



ARTICLE

Application of Feature Curves and Shape Blending on Yacht Designing

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ABSTRACT

The global yacht market share and industry might expand continually since increasing people are willing to enjoy the yacht life in lower price nowadays while yacht activities were regarded as a luxury activity in the past. Additionally, Taiwanese yacht manufacturers are well-known worldwide. They show excellent performances on the international annual rankings which implies Taiwan has excellent manufacturing technologies. However, Taiwanese manufacturers so far do not have a mature local design team. Therefore, this study goals to developing a systematic and objective design method for hull designing, which facilitates designers to design innovative yachts or create a series product with brand recognition. This study is divided into three parts: the first part is the investigation of the yachts market; the second is establishing a shape blending platform; the third is 3D forming. Finally, it is used the existing ship CAD software to design an innovative yacht based on the blended curves and then calculates its basic hydrostatic performance. This study provides a quantitative method to create a new form and to preserve the features for a brand. The exist yacht combines with other graphics to create a new form and maximizes the features of the original graphics.

1. Introduction

The yacht industry has had a stable demanding market in Europe and American. In recent years, the market for yachts, water amusement facilities and related industries has expanded depending on the people's attention to leisure and entertainment. At present, the market capacity of the entire yacht industry in the world has exceeded USD 40 billion. Because of the world economic growth, the adjustment of the supply and demand scales, and the large number of old ships that need to be renewed, the overall demand for new ships will remain above a certain amount.

In the past, the yacht market was mainly distributed in North America, Europe, the Mediterranean, and New Zealand and Australia. With the rise of Dubai and China in recently, the demand in these two regions has grown rapidly. According to the global luxury yacht market survey report of Wise Guy Reports in 2017^[1], the market and growth trend of the future yacht industry are pointed out in the article because of the growth of millionaire families and the popularity of yachts as luxury sports. Thus, they have increased the market demand for private yachts. In addition, the market size in the following ten years is forecast to grow. By 2022, the global market can reach USD

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74.7 billion ^[1].

Taiwan has a land area of about 36,000 km² where contains 31 yacht manufacturers and several of which are well-known worldwide. Our construction abilities have been favored around the world as well. Also the yacht manufacturers have been ranked in the global rankings recently. For example, Horizon Yachts has been ranked among the top ten manufacturers in the world for many years ^[2], and the Ocean Alexander, their number of yacht sales in 2016 also jumped to the fourth place in the world ^[3]. Those show Taiwanese yacht manufacturers have good reputation and are trusted by the international customers. However, Hsing Hang Marine states on its official website that the yachts produced by Taiwanese brand have not yet established their own distinctive style and brand characteristics. It is to say that Taiwan still hasn't had its own yacht designer team. Most of the current ship plans are designed abroad. It is more difficult to develop the specific characteristics of the company.

In recent years, the manufacturers in Asia, such as South Korea and China, has also been continuously improving. Among these countries, China progress the most. In such a competitive environment, to maintain market share and the company's profitability, Taiwan should break through the present operation modes of buying designs from abroad, and consider both future trends and one of the major features of Taiwan's yacht industry. Adding features to their products highlights the values and significances behind the brand, while the product can be modularized, launched a series of products, and used for innovative design to increase recognition.

For many modern industries, the application and design extension of the brand series are the design direction of the new era. Yacht design can also use this concept to develop specialty products. The purpose of this study is to apply computer-aided design (CAD), systematic collaboration design, and the concept of brand feature to establish a system that is suitable for yacht design: develop new forms with the shape blending method, and judge the form with the principles of aesthetics, which is no longer relying on the designer's personal aesthetic to design the appearance of the yacht.

2. Related Works

2.1 Feature Forms and Aesthetics

In the product design, the appearance is the most basic form of a product. Regardless of the functions, the appearance has a tremendous influence on product sales, and sometimes plays an important role in whether the product can survive successfully ^[4-6]. Therefore, for mature prod-

uct makers in the market, it is critical to stand out from the vast competitors in the case where the market share of the product is close to saturation and the product function and manufacturing technology are highly mature. When the brand is identified as a combination of elements, nothing can be ignored and the product conveys brand value through its appearance ^[7]. Overall, family features and the establishment of perceived connections between brands and consumers, with their design needs and business economic considerations, which may be a key factor in determining whether the product is sold successfully in the market.

Regarding the basic principle of aesthetics within the past days, Plato once stated that the thing with symmetry and regularity was beautiful. Most forms of beauty were possessed regular geometric shapes, conforming to the appearance of natural look. Birkhoff, the first scholar proposing quantitative beauty, applied the calculations of beauty on forming, poetry, music and other fields in his book Theory of Aesthetic Mathematic. He applied the above concepts to quantify the beauty by mathematics. ^[8] Later, Staudek used Birkhoff's aesthetic formula to discuss the contribution of the measurement method regarding the aesthetic quantification of the appearance of the object and he verified it by vases (shown in Figure 1) ^[9]. The several types of characteristic points were created along the outline: terminal point, point of inflection, point of vertical tangent, and point of abrupt change in the direction of tangent. (Eq. (1)).

$$M = \frac{H + V + P + T}{C} \tag{1}$$

Where H is the number of the horizontal order, $H \leq 4$; V is the number of the vertical order, $V \leq 4$; P is the number of the proportional order, $T \leq 4$; C is the number of the tangent order, ; is the complexity of the characteristic points and M is the aesthetic measure.

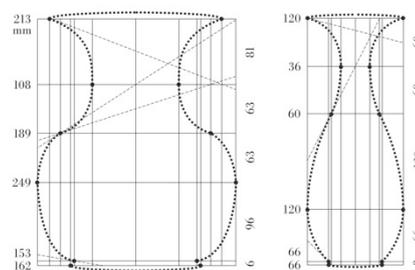


Figure 1. Tomáš Staudek's aesthetic measurement of vases

Hsiao & Tian added the appropriate parameters into the original aesthetic measure. The new formula could

be applied to the 2D curves and 3D surface. Also, they proposed the measurement of the order, complexity, and aesthetics of the form as the evaluation basis of the form aesthetics for designers. Finally, it assisted designers to design new products.^[10]

2.2 Shape Morphing

Shape homogenization and shape blending can generate new forms by interpolating and extrapolating the parameters of product forms, following certain rules to produce changes in the form, such as displacement, shrinkage, elongation, inversion, etc. Hui and Li in their feature-based shape blending study decomposed the form by semantics, components and points, thereby proposing features that could be blended and establish the correspondence between object features. The normalized weights were used in interpolation to find the corresponding relationship of feature points and to blend two models.^[11] With the operations, the features of the form could be preserved during the blending process. In addition, the property of the interpolation was that the new blended feature was predictable when the two patterns were blending and tended to be similar with which pattern. After blending the 2D curves, the final 3D model was synthesized by the 2D curve boundary outlines. Finally, 3D model was generated.^[12]

Hsiao et al used reverse engineering in combination with shape blending to create a reverse engineering methodology which could be applied to shape morphing. Combining with the existing CAD software provided industrial designers to structure ideation more quickly. The different part from the former study was the corresponding various point methods. Ray firing method calculated the angle between the end-to-center point line and the horizontal line through the center axis of the input shape. It was determined that the two end points were on the same ray diverging from the center point. When the difference between the two angles was the closest, it was regarded as a group of similar corresponding points. After the points were determined, blending operations could be performed. This study proposes four blending methods and uses different weights to adjust the specific gravity of the two components.^[13-14]

3. Methodology

This study contains only determination of “design requirements and major dimensions” and “ship design and hydrostatic performance”. The rest is not considered in the study. The research process is mainly divided into two parts, as shown in Figure 2, which are the forming design

and the conceptual yacht design. Finally, it is to present a new yacht with distinctive features and a system model that could be applied to design concept yachts.

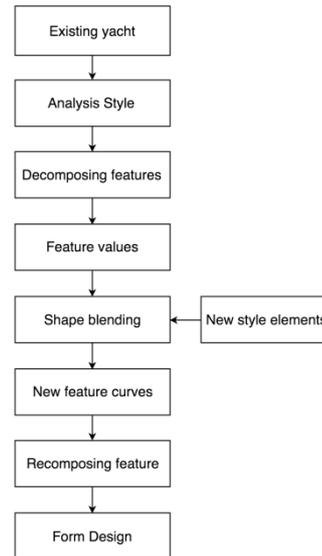


Figure 2. The process of the research

3.1 Limitation and Specification

This study selects the yacht's feature form as the research object and focuses on the exterior design only although numerous factors have to be considered in designing a yacht. The color of the appearance is also excluded so all the yacht samples in the study show black and white. Except for the forming factors affected by regulations, the other factors might make a concession to the exterior design. The interior compartments will be referenced to the planning of the original yacht. Due to the huge scale of the yacht, this study focuses on the elements and features of the sideways. Other perspectives are used as an assistance. Finally, it presents in 3D computer model.

In this study, the rulers of an existing yacht are used as a reference to obtain a datum model. In order to simplify the research scale, few factors are taken into consideration, such as speed, stability, resistance, load, and buoyancy requirements. There is not a specific owner and shipyard, so the budget and the manufacturing technology cannot be confirmed, and this study doesn't consider the main engine as the variable. Also, the overall cost and total weight cannot be estimated. Finally, the calculation of manipulability, resistance to wave and sinking are excluded as well.

3.2 Setting of the Design Samples

3.2.1 Yacht Samples Selecting

In this study, it was going to combine the existing

yacht's form with other features, so the eight samples, named in order from A to H, were selected as a reference based on the survey results. (See as appendix A.1) The first choice for yacht samples was that the manufacturer designed and built the length between 25 to 40 meters of yacht. For its style to reach the modern trend, the ship should be built within five years, and its main function was leisure. There was at least one closed interior space on the deck. It was mainly driven by fuel and achieving the buoyancy requirements and the regulations.

To concentrate on the exterior design, the samples presented to the participants should be displayed by outlines and feature curves, and excluded materials, color. At the same time, the influence of brand preferences on the participants was excluded as well. At the time of the investigation, the brands of the eight yachts were not disclosed: the participants only knew the length, beam and draught of the yachts.

3.2.2 Expert Survey

The study interviewed 11 yacht experts and conducted a survey of preferences, including engineers, designers and operations managers of ship researchers, shipping agents, and who were interested in yachts and had a certain level of understanding multiple yachting experience and understand the Taiwanese yacht brands, concerning about the latest yachts often.

11 experts conducted style analysis on eight ships and ranked them in order of preference. The interview results showed that the eleven experts disagreed on the style view, but only the G (Figure 3) had a similar view. In terms of the preference ranking, the number G also was scored the highest. Thus, it was going to use the number G yacht on the following study.



Figure 3. The yacht G

In addition, the interview also questioned the experts' views on the innovative yacht styling and their acceptance of the design of the Taiwanese elements. The acceptance was also divided into 11 stages, more score more acceptance. The answers were all positive, the score statistics were shown in Figure 4. At the same time, this study provided several Taiwanese elements, namely: butterfly, Taiwanese salmon, Taiwanese leopard cat, Hakka pattern, aboriginal pattern, Taiwanese aborig-

inal canoe, orchid and Taipei 101 (shown in appendix A.2). The eight options for the subject to choose and to add in the yacht design were ranked. According to the top five elements of the most wanted element and based on the result, the highest score of the aboriginal pattern and the second highest score of Taiwanese leopard cat are selected to add in the design.

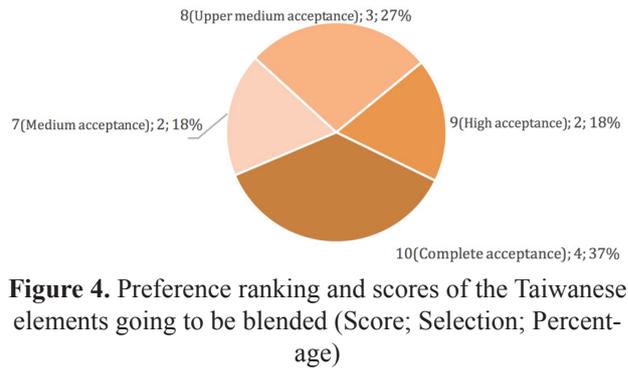
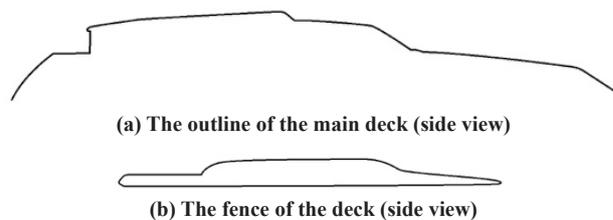


Figure 4. Preference ranking and scores of the Taiwanese elements going to be blended (Score; Selection; Percentage)

3.3 Shape Blending and Selecting the Feature Curves

According to the results, this study selected the top two scores: Taiwanese aboriginal pattern and Taiwanese leopard cat as the Taiwanese feature elements for the new concept yacht design, respectively decomposing the feature curves, and then composing new elements and shape blending of hull.

The hull sample used the G yacht as a reference and the study selected its local feature curves. According to the side-view diagram above the waterline, the yacht curves could be divided into outlines, windows, structural lines, details, the parts of which to adjusted are selected. Then, they were blended with the same or different feature elements. The datum hull was created by DELFTship™ free, from which the outlines of the various views were obtained, and the side view and top view of the G yacht were used to obtain more detailed curves, shown as Figure 5. With the lines in the front view, top view, and right view, the curves that represent the features of the Taiwanese leopard cat could be selected. The curves of Taiwanese leopard cat's round head and strong musculoskeletal features were the final decision to join the new form of the yacht, shown as Figure 6.



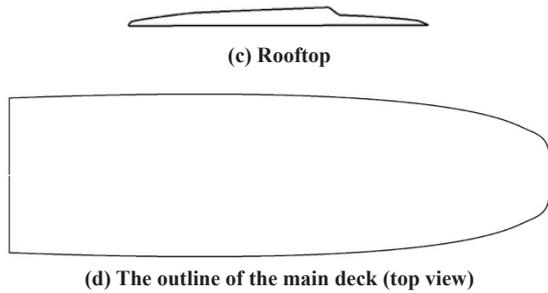


Figure 5. The feature curves of the G yacht

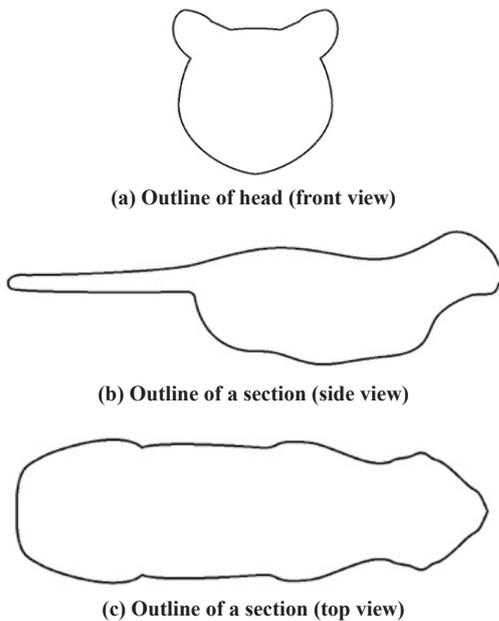


Figure 6. The selected feature curves of Taiwanese leopard cat

The function of the aboriginal patterns could be classified to records, legends, blessings, etc. After referring to the shape, story behind the pattern, the study selected the hundred pacer (Deinagkistrodon), a kind of snake, and the eye of the sun as the blending elements.



Figure 7. Taiwanese aboriginal patterns

The hundred pacer is an important god in the group of Taiwanese aborigine, called Paiwan, faith. The people believe that the hundred pacer could bring good luck, and only the nobles can engrave the hundred pacer pattern on the ornament, which is a symbol of status. The eye of the sun is the decoration on the Dawu's canoe, another group of Taiwanese aborigine. This pattern means the eyes of their unique fishing boats, leading the way for seafarers and blessing safe and healthy.

4. Results

The study, based on the feature parameterization method, shape morphing and other methods combining with the existing 3D CAD software DELFTship™, established a new concept yacht design process and connects them in JAVA programming language.

4.1 The Framework

After understanding the steps of the overall yacht design, the preferences of the current existing yachts from the experts and the speculations of experts on the future forming trends were obtained, as well as the features of Taiwan to be blended through the data from interviews with experts. Then the platform in JAVA could calculate the new feature curves by shape blending method, and exported the result image to DELFTship™ in order to build a 3D model and calculate the hydrostatic performance. After adjusted to a workable vessel, it was finally calculated its aesthetics values.

4.2 The Interface and Method of Shape Blending

A blending platform was written by JAVA, shown as Figure 8. After the hull and one of the sectional curves of Taiwanese leopard cat were inserted into the platform, the blending operation could be performed. The steps were as follows:

- (1) Inserted the point data (.txt) of the yacht and the element separately.
- (2) Adjusted the yacht weight W_s and the element weight W_e , $W_s + W_e = 1$.
- (3) Clicked the Blending button to blend.
- (4) The SAVE button stored the blending result in the image file (.jpeg).
- (5) The Clear button cleared all point data and display curves shown on the interface.

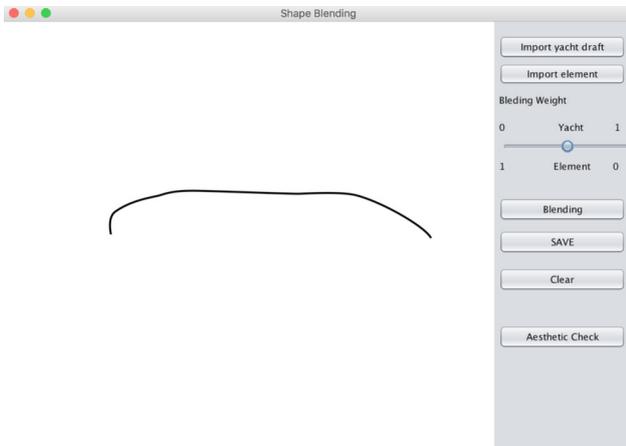


Figure 8. The blending interface

After inserting the feature curve data, the point clouds would be converted into eigenvalues in the platform which would be normalized, and then the blending operation would be performed, converting the new eigenvalues calculated in the platform. After the data was formed, the points were connected in order by interpolation and a new feature curve was created. The result was accessed in the JPEG file.

There were four different methods for the above-mentioned blending operations: arithmetic mean method, geometric mean method, harmonic mean method and generalized weighted mean method. The four algorithms were input into the same weighting operation and compared. Because this study still emphasized on the feasibility of the hull, the blending pattern should be closer to the original one. The arithmetic mean and the geometric mean were closer to the original hull line plan. The harmonic mean showed more features of the blended element. The generalized weighted mean method had obvious differences between the original hull line plan and the characteristic elements (the four methods under the same weight value). Therefore, the arithmetic average was chosen as the calculation method of shape blending.

4.3 The Results of Shape Blending

The point clouds of the new form curves were calculated by the arithmetic mean and the new curves were calculated by interpolation in order to find the most suitable result with different weight values. The two curves of the blending process must be at the same view, such as the most upper waterline of the basic hull and Taiwanese leopard cat in the top view and the side hull outline and the side outline of Taiwanese leopard cat, as shown in the Figures 9 and 10. Some were mainly selected from yachts and blended with part of Taiwanese leopard cat curves. Figure 11 shows the outline of the fence on the deck and

the curve of Taiwanese leopard cat from back to hip. Additionally, there were selecting part of two samples, namely the front end of the upper deck of the main deck and hundred pacer's head, as shown in Figure 12.

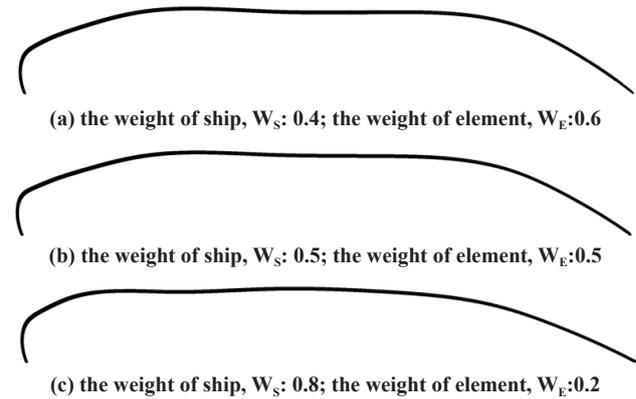


Figure 9. The blending results with different weights from the waterline of the datum hull and the top view of Taiwanese leopard cat

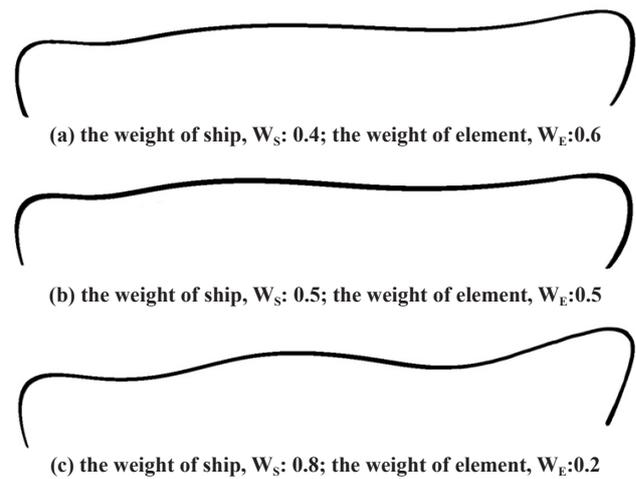


Figure 10. The blending results from the side outline of the datum hull and the side outline of Taiwanese leopard cat

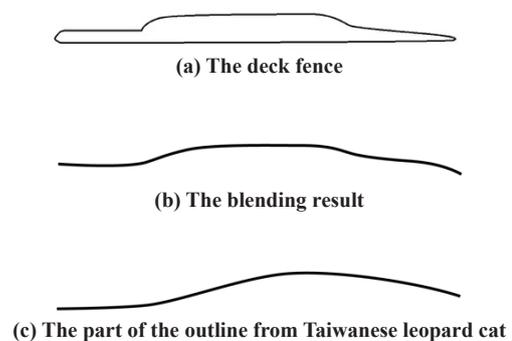


Figure 11. The blending results from the deck fence and part of the Taiwanese leopard cat's outline



Figure 12. The blending results from the top view of main deck and the hundred pacer's head

4.3.1 3D Forming and Hydrostatics Test

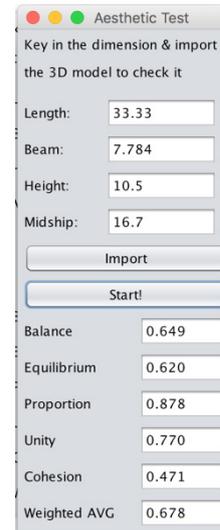
The basic model had been obtained by DELFTship™ free, and then a new feature curve was obtained by the software calculating. The original model was adjusted according to the new feature curves to obtain a new model of the yacht. Finally, it was necessary to calculate the hydrostatic performance of the new yacht. If it failed the testing, the form of the yacht had to be adjusted. It was three revises to obtain the yacht that achieved hydrostatic performance standard in the study.

4.3.2 Aesthetic Test

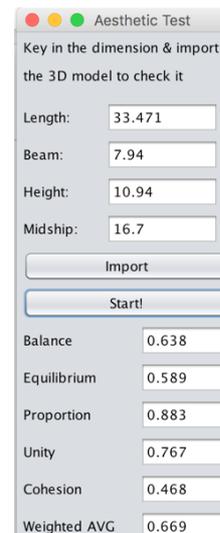
After the hydrostatic performance test, the 3D stereo model was output, and then returned to the JAVA platform for aesthetic testing. The new yacht model was divided into two main objects and elements. The centroid position and plane projection position were calculated respectively. It was five aesthetic factors, such as balance, unity, equilibrium, proportion and cohesion to be tested. Finally, combined the five factors to calculate the average aesthetic value (all weights were 1), and the values were all between 0 and 1. The closer to 1, the more objects met the ideal standard of aesthetics.

The final result obtained in the previous step was imported into the JAVA for aesthetic test. The following results obtained were 0.649 for balance, 0.620 for equilibrium, 0.878 for proportion, 0.770 for unity and 0.471 for cohesion, as well as 0.678 for the average (Figure 13 (a)). The result was greater than 0.5 for the aesthetic test, so in this test, the cohesion project did not achieve the standard. It was necessary to get back to the previous steps to adjust the yacht model.

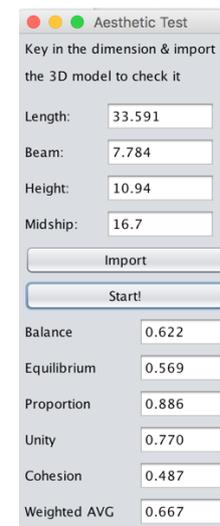
After the revise, the aesthetic test results were shown in Figure 13 (b). It could be known that the cohesion value in the second result had not passed the test, so the yacht model had a fine adjustment again. The third results obtained by the test were balance 0.622, equilibrium 0.569, proportion 0.886, unity 0.770, cohesion 0.487, average 0.667 (Figure 13 (c)). Although the value of cohesion was improved, but it was still less than 0.5. However, this study focused on the accessibility of the yacht, so the step could move on to the next step if it failed over three times.



(a) the first result



(b) the second result



(c) the third result

Figure 13. The results of aesthetic test

4.3.3 The Final Result

After repeatedly adjusted the yacht model through the hydrostatic performance and aesthetic test, the final result was shown in Figures 14 and 15. This new yacht was a private yacht for leisure and entertainment, suitable for families or entertaining guests. The design had a length of 33.40 m, a total length of 33.59 m, a design beam of 7.30 m, a total beam of 7.78 m, a design draft of 1.7 m, and a hydrostatic performance result of a relative water density of 1.025 and a mean shell thickness of 0.015 m. The molded volume was 122.038 m³, the displacement was 127.37 tons, the longitudinal center of buoyancy is 16.301 m, the block coefficient was 0.2998, and the waterplane coefficient was 0.4932. There were two closed cabins and an open platform above the deck.

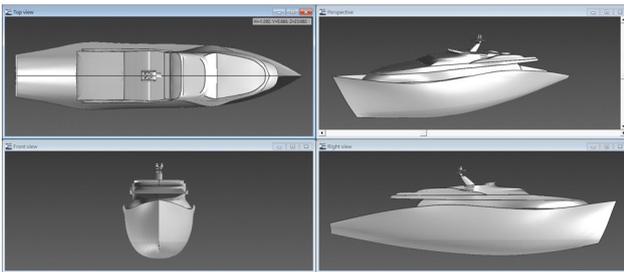


Figure 14. The final result



Figure 15. The rendering diagram of the final result

The hull is mainly blended with the Taiwanese leopard cat, showing the body curve of the Taiwanese leopard cat. The other parts that has more angular curves and the fence on the deck are also blended with the Taiwanese leopard cat's feature curves to make it more round. Also, above the main deck, a part of the yacht outline segments uses the hundred pacer's head to blend. The hundred pacer is a respected god in the belief of the Paiwan people. It implies blessings that the hundred pacer on the deck leads the vessel going forward, wishing sailing safe. In detail, the new yacht shows the features of the aboriginal patterns, repeated and regularly arranged. Thus, a little decoration is added to enhance the image of the aboriginal patterns.

The eye of the sun is installed on the bow which follows its original meaning: the eyes of vessel. Such pattern is bound to be engraved on the canoe of the Dawu people to protect the crews from the navigation. In the results of this study also adds such elements. However, in order to make it more concise, this design slightly simplifies the original graphics, but carries the same meaning as the origin, a wish of safe sail.

5. Discussion and Conclusion

Based on the feature parameterization method, shape blending and other methods combined with the existing 3D CAD software DELFTshipTM free and Rhino 5.0, this study established a new concept of yacht design process, and uses the JAVA programming language to carry out the calculation of point data.

5.1 Feature Curves and Blending Method

In this study, the feature forming is decomposed, and the feature curves are defined by the quantitative method. The necessity of the original yacht feature curves is analyzed, which can match the appropriate product image to know the understanding of the forming curve on the consumers' perceptive, and then it is possible to select the appropriate feature curves, blended with the feature curves of other items to obtain a new feature curves. The feature data established through this mode is not only fast and objective, but accessible and possible to redevelopment in the future, which is easy to analyze in the research. The method can help the designers to develop new form, provide the designers new inspirations, and be able to mix the features curves of different things altogether at the same time. Such benefits are conducive to the development of regional style. Also, it is easy to preserve the feature data, which can be further developed and updated from this data, renewing the brand characteristics.

The platform written by JAVA program reads and blends the point data, and generates the image files that can be used for DELFTshipTM free in the study. The obtained two data of point clouds are sorted out and then the remaining points are relocated and arranged in order. Finally, the two points data are integrated by ray firing method to obtain the same number of points for following calculation; in the blending process, the sorted point data is first converted into feature values and then normalized. Blending is performed on the same scale to avoid distortion due to different sizes. Calculate the new feature value, and then go backward of the previous steps to get a new feature curves.

The comparison of the results of the four formulas of

the blending method shows that the results of the arithmetic mean and the geometric mean method are similar to the original graph, and the blended curves are more predictable. The result of the harmonic mean method is significantly different from the original graph. However, it can still be seen that it is a little similar to the original, and the generalized weighted mean method has the biggest difference. Because this study focuses on the feasibility of the vessel, the arithmetic mean and geometric mean method are more suitable so this study uses the least difference method - arithmetic mean. At the same time, it can be seen that the harmonic mean method is suitable for the development of brand new product, subverting the impression of the past.

5.2 Problems and Discussions

The results of interviews with relevant industry workers and experts show that the participant's perception of each yacht is different, only a few in common. The possible reason causing the problem is that the definition of each adjective is not clearly defined, so the participants might follow their thinking based on growth background, experience and understanding of the vocabularies. These results in different imaginations, which lead to divergence of results. Therefore, it is necessary to guide the participants to understand before they fill in the questionnaire, to describe the connection between words and images, and to present photos in a monochrome stereoscopic model.

In the discussion of style and feature curves, this study only interviews workers and experts in related industries. In the future, it is better to add a large number of consumer opinions in this part, and further subdivide into statistical data of different regions, and even join the age segment for analysis. It can better reflect the market orientation, assist in the decision-making of the design, and then the accurately position in the market can capture consumer curiosity and inspire desire of purchase.

In this study, some blended feature curves are segment of the initial curves. This research method does not provide a feature curve that can be more automatically selected. In contrast, it is necessary to manually select the required curve segments. In this aspect, the computer program of the platform can add the ability about selecting partial curves, making the whole process more automatic and convenient. In addition, each software and platform are independent on each other at present. When data is processed, it is often necessary to switch between several software. If the platform for calculation can be rewritten as a plug-in for a forming software or doing operations inside the CAD software, it will be more convenient from blending to the forming process.

5.3 Conclusion

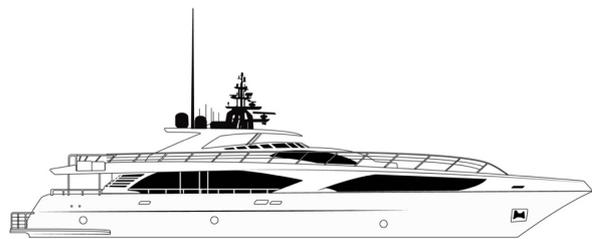
This study provides a systematic method to design the concept of yacht design: the existing yachts, with the actual animal, graphics, etc. into the yacht, constitute new curves, so that the figures can be properly combined with the existing yacht, the maximum present the special characteristics of the original graphics, and can meet the basic performance of the yacht and the legal norms. The new curve obtained from the shape blending method can also be completely preserved and provided for the next design use. The future development is to further improve the shape blending software, making the selected feature points more accurate and more representative in order to preserve the feature. Also, improving the software can decrease the time of the design process. Widely application for the brand company, it can be effectively established and save its own brand features, and further add new elements into the old product style. If a brand company wants a cross-over with different domains, this method can provide a higher level of cooperation.

Appendix

A.1 Eight Selected Yacht Samples



(a) Raised pilothouse yacht A



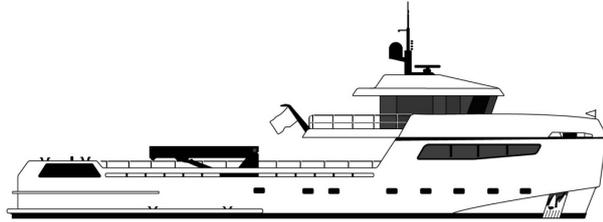
(b) Luxury leisure yacht B



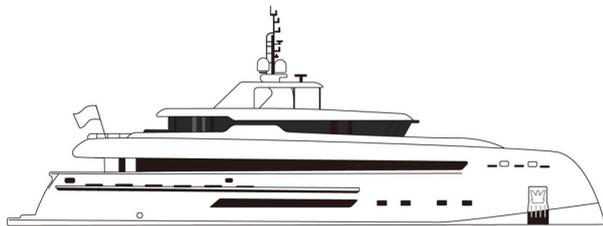
(c) Luxury sport fisher yacht C



(d) Luxury leisure yacht D



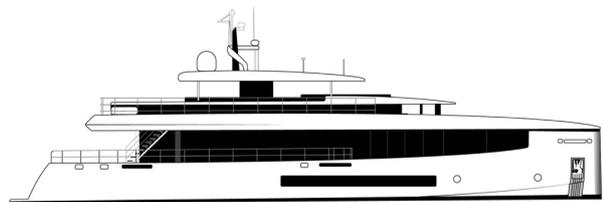
(e) Sailing support yacht E



(f) Luxury leisure yacht F



(g) Luxury leisure yacht G



(h) Luxury leisure yacht H

A.2 Taiwan's feature pictures used in the survey



(a) Butterfly



(b) Taiwanese salmon



(c) Taiwanese Leopard cat



(d) Hakka pattern



(e) Taiwanese aborigine pattern



(f) Taiwanese aboriginal canoe



(g) Orchid



(h) Taipei 101

Resources: Google Images, www.google.com.tw/imghp

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