KINETAIR: INTERACTIVE STAIRS WITH MULTIPLE FUNCTIONS

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Abstract. Kinetair is an interactive stairs prototype which could change its appearance according to the surrounding conditions, providing a diversity of functions, such as stairs, exhibition walls, furniture and so on. This research is based on the Interactive Architecture theory, integrating with digital fabrication technology. This paper will illustrate the origin of the concept, the concept development process, the fabrication process and the various possible application of Kinetair. This experiment evokes us to rethink the fundamental meanings of the architecture components in a brand new perspective, and stimulates designers to explore the new features of conventional constructions with cutting-edge technologies.

Keywords. Interactive stairs; stair design; kinetic structure; dynamic design; adaptive form.

1. Introduction

Stairs, as a common elements of architecture, allows people to complete the transition between different levels, encouraging the people’s activities to jump out from the horizontal spaces into the vertical spaces, thus increasing the complexity and the hierarchy of the architecture.

As the stairs were primarily designed to avoid a slope, thus for hundreds of years, people aimed on its functional attribute above other characteristics until the Renaissance, when Michelangelo designed the Laurentian Library. In this design, the stairs were first liberated from the cloaked corner of the building and turned into a sculpture-like design placed in the middle of the building’s hall, acting like the ornament of the building, showing the aesthetic performance of the stairs.

Since then, architects started to dedicate a increasing amount of energy into the formal design of the stairs, especially with the concept ”everyday objects with a functional beauty” which introduced by Bauhaus. Considering the stairs represent the activity of individuals’ movement, architects tried to use curves and other biology symbols to reform the design of stairs for displaying a kind of dynamic, turbulent, trending, winding perception, such as the Infinite Staircase, a sculpture design by Olafur Eliasson (2004).

Considering the gravity and other practical requirements, although the style of the stairs has undergone tremendous changes from ancient to present, steps
maintained horizontal. Some cases may be rotating and twisting, but not in a vertical direction. In this scenario, a question has been raised: could the stairs be rotated and twisted in three-dimensions?

With suspicion, we started to re-examine the functionality of the stairs, we suddenly aware that not all steps need to maintain level, but only the steps in using. Without servicing users, the stairs are only act as decorations. At this point, we decided to design a prototype of interactive stair called Kinetair which can detect the individual’s position, interactive with the users, present horizontal plane when people need to stand on it and spinning when vacant.

This paper details the concept development, the fabrication process and proposes various application of Kinetair. This experiment evokes us to rethink the fundamental meanings of the architecture components in a brand new perspective, and stimulate us to explore new attributes of conventional constructions with cutting-edge technologies.

2. Related Works
With the prosperity of parametric design and the flourishing of concept of interactive architecture during the past few years, many related works about kinetic-stairs have popped out front of public.

Caminando, designed by Victor Barriquand (2009), is a transformable staircase, delivering the concept that the step of the staircase can be folded as a column when nobody using it and unfolded as a plane when individuals set foot on it. Kinetic Stairs, designed by William Page, Brian Tait and Rob Stethem (2014) from Emily Carr University, proposing a kind of kinetic stair system that can transform from a sculptural element into a staircase, offering a temporary path between a bar and a brewery space. Reveal, as a kinetic architecture, designed by Bobby Stafford, Chase Collins, Amanda Menschel (2015), creating a retractable staircase in the gallery, which can rotate out of the wall as a linear path and rotate back into the wall as a mural. The convertible stair ramp, designed by Chan Wen Jie (2013), picturing an ideal stair model which can quickly transform from stairs into a ramp for the places where are difficult to build both dedicated stairs and ramps.

Via background research, we found that most of the current works about dynamic stairs design are exploiting the folding system as the transforming method. The steps only have two different statuses, folded or unfolded, vertical or horizontal. When the steps are folded, all the steps are in a vertical position, the stairs disappear, and the steps merge into a decorative surface. When the steps are unfolded, all the steps are in a horizontal position, forming a platform for people to step on and the stairs put in an appearance. The design intention is simple, the purpose of mobilizing the stairs is merely for space saving. In this scenario, we define our prototype as a multiply functional installation with countless statuses under a rotary system.

3. Kinetair
During the process of exploring our concept, we came through four phases: the form design, the mechanical system design, the interactive system design, and
the fabrication design. In our prototype system, we employed sensors to detect individuals’ position, Arduino microcontrollers to analyze the surroundings status in order to find the most suitable mode for the installation, stepper motors to execute orders from the microcontrollers to locate steps that offer the horizontal planes for users.

3.1. FORMAL DESIGN

Considering the practical requirements and our goal of pursuing a spectacle that the stairs could dynamically changing shape in all three dimensions, we formalized our installation as a spiral twisting shape which has similarity to vortex.

There are mainly four components constitute the whole structure system: keels, gears, steps, and handrails (Figure 1). Keel plays the role of core load-bearing structure. The gears are mainly responsible for transmitting force between the different dynamic components of Kinetair, such as controlling positions of steps and handrails. The steps and the handrails are spinning individually in general conditions, combining a plurality of dazzling spiral curves which shifting in three dimension directions. The rotated angles of the steps and the handrails are rational, sequentially increased in with equal intervals, constructing a Mobius-like form.

Figure 1. Kinetair Form Design.

3.2. MECHANICAL SYSTEM

In order to reduce the friction caused by multiple gears collaborating, we discarded the idea of integrating the entire steps mechanically into a unitary transmission but individually set each step and its corresponding handrails as a unit module (Figure
2). The movement of each module is driven by a stepper motor stabled in the center of the module which determine the morphological position of all the components according to the angle message delivering by the microcontroller.

![Module Structure](image)

**Figure 2. Module Structure.**

All the components work in a specific way. When the stepper motor is activated, it twirls gears, and with the elaborate combination of multiple gears, the step and the handrail rotates in opposite directions (Figure 3), which forming a dazzling scene that the step and handrail cross-merging and disappearing periodically.

![Rotation Direction and Angle Series](image)

**Figure 3. Rotation Direction and Angle Series.**

3.3. INTERACTIVE SYSTEM

In this prototype, we set two interactive modes which can switch spontaneously based on the information collecting by the sensors. There are two types of sensors,
the sound sensor and the ultrasonic distance sensor. These sensors collect the volume data of the environment and the position data of the human, then send data to the microcontroller which we selected Arduino Uno. Since there are limited digital pins on each microcontroller, we choose distributed computer system as the interactive control system to improve the flexibility and freedom of the hardware installation. Each module of stairs has one microcontroller and one ultrasonic distance sensor. Each microcontroller sends signals to the next one continuously by serial port, and the last one sends signals to the first, thus forming a loop. When one senses the walker, then all the modules are aware of the walker’s position and response individually at once to the optimal positions. Besides, the whole system shared one sound sensor which connected to the first microcontroller for adjusting the dynamic range when the staircase is in the vacant mode(Figure 4).
3.3.1. Vacant Mode

When nobody using the stairs, the stairs spinning rhythmically in a variable speed according to monitoring of the environmental noise level. The principle is louder noise, faster spinning. When there is a flock of people gathering around the stairs, the environment will become clamorous, and the stairs will rotate at high speed which representing a feeling of turbulence. When there are limited people around the stairs, the environment will be tranquil, and the stairs will rotate slowly to reflect a kind of smooth, peaceful atmosphere (Figure 5).

![Figure 5. Vacant Mode.](image)

3.3.2. Occupancy Mode

When the stairs detect the people are within range and approaching the stairs, the first two steps of the stairs will become horizontal to present a stand space. With the movement of the individual, the occupied steps will follow the position of the user turning into horizontal sequentially, and the unused steps will locate into a series of angles orderly forming a continuous wavy shape (Figure 6).

![Figure 6. Occupancy Mode.](image)
3.4. FABRICATION

For lacking of available construction site and expenditure, we built a one-to-five reduced scale model instead of the full-scale installation. The form design was developed on Rhino. The entire fabrication manufacture is based on CNC, laser cut, and 3d printing. Acrylic is the primary material. Beyond that, we combined metal (lead screw), high density fiberboard and other common building materials. In this model, we embedded eleven Arduino Uno, ten ultrasonic distance sensors, one sound sensor and ten stepper motors in total (Figure 7). We developed the whole control system software on Arduino.

![Fabrication Process](image)

4. Possible Applications

Extending proposed system and our prototype, we define possible scenarios in which Kinetair could be used. Since each individual step of the stairs could control its rotation angle and flexibly, a variety of functions can be evolved depending on the angle permutation of steps. We envisioned mainly three contexts that demonstrate the variety of possible applications: atrium space, performance space, exhibition space.

4.1. ATRIUM SPACE

Commercial buildings, such as hotels and office buildings always designed with an atrium space which usually determines people’s first impression of the building. Placing a spiral staircase or a sightseeing elevator to enhance the artistry and the exquisiteness of the hall becomes architects’ modus operandi. Using Kinetair in this space could evoke visitors’ curiosity, attracting visitors’ attention and establishing a powerful impression. By presenting a dramatic and novelty perspective with Kinetair, the commercial value of the building could increase dramatically (Figure 8).
4.2. PERFORMANCE SPACE

Kinetair can be practiced as a part of performance stage, such as costume show stage and concert arena etc., for improving the atmosphere of the performance venue and creating an attractive visual experience to audiences. Specifically, in the fashion show, the models often appear from a high-level space then walk down through a path to the T-stage for expressing a metaphor that the item alters from an inaccessible art to an available commodity. If the path replaced by Kinetair, it will augment the metaphor effect and enhance the displayability. In the concert scenario, the Kinetair can also be a part of a stage, offering the singer a higher platform and performing as a dancer coordinate with the rhythm of the music (Figure 9).
4.3. EXHIBITION SPACE

Kinetair is ideal for the exhibition space since the exhibition space is always full of uncertainty. With installation of a hydraulic telescopic rod on each module of the Kinetair, the height of the steps could be changeable into any levels. Through diligent analysis of the environment parameters, the microcontrollers will easily determine the best form of the installation, and then all the steps could adjust their vertical position promptly and spontaneously. As a result, the Kinetair (Figure 10.1) may evolve into a multifunctional and transformable furniture. For example, when all the steps are turning in a vertical position simultaneously, they could orderly combine into a continuous surface which could be utilized as a space divider or temporary exhibition wall (Figure 10.2); and when all the steps locating at horizontal level, the steps could integrate as a whole horizontal plane which could be recognized as a table, a bench or a counter depending on the height of the plane (Figure 10.3). Furtherly, due to the unlimited possibility in both horizontal and vertical directions, it may tactfully syncretize the exhibition space and rest space as a whole (Figure 10.4).

![Figure 10. Exhibition Space Scenario.](image)

5. Conclusion

This paper mainly discussed the origin of Kinetair concept and how we develop an idea into a physical installation prototype, then described the possible application scenarios and prospects of this prototype.

In the process of implementing this installation, we encountered a lot of problems which need to be further resolved, such as the signal disturbance between the sensors, the comparatively slow response of the steppers, the load-bearing structure system problem for larger scale version, etc. Via this research, we started to re-exam the meaning of the architecture elements. We realized that based on the current technological background, the original meanings of the
building components might be altered dramatically, and their appearance might also encounter a radical change. In the next step, we will further optimize the prototype, trying to upgrade it to a new version and expanding our research to other architecture elements.

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References