COMPUTER AIDED ANALYSIS TO UNDERSTAND THE BEHAVIOR OF A MODULAR CHAINED BLOCK

Towards an intentional control of a transformable architecture

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Abstract. This paper reports on the outcome of several tests that are run to examine the behavior of virtual and physical models of a chained block. Correlations between parameters of the component and the global geometry are studied using parametric modeling and physical model. Studies are limited to proportional and non-proportional relations according to the direction of the force. Further experiments are expected in the future to explore other forces. These computer-aided analyses offer a deeper understanding of the behavior of the system towards an intentional control of the global geometry.

1. Introduction

The research investigates the behavior of a transformable structure that consists of discrete identical modular objects in order to obtain more controllability of the structure in the future. The structure consists of hexagonal hollow blocks with three legs (Figure 1). One component is connected to six adjacent components with ribs that keep them from falling apart. The range of movement is similar to that of a cloth and at specific point, it becomes a stable structure. On one hand, it overcomes the limitation of conventional compression structure that is built by joining blocks one by one using a substructure, on the other, it offers another strategy in transforming a global geometry for interactive architecture.

In most recent research, applications of computational design to the compression structure enabled architects to design and materialize complex geometry. For instance, interlocking structure (Tessmann, 2012) and vault structure (Varela & Merritt, 2016) gained free forms. In these examples, target geometries were designed first and then they were divided into processable unique components. During the construction, a substructure that serves to hold and support the blocks up until the last piece is assembled were built, and objects were laded on top of it. This results in needless consumption of time and materials, since the formwork eventually turns into waste.

Figure 1. A full picture of the mock-up.

Precedents in research for interactive architecture includes adaptive roof structure, that has individual unit controlled by a computer (Hotta & Hotta, 2016), which requires heavy wiring and soft acoustic tiles that deform but cannot bear the load (Decker, 2015). Transformation by shifting components' configuration is the alternative strategy for controlling a shape of a transformable architecture. The form will be changed neither by material deformation nor by an individual actuator attached to the each component.

In the proposed structural system, one can lay the component in any shape with any number and once the force is applied, it supports itself. Thus, this chained block system exhibits two interesting properties: incremental modularity as a discrete material and uniformity of transformation as a continuous material.

2. Aim and Problem Statement

The work attempts to understand the behavior of this structural system in order to establish a simulation methodology. If the accurate simulation is achieved, then it follows that the global geometry is predictable and thus can be intentionally controlled. This paper attempts to reveal how an example of modular design of components affects a global geometry. Parametric modeling was used to produce variations of the physical model.

As is often the case with physical phenomena, simulation of physical environment often comes with difficulties. In the proposed case, each component has six degrees of freedom and collides with neighboring six components (Figure 2). Although author built the previous mock-up, the actual mechanism of how each component transfers pressure and get stabilized, is not fully understood yet.

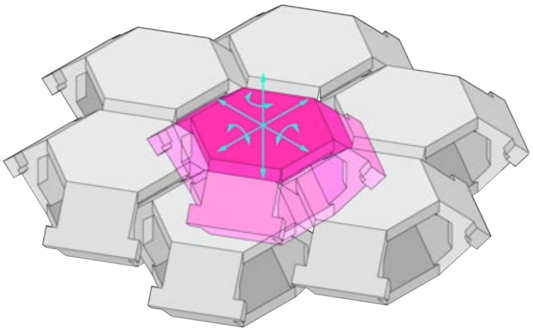

Figure 2. Relationships between components.

3. Methodology

Physical models were used to understand the behavior as "only synthesized information sets from both analog and digital realms can render a granular behavior comprehensively (Dierichs & Menges, 2013)." Two parameters, leg length and height, were changed to examine the correlation with a global geometry. Table 1 shows parameters used for this experiment. Models were 3d-printed with 0.4mm of layer height and the thickness of the surface was 1.5mm.

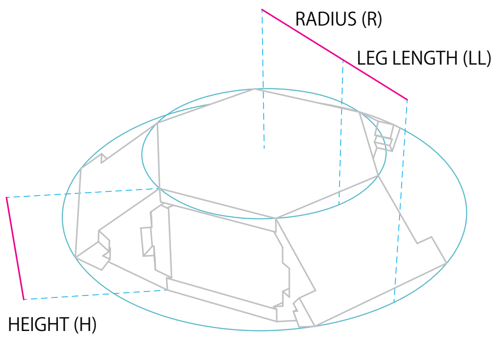

Figure 3. Three main parameters.

TABLE 1. Five models with different parameters.

Version (No.)	1	2	3	4	5
Radius [R] (mm)	8	8	8	8	8
Leg Length [LL] (mm)	5.5	4	7	5.5	5.5
Height [H] (mm)	5	5	5	4	6

For each version, two cases, A and B, were studied (Figure 4). In both cases, a force of 20N was applied to the sheet of components by pushing through a spring balance. Five variables were measured through this experiment.

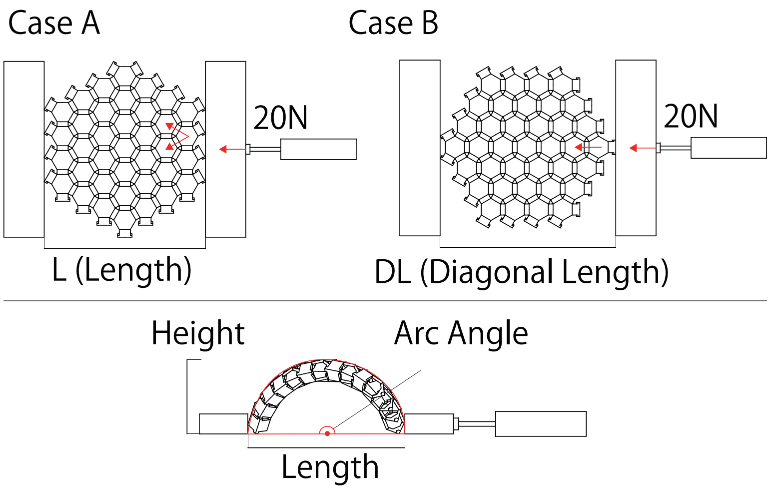

Figure 4. Definitions of measured variables.

4. Results

When certain amount of force is applied until model gets stable, the variables were measured (Table 2). The information on the angle of the arc that a group of components can afford is utilized in the future work for restraining a range of global geometry so that it does not locally collapse.

The mean angle of version 1, 2, and 3 in case A and B were compared to see how a difference in leg length affects global geometry (Figure 5). Similarly, the mean angle of version 1, 4, and 5 in Case A and B were compared to see how a difference in height affects global geometry. In Case A, proportional relations can be observed. On the other hand, in Case B, the value of version 1 is relatively high and hence, the relation is non-proportional.

TABLE 2. Properties of the physical models.

		Standard				Leg Length								Height							
R : LL : H		Version 1 8 : 5.5 : 5 L: 110, DL:120				Version 2 8 : 4 : 5 L: 105, DL: 112				Version 3 8 : 7 : 5 L: 117, DL: 121				Version 4 8 : 5.5 : 4 L: 111, DL: 120				Version 5 8 : 5.5 : 6 L: 110, DL: 117			
Case A																					
		Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7
	1st	32	90	140	20	25	98	98	14	54	77	204	29	11	107	60	9	50	76	199	28
	2nd	33	94	132	19	20	97	87	12	49	78	196	28	8	110	56	8	48	78	194	28
	3rd	35	91	133	19	20	97	76	11	55	75	202	29	8	108	56	8	49	77	198	28
	Mean	35	91	133	19.3	20	97	76	12.3	55	75	202	28.7	8	108	56	8.3	49	77	198	28
Case B																					
		Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7	Height	Length	Arc Angle (X)	X*1/7
	1st	50	83	187	27	19	107	78	11	65	77	217	31	19	117	58	8	60	75	218	31
	2nd	52	79	199	28	23	104	88	13	65	76	228	33	17	118	67	10	58	71	227	32
	3rd	51	81	196	28	21	105	81	12	55	79	201	28	16	116	63	9	58	73	226	32
	Mean	51	81	196	27.7	21	105	81	12	55	79	201	30.7	16	116	63	9	58	73	226	31.7

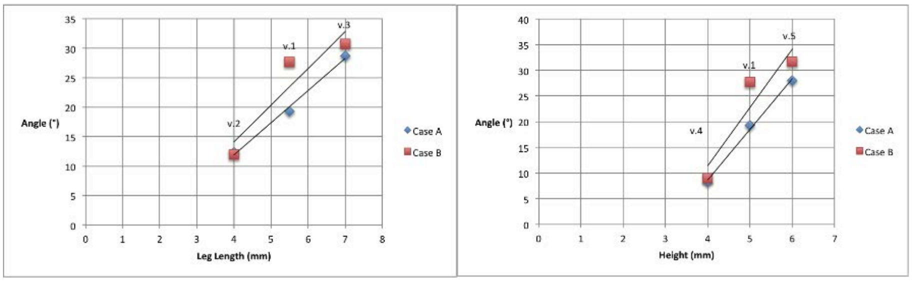

Figure 5. Correlations between parameters.

5. Conclusion

The behavior of the modular chained block was studied by a combination of digital and physical models. The correlation of parameters of a component and a global geometry was proportional in Case A and non-proportional in Case B. Further investigation has to be conducted to clarify what governs the angle between components. These findings and properties of a global geometry will be imported into a computational model in order to simulate the behavior for establishing a controlling system of a transformable architecture in the future work.

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