Completing Digital Cultural Heritage Objects by Sketching Subdivision Surfaces toward Restoration Planning

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Abstract. In the restoration planning process a curator evaluates the condition of a Cultural Heritage (CH) object and accordingly develops a set of hypotheses for improving it. This iterative process is complex, time consuming and requires many manual interventions. In this context, we propose interactive modeling techniques, based on subdivision surfaces, which can support the completion of CH objects toward restoration planning. The proposed technique starts with a scanned and incomplete object, represented by a triangle mesh, from which a subdivision surfaces can be generated. Based on the mixed representation, sketching techniques and modeling operations can be combined to extend and refine the subdivision surface, according to the curator's hypothesis. Thus, curators without rigorous modeling experience can directly create and manipulate surfaces in a similar way as they would do it on a piece of paper. We present the capabilities of the proposed technique on two interesting CH objects.

Keywords: Sketching, Subdivision, Modeling, Restoration Planning, Hypothesis

1 Introduction

The preservation and conservation of Cultural Heritage (CH) objects is one of the most important objectives of any Cultural Heritage institution. This objective is associated with many activities, ranging from storage to exhibition, passing over the conduction of restoration works. In the context of restoration, the restorer deals with the examination of CH objects, in order to evaluate the condition of the object and the need of a restoration work. If a restoration work needs to be conducted, the restorer (in cooperation with the curator) starts developing a set of restoration hypotheses, considering dimensions, shapes, transitions, and colors among others. These hypotheses are illustrated with sketches and paintings or in very special cases with simple mock ups, which are then assessed by a committee of experts, including historians, researchers and additional curators and restores. Nevertheless, this process is very complex, time consuming and many times the restoration result is beforehand difficult to envisage given the provided evidence. Thus, a mechanism for easing the development and selection of a hypothesis would be of great benefit for the professional community and the Cultural Heritage itself, it would not only ease the process, but also streamline the tasks and therefore more Cultural Heritage object would be able to be restored, avoiding its further deterioration and possible total destruction.

In this paper, we propose the use of interactive modeling techniques and subdivision surfaces for the completion of digital cultural heritage objects toward restoration planning. The first step requires the scanning of an incomplete CH object, which is then represented by a triangle mesh and from which a subdivision surface can be generated. This mixed representation (mesh and subdivision surface) allows for combining modeling operations and other operations with sketching techniques, in order to extend and refine the subdivision surface. In this way, restores without rigorous modeling experience can directly create and manipulate surfaces according to their needs, in a similar fashion as they create their sketches on a piece of paper. The result of the sketching-based modeling operations is a regular and clean control mesh by design, which supports easy modification, usability and a high surface quality. Furthermore, the functional description of the sketching gestures allows for a flexible reuse of the procedures in copying operations.

We believe that this technique will assist the generation and evaluation of restoration hypotheses and therefore the development of the restoration planning in the Cultural Heritage professional context. Additionally, digital versions of the CH object enable their exploration by experts, facilitating discussions as well as additional activities, such as 3D documentation, presentation or exhibition planning. In order to show the capabilities of the proposed technique, we use two challenging and interesting CH objects: i) an Islamic vase of the XIVth – XVth century, and ii) a dagger for King Richard used in the Lyceum theatre in 1910 (see Fig. 1), which are illustrated in section 4. We also evaluate the scope of the proposed technique with the current state of the art in section 2, and we describe the principles of our 3D modeler and its surface representation in section 3. In section 5 we conclude our work and discuss the future work in the field.

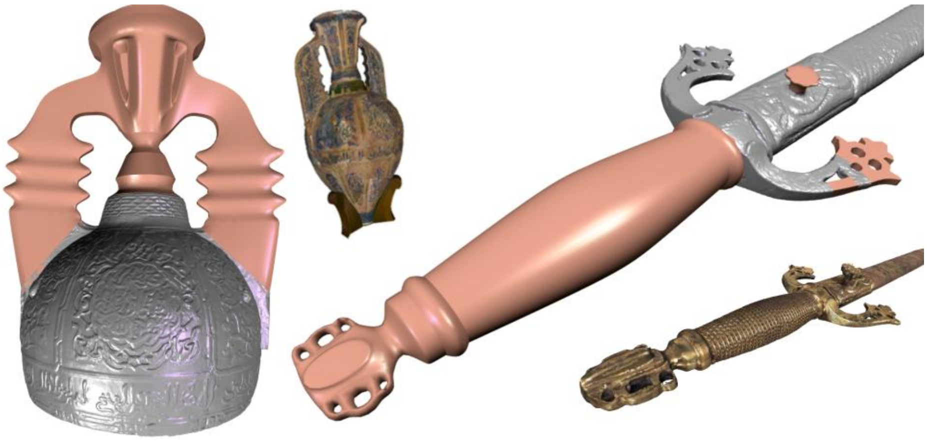

Fig. 1. Two digital restored objects. The scanned input mesh is shaded in grey, the generated subdivision surfaces in brown. Left: Islamic vase of the Louvre museum in Paris. Right: dagger of the Victoria and Albert Museum in London.

2 Related Work

Sketching is often perceived as a method for the early design phase, with focus on rapid creation. It also is a method for directly describing a desired shape without the use of WIMP-style (windows, icons, menu and pointer) interactions or low level picking and dragging operations. Therefore, it is a powerful input method for users without rigorous modeling experiences.

Stroke-based modeling methods can be categorized into semi-discrete and semi-continuous methods. Semi-continuous methods directly operate on the surface (e.g. dense triangle meshes). The pioneer work "Teddy" from Igarashi [1] is among the first publications in this field. More recent examples are inflation-based systems like Matisse [2] or Répousse [3]. In the work from Nealen, Alexa et al., silhouette or contour strokes are used to modify a mesh [4, 5, 6].

Our system belongs to the semi-discrete methods, where strokes generate discrete proxy objects which in turn control the surface. Bein et al. [7] present a sketch based system for modeling with subdivision surfaces, which is the basis for this paper. The FreeDrawer application from Wesche [8, 9] allows for drawing curve networks between surfaces, which are suspended. Schkolne et al. [10] draw surface strips with free hands. Hui et al. [11] use profile curves to generate 3D surfaces. Wang et al. [12] construct 3D objects from sets of tubular pieces, which axes and silhouettes can be controlled with strokes. Deforming implicit surfaces by oversketching skeletons is presented by Sugihara et al. [13]. The ILoveSketch [14] system captures some of the affordances of pen and paper for professional designers, allowing them to directly iterate on concept 3D curve models.

3 Modeling Principles

In this section, we discuss design decisions in the context of completing Cultural Heritage objects. Additionally, we briefly introduce the surface representation behind the 3D modeler.

Our modeling system ([7]) focuses on immediate and visual interaction. Therefore, it does not make use of WIMP-style (windows, icons, menu, pointer) interactions, which are tedious to use and learn. Instead, all operations are directly executed from and through 3D widgets. In Fig. 2, the widgets of a control mesh are shown. Vertices are blue spheres, edges are green or red tubes and faces are represented by a purple sphere. Example operations working on the widgets are shown in section 4. In order to make the system compatible with touch and pen devices, there is no differentiation between the mouse buttons. A small head-up display allows for altering between different operation modes (sketching, dragging, removing, etc.) and for performing operations which are not attached to any 3D widget such as copy, undo, and visual settings.

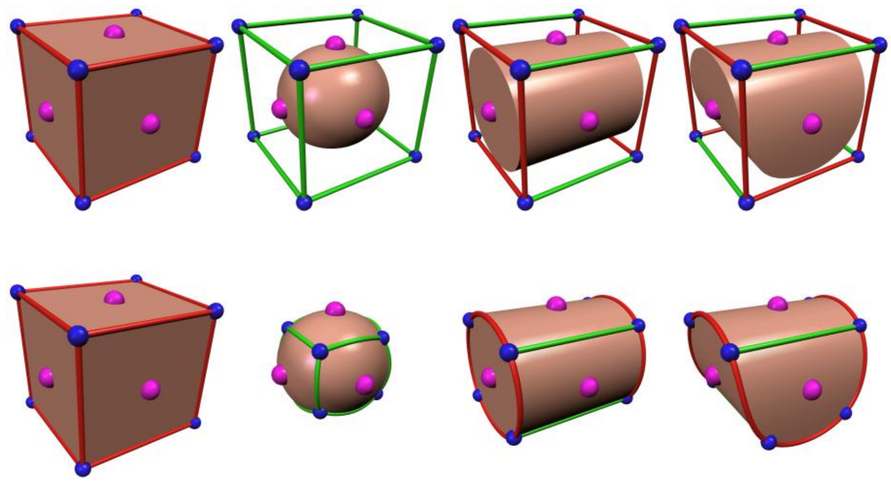

Fig. 2. The same control mesh with different tagged edges describes different shapes. Smooth edges are green, sharp edges are red. The first row shows the raw control mesh. In the second row, the control mesh is projected on the subdivision surface.

Even in modern modeling tools, it is a challenge to transfer the idea of a shape to a digital version. Sketching operations create a link between those worlds. Drawings are a natural expression of a shape and can be performed by everyone. An interactive setting guides the user in the construction process by allowing step by step modifications and visualization of the intermediate result. Our modeler allows three established sketching operations (illustrated in section 4): i) rotational extrusion, ii) sweeping, and iii) lofting. A new surface can be generated by drawing a silhouette. In addition, for completing a digitized object, it is also possible to sketch on an existing meshed surface.

Naturally, sketching techniques are not useful for all operations needed in a modeling process. Low level modifications like dragging vertices, inserting edges and switching the sharpness of edges are handled by direct mouse interaction with the 3D widgets. High level modifications like tilting or rotating faces and scaling mesh parts can be executed in 3D as well. In order to take into account the 2D limitations of input devices, all operations are done on 2D planes, which are embedded in 3D space. Depending on the operation, the 2D plane can be defined by the user or is predefined by the operation. For instance, dragging can be done on arbitrary planes while the degrees of freedom of tilting a face are defined by the face normal and the camera view.

Predictability of the offered operations is of great importance. For constructing a desired shape, the user should know in advance, which operations lead to which surface modifications. Or in the inverse direction, which operations are needed to reach a desired shape. Our system follows the "what you see is what you get" paradigm. The user directly works on and with the subdivision surface control mesh. The surface representation we use is a Catmull and Clark subdivision surface with tagged edges, as presented by Havemann [15]. It is derived from a bicubic B-Spline tensor product, hence intuitive for natural human quad based modeling. It is an excellent compromise between compactness and flexibility. By definition the sketching operations generate a regular mesh. The conversion of a drawn stroke to a control mesh is handled by a genetic approximation method [16], focusing on very few control vertices. Both features assure the usability of the modeling tool, good modifiability of the surface, and a high surface quality.

4 Examples of Digital Restorations

The first part of this section demonstrates the process of completing a Cultural Heritage object exemplarily on the Islamic vase. Fig 3. illustrates the creation of a new subdivision surface. First, the user sketches a silhouette of the desired shape on an existing mesh or its border. Alternatively, a sketching plane can be placed freely in space to record a stroke. The algorithm generating the corresponding control mesh detects sharp features and flags edges accordingly. It also minimizes the number of control points needed for a better modifiability.

In Fig 4. multiple sketching operations create the neck of the vase. The sketching operations create a regular quad based mesh by definition. This leads to maximizing surface continuity. A sketched extrusion or sweep can parametrically be copied, which means that a similar operation can be applied on a different part of the object. For instance, an extrusion can be used on a different shaped face or a sweep can be reapplied with different orientation and scaling. Fig 5. shows the main steps for modeling the handle of the vase.

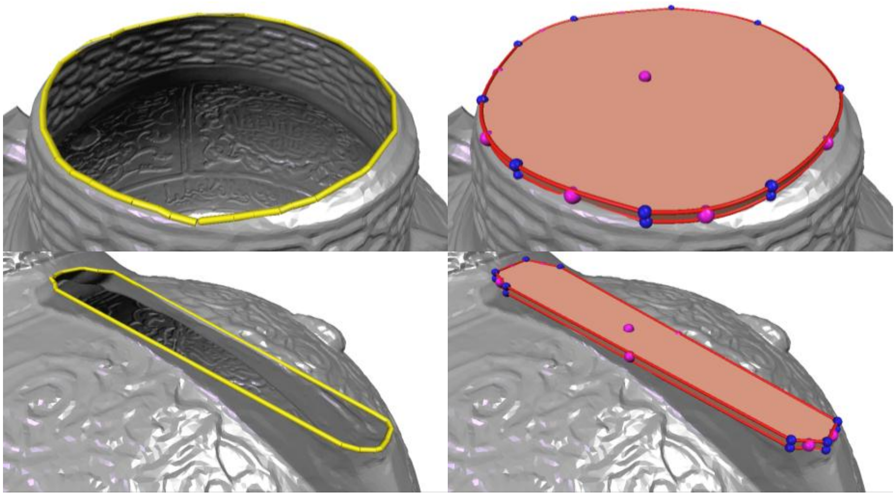

Fig. 3. Sketching operations on a scanned mesh create the first subdivision surfaces. Top row: neck, bottom row: handle.

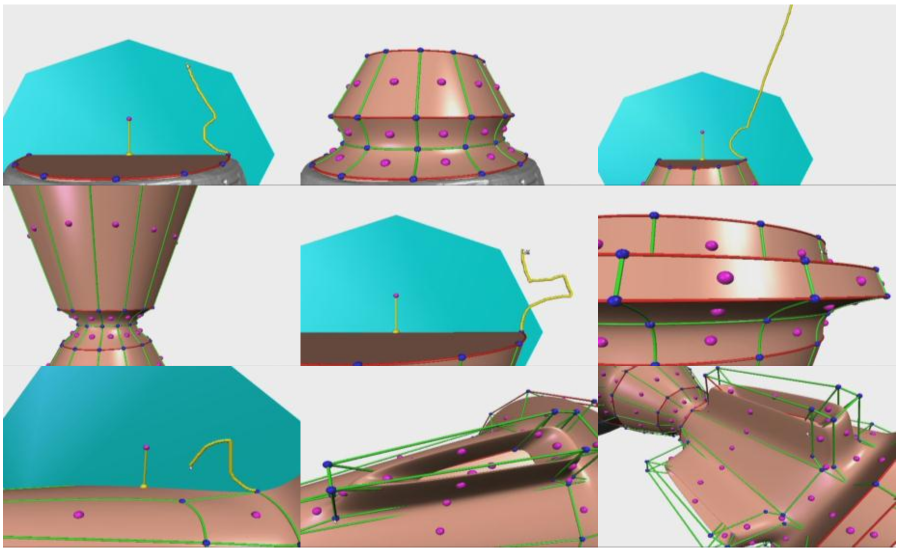

Fig. 4. A series of sketching operations complete the neck of the vase. One picture with the drawn stroke is alternated with one picture with the resulting surface modification. In the last picture, an extrusion operation is copied.

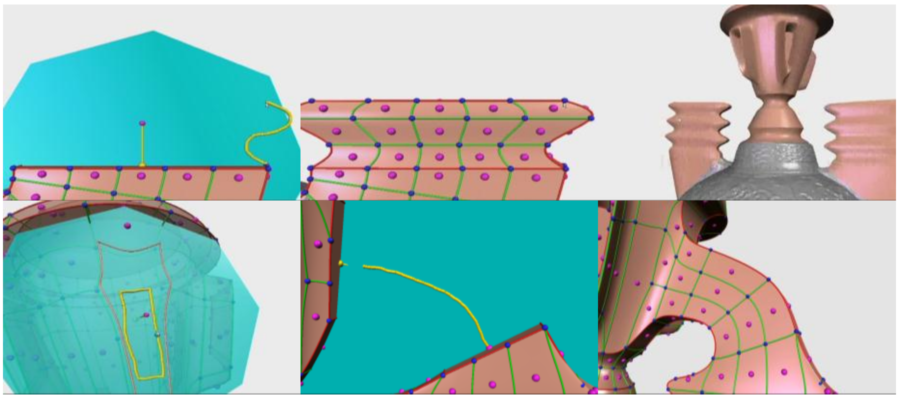

Fig. 5. A series of sketching operations complete the handle of the vase. In the top row: an extrusion is drawn and then copied several times. In the bottom row: a lofting and sweeping operation are executed. The result is shown in the last picture.

Fig 6. shows the result of the completion process for the Islamic vase. Note that the original vase served as source of inspiration only. A detailed replica was not the target of this modeling process. To demonstrate creative freedom, an alternative handle has been modeled as well. Fig 7. shows the digital restoration example of the dagger used in the Lyceum theatre. Parts of the original mesh have been cut out and completed in our modeling system with similar operations as demonstrated in the vase example.

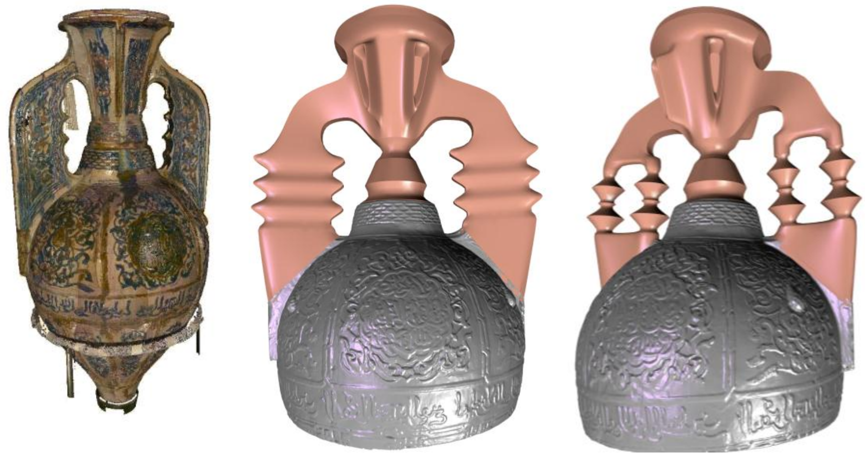

Fig. 6. Left: original vase. Middle: result of the completion process. Right: alternative result with different handle.

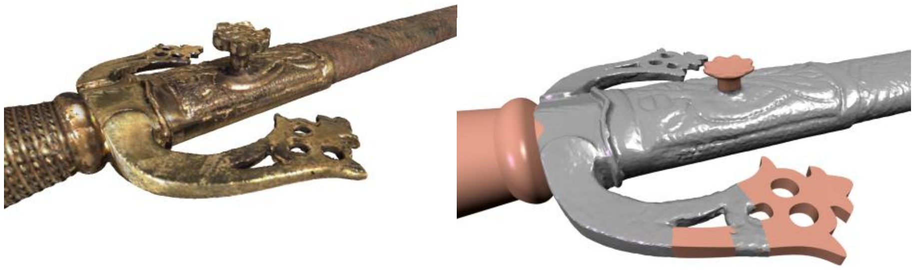

Fig. 7. Details of the dagger used in the Lyceum theatre. Left: original dagger. Right: generated subdivision surfaces starting from an incomplete mesh.

5 Conclusion

We proposed the combination of sketching-based modeling operations and subdivision surfaces for completing digital Cultural Heritage objects in the context of restoration planning. We presented the modeling principles for sketching over the combined representation (mesh and subdivision surface). Additionally, we illustrated the capabilities of the proposed techniques with two interesting and challenging Cultural Heritage objects of the Louvre and the Victoria and Albert museums. We believe that this technique will assist the generation and evaluation of restoration hypotheses and therefore the development of the restoration planning in the Cultural Heritage professional context. Moreover, we plan to increase the modeling operations of the sketching process, in order to better support the restoration task, for instance by means of copying engravings or by comparing hypotheses.

Due to the nature of the sketching techniques, some 3D objects might not be suitable for reconstruction. If the surface cannot be described by a series of extrusions, loftings or sweepings, the user has to fall back to low level modifications. These modifications are tedious like in any other 3D modeling system (see limiting examples in Fig. 8). While the 3D widgets still allow for direct and fast execution of these modifications, the time needed for reconstruction will be a lot higher compared to objects, which allow the use of high level sketching operations.

Fig. 8. Examples of objects with challenging features for the sketching techniques from the Victoria and Albert Museum.

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References

1. Igarashi, T., Matsuoka, S., Tanaka, H.: Teddy: A sketching interface for 3d freeform design. In: Proceedings of SIGGRAPH 99, Computer Graphics Proceedings, Annual Conference Series, pp. 409–416, (1999)
2. Bernhardt, A., Pihuit, A., Cani, M.-P., Barthe, L.: Matisse: Painting 2d regions for modeling free-form shapes. In: Eurographics Workshop on Sketch-Based Interfaces and Modeling (SBIM), Alvarado C., Cani M.-P., (Eds.), pp. 57–64, Annecy, France (2008)
3. Pushkar, J., Carr, N. A.: Répousse: Automatic inflation of 3d artwork. In: Eurographics Workshop on Sketch-Based Interfaces and Modeling (SBIM), Alvarado C., Cani M.-P., (Eds.), pp. 49–55, Annecy, France (2008)
4. Nealen, A., Igarashi, T., Sorkine, O., Alexa M.: Fibermesh: designing freeform surfaces with 3d curves. In: SIGGRAPH '07: ACM SIGGRAPH 2007 papers ACM, p. 41, New York (2007)
5. Nealen, A., Sorkine, O., Alexa, M., Cohenor, D.: A sketch-based interface for detail-preserving mesh editing. In: SIGGRAPH '05: ACM SIGGRAPH 2005 Papers, ACM, pp. 1142–1147, New York (2005)
6. Zimmermann, J., Nealen, A., Alexa, M.: Sketchbased interfaces: Sketching contours. Comput. Graph. 32, 5, 486–499, (2008)
7. Bein, M., Havemann, S., Stork, A., Fellner, D.: Sketching subdivision surfaces. In: Proceedings of the 6th Eurographics Symposium on Sketch-Based Interfaces and Modeling (SBIM '09), 61-68, ACM, New York (2009)

8. Wesche, G., Droskem.: Conceptual free-form styling on the responsive workbench. In: VRST '00: Proceedings of the ACM symposium on Virtual reality software and technology, ACM, pp. 83–91, New York (2000)
9. Wesche, G., Seidel, H.-P.: Freedrawer: a free-form sketching system on the responsive workbench. In: VRST '01: Proceedings of the ACM symposium on Virtual reality software and technology, ACM, pp. 167–174, New York (2001)
10. Schkolne, S.: Making digital shapes by hand. In: SIGGRAPH'06: ACM SIGGRAPH 2006 Courses, ACM, pp. 84–93, New York (2006)
11. Hui, K. C., Lai, Y. H.: Generating subdivision surfaces from profile curves. Comput. Aided Des. 39, 9, 783–793, (2007)
12. Wang, H., Markosian, L.: Free-form Sketch. In: Proceedings of the 4th Eurographics workshop on Sketch-based interfaces and modeling (SBIM '07), 53-58, ACM, New York (2007)
13. Sugihara, M., De Groot, E., Wyvill, B., Schmidt, R.: A sketch-based method to control deformation in a skeletal implicit surface modeler. In: Eurographics Workshop on Sketch-Based Interfaces and Modeling (SBIM), pp. 65–72, Annecy, France (2008)
14. Seok-Hyung, B., Ravin, B., and Karan S.: ILoveSketch: as-natural-as-possible sketching system for creating 3d curve models. In: Proceedings of the 21st annual ACM symposium on User interface software and technology (UIST '08). 151-160, ACM, New York (2008)
15. Havemann, S.: Generative Mesh Modeling. PhD thesis, Braunschweig Technical University, Germany (2005)
16. Bein, M., Fellner, D., Stork, A.: Genetic B-Spline approximation on combined B-reps. *Vis. Comput.* 27, 6-8, pp. 485-494, (2011)