

Active Shapes

Introducing guidelines for designing kinetic architectural structures

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Abstract: *This paper proposes guidelines for designing kinetic architectural structures, in which rules based on Shape Grammars are used for motion capturing and design. There is an increasing demand for adaptive architecture that reconfigures itself physically to meet functional or climatic changes. These guidelines provide a way for the designer to describe and design novel kinetic structures. Based on Shape Grammars, the rule $A \rightarrow t(A)$ is introduced. (A) means an Active Shape, that is a physical shape with motion observed or created by the designer. $t(A)$ means a new Active Shape produced by applying one or more transformations t on the original Active Shape to produce a novel motion.*

Palabras clave: Motion Grammars; Kinetic Architectural Design; Shape Grammars.

Introduction

William Zuk and Roger Clark defined kinetic architecture as “the architectural form, which could be inherently be displaceable, deformable, expandable or capable of kinetic movement” (Zuk and Clark 1970). There is now an increasing demand for adaptive architecture that reconfigures itself physically to meet functional or climatic changes. There have been some precedents on how to design these kinetic architectural structures, but they all just presented the types of motions and elements used in these structures. There aren't any guidelines or frameworks to help the designer to design novel kinetic architectural structures. In addition, the motion of these structures is always described in a discrete way as a change from one state to another without considering what's really happening between the two states to make the change. This paper proposes guidelines for designing novel kinetic architectural structures, in which rules based on shape grammars, are used for motion capturing and design.

Precedents for Kinetic architectural design

By studying the precedents for designing kinetic architectural structures, it was found that there aren't any guidelines or frameworks to help the designer to design novel kinetic architectural structures. Zuk and Clark presented some students' work for kinetic architecture

projects in design studios at the University of Virginia. But they didn't explain their pedagogical approach or the design process for these kinetic structure projects (Zuk and Clark 1970). Michael Fox and Catherine Hu introduced a pedagogical approach for creating responsive architecture systems. They used a different design approach from typical design courses, instead of starting by finding the problem, then research and then design, they started by designing the mechanical structures first, then “grow” the system by adding sensors and motors (Fox and Hu 2005). In 2007, Angeliki Fotiadou attempted to formalize and systemize a basis of knowledge and information, which is indispensable to turn a design support for kinetic structures into representation by means of a 3D animating program (Fotiadou 2007). Masiar Asefi presented design guidelines to help architects through the selection process of transformable structures. He grouped the criteria in 4 categories: (1) design, (2) construction and operation (3) maintenance and costs, which includes Life expectancy, and maintenance management strategies. (4) application (Asefi 2010). Also, Schumacher et al. investigated how dynamic movements in buildings could be “illustrated, accommodated, and controlled” (Schumacher, Schaffer and Vogt 2010).

Active Shapes

Herbert Simon states that designers start from something and nobody starts from scratch, and designers use precedents, “existing situations”, and edit them to get their own design, “the preferred one”(Simon 1996). This also applies to designing kinetic architectural structures. The question here is: what should the designer do, when he looks at a moving structure, and becomes inspired by it to change it, add to it, and use it in his own kinetic structure? In 1972 George Stiny and James Gibsintroduced Shape Grammars in 1972 as a new visual approach to design and analysis (Stiny and Gibs 1972). These computations on shapes are performed in 2 steps; first recognizing a particular shape, and second applying a rule that specifies which shape could be replaced, and how it could be replaced. This paper is introducing Active Shapes and rules based on Shape Grammars, where Active Shape (A) is a physical shape with motion observed or created by the designer. The Active Shape (A) could be composed from one physical component or several physical components together (Fig. 1).

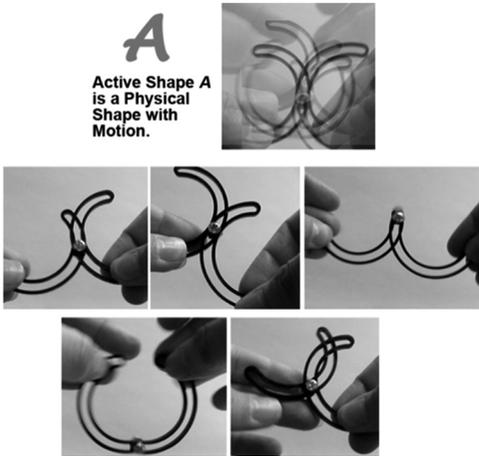


Fig. 1. Active Shape A is a Physical Shape with Motion.

Active rules

Based on Shape Grammars, the rule $A \rightarrow t(A)$ is introduced as a design guideline for designing kinetic architectural structures. (A) means here Active Shapes, in which Active shape (A) is a physical shape with motion observed or created by the designer. $t(A)$ means a new Active Shape produced by applying one or more transformations t on the original Active Shape to produce a novel motion. These transformations could be (1) a transformation of the arrangement of the parts of the Active Shape, (2) a transformation of the motion con-

trol means between the parts of the Active Shape (3) a transformation of the geometry of the parts of the Active Shape or it can be any other transformation, such as a transformation in the materiality of the Active Shape.

$A \rightarrow t(A)$

Active Shape A is a Physical Shape with Motion.

$t(A)$ is a new Active Shape produced by the transformation t applied on the original Active Shape A.

Fig. 2. The active rule.

a. Arrangement

This is a transformation in the arrangement of the components of the Active Shape. In the mentioned example here, a scissor pair mechanism with a central pivot point is considered as Active Shape (A). By applying a transformation in arrangement on the Active Shape (A), the pivot point of the scissor pair structure is shifted above the center point, which results in $t(A)$, a new Active Shape with a new motion(Fig. 3).

b. Control means

In the mentioned example here, a scissor pair mechanism with one central pivot point is considered as Active Shape (A), it has a rotational motion around one point. By applying a transformation in the control means of the components of the Active Shape (A), the pivot point of the scissor pair structure is replaced by a sliding controller, which results in $t(A)$, a new Active Shape with a new motion and new degrees of freedom(Fig. 3).

c. Geometry

The third transformation in the above mentioned rule could be a transformation in the geometry of the components of the Active Shape. In the mentioned example here, a scissor pair mechanism with one central pivot point is considered as Active Shape (A), it has a rotational motion around one point. By applying a transformation in the geometry of the components of the Active Shape (A), the straight components are replaced by a

curved components, which results in $t(A)$, a new Active Shape with a new motion (Fig. 3).

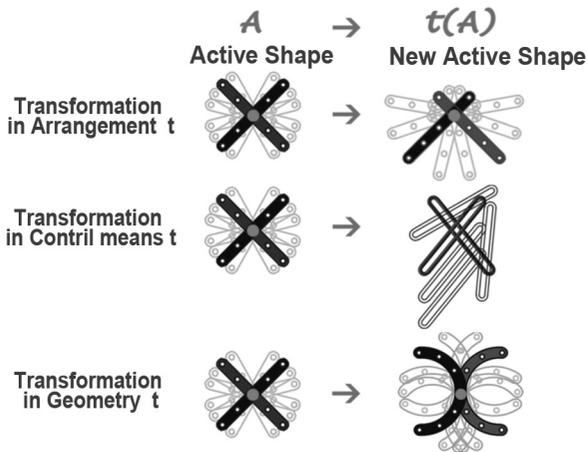


Fig. 3. The rule showing the original Active Shape A and once the transformation t is applied on it, it becomes a new Active Shape $t(A)$.

Motions

In order to test the above-mentioned transformations, 3 basic types of motions are studied. The studied basic motions are: (1) Rotation, (2) translation and (3) Rotation and translation.

a. Rotation

One pivot point as a control mean is used to create a rotational motion from the components of the Active Shape (A). In order to create a matrix among the three transformations on the components t of the Active Shape (A), the control mean stays the same in this table, and the change is between the transformation in geometry t and transformation in arrangement t of the components of the Active Shape (A) (Fig. 4).

		Transformation in Arrangement $A \rightarrow T(A)$		
Transformation in Geometry	Geometry			
	$A \rightarrow T(A)$			

Fig. 4. A table showing the change in the transformations in Geometry t of the components of the Active Shape (A) with respect to the transformations in the arrangement t of the components of the Active Shape (A).

b. Translation

A slider is used as a control mean to create a translational motion from the components of the Active Shape (A). In order to create a matrix among the three transformations, the control mean stays the same in this table, and the change is between the transformation in geometry t and transformation in arrangement t of the components of the Active Shape (A). All Active Shapes (A) in the table have the same motion (translation), they have the same control mean, but they vary as a transformation t in the arrangement or the geometry of their components.

		Transformation in Arrangement $A \rightarrow T(A)$	
Transformation in Geometry			
	$A \rightarrow T(A)$		

Fig. 5. All Active Shapes (A) in the table have the same motion (translation), they have the same control mean, but they vary as a transformation t in the arrangement or the geometry of their components.

c. Rotation and Translation

A pivot point and a slider are used together as control means to create a rotational motion from the components of the Active Shape (A). In order to create a matrix among the three transformations on the components of the Active Shape (A), all Active Shapes (A) in the table have the same motion (rotation and translation), they have the same control mean, but they vary as a transformation t in the arrangement or the geometry of their components.

Conclusion and future work

Although it is still difficult for the designer to predict the exact behavior of the motion of a kinetic structure in the design process, once the designer follows the presented guidelines, s/he gets a better idea of what would happen to the motion if s/he applied one or more of the transformations on the components of the Active Shape.

The trial and error process will still be used to give an idea how a kinetic structure moves, but the introduced guidelines in this thesis proved to be more efficient, and give the designer the ability to produce novel kinetic structures. A workshop was held, where some students started using the guidelines in designing kinetic structures. These guidelines also proved that they could be used as descriptive tools for the motion of a kinetic structure. This would help the designers to look at different kinetic motions and describe them with these tools and get an Active Shape (A). By applying transformations on the Active Shape (A), the designer forms a new Active Shape (A) that could fit his design problem.

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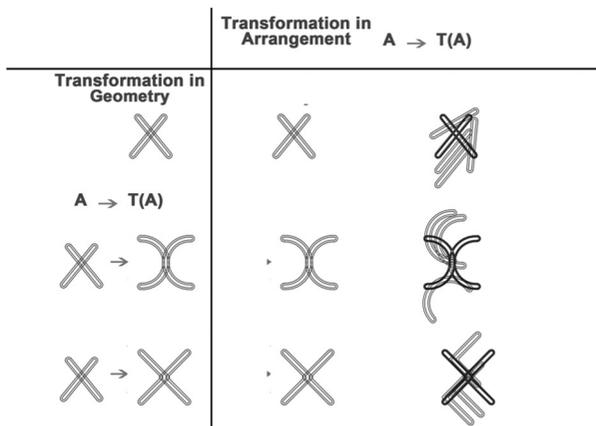


Fig. 6. All Active Shapes (A) in the table have the same motion (rotation and translation), they have the same control mean, but they vary as a transformation t in the arrangement or the geometry of their components occurs.

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