td>Z</td>
</tr>
</tbody>
</table>

**Figure 2.** The side contour of the yacht refers to the coordinate variables

**Figure 3.** Gene expression of side-view characteristic lines of Ferretti yacht
4. DIFFERENCES OF PRODUCT LINE STRATEGY OF SHIPOWNER’S EXPECTATION IMAGE AND EVOLUTIONARY FUNCTION

4.1 Differentiated Product Line Planning Based on Shipowner's Expectation Image

In order to obtain the expected image characteristics of the yacht by the ship owner, based on the semantic difference method, and combined with the Likert scale to obtain the expected image evaluation of the owner, this paper transforms the yacht sample subjective preferences of the owner into quantitative values.

(1) Sample selection: chose 18 Ferretti yacht side shape sample images, and conduct grey processing.

(2) Subject selection: hire 40 ship owners and designers around the Pearl River Delta as the objects of investigation, who are aged from 25 to 50 years old, with more than 2 years yacht driving experience or 5 years yacht design resume.

(3) Experiment conducted: Compare the 18 Ferretti yachts with each others, score them according to the participant's subjective image and ask the participants to describe their inner feelings with simple adjectives.

(4) Result analysis:

In order to determine the appropriate clustering value, principal component analysis processing is added in the SPSS, as shown in Figure 4.According to the analysis results, it is found that the clustering system eigenvalue falls below 1 when the number of components is up to 11. Although the larger the number of categories can make the system more comprehensive, the difference between the clusters may be reduced. What’s more, the difficulty to distinguish the characteristics of each group adversely affected the subsequent product line planning. The principal component analysis also includes another way to observe the appropriate principal component: When the principal component is 1, the eigenvalue is at a high position. When the number of components is 2, the eigenvalue declines sharply and the curve meets the first inflection point. After the inflection point, the curve gradually becomes smooth, the number of components increases and the eigenvalue decreases. According to the component analysis principle, the component number of inflection points or nearby is usually used to interpret the target system. In this paper, we choose 2 as the appropriate clustering value, which on one hand can explain the type of preference approximately, on the other hand can also ensure that each type has significant differences.

The number of components

Eigenvalues

Figure 4. Gravel map

The clustering numbers were substituted into the K-means clustering analysis. The two groups G1 and G2 with the desired image difference were calculated as shown in Table 2. Members of the same group have similar design preferences.

Based on the data above, preference of the same sample from different groups involved in the test is not exactly the same as shown in Table 3.

Simultaneously, a total of 32 yacht designers with design background and 3 years of design experience (23 to 28 years old, 14 females and 18 males) were invited to evaluate 12 yacht design styles combined with semantic difference method by the score scale. As a result, three yacht design style image dimensions were identified, respectively, A1: sports - elegant; A2: ordinary - fashion; A3: mature - young.
Table 2 The Expected Image Mean of The Members of The Test Group

<table>
<thead>
<tr>
<th>Sample</th>
<th>P01</th>
<th>P02</th>
<th>P03</th>
<th>P04</th>
<th>P05</th>
<th>P06</th>
<th>P07</th>
<th>P08</th>
<th>P09</th>
<th>P10</th>
<th>P11</th>
<th>P12</th>
</tr>
</thead>
</table>

Table 3 Yacht samples preferred by each group of subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>Preference yacht samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>P06, P07, P08, P09, P10</td>
</tr>
<tr>
<td>G2</td>
<td>P01, P02, P03, P04, P05, P11, P12</td>
</tr>
</tbody>
</table>

A total of 12 yacht samples were extracted, and each factor score was taken as an independent variable. The expected image of each population was the dependent variable. Multiple linear regression analysis was performed in SPSS. The following indexes were obtained:

G1: \( R=0.784, \ R^2=0.856, \ \text{Anova measured equation} \)
\[ \text{Sig.}=0.046. \]

G2: \( R=0.778, \ R^2=0.606, \ \text{Anova measured equation} \)
\[ \text{Sig.}=0.078. \]

At the same time, the significant coefficients of G1 and G2 equations were less than 0.1, indicating that the expected images of the two groups were strongly correlated with the three common design factors. The model coefficients for each group are shown in Table 4, among which, the positive and negative coefficients represent the expected image level of the yacht design style.

Table 4 Model coefficients of each group

<table>
<thead>
<tr>
<th>Style factor</th>
<th>G1 Coefficient</th>
<th>Sig.</th>
<th>G2 Coefficient</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Sport - elegant</td>
<td>0.13</td>
<td>0.234</td>
<td>-0.534</td>
<td>0.214</td>
</tr>
<tr>
<td>A2 Ordinary - fashionable</td>
<td>0.27</td>
<td>0.142</td>
<td>-0.58</td>
<td>0.157</td>
</tr>
<tr>
<td>A3 Mature - young</td>
<td>-0.463</td>
<td>0.045</td>
<td>0.312</td>
<td>0.123</td>
</tr>
</tbody>
</table>

By comparing the model coefficients of each group, two different yacht product lines are obtained: sports yacht (L1) and business yacht (L2).

4.2 Evolutionary Function of Ship Owner's Expected Image

The personalized gene is described by the coordinates of hard points and control points on the three Bezier curves. The multivariate linear model coefficients were obtained by performing multiple linear regression analysis in the SPSS, and the mapping model was established by using the expected variables of two groups as the dependent variable and genes of 12 yacht samples as independent variables. The equation coefficients are shown in Table 5.

Table 5 The test group G1 and G2 corresponding to the mapping model coefficients

<table>
<thead>
<tr>
<th>Model G1 Non-standardized coefficient</th>
<th>Model G2 Non-standardized coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>(constant)</td>
<td>(constant)</td>
</tr>
<tr>
<td>16.590</td>
<td>2.332</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>-1.828</td>
<td>1.711</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>0.256</td>
<td>-0.673</td>
</tr>
</tbody>
</table>
According to the non-standard coefficient, the multiple regression model is obtained.

L1: sports yacht

\[
\text{Pref}_1 = 16.590 - 1.828A + 0.256D - 0.065E + 0.848J + 0.099K - 0.070O - 0.263Q + 0.265R + 0.180S - 0.162U - 0.291Z
\]

L2: business yacht

\[
\text{Pref}_2 = 2.332 + 1.711A - 0.673D - 0.164E + 0.664J - 0.016K - 0.021O + 0.284Q - 0.005R - 0.081S - 0.040U - 0.046Z
\]

### 5. Expected Evolution and Family Design of Yacht Side Profile of Shipowner

Based on the genetic algorithm, after the evolutionary calculation of the personalized gene, the family gene is superimposed on the personalized gene to complete the whole application.

1. **Initial population.** Use population function to create discrete random population:
   \[
   \text{[chrom,lind,basev]}=\text{crtbp(nind,lind)}
   \]
   Create a random binary matrix of nind × lind size. Nind refers to the number of individuals in the population while lind refers to the length of the individual, the sum of the length of the 26 variables in the individual variable pool. By assigning independent variables and converting them from decimal to binary, the initial population is formed.

2. **Fitness function.** According to the expected image adjectives of ship owner and their weight analysis, the gene evolution function conforms to \(F(X) = f(x)\), so it can be directly used as the artificial fitness function of the genetic algorithm.

3. **Algorithm parameters.** In the conventional genetic algorithm, the population size is large, so the crossover probability \(P_c\) is usually between 0.25 ~ 0.75, and the mutation probability \(P_m\) is usually between 0.01 ~ 0.20. In this study, due to the complexity of yacht modeling and the limitations of scope of the case and artificial participation in the evaluation of fitness, the population is small. Therefore, the variation probability \(P_m\) is added in the process of modeling characteristic line evolution. After the algorithm is debugged, it is suitable that mutation probability \(P_m\) is between 0.2 ~ 0.4.

4. **Convergence conditions.** Preference-driven yacht side profile design gene evolution is searching for a collection of "consumer satisfaction" solutions. Based on the fitness filtrating, experts combined the satisfaction of consumers to set convergence conditions. The evolutionary iteration ends after an optimal solution.

5. **Algorithm programming.** Use the Sheffield genetic algorithm toolbox in Matlab for algorithm programming. Each product line is coded independently according to their corresponding evolutionary function and corresponding initial population.

Through the genetic algorithm above, optimal subgenus after the evolution of individual gene is obtained, and the 26 variables representing the personalized gene are reduced to the corresponding coordinate values, through which the Bezier curve Line can be reproduced in the two-dimensional coordinate system. Table 6 shows respective coordinate variables of two product lines after the optimum algorithm. Figure 5 shows the optimal descendants of the two products after the optimum algorithm.
On the basis of personalized genes, the yacht family of genes are added to build a complete yacht side view design, successfully shaping side view images of different product lines which are both differentiated and inherited, as shown in Figure 6.

Considering a single yacht product line, we first need to obtain a key contour design scheme through the genetic algorithm. The superimpose family genes it is used to build a consistent style of the yacht side line of sight scheme. The two designs are highly similar but also have nuances. Therefore, by applying this method, yacht product family spectrum can be quickly built, and multiple product lines can be generated at the same time, which enables yacht enterprises to create and present consistent brand image.

6. CONCLUSION

Taking the characteristic line of luxury yacht as the research carrier, and based on the genetic algorithm, this paper combines the evolutionary calculation of the yacht with the gene design theory of family shape, studies the evolution of ship owner's expected yacht lateral appearance gene, and preliminarily proves feasibility of the method, which provides reference for shaping the branding of yacht and the innovation of individual design.

(1) This paper discusses the process of family design of yacht appearance modeling, and analyzes the whole process.

(2) In the field of yacht design, the artificial fitness assessment mechanism based on ship owner's expected image is explored to realize the evolution goal of yacht.

(3) The evolutionary design project of luxury yacht appearance modeling gene is applied and the rationality and feasibility of the method are verified.

Further Works:
Due to the complexity of the appearance design process of the luxury yacht, this method still needs to be further studied. The author's is going to carry out a computer concept design system, preferably connecting the

### Table 6: Each Product Line Evolved After the Personalized Gene

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>D</th>
<th>E</th>
<th>J</th>
<th>K</th>
<th>O</th>
<th>Q</th>
<th>R</th>
<th>S</th>
<th>U</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.69</td>
<td>0.82</td>
<td>15.53</td>
<td>1.50</td>
<td>22.32</td>
<td>30.35</td>
<td>37.65</td>
<td>7.10</td>
<td>50.25</td>
<td>55.22</td>
<td>5.36</td>
</tr>
<tr>
<td>G2</td>
<td>1.03</td>
<td>1.20</td>
<td>9.02</td>
<td>2.33</td>
<td>26.59</td>
<td>30.20</td>
<td>34.20</td>
<td>8.23</td>
<td>55.44</td>
<td>60.20</td>
<td>7.23</td>
</tr>
</tbody>
</table>

![Figure 5: Examples of Personalized Genes](image)

![Figure 6: Superimposed After the Design](image)
evolutionary results with post-modeling design, and to fully verify the method.

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