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3D LASER SCANNERS: HISTORY AND APPLICATIONS

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Abstract: A 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color). The collected data can then be used to construct digital three-dimensional models. 3D laser scanning developed during the last half of the 20th century in an attempt to accurately recreate the surfaces of various objects and places. The technology is especially helpful in fields of research and design. The first 3D scanning technology was created in the 1960s. The early scanners used lights, cameras and projectors to perform this task. Due to limitations of the equipment it often took a lot of time and effort to scan objects accurately. Collected 3D data is useful for a wide variety of applications. These devices are used extensively by the entertainment industry in the production of movies or virtual reality. Other common applications of this technology include industrial design, orthotics and prosthetics, reverse engineering and prototyping, quality control/inspection and documentation of cultural artifacts.

1 Introduction

In modern engineering, the term `laser scanning' is used to described two related, but separate meanings. The first, more general, meaning is the controlled deflection of laser beams, visible or invisible. Scanned laser beams are used in stereolithography machines, in rapid prototyping, in machines for material processing, in laser engraving machines, in ophtalmological laser systems for the treatment of presbyopia, in confocal microscopy, in laser printers, in laser shows, in Laser TV, and in barcode scanners.

The second, more specific, meaning is the controlled steering of laser beams followed by a distance measurement at every pointing direction. This method, often called 3D object scanning or 3D laser scanning, is used to rapidly capture shapes of objects, buildings, and landscapes.

Since the early 1980's, the analytical stereo-compiler has been the workhorse for broad-acre spatial data acquisition tasks including exploration mapping, regular mine planning and stockpile measurements (Byrne, 1997). It has also played a lesser role in subsidence monitoring, environmental lease statistics and infrastructure mapping.

Terrestrial laser scanning has already found its place between the standard technologies for objects acquisition. The laser scanner can be described as a motorized total station, which measures automatically all the points in its horizontal and vertical field. For each measured point, its distance to the laser scanner together with the horizontal and the vertical angles are recorded. So, the space coordinates relative to the scanner position can be easily computed.

Hand-held laser scanners create a 3D image through the triangulation mechanism described above: a laser dot or line is projected onto an object from a hand-held device and a sensor (typically a charge-coupled device or position sensitive device) measures the distance to the surface (Figure 1).

The purpose of a 3D scanner is usually to create a point cloud of geometric samples on the surface of the subject. These points can then be used to extrapolate the shape of the subject (a process called reconstruction). If color information is collected at each point, then the colors on the surface of the subject can also be determined [1].

This article is focusing in presenting a brief look on the 3D laser scanners. In addition, it gives a general presentation about the 3D laser scanners' history and applications.

Figure 1 3D lasser scanner Faro for industrial scanning

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2 History of 3D scanners

3D laser scanning developed during the last half of the 20th century in an attempt to accurately recreate the surfaces of various objects and places. The technology is especially helpful in fields of research and design. The first 3D scanning technology was created in the 1960s.

The early scanners used lights, cameras and projectors to perform this task. Due to limitations of the equipment it often took a lot of time and effort to scan objects accurately. After 1985 they were replaced with scanners that could use white light, lasers and shadowing to capture a given surface. Next is a brief history of the 3D scanning development.

With the advent of computers, it was possible to build up a highly complex model, but the problem came with creating that model. Complex surfaces defied the tape measure as shown in figure 2.

Figure 2 Object tape measuring

By the mid-nineties they had developed into a full body scanner as shown in figure. This is where 3D Scanners appeared.

In 1994, 3D Scanners launched REPLICA - which allowed fast, highly accurate scanning of very detailed objects. REPLICA marked serious progress in laser stripe scanning.

Meanwhile Cyberware were developing their own high detail scanners, some of which were able to capture object colour too, but despite this progress, true three-dimensional scanning - with these degrees of speed and accuracy - remained elusive.

One company - Digibotics - did introduce a 4-axis machine, which could provide a fully 3D model from a single scan, but this was based on laser point - not laser stripe - and was thus slow. Neither did it have the six degrees of freedom necessary to cover the entire surface of an object, neither could it digitise color surface.

While these optical scanners were expensive, Immersion and Faro Technologies introduced lowcost manually operated digitisers. These could indeed produce complete models, but they were slow, particularly when the model was detailed. Again, they could not digitise color surface.

By this time, 3D modellers were united in their quest for a scanner, which was:

- accurate,
- fast,
- truly three dimensional,
-capable of capturing color surface,
- and realistically priced.

One of the first applications was capturing humans for the animation industry. Cyberware Laboratories of Los Angeles developed this field in the eighties with their Head Scanner as shown in figure (3).

Figure 3 Humans head scanning

In 1996, 3D Scanners took the key technologies of a manually operated arm and a stripe 3D scanner - and combined them in ModelMaker as shown in figure 3. This incredibly fast and flexible system is the world's first Reality Capture System.It produces complex models and it textures those models with color.

Color 3D models can now be produced in minutes. field in the eighties with their Head Scanner as shown in figure 4.

Figure 4 Manually operated arm and strip 3D scanner

3 3D laser scanning application

A virtual reality application may be employed to create a three dimensional virtual space from an existing architecture. The virtual reality space may then be used in computer simulations of various desired activities. Such activities could include a workflow or manufacturing line simulation [2].

The 3D virtual space may be used for entertainment, such as animation or a movie action scene simulation, keeping even the stunt professions safe from harm.

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Transportation applications, such as a accident investigation. The scene of the accident could be 3D laser digitized, and a simulation of an actual accident event or "what if" scenarios explored.

3.1 Applications

3D laser scanning is used in a variety of fields and academic research. It has benefited clothing and product design, the automotive industry and medical science. Laser scanning can also be used to record buildings, especially in places that people may not be able to access due to safety hazards. 3D Laser Scanning is used in numerous applications: industrial, architectural, civil surveying, urban topography, mining, reverse engineering, quality, archaeology, dentistry, and mechanical dimensional inspection are just a few of the versatile applications. 3D laser scanning technology allows for high resolution and dramatically faster 3D digitizing over other conventional metrology technologies and techniques. Some very exciting applications are animation and virtual reality applications [3-5].

3.1.1 Material procesing and production

Laser scanning describes the general method to sample or scan a surface using laser technology. Several areas of application exist that mainly differ in the power of the lasers that are used, and in the results of the scanning process. Low laser power is used when the scanned surface does not have to be influenced, e.g. when it only has to be digitized. Confocal or 3D laser scanning are methods to get information about the scanned surface. Another low-power application are structured light projection systems that are used for solar cell flatness metrology enabling stress calculation with throughput in excess of 2000 wafers per hour.

3.1.2 Construction industry and civil engineering

- As-built drawings of Bridges, Industrial Plants, and Monuments.
- Documentation of historical sites.
- Site modeling and lay outing.
- Quality control.
- Quantity Surveys.
- Freeway Redesign.
- Establishing a benchmark of pre-existing shape/state in order to detect structural changes resulting from exposure to extreme loadings such as earthquake, vessel/truck impact, or fire.
- Create GIS (Geographic information system) maps and Geomatics.

3.1.3 Reverse engineering

Reverse Engineering refers to the ability to reproduce the shape of an existing object. It is based on creating a digitized version of objects or surfaces, which can later be turned into molds or dies. It is a very common procedure, which has diverse applications in various industries. Non-contact 3D laser scanning allows even malleable objects to be scanned in a matter of minutes without compression, which could change their dimensions or damage to their surfaces. Parts and models of all sizes and shapes can be quickly and accurately captured. 3D laser scanning for reverse engineering provides excellent accuracies and helps to get products to market quicker and with less development and engineering costs. 3D Laser scanning provides the fast, accurate, and automated way to acquire 3D digital data and a CAD model of part’s geometry for reverse engineering when none is available. Also, new features and updates can be integrated into old parts once the modeling is accomplished [Site 12]. A practical mechanical and civil engineering application would be to assist in the production of "as built" data and documentation. Currently, many manufacturing or construction activities are documented after the actual assembly of a machine or civil project by a designer or engineering professional. 3D laser scanners could expedite this activity to reduce man-hours required to fully document an installation for legacy.

3.1.4 Mechanical applications

Reverse engineering of a mechanical component requires a precise digital model of the objects to be reproduced. Rather than a set of points a precise digital model can be represented by a polygon mesh, a set of flat or curved NURBS surfaces, or ideally for mechanical components, a CAD solid model. A 3D scanner can be used to digitize free-form or gradually changing shaped components as well as prismatic geometries whereas a coordinate measuring machine is usually used only to determine simple dimensions of a highly prismatic model. These data points are then processed to create a usable digital model, usually using specialized reverse engineering software [6-8].

3.1.5 Civil applications

Civil activities could be for a roadway periodic inspection. The digitized roadway data could be contrasted to previous roadway 3D scans to predict rate of deterioration. This data could be very helpful in estimating roadway repair or replacement costing information. When personnel accessibility and/or safety concerns prevent a standard survey, 3D laser scanning could provide an excellent alternative. 3D Laser scanning has been used to perform accurate and efficient as-built surveys and before- and after construction and leveling surveys [9].

3.1.6 Gargoyle models

The combined use of 3D scanning and 3D printing technologies allows the replication of real objects without the use of traditional plaster casting techniques, that in many cases can be too invasive for being performed on precious or delicate cultural heritage artifacts. In figure 5, the gargoyle model on the left was digitally acquired by using a 3D scanner and the produced 3D data was

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processed using MeshLab software. The obtained digital 3D model was used by a rapid prototyping machine to create a real resin replica of original object as shown on the right of figure 5.

Figure 5 An example of real object replication by Means of 3D scanning and 3D printing

3.1.7 Medical CAD/CAM

3D scanners are used in order to capture the 3D shape of a patient in orthotics and dentistry. It gradually supplants tedious plaster cast. CAD/CAM (Computer-Aided Design/ ComputerAided Manufacturing) software are then used to design and manufacture the orthosis, prosthesis or dental implants.

Many Chairside dental CAD/CAM systems and Dental Laboratory CAD/CAM systems use 3D Scanner technologies to capture the 3D surface of a dental preparation (either in vivo or in vitro), in order to produce a restoration digitally using CAD software, and ultimately produce the final restoration using a CAM technology (such as a CNC milling machine, or 3D printer). The chairside systems are designed to facilitate the 3D scanning of a preparation in vivo and produce the restoration (such as a Crown, Onlay, Inlay or Veneer).

3.1.8 Design process

Design process including:

- Increasing accuracy working with complex parts and shapes,
- Coordinating product design using parts from multiple sources,
- Updating old CD scans with those from more current technology,
- Replacing missing or older parts,
- Creating cost savings by allowing as-built design services, for example in automotive manufacturing plants,
- "Bringing the plant to the engineers" with web shared scans, and
- Saving travel costs.

3.1.9 3D photography

3D scanners are evolving for the use of cameras to represent 3D objects in an accurate manner. Companies are emerging since 2010 that create 3D portraits of people (3D figurines or 3D selfies) (Figure 6) [10].

Figure 6 3D selfie

3.1.10 Law enforcement

3D laser scanning is used by the law enforcement agencies around the world. 3D Models are used for on-site documentation of:

- Crime scenes,
- Bullet trajectories,
- Bloodstain pattern analysis,
- Accident reconstruction,
- Bombings,
- Plane crashes, and more.

4 Conclusion

3D laser scanning equipment senses the shape of an object and collects data that defines the location of the object's outer surface. This distinct technology has found applications in many industries including discrete and process manufacturing, utilities, construction, archaeology, law enforcement, government, and entertainment. Laser scanning technology has matured and developed in the past two decades to become a leading surveying technology for the acquisition of spatial information. Wide varieties of instruments with various capabilities are now commercially available. The high-quality data produced by laser scanners are now used in many of surveying's specialty fields, including topographic, environmental, and industrial. These data include raw, processed, and edited dense point clouds; digital terrain and surface models; 3D city models; railroad and power line models; and 3D documentation of cultural and historical landmarks.

3D laser scanners have a wide rang of applications which applicable to very small object to a wide range areas.

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