Andrei Sharf - Research Statement

As computer graphics matures, data is becoming a driving force of increased importance in this progress due to its large quantity and disparateness. Visualization, a domain in computer graphics, is specifically centered around the problem of data-dependent understanding and representation. However, since data is always imperfect, additional assumptions and information are required in order to process it.

The acquisition process of three-dimensional shape data involves capturing and modeling of three-dimensional shapes. Such data is at the core of many applications in computer graphics, computer aided design, visualization, multimedia and other related fields. My research focuses on shape modeling and geometry processing techniques for imperfect data typically generated by range scanners. I am predominately interested in the problem of imperfect data reconstruction from different algorithmic, representational and data structure aspects.

Currently the most common technique for three-dimensional shape acquisition is range scanning. The physical object is typically sampled by emitting a light and detecting its reflection. Although acquisition technology constantly advances, scanning complex objects will remain a difficult problem. Due to physical inaccessibility, regions of the object cannot be scanned properly. Scan data contains large missing parts, outliers and under-sampled regions. Therefore, the reconstruction of a complete watertight model that is faithful to the original physical object is difficult.

Surface Reconstruction A major part of my research is focused on various techniques and algorithms for reconstruction from imperfect data. In (Sharf et al., SIGGRAPH 2004) we present a context-based method for completing holes in irregularly sampled surfaces. Despite progress in surface reconstruction, holes are still commonly filled using a smooth surface. While this works well for small holes relative to local geometric variation, more complex treatment is required for large holes. We analyze the existing surface around the hole and exploit intra-shape similarities to fill holes in a coarse-to-fine manner.

Shape Deformation The importance of detail-preserving and topology awareness in reconstruction process is constantly growing as more complex highly detailed objects are scanned. In (Sharf et al., Eurographics 2006) we develop a novel method that automatically reconstructs a watertight surface and correctly interprets the topology of the shape. The method is based on a deformable model evolution. We show that this approach yields better interpretation and control of shape geometry and topology. In (Ghosh et al.,2008) we present a technique for computing good cross correspondences between imperfect scanned models in a database. The technique uses a common template model that undergoes a set of constrained as-rigid-as-possible deformations to fit onto the database models. Such cross correspondence permits to conduct in-depth analysis and visualizations of the data.

Dynamic Reconstruction In (Sharf et al., SIGGRAPH ASIA 2008), we show the adaptation of physical flow concepts to four-dimensional data reconstruction of scanned moving objects. We describe the motion of the object as an incompressible flow of material through time; the distance material moves between adjacent frames is bounded, material density remains constant, and the

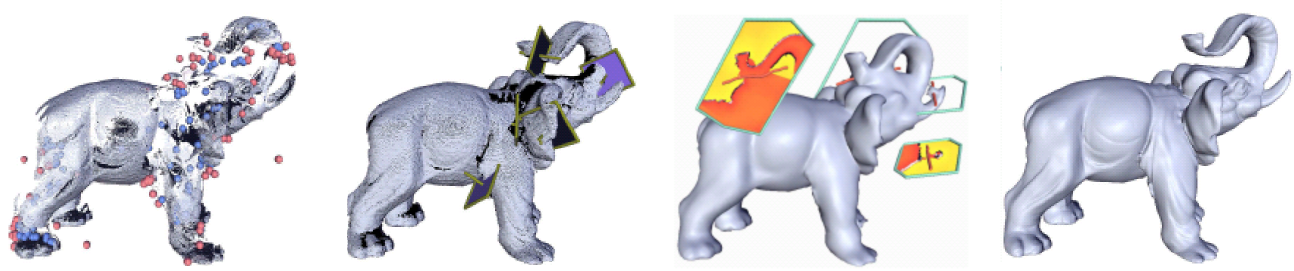

Figure 1: Interactive reconstruction excerpts of an elephant model. The topological analysis of the scanned data detects weak regions (center-left), where the user can make local decisions by scribbling over 2D tablets (center-right). Further iterations lead to the correct reconstruction of the model (right).

object remains compact. This formulation overcomes deficiencies in the acquired data, such as persistent occlusions, errors, and missing frames.

Interactive Modeling Part of my research has been focused on user interaction methods with application to complex problems in computer graphics. Interactive tools are easy-to-use and at the same time provide minimal but necessary hints needed to solve a problem, which is otherwise extremely hard or even impossible to solve. In (Sharf et al., SIGGRAPH 2007) we introduce an interactive topology-aware reconstruction method: it uses minimal user input to correctly reconstruct regions where the topology of the model cannot be automatically deduced. Given very low quality scans, automatic reconstruction may fail to faithfully reconstruct the expected topology of the model. Automatic reconstruction of poorly-sampled areas is ill posed; an infinite number of surfaces pass through or near the data points. We analyze the local topological stability of a continuous field defined on the point set. This directly relates to strong mathematical notions derived from Morse theory. Low stability regions are suggested to the user for adding local inside/outside constraints by merely scribbling over a 2D tablet. Each new user constraint modifies the field interactively, converging to a topology coherent reconstruction. We demonstrate the effectiveness and ease-of-use of our method on low quality scans that are acquired in a simple manner from only few view points.

Interactive Shape Editing In (Sharf et al., 2006) we focus on a user interface operation borrowed from editing applications – the *cut-and-paste* operation. In the context of direct shape manipulation, cut-and-paste is used as a metaphor for cutting and connecting mesh parts and surfaces. A key point in designing this tool is responsiveness: fast geometry processing at interactive rates. To support simple cutting, we develop a simple mesh cutting tool based on graph-cut. To support simple pasting, we turn to a useful notion in graphics applications - *snapping*. By extending this notion to 3D surfaces, our tool snaps two mesh parts together with a local graceful warp using our Soft-ICP algorithm.

Skeleton Extraction In many domains in computer graphics a high level of shape understanding and structure are often needed. Such an understanding can be conveyed through the use of an inner curve-skeleton. In (Sharf et al., Eurographics 2006) we present an algorithm to extract the curve skeleton from 3D objects by tracking the reconstruction process of a deformable model evolution.

Future Research My past and current research is focused on various fundamental modeling and reconstruction problems in a computational topology and geometry realm. Building on this experience, my goal is to develop new algorithms and techniques to broaden the foundations of shape modeling and geometry processing and extend their application to additional domains.

In order to increase the scanning effective power and usability, there is an emerging need to allow users to create high-quality surfaces from imperfect scans. Following recent tools and applications for point processing (Pointshop3D, Scanalyze, Geomagic©, RapidForm©) my goal is to design and develop a comprehensive software suite that would provide state-of-the-art tools for scanning, point processing, modeling and interaction.

Recently, research in user interaction has gained a lot of popularity in various computer graphics domains. It has been fascinating to explore man-machine interaction paradigms in order to effectively solve elaborate computer tasks. My goal here is to further research interactive tools and broaden the man-machine interaction language.

In addition, to continued research on topics mentioned throughout this statement, I plan to use my experience to pursue new problems in a range of old and new domains. I expect my future research to continue to focus on related computer graphics subjects while expanding and blending with other domains and mathematical foundations to broaden computer graphics tools and algorithms.