Digital-based Design Research on Interactive Installation Art--Taking the Ecological Diversity Development of Coral Reef as A Case

Hanxi Lin
Dalian Polytechnic University, Dalian China

Abstract: Surpassing traditional communications, interactive installations in the digital era prefer a sophisticated integration of sensing technologies and programming languages, so as to provide viewers with more profound experience. In this study interactive installations are taken as media to explore the ecological development of coral reef in further digital process through Arduino and Touch Designer programming. In this way, users can have immersive experience by two-way interactions with the device, thus expanding the understanding between humans and the natural environment. In addition, the innovative use of interactive installations in advancing ecological researches and potential new solutions to environmental problems through the art of programming are also discussed. Therefore, this study inspires new ideas from the harmonious coexistence of humans and the nature, providing insights into coral reef conservation and its sustainable ecological diversity.

1 Introduction

1.1 Interactive installation art boom

Interactive installation is an art form that "allows art to fulfil its purpose by involving viewers", which often requires the viewer to "approach", "walk back and forth" around or "touch" corresponding works. As described by Edmonds (2011), "Interactive art is featured by a dynamic response to external stimuli. That is, art is interactive when users participate in and become part of the artwork. Particularly, immersive visual experience is considered as a unique way for digital art to communicate artistic ideas with viewers, which is also clearly taken as part of new media art due to its origin from and dependence on computer technologies." The core idea of such art lies in the integration of viewers and the artwork, an interaction to fully reveal the artwork’s uniqueness through viewers’ involvement rather than visual effects.

1.2 Artistic innovation

Previous extensive literature on interactive installation art describes its unique form, highlighting the indispensable role of viewers in the creative process. It grows from computer technology advances and technological innovations, which provides viewers with a more immersive art experience and stronger sense of participation. Similarly, the immersive visual experience of digital art is also a method of deep interaction with the audience. Instead of traditional visual performance, this art enables more direct and profound impressions of the artwork combining technological power, which is not only a product of the digital era, but also the result of continuous evolution in art creation.

2 Combination of sensing technology and programming language

2.1 Sensing technology and programming languages

The rapid rise of AI technology boosts human-computer interaction boom in the art world. Among them, Arduino is an opensource electronic platform relevant to programming language, which is designed to simplify the interactions between hardware and software. It consists of a development version of the hardware part, and a software part based on an opensource IDE (Integrated Development Environment). Designed for non-professionals with a simple and flexible way to create interactive electronic prototypes, Arduino’s real-time performance allows quick responses to inputs from touch sensors.

In addition, Touch Designer is a node-based visualisation programming software developed by Derivative Canada, which integrates multimedia functions such as network and local data processing, sending and receiving of sensor signals, image algorithm recognition, multimedia audio-visual output along with virtual reality simulation. Through this software, sensor data can be captured, analyzed and processed in real time, then fed
back into physical devices or virtual environment. Such real-time interaction provides creators with more precise control and more creative design space.[1]

To realize such interaction design, the author leverages Touch Designer (video image presentation), visualisation software in code form (processing) and external hardware (projector, touch buttons, Arduino, etc.). The principal logic is to touch to start. That is, after viewers touch the microcontroller Arduino button, the system can present visual feedback on the screen. In this process, touch sensing equipment is the core signal catcher, mainly responsible for collecting human touch patterns and converting into transmission signals.

2.2 Application of sensing technologies and programming languages to interactive devices

This study digs deep into the Touch Designer and explores its innovative application of digital design in the marine ecology development. Firstly, big data analysis is utilized to figure out current development of coral reef ecology and the possible hazard causes. Then supported by visual programming techniques, analysis results can be presented by clearer visual designs of coral reef ecosystems in different situations. In this process, particular visualisation elements that are most suitable for conveying information are selected, so as to ensure the final installation is both scientifically and artistically designed.

With the help of Touch Designer, the visualisation design of marine ecology is no longer theoretical discussions, but also pragmatic explorations through practical case studies. Such programming language enables further studies of experience and multidimensional expressions of multi-dimensional interactions and immersive presentation techniques in the coral reef ecosystem. This innovative design enhances the sense of participation and more intuitive impressions of coral reef crisis.[2]

To be noted, sensing technology and programming language welcome a brandnew presentation for marine ecology development. These advanced technological elements inject new vitality into the digital design of marine culture, inspiring future innovations of marine ecological conservation underartificial intelligence scenarios. In this sense, this study is a novel attempt combining digital art and ecology and provides useful experience and inspirations for further integration of technologies and ecology in the future.

3 Design and Application of Interactive Installation "Tidal Sound Resonance"

3.1 Precreative ideas

3.2 Background research

Coral reefs are complex assemblages of reef-building corals and carbonate sediments that have accumulated to form a rich diversity of reef-dwelling animals and plants. It is a unique biotope with rich diversity and signs of life exuberan in the tropical sea area. [3] Mainly distributed in tropical and subtropical shallow sea areas between 30° north and south latitudes, coral reef ecosystems with abundant biodiversity plays a key role in resource supply, coastline protection, marine disaster mitigation, and the global carbon cycle. However, coral reef ecosystems are facing significant decline due to bleaching problems based on current climate impacts and human activities, specifically serious threats from weakened protections and less sedimentary material. [4] According to scientific researches, global temperatures are predicted to rise by 4°C by 2100, with warnings of a "marine ecological crisis". Such global temperature rise could lead to coral bleaching and widespread loss of zooxanthellae. In summary, frequent or severe bleaching has serious negative impacts on coral reef ecosystems, including reproduction ability, growth rates, resistance to disease and survival rates. In recent years, mass bleaching is mainly the result of rising near-surface ocean temperatures, and future temperature changes will surely lead to more extensive degradation of coral reefs. Moreover, external factors such as over fishing and wastewater pollution are also damaging marine ecosystems. As these problems gain more presence, traditional education and publicity means can barely reach vast audiences. To solve it, the boom in digital media technology has provided fresh opportunities for innovative artistic approaches.[5]

3.3 Ideas for Interactive Devices

“Tidal Sound Resonance” is an interactive installation inspired by the ecological crisis of coral reefs, exploring the close connection between humans and the marine ecosystem. Particularly, the Arduino hardware control and Touch Designer programming are sophisticatedly utilized, integrating scene interactions and human-computer interactions. The goal is to create an appealing virtual environment that allows deep experience of coral reef ecology for visitors. The sounds delivered by head phones fully simulate the ebb and flow of the sea, inviting viewers to an immersive journey of sound and light. This two-way interaction is not limited to viewing, but instead, a deep engagement, to realize a real interaction with the virtual marine ecosystem through sensory behaviours. Beyond the entertaining experience, it aims to provoke deeper thinking and sense of responsibility about coral reef conservation and sustainable development of ecological diversity. This inspiring installation featuring an immersive experience can provide a creative example of integrated contemporary technology with marine ecological conservation. [6] In this way, the design involves viewers as part of the ecological interaction, so as to rethink the impacts of their behaviours on the environment, the relationship between humans and the nature, along with the due responsibilities of maintaining ecological balance.

3.4 Pre-preparation

The whole "Tidal Sound Resonance" installation is base on both two -dimensional and three -dimensional
perspectives, with subtle use of hardware devices and exterior design. As can be seen from Figure 1, in terms of hardware, selected devices include Arduino UNO development board, projector, LED lights, breadboards, Dupont cables, HC-SR501 human infrared sensing module, touch sensors, and servos.

And the exterior design covers elements such as coral reef cluster, simulated heart, behavioural bacteria, modelling model and water ripple ambient light. For example, Figure 2-3 shows the author's process of making the model. Among them, touch sensing and infrared sensing are fully utilized to recognise the user's signals for designed more flexible interactions and subsequent installation scenarios.

With careful selection and configuration of hardware devices, the installation becomes more creative and practical. More specifically, the Arduino UNO development board serves as the core control unit that coordinates each hardware component and realize precise control. The projector is adopted to present virtual marine ecology, while the LED lights and ambient lighting enhance the overall visual effect. With clever combination of simulated hearts, coral reefs and other exterior equipment, the installation is closer to nature in form, encouraging viewers to a more in-depth interactive experience. The cost breakdown of the device is as follows:

- **1. Arduino UNO development board**: Approximately $20 - $25, serving as the core control unit for coordinating and managing the entire apparatus.
- **2. Projector**: Price varies depending on brand and performance, generally ranging from $100 - $500 or higher.
- **3. LED lights**: Cost depends on quantity and type, typically ranging from $1 - $10.
- **4. Breadboard and DuPont cables**: Basic components for connecting electronic elements, with a total cost ranging from $5 - $20.
- **5. HC-SR501 human infrared sensing module**: Around $2 - $5, utilized for detecting participant presence.
- **6. Touch sensor**: Costing between $5 - $15, employed for facilitating user touch interaction.
- **7. Servo motor**: Price contingent on model and quality, generally falling within the range of $5 - $20, used for controlling object movement.

**3.5 Operation process of interactive installation**

In this interactive game, the projector firstly displays the welcome message and purpose of the game, clarifying that participants will explore coral reef emotions. Once a visitor is in range, the screen plays an introduction message and directs him/her to put on the headphone, accompanied by a background sound of deep-sea vibrations. After that, the screen presents different reef conditions caused by various external pollutants by simulating coral heart state, with a blue light for good health and a red light for threat. Then the visitor is guided to look for harmful substances simulated as bacteria. When the visitor successfully put behavioural vectors in place, the coral heart turns blue and the screen re-presented a new scene based on the participant's behaviour with corresponding knowledge and guidance. After repeating for three times, a complete ecological balance of the coral reef is achieved. Finally, the game ends with an explanation of the importance and the needs of coral reefs to the Earth's ecosystem based on some educational tips and information. Achievements and rewards are given according to users' performance, so as to encourage experience sharing and promote an incremental relationship between humans and marine ecosystems. Finally, remove the Headphones.
3.6 Programming process

Figure 4 Hardware assembly and code testing.

Figure 4 shows the author testing the code and assembling the device, and the following is the code rendering section.

```cpp
#include <Servo.h>
#define SERVO_PIN 6
unsigned int PWM = 0;
Servo myservo.

int irSensorPin = 8; // Connect infrared sensor pin
bool irSensorOutput; // infrared sensor output signal
int led1 = 9;
int led2 = 10;
int led3 = 11;
bool touch1;
bool touch2;
bool touch3.

void setup(){
  Serial.begin(9600);
  My servo. attach(SERVO_PIN);
  Pin Mode(led1,OUTPUT).
  Pin Mode(led2,OUTPUT).
  Pin Mode(led3,OUTPUT).
  Pin Mode(2, INPUT_PULLUP).
  Pin Mode(3, INPUT_PULLUP).
  Pin Mode(ir Sensor Pin, INPUT).

  if(ir Sensor Output == HIGH){ //when the infrared sensor detects someone approaching
    Serial.Println("B"); //Trigger the opening intro animation
    for(k=0;k <5;k++){ //heart blue breathing light
      for(i=0;i <256;i ++){
        set Colour(0,i,j);
        delay(10);
        j++;
      }
      for(i=255,j =255;i >1;i- -){
        setColour(0,i,j);
        delay(10);
        j- -;
      }
      delay(100);
      Serial.println("C"); //trigger coral damage animation
      for(k=0;k <5;k++){ // Heart yellow breathing light
        for(i=0;i <256;i ++){
          setColour(0,i,j);
          delay(10);
        }
      }
      if(touch1 == true){ //if the wrong behaviour is selected
        Serial.println("D"); //trigger coral dissipation effect
        for(k=0;k <5;k++){ // Red breathing light blinking
          for(i=0;i <256;i ++){
            setColour(i,0,0);
            delay(10);
          }
        }
      }
    }
  }

  if(touch1 == true){ //if the wrong behaviour is selected
    Serial.println("D"); //trigger coral dissipation effect
    for(k=0;k <5;k++){ // Red breathing light blinking
      for(i=0;i <256;i ++){
        setColour(i,0,0);
        delay(10);
      }
    }
  }

  touch1 = digital Read(2);
  touch2 = digital Read(3);
  touch3 = digital Read(4);
}
```

```cpp
if(touch1 == true){ //if the wrong behaviour is selected
  Serial.println("D"); //trigger coral dissipation effect
  for(k=0;k <5;k++){ // Red breathing light blinking
    for(i=0;i <256;i ++){
      setColour(i,0,0);
      delay(10);
    }
  }

  if(touch1 == true){ //if the wrong behaviour is selected
    Serial.println("D"); //trigger coral dissipation effect
    for(k=0;k <5;k++){ // Red breathing light blinking
      for(i=0;i <256;i ++){
        setColour(i,0,0);
        delay(10);
      }
    }
```
if((touch2 == true)&&(touch3 == true)){ //if both select the correct behaviour
for(k=0;k <5;k++){//heart blue breathing light
for(i=0,j=0;i <256;i ++){
    set Colour(0,i,j);
    delay(10);
    j++;
}
for(i=255,j =255;i >1;i- -){
    setColour(0,i,j);
    delay(10);
    j- -;
}
delay(1000);
for(PWM = 50;PWM <1500; PWM =PWM+5){
    myservo.writeMicroseconds(PWM);
    delay(70).
}
for(PWM = 1500;PWM >50; PWM =PWM-5){
    myservo.writeMicroseconds(PWM);
    delay(10);
}
}else{//when no one is close by
    Serial.println("A");//play the opening scene picture
}
delay(1000);

3.7 Final assembly and presentation

As the discussion topic is located on the seashore of the Xisha Islands, the installation is designed to appeal to participants from all age groups given their diversity. This installation is expected to place in oceanariums or around dive programme experiences near the South China Sea, or further displayed and promoted in major coastal cities in the future as a flash installation. The overall device and scenario of the device are shown in Figures 5 and 6.

Through this installation, visitors are encouraged to reach out and participate in ecological conservation activities from their own perspectives, so that more attention is expected to current problems facing coral reef ecosystems. In the end, the self-made coral reef model was assembled by parts including a simulated heart, ambient lights, behavioural bacteria, sensors, servos and a main control board. [7] After ensuring that all components could function properly for user feedback, final debugging and tweaking via a Mac connected to an Arduino were conducted for final desired results. All the delicate tuning and precise control of the entire system contributed to a smooth and engaging user experience. Moreover, this innovative device is designed for a sense of responsibility for ecological conservation, together with a more concrete and deeper understanding of coral reef protection. The design of this device prioritizes user experience, aiming to provide an engaging environment for participants to immerse themselves in and interact with the coral reef ecosystem. According to interviews, users felt deeply immersed in the virtual marine ecosystem during the experience, especially through the tidal sounds transmitted via headphones and the visual effects on the screen. According to participant interviews, users reported a profound sense of immersion in the virtual marine ecosystem during the experience, particularly with the immersive tidal sounds through headphones and the captivating visual effects on the screen. This sensation enhances their sense of engagement and depth of experience, facilitating a better understanding of the coral reef ecosystem. Users expressed admiration for the virtual marine ecosystem presented by the projector, as well as the visual effects produced by LED lights and ambient lighting. The sound emitted by the headphones faithfully replicated the ebb and flow of the ocean, enhancing realism. The integration of these visual and auditory effects is poised to captivate users, encouraging deeper exploration of the device. Moreover, users were excited and satisfied with the bidirectional interaction offered by the device. Through touch and infrared sensing technologies, they could engage in games and alter the state of the coral reef. [8]This interactivity made users feel not just spectators, but integral parts of the device, thereby enhancing their sense of involvement.
4 Discussions and conclusions

“Tidal Sound Resonance” is an intelligent hardware device developed using the Arduino UNO development board as its core control unit. The Arduino UNO coordinates various hardware components, ensuring precise control. The device's stability and accuracy are achieved through careful selection and configuration of hardware components, coupled with meticulous software programming. The device employs touch and infrared sensing to detect user signals, enabling more flexible interactions. These technologies accurately capture user actions and behaviors, ensuring precise device responsiveness. Through elements such as screens and LED lights, the device presents various scenes and coral reef states. User actions directly influence these changes in states, thus facilitating an accurate interactive experience.

The combination of technology and art presents promising prospects, supported by the golden opportunities in the digital era. Rapid technological advances enable artists to explore a wider and deeper range of creative fields, with interactive installations as a pacesetter in the future. In the future, we contemplate incorporating advanced sensor technologies such as depth cameras or laser sensors to enhance the precision of perceiving user movements and positions. Exploring novel biometric sensing techniques, such as heart rate monitors and electroencephalogram sensors, aims to adjust interactions based on participants' physiological responses. Integrating virtual reality (VR) or augmented reality (AR) technologies allows users to immerse themselves in a more authentic marine environment, heightening the realism of the visual experience. Simultaneously leveraging spatial audio technology to provide more precise sound direction based on user position and orientation enhances the three-dimensional perception of diving and ecosystem sound effects. Exploring adaptive audio technology adjusts background sound effects according to user behavior and responses, enhancing the dynamism of interaction. Introducing additional elements of ecological education, such as interaction with coral reef species and marine life, augments participants' understanding of marine ecosystems. Combining artificial intelligence (AI) and machine learning (ML) technologies personalizes the user experience by offering customized information tailored to their academic background and interests.

Firstly, the boom in digital media technology has provided a new platform for artistic creation. With the help of computer programming, virtual reality, augmented reality and other tools, artists can create new art forms beyond traditional media. Especially the interactive installation art has broken traditional barriers to involve both viewers and artworks. The viewers are no longer passive bystanders, but also part of the work through touch, induction and other ways.

Next, technology boom has empowered wider expression space for art. From holographic projection to artwork generated by artificial intelligence, art creations powered by technologies have surpassed traditional forms such as canvas and sculpture. Artworks can better express complex concepts, emotions and ideas through digital means, so as to present a more colourful visual and auditory experience. In another word, the integration of art and technology has become a medium for showcasing future creativity and imagination.

In addition, such combination is also refreshing social perception of innovation. Art is no longer simply an aesthetic pursuit, but also a joint for multiple elements of society, technology and culture. Technology-driven artworks can motivate thoughts about the future direction of development and deeper explorations of the relationship between technologies and the society. This multi-disciplinary art helps to create more forward-looking and inspiring works, together promoting social understanding and acceptance of technological advances.

However, this integration also faces challenges, such as concerning technology dependency or privacy and security issues. Moreover, more inter-disciplinary cooperation should be encouraged for a common future, including the expertise of artists, scientists and engineers. In the future, the combination of technology and art will give rise to more creative and diverse artistic presentations, which is not only a natural development in the digital age, but also new challenges and infinite opportunities for art creators towards a blooming future!

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