Introduction

3D photography is an emerging technology for capturing richly detailed models of objects in the real world. Whereas traditional optical cameras capture scene appearance in the form of radiant light energy, 3D photographs measure surface characteristics like 3D geometry and reflectance—exactly what is needed to construct graphical models. Consequently this technology provides a means for acquiring graphical objects and scenes of unprecedented detail and realism by *scanning* them in from the real world.

Methods to digitize and reconstruct the shapes of complex three dimensional objects have evolved rapidly in recent years. The speed and accuracy of digitizing technologies owe much to advances in the areas of physics and electrical engineering, including the development of lasers, CCD's, and high speed sampling and timing circuitry. Such technologies allow us to take detailed shape measurements with precision better than 1 part per 1000 at rates exceeding 10,000 samples per second. To capture the complete shape of an object, many thousands, sometimes millions of samples must be acquired. The resulting mass of data requires algorithms that can efficiently and reliably generate computer models from these samples. The future of 3D photography will see systems that capture precise geometry and reflectance information at even larger spatial scales, enabling the acquisition of landscapes and complex urban scenes, and fast scanners that enable 3D video at real-time rates.

The applications of 3D photography are wide-ranging and include manufacturing, virtual simulation, human-computer interaction, scientific exploration, medicine, and consumer marketing.

Dissemination of museum artifacts

Museum artifacts represent one-of-a-kind objects that attract the interest of scientists and lay people world-wide. Traditionally, to visualize these objects, it has been necessary to visit potentially distant museums or obtain non-interactive images or video sequences. By digitizing these parts, museum curators can make them available for interactive visualization. For scientists, computer models afford the opportunity to study and measure artifacts remotely using powerful computer tools. A case in point is the *Digital Michelangelo Project* headed by Marc Levoy at Stanford University. The goal of this multi-year project is to create a high-quality 3D computer archive of the sculptures and architecture of Michelangelo. This course features the first presentation of the Digital Michelangelo Project to the SIGGRAPH community.

Special effects, games, and virtual worlds

Synthetic imagery is playing an increasingly prominent role in creating special effects for cinema. In addition, video games and gaming hardware are moving steadily toward interactive 3D graphics. Virtual reality as a means of simulating worlds of experience is also growing in popularity. All of these applications require 3D models that may be taken from real life or from sculptures created by artists. Digitizing the shapes of physical models will be essential to populating these synthetic environments.

Reverse engineering

Many manufacturable parts are currently designed with Computer Aided Design (CAD) software. However, in some instances, a mechanical part exists and belongs to a working system but has no computer model needed to regenerate the part. This is frequently the case for machines currently in service that were designed before the advent of computers and CAD systems, as well as for parts that were hand-tuned to fit into existing machinery. If such a part breaks, and neither spare parts nor casting molds exist, then it may be possible to remove a part from a working system and digitize it precisely for re-manufacture.

Collaborative design

While CAD tools can be helpful in designing parts, in some cases the most intuitive design method is physical interaction with the model. This is especially true when the model must have esthetic appeal, such as the exteriors of consumer products ranging from perfume bottles to automobiles. Frequently, companies employ sculptors to design these models in a medium such as clay. Once the sculpture is ready, it may be digitized and reconstructed on a computer. The computer model is then suitable for dissemination to local engineers or remote clients for careful review, or it may serve as a starting point for constructing a CAD model suitable for manufacture.

Medicine

Applications of 3D Photography in medicine are wide ranging as well. Prosthetics can be custom designed when the dimensions of the patient are known to high precision. Plastic surgeons can use the shape of an individual's face to model tissue scarring processes and visualize the outcomes of surgery. When performing radiation treatment, a model of the patient's shape can help guide the doctor in directing the radiation accurately.

Web commerce

As the World Wide Web provides a backbone for interaction over the Internet, commercial vendors are taking advantage of the ability to market products through this medium. By making 3D models of their products available over the Web, vendors can allow the customer to explore their products interactively. Standards for disseminating 3D models over the web are already underway (e.g., the Virtual Reality Modeling Language (VRML)).

Course Objectives

In this course we will focus on the technology underlying the field of 3D photography, focusing on the current state-of-the-art and the principles underlying several leading approaches. Our intent is to cover the fundamentals but also to give an understanding of current research directions and exciting applications. With these objectives in mind we have designed a course that brings together several leading researchers and practitioners to present state-of-the-art 3D photography approaches from the ground up.

The course will cover a variety of methods for recovering shape and reflectance from images. Introductory material will describe the fundamentals of cameras, from lenses to CCD's, and ways of calibrating them. Several passive vision methods will be presented, including stereo, structure from motion, shape from shading, volume intersection, and voxel coloring. Active vision methods will include imaging radar, optical triangulation, moire, active stereo, active depth from defocus, and desktop shadow striping. The course concludes with a field study: capturing 3D photographs of Michelangelo's statues.

We hope the material in this volume will prove useful to you to help gain a deeper understanding of the concepts behind 3D photography, but moreover to help you build your own 3D photography system on your desktop. To this end, we have provided material that we believe is sufficient to design and build practical 3D photography systems from scratch.

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