BODY + SPACE

Exploring Morphological Transformations of Body Movements in the Design of a Transformable Structure

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Abstract. This paper reports a process of designing a kinetic structure that offers an interactive environment where one can experience the continuum of body and space. The structure emulates ten body movements, derived from the principles of physical Zen training as its transforming mechanism. In this paper, the series of computational methods for establishing the mapping between morphological transformations of the movements and the geometries of the structure are demonstrated.

Keywords. Interactive environment; body movements; mapping.

1. Introduction

In the history of art and architecture, various systematic mappings have been made in order to transpose a human body and its movement through space into the abstraction of complex geometries (Dürer, 1989; Naumann, 1999; Hammer and Lodder, 2000). With the help of contemporary technology, the human body movements have become the interface for negotiating architectural space and form (Lynn and Rashid, 2002; Matushima et al, 2008). The geometrical formations analyzed in the body movements provide the trajectory for scribing the influence of the movements to the spatial domain. They allow a designer to explore new architectural forms that lie in a boundary of ambiguity in the flux of time, space and human body movements. The architectural forms become the frozen memory of the movements. This paper introduces the design process for a kinetic structure emulating the movements of a human body. In this process, various computational methods are employed for translating the movements

into the design of the structure. Particularly, ten body movements from Zen physical training were selected for the source of this kinetic structure design.

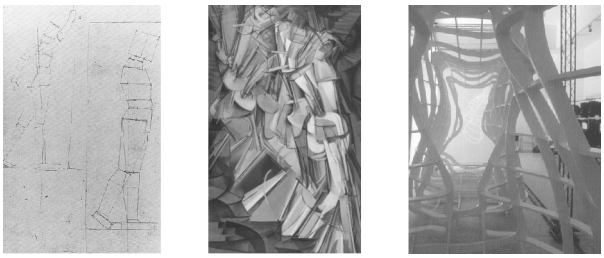


Figure 1. (a) The stereometric man (Dürer, 1989)
(b) Nude descending a staircase (Naumann, 1999)
(c) Broadcast architecture (Lynn and Rashid, 2002)

2. Ten Movements From Zen Physical Training

Thousands of years spent exploring the continuum of body and space have culminated in present day Zen philosophy, which informs and directs spatial concepts in relation to the human body. As such, the tradition of physical Zen training provides a highly refined understanding of the human body in space. The Zen tradition relies on physical training in developing one's spatial perception to a high level of sensitivity (Sogen et al, 2001).

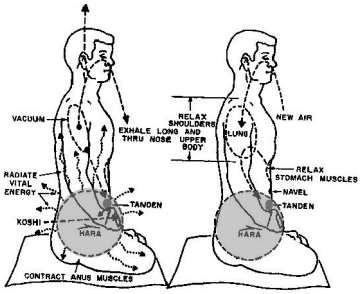


Figure 2. The diagram of personal energy flow in breathing (Sogen et al, 2001)

This tradition gives us benchmarks to check if our design decisions regarding the shifting of the kinetic space are rooted in an accurate response to human movement. With the help of Zen masters, this paper employs this highly refined sensitivity to guide the transformation of space. The experiment begins with the analysis of ten movements selected from the Tai Chi tradition. The selected ten movements are representing numbers from one to ten, which are "yut,"

"ni," "sam," "say," "mng," "luk," "chut," "baht," "gao," and "sup" in Cantonese. Each of the movements is distinct yet simple, and digitally capturing the refinement of these movements provides geometric models for analyzing human movement as well as the accompanying breathing and posture. The digital representation of the movements provides a new understanding of human movement and its spatial implications.

3. Capturing, Mapping, and Simulating

The process of designing a kinetic structure according to ten movements consists of three phases; capturing, mapping and simulating. With the help of original video capturing of ten movements, initial body movements are analyzed digitally. The initial movements are adjusted and enhanced with the guidance of Zen masters. Through a mapping process, the movements are then translated into geometric representation of the kinetic structure. Finally, the interaction between the structure and the movements is simulated to examine the flow of space.

3.1. CAPTURING

Capturing is the process of recording body movements in various digital formats. Based upon the video recordings of a Zen master's ten movements in different viewpoints, the characteristics of each movement are analyzed.

The initial formation of the movement was laid out with a three-dimensional human object in Autodesk Motion Builder, which is a real time three-dimensional character animation software. This transition from two-dimensional information of the video recording to three-dimensional geometric data in Motion Builder allows the master to engage in the development of ideal movement geometry.

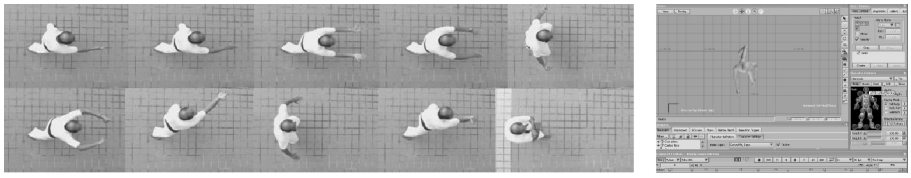


Figure 3. The development of an ideal movement in Motion Builder

3.2. MAPPING

Mapping is the process of establishing a relation between body movements and the movement of a kinetic structure. From this process, the spatial interaction

of the body movements becomes the source of defining the geometric form of the structure. In this paper, mapping starts after the conversion of three-dimensional geometric data inside Motion Builder to the one in Autodesk Maya, which is an integrated 3D modelling, animation, visual effects, and rendering solution. Maya provides various mapping options for generating the influence of the body movements in space. Three mapping options are experimented. They are 1) motion trails, 2) particle systems, and 3) skinning.

3.2.1. Motion Trails

Motion trails are one of the functions embedded in Maya for displaying the trajectory of an animated object with a series of coordinates. In this paper, this function was employed for representing a direct influence of the movements in space. With the following MEL (Maya Embedded Language) script, the trajectory becomes a Non Uniform Rational Bi-spline (NURBs) curve that can be manipulated for generating various geometric forms.

```
global proc mtrails2nurbs (){
     $selected=`ls -dag -et snapshotShape`;
          for ($obj in $selected){
            $pts=(getAttr($obj+".pts"));
            $size=size($pts);
            $curve=`curve -d 1 -p $pts[0] $pts[1]
            $pts[2] -p $pts[4] $pts[5] $pts[6] -k 0 -k
            1`;
            for($i=8;$i<$size;$i+=4)
            curve -os -a -p $pts[$i] $pts[$i+1]
            $pts[$i+2] $curve ;
          }
}
```

Figure 4. A MEL script for converting motion trails into NURBs curves

The generated forms represent the calligraphy of the body movements in space. The process of generating forms with motion trails is straightforward; 1) selecting key components of the body movements, 2) generating motion trails from the components, 3) converting the trails to NURBs curves, 4) making various surfaces with lofting, extruding, sweeping the curves.

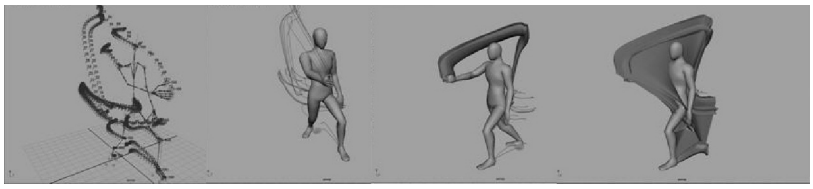


Figure 5. The process of generating forms with motion trials – a body movement (YUT)

However, the implication of the generated forms for this design development is limited to the representation of external body movements. How to introduce the energy flow of the inside of the body still remains as a challenge. This leads to the use of particle systems to representing the energy flow.

Figure 6. The calligraphy of various body movements in space

3.2.2. Particle systems

In Maya, particle systems consist of emitters, particles, and fields. Emitters are the source objects to create particles. Particles are abstract geometry that has no shape or form. They can be displayed as points, streaks, spheres, or other shapes. Fields simulate the forces of nature, such as Newton force, gravity, air, turbulence, and vortex. If fields are applied to particles, the particles animate and render to simulate natural phenomena.

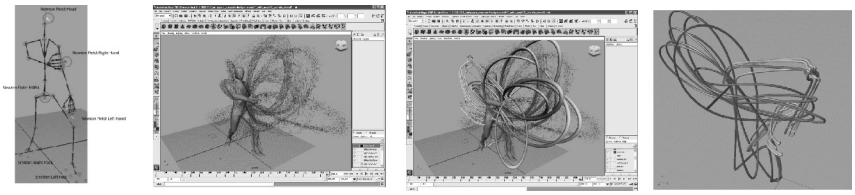


Figure 7. Various geometric forms from particle system of a body movement (YUT)

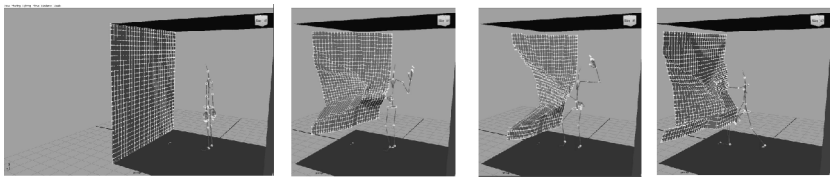
According to the guidance from Master Kow Roshi, individual emitter is set on each foot, which is the gate for transmitting energy from earth to the inside of body. Four Newton fields are then created as attractors to control the flow of the energy. One is at about three finger widths below and two finger widths behind the navel, which is called *HARA*: the central point of the energy flow. Another one is set at the top of head, and the other two are attached to

each hand. These points are the gates for transmitting energy out of the body. By converting simulated particles from the emitters to NURBs curves, using a MEL script, various geometric forms are modelled.

Even though the particle system represents the energy flow from inside to out, the representation defines only the boundary of the energy flow in space and the form of the trajectory.

3.2.3. Skinning

Skinning is the process of binding deformable objects to a skeleton. Instead of observing the influence of the body movements in empty space, the surroundings of the movements are constructed. Based upon the guidance from the Zen master, the surrounding objects are connected to the skeleton of the body with skinning function in Maya. The surrounding surfaces transform with the body movements controlled by the skeleton. The movements of the surfaces and the skin of the body originate from the same skeleton; movements are synchronized.



(a) The process of skinning a body movement (YUT)

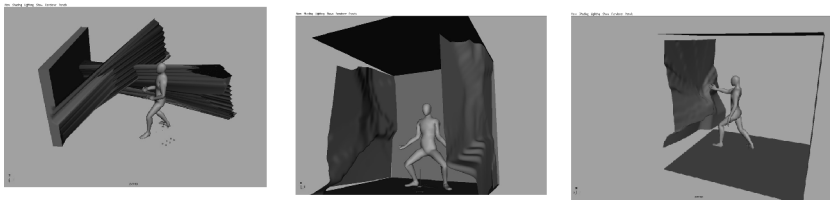


Figure 8. (b) Various skinning examples from different movements

3.3. SIMULATING

Simulating is the process of imitating body movements with the movements of surrounding objects. After the surrounding surfaces are connected to body skeletons with skinning, all the components of the kinetic structure are defined accordingly. The kinetic structure consists of four surfaces, 100 moving bars attached to each surface, and a structural frame to hold the surfaces. The movements of the four surfaces create a temporary entrance at each corner. The boundary between the interior and exterior space of the shelter is blurred

by the dynamic space defined by the surface movements. The fluctuation of the surfaces offers an interactive environment between body and space in time.

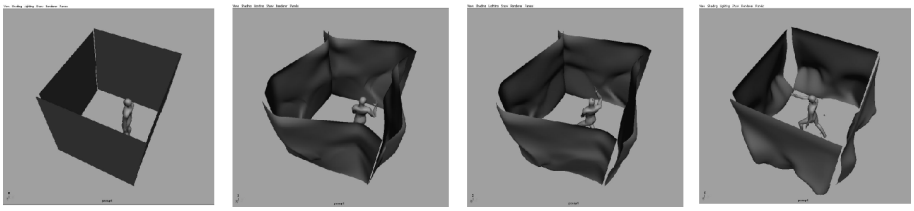


Figure 9. The fluctuation of surrounding four surfaces of body movement (YUT)

4. Outcomes

The process of designing a kinetic structure that emulates body movement is developed in this paper. Motion trails, particle systems, and skinning functions in Maya are employed as instrumental components in the middle of design development rather than in the post-production process of analyzing a design result. As an outcome, the conceptual model of a kinetic structure emulating ten body movements is produced as below.

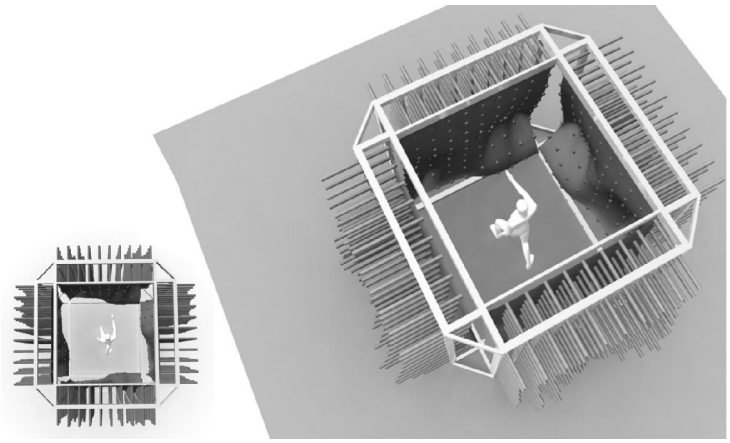


Figure 10. A design of a kinetic structure based on a body movement (YUT)

5. Conclusion

With the help of animation capability in Motion builder and the series of dynamic simulation functions in Maya, this research sheds some light on a way of translating universal Zen principles, embedded in ten movements, into

the discipline of architecture. The method represents mind and body becoming one, as the interior and exterior space of the structure transform into a single transitional space. Furthermore, various evolving technologies are introduced as the axis centring the convoluted efforts among professionals from various disciplines.

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