3D Vision

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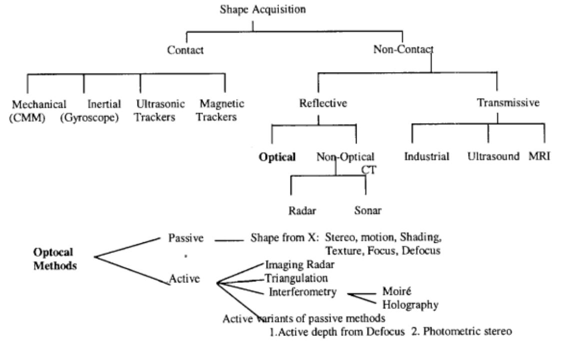
Summary

- 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

Overview



[Mada2003]

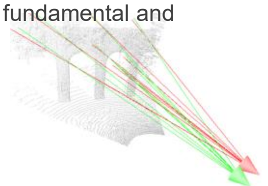
Passive

Passive - Shape from stereo

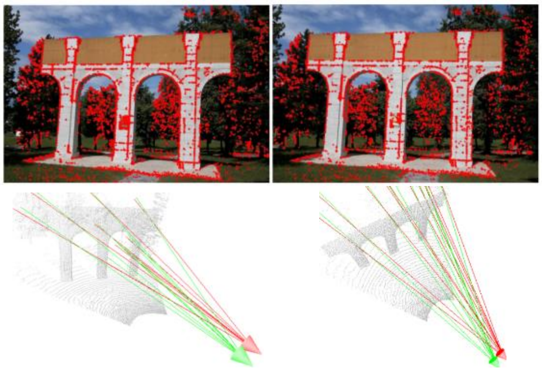
- See last lecture

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.



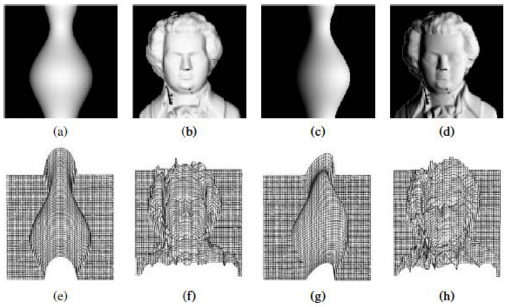
Passive - Shape from motion



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 lighting difficult to control - normally combined with other methods.

Passive - Shape from shading



Depth Map and 3D Imaging Applications: Algorithms and Technologies
IGI Global Editors: Aamir Saeed Malik, Tae-Sun Choi, Humaira Nisar
Three-Dimensional Scene Reconstruction: A Review of Approaches

Passive - Shape from focus

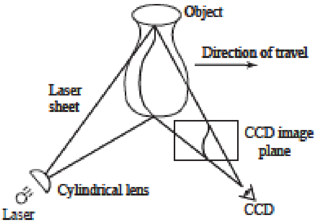
- Shape from focus
  - Objects away from focal plan are out of focus.
  - With several images with different focus, possible to extract depth information.

Favari and Soatto: A Geometric Approach to Shape from Defocus

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

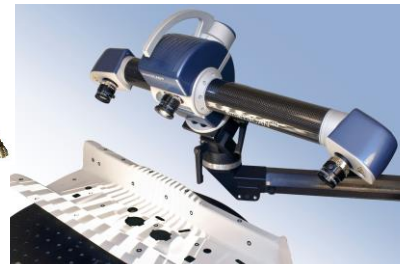
Shape Grabber

Minolta Vivid

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

Active – Structured Light Techniques

- Commercial solutions



SmartScan Breuckman

Skull with 1.5 Million points – Error below 30 µm

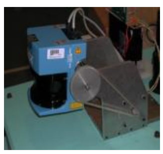
Active - Laser Range Scanner – Long Range

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

Riegl

Zoller & Frölich

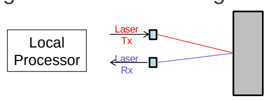
Cyra



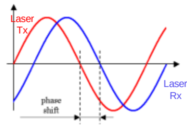
Adapted SICK
Mechanical department

Active - Laser Range Scanner – Long Range

- Working principle:
  - Light Pulse Time of Flight.



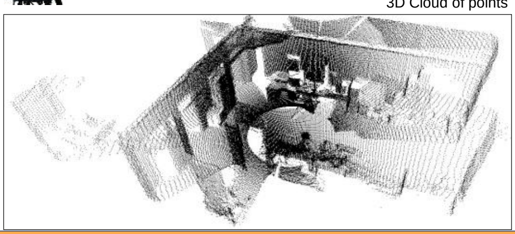
  - Phase Shift: Amplitude of frequency modulation – Comparison of phases.



Range Image example

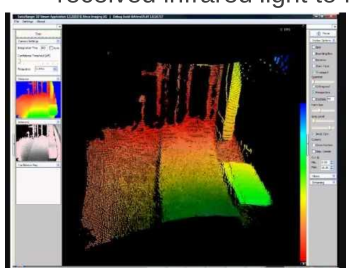
Reflectance
1000 x 175 (Riegl LMS Z210)

3D Cloud of points



Active – 3D ToF Cameras

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

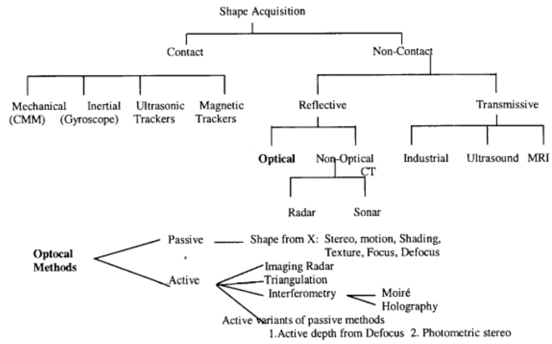


Swiss Ranger SR4000
3D ToF Camera
Resolution: 176x144
Range: 5–8m
54 fps

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

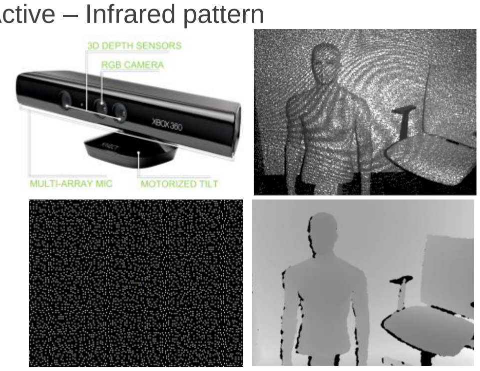
Kinect?



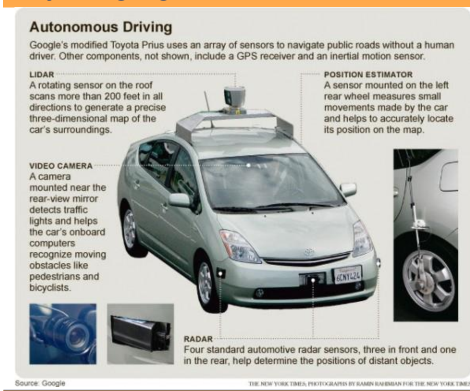
[Mada2003]

E o Kinect?

- Active – Infrared pattern



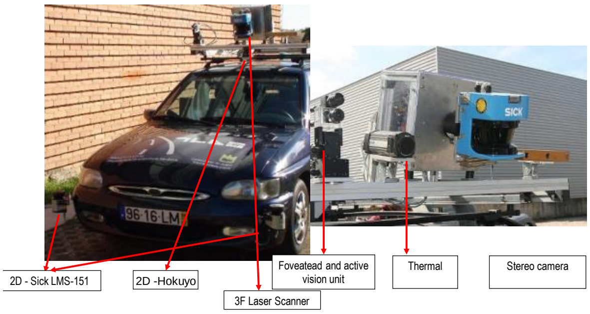
Projects: google car



Darpa Grand Challenge: Stanford

Atlas Car: Universidade de Aveiro

Atlas Car: Universidade de Aveiro



Visão / Condução Autónoma – AtlasCar v2

Visão / Condução Autónoma – AtlasCar v2

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

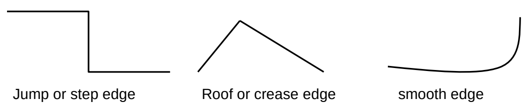
- **Edges in intensity images**

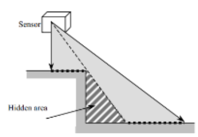
  edges related to intensity changes (due to geometry or aspect - for example colour or shadow)

Range image characteristics

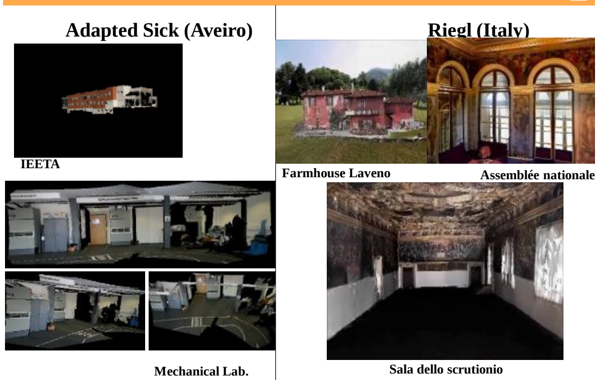
- **Edges in range images**,

  3 different type of edges:

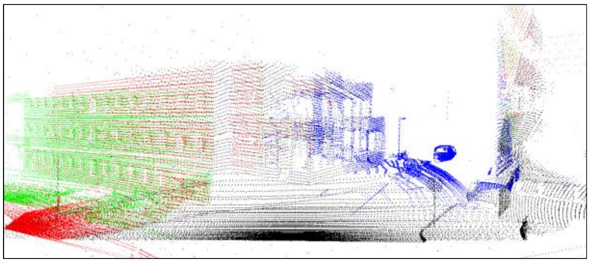




Range Image Processing

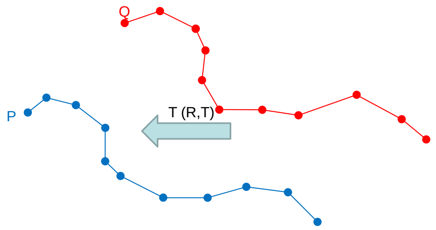


Registration



Registration

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

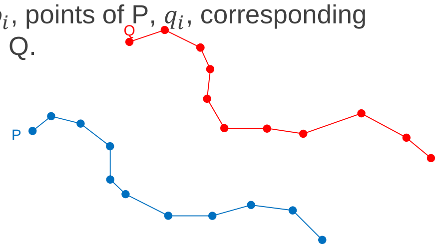


Registration

- An aproximation of distance between 2 scans:

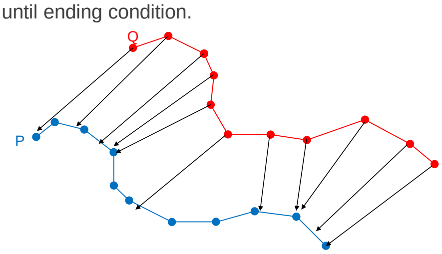
$$Error = \sum_i^{N_p} (Tq_i - p_i)^2$$

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



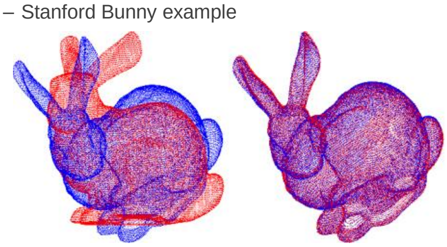
Registration - ICP

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



Registration - ICP

- Iterative Closest Point algortithm [Besl92]:
  - Stanford Bunny example



Stanford Bunny example: https://www.youtube.com/watch?v=uzOCS_gdZuM

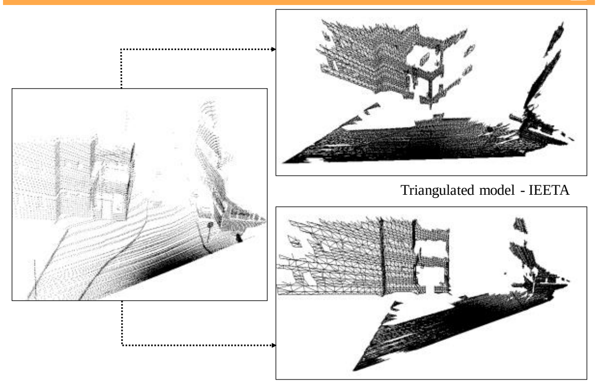
Registration – ICP problems

- 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,…)

From points to surfaces

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

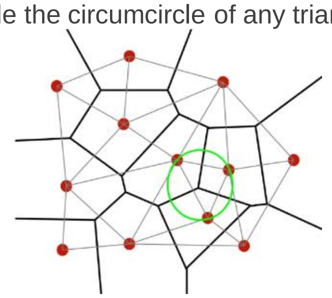
Triangulation



Triangulated model - IEETA

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/)

Zippering

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

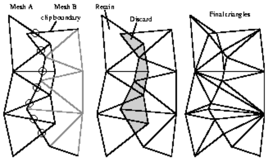


Figure 5: Mesh *A* is clipped against the boundary of mesh *B*. Circles (left) show intersection between edges of *A* and *B*'s boundary. Portions of triangles from *A* are discarded (middle) and then both meshes incorporate the points of intersection (right).

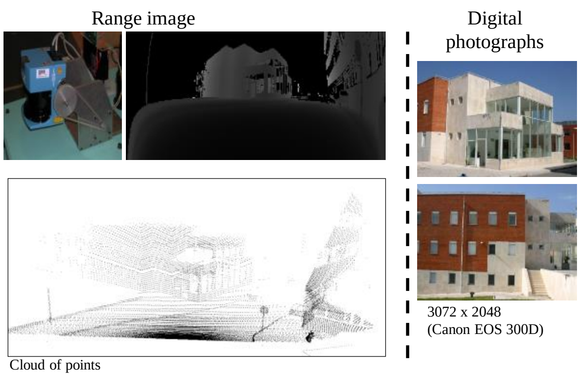
Texture Mapping

- 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



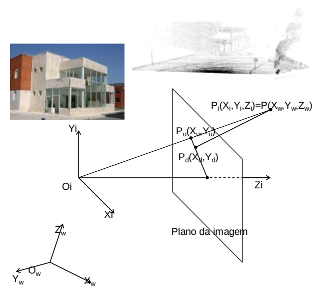
Texture Mapping – Camera calibration

Tsai camera model

11 parameters:

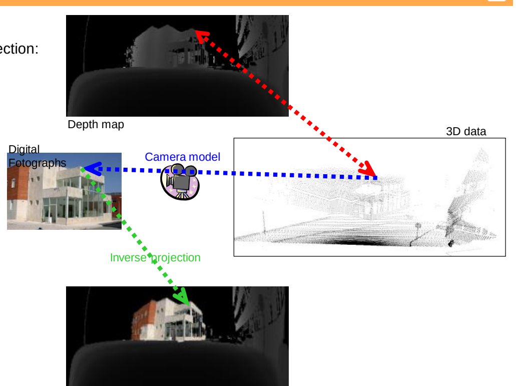
5 internals
- *f* – focal length,
- *k* – radial distortion,
- *Cx*, *Cy* – image centre,
- *Sx* – scale facto,

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

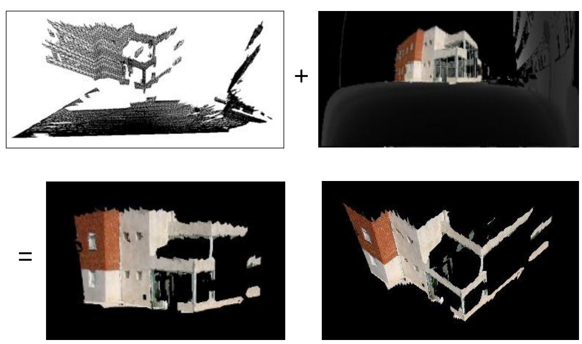


Camera Calibration

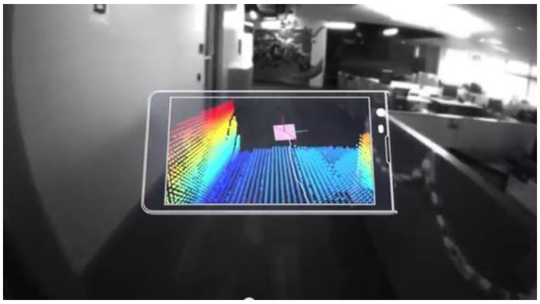
Re-projection:



Texture



Google Tango



- Model “Gabinete 005“

Chisel algorithm

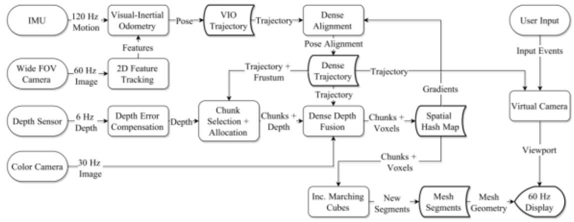


Fig. 2: CHISEL system diagram

Chisel: Real Time Large Scale 3D Reconstruction Onboard a Mobile Device

Chisel algorithm

(a) CHISEL creating a map of an entire office building floor on a mobile device in real-time.

(b) Reconstructed apartment scene at a voxel resolution of 2cm.

Chisel: Real Time Large Scale 3D Reconstruction Onboard a Mobile Device

Some references

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