3D Vision

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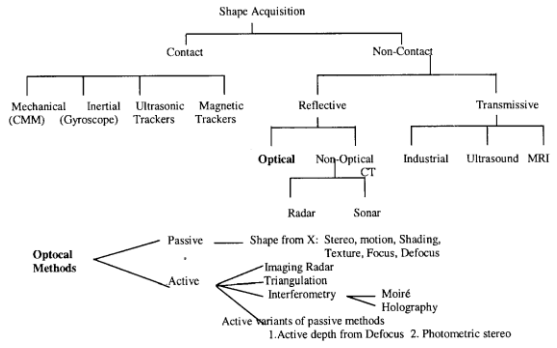
Overview



[Mada2003]

Summary

- Methods for 3D data acquisition
  - Passive
    - shape from X (stereo, motion, shading, focus)
  - Active range sensing
    - Structured Light Systems
    - Laser Range Finder
    - Depth Camera
- Manipulation of range/depth images
    - Edges
    - Triangulation
    - Registration
    - Texture

Passive

Passive - Shape from stereo

- See last lecture

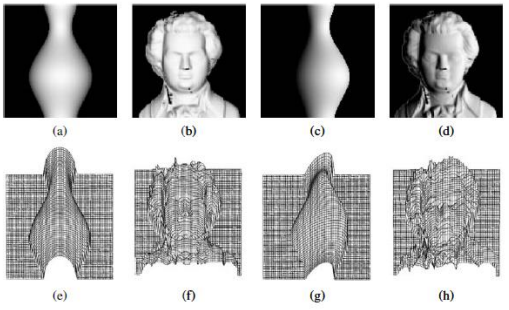
Passive - Shape from motion

- Shape from motion
  - Similar to stereovision in many ways
  - Successive images might be considered as stereo pairs
  - With texture, possible to find correspondences (matching techniques, optical flow…) and find fundamental and essential matrix.

Passive - Shape from shading

- Shape from Shading
  - Given a continuous surface, and known illumination, intensity variation in the surfaces depends of its orientation.
  - Most surfaces are not uniform and lighthing difficult to control - normally combined with other methods.

Passive - Shape from shading



Passive - Shape from focus

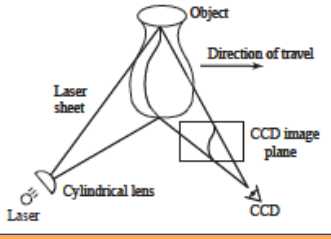
- Shape from focus
  - Objects away from focal plan are out of focus.
  - With several images with different focus, possible to extract depth information.

Curiosity: Capture light field allow focus later
www.lytro.com/camera

Active

Active – Structured Light Techniques

- Projection of a known pattern
- Acquisition with camera, 3D from pattern deformation in scene.

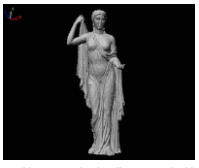


Active – Structured Light Techniques

- Several commercial for small distances

Shape Grabber

Minolta Vivid

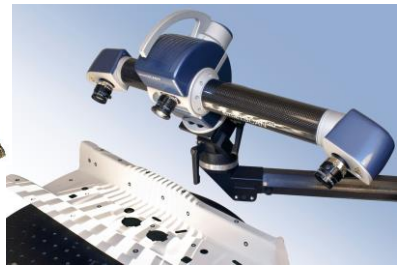


Marble Statue of Aphrodite scanned with the VIVID 910 using the rotary stage option

Active – Structured Light Techniques

- Commercial solutions

Skull with 1.5 Million points



SmartScan Breuckman

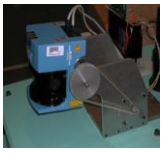
Active - Laser Range Scanner – Long Range

- For larger areas (buildings, rooms) use of Laser Range scanners.

Riegl

Zoller & Frölich

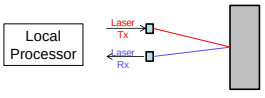
Cyra



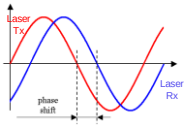
Adapted SICK
Mechanical department

Active - Laser Range Scanner – Long Range

- Working principle:
  - Light Pulse Time of Flight.



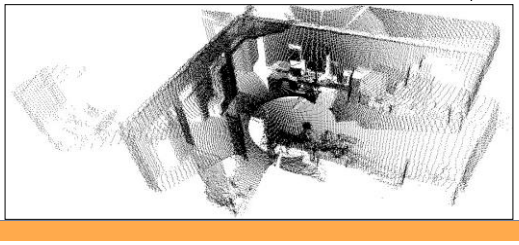
  - Phase Shift: Amplitue of frequency modulation – Comparison of phases.



Range Image example

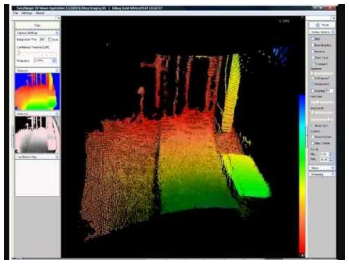
Reflectance
1000 x 175 (Riegl LMS Z210)

3D Cloud of points



Active – 3D ToF Cameras

- Phase shift principle of emitted and received infrared light to measure depth

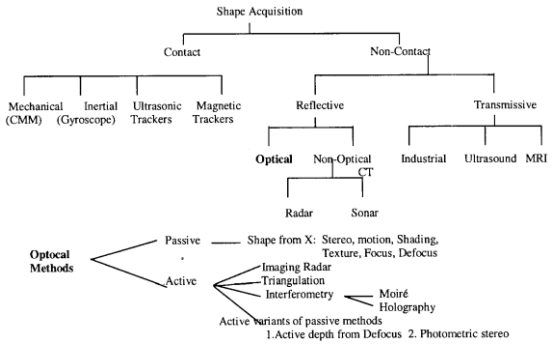


Swiss Ranger SR4000
3D ToF Camera
Resolution: 176x144
Range: 5–8m
54 fps

Active vs Passive

	Range	Intensity
Cost	Laser Range Finders are expensive sensors	Low cost since any digital camera can be used
Acquisition	Often difficult with large sensors	Easy, with a digital camera
Resolution	Limited spatial resolution	High-resolution digital photographs
Texture map	No colour texture map, or black and white reflectance	Possibility to provide a realistic colour texture map
Lighting	Independent from external lighting	Highly dependent on lighting conditions
Texture relevance	No need of texture in scene	Texture is crucial for good results
3D processing	Provide directly 3D measurements	Difficult to extract 3D depth from images

Kinect?



[Mada2003]

E o Kinect?

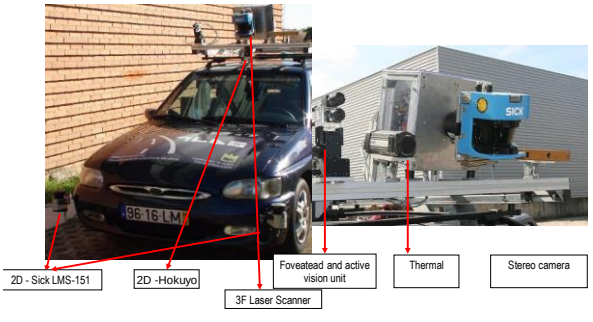
- Active – Infrared pattern

Projects: google car

Darpa Grand Challenge: Stanford

Atlas Car: Universidade de Aveiro

Atlas Car: Universidade de Aveiro



Range Image

- Range image is a rectangular array of numbers that quantifies the distance from the sensor to the surfaces within the field of view.
- Also referred as depth image and easily transform to cloud of points.

Range image characteristics

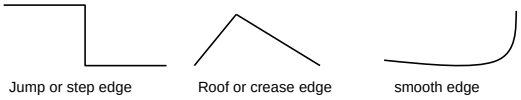
- **Edges in intensity images**

  edges related to intensity changes (due to geometry or aspect - for example colour or shadow)

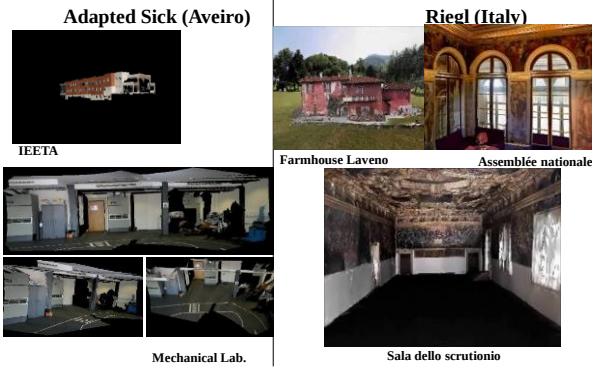
Range image characteristics

- **Edges in range images**,

  3 different type of edges:



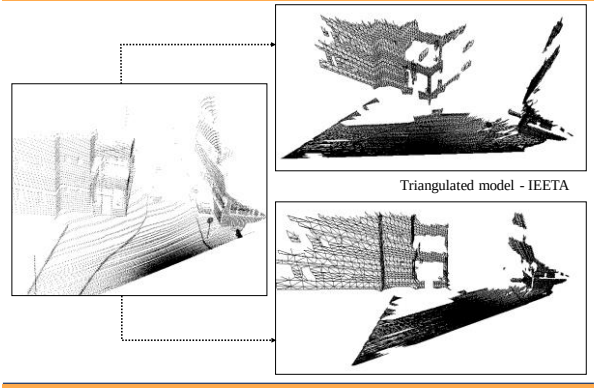
Range Image Processing



From points to surfaces

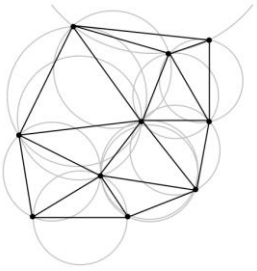
- From cloud points to surfaces:
  - Parametric curves (cilinders, quadrics, …)
  - Non parametric curves (triangles,…)

Triangulation



Triangulação Delaunay 2D

- Delaunay triangulation: for a set of 2D points P ensure that none points of the set is inside the circumcircle of any triangle.

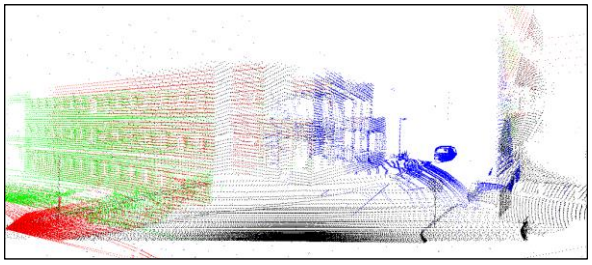


Other triangulation algorithms

- Marching cubes
- Marching triangles
- Ball-pivoting
- Poisson Surface Reconstruction
- Moving least-squares (MLS)

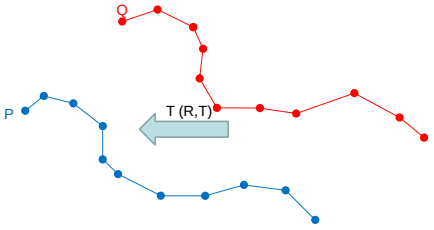
  – Possible to test some with open source Meshlab from Visual Computing Lab (http://meshlab.sourceforge.net/)

Registration



Registration

- Finding the Rigid Body Transform that minimize the distance between 2 scans



Registration

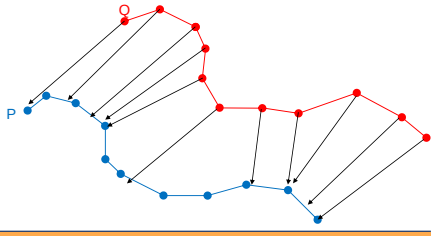
- An aproximation of distance between 2 scans:

$$Error = \sum_i^{N_p} (Tq_i - p_i)^2$$

- Where p_i, points of P, q_i, corresponding points in Q.

Registration - ICP

- Iterative Closest Point algortithm [Besl92]:
  - Find closest point
  - Compute transform that minimizes error
  - Repeat until ending condition.



Registration – ICP problems

- Surfaces are matching only in small area may result in many outliers
- Algorithm might fall in local minima.
- Typically an initial guess is used (3 corresponding points, additional information such as GPS,…)

Zippering

- Remove overlapping portion of meshes
- Clip mesh together
- Remove triangles introduced in clipping

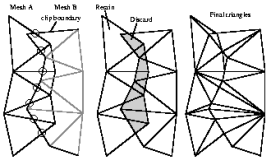


Figure 5: Mesh *A* is clipped against the boundary of mesh *B*. Circles (left) show intersection between edges of *A* and *B*'s boundary. Portions of triangles from *A* are discarded (middle) and then both meshes incorporate the points of intersection (right).

Texture Mapping

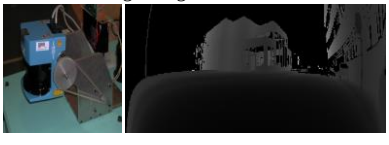
- Some 3D reconstruction techniques provide automatically texture:
  - Shape from X.
  - Structured Light Techniques
- Other do not (Laser Range Finder)

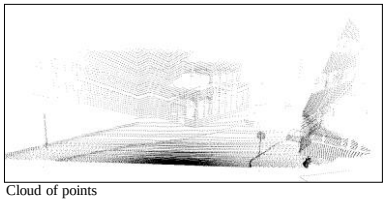
Texture mapping

- Additional acquisition of images
- Camera calibration (might be fixed to the 3D sensor)

Textura

Range image





Cloud of points

Digital photographs

3072 x 2048
(Canon EOS 300D)

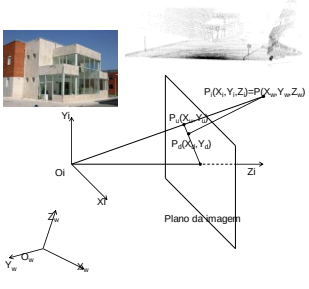
Texture Mapping – Camera calibration

Tsai camera model

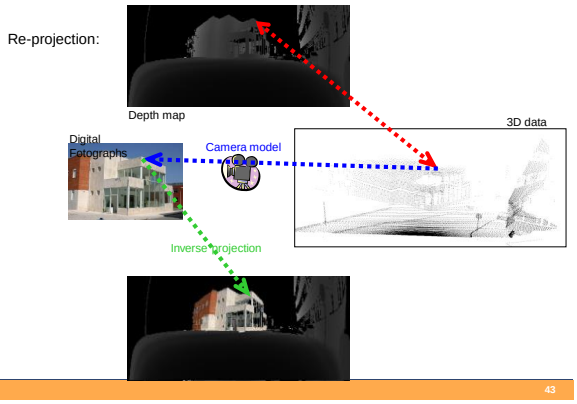
11 parameters:

5 internals
- *f* – focal length,
- *k* – radial distortion,
- *Cx*, *Cy* – image centre,
- *Sx* – scale facto,

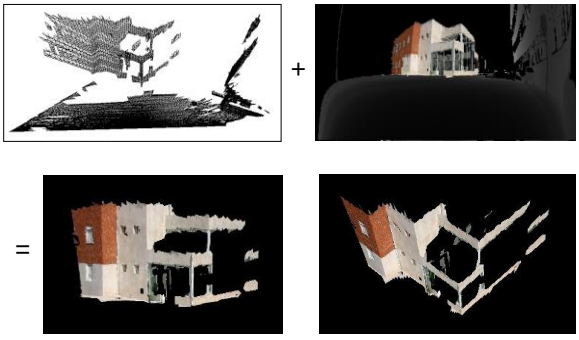
6 Externals
- *Rx*, *Ry*, *Rz* – rotation,
- *Tx*, *Ty*, *Tz* – translation.



Camera Calibration



Texture



Some references

- Mada, S. K., Smith, M. L., Smith, L. N., and Midha, P. S. (2003). Overview of passive and active vision techniques for hand-held 3D data acquistion. In Shearer, A., Murtagh, F. D., Mahon, J., and Whelan, P. F., editors, *Proceedings of the SPIE: Optical Metrology, Imaging, and Machine Vision*, volume 4877, pages 16–27.
- Gary Bradski and Adrian Kaehler. *Learning OpenCV: Computer Vision with the OpenCV Library*. O'Reilly, Cambridge, MA, 2008.
- Szeliski, R. (2010).. Computer Vision: Algorithms and Applications, Springer
- P. Besl and N. McKay. A method for Registration of 3-D Shapes. *IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)*, 14(2):239 - 256, February 1992.
- Reg G. Willson, *Modeling and Calibration of Automated Zoom Lenses.*Ph.D. thesis, Department of Electrical and Computer Engineering, Carnegie Mellon University, January 1994
- Z. Zhang. *A flexible new technique for camera calibration.*IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 22, No. 11, pp. 1330-1334, 2000
- Richard Hartley and Andrew Zisserman (2003). Multiple View Geometry in Computer Vision. Cambridge University Press. pp. 155–157. ISBN 0-521-54051-8.
- Turk, Greg and Mark Levoy "Zippered Polygon Meshes from Range Images" SIGGRAPH 1994