3D Scanners

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Topics

- What we already know about a 3D scanner
- Various Examples and Technologies
- Some Comparison

What we already know about a 3D Scanner?

- It collects data on (or scans) the shape of a real world object or environment to construct 3D models.
  - Normal cameras collect color information about surfaces within its field of view
  - 3D scanners collect color information **and depth** about surfaces within its field of view.
- Single scan is not enough to produce a complete model
- Multiple scans have to be made. This is called Scanning Pipeline
- Scanning Pipeline:
  - Data Collection
  - Alignment or Registration

Technologies

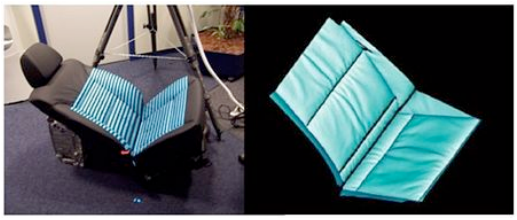
- Contact and non-contact
- Contact
  - They probe the subject through physical touch
  - EX: Coordinate Measuring Machine
  - CMM Demo - 1
- CMM
  - The main structure which include three axes of motion
  - Probing system
  - Data collection and Reduction system - typically includes a machine controller, desktop computer and application software.

CMM continued

- Pros
  - High accuracy, hence used in manufacturing
- Cons
  - It is very slow as you have seen in the video.
  - Requires contact. Not suitable for delicate objects like historical artifacts.
- Hence, non-contact (optical systems) are used

Non-contact

- Passive – It uses natural light
  - Stereoscopic system
  - Photometric system
  - Silhouette techniques



- Active
  - They use a different light source
  - Rangefinder
    - Time of Flight
  - Triangulation
    - Structured Light
    - Laser Scanning

Non-contact - Passive

- Passive scanners – rely on detecting the ambient radiation. Other types of radiation, such as infrared could also be used.
  - **Stereoscopic** systems usually employ two video cameras, slightly apart, looking at the same scene. By analyzing the slight differences between the images seen by each camera, it is possible to determine the distance at each point in the images.
  - **Photometric** systems usually use a single camera, but take multiple images under varying lighting conditions. This is used to find the normal of a surface.
  - **Silhouette** techniques use outlines created from a sequence of photographs around a three-dimensional object against a well contrasted background. These silhouettes are extruded and intersected to form the visual hull approximation of the object. With these approaches some concavities of an object (like the interior of a bowl) cannot be detected.

Non-contact - Active – Range Finder

- Uses a laser beam to determine the distance to an object. The round trip time is measured, t. The speed of the light beam used is known beforehand. Depth, d = ct/2.
- Time of Flight scanners

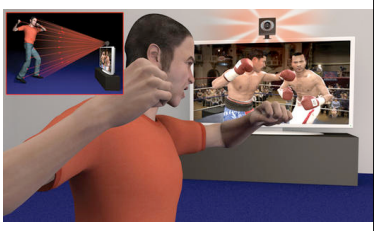
Leupold RX-II

Time of Flight

- LIDAR Scanner- Light Detection and Ranging
  - Laser rangefinder
  - image.gif demo
- It may also use 2 pulses this way.
  - First pulse is an object pulse that is reflected back to the sensor
  - Second pulse is a reference pulse that is passed through an optical fiber and reflected back to the sensor.
  - The time difference of the two pulses is converted to distance.

Time of Flight Cameras – Xbox uses Zcam

- Time of flight cameras capture the whole scene at the same time
  - **Illumination unit:** It illuminates the scene. Only LEDs or laser diodes are feasible as the light has to be modulated with high speeds up to 100 MHz. infrared light is used to make the illumination unobtrusive.
  - **Optics:** A lens gathers the reflected light and images the environment onto the image sensor. An optical band pass filter only passes the light with the same wavelength as the illumination unit. This helps suppress background light.
  - **Image sensor:** This is the heart of the TOF camera. Each pixel measures the time the light has taken to travel from the illumination unit to the object and back.



Time of Flight Cameras

- **Driver electronics:** Both the illumination unit and the image sensor have to be controlled by high speed signals. These signals have to be very accurate to obtain a high resolution.
- **Computation/Interface:** The distance is calculated directly in the camera. To obtain good performance, some calibration data is also used. The camera then provides a distance image over a USB or Ethernet interface.
- Demo


FOTONIC-B70 by Fotonic


SwissRanger 4000 by MESA Imaging

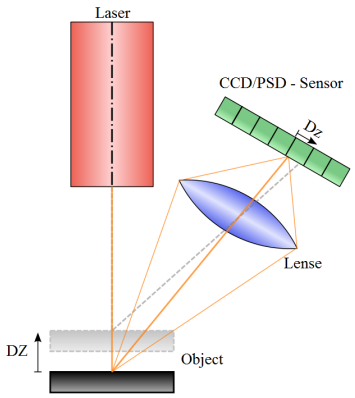

PMD[vision] CamCube by PMDTechnologies


USB-powered TOF camera out of the European ARTTS project


USB-powered single board PMD camera

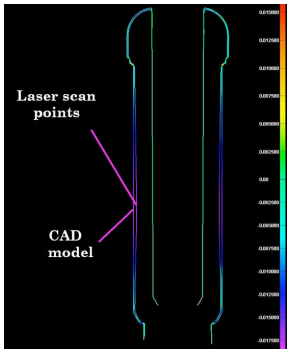
Non-contact - Active - Triangulation

- Shines a laser on the object and exploits a camera to look for the location of the laser dot
- Depending on how far away the laser strikes a surface, the laser dot appears at different places in the camera's field of view.
- the laser dot, the camera and the laser emitter form a triangle and hence it is called triangulation
  - The length of one side of the triangle, the distance between the camera and the laser emitter is known.
  - The angle of the laser emitter corner is also known.
  - The angle of the camera corner can be determined by looking at the location of the laser dot in the camera's field of view.



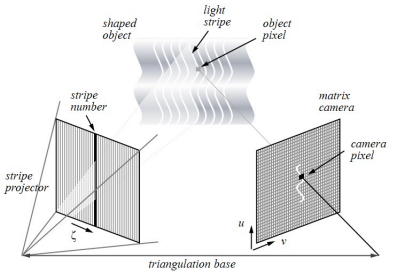
Laser Scanning – hand held lasers

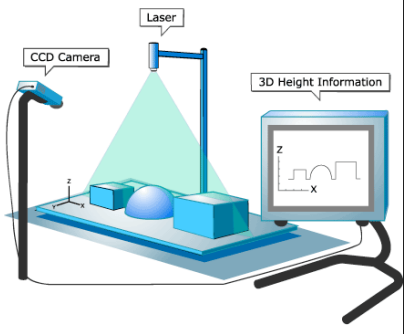
- Uses the triangulation method
  - a laser dot or line is projected onto an object from a hand-held device
  - a sensor (typically a charge-coupled device or position sensitive device) measures the distance to the surface.
- Data is collected in data points – points cloud.
- Demo – 2 videos
- Data is collected in the local coordinate reference which has to be converted to world coordinate reference.
- The scanner is in motion. So, the scanner has to be tracked
  - Adhesive reflexive tabs
  - External tracking system – laser tracker to provide the sensor position with an integrated camera for the orientation
  - Photogrammetric solution using 3 or more cameras providing a complete six degrees of freedom.

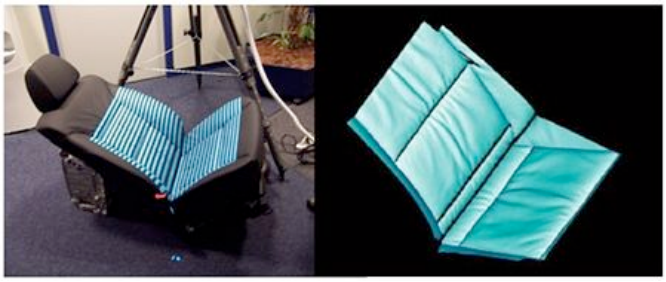


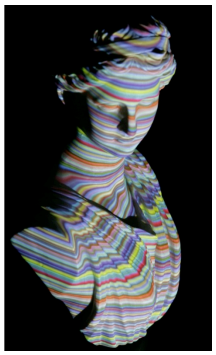
Structured Light 3D Scanner

- Projector and Camera System
- Projector projects a known pattern (line or plane) of pixels.
- The camera looks at the shape of the line and uses a technique similar to triangulation to calculate the distance of every point on the line.
- The projector is typically a LCD or LCOS
- Demo









Measuring 360° shape of an Object

- Global coordinate system is set up
- For measuring, local coordinate system is used
- Multiple Scans can be done in 3 different ways
  - Object rotation method
    - Camera is fixed
  - Camera/imaging system transport technique
    - Typically used for large data models
  - Fixed imaging with multiple camera transport
    - Typically used for delicate objects and historical artifacts
- For each scan, Local 3D coordinates or point clouds are converted to global coordinate system and patched together using least squares fit method or other methods

Comparison

Time of Flight

- They operate on very long distances - order of km
- Typical accuracy is 1 mm (low)
- Xbox 360 natal project used Zcam
- Typically used for scanning buildings

Triangulation

- They operate on a limited range
- Typical accuracy is 10 µm
- Hand held scanners
- Typically used for scanning small objects

Sources and References

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- http://en.wikipedia.org/wiki/Coordinate_measuring_machine
- http://en.wikipedia.org/wiki/Time-of-flight_camera
- http://www.polhemus.com/?page=Scanning_Fastscan
- Google, Youtube and Wiki