Research on Interactive Prototype Design and Experience Method Based on Open Source

Yanrui Qu[1(✉)], Yanhong Jia[1], Tong Qu[2], Zhaoyu Chen[1], Heng Li[1], and Wanqiang Li[1]

[1] Beijing University of Technology, Beijing, People's Republic of China
qyr@vip.sina.com

[2] University of Pittsburgh, Pittsburgh, PA, USA

Abstract. This paper argues that, from the perspective of interactive prototyping and experience, the hardware technology based on open source and thinking, can promote further development of interaction design research. The purpose of this paper is to explore the design methodology considering interactive prototype design process and experiencing process, and provide theoretical and technical support for the design of interactive products, with open source resources as the platform and task method. The results show that the open source code can be obtained in a variety of formats, and can be freely and easily modified to solve the design problems encountered by individuals or teams, to support the design goals. Through open source resources everyone can get electronic components and a variety of materials, as well as infrastructure and standardization of the production process. So that a number of design elements and open source code can be iterated quickly, having everyone maximize using open source resources efficiency. The design of interactive prototype is based on Arduino/Max6/MSP experiment method and emotional experience method. After the initial design and prototyping, the design concept can be realized. A design route combining usability and ease of use could be established which can be used in the field of industrial design engineering.

Keywords: Interactive design · Open source · Prototype · Emotional experience · Method

1 Introduction

As early as the spring of 1997, the idea of open source code, as a resource that can be shared with the public was firstly brought up by a group of aspirants in the software industry [1] (Linus's Law, Eric Raymond, 1997). Since then, the concept of open source resource has been infiltrated into various areas including information technology, education and health care and recently has widen its scope to the field of philosophy [2, 3]. In the modern information society, open source resource refers not only to the free access to the source code of the software. More importantly, it is a culture and also a spirit that represents the freedom of sharing and the awareness of making full use of resources. The prominent characteristic of sustainability has made it a strong pushing power to promote social development.

A. Marcus and W. Wang (Eds.): DUXU 2017, Part I, LNCS 10288, pp. 633–651, 2017.
DOI: 10.1007/978-3-319-58634-2_46

Open education is a crucial idea in modern education. Open-minded educators hope to see open source technology and open education combined for a shared vision. Based on the open source code, educators can share the teaching achievements together through the Internet; the students and self-learners will be able to communicate and collaborate more efficiently through an open source educational environment. The process of delivering reviews and feedback between educators and students will become accurate and timely. Therefore, open source resources can be integrated with open education. This is why open source software, hardware and open education are closely related [4].

Beijing University of Technology, School of Architecture and Urban Planning, Department of Industrial Design, together with Delft University of Technology, School of Industrial Design and Engineering, have held four interactive design workshops from 2012 to 2015. Participants from more than 50 universities around the world, took part in the discussion about the teaching model that is based on the integration of open source code and open education. The following content demonstrates several real cases during the practical teaching process, along with the experience and lessons learned. Generally speaking, human beings have two ways to know about the world: One is to understand others' experiences through learning. The other is forming personal experiences through direct contact with actual event in life. There is no doubt that open source resources can accelerate this cognitive process of learning. From the perspective of interaction design and the Maker movement, the support offered by the open source hardware technology is of great significance for open education, especially the development of interaction design.

2 Open Source Hardware Overview

Open Source Hardware (OSHW) Definition: Open Source Hardware (OSHW) is a term for tangible artifacts – machines, devices, or other physical things – whose design has been released to the public in such a way that anyone can make, modify, distribute, and use those things.[1] Open Source Hardware (OSHW) Statement of Principles: Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that. The hardware's source, from which the design is made, is available in the preferred format so modifications can be made. Ideally, open source hardware uses readily-available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware.[2] Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.

Currently the most successful representative of open source hardware is Arduino. As one of the earliest open source hardware, its influence cannot be ignored. All kinds of Arduino are based on the same hardware and software development platform, technical information, accessories, etc. They are available to entry-level novices. The software development tool is Arduino IDE, which has rich Arduino driver code. For the

[1] Open Source Hardware (OSHW) Definition. http://www.oshwa.org/definition.
[2] Open Source Hardware (OSHW) Statement of Principles. http://www.oshwa.org/definition.

maker who are fond of open source hardware, the huge amount of resources about Arduino, a variety of superimposed expansion boards and a series of sensor boards are admired. In addition to Arduino, there are many other kinds of open source hardware that are also familiar to everyone.

51 single-chip microcomputer is one of the basic introductory microcontroller and is also one of the most widely used. However, because of its internal structure and abstract of the programming language, in practice, the learner needs the knowledge of electronics and other components, that can be combined with design and development products. So it is a very big challenge for the beginner who doesn't have the foundation for programming.

Raspberry Pi: Compared with Arduino and single-chip microcomputer, Raspberry Pi provides higher performance of processing capability. It can easily achieve I#O control, high-speed data communication, video processing and real-time calculation etc. Makers can do programming in Debian Linux environment and realize various functions that could only be done in PC environment before. Raspberry Pi is an ideal platform for beginner makers to develop into high-level makers.

Based on the brand new Intel architecture, the Galileo Board is a kind of circuit board that can be developed and fully adapted to be compatible with Arduino (including the interface and the development environment, etc.). Overall, the Intel Galileo provides an excellent tool for the rapid development of simple interactive prototype designs and complex projects such as the household appliances automation, achievement of smart mobile phones controlling life size robots, construction of networking systems and so forth.

Table 1. Four different open source hardware

	Target users	Application domain	Requirements of the ability
Arduino	Adolescents, Designers, Makers	Multi-media art design, Interactive product prototype presentation, education fields of teaching, competitions, etc.	C language programming
51 single-chip microcomputer	People with the programming ability and the electric circuit build ability	Automation control intelligent household, etc.	C language programming and circuit design knowledge
RaspberryPi	Makers, Embedded developers	The Internet of Things, image identification, intelligent robots, etc.	Knowledge of Linux and based programming
Galileo Board	Makers, Embedded developers	The Internet of Things, image identification, intelligent robots, etc.	Familiar ×86 environment, as well as the arduino programming

Table 1 shows the different Development Board characteristics, target users and the requirements of the ability to target users.

3 Interactive Prototype Design Based on Open Source Hardware

3.1 Interactive Prototyping and Topic Classification

According to Klaus Lehmann, we live in a realistic and material world. When human senses are ignored, people lose the significance of existing (Klaus Lehmann, [5]). This is a continuation of the idea of Bauhaus' "Designing for People" (Staatliches Bauhaus, 1919). Interaction design originated in the 1980s (Bill Moggridge, [6]). In contrast with product design in the industrialization era, interaction design is characterized by implementing function through information technology. For a long time, the "black box" of information technology has plagued the product design. After years of efforts, the design semantics and design psychology have contributed to the design of human-machine interaction, which provides a design methodological significance. In today's user experience, two model-matching theories (user mental models and designer conceptual models, Donald Norman), prototyping experiments, etc., provide theoretical framework for in-depth study of interaction design. Interactive prototype design and experience of the teaching process based on the open-source, is the continuation of the theoretical framework and addenda.

Interactive prototype design takes the real material as the carrier, embedded in open source hardware, using computer programming to control or drive so as to achieve human-computer interaction process. The functional tests based on prototype gradually go further along with the human-product experience. Therefore, the interactive prototype subjects require a combination of technology and emotion [7].

In order to make the design process more clear, the prototype design experience training topics are divided into two types: the first type, for basic training purposes. As a basic introductory exercise, according to the people's problems in the use-application-emotion-experience aspects of the design process, as well as the material-process-technology aspects, students abstract the basic questions, design and implement an abstract model as a design goal. This approach is often called Design Training, also known as "useless design". Calling it useless is because the design is not for practical purposes, but as a problem-solving design of an abstract thinking training method. The second type, practical product design, designing for a clear practical goal the requirements of the user needs to be targeted in this product design method.

In this chapter, through the revelation of natural phenomena, design concept generation, prototyping, open source hardware embedded and computer programming control design development process, we present an interactive prototyping and experiential approach based on open source hardware through a bionic design with abstract features (the author is Luo Zhang, a 2013 graduate student in industrial design engineering at Beijing University of Technology).

3.2 Abstract Structure Design from Bionic Inspiration

Topic: Learning from nature. Choose a natural form, describe its external environment and internal structure characteristics, design and produce an abstract interactive form. Requirements:

a. The natural form selection and analysis process is clear. b. Design objectives and process and summary of the expression are concise and easy to understand. c. Embedded prototype design, through dynamic demonstration shows that the morphological advantages, such as structure, strength, speed and so on. d. Through the prototype demonstration, the expression of the design concept can be recognized, understood and its feasibility is persuasive, also it has a good emotional experience.

Analysis of Mimosa Functional Principle. Mimosa motility is usually due to change in intracellular turgor pressure. Most mature plant cells have a large vacuole. When the vacuole is filled with water, the pressure constricts the surrounding cytoplasm and drives it close to the cell wall. The pressure given to the cell wall is known as the turgor movement. Vacuole contains both organic and inorganic substances. Their concentration levels determine the level of osmotic pressure and sequentially determine the direction of water diffusion. When the vacuole concentration increased, the osmotic pressure increased, the water goes from the extracellular into the intracellular proliferation and into the vacuole, increasing cell turgor, leading to the cells bulge; on the other side is atrophy [8].

This process can only cause slow movements, such as the opening and closing of the pores. However, when the semi-permeability of the cell membrane changes instantaneously, it may cause a very rapid action. Chloride ions move into the cell, while the positive ions move out of the cell. Causing the cell membrane and adjacent areas are able to maintain a certain potential difference, which is called rest potential. When the external stimulus exceeds a certain limit, the cell membrane potential increases, or even become positive potential, thus generating the action potential. This phenomenon is called depolarization. Action potential can be transmitted. When the cell reaches the action potential, that is, when the phenomenon of depolarization occurs, the difference between the permeability of the cell membrane disappears, so the original water stored in the vacuole was discharged in an instant, so that cells lose the turmoil, becoming limp [9]. When we touch the leaves of mimosa, the leaf pillow cells are stimulated, resulting in the depolarization. The cells immediately lose water and turmoil. Leaf pillow becomes limp. Small pinna loses the pillow support, so it becomes closed in turn. In the lower part of the leaf pillow, there are some sensing cells which have very low rest potential. They are particularly vulnerable to stimulation [10]. As long as a slight touch, they will immediately release the water, so that the petiole would droop, looks like that the mimosa is bashful. The following is a rough sketch of appearance description and motor function of mimosa (Fig. 1).

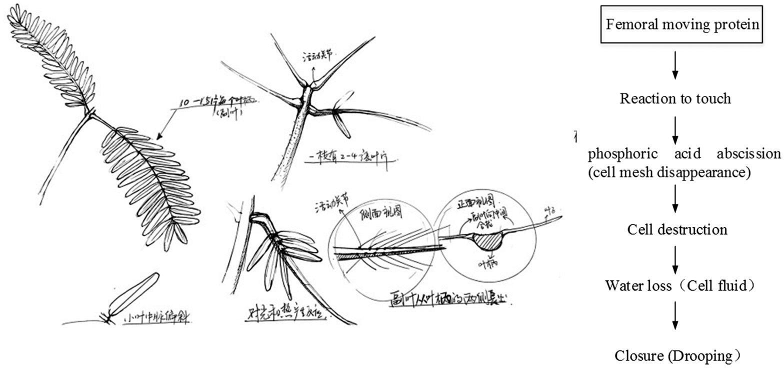


Fig. 1. Schematic diagram of appearance description and motor function of mimosa

Biomimetic Design and Interactive Technology of Mimosa. After defining the topic and direction, the initial conceptual design began, and feasibility simulations were carried out on the sketch and the preliminary model. After continuous exploration and experiment, three sets of concepts were drawn. Comparative analysis was made to choose the best concept for prototyping. To explain the reasons for the options clearly, in the following, the advantages and disadvantages of the three sets of design ideas will be explained in detail.

Scheme 1: From the way mimosa open and close the leaves, build structures aiming at finding the prototype program most similar to the appearance of mimosa. The specific method is as follows: In order to conceal the mechanical structure, use the smallest original: rods, lines. The root of the blade is designed with a circular hole, which is engraved by the acrylic plastic, and connected with the petiole (connecting rod), so that it has the ability to move up and down. Connecting rods are placed on the trunk (rack) in order to make its appearance more similar to an actual plant. There are two holes in the lower part of each of the first pair of compound leaves and a wire in between to connect both leaves. The length of the line is determined by the maximum angle at which the blade is opened. Another wire connects the midpoint of the previous wire to the steering engine. The first pair of compound leaves and the remaining compound leaves are connected with viscose at the lower part of the blade. So which can be integrated with the linkage to realize the open and close of the blade. The principle is to use the gravity of the blade itself to achieve natural droop (the open form). After the steering gear is actuated, a downward force is generated, and the servomotor rotation causes the connecting wire to be constantly wound, resulting in a downward force to close the blade.

Advantages: Meet the function under the premise of making the appearance maximumly similar to the appearance of mimosa, so that is an appearance bionic design. Disadvantages: As the wire (soft, the direction of the poor precision control) and the strength of the connecting rod's poor stability, in the course of the experiment the leaves usually cannot always achieve the normal opening and closing (Fig. 2).

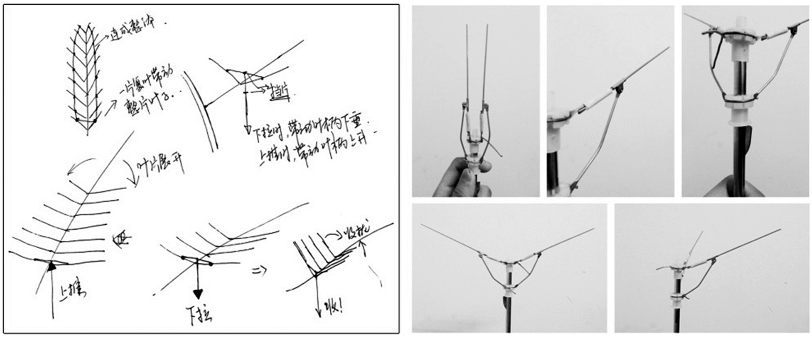


Fig. 2. Scheme 1(Left) and Scheme 2(Right)

Scheme 2: This is a more eclectic solution which needs a compromise between the stability and appearance similarity, mainly using the connecting rod body. The specific method is as follows: the principle and concept is similar but a little different with Option1, the differences are: 1, turn the fragile wires and connecting rod into the metal linkage that could provide a better strength and stability; 2, no longer use the blade's own gravity, rely on more stable steering gear to control the blade opening and closing. The slider and the petiole are connected to the use of sliders to control the opening and closing rather than simply stick and the stent and the petiole. The frame becomes an integral part of the linkage assembly. In practice, in order to maximize the use of existing conditions, we transform the structure of the umbrella into a model, to complete the test.

Advantages: the compromise in this way can maintain the function and appearance to be certain balanced. Disadvantages: In the model test, it is found that some structures cannot be obtained through the procurement, and there is no way to process through the existing conditions, and model's accuracy cannot meet the requirements (in the test the stability is still poor). And finally we had to seek new solutions.

Scheme 3: Draw on the experience and lessons learned from the first two options, the main consideration of this scheme is the feasibility of interactive behavior. Interactive features will be achieved as the primary starting point. So the structure, strength and accuracy of the racks, has been put forward to higher requirements. Therefore, it has to make some compromises on the appearance of the "bionic". The specific methods are as follow: using the standard components which can be purchased through the shelf, including gears, steering gear fixed base, screw nut, the standard mechanical handle, touch sensors etc. According to the design requirements, the combination of components has changed, based on these standard components. So, here Mimosa's "opening and closing function" is achieved through the transformation of the mechanical handle. Remove the excess part of the handle, then extend the rod as a petiole, and then the blade will be fixed on the leaf to complete the blade part. Servo drives mechanical gripper gear rotation, directly controls the blade opening and closing (Fig. 3).

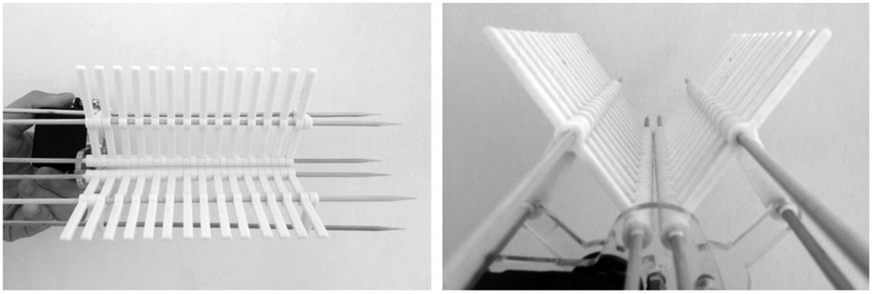


Fig. 3. Scheme 3

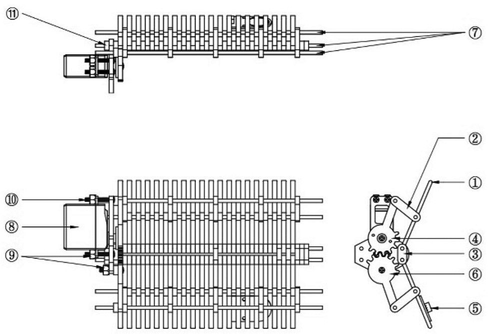
Advantages: As a prototype, the main purpose is to complete the design of the function. Through the touch can control the "blade" opening and closing. Standardized components maximize the accuracy and stability to meet the function. Disadvantages: As the function meets the requirement, at the same time, the appearance seems to have a lack of bionics. In summary, Scheme 3 was chosen for its functional advantage. The following sections will detail the principles of this program, production and presentation.

Mimosa Bionic Interactive Design, Model Production and Demonstration. Before production, the team purchase components at first. Including control system: Arduino kit. Powertrain: Tower Pro SG5010 dual-bearing standard steering gear. Drive system: Mechanical gripper assembly (after adaptability). Operating system: home-made leaves, touch sensors. The following sections describe the design and manufacturing process in detail.

Arduino is a convenient and flexible, easy-to-use open-source electronic prototype platform, including hardware (various types of Arduino boards) and software (Arduino IDE). Arduino can sense the environment through variety kinds of sensors, by controlling the lights, motors and other devices to feedback, affecting the environment. The microcontrollers on the board can be programmed in Arduino's programming language, compiled into binary files, and incorporated into the microcontroller. This program using its open source features can be easily and quickly connected to various sensors and achieve the expected behavior.

Servo is a common power system, the choice of Tower Pro SG5010 dual standard servo, can achieve 0°–180° free angle control, to meet the design requirements. The 3.5 V–6 V voltage through the USB interface could provide power supply without the need for an external power. The accurate control of the angle is one of the keys of this interactive design.

Transmission system–mechanical gripper is mainly composed of a pair of arm gears and connecting rods, to meet the grasping object function. The angle control of this interaction requires a great deal of similarity to that of the gear-driven linkage of the mechanical gripper. Modifying the mechanical gripper to realize the new interactive mode is feasible. In addition, the use of existing standard components for transformation is conducive to reduce the difficulty of production and improve accuracy (Fig. 4).



11	Round washers	22	
10	Screw	5	
9	Nut	5	
8	SERVO	1	
7	Connecting shaft	6	
6	Driving wheel	1	
5	Touch sensors	1	
4	Drive pulley	1	
3	Limit blade	4	
2	Connecting rod	10	
1	Blade	40	
Serial Number	Name	Quantity	Remark
Bionic assembly of Mimosa blade		Set 1 / Proportion 1: 2	1-1
Drafting	Zhang Luo 2014.4.10	Student ID	S201312058
Tracing / Audit	Zhang Luo / Zhang Luo 2014.4.10	Industrial design engineering, Beijing university of technology	

Fig. 4. Schematic diagram of the engineering assembly

The execution system is part of the machine (in this case, the mechanical system of the interaction device) and is the direct medium of human-machine interaction. People interact with each other by performing system input and output behaviors (instructions). Here the implementation of the system refers to the "Mimosa leaves", that is integrated touch sensor. After the functional transformation of the mechanical handle, which is directly to people to receive and receive feedback part. 4 mm thick ABS board in accordance with the design dimensions after cutting, assembled into the blade part. Finally, the touch sensor is placed in the blade part as the input device of the interactive signal, and the servomotor drives the blade driven by the gear to complete the feedback action (output). The components through repeated modifications to debug, the final complete assembly, in order to achieve the best results. Then start the program by programming the computer into the Arduino control board to complete the final debugging (Fig. 5).

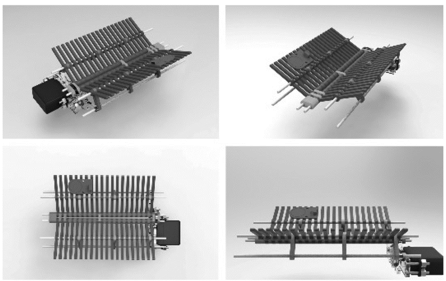


Fig. 5. Three-dimensional assembly renderings

Programming. Before writing the Arduino program, you must first clarify the program logic that you want to achieve. After you have defined the program logic, start programming with the Arduino programming software and find the ArduBlock visualization programming plug-in under the Tool menu. According to logic programming, and then import Arduino programming software to generate the program code (Fig. 6).

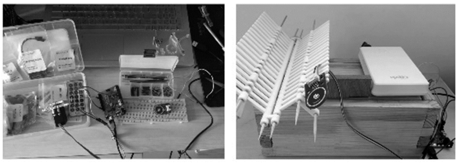


Fig. 6. Hardware assembly and line connections

After the program code is compiled, it has been imported into the Arduino motherboard. And then the hardware parts are connected correctly to verify the feasibility and accuracy of the program. And then fine-tune the program through the performance of the hardware, so that the final hardware could achieve the expected interactive experience.

After the program code is compiled and debugged, the final assembly, connection, and debugging are performed. After the line was connected, the group installed the blade part onto the gear empty, then connected to the steering gear. After the steering gear was fixed, they use mobile power as a power supply. Once the final assembly is complete, the model can be demonstrated. The final result is shown below (Fig. 7).

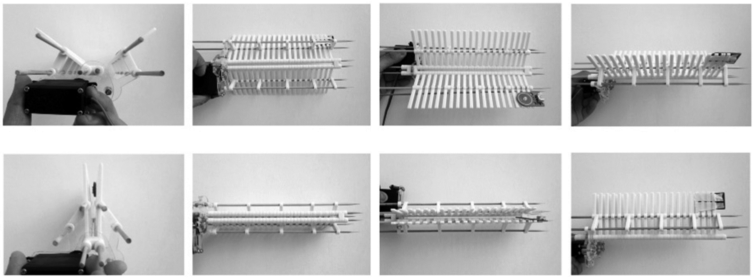


Fig. 7. Model demonstrations (above: open state, below: closed state)

3.3 Prototype Design and Production Process Conclusion

The above examples show that sketching and paper prototyping are the most widely used prototyping methods in interaction design. The interactive design archetypes discussed in this chapter belong to tangible interaction, also called embodied interaction, and are distinguished from ordinary interactive prototypes in attributes. The prototypes in the physical interaction design have the following properties: 1, The prototype is a real three-dimensional physical space in the material form, through the prototype, human-computer interaction can be achieved; 2, For designers, the prototype is a preliminary verification, which can let them intuitively feel the design conception in the realization of some minor changes in the process, leading to facilitate discussion and improvement of design, in order to further enhance and improve the design work to do the foundation. 3, when the human-computer interaction occurs, the users can feel the power, speed, fast and slow, elegant or vulgar, melody and rhythm and other interactive experience. From the prototype of embodied interaction design, these characteristics are obviously different from other design prototypes. Because the prototype of the embodied interaction is based on valid feedback of the action of the testers, in terms of its design purpose and implementation level, that is, it can be practiced as expected in the conceptual design phase.

Through the tangible prototype design and production process, the properties of tangible interaction prototype design, which can be divided into five important key nodes, behavior research, emotional appeal and essential technology, to expand to achieve the goal. This reflects in the following five parts. Emotional collage board. Storyboard. Role creation and play. Hardware/software applications. Interactive prototype experiment.

These properties of interaction prototype could be realized by keynote activities such as behavior research, emotional appeal and technology realization. Specifically, they could be elaborated in five aspects: Emotional Board; Storyboard; Role creation and play; Hardware/software applications; Interactive prototype experiment.

The primary function of the prototype is to validate the conceptual design. Interactive prototype design achieves interactive features through the sensor circuit and the corresponding mechanical structure, designed to illustrate the interaction design principles. Interactive prototyping is an important method of interactive design, and it is also an indispensable part in the interaction design process. Through the production of interactive prototype, we can test whether the software circuit is reasonable, whether the connection is consistent or whether the design can achieve the initial goal.

4 Emotional Experiences in Interactive Prototype

4.1 Emotional Design in Prototype

Donald A Norman put forward three levels of emotional design through the study of emotion in Psychology: instinctive level, behavioral level, and reflective level. The instinctive level refers to the first impression of the user to use the interactive products. The implementation of behavior level design corresponding functional level of demands that is one of the basic attributes of the product. At present, the function of interactive products is more and more powerful, but the demand of target people has changed, users began to look forward to move by personalized and ideal product, beginning the pursuit of product to meet the emotional level. The emergence of emotional design is based on the designer to meet the product functional requirements and provide users with emotional and psychological support for higher levels of spiritual needs.

4.2 Music Player Design

2014 interactive design workshop theme is a design for the purpose of utility. In this interaction workshop, each team was asked to complete a specific context based interactive music player design. In this process, the student learned Arduino programming techniques, interactive design methods, and how to use video as a tool for design and communication. In this workshop, our student will learn: Video sketch, embodied interactive product model, theme concept product design, design expression, model making skills, Arduino software programming [11].

Aadjan van der Helm Marco, Professor Rozendaal and Dr Liu Wei, From the Technische Universities Delft in Holland, proposed a number of abstract concepts, such as anger, sadness, doubt, fear, kindness etc., require a special emotional reflect in the design of music player, analyzing the variation characteristics of the emotion and the interaction based on the final results show. Combine the emotional changes with the products form and structure. In the creative process, the group combined integrated technology, aesthetics, interactive design principles and prototype and video as design and communication tools.

4.3 Topic1-Interactive Music Player Design on the Keywords "Kindness"

Video Sketches: In determining the subject, each group took some action video to the three music control functions: "start/stop" and "big/small volume" and "a song/next song". Used some things around as auxiliary props, users hold the props and did some actions interact with the props. Different actions represented different emotion and functions. With the "start/pause" function as an example; the group of students used four materials to demonstrate the control of this function (Fig. 8).

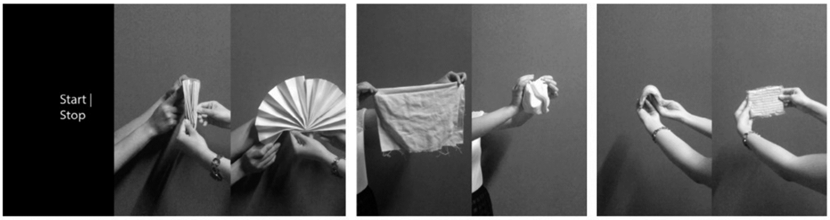


Fig. 8. Video sketches

Improved Video: After the analysis of several groups of actions, combined with emotional keywords and whether the technology is easy to achieve, student decided to take folded papers to express emotions and the interactive actions. Slowly folding unfolded objects, reflecting the harmony between man and things and harmonious process inflect the keyword "kindness". Relax stretch the objects, music start; tighten compressed objects, music pause; turn right start to switch to the next, turn left is opposite; radial spread the objects, the volume becomes larger and the radioactive contraction makes the volume smaller. The three groups of control actions are in Fig. 9.

Brainstorming: In order to combine action, function and shape more perfectly, the group members began the brainstorming. Before brainstorming, the group members got the theme of brainstorming: to combine the folding action with the music player's functional control, as well as the shape fits the use of the scene.

Given the Four Key words of this brainstorming: "music player" "interactive action" "compression and folding" "kindness", members of the group started divergent thinking.

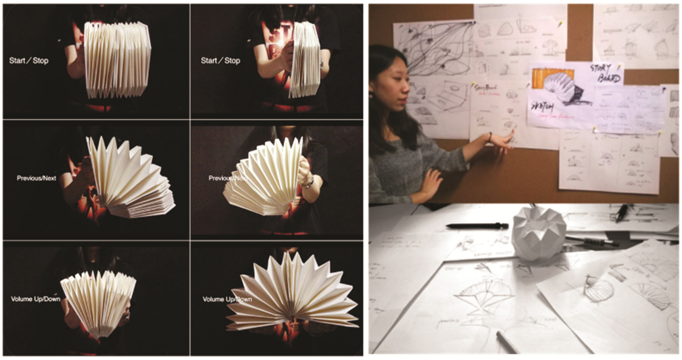


Fig. 9. Video sketch deepening

After obtaining a sufficient amount of ideas, the ideas were evaluated in a multi-dimensional manner. Through the classification of the results and cost, the group found the best idea.

Storyboard: Storyboard shows the scene of using the product, illustrating how the user to solve the problem. Through the assumption of user roles and usage scenarios, the designers try to simulate the actual user interaction and interaction mode for product usability evaluation. Good user scenarios can be beneficial for the product design process (Fig. 10).

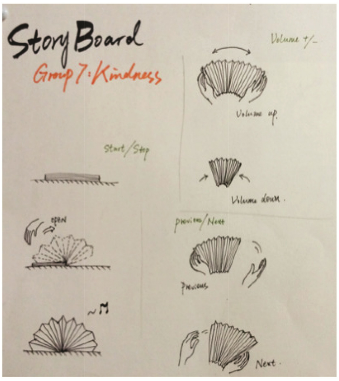


Fig. 10. Storyboard

Fig. 11. Draft prototype

Draft Prototype: The best way to verify the idea of staying on paper is to make full use of the material around and quickly make a prototype to verify ideas to find problems. The group members use the origami to build prototype, in order to show the way of interaction between people and music player control quickly (Fig. 11).

Interactive Technology: Through the use of open source hardware technology, the group members started to build product circuit prototype quickly to verify whether the interactive approach to achieve the effect planned. In the hardware platform, they selected Arduino as the open source hardware platform. On the basis of this, select the Seeed Studio music control module and sensor board to realize the interactive functions need to achieve. The sensor been chosen was the rotation angle sensor which can be used to measure the rotation angle of the control the music player's volume and switch. Tilt sensor has also been chosen to measure whether the music player is tilted to the left or right to achieve the previous/next function.

Final Design & Prototype: After the iteration of the model and the verification of the technology, the final prototype combines the appearance structure with the technology. Able to demonstrate independently and achieve desired interaction (Fig. 12).

Fig. 12. Draft prototype final design prototype (designed by: Yanhong Jia, Jingpeng Jia, Lu Bian, Peng Chen, Xingjian An etc.)

4.4 Topic2- "Inspiration" Interactive Music Player Design

Behavior Research: Another group from this workshop designed an embodied interactive music player. The emotional vocabulary they chose as the theme is "inspiration". Through the previous observation research and discussion, they came up with a conclusion that the core of interaction design is to aim at user behavior. Thus the primary task is to find out the specific behaviors that can be helpful and applicable for users in terms of expressing emotion. And digging out the logic and the semantic meaning behind the behaviors is the next move. According to the dictionary, the group of students summarized several meanings for "inspiration": A. Inhalation. B. Encouragement. C. Inspiring things and objects. D. Wonderful ideas. E. Enlightenment from god. According to the understanding of each group member and the result of the discussion on semantics relevance, the final key words are "sudden", "wonderful", "magical", "exciting", "surprising", "positive".

Action is the basic unit during the process of user expressing the intention to interact. It consists of action sequences, and makes up the basic vocabulary of interactive context. Building up a human-computer interactive movement set that applies to embodied context is the foundation of implementing embodied interaction design. At the current stage, group members picked up raw material, including wood boards, hemp rope, nails, bamboo boards and paper clips, aiming to find inspiration through the interaction of material and behavioral action. For instance, blowing the balloon to almost explosion reflects anxiety; placing one finger gradually near the tip of a needle reflects fear. Before the specific design process started, the team members studied the relationship between behaviors and emotion expression through video sketches and explore the emotional semantics behind the behaviors by observing the action itself or changes in the material to get prepared for the next step in the design process (Fig. 13).

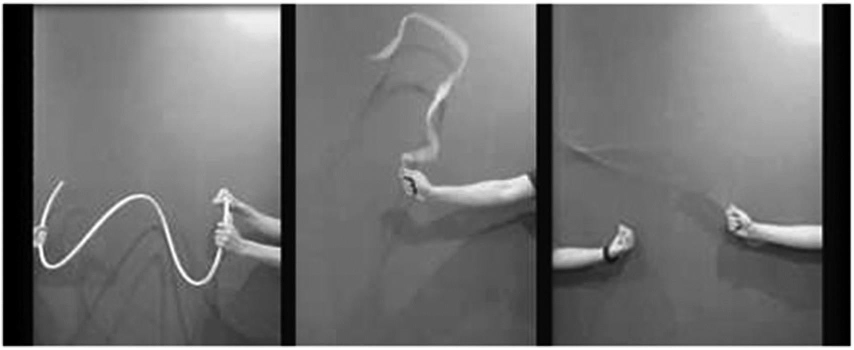


Fig. 13. Video presentation during video sketch

Emotional Demands: The combination of behavior and emotion is the key to this design. At this stage, the group concluded that "unexpected but reasonable" may be able to produce the feeling of "inspired". Corresponding to the three basic functions of music player: pause and start, turn up and down the volume and switch songs, the team selected uncommon actions to design the interaction pattern. Stretching and compressing represents increasing or decreasing the volume; waving ribbon can skip to the next song depending on the direction of waving; bending and straightening the bamboo board are respectively corresponding to pausing and starting. The correspondences between these actions and functions are mainly matched with the semantic features of behavioral

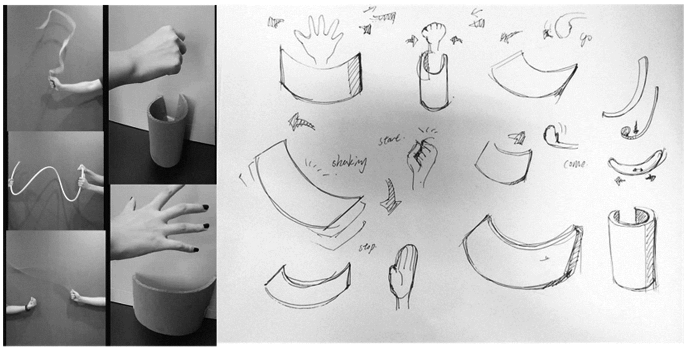


Fig. 14. The prototype structure combines with the video

language and function. One thing worth mentioning is that there might be differences in understanding of the same behavior for people from different cultural backgrounds.

The video sketch demo displayed a magical hand and a cork wood mat that has simple shape and texture. After the gesture is made, the cork wood mat will transform and give motion feedback in a subtle way, and play feedback sound effects accordingly based on that theme (Fig. 14).

In the following design stages, group members optimized the project further on the realization of specific functions. They changed the gestures of controlling the volume into raising and lowering one hand. In the meantime, the prototype will perform a corresponding feedback in terms of the extent of swinging. What's more, waving towards left and towards right respectively correspond to switching to the previous song and the next song. Based on demonstration, this interactive behavior is also clear in the product semantics. On top of that, adding the feedback sound effect in parallel with different semantic behaviors increases emotional empathy. It is a way to try to create a pleasant emotional experience for users while using the product (Figs. 15 and 16).

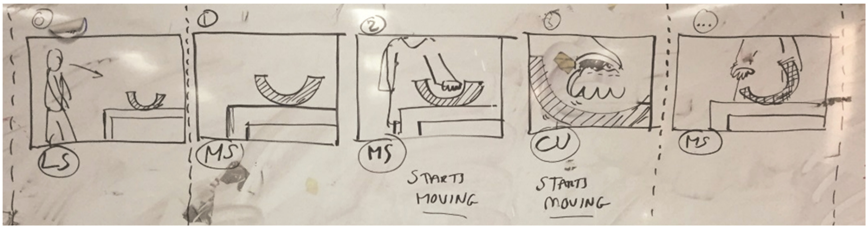


Fig. 15. Story version-1

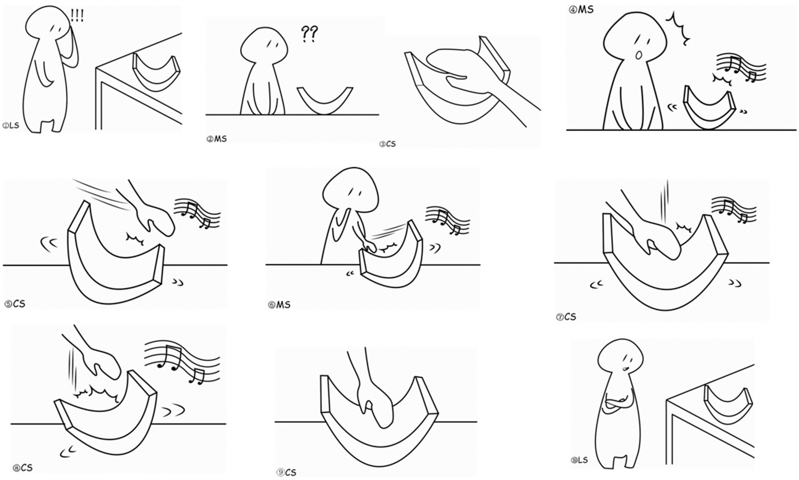


Fig. 16. Story version-2

Implementing Technology: In the process of prototype design, from a concept to the realization, technical considerations are essential to the transformation. After the design of interactive behavior and operation mechanism, students began to carry out a detailed physical structure and design based on an operational logic level, the following are some details:

A. Physical structure and hardware & software technology: Workshops provide model production sites, according to the actual needs, the groups can select 3D printing, ABS sheet metal engraving cutting, hot pressing and other technologies. In the prototype production, the group applied hot-pressing technology in the creation of the external contour. After bonding with the screws and nut coupling, the group went on painting and performing other surface treatment. As for the internal structure of the part, students designed their own internal linkage and gear, and used CAD to produce engineering drawings and carving. The final step was to connect and assemble.

This group selected Arduino as the hardware support for their prototype. It was easier to use and control the required sensor with the support of the Grove tools set.

B. Iteration and optimization of prototypes: During the prototyping process, as time goes by and the design improves gradually, the original prototype became mature and complete progressively. Nevertheless, with the addition of structures and programming, there are always problems that cannot be anticipated in advance, and some new architectural ideas may arise in the process of soluting problems, which, after continual alternation of problem arising and problem solving, prototypes are iterated and optimized. After assembling the materials and the components, the group found that the original counterweight and the slide itself were not enough to bring wobble to an ideal angle. However, the body space was limited, and new related structures need to be carried out again. After optimization and re-design, the group came up with a better solution ultimately. The hardware assembly prototype has shown in Fig. 17 below.

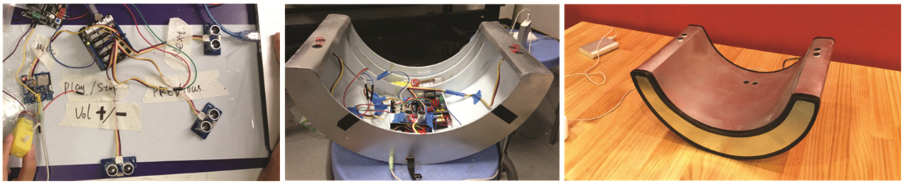


Fig. 17. Arduino/Grove hardware assembly prototype (Designer: Tianwei Shu, Jiyuan Liu, Tong Qu with, Fengyu Zhao)

5 Conclusions

Material object interaction design is gradually changing the traditional mode of human-computer interaction. And it has a positive impact on the relationship between people and products. Although there are still some unsolved problems, but those do not prevent it from becoming an important direction of future interaction. In contrast with the traditional product design, interactive design is more concerned with the consideration of human behavior, the transmission of human emotions, and the technology implementation aiming at user-friendly experience. With the addition of the time dimension, users will have richer human-computer interaction experience. From this point of view, embodied interaction can reflect the closer essence of interaction design. With the development of embodied interaction design, the prototype design process will become more scientific and improved, and will receive more attention from many other fields.

In the context of virtual interaction and interface interaction becoming more and more mature, the methods of interaction design have shown increasing variety. Different design methods can be selected according to different problems. Industrial design and product interaction will be greatly improved as well. It is not a simple issue about interface interaction anymore. People now can interact with the product through behavior and information exchange, with a real three-dimensional embodied interactive experience. But it also requires further research through the integration of user research, computer technology, sensor technology, anthropology, psychology and other disciplines of knowledge, in order to achieve development in interactive products that meet user needs and that are able, easy and also fun to use.

Teamwork in open education is a huge guarantee of success. Whether it is a small project or a large one, these words are equally applicable. Designers should acquire certain extent of divergent thinking and logical thinking, and understand the importance to have different focus in different stages of a project. They need to know the way to benefit from their own strength, so that they can maximize the final design achievement, which reflects the advantages of cross-disciplinary in open education. However, the condition that a team is superior to the individual depends on differences among team members. The greater the differences of knowledge hierarchy and personality characteristics are, the greater the value produced by mutual collaboration will be.

References

1. Raymond, E.S.: The Cathedral and the Bazaar. O'Reilly Media, California (1999)
2. Torvalds, L.: Just for Fun. HarperCollins, New York (2001)
3. Schon, D.A.: Educating the Reflective Practitioner. Wiley, New Jersey (1990)
4. Saffer, D.: Designing for Interaction. New Riders, California (2006)
5. Lehmann, K.: Design Training. Merz Akademie, Stuttgart (1992)
6. Moggridge, B.: Designing Interactions. MIT Press, Massachusetts (2006)
7. Qu, Y., Mousavi, J.: Research on system design based on product functions and structure Elements. Packag. Eng. **24**, 78–81 (2012)
8. Robin, G.: Mimosa pudica: a model for the study of the excitability in plants. Biol. Rev. **54**(2), 135–153 (1979)
9. Lu, S.: The pathways and means of plant electrical signal transmission. Chin. Bull. Bot. **13**(4), 23–27 (1996)
10. Li, C.: Why mimosa has a shy look. Guangxi Forestry **1**, 43 (2002)
11. Liu, W.: Interaction Design. China Architecture & Building Press, Beijing (2013)
12. Sun, J., Dai, Z.: Bionics today and tomorrow. Acta Biophys. Sin. **2**, 109–115 (2007)
13. Liu, Y.: Talk about product innovation from the bionic design. Guangxi J. Light Ind. **1**, 59–60 (2010)
14. Warren, J.D., Adams, J., Molle, H.: Arduino Robotics. Publishing House of Electronics Industry, Beijing (2014)

15. Blum, J.: Exploring Arduino: Tools and Techniques for Engineering Wizardry. Wiley, New Jersey (2013)
16. Liu, W., Stappers, P.J., Pasman, G., Taal-fokker, J.: Supporting generation Y interactions: challenges for office work. In: Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW), vol. 12, no. 4, pp. 321–328. ACM Press, New York (2011)
17. Wu, J.: On Top of Tides. Publishing House of Electronics Industry, Beijing (2011)
18. Xin, X.: Interaction design: from logic of things to logic of behaviors. Art Des. **1**, 58–62 (2015)
19. Arduino - Home. http://www.arduino.cc/. Accessed 12 Feb 2016
20. Open Source Hardware (OSHW). http://www.oshwa.org/definition. Accessed 12 Feb 2016