Bringing Interaction Design Methods and Experimental Technologies Together into Designing and Developing Interactive Products

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Abstract: This study aims to design and develop interactive toys. There are fifty master and bachelor industrial design students from the Beijing University of Technology involved in this project. This study adopts interaction design theory and experimental prototyping practices, enabling students to apply simple mechanical and electronic technology on generating interactive design concepts. There are five stages in the design and development process. The first stage begins with user research. Accordingly, product functions and morphology are investigated. Text and visual user scenarios are created as well. In the second stage, user-product interactions are examined in order to explore the context of usage. In the third stage, ten sets of conceptual designs are built with the application of Arduino based interactive prototyping platform. In the fourth stage, these conceptual designs are evaluated by users and technical experts. In the last stage, the design concepts are further improved based on evaluation feedback, and are processed into engineering and technical prototypes. The challenge lies in the correlation between interaction design considerations and application of technologies. The findings of our study imply a principle to face this challenge: bringing users, context, morphology and technology together to design and develop interactive products. Interaction design methods provide our students guidance and inspirations to generate conceptual design ideas. Experimental prototyping practices facilitate our students' ability to turn ambiguous ideas into feasible design artifacts. We envisage further developing our experience by conducting similar interaction design research studies again in the future.

Key words: Interaction Design, Prototype, System, Elements, Relevance Principle

1. Introduction

Interaction Design is initiated in the 1980 s, by Bill Moggridge in IDEO Design Company [7]. At preliminary stage, the human-computer interaction design that applies to visual interface design, such as human-computer interface interaction, multimedia game and immersive circumstances design. The purpose is to improve the ease and pleasure of use for the product. Later interaction concern becomes one of products entities, such as interactive toys for children, the elderly supplies, seats on the airplane, driving, etc. In this development process, the "ease of use" concern is gradually accumulated and it becomes the goal of interactive product design.

The concept and technology of Mechatronics is first proposed by Japan in the 1970 s, after 10 years, the idea of interaction design is spread around the world [5,7]. It is thought-provoking [5]. Due to the prevalence of computer, it is easier to combine with computer technology, which makes the mechanical, electronic, hydraulic, and optical technology into the high-tech era rapidly. Digital product is a modern trend. It replaces the classical mechanical

products and electronic products gradually, which is known as a complex system product. Whereas digital products also bring new problems at the same time since people's behavior can't keep up with their complex systems. Such as speed and sensitivity, dazzling interface and buttons (keys). In the past, simple operation of relay switch is functional enough to control a machine, but now it requires twice operations for the digital products. It distant people from seeing and touching, so there is a gap between users and products. Interaction design means to resolve the problem of human-computer interaction when advancing to complex systems. Whether should the machine adapt people's reactions and actions? Or the users should adapt the speed and efficiency of the machine? Bill Moggridge answered the question. Let the computer do the work that it is adopted in, and let people do the work that he (she) is good at [2,5]. Let the strengths of computers combine with human advantages. Ease of use thus becomes the friendly design philosophy of human-computer interaction. So interaction design was accepted and rapidly spread over the world [4,10].

The guiding ideology of this project is system theory. The technical route is human-computer interaction system design. It establishes the product analysis model for purpose, elements, structure and form, analyses the relevance principle of production system and module, and raises the concept of human-computer interaction design and design ability of digital product for students through a digital toys product design process. There are 10 teams from 14 graduate and 36 undergraduate students participating in this topic. The tutoring team includes 5 teachers from multi-disciplinary field such as industrial design, electronics and automation control engineering, industrial design engineering, art design, computer software engineering.

1.1 Design Tasks

Students are asked to choose an animal or plant with natural form, and to describe the external environment for existence and internal structure characteristics, understanding gradually with interest, extracting an abstract motion principle or survival technology sample by analysis, and design and producing a digital toy product with human-computer interaction that ease of use by a prototype of the sample [1,6].

- The selection and analysis process of the natural form. Description of principle and diagram of summary, words are easy to understand (sketches, video, storyboard, model, animation, etc.).
- Make a prototype or model with any material. Describe the advantage of this form and technology support by dynamic illustration of the model. Through the description of the principle, structure, strength, speed and user research, ordinary users can understand and believe in this product with good interaction of ease of use.
- Use MAX/MSP software for programming and one or two Phidgets sensors to control machine operation. Such as, use the sound sensor to control the speed machine. Or you can choose other programming software, which can make the machine run offline, such as Arduino.
- Allows getting standardized modules, mechanism, parts technical support by international shelf acquisition method (Internet of Things). But it has difference with traditional electric toy that is controlled unilaterally. The new digital products must have mutual communication effect with human-computer interaction. It makes product friendly and integrates it with the joyful scene quality.

2. Research Topic

This research topic is based on an interaction design event last year. From April 28, 2012 to May 5, 2012, there was an Interactive Technology Design Workshop hold by both Department of Industry Design, College Architecture and Urban Planning, Beijing University of Technology and Faculty of Industrial Design Engineering, Delft University of Technology [9]. There are more than 50 participants in the 9 days workshop. Most of the participating students are from industrial design background, few of them are employees and the people in hobby. The teachers of teaching team are from Beijing University of Technology and Delft University of Technology.

Students will use the classic computer table tennis games to explore the interaction quality of the sensor quality. When the host says resistance sensor, pressure sensor and vibration sensor, in fact, he is just saying some empty words. How fast are these sensors able to response? How to ride them? Although the students can answer from the model and quantity, but we hope that through specific interaction, it allows users to intuitively understand these sensors. For example, experiencing rapid flashing lights to understand active sensor, and unstable operation to understand the delay type sensor. Students' task is to design and to express this kind of interaction.

There are two purposes in this workshop. First is to understand and experience the interaction design. Second is to make the prototype and computer programming by the students themselves and control the game by MAX system. The Students are divided into 12 teams, and are required to finish 12 interactive design works. For example, "The Bird and The hunter", "The Trojan Horse", " The Crazy Bunny", "The Exercise Pong", etc. Through the demonstration and evaluation, students are able to understand interaction design. This workshop has strong support from schools and colleges. They give a positive guidance on students' enthusiasm, problem solving and ability to cooperate. Three of the twelve works attended The 10th Asia Pacific Conference on Computer Human Interaction conference in Matsue, Japan, 2012.

After this workshop, students have great interest in interaction design and show high enthusiasm. Department of Industry Design in Beijing University of Technology makes the interaction design a new discipline development direction that based on the traditional industrial design. The purpose is to combine elements of design and technology that based on the electromechanical integration technology of the information age, with mechanical, electronic, computer programming, network technology, and to create the digital products with ease of use by human-computer interaction design.

3. Methodology

This topic adapts integrated design theory and design methods.

3.1 Design Methodology of Systems Science

This topic based on systems science theory, human-computer interaction design method is combined with electromechanical integration technology, establishment of the purpose, elements, structure, and form of product system analysis model [3,8]. Through the analysis of the problem of hierarchy in product system and elements: (1) By the study of bionic design, observe the adaptability principle and technology in the evolution process of life, get inspiration from nature, and to understand multiple contradictions and how to optimize the adaptation of life in particular survival environment. (2) Understanding the human-computer interaction design method and electromechanical integration technology in order to make a digital product system, and to establish product overall purpose consciousness and the relationship of system purpose - elements - structure – form. (3) Use

standardized module, including the design element of module, mechanism, parts by international shelf acquisition method (Internet of Things). Combine a new products system with the requirements of ease of use. Through the prototype experiment control feedback and interaction feedback, researcher can complete the user experience testing and realize the ease of use of digital products.

3.2 Human-Computer Interaction Design Method

This topic uses integrated design theory and design methods [3,4]. Researchers study cognitive psychology and pay close attention to the sense of user in order to know that the interaction design is a kind of how to make the product easy to use and can make user cheerful: (1) to understand the target users and their expectations; (2) to understand the users' behavior when interacting with products; (3) to understand the psychology and behavioral characteristics of people; (4) to understand all kinds of effective interaction, and enhance and expand. Interaction design involves many subject, need to communicate with people from different field. To focus on user behavior, cooperate and respond to the user behavior is the mission of interaction design and the important design method of this design.

3.3 The Method of Electromechanical Integration Technology

At the period of traditional industry, in technical fields, such as Mechanics, electronics, optics, computer software design, are separated with each other [3,4]. For example, the first relationship between human and machine is through an electromagnetic switch, it is simple and effective. In the informatization period of electromechanical integration, humans and machines have relationship by single chip coupling. The mechanical structure is the basis of product system in electromechanical integration design method. Computer becomes the system control center, light - mechanical - electrical - hydraulic module as the running system, mutual information as the system neuron. So the human-computer interaction becomes more complicated. Because the update of technology all the time and the upgrading of new products is rapidly, people haven't adapt to this kind of product technology before new product comes out. The digital products are short of "ease of use" with complex operation and semantics, which lead to the complaints of user. People are confused in front of the technology due to the fact that people feel strange for technology. According to the survey, ease of use for product is welcomed by most of the people.

Electromechanical integration is an important element of science and technology. Interaction design method combined with electromechanical integration technology, can solve the problem of "ease of use" and provide the design method and the technology development way. Based on the rationality and standardization of electromechanical integration technology, choose the applicable technology for the purpose of the usability digital product and structure the interaction design and electromechanical integration method as the technical route. The control, feedback and human-computer interaction of mechanical products give a higher biological function feedback mode to traditional complex products, and furthermore, achieve the highest level of humanized design eventually.

3.4 Interaction Design Prototype Test Method

Product prototype is the original aggregate of product function structure elements and the overall purpose of the product [8]. As a physical prototype entity, product prototype has two basic meanings: first, shape its own characteristics on behalf of products purpose; second, put forward inspired new product in the process of the prototype modifying. Prototype is the important process of product from concept to real model.

Prototype is an evaluation method that combines qualitative with quantitative approaches. It is the only way to import the product conceptual design into system engineering. Samples and data creation is needed for prototypes. Design teams should work together and try to understand the product concept and the screening product function structure elements in order to ensure the implementation of product concept. In the interaction product design, involves the user experience of product visual, hearing, touch, taste, etc., and many scientific and technological achievements, such as sensors, circuit boards, program design, software control and so on. These component elements of function structure can be selected and evaluated by prototype experiment, and to realize the request of the user experience.

4. Design and Manufacture Process

The first stage is conceptual design. Students gather insights from natural form, find a logical starting point, and then put the "interactive toy" into user research, set function and propose overall concept of interaction form system. The design describing method is: put forward design basis with scene graph, chart and characters. In the second stage, product overall form is decomposed into the: purpose - element - structure – form. Students are required to understand the overall purpose and the relationship between the various elements of interaction design system. The design describing method is: put forward data from graph, chart and characters and optimize choice. The third stage is to construct interaction prototype experiment platform by oneself. The mechanical and electrical technology system is decomposed into: system - module - mechanism - parts. Make technology selection of mechanism, electronic institutions, and parts, test respectively, obtained experimental data, optimize the evaluation. The fourth stage is to establish mechanical and electronic modules data under the requirement of product overall measurement. After the link of supporting institutions and parts, complete the test of prototype and sub model, determine product overall function, optimize evaluation. The fifth stage: the product into the design engineering process. This process requirement is: concept design - technology design - prototype test - optimize the evaluation - product improvement (see Figure 1).

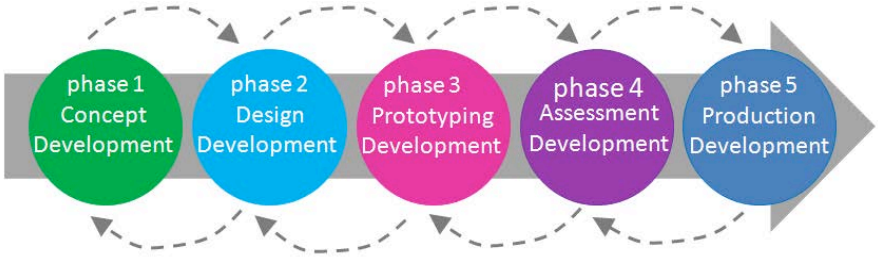

Figure.1 Five stages of different development stage and feedback system

4.1 Morphological Analysis of Orangutan

According to the survey, it is very interesting when orangutan is in the tree. It is worth learning and imitating, and it can be used as some interesting elements in toy design. In accord with the requirement of bionic design task, interaction design is combined with the bionic mechanism based on the characteristics of orangutan (see Figure 2).

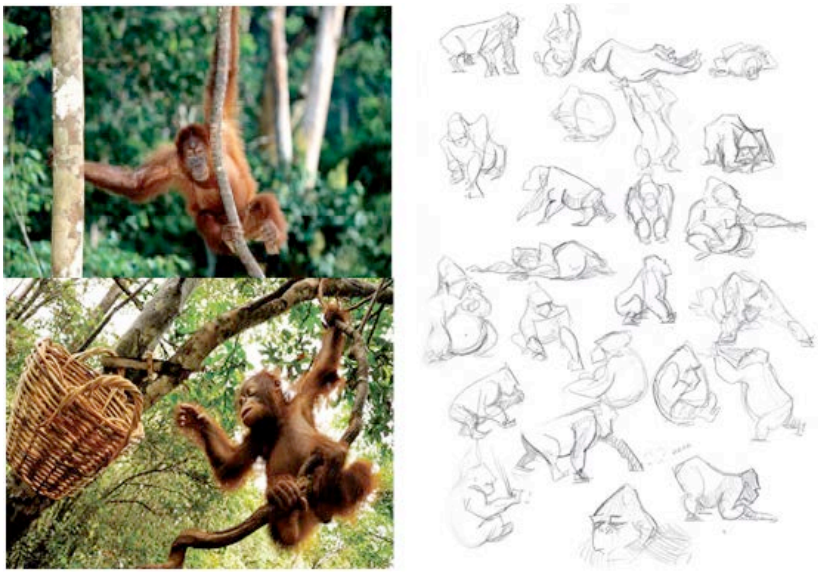

Figure.2 Morphological observation of orangutan

4.2 Design Goals

According to the feature of orangutan like to climb, we conceive a game. It has not only the imitation of orangutan arms movement regularly, but also interactive function. People are involved in, and the whole process is full of fun.

4.3 Storyboards

Two opponents to PK in this game, first put the ball into orangutan's dosser, after receiving instructions, the mechanical orangutan will climbing on rope, when reach the target basket, clapping, the dosser on orangutan will pour the ball into the target basket, the quicker is the winner (see Figure 3).

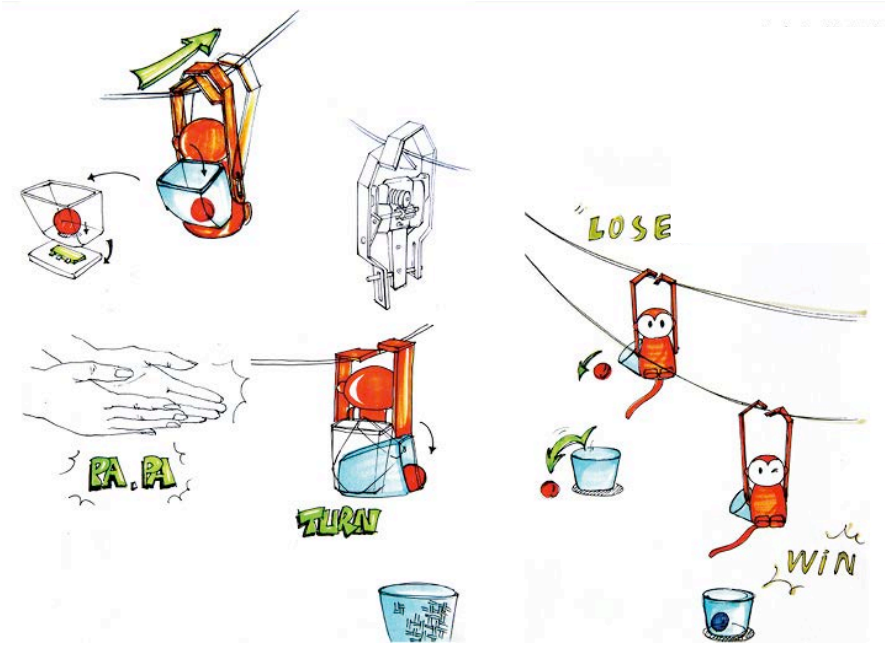

Figure.3 Storyboards

4.4 The Design

Due to the rocking of the rope, it needs to consider the limit position to make sure that the orangutan's hands can grasp a rope stably. Basic principle - link mechanism: the orangutan is driven by an electric reduction gear, and it performs the rope climbing movement by a link mechanism. This mechanism depends on the arms' forwarding and gripping alternately on the rope. (1) The body moves forward by the arms that grasp the rope; (2) then another arm move forward to grasp the rope; (3) then the first arm loosen the rope; (4) realize the rope climbing circularly (See Figure 4).

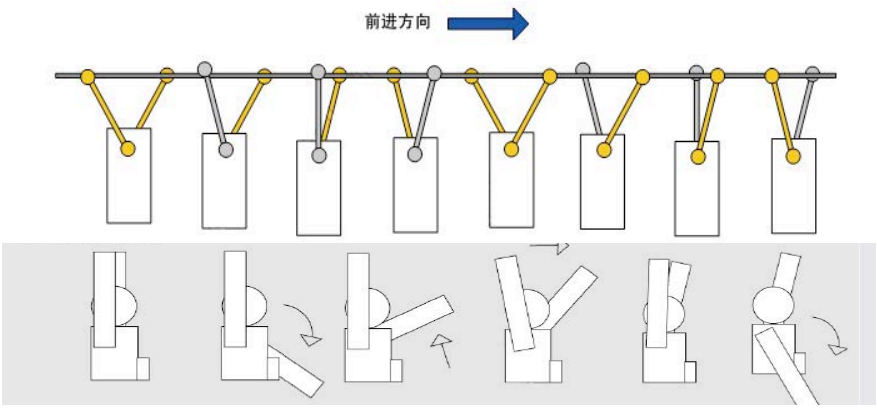

Figure.4 Movement way analysis

As the rope climbing, it needs not fast movement but enough strength. Reduction gearbox can convert high speed and low torque to low speed and high torque. Through it reduces the gear speed to increase the output torque. This topic selection swinging crank-link mechanism is a kind of a link mechanism that can transform rotary motion into reciprocating swing motion. The main structure is: one side of rocker is fixed on one side of a rotating wheel, the rocker with a guide groove and can slide (See Figure 5).

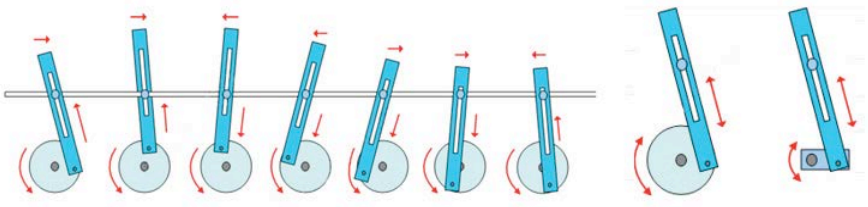

Figure.5 The crank-link mechanism

In order to make the mechanical orangutan to grasp the rope steadier, the connective part between orangutan and rope is in the shape of a hook. We use two sets of the same link mechanism in coaxial installation but design them in the opposite way (see Figure 6).

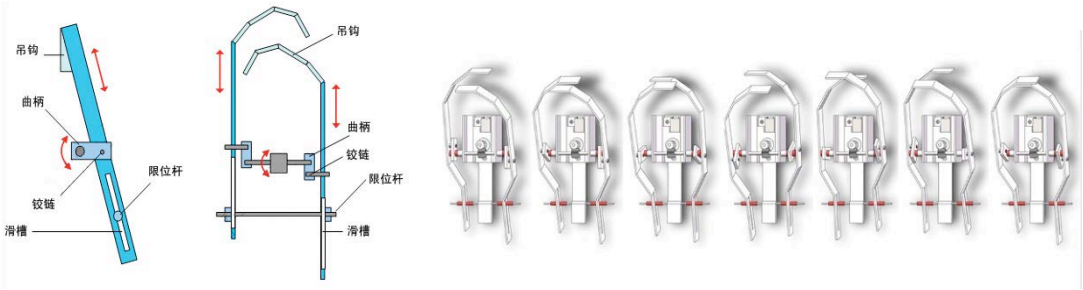

Figure.6 The overall link mechanism

In the prototype experiment, using resistance bridge pressure sensor to control mechanism (see Figure 7). Three groups of experimental data:

This topic uses integrated design theory and design methods.

Maximum value: 379

Minimum value: 379

Data description: at an average of 379

Maximum value: 388

Minimum value: 380

Data description: a + 10 amplitude change

Maximum value: 379

Minimum value: 378

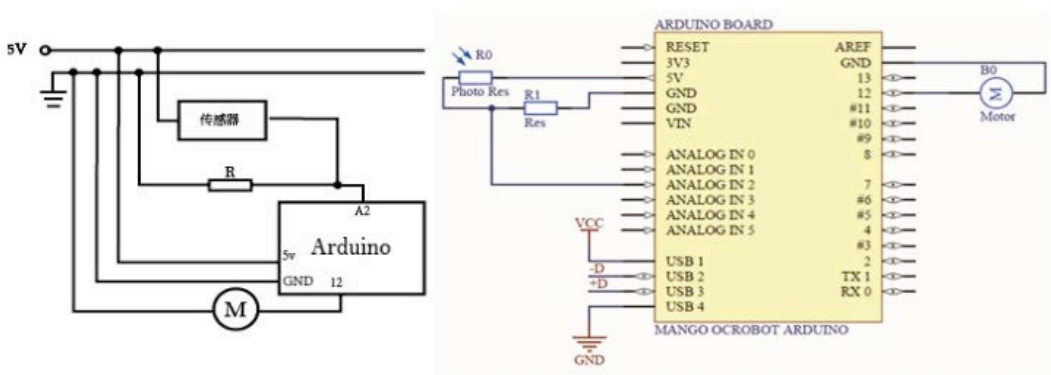

Figure.7 The circuit diagram design

Use Analog Readsrial of Arduino to read data detection from pressure sensor under three states. The critical value of pressure control is 379. Then, we did further modification by Arduino program to realized that the motor can be controlled by pressure sensor (see Figure 8). Figure 9 shows the final design.

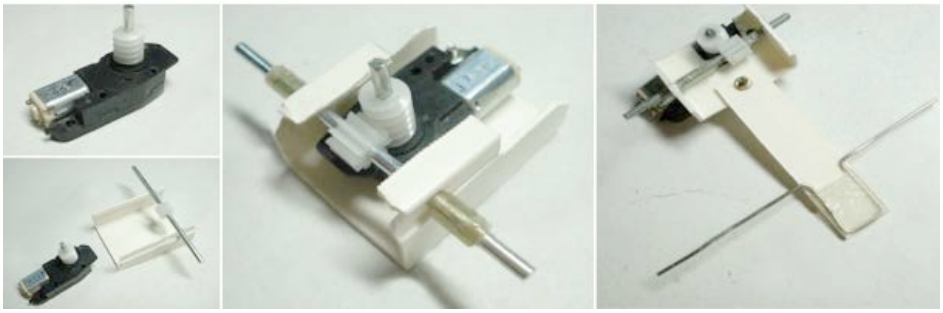

Figure.8 The link of devices

Figure.9 The link of devices

5. Discussion

User group: the target users of the interactive toys are users who like throwing sports and competition game in all ages of people. Interactive mode: After the mobile way was determined, considering the interaction and playability of interactive toy, we add three props for "orangutan", ball, dosser and basket. The user triggers the orangutan to mobile by throwing a ball, the orangutan move by hand-clapping voice control, then pour the ball into the specified basket on the ground. It tests the player's throwing speed and accuracy as well as the cooperation of eyes and hands. At the same time, we also combine the characteristics of playing games. There are two teams in a same game; the team who use less time is the winner.

Difficulty 1: mechanical settlement problem (resolved). While making prototype, all of the mechanical parts and motor assembly is settled but the motor does not drive mechanical rotation very well. It has a bottleneck that there were no problems about the size of the parts and the assembly method. With the help of others, we found that all of this is due to mechanical settlement. So we change the professional locating ring to replace the original adhesive tape, and then we use super glue to settle all parts. We realize that the assembly of all parts should be very accurate. Any slight loose can cause the malfunction of the machine. We will avoid such mistakes when we do such design again, and try to use more professional mechanical parts to optimize the assembly of mechanical structure.

Difficulty 2: the purchase and appearance integration of the pressure sensor (unresolved). At present, the pressure sensor that we use is 5 kg resistance strain type pressure sensor. This sensor has a high precision, simple and compact structure. It can be used in the prototype experiment. But when we do appearance integration, we

need to install the pressure sensor inside the dosser on the back of a little orangutan, we found the large volume and weight is not suitable for this design. Our solution would be looking for some pressure sensors that are smaller and lighter.

Difficulty 3: appearance integration (unresolved). After the success of the all the interaction and machinery experiment, there comes the biggest problem about how to put all interaction device in to the exterior mode. Although the Arduino is simple and easy for experiment, but the size is too big. If we want to put all the parts into the dosser and orangutan, we need to reconsider the problems, such as wiring layout, material selecting, appearance size etc. It is not easy for a climb interactive toy. Weight and size will slow the climbing and reduce the gameplay effect.

6. Conclusion

Through the design research of this topic, we integrate morphology research, mechanical structure and interaction circuit design. Every subtle structure settlement can affects the overall success of the mechanism. It needs an overall consideration at the beginning, thinking about the feasibility of the design gradually; reduce the waste of duplication of labor and resources. It requires student to have enough preparation and an overall planning of morphology, structure, circuit and appearance. The planning needs to adjust in each stage. We should think of every detail of production and design, and predict the difficulties and result in advance in order to improve the efficiency of design and production, to reduce the waste of time, energy and material resources. If this design can be continued, it needs more user experience examination after prototype design in order to know whether the interaction products can be accepted and played by user quickly. We should track the time of the entire game, the difficulty and the corresponding analysis. Second, we should continue to solve the problems of exterior integration and engineering technology, etc. It is advisable to execute load test, and explore the relationship between the product weight and motor power. Researcher should try to find a set of design research method of internal structure and appearance model, so the similar problems can be solved more smoothly in the future.

7. Acknowledgement

We would like to thank all students who participated in the Department of Industrial Design. We also would like to thank Hsueh-Ming Steve Wang, Xichang Wang, Zhongliang Zou, Aadjan van der Helm, Walter Aprile and Wei Liu, for their dedication in teaching.

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