Virtual Reality & Laser Scanning Applications

3D Engineering Solutions from Iowa State University

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INTRODUCTION

Two state-of-the-art technologies—virtual reality (VR) and laser scanning—have the potential for improving efficiency and cost-effectiveness in many areas, including planning, design, construction, and project maintenance.

In September 2001, the Center for Transportation Research and Education (CTRE) at Iowa State University (ISU) hosted a workshop on virtual reality and laser scanning. The workshop was part of an effort to expand ISU's role in providing construction information technology research and to strengthen ISU's present private-sector relationships.

Virtual reality—an immersible, synthetic environment—can be used to investigate complex three-dimensional (3D) data and to explore human interaction with products that are still in digital form. Many VR applications have been developed to provide solutions to civil, structural, and mechanical engineering problems. ISU's Virtual Reality Applications Center (VRAC) is one of only four facilities worldwide with six-surface VR capabilities. The Cave 6 (C6) is an ideal environment for the testing and development of interactive design applications, which will allow design teams to explore many "what if" situations quickly.

Laser scanning can be used to efficiently and cost-effectively create accurate 3D models and drawings. Construction design is a focus for many laser scanning application developments. This technology has been successfully used to develop retrofit designs; create faster, safer, and more complete topographic and engineering surveys; and provide for more efficient operations and maintenance. Laser scanned images can also be used in virtual reality applications.

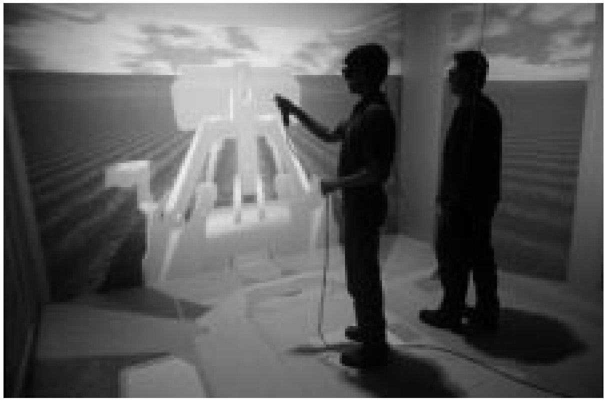
While virtual reality and laser scanning offer many benefits to the construction industry, they also have applications in other areas such as accident investigation and the modeling of historical sites. Because these technologies are easily adapted and can be tied to real-world data and problems, their virtual, 3D methods offer many fast, cost-efficient alternatives to traditional methods. Iowa State University, through its Center for Transportation Research and Education, Virtual Reality Applications Center, and private-sector partners, is committed to developing applications and providing solutions using these two very important technologies.

VIRTUAL REALITY

Virtual reality is a synthetic environment with three-dimensional, multi-sensory, immersive, and interactive characteristics.

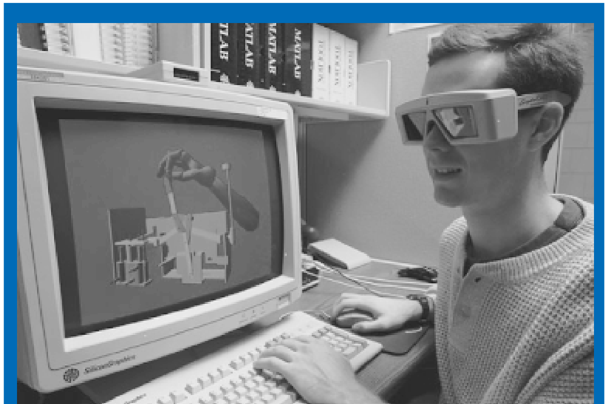
VR is created through the combination of visualization/interaction technologies, high-performance computing, and complex information management.

A virtual reality participant is able to interact with a virtual world through the use of “position tracking,” which is a method of tracking the position of a real world object such as a head or a hand. Stereo viewing is achieved through the use of stereo glasses and head-mounted displays (see figures on this page).



Virtual Reality: A 3D, Multi-sensory, Immersive, Interactive, Synthetic Environment

Different types of projection systems offer different virtual reality capabilities. Many VR facilities have four-surface projection; a few facilities, including ISU’s C6, offer six-surface projection.



Stereo Glasses

Head-Mounted Display

Virtual Reality Applications

Virtual reality is used to investigate complex three-dimensional data and to explore human interaction with products that are still in digital form. VR data can be tied to physical models and be applied to real-world problems.

Mechanical Engineering

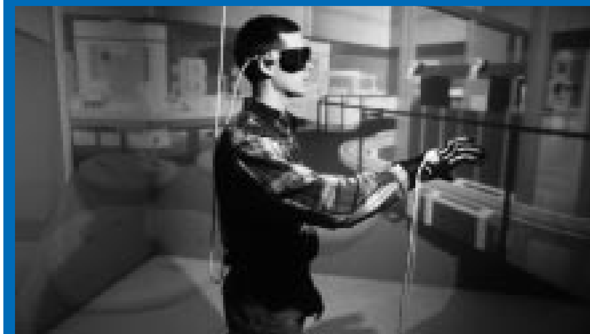
Many virtual reality applications—for example, assembly prototype evaluation, factory layout modeling, and spatial mechanism design—have been developed to provide solutions to mechanical engineering problems (see figures).

Transportation-Related Applications

Virtual reality applications in highway design show great potential. For example, complicated interchange designs can be modeled and tested in a virtual environment before construction.

VR applications can improve the constructability and maintainability of roads and bridges. The stress distribution on pavement under different loading conditions can be modeled in a virtual environment. Virtual reality can also be used by designers and builders to better plan and schedule road and bridge maintenance operations.

Assembly Prototype Evaluation



Factory Layout Modeling

Spatial Mechanism Design

In the area of driver testing and research, many applications have been developed to evaluate driver response and performance in computer-generated environments (see figure).

Driving Simulation

Accident Investigation

Accident investigation is yet another area for future VR applications. “What if” scenarios in virtual reality could be very useful in accident investigation software and to juries.

Collaborative, Interactive Design

Collaborative, interactive design is the next frontier in virtual reality. The goal of collaborative, interactive design is to provide a tool that will allow the design team to explore many “what if” situations quickly, with real-time interaction.

Collaborative, Interactive Design

Capabilities of the Virtual Reality Applications Center at Iowa State University

The Virtual Reality Applications Center is an interdisciplinary research center at Iowa State University. VRAC’s focus is the emerging field of engineering and science applications of synthetic environments. Since it was founded in 1990, VRAC has grown rapidly, drawing faculty and students from a variety of academic disciplines.

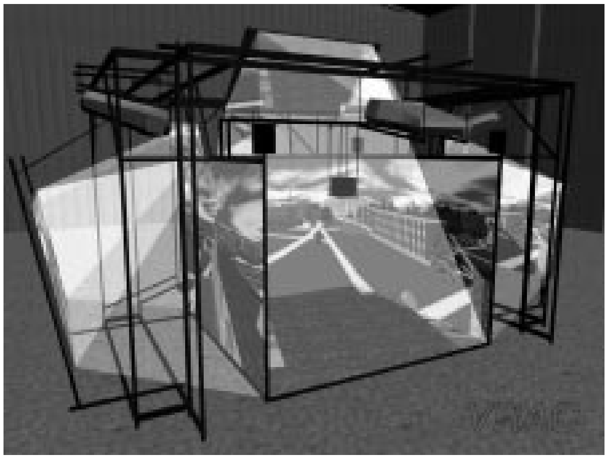
Research at VRAC involves the integration of humans and computers with advanced interfaces to enable visual, haptic, and audio interaction between users and computer-generated virtual environments. Ongoing studies are providing new and important insights for a diverse range of challenging problems, from rapid prototyping to human-in-the-loop simulations to computational fluid dynamics.

Current VRAC resources include more than twenty silicon graphics computers and a wide variety of synthetic environment interface devices, including the C6, where the user is immersed in real-time 3D-image projections and full surround audio.

The C6, located in Howe Hall, is one of only four six-sided virtual reality rooms in the world and the only one in the United States. The C6 has a dimension of 10 feet by 10 feet by 10 feet, with six display screens. This is also the first known cave to demonstrate wireless tracking and input devices. The C6 facility opened in June 2000.

The C2, built in 1996, was a four-sided virtual reality room with four display screens. This facility has been retired and is being replaced by the C4. The new C4 system will support several configurations, including a three-screen theater-presentation mode and a cave-like three-sides-plus-floor immersive environment.

VRAC's C6 Facility



VRAC's C2 Facility

LASER SCANNING

Laser scanning is a fast, accurate, and cost-efficient method of gathering three-dimensional data for use in 3D models and mapping. Laser scanned images can also be used in virtual reality applications.

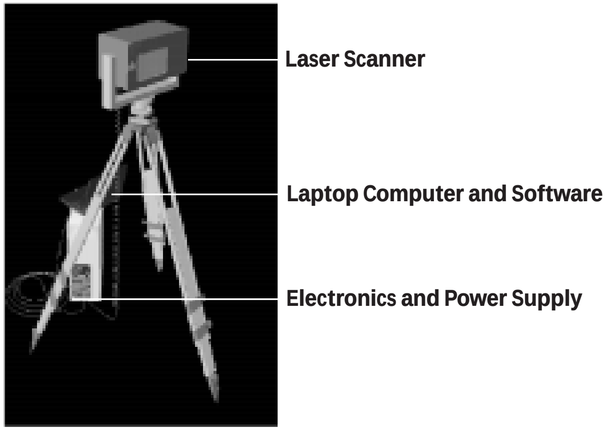
Laser scanning technology includes a laser scanner positioned on a tripod (see figure). A Cyrax laser scanner provides 2–6 mm accuracy, 1–150 m scanning range, and 40° x 40° field of view at a speed of more than 1,000 points per second. The 3D data are stored in a computer and can be manipulated with software designed for that purpose.

The 3D modeling process involves six primary steps:

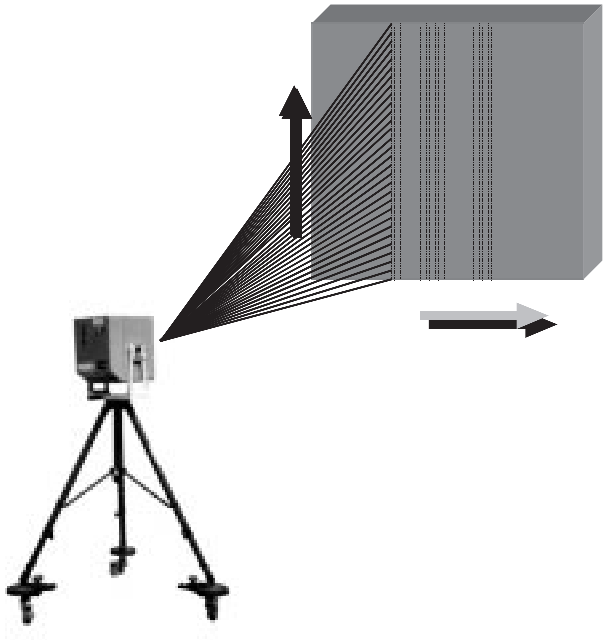
1. target the area or structure
2. scan the area or structure and create a “point cloud”
3. color the points
4. “shrink wrap” the surfaces in the field
5. register the scans together and create the virtual database
6. create the detailed 3D model

See figures on the following page for a demonstration of these six steps.

The 3D models created through laser scanning include extensive detail and allow for ultra-fast measuring. If desired, two-dimensional drawings can be created from the 3D models.

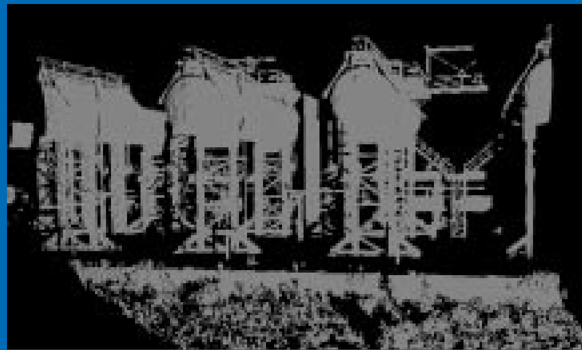


Laser Scanning Equipment

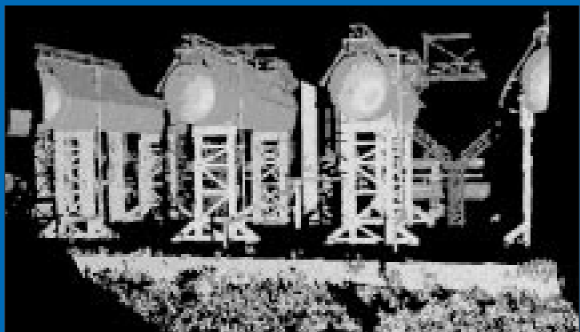


Laser Scanning Process

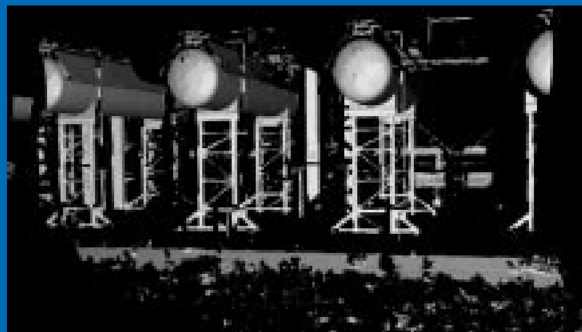
Step 1: Target the Area or Structure



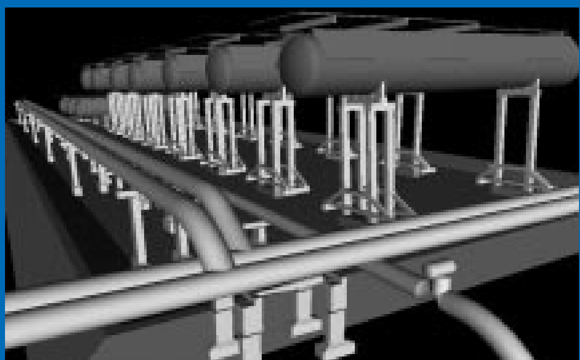
Step 2: Scan the Area or Structure



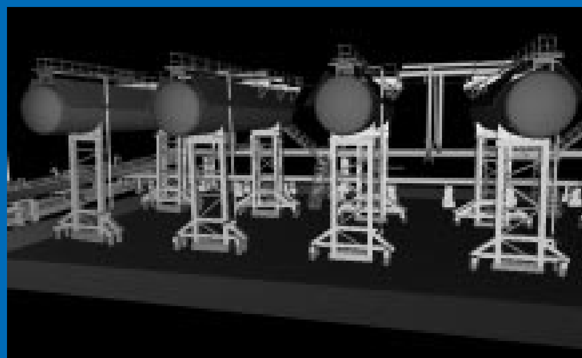
Step 3: Color the Points



Step 4: Shrink Wrap the Surfaces



Step 5: Create the Virtual Database



Step 6: Create the Detailed 3D Model

Laser Scanning Applications

Because 3D modeling using laser scanning is both fast and cost-effective, it is well suited for many applications.

Mechanical Engineering

Laser scanning is ideal for mechanical applications because the software solutions available convert point data into CAD primitives quickly and accurately.

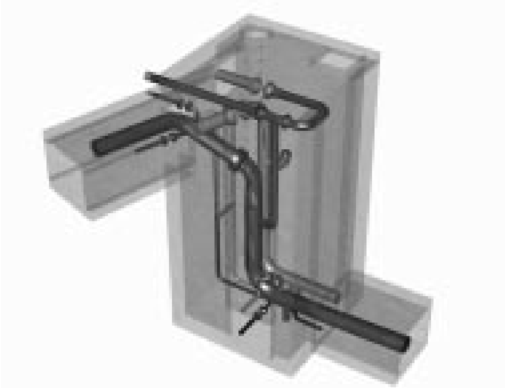
Construction Design

Construction design is one of the largest areas for 3D modeling development. Applications include roadway, bridge, and building design and rehabilitation. Designing construction projects using 3D modeling has been found to have many benefits:

- Coordination issues can be minimized with virtual design and construction.
- 3D modeling provides efficient generation of multiple views.
- The 3D modeling process can generate automated bills of material.
- The data generated through laser scanning and modeling can be efficiently integrated into analysis software.

See the figures for examples of 3D design applications.

Central Plant Model



Steam Distribution Manhole Model

Sports Facility Model

Transportation-Related Applications

Using laser scanning for highway design can provide many benefits, such as the ability to survey during heavy traffic times without positioning surveyors in the roadway and without closing the road. An example of a highway widening project that utilized laser scanning is shown on the right.

Laser scanning can be used for creating as-built drawings of bridges to assist in modifications (see figure below).

This technology also has the potential to perform storm simulations to evaluate the flooding and ponding effects of current and proposed drainage structures.

Laser scanning also provides an excellent method for rebar inspection, assessing pot holes, and inspecting roads for rutting.

3D Modeling of Existing Bridge
(Pennsylvania DOT project)

Highway Widening Project Using Laser Scanning
(Mark Thomas & Co. project)

Surveys

When accessibility and safety issues prevent a traditional survey, laser scanning provides an excellent replacement. Laser scanning can be used to perform accurate and efficient as-built surveys and before-and-after surveys. Inaccessible locations, complex arrangements, and hazardous locations can all be easily modeled.

Historical Modeling

Laser scanning provides new options to the modeling of historical sites and large ornate structures. See the original, point cloud, and shrink wrap stages of the 3D modeling of the Kentucky Capitol Building in Frankfort, Kentucky, below.

Accident Investigation

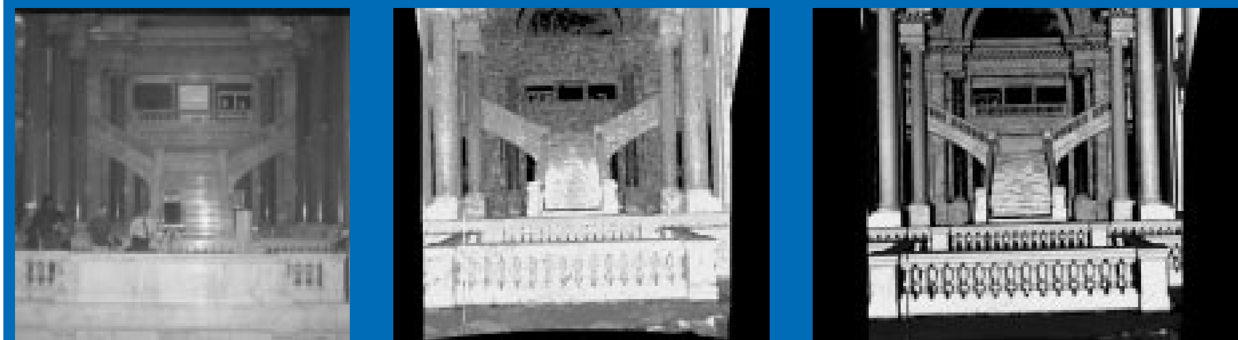
Laser scanned data are very useful in forensics, as well as in general investigation and documentation. For example, in the area of accident investigation, the Iowa State Patrol could develop 3D models related to accidents and accident scenes.

Planning, Logistics, and Management

Existing buildings in an area (such as the Iowa State University campus) can be laser scanned, and then "what if" scenarios related to installing new buildings can be performed using 3D modeling. A 3D hologram could show where everything is located, allowing the designer and builder to "walk through" walls and see the studs and other components.

Many applications also show promise in other areas of logistics and management. 3D modeling could be used to measure and verify quantities of work to be performed. Laser scanning could also be useful in improving quality control (e.g., measuring the location of anchor bolts, scanning rebar prior to pour, and evaluating cut/fill requirements).

3D Modeling of the Kentucky Capitol Building



Original **Point Cloud** **Shrink Wrap**

CONCLUSION AND CONTACTS

This document is intended as an introduction to virtual reality and laser scanning technologies and applications. CTRE hosted a workshop in September 2001 to demonstrate the capabilities of VRAC and ISU's private-sector partners in these two areas and to generate discussion on possible future applications. An appendix to this document, including the Virtual Reality and Laser Scanning Workshop invitation, agenda, participant list, and discussion notes, is available upon request.

For additional information about laser scanning, the workshop, or this document, please contact

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