

Statue of Liberty 3D Cyra scan provides historical

State-of-the-art Cyra laser-scanning technology was adapted to quite an extraordinary task recently when it was used to document the detailed surface geometry of New York's most famous landmark – the Statue of Liberty. Traditionally used in the industrial plant and civil infrastructure fields, laser scanning's ability to capture highly detailed, 3D surface geometry of large structures made it a good match for the complex geometry of the Statue of Liberty.



Above: Frog's eye view of the Statue of Liberty. Most of the scans were taken from the base of the statue and a few from the top observation balcony.

Above Right: The University of Texas used their Cyrax 2500 laser scanner to produce a detailed survey of the statue.

Historical Documentation

The College of Architecture at Texas Tech University in cooperation with Historic American Buildings Survey (HABS) and the National Park Service (NPS) began digitally documenting the Statue of Liberty in order to create, for the first time, complete architectural drawings of the statue's exterior, accurate to 1/4 inch. These scaled drawings will be used to monitor and care for the statue, providing a complete historical documentation. The drawings could also be used to reconstruct an exact, full-scale duplicate of the statue, in the event of any catastrophic loss. The project team consisted of Associate Professor Glenn Hill, Associate Professor Elizabeth Loudon, Professor John White, several grad students, all from Texas Tech University,



as well as Tim Woodruff from Cyra Technologies, Inc.

Point, Shoot, Survey!

Using the Cyrax 2500 3D Laser Scanner, a complete 3-D digital scan in the form of a dense, data point cloud was made of the statue. The first step was to set 32 highly reflective scan registration targets on the statue. Easily identified by the scanner software, these targets would be used to very precisely connect multiple scans that were collected as the scanner was repositioned around the statue. The target centers were also surveyed using a Leica Geosystems TCR702 reflectorless total station for

independent quality control. The optimum location for scanning was at the promenade level – involving 13 scanner locations around the base. The scanner was simply oriented toward the scene, the desired measurement area and scanning density was selected, and then auto-scan began.

Each of the highly detailed scans took approximately 15 minutes requiring about 2 hours for each of the 13 scan locations. To speed up the process, the team broke into two shifts, morning and afternoon. Each day, a two-person crew would arrive on the first boat to Liberty Island at 6:30 am and work

Bentley and Cyra Technologies announce partnership to spur growth of "3D point cloud" content

Bentley Systems, Incorporated, a global provider of collaborative software solutions and Cyra Technologies have formally announced that Bentley will distribute Cyra's CloudWorx™ application software for Bentley MicroStation™.

The CloudWorx application, first announced by Cyra in December 2001, lets engineers and designers take advantage of rich, 3D point clouds directly in MicroStation. Pointclouds created by Cyrax® 3D Laser Scanning systems represent a powerful, new source of information content for organiza-

tions and projects that require accurate "as-built" or "as-is" information. "As-built" information derived from point clouds is being increasingly used by professionals to create better designs of modifications to existing facilities, for better construction planning and quality assurance, and for more efficient asset management. Industries taking advantage of point clouds include plant manufacturing, transportation, and building.

In addition to providing a familiar interface for MicroStation users,

CloudWorx for MicroStation also slashes time requirements for processing 3D point clouds into as-built 2D drawings and 3D models. Another advantage for MicroStation users is that they can use 3D point clouds as a backdrop against which to better design a modification to an existing site or structure. Better retrofit designs enable retrofit construction projects to run more smoothly by eliminating construction interferences and construction fit-up problems.

documentation

until 2.00 pm with the second crew working from 2.00 pm until the last boat left the island at 9.30 pm. Since the scanner works as effectively in total darkness as in light, the 6.00 pm sunset did not hinder the effort. In just four days, the team scanned over 500 million points, measuring every quarter of an inch of the statue's visible complex surface!

Creating a polygonal model

Returning to Texas Tech University, the university team downloaded all of the data to their servers and began converting the 200 million xyz data points into a 3D model and 2D drawings in order to create a complete architectural drawing record of the Statue, Pedestal and Fort.

For the 3D model, the first task was to register the separate ScanWorlds (scans taken from different scanner positions) into a single point cloud consisting of polygons, often referred to as a polymesh or polygonal model. Geometrical anomalies around the torch and the spires of the crown caused by swaying of the statue in 50 mile per hour winds were corrected or eliminated to achieve better results. Registration solutions based on scan targets were supplemented in certain cases with mathematical stitching of the different point clouds to create the final registration of all 13 ScanWorlds. The completed polygonal model was then used to derive 2D drawings.

Future phases

This initial scanning effort has digitally registered approximately 60% of the Statue, which represents the most prominent and distinctive features. However, from the scanning position at pro-

menade level, the pedestal blocks the feet and the top of the crown is out of view. Future scans would require some limited scaffolding and the remainder will require access to the Statue in some other way, such as photogrammetry or airborne scanning.

Generating the eight elevation drawings of the statue presents a different problem. One method involves capturing line drawings using hidden line procedures in a CAD program. The other captures images of the 3D model from an orthographic view. These rendered images could serve as dimensionally correct photographs and, thus, could be traced in a process similar to photogrammetry. The team plans



The Statue of Liberty

The Statue of Liberty was a gift of international friendship from the people of France to the people of the United States in recognition of the friendship established during the American Revolution. The 93-metre tall statue has been standing proudly over New York Harbor since 1886. Master sculptor Frédéric-Auguste Bartholdi reproduced the statue, not from architectural drawings, but from multiple scaled models. It took a team of craftsmen over 10 years to shape over 81,300 kg of copper and 113,400 kg of steel.

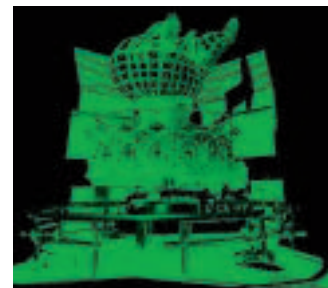
Visitors climb 354 steps to reach the crown or 192 steps in order to reach the top of the pedestal. There are 25 windows in the crown that symbolize gemstones found on the earth and the heaven's rays shining over the world. The seven rays of the Statue's crown represent the seven seas and continents of the world. The tablet, which the Statue holds in her left hand, reads (in Roman numerals) "July 4th, 1776." In 2001, more than 4 million people visited the Statue of Liberty.

More information can be found at:
http://www.arch.ttu.edu/digital_liberty/

to use both methods. Phase II funding is currently being sought to scan from the Pedestal and photograph the statue. The team is also exploring airborne technology utilizing drone helicopters with similar laser scanning technology. Unfortunately, this method is less accurate ($\frac{3}{4}$ " to 1"). Phase III of the project is to begin to

use the 3D model and high-resolution photographs to create a small-scale GIS system for the maintenance and management of the statue.

Once finished drawings and models of the Phase I work are delivered to HABS and the NPS, the NPS will use the 3D model for mainten-



*Above: A detail of the point clouds containing the face. Some details were scanned at very high resolution (points placed densely) such as the highlighted green area on the crown.
Below: A detailed view of the torch.*

ce. The 2D drawings will become part of the Library of Congress archives, part of recorded history for at least the next 500 years.