ShapeShift: A Projector-Guided Sculpture System

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ABSTRACT
ShapeShift is an interactive camera-projector system that augments the traditional artistic sculpture process with visual guidance directly on the sculptured surface.

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INTRODUCTION
Art projectors are commonly used by painters to make perspective and overall composition sketches early in the painting process. In our previous work, we replaced the art projector with a computational camera-projector system to provide assistance throughout the entire painting process [1]. While the art projector, interactive or otherwise, lends itself to the 2D representations of painting, it is of little use in constructing 3D sculptures. This is primarily due to the surface of a sculpture being generally non-planar and spatially in flux as the work progresses.

We overcome this limitation by augmenting the interactive art projector with 3D scanning capabilities and projecting surface aware guidance on to the sculpture material. Using a 3D model as the sketch of the sculpture to be built, the scanned surface of the physical material is compared to the sketch. The guidance is then projected in the form of depth changes needed to make the sculpture in progress more like the 3D sketch. This provides automatic and comprehensive information similar to the current sculpting practice of using rulers and calipers to check proportion and perspective.

SYSTEM OVERVIEW
The ShapeShift system uses a standard digital camera and DLP projector calibrated as a stereo pair. This allows for structured light 3D surface scanning [2] as well as accurately registered surface projection [3]. Guidance is projected in the form of colored contours corresponding to depth differences between the sculpture surface scan and the 3D model sketch stored in the system. One option for storing the model sketch in to ShapeShift is to use the built in scanning facilities to scan in an existing sculpture (for recreation) or an original maquette. Alternatively, sketch model ideas are designed in a 3D modeling package such as Maya and then imported.

SCULPTURE PROCESS
An initial amount of sculpting material is placed on the work table, for example a block of modeling clay (figure 1a). The surface of the material is scanned in 3D and the depth differences between the material and the reference 3D model is computed. The depth differences are then computed into graphical contours that differ in color depending on the type of depth difference (figure 1b-e). For regions where material must be removed, a continuous color range from red to yellow is used with red meaning "remove a lot" and yellow meaning "remove a little." For regions where material needs to be added, a green to light blue range is used with green meaning "add a lot" and light blue meaning "add a little". For regions where the sculpture matches the depth of the reference 3D model, the color purple is used. For regions where the material is outside of the model, a royal blue color is used. The sculptor then adds and removes material according to the projected guidance contours. When the sculptor is satisfied with the changes made, the surface is rescanned and new depth contours are projected. The new guidance contours incorporate the sculptor's changes as well as show the remaining areas to modify, thereby advancing the iterative process closer to the final sculpture. When the sculptor wishes to work on a different area of the sculpture, the material is rotated on a revolving platter. The system is aware of the platter's rotation to allow depth difference computation for any view the sculptor wishes to work on, e.g., the back or sides (figure 1b-e).

ALTERNATIVE DISCUSSION
To provide guidance ShapeShift requires a 3D model sketch of the sculpture that is to be built. Since a 3D model of the desired outptut will be available before the sculpture is begun, an alternative to using ShapeShift to sculpt the model by hand is to output the sculpture using a 3D printer. However for even the most expensive 3D printers, the out-

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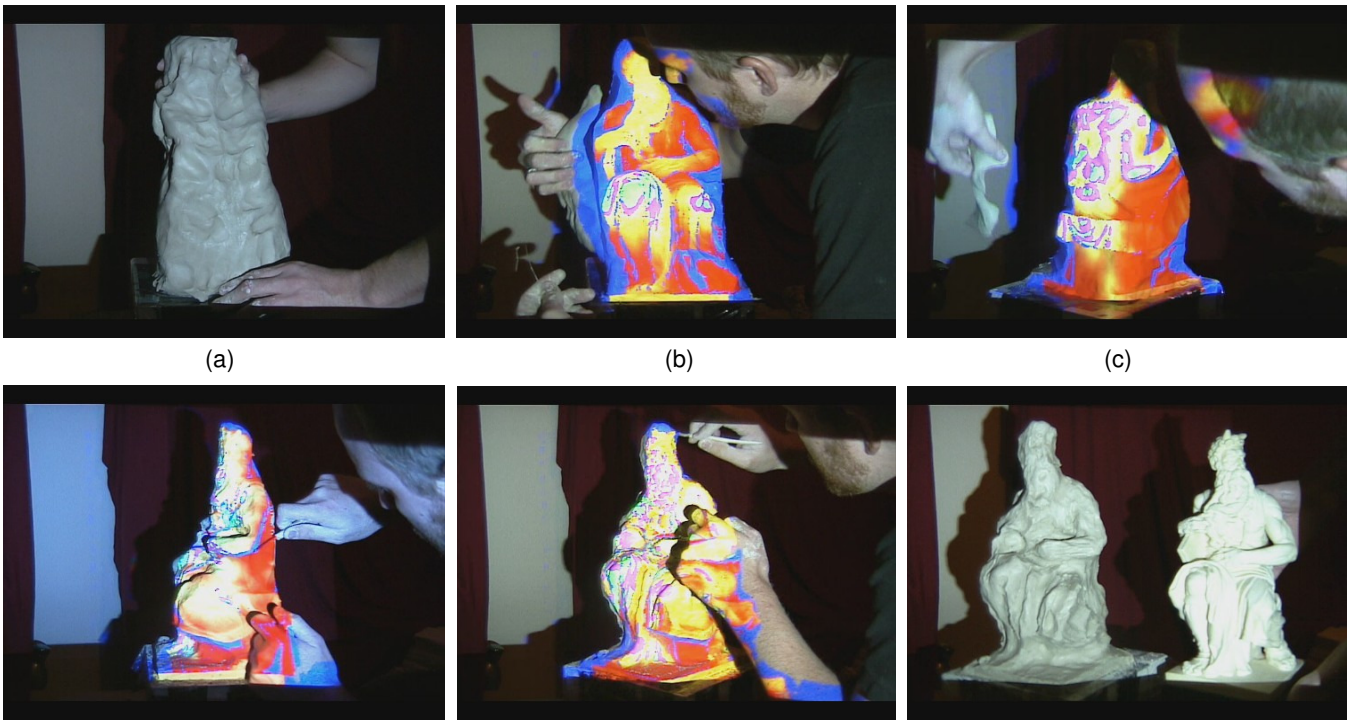

Figure 1: (a) Sculptor's initial block of clay (b) & (c) Sculptor recreating the overall form of Michelangelo's Moses by trimming the unneeded blue regions (d) & (e) Sculptor using the colored depth contours to work out details of Moses (f) Sculpting progress after an hour on the left compared to a finished replica of Moses on the right

put volume is relatively small at approximately 16"x16"x16". Our initial prototype which uses a cheap 720x480 resolution camera, 1024x768 resolution projector, and an un-optimized scanning algorithm handles a volume of 24"x24"x24" at an interactive rate that was acceptable to our prototype test users. Another issue is that of the 3D printer's output material. ShapeShift works on many surfaces, most notably stone, a popular sculpting material that is not currently supported by 3D printers. Finally, with ShapeShift the 3D model sketch can be revised mid-process if the sculptor wishes to take the sculpture in a different conceptual direction whereas a 3D printer would require several expensive cycles of printing and model revision.

FUTURE WORK

In addition to being used by an experienced sculptor to realize original sculptural ideas, ShapeShift has the potential to be used in the education of novices (e.g. through recreation of classic sculptures). We plan to formally evaluate the use of ShapeShift by both of these populations. For expert sculptors we will rely on comparisons of their previous experience to that of their ShapeShift experience. For novices, we will compare the quality of the sculpture and time to completion for users of ShapeShift against the same measures of a control group not using ShapeShift.

CONCLUSIONS

By providing surface aware sculpture guidance in the form of intuitive colored depth contours, ShapeShift provides a computational tool to enhance the traditional process of sculpture. Initial prototype testing is promising, suggesting that ShapeShift could be useful for experienced and novice sculptors. Using inexpensive off-the-shelf components, ShapeShift has the potential to be an affordable tool for producing better sculptures faster.

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