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3D scanner technologies

[1]*Roman SULLA*, [2] *Tibor VINCE*

[1-2] Department of Theoretical and Industrial Electrical Engineering, FEI TU of Košice, Slovak Republic

[1]roman.sulla@student.tuke.sk, [2]tibor.vince@tuke.sk

***Abstract* — This article is devoted to the consideration of various methods of 3D scanning. At the beginning of this article describes the use of scanners. The next part describes the types and methods of 3D scanning that is used now. The following describes the scanners by the method of construction.**

***Keywords* — 3D scanning, 3D scanner, 3D, Scanners, Model**

I. INTRODUCTION

Three-dimensional scanners themselves are devices that translate real objects into so-called polygonal models for further editing. In the first stage of the scan, we get a cloud of points that has a grid with the vertices formed by the coordinates of the points of the scanned object's surface. Subsequently, some parts of the model are automatically or manually scanned, then we build and re-create the ultimate 3D model. 3D scanning technology is popular in many areas, from preservation of monuments, museums to building and forensics.

The reason why this technology is now widely applicable to high-speed surface data collection; without contacts, that is, the device itself does not have a special probe to bypass the object, reducing the possibility of damage to the original when scanning, this is particularly important when working with fragile materials.

II. 3D SCANNER

A 3D scanner is a device that analyzes a physical object and creates its 3D image based on the information it receives. The scanned models can then be processed using CAD tools and then used for technological and engineering developments. A 3D printer and a 3D scanner are used to create a 3D model.[1]

When creating a three-dimensional scanner, several technologies participated at once, differently among themselves. Objects that are digitized also have some limitations. Mirrored, shiny or transparent surfaces may experience difficulties. It should be recalled that three-dimensional data is also important in other areas of activity. For example, it is used in the entertainment industry: to create video games, movies, drawings. 3D technologies find their application in orthopedic and prosthetics, in industrial design, reverse engineering, prototyping, as well as in the control and documentation of historical objects or other cultural artifacts. [1] [3] [4]

During operation, the 3D sensor creates a set of dots according to the geometric dimensions of the scanned object. In the future, these points will recreate the shape of the object, that is, reconstructs it on the monitor. If color information is used, it determines the color of the future digital surface.

The 3D scanner can be compared to a conventional camera: their field of view is cone-shaped and information can only be obtained from surfaces that have not been shaded. Differences between these devices are essential. The camera transmits only the image and the object's color, and the scanner examines the object more closely, creating an image with the exact distance of each point from the surface. Allows you to display the image at three planes at once.

Generally, it is not enough to simulate the subject of a single scan. Several such operations are required

at a time. Scanning an object from different directions is necessary to get accurate information about its sides. All scanned data is located on a common coordinate system where the image is aligned.

There are several technologies for 3D object scanning and scanning of its form. According to the classification, 3D scanners are divided into two types: contact scanners and contactless. Contactless are divided into two types - passive and active.

III. Types of 3D scanner

A. *Contact 3D Scanners*

Scanners of this type examine the object directly - through physical interaction. At the time of the study, the subject is on a special test board. If the thing is asymmetric or cannot lie exactly in one place, it is held by special clips. [1] [3]

Fig. 1 Contact 3D Scanners [2]

Existing mechanisms 3D scanner:

- The method by which the probe moves as a needle in the sewing machine, tapping the target surface as it moves forward. This method is not very good for complex objects and is very slow compared to other methods.
- Analogue probe - is a sensor that keeps in touch with the target when moving, collects continuous data flow and makes the process much faster. This method is further divided into two additional methods: Open Loop and Closed Loop.
  - Open loop scanning - the target object is also known to have a defined shape. The probe monitors the basic shape of the object that has been programmed and records variations at extreme speed. Sometimes, open loop scanning is performed after a closed loop scan to improve results.
  - Closed-loop scanning - is used to scan undefined, more complex objects. In this scan, the probe not only collects accurate data from the object surface, but actively detects changes.
- The touch trigger probe is very similar to an analog probe, but instead of still being in contact, it only touches the target object at some point to get data. The analog probe can also be used as a touch probe with proper programming.

Three-dimensional contact scanner - they are very accurate and are widely used in various industries. The essential minus machine can be attributed to the need for mandatory contact with the object being studied. A great chance of damage to the object or its deformation. [1] [3]

Another disadvantage is its slowness. It may take a very long time to move your hand along a set goal. While modern optical models can work much faster.

This group can also include handheld metering devices that are often used for 3D modeling of animated films.

Features

- High precision work, with the possibility of subsequent export to CAD packages
- Can be purchased at a relatively cheap price, especially older systems.

B. Laser 3D Scanners

One of the most common on the market are laser 3D scanners, they are of several types: from large ones that are mounted on a tripod, to collecting data over long distances, to handheld that can measure the texture of a person's face. They work on a variety of principles (acousto-optical deflectors, vertical cavity emitting lasers, etc.). Surface emission lasers are used to calibrate spacecraft docking used by NASA. [1] [3]

Fig. 2 3D Scanner Mounted on Tripod [3]

Usually, laser 3D scanners are used for long-range scanning, and the principle of operation is similar to the operation of a laser rangefinder: in a three-dimensional space, the speed of the laser pulse is calculated from where the device is installed to the object and back. If it combines all the data - it acquires a certain point cloud in three-dimensional space. [1] [3]

Triangulation method

These devices use a laser beam to sense the subject. The scanner sends the beam to the subject and the camera records the position of the specified point. When the lasers move along the surface, the camera fixes the point in different places. They were called triangulation because the laser emitter, the endpoint, and the camera itself form a triangle. [1] [3]

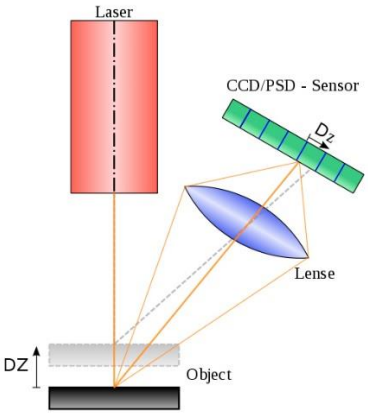

Fig. 3 Triangulation Scanners [3]

Triangulation is used in portable 3D sensors and the principle of operation is to record the position of the object, which is then used to position the object relative to the camera's field of view. To accelerate the process, a laser pulse is used simultaneously to calculate several points.

Time-of-flight method

Time-of-flight 3D-scanner - This is an active view of a scanner that uses a laser beam to explore an object. It is based on TOF. Specifies the distance from the surface and calculates the time the laser went back and forth. In this case, the laser beam is used as a light pulse whose reflection time is measured by the detector. The speed of light, as we know it, is constant, so you know that the time the beam is doing back and forth can easily calculate the distance from the scanner to the surface of the object being examined. The 3D-scanner is a time-scan device that can measure up to 100,000 dots per second. [1] [3]

Conoscopic holography

In a conoscopic system, a laser beam is projected onto the surface, and then the direct reflection along the same beam path is translated through a conoscopic crystal and projected onto the CCD. The result is a diffraction pattern that can be analyzed by frequency to determine the distance from the measured surface. The main advantage of conoscopic holography is that only one beam path is needed to measure, giving the ability to measure, for example, the depth of a finely drilled hole. [2] [4]

Structured light

Structured 3D scanners project light to the subject and look at the pattern distortion on the object. The pattern is projected onto the subject using an LCD projector or other stable light source. The camera, slightly offset from the pattern projector, looks at the pattern shape and calculates the distance of each point in the field of view. [2] [4]

Structured scanning is still a very active area of research, with numerous scientific papers published each year. Perfect maps have proven to be structured light patterns that address the problem of correspondence and enable error detection and error correction. [2] [4]

The advantage of structured 3D scanners is speed and accuracy. Instead of scanning at one point, structured light scanners scan multiple points or the entire field of view at once. Scanning the entire field of view in a fraction of a second reduces or eliminates motion distortion. Some existing systems are capable of scanning moving objects in real time. The Vision Master creates a 3D scanning system with a 5-megapixel camera - 5 million data points in every frame. [2] [4]

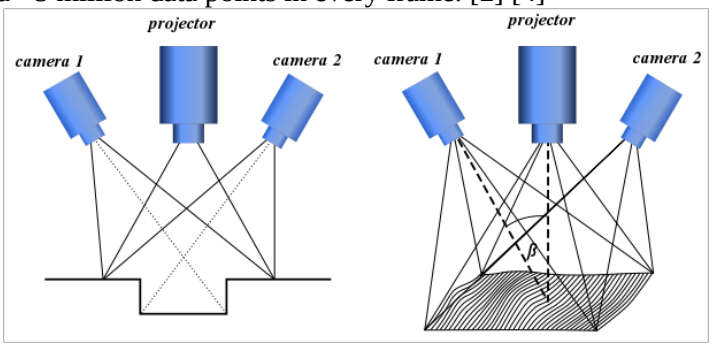

Fig. 4 Pattern recording system with 2 cameras

A real-time scanner using digital edge projection and phase shift technique (certain types of structured light methods) has been developed to capture, reconstruct and display details of dynamically deformable high density objects at 40 frames per second. with. Another scanner was recently developed. Different patterns can be applied to this system, and frame rate for capture and processing is 120 frames per second. It can also scan isolated surfaces, such as two moving hands. Using binary blurring techniques, breakthroughs were made that could reach hundreds to thousands of frames per second. [2]

Modulated light

Modulated light 3D scanners shine on the subject of constantly changing light. Usually a light source simply cycles its amplitude in a sine wave pattern. The camera detects the reflected light and the amount by which the pattern is shifted determines the distance the light has passed. Modulated light also allows the scanner to ignore light from sources other than the laser, so there is no interference. [2]

Features of 3D laser scanners:

- Can be used in rooms with any light
- Can scan parts of any material
- Great depth of field.

C. Photogrammetry

When shooting, several cameras are placed at different angles and other images are linked together by certain algorithms to create a 3D model. With handy settings, this method can be called the fastest 3D scanner. Companies such as Infinite Realities use 3D models to create the best photogrammetric installations, from 50 to 120 high-speed cameras. [4]

Fig. 5 Developing 3D Models with Photogrammetry [3]

Google uses stitching of aerial imagery and creates three-dimensional topographic models of the earth. If you only have one camera, the capture process slows down because you have to move around the object and need a large number of photos to get the best results. But this is a relatively cheap solution because the device needs a camera and several programs. Depending on the quality of the images obtained, good or poor quality models can be obtained. [2]

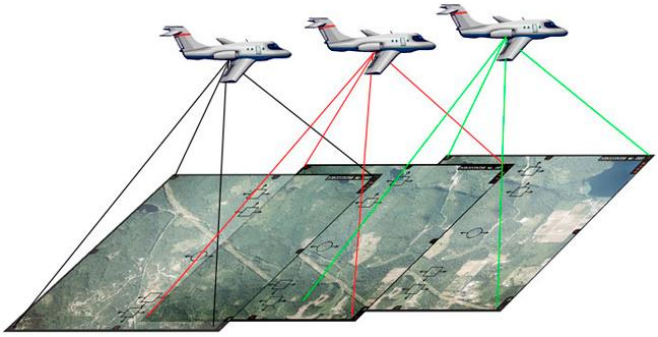

Fig. 6 Three-dimensional Topographic Models of Earth for Google Maps [3]

Photogrammetry is based on artistic algorithms that determine unique features in the image and stitch together based on the results.

D. Stereoscopic contactless passive 3D scanning system

The devices are equipped with two cameras and an infrared sensor. The 3D Systems Sense scanner is made in the form of a stapler, it is a compact handheld device, can be used with a tripod, in Gotcha (with tripod and handle), is included. The principle of operation is passive optical. In both cases, the power and data transmission is via the USB cable. Devices have standard modes: person and subject scanning. [4]

Fig. 7 Sense 3D scanner [4]

The camera uses this technology to detect infrared (thermal) radiation and ordinary light reflected from the object. Stereoscopic systems, that is, they use two cameras. The device compares frames based on a small comparison of differences between them, determines the distance at each point of the image, and restores the object in digital form.

IV. Structure of 3D-scanners

There are many methods to perform 3D even there are many types of scanners. With the development of related technologies, the necessary components have shrunk and smaller and more mobile devices have begun to appear on the market. In addition, improved camera technology has further use, some companies have begun to plan ways to turn previously unrelated devices into 3D scanners.

A. Hand scanner

Handheld laser scanners create a 3D image through a triangulation mechanism: a laser dot or line is projected onto an object from a handheld device, and a sensor (typically a charge bonded device or position sensitive device) measures the distance to the surface. The data is collected relative to the internal coordinate system and therefore the scanner position must be determined to collect the data where the scanner is in motion. The position can be determined by the scanner using reference elements on the scanned surface or by an external tracking method. [3]

External tracking often takes the form of a laser tracker (to position the sensor) with an integrated camera (to determine the scanner's orientation) or a photogrammetric solution using 3 or more cameras that provide a full six degrees of scanner freedom. Both techniques tend to use infrared light emitting diodes connected to the scanner, which are viewed by the camera (s) through filters that provide ambient light resistance. [3]

Data is collected by computers and recorded as data points in three-dimensional space, and processing can be converted to a triangular network. Handheld laser scanners can combine data with passive visible light sensors that capture surface textures and colors to create a 3D model.

The most popular type of commercial 3D scanner is the pocket type, although the exact method of scanning varies, especially between laser scanning and structure scanning. This popularity has only increased as it has improved scanning accuracy with modern technology and eliminated the need for additional reference points. Modern Handheld 3D - The scanner is usually not much larger than a hand and can be used without a cord. [3]

Fig. 8 Typical handheld scanner

This type of scanner is very popular in industrial use as part of quality control, product design and inspection. Scanners are easy to use, with the operator only having to scan the subject from different sides.

B. Measuring Arms

With the turret arm, the measuring arm scanners are more voluminous and have less freedom of movement than handheld scanners, but since the measuring instruments have position sensors in the joints of the arms themselves, the data they collect is more accurate. Exact measurement of the object can be achieved with the help of contact and contactless methods. In fact, with the right type of sensor, the measuring arm can provide as good results as a CMM machine. [3]

With the measuring arm, they see industrial applications in quality control, inspection, machine verification, reverse engineering, virtual assembly, and 3D modeling with typical uses such as sheet

metal and machined parts.

C. Tabletop

The third type of 3D-scanner is called the desktop scanner and has two parts: the scanner itself and the turntable. Scanners usually prefer the same short-range scanning methods as hand-held scanners, with the true difference coming from a turntable. The turntable plate is a round table on which the target object is placed and which then rotates for the duration of the scan, providing the scanner with excellent images at all angles. However, the size of the board greatly limits the possible size of the target object.

D. App

Over the past decades, cameras have become the foundation of smartphones and tablets. With the advancement of software, photogrammetric programs can now be used. These programs are of varying quality and ability, but just like any other software, but I need to have good hardware on which software is installed, with more powerful machines getting better results. [3]

Fig. 9 App 3D - Scanner

In the case of tablets, companies have developed special sensors that connect to tablets to improve their scanning capability. These additions significantly improve the quality of the scan.

V. Conclusion

This document describes the main scanning methods used in our time. A 3D scanner can be based on many different technologies, each with its own limitations, advantages and costs. Many limitations in the kind of objects that can be digitised are still present. 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 and video games, including virtual reality.

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