Appendix B

Stereolithography

The field of rapid prototyping, also known as agile manufacturing, is growing quickly to fill the need for visualizing and testing complex solid parts without the use of time consuming milling processes. These rapid prototyping technologies typically use a layered manufacturing strategy, where the object is built in horizontal sections, one atop another. This strategy allows for complex parts to be built without restrictions on internal cavities and accessibility issues that confront conventional milling methods. [Dolenc 1993] gives an overview of some of the rapid prototyping methods in use today.

One of the more successful layered manufacturing strategies has been the method of stereolithography, the method used for constructing the “hardcopy” of the Happy Buddha model described in Chapter 8. Figure B.1 shows how the process works. The computer model is first sliced horizontally, yielding a stack of polygonal outlines – well-defined regions the separate the inside of the model from the outside. Next, a support platform is raised to the surface in a vat containing a liquid photopolymer that hardens when exposed to ultraviolet light. A sweeper spreads a thin layer of the photopolymer over the surface of the platform, and an overhead UV laser scans and hardens the interior of the polygons in the first slice. The platform then lowers one slice thickness, the sweeper distributes a new layer of photopolymer, and the process repeats for the next slice. In this way, the object is constructed slice by slice. The process for building the Happy Buddha model required about 10 hours. Note how important it is that the model have no holes – such holes would lead to open polygons in the slicing step, and the definition of inside and outside the object would

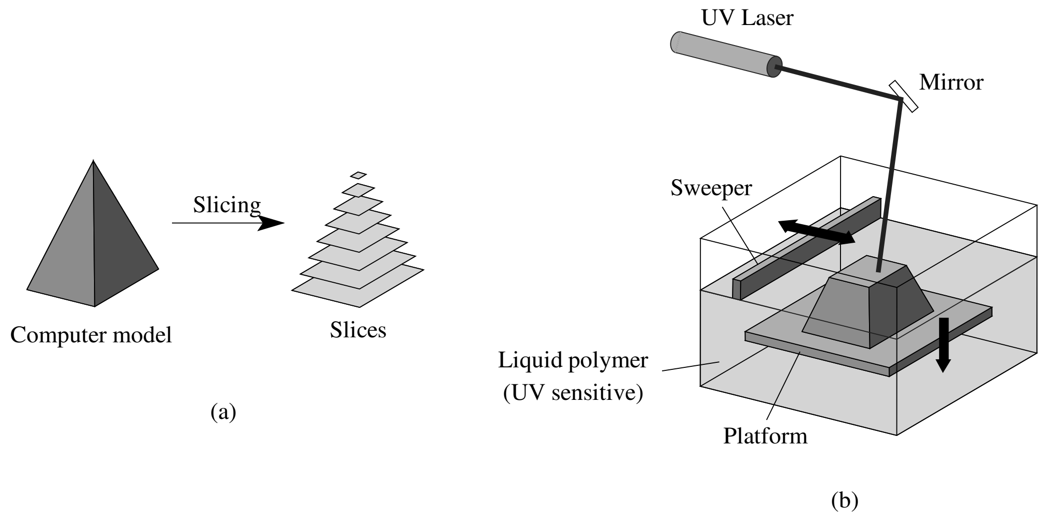


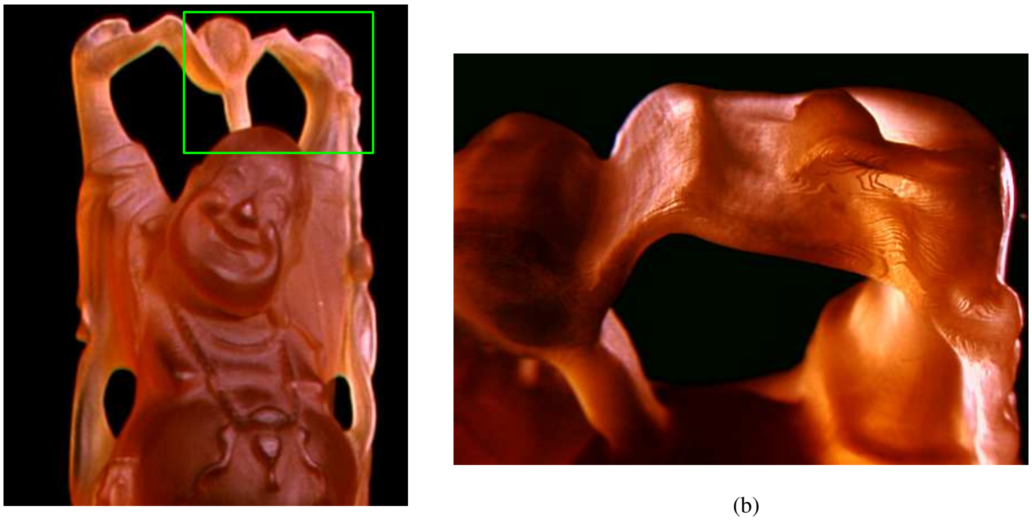
Figure B.1: The stereolithography process. (a) First the computer model is cut into horizontal slices. (b) The interior of each slice is hardened by a laser scanning over a photopolymer. The sweeper delivers even layers across the surface, while the platform lowers after each slice is hardened.

no longer be meaningful. Thus, the contribution of being able to make “watertight” models as described in this thesis is essential to the manufacture of three dimensional replicas of the original model using stereolithography.

When the layering process is finished, the solid object sits immersed in the vat of liquid. The object is then lifted out of the vat, and excess liquid is removed. To save time, the laser may only sweep the interior of the object enough to make it structurally stable, but not completely hard. In this case, the object is “baked” in an ultraviolet oven to complete the hardening process.

The thickness of the stereolithography slices in the Happy Buddha model is about 150 microns. This may seem very accurate, but it still leaves noticeable contouring artifacts between slices. Figure B.2 shows some of these contours. To remove the contours, a post-processing step of bead-blasting and manual sanding is typically required.

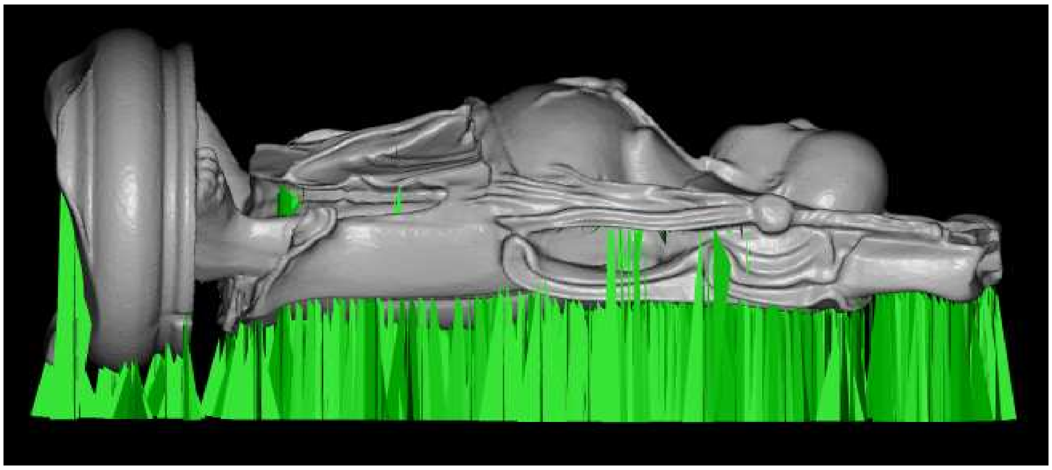
One difficulty in constructing models with stereolithography is the problem of overhanging surfaces. If a portion of the surface is not supported from below or from the side, then, when it is hardened, it will sink into the vat of liquid. As a result, a support must be inserted into the computer model before slicing and manufacture. This support is typically very narrow so that it requires little time to create as the model is being built. Further, it comes to a



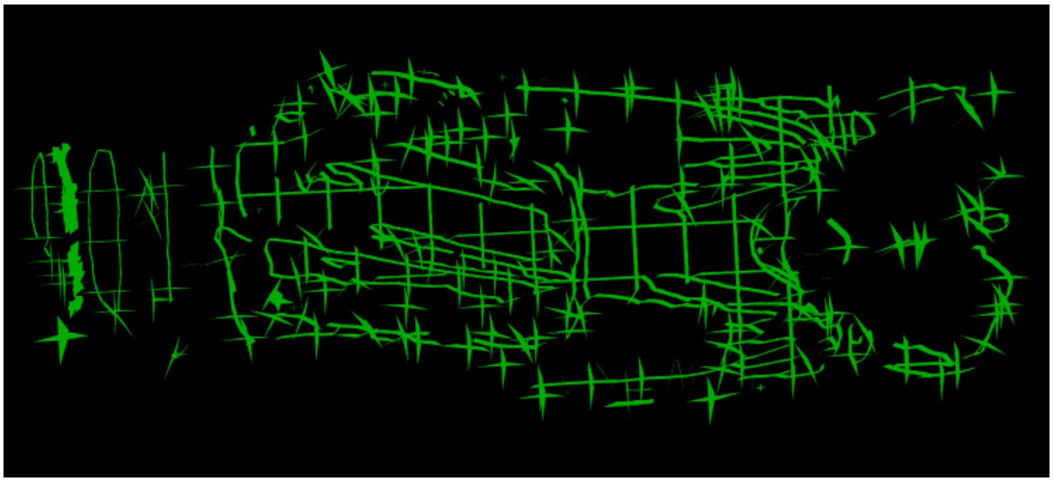
(a) (b)

Figure B.2: Contouring due to layered manufacture. (a) The Happy Buddha stereolithography hardcopy. The green rectangle is viewed from a different angle and magnified in (b). Notice the contouring due to the layered manufacturing method. These contours are typically smoothed out with a post-process of bead blasting and hand sanding.

sharp point so that it may be removed easily after the model is finished. In general, a complex model will require a network of supports as shown in Figure B.3.



(a)



(b)

Figure B.3: Supports for stereolithography manufacturing. (a) Shaded rendering of the Happy Buddha model and the supports (show in green) that were needed to handle overhanging surfaces. These supports come to narrow points and break off easily after the model construction is finished. (b) A plan view of the supports by themselves.