The Basics of Laser Scan Processing

By Scott Leacox

Introduction

The data produced by a 3D laser scan is called a "point cloud". It is the same type of data as that produced by a Total Station, but there is a lot more of it. Current scanners can collect anywhere between 200 and 10,000 points per second. Traditional surveys using a Total Station or GPS typically generate less than 1,000 points in a day's work.

Processing point clouds is a relatively new area in the survey business, and presents unique challenges, and opportunities. The benefits to a client are many, if they know the new questions that can be answered (like how straight, square or flat something is).

The steps used to convert laser scanner data (point clouds) into final products are:

1. Combine and **register** the points clouds
2. Segment the clouds for **object extraction**
3. Extract the desired objects (Must be single valued somehow)
4. Combine extracted objects into a model file, perform any **editing and modeling**
5. Create the final deliverables (**rendering** and/or text **drafting**)

These steps will be discussed in more detail. And the procedures used to convert point clouds into deliverables reveal several issues regarding the software and hardware needed to do the job effectively. To really understand this, let's look at an example.

Mega Data

Let's assume a typical scan includes 1 million points (this is the limit for a single scan from a Cyra 2500 scanner). Let's also assume that 16 scans can be obtained in a full day's work. Each scan is about 20 megabytes of data. With 16 of these, we start with 320 megabytes of data, right out of the chute. This is also about the maximum amount of data that today's affordably priced computers can handle all at one time.

Once the scan data hits the office server (all 320 Megs), it must be processed. During the office processing, this raw data grows to about 5 times its original size. And remember, this is just for one day's scanning. Keeping this large amount of data organized, and properly backed up each day, is not something to be taken lightly. A very large server space, and backup system, must be in place. Also, gigabyte connections (1000 base T) between the scanner laptop, office workstations, and the server, save valuable file transfer time.

With the digital photos taken of the site (required for proper processing), data gathered via Total Station or GPS, and existing client computer files (drawings, etc.), about 100 new files hit the server for each full day's scanning.

Once the data is available to the scan-processing technician (3D CAD Operator), the point cloud work really begins. The points are used to extract information about the building, structures, scene or subject that was scanned. This is called object extraction, or reverse engineering. The basic objects must be "extracted" from the points. The extracted objects can then be used to create a number of valuable final products.

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Object Extraction

In any single field of view for one scan, there are usually 20 or so objects that are being captured. These objects are what the final product will be all about. In our example, there could be well over 200 objects to be mined, each one requiring individual attention.

Extracting objects from point clouds is a tricky business. There are three basic obstacles that must be overcome in order to assure accuracy, and a satisfied client:

1. **The scans must be registered.** This means that the overlapping portions of each scan are correctly and exactly oriented to each other when all scans are combined. This could also mean that the coordinate system of the points must be translated into the client's coordinate system, so client's can easily incorporate the new data.
2. **The point cloud must be segmented.** The points to be used to extract a particular object must themselves be separated from the rest of the points in order to perform the extraction. This process is called "segmenting" the point cloud.
3. **Corners of objects do not get scanned.** The laser beam does not provide a return from corners and edges, so these features must be interpolated by the CAD tech, by intersecting surfaces or some other method.

Each of these challenges can sometimes be handled "automatically" by software, but for the most part, the CAD tech must understand these issues and handle them "manually", buy using a series of software commands to accomplish each task.

Single-Valued Segmentation

Objects extracted from point clouds are mathematically "single-valued" in some way, depending on which coordinate system is being used: Cartesian, spherical or cylindrical. Here is a complete list of these single-valued objects:

Point	Plane	Bezier curve
Line	Sphere	NURBS* curve
Circle	Cylinder	NURBS* surface
Arc	Cone	Extruded shape **

* NURBS = Non-Uniform Rational B-Splines (complex curves)

** Extruded shape means fitting a specifically know item (like a typical size I-Beam) to that point cloud segment.

Note that most of these single-valued objects do not have any corners. Aside from extruded shapes, only the ends of the cylinder and the ends of the cone have edges.

To segment the cloud down to just the points required to extract the corresponding object, the CAD tech must have a good computer and the right software to do the job efficiently.

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Computer Hardware

There are six features of the CAD operator's computer that must be right if he or she is to be effective:

1. Number of CPU processors, and CPU processor speed
2. Number of hard disks, size and speed
3. Number of computer screens, type, and size.
4. Amount of RAM
5. Style and speed of video card
6. Operator control devices (mouse, joystick, space ball, tablet)

For purposes of this discussion, the details behind the following choices are not presented here. However, there are important and valid reasons to use each item listed below.

Best performance (from software & technician), for the price, comes from these choices:

1. Two CPU Processors, each at least 3GHz (32 bit architecture) with 1MB Cache
2. Two SCSI hard disks, configured with Raid-0, each being at least 36 gigabytes
3. Two 22" LCD flat panel monitors
4. 4 to 16 gigabytes of RAM
5. One of the high-end video cards from ATI, NVIDIA or 3DLabs
6. Any control device that the CAD technician desires

Computer Software

Besides the common CAD programs (AutoCAD and MicroStation), and the Point cloud processing software, there are a few software packages that must be available on all point cloud processing machines:

- Photoshop, to enhance photos viewed during processing
- Z-Tree or other file handling program, to quickly manage the massive data flow
- DVD Writer, to create disks from the workstation if needed

The software used to process the point clouds and create final deliverables will vary depending on:

- What scanner was used
- The subject of the scan
- What valuable final products are to be created

The processing of point clouds really takes place in two steps:

1. Processing the points. This includes registration, segmenting, cleaning and re-sampling.
2. Converting the points to some other type of mathematical element that more simply represents the object(s) in question.

Important note: Workflow is much faster if digital images of the subject are easily available during each step of the process.

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Editing and Modeling

There is, mathematically speaking, **only** four ways to convert point clouds.

1. Tracing (The game of dot to dot will never be the same :)
2. Conversion to primitives (lines, planes, spheres, cylinders, etc.)
3. Conversion to polygons (2.5D/Topographic or 3D piece-wise)
4. Conversion to curves (Bezie or NURBS)

Unfortunately, each method uses different programming algorithms, and hence requires a different software package to accomplish each task most efficiently.

Every point cloud software package has methods for segmenting, cleaning and isolating points for object extraction, although each has its own strengths and weaknesses here.

More importantly, each software program has a few unique tools that the others do not have. And these special tools can make - or break - the profitability of a particular job, just because of that one tool's availability. Without a full selection of available tools, any one job can become a nightmare.

Today, the various software packages available have different primary purposes:

- Reverse engineering
  - Scan tracing
  - Extracting primitives (planes, spheres, cones & cylinders)
  - Polygon fitting
  - NURBS fitting
  - Placing "best-fit" shapes
- Modeling
  - Surface modeling
    - Primitive surface modeling
    - Polygon surface editing
    - NURBS surface modeling
    - Sweep modeling (extrusions, rotations and lofts)
  - Solid modeling
    - Surface to solid conversion
    - Primitive & NURBS solid modeling
    - Polygon solid modeling
- Deliverable preparation
  - Drafting
  - Layer / level organization
  - Rendering (Single viewpoint, movie)

3D Services Department with the software and talent to handle all the above functions will be able to create any type of deliverable. The available choices and capabilities of software are changing rapidly. Making the correct software choices, for your target markets, is difficult to resolve between management, technicians, and software venders.

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Deliverables

The most common types of deliverables are:

- 2D Architectural drawings
  - Plan view
  - Elevation / cross section
  - Clearance
  - Other measurements
- 3D Models
  - Point cloud
  - Wireframe
  - Surface model
  - Solid model
  - Data for engineering calculations
- Renderings
  - Single viewpoint rendering
  - Multiple viewpoint renderings (movie)
- 3D Prints
  - Rapid prototype creation

One of the biggest challenges of producing products from a scanner is determining exactly what the client really needs and wants in the final deliverable. For example, will a simple polygon mesh be adequate? Or is an organized 3D model needed? Do certain objects need to have exact dimensions? If modeling a building, does each window require separate modeling or can similar ones be created from a "typical"? And if using a "typical" item and one of them doesn't fit right, how is the gap/overlap handled? The answers to these type questions can make or break the profitability of any one project.

Special Challenges

Inherent to the scanning process come some special challenges:

1. **Some data points can be missing**. Due to obstructions during scanning, some data points are just not there. If a tree or pole was in the way, or if the scanner angle is such that an important portion of a key object was hidden, these points must somehow be re-created manually by the CAD operator.

2. **File size.** An important function of point processing is to reduce the amount of data to a file size that the client can handle. The files from just one day's scanning can be too large for a normal CAD program to handle all at once. Also, even with the most powerful PC, projects that include more than 15 or 20 scans must be broken down into smaller pieces to perform the processing.

3. **Proving accuracy.** As with any new technology, the results come under special scrutiny by the client. It is difficult for some to believe how "not-straight" or out-of-square a particular object is. Justifying the results can be time consuming.

4. **Client requests.** As mentioned earlier, without a full compliment of software tools to accomplish a variety of tasks, you will probably have clients with failed expectations. The ability to deliver whatever the client wants, from everything the scanner sees, will build client confidence in your service.

   Take, for example, the scanning of a steel beam. One software package can show you (and the client) that the beam is not straight. This is observed by noting that the points don't fit a straight beam that has been "best fit" to the points. Now the customer asks, "Well, how curved is it?" The software package that was used initially cannot answer this question; it only handles objects that are straight. This question can only be answered by a software package that handles curves. The point is, you can easily be made to look unprepared by not knowing how to answer new questions that come up.

<u>Be Prepared</u>

Processing scan data can be accomplished using several different techniques. And there are many variables that affect the choices:

- The subject of the scan, and the scanner itself
- The hardware and software available, and established procedures for using them
- The client's requirements

The key to obtaining efficient results is to Be Prepared. The effective scan processing group must:

- Be Prepared to properly handle the large volume of data
  - Fast computers and fast connections
  - Large data storage capacity and adequate backup procedures
- Be Prepared to use a variety of techniques to create deliverables
  - Know the different software programs, and what they can do
  - Correctly apply this knowledge to the creation of deliverables
- Be Prepared to manage the work flow
  - Have a clear understanding of what is required for each project
  - Perform work only if it contributes to contract fulfillment
- Be Prepared to handle the client with kid gloves
  - Help clients to understand the various questions that can be answered with scanning results, as well as the limitations of this technology.
  - Keep the client informed at key intervals of a complex project, especially as it relates to artistic decisions, as during production of a movie.

The world of survey will always have a need for some type of scanning, as well as the different techniques used to create valuable final products from point clouds.
And although a relatively new technology, Laser Scanning, and the ability to process the data efficiently and accurately, is a must for the well-equipped surveyor.