Automated 3D Model Reconstruction from Real Images

George T. Chou*
MIT Laboratory for Computer Science
gtc@graphics.lcs.mit.edu

1 Overview

A formidable problem in the synthesis of realistic computer imagery is the construction of complex 3D models used in the rendering process. Existing solutions to this task typically require a great amount of human intervention and lack the flexibility to deal with diverse inputs. We envision a fully automated solution based on an integrated software/hardware system that can generate 3D models of any environment through analysis of digital images.

Specifically, we are working on a project that aims to build a high-precision, textured 3D model of the City of Cambridge. By annotating input image sequences with camera parameters obtained using mobile GPS instruments, we intend to produce output with sub-meter resolution. Moreover, by explicitly characterizing uncertainty in the internal data structure, we can make the output model improve over multiple, overlapping sequences.

2 Line Extraction

Given an image sequence, we first apply the standard Canny edge detector to localize regions of high intensity contrast in the images. The output of Canny edge detector tend to be short, noisy pixel chains that are not directly suitable for further processing. A line extractor is then applied to convert the noisy edge signal into a useful parameterized representation, The current version uses the minimum description length (MDL) algorithm for aggregating edge pixels into lines.

3 Feature Tracking

Once the line representation has been extracted, the next step involves solving for line correspondences and tracking them across successive images. To handle line correspondences with different degrees of certainty, multiple tracking processes are instantiated and applied in parallel on the sequence of lines. Different tracking processes use different criteria and methods for initiating and verifying correspondences. The line correspondences form the primitives to the 3D reconstruction process.

4 3D Reconstruction

Depending on the type of line correspondences, either an incremental reconstruction or a batch reconstruction will be attempted. Both approaches for 3D triangulation utilize camera parameters that were recorded when the images were taken. The incremental algorithm uses only lines from two adjancent frames in computing a new estimate, whereas

*GTC is advised by Prof. Seth Teller. Office: NE43-226, 545 Technology Square, Cambridge MA 02139.

the batch algorithm uses lines from multiple consecutives frames. Once a reliable 3D estimate has been obtained, it can then be used to predict the position of the corresponding line in a new image in the tracking process.

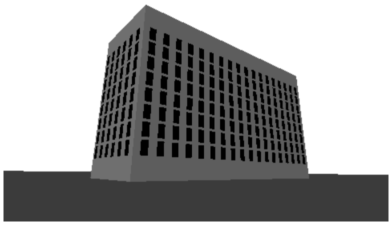

Figure 1: Image taken with known camera position.

5 Work in Progress

Presently, we are working on extending our system to work on images with real textures and occlusions between objects. Real-world textures present a problem for our system because there tend to be many spurious edges and illusory contours. Occlusion presents a problem for the tracking system in that line correspondences may be temporarily disrupted and lost. To deal with these problems will require more sophisticated line extraction algorithm and feature tracking system.

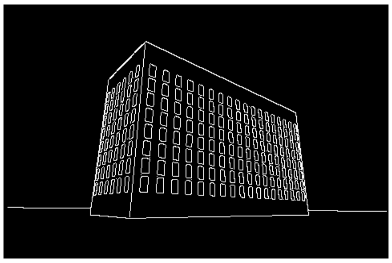

Figure 2: Output of Canny edge detector.

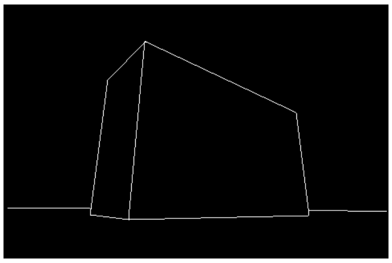

Figure 3: Long lines extracted from above.

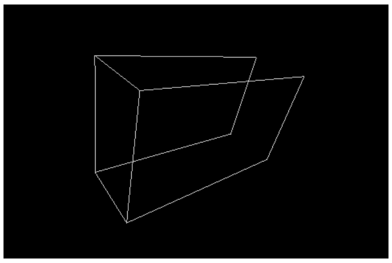

Figure 4: Reconstructed 3D model from 18 images.

References:

1. Canny, J., "A Computational Approach to Edge Detection", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 8: pp679-698, 1986.

2. Debevec, P., Taylor, C. & Malik, J., "Modeling and Rendering Architecture from Photographs", *UCB Technical Report CSD-96-893*, pp1-33, 1996.

3. Faugeras, O., *Three-Dimensional Computer Vision: A Geometric Viewpoint*, MIT Press, 1993.

4. Teller, S., Lozano-Perez, T. & Edelman, A., "Digitizing Cambridge", *White Paper*, pp1-28, 1995.