Research related to the Appearance Design of Water Surface Cleaning Robot based on Bionics

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Abstract—This thesis analyzes five representative water cleaning robots selected from three countries and combines the top-down design process of bionics and the basic elements of product design to clarify the problematic points of existing water waste cleaning robots and propose a bionic design solution. The results of the analysis show that the shape design is not optimized according to the shape of the hull, and the environmental and aesthetic aspects are not satisfactory. By applying the three bionic principles of color, form, and material to the appearance of the robot, a robot that meets the needs of cleaning small urban waters is designed and derived. This proposal is an optimized solution to solve the existing defects of the product and complete the solution that meets the modern market demand, aesthetic patterns, and production methods.

1. Introduction

1.1. Background and Purpose
With the development of modernization and urbanization in the world, a large amount of urban waste is flowing into the urban water space, resulting in a serious over pollution of the water and an increasing amount of floating garbage. The ecological environment of urban waters is particularly important for building green ecological cities [1], and in order to clean and optimize urban waters, the demand for small cleaning robots on water is increasing. The purpose of this thesis is to design and derive a robot that meets the needs of small water cleaning in the city, using bionic principles of color, form, and material for the robot's appearance, so that the robot can meet the needs of the scene, meet the high efficiency of environmental protection work, solve the open, closed/semi-closed water scene, meet the needs of parks, scenic spots, parks, It can meet the needs of water surface cleaning in open and closed/semi-closed water scenes, such as parks, scenic spots, parks, small reservoirs and offshore waters. According to the relevant elements and theories of product design, combined with the design process of bionics, to complement and improve the product from the perspective of bionics, and finally propose a design plan.

1.2. Methodology and Scope
This thesis uses literature survey, domestic and foreign case investigation, comparative analysis and bionic design methods to conduct research. Through the study of the current situation of the appearance design of domestic and foreign water garbage cleaners, the analysis of the laws and information and characteristics, as well as the analysis of its problematic points, and then through the excellent product design cases using bionics at home and abroad, the analysis of the biological characteristics extracted from the product, and the comparative analysis of the product appearance elements to find the bionic
design laws, and the practical application of this design method in the final derivation of the scheme. This paper is a case study of product design from the perspective of product appearance, with the urban water environment as the main setting.

2. Theory Study

2.1. The concept and content of bionics

The term bionics is composed of the word's "biology" and "electronic". Bionics is the science of imitating the special skills of living things. Bionics was first introduced by J.E. Steele in August 1958, and is a science that integrates the principles of structure and function of living things to develop new machines and technologies, or to solve problems in mechanical technology. Bionics is a cross-discipline of life science, material science, information science, brain and cognitive science, engineering, mathematics, mechanics, plastic arts and system science[4]. The scope of research includes: mechanical bionics, molecular bionics, energy bionics, information and control bionics. Bionic design takes nature as the object of study, takes inspiration from everything, applies it rationally to design, and combines the results of bionic research to provide new ideas, new methods, new principles and new ways of design. The top-down product shape bionic design process can efficiently find solutions that can contribute to the innovative design of products, which can be more focused on the extraction and expression of biological shape eigenvalues and can better grasp the direction of innovative design development.

2.2. Concept and content of water cleaning robot

Table.1 Basic information about the water surface garbage cleaning robot

| Scope of work | Closed waters, scenic spots with small water areas, small reservoirs. |
|--------------|-------------------------------------------------------------------|
| Cleaning Type | Leaves, plastic, packaging and other garbage floating on the water surface. |
| Structure    | Most of them are composed of microcontroller, camera, ultrasonic sensor, battery, mechanical transmission device and impeller conveyor belt. |
| Principle    | Most of them use "harvester wheel" and "elevator transport" rotating transport form, and have the function of intelligent search and recognition of waste. |

When there are floods or typhoons, a lot of trash accumulates on dams and beaches, and it also floats for a long time in urban rivers. Water cleaning robots are intelligent boats and robots designed for water cleaning. It includes devices such as robotic boat interceptors and trash-absorbing robots that operate intelligently on water. Nowadays, small water robots are mainly autonomous floating cleaning robots. Water trash cleaning robots are more suitable for scenic spots or small reservoirs with small water areas.
[5]. It can salvage most of the trash that is floating on the water surface, such as leaves and packaging. Due to the simplicity of the operation process and the mobility of the radio remote control technology, it can achieve good results in the small water area of the park or scenic area.

2.3. The concept and content of product design
First of all, the design of the product appearance refers to the effective design of the product, so that it can have decorative features and high aesthetics, so that the product appearance design can be reasonably integrated in the three-dimensional, flat and other factors. At the same time, the product can also be made more personalized by adding various colors and lines. The basic principles are based on the market and consumer needs, enhancing aesthetics and personalization, multi-functional integration, applying modern science and technology, and following the human-centered design concept.[6] The so-called evaluation method, including two main aspects: one is the standard of evaluation, the second is the way of evaluation. Good product design should be measured by the five aspects of the criteria in the Fig.3[7].

Fig.3 The five elements of product design

3. Status Survey and Case Study

3.1. Survey on the appearance and characteristics of water cleaning robots

| Name      | Region        | Pictures | Morphology                                                                 | Material       | Color                        | Efficiency | Capacity | Function                                                                 |
|-----------|---------------|----------|----------------------------------------------------------------------------|----------------|-------------------------------|------------|----------|-------------------------------------------------------------------------|
| Clearbot  | China Hong Kong | ![Image](image1.png) | The overall shape of the ship is semi-submersible, with an arc shape as the main component, the front opening, and the internal conveyor belt. | PE plastic, waterproof coating | White hull, yellow light belt, red warning light | 8h/1 Square kilometers | 250KG     | - On-board camera detects trash - Artificial intelligence algorithm detects trash - Collects trash and brings it to shore |
| WasteShark | South Africa | ![Image](image2.png) | 164cm long, 46cm high, 114cm wide, with a rectangular catamaran form as the theme, the hull is flanked by two floats, the bottom is installed with a mesh structure shovel, both sides of the external propellers. | PE plastic     | White hull, yellow warning light, yellow logo and black font. | 1000 m²/h (11000 ft²/h) at 1 kn | 45KG      | - Removable basket cartridge for easy disposal - Onboard POI operator camera - Live data-capable - real-time water health quality data/depth |
| ORCA-SMURF | China         | ![Image](image3.png) | Length 2510mm, width 1580mm, height 1050mm. Semi-submersible ship form, more complex structure, with two square strainers protruding from the front. Externally equipped with electric propulsion. The structure is mostly linear. | Aluminum alloy  | The hull is made up of dark gray, cyan and white. | 24h/360KG | 20-40KG  | - Autonomous cruising of unmanned boats - Autonomous identification of floating garbage on the water surface - Timely cleaning of floating garbage in the water |
Wind and solar complementary water surface robot

The lower part is a catamaran structure and the upper part is a wind turbine propeller. The deck is a flat elliptical solar panel. The curved line is the main feature.

Wind and solar power generation technology
- Autonomous navigation, intelligent obstacle avoidance, path optimization
- Transmission and networked monitoring and other functions
- Grabbing garbage cleaning method, all kinds of water surface floating materials, cyanobacteria, etc. can be cleaned

SEAVAX

The lower part is a catamaran structure, consisting of two conical pontoons and a deck bridge. The upper part is composed of separate solar panels and the front part is composed of two propellers and a funnel.

Table.3 Analysis and Evaluation

| Analysis content | Morphology | Material | Color |
|------------------|------------|----------|-------|
| Advantages        | The double hull structure has a wide front section, which allows a large amount of waste to be sucked in. Large capacity. | PE plastic and aluminum alloy are more stable. | White, black and yellow are the main colors. |
| Disadvantages     | Too much external equipment and the machine itself form of resistance to wind and water resistance is large, resulting in low efficiency. | No environmentally friendly materials and hydrophilic materials are used. | The colors are monotonous, and the design does not take into account the environmental factors of the water. |
| Comprehensive appearance evaluation (0-5) | | |

As shown in the table, five representative water cleaning robots from three countries were selected to analyze the appearance factors. The analysis results show that the shape of the hull itself is not optimized in terms of appearance design, resulting in high resistance to wind and water resistance, and wind and water resistance should be considered. The exterior materials should be considered to be environmentally friendly so as not to cause damage to the water environment. The appearance of color needs to be combined with the characteristics of the urban water environment. On average, the overall appearance of the existing water cleaning robots are complete in terms of basic functions, adapt to market demand, safe and reliable quality, but the psychological appeal, innovative and aesthetic performance is insufficient, no clear value positioning. Due to morphological and technical problems, mass production is difficult, and the impact on the environment and society is small.

3.2. Bionic product design examples

Table.4 The use of bionics in product design

| Type of organism | Biological organs | Extraction type | Bionic product design | Application results |
|------------------|-------------------|----------------|-----------------------|---------------------|
| Butterfly wings  | Morphomimetic     |                 |                       | The seat has a symmetrical shape, with soft and modern lines. The curved form conforms to the body’s needs. |
Conch shell morphology  Morphomimetic  The staircase takes the form of a spiral, which makes use of space and saves floor space.

Pangolin dorsal stripe  Structural bionics  The overlapping design expands the backpack's capacity, provides better waterproofing and enhances its aesthetic appeal.

Honeycomb hole  Structural bionics  Increased air exchange, good ventilation and air permeability, reduced material consumption. High fit.

Protrusion on the front of a whale's fin  Functional bionics  A significant increase in efficiency, a 32% reduction in drag and an 8% increase in lift.

Mimicking fish behaviour  Functional bionics  An anti-collision system has been designed to automatically avoid nearby objects when they are detected.

**Table 5 Combination of appearance elements of aquatic robots and bionics**

| Elements for improving the appearance of water robots | Type of claim | Extraction type | Type of organism |
|------------------------------------------------------|---------------|----------------|-----------------|
| Form                                                 | reduced resistance, reduced energy consumption | functional bionics | Sea turtles swim with a low resting metabolic rate or high drag coefficient and require the least amount of energy to move a given distance, known as the 'optimal swimming speed'. Sea turtles and freshwater turtles have lower shells to reduce drag when swimming. |
| Sustainability                                       | Environmentally friendly, environmentally friendly, hydrophobic surfaces | Structural bionics | The sharkskin has hundreds of folds on its surface, known as skin teeth, which greatly reduce the resistance to water flow. The underwater stabilisation of hydrophobic leaves of Sophora applescens and the super-slip effect of Porphyra, with a micro/nano-scale rough structure that traps air pockets and holds up liquid droplets, thus achieving superhydrophobicity. |
At the microscopic level, the brick-mud structure of mother-of-pearl allows for the construction of high-performance materials based on common natural substances, making it a natural bio-based sustainable structural material with high strength and toughness characteristics.

The colours of natural creatures are first and foremost a feature and necessity of life, and chameleons are good at camouflage and have the ability to blend into their natural environment.

The simple curved lines and curved surfaces of the elephant are not only visually comfortable, but also protect children in the home and increase the emotional element between people and the product.

The existing bionic designs are mainly classified into three categories, namely morphological bionic, structural bionic and functional bionic [8]. The starting point of morphomimetic design is aesthetics as the core, combined with a small number of functional elements for production, which is based on the knowledge of the typical external form of animals, plants, microorganisms, humans, etc., seeking a breakthrough and innovation of product form, emphasizing the extraction of the aesthetic characteristics of the external form of living things and the expression of the aesthetic needs of human beings. It is characterized by abstraction and association. The core of structural bionic design is to study the reasonable composition relationship, based on the structure and organization of the whole and parts of natural organisms from the inside out, summarize the composition law and apply it to the innovative design of products. In the research of structural biosynthesis, we should accurately grasp the relationship between structure, function and environment, and focus on the inner principles of biological structure. The core of functional mimicry is the principle of function, which is to transplant a certain principle, structure and material of living organism to the related research field. The common purposes of functional mimicry are to imitate the working principle of biological sensory organs (eyes, ears, nose, etc.) or motor organs (legs, arms, fins, wings, etc.), to reduce the resistance of air or water, to improve the load-bearing capacity, to reduce the load of a component, to reduce noise, to reduce vibration, to reduce the adhesion of external materials, to control temperature changes, etc.
In short, to increase the aesthetics of product appearance, we can use the morphological bionic principle to generalize and change the biological image and extract the morphological elements; to increase the rationality of product appearance, we need to use the structural bionic principle to investigate the inner law of biological structure and external environment; to increase the functionality of product appearance, we can imitate the movement principle of biological organs or material organization according to the needs of the product itself.

Based on the preliminary analysis of the water waste cleaning machine, we selected the three most important elements to be improved, analyzed the type of demand and the type of extraction, and investigated and screened the biological types according to the demand, as well as analyzed the reasons, characteristics and effects of the selection. As shown in the Table.5.

4. Derivation of bionics-based design solutions

| Clarity design objectives | Design Solutions |
|---------------------------|------------------|
| The design of a sustainable, environmentally friendly, efficient, and emotionally designed intelligent water waste cleaning robot. | Because the robot works on the surface of the water, a hydrodynamic marine animal form was chosen for this design. It needs to be large and low in consumption. |
| Screen for bionic organisms | Sea turtles can reduce energy loss in the ocean and have a streamlined body shape with large body parts, large forelimbs to control water flow and direction and speed, and low noise levels. |
| Extraction of bionic appearance features | |
| Combination of product shape and biomorphic features | |
5. Conclusion
This paper first investigates the basic information on the scope of work and type of cleaning of water cleaning robots, clarifies the bionic top-down design process and product design elements, and provides theoretical support for the analysis of existing products on the market. Five representative water cleaning robots from three countries were then selected for the analysis of appearance factors. The results of the analysis showed that the design of the exterior form was not optimized for the form of the hull itself, and that the environmental and aesthetic aspects were not satisfactory. To compensate and improve these three factors, the author conducted a selection and investigation of bionic product design cases, mastered the three biological extraction methods and types of bionic design, and deduced the appeal points and solutions for improving the factors. Finally, a new design for a water cleaning robot is derived based on the bionic design process. Through research, study and analysis, this thesis derives a regular approach to guiding design practice, solving existing defects in the product and completing an optimised solution to meet modern market demands, aesthetic patterns, and production methods.

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