Digital Architecture - What Would 6000 Points Turn Out To Be?

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Abstract

This paper presents students' fulfillment of an assignment that explored the concepts of digital architecture using rapid prototyping (RP) process. A point cloud was given to students, and different representational data were substantiated as real 3D physical models. The presence of RP models and the sequential illustration of working steps in their reports revealed that the control of shapes often differed from what students perceived in VR worlds. The results thus confirm that physical models are useful for visualization as well as in design pedagogy.

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1 Introduction

A rapid prototyping (RP) machine can fabricate 3D models for visual inspection. Applications in architecture are made in the fabrication of building parts and design concepts (Krishnamurti & Earl 1992; Novitski 1999; Rotheroe 2000; Ryder, etc. 2002; Streich & Weisgerber 1996; Wang & Duarte 2002). RP in architecture is limited by the restrictions on size and time required to output a model. The footage of the model is another limit of an ordinary RP machine. A large model has to be separated into parts and assembled afterward. Another drawback is that the process is time-consuming. Normally, an RP production of industrial parts the size of a cell phone cover may take up to 10-20 hours. Ordinary RP materials like polymer can create a thin cover with the strength of plastic. Another drawback is that RP models are made in white or a plain color. Although color-keyed components have been created recently, so that a uniform color can be assigned to a part (Karapatis, etc. 1998; Ming & Gibson 1999; Pham & Gault 1998), still, the limited variety of colors cannot provide adequate surface attributes such as the texture that is needed in architecture visualization, whether it is procedure texture (texture allowing for parameter change) or direct image mapping (texture using a predefined image as content).

The data used for RP do not have to be the final results of visualization; instead, this stage of application can offer benefits in the early design stages (Simondetti 2002). Similar RP application in the field of art can be seen in the creation of cartoon characters and visual arts (Connolly 2001; Tome 2001). It seems RP has worked well with current modeling processes in a specific and purposely integrated manner. But how useful is it in architecture? It is still to be seen whether a direct connection with a modeling process can be established.

2 An Assignment

In a course entitled “Digital Architecture” offered by the author, an assignment was given to students to create forms based on any simulated behavior of objects. With the enlightenment of forms manipulated in digital designs, most of the students produced free forms (see Figure 1). These outcomes led to a second assignment for which works were to be created from an ill-defined structure of geometric data. Assignment 2 was designed to use smoke particles generated from Hazard II (a fire simulation program) as a raw data set of point clouds. Although each point represented a particle of fire or smoke, the attributes were removed and hidden from students for a pure geometric study of the potential development of forms. The point cloud and the instructor’s illustrations of possible developments can be seen in Table 1.

Figure 1. An RP exemplification from assignment 1 and its original digital form

3 Observation of student work

When the assignment was given to students, the instructor hypothesized that they had no preconceived notions of tools, data interpretation, and presentation. The kinds of titles students used for the second assignment were “6000 points,” “Inside or outside!?,” “Combination of three-way frames,” etc. (see Table 2). Their reports showed they perceived that points were disoriented and not measurable by size. 6000 points were considered as a single entity as well as a group of multiple objects. For some students, points were static, so a “wrap” operation could be made. For other students, in contrast, points were dynamic, so the connections among them either showed the movement of parts or that their presence enabled turbulence made by other types of geometry. Points were the subjects that “interfere” with a plane in order to reveal their presence in a certain form.

A typical development of concept starts from a theme (which could be a metaphor), involves parts buildup, and ends with RP output (see Figure 2). In creating forms from a point cloud, the development of student concepts can be classified as using:

- Feature-oriented approaches: involving the boundary of a point cloud, the behavior within this cloud, or the roles of being active or passive in relation to intrigued points
- Application-oriented approaches: involving path extrusion, section sweeps, wraps, traces, and turbulence
- Methods of illustration: involving stepwise proof of rendering or screen captures

4 Discussion

Comments were given to students and RP outputs were displayed based on their input. A Z-406, also called a 3D printer,

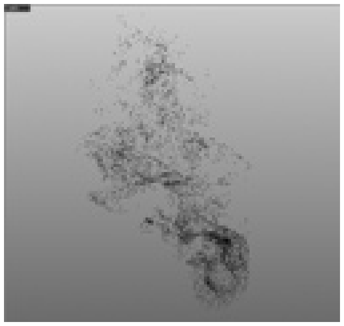
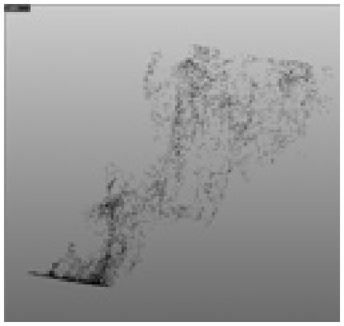
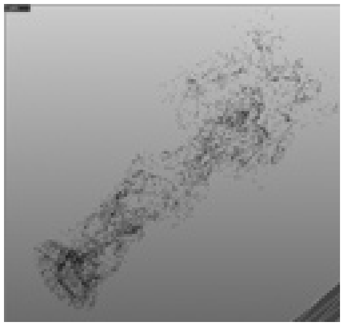
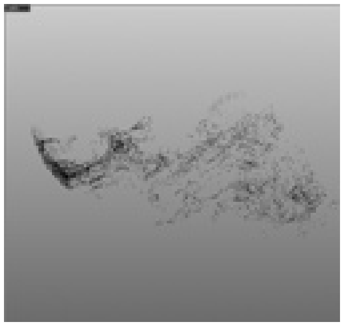
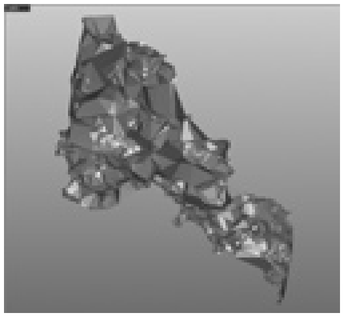
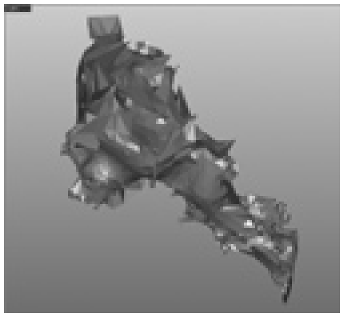
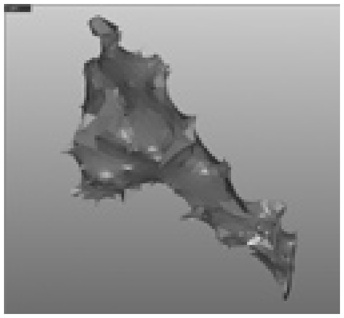
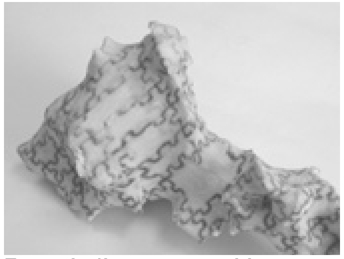
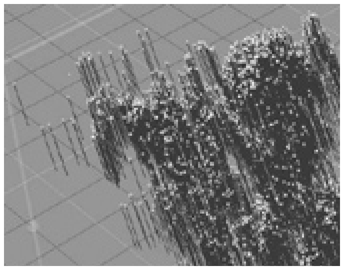
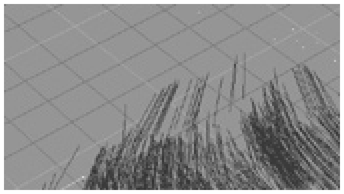
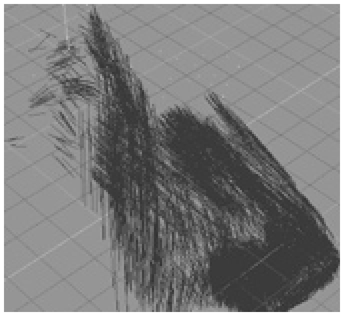
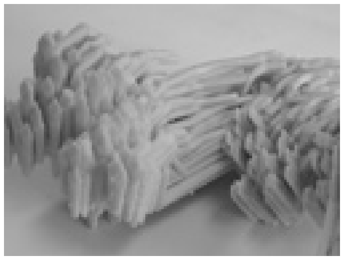
			
 **Initial wrap**	 **Surface smoothed**	 **Smoothed more**	 **Example 1's rp output with curvature-enhanced texture mapping**
 **Point extrusion**	 **Extruded lines are stretched like skins in different directions**		 **Example 2's rp output**

Table 1. Point cloud and the instructor's illustrations for assignment 2.

was used for layering type output of models. Students were asked for VRML model files to allow color textures to be added to output.

- Students developed a method to create forms out of a cluster of basic geometries. When elements were modeled one by one, the initial piece of the installation had a strong influence on the following pieces, as it changed the spatial relationship of the installation. The presence of sequences sometimes acted as a strong guide for the following installation. Since the number of points had increased to a level that, in one way, was difficult to control point by point, and in another way, made the distribution of points unable to lead to a clear distinction in density as a clue to develop forms, students were working on the development of orders to interpret these points from boundaries or from the inside. But most of the time, the more than expected number of points gave possibilities to fulfill the declaration of orders because there were always some points available. It turned out that a framework for geometric form emerged for each student to use to define forms.
- The development of order needs to be controlled by explicit procedures. So frames of the development process (see Figure 3) are shown not only for illustrating the requirements of the assignment, but also to act as tracing the previous steps in order to facilitate personal control over the following development of concepts. Frames of

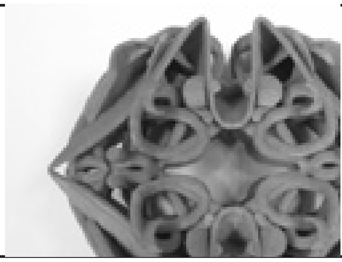
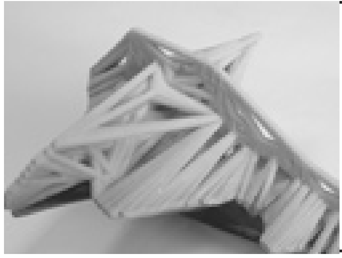
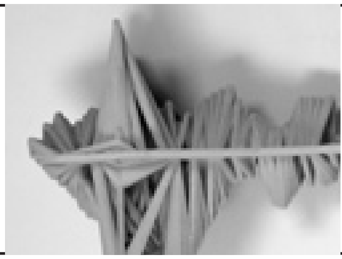
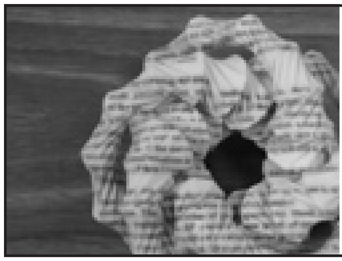
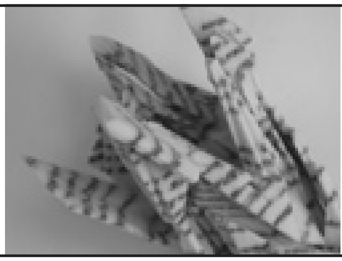
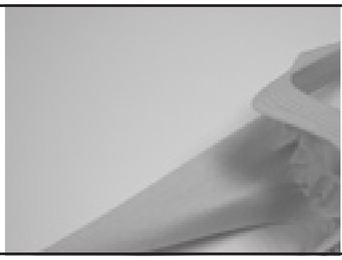
		- a heterogeneous presentation of elements - space wrap-up with planes and tubes interlaced - a point–face, point–sweeping path process of modeling - an active representation of a point cloud
		-a heterogeneous presentation of elements -space fill-in with three orthogonal interlacing frames which were made by linear elements of inter-connecting vertices inside each frame -a point–three-way frame–inter-connecting process of modeling an active representation of a point cloud
		- a void space defined by multi-orientational tracing of a 3D boundary - a point–sweeping path process of modeling - a passive representation of a point cloud
		- a volumetric wrap-up of juxtaposing sets of point clouds - an active representation of a point cloud
		- a void space description made by a point cloud’s interference to planes - a point-plane interaction process of modeling - a passive representation of a point cloud

Table 2. Exemplifications from assignment 2

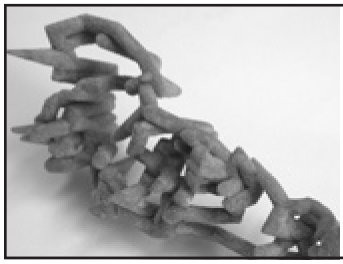
	- space fill-in of three juxtaposing routes made by different configurations of a section - a point–path–extrusion process of modeling - an active representation of a point cloud
	- space fill-in of paths made by tracing points with a point cloud - a point–line–face process of modeling

Table 2. [continued]

views were used afterward to inspect the series of steps previously done for the instructor as well as for the students themselves. The sequence of views did not have to follow original process, but interpretation could be subject to it.

Figure 3. An example of frames of concept development

- A modeling process is also an interpretation management process of views and vocabulary. Almost all the students presented their works as frames of views or steps to enhance the concept delivery. A typical differentiation of views comes from default computer windows; despite that there are still many angles unseen. These discrete views are usually associated with an enriched vocabulary of description. For example, the third case from Table 2 was interpreted by the student as a baby lying down from a top view, as a stock chart from a front view, as a walking phantom from a left view, and as a high-heel shoe from a perspective.
Most of the responses to RP models from viewpoint-based illustration were complex. Just as it is confusing to merge the four characteristics together, it is difficult for the student initially to come up with a summarizing term for the RP model. Interestingly enough, the description, which used to be a kind of proof shortening the distance between a real world and a virtual world, becomes useless when the switch of views becomes so intuitive, continuous, and straightforward as it does with an RP model in hand. It seems a larger gap exists between before and after an RP model is made, along with the management process involved in point cloud interpretation.
- From the instructor's side, the output of the digital model did not come in plain colors. In order to enhance the order of forms, color texture was purposely mapped to models (see Figure 4). The content-explicit texture helped to identify collapsed parts and their relative positions to the original form. The texture also helped to enhance the curvature made by turbulence on a surface. In several cases, the instructor applied RP to enhance the configuration of shapes as a way to allow for better comprehension.

Figure 4. The "Dao" (left) and its detached parts printed with texture clues (right)

- Most of the students declared that the RP models helped them to identify parts of a model; i.e. the relative location of parts came with visual depth that could not be achieved in a VR environment without auto-stereographic display. For those students who had discussed their assignments beforehand, observations were threefold: the inspection of the RP model either 1) made some students doubtful of their original perceptions; 2) confirmed their expectations; or 3) shed light on other's deviations between original perception and outcome. The physical output helped students to critique each other's designs in a more substantial manner by allowing them to point to

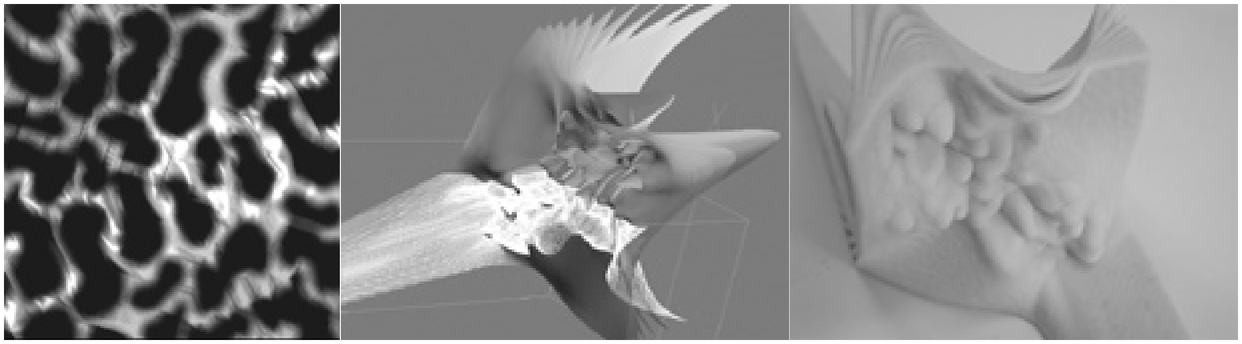


Figure 2. Concept development from an image metaphor, to parts buildup, to RP output

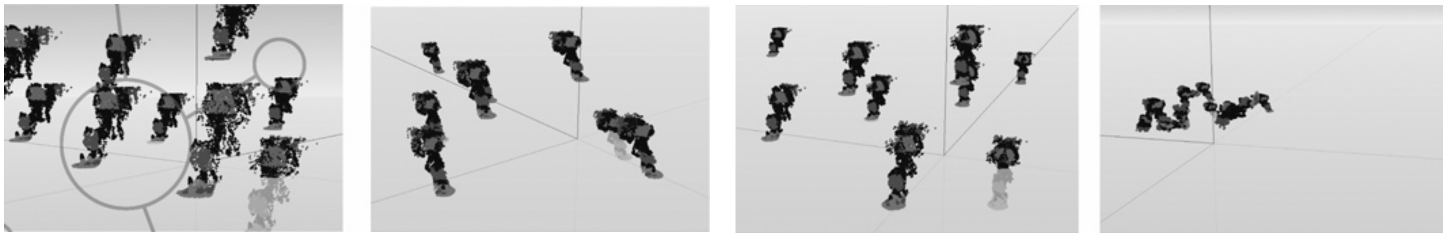


Figure 3. An example of frames of concept development

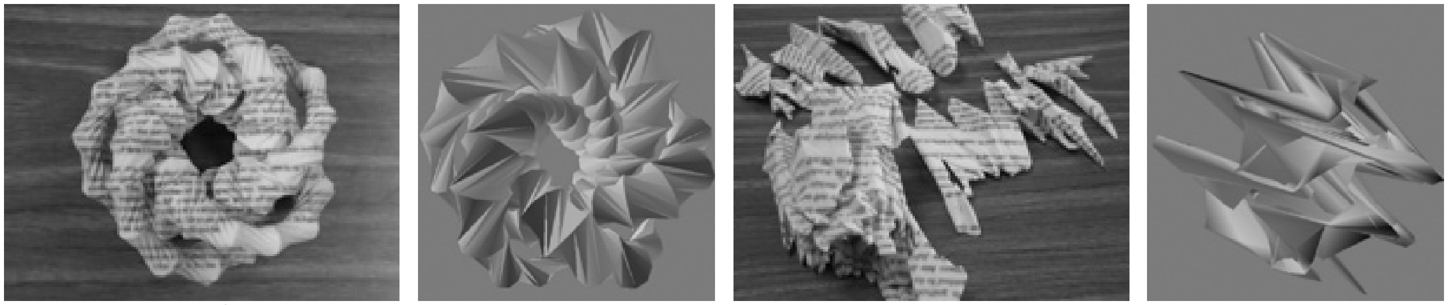


Figure 4. The "Dao" (left) and its detached parts printed with texture clues (right)

particular parts, locations, or relationships. When dealing with geometries alone, it seemed hard to tell whether students knew what they were doing. A VR world seemed not quite adequate enough for distinguishing an object's components under certain deformation circumstances. Responses showed that computers need more capability in real-time display of shaded forms with depth of field in true color. Unlike the continuous display that is possible when an RP model is held in hand, discrete displays cause a delay in the design response or an inactivation of an individual's sensitivity to forms.

5 Conclusion

A frozen state of particle movement is as enlightening as a particle's trails of movement. From assignment 1 to 2, it was shown that an un-preconceived operation could lead to many answers. Some of the forms under development were too abstract to be realized as output; otherwise, a frozen state would have been presented in the design process. The outcome of this assignment was a total surprise in that not only did students show personal styles of CAD tool application, but the development of concepts also led to diversified digital forms. When personal interpretation meets digital media, we found a VR world was not enough to state the actual appearance of artifacts. RP models helped by allowing for actual physical touch. The influence is not merely at the level of reality, but also one that gives students a sense of control over the forms being created.

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Model credits

Figure 1: Jeh-Zen Hu
Figure 2: I-Don Shu
Figure 3, 4: Jan-Cha Chang
Table2: 1.:Ham-Gin Kan, 2:Bou-Yang Chang, 3:Der-Luan Huang, 4:Jan-Cha Chang, 5:I-Don Shu, 6:Chien-U Cheng, and 7:Jeh-Zen Hu.