3D VISION

Introduction

Systems Engineering and Automation

Miguel Hernández University

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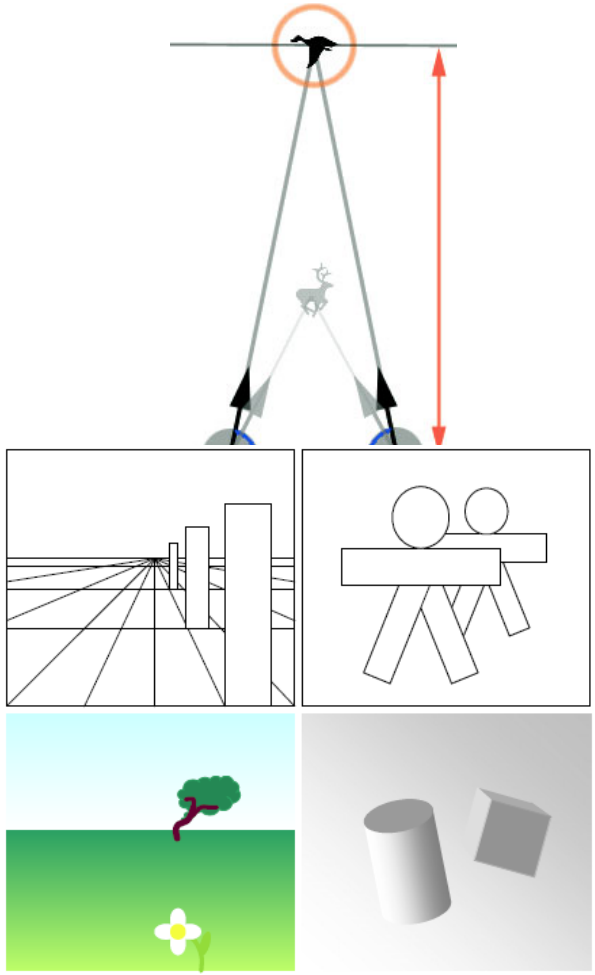
Introduction to 3D Computer Vision

- Central Problem of 3D Vision
  - From an image, or sequence of images, of a stationary or moving object, taken from a monocular (one camera) or policular (several cameras) observer, *the understanding of the object or scene, and its three-dimensional properties*

- Examples:
  - Distance measurement
  - Speed measurement and direction of movement
  - Generation of 3D surface models
  - Location ('pose') of objects or persons
  - Detecting obstacles
  - ….

Introduction to 3D Computer Vision

- Human 3D Vision:
  - Binocularity of images:
    - Viewing images from different points of view
    - Disparity
  - Movement of the point of view:
    - Obtaining a series of consecutive images
    - Relative displacement of objects
  - Overlaps, reflections and shadows
  - Realism of the images:
    - Texture gradient or perspective projection allows you to set relative distances



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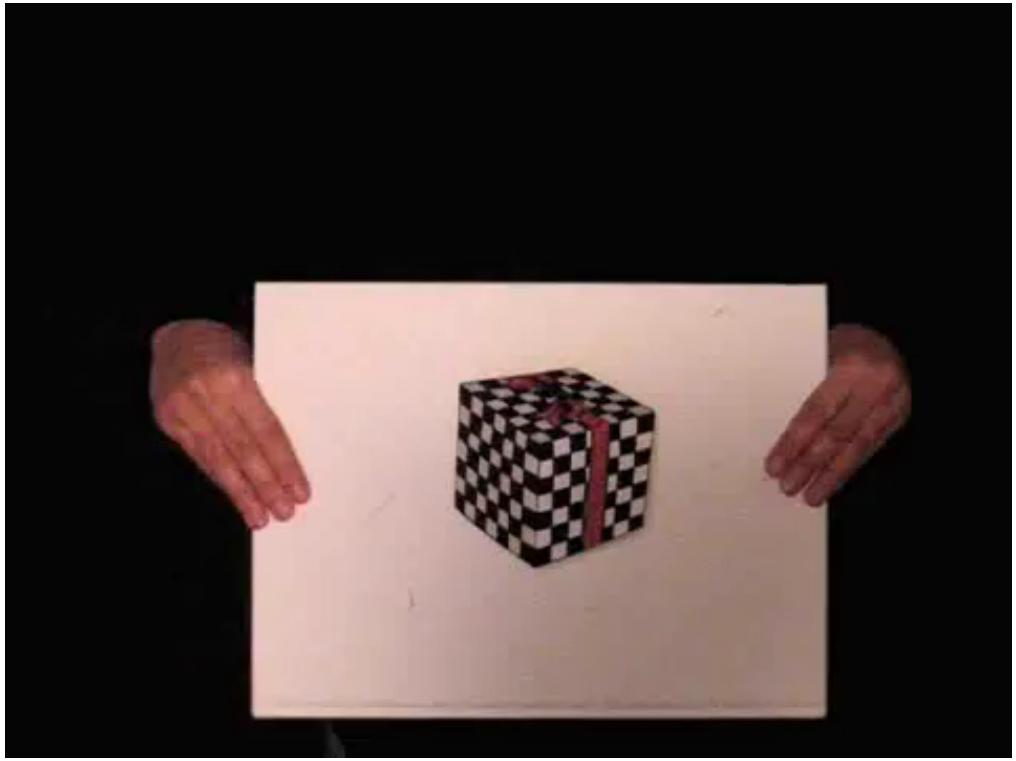
- Human 3D Vision:



Introduction to 3D Computer Vision

- 3D Reconstruction Techniques:
  - Active methods
    - They project controlled beams of energy (light or sound over the scene)
    - They use an active observer
  - Passive methods
    - Those not considered to be actives

Methods are based on principles: such as
Space Triangulation

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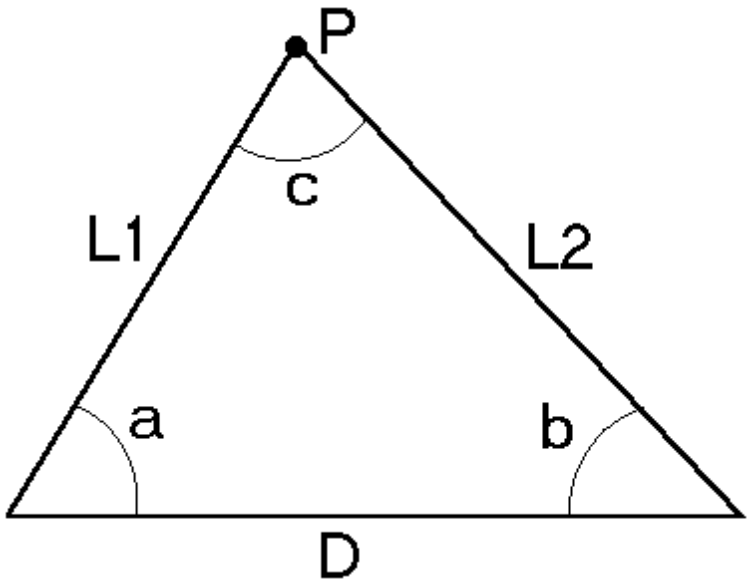
- Space Triangulation

$$L1 \cos(a)+L2 \cos(b)=D$$

$$L1 \sin(a)=L2 \sin(b)$$



Introduction to 3D Computer Vision

- 3D Reconstruction Techniques:
  - Time of flight
  - Stereoscopy
  - Structured light projection
  - Focus
  - Optical flow

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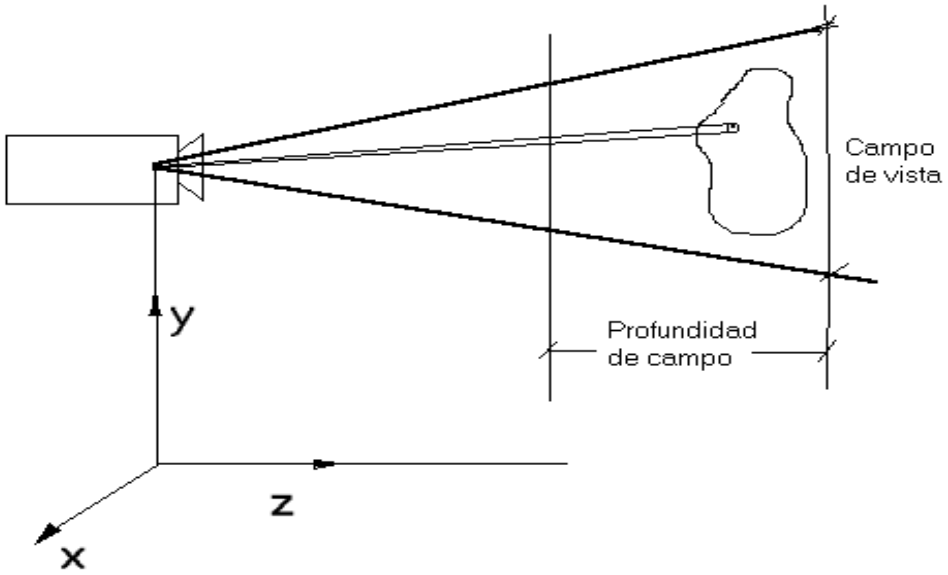
- Time of flight
  - It is based on the direct or indirect measurement of time spent by a known speed signal, in traversing the distance separating a region from the scene of the emitting/sensor device



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- Time of flight
  - Nature of the energy beam
    - Acoustics (ultrasound)
    - Electromagnetic (laser). It has a better directionality

- Disadvantages
  - Low directionality (limits angular resolution)
  - Low reflected energy, causes high integration time and continuous adjustment of detection thresholds

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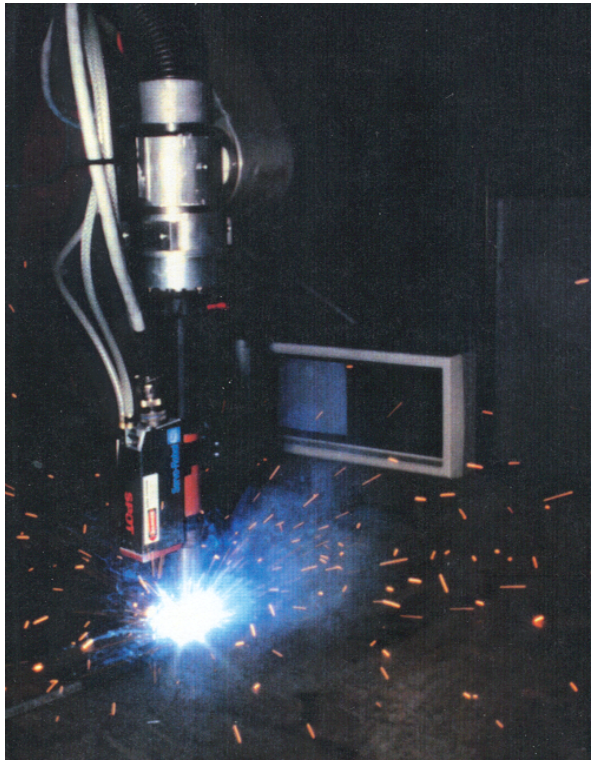
- Time of flight: examples

Velodyne Lidar

SICK Sensors

Riegl Laser Mesurements



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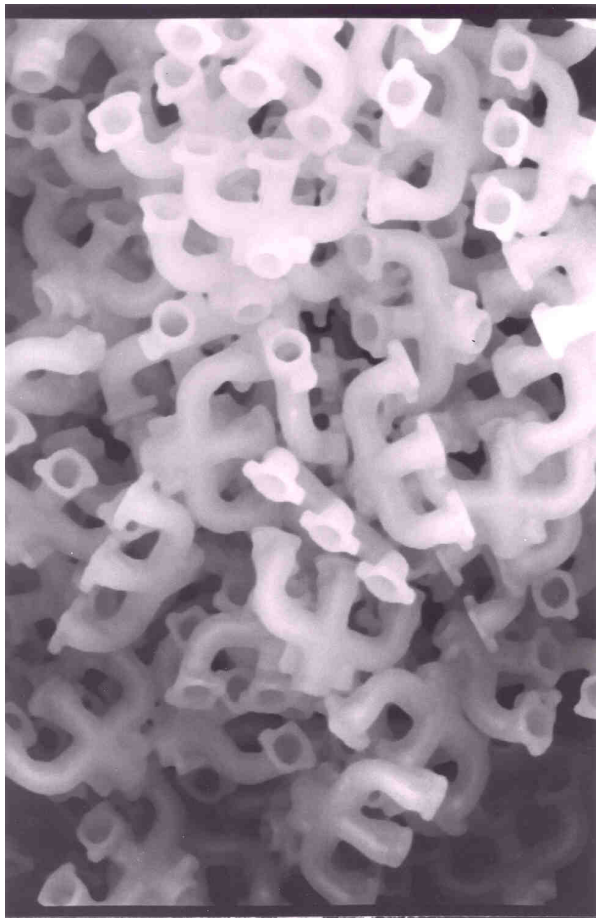
- Time of flight: examples

Perceptron Metrology



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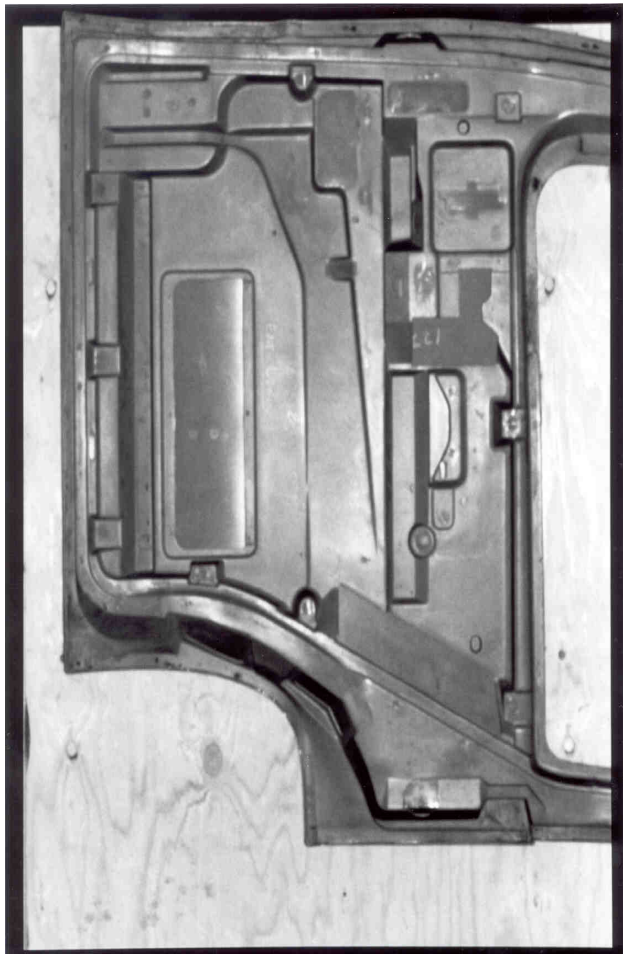
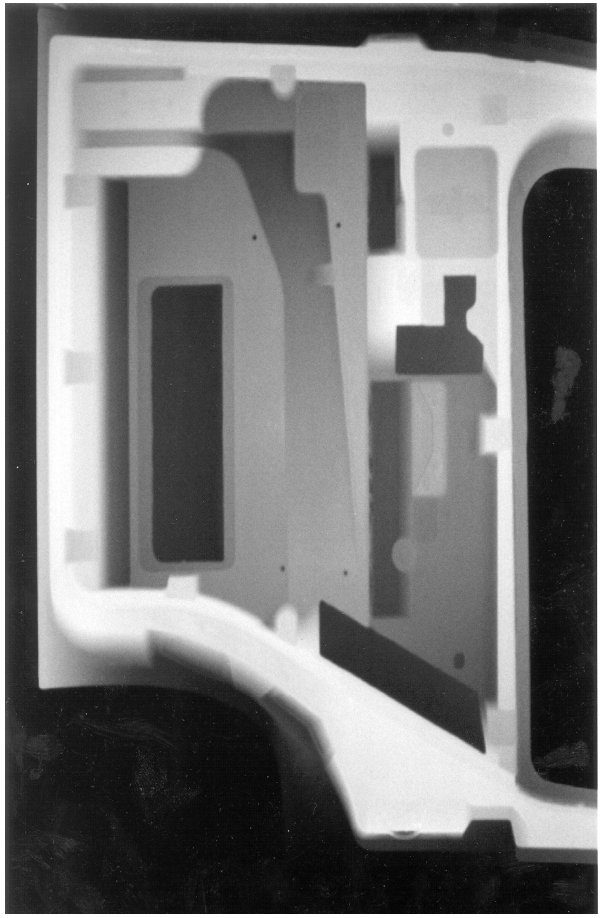
- Time of flight: examples



Perceptron Metrology



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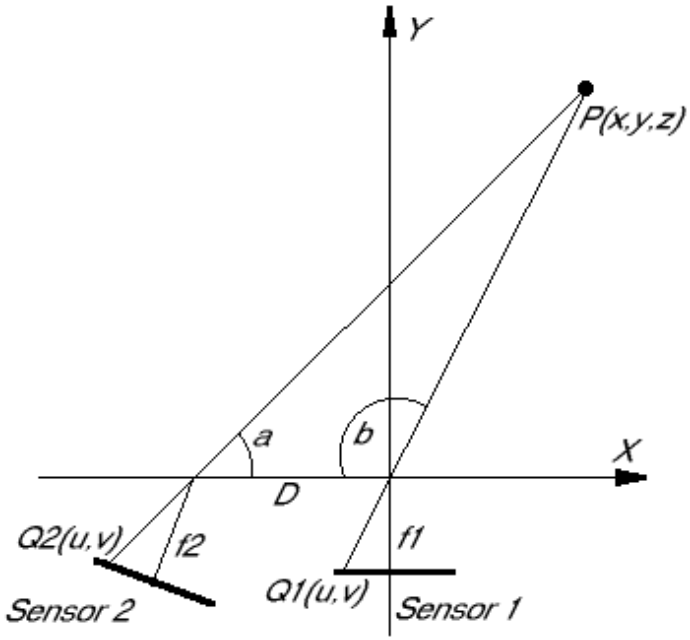
- Stereoscopy (Disparity)
  - The third dimension is retrieved by triangulation from the scene observed by two or more camera sensors



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- Stereoscopy:
  - Advantages
    - Both active and passive solutions are used, depending on whether or not the camera sensors have some controlled activity (convergence, focus or movement)
    - It only requires the capture of one image per camera
  - Disadvantages
    - Those inherent in all triangulation, occlusions
    - Correspondence (matching) between images
    - Three-dimensional sparse map (scene regions with high luminance or color gradients)

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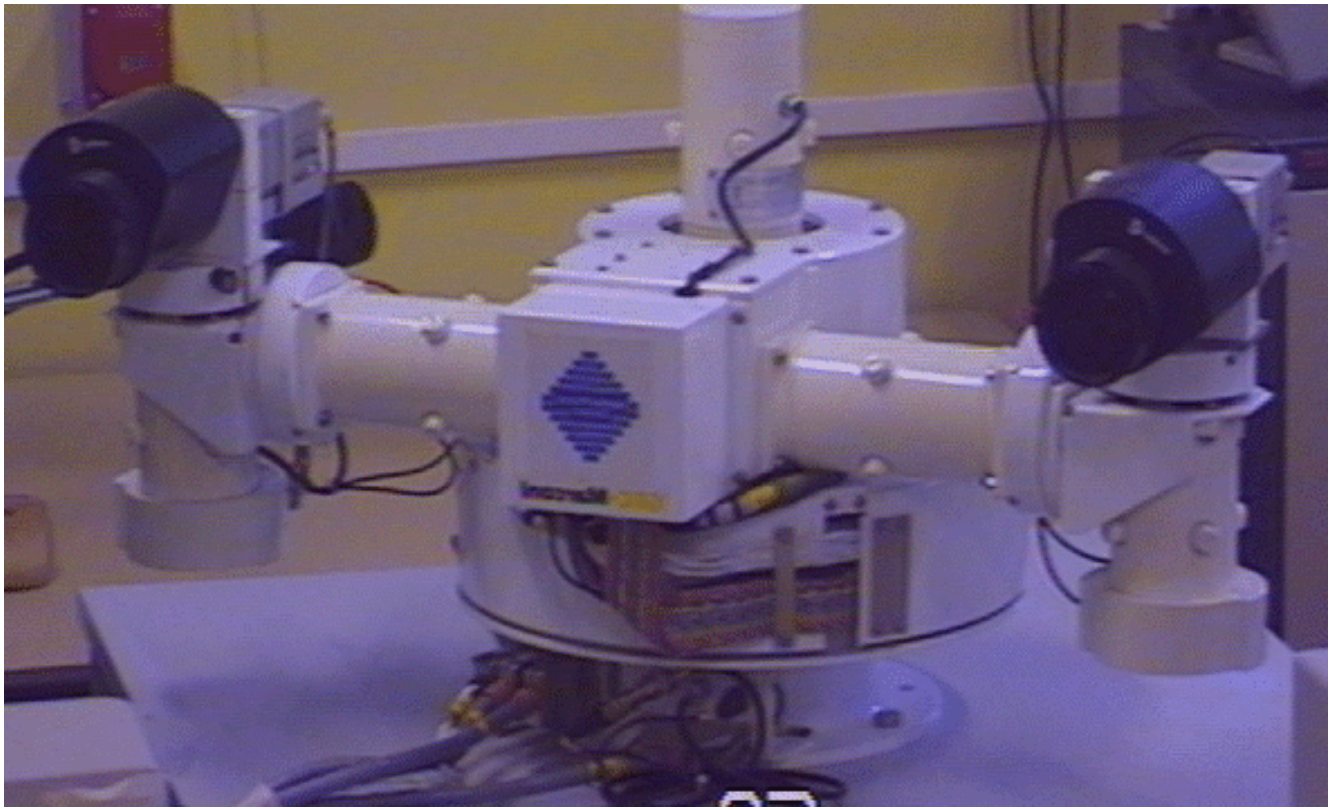
- Stereoscopy: example



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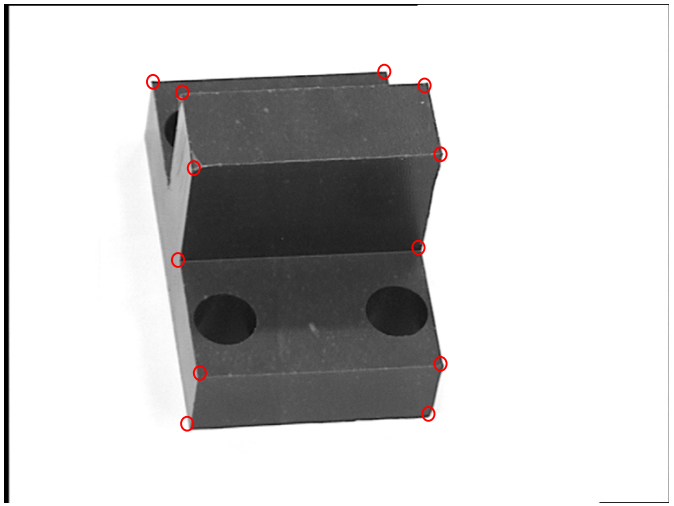
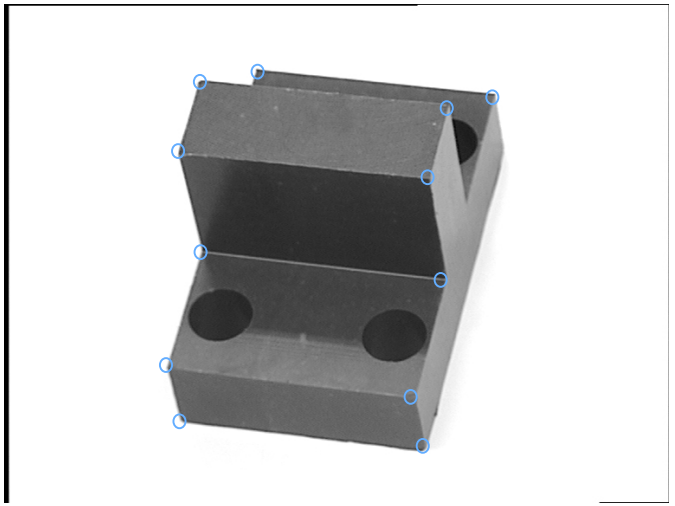
- Stereoscopy: example



Izquierda



Derecha

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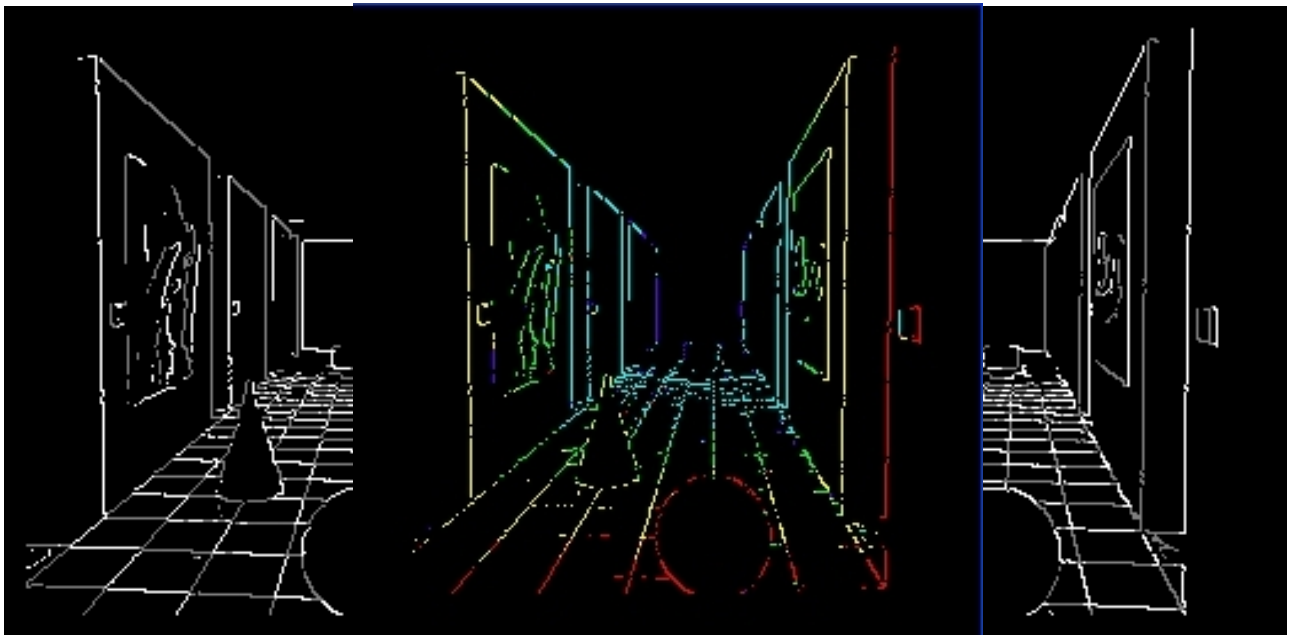
- Stereoscopy: example

Izquierda Derecha



Mapa Disparidad

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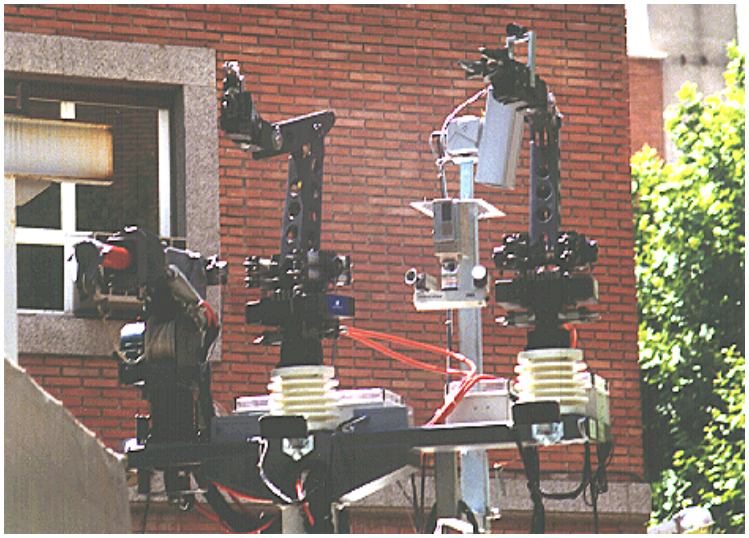
- Stereoscopy: example



ROBTET: robot para mantenimiento de torres de alta tensión: UPM/Iberdrola/Cobra

TRC Unisight Pan/Tilt

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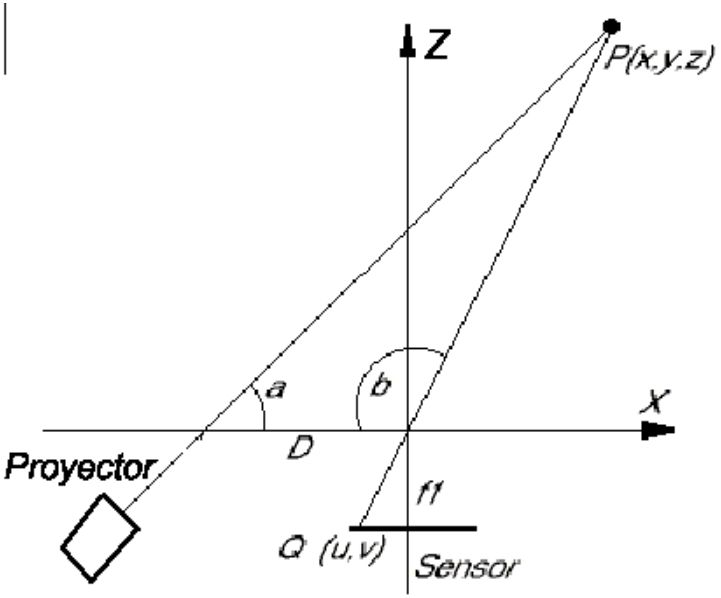
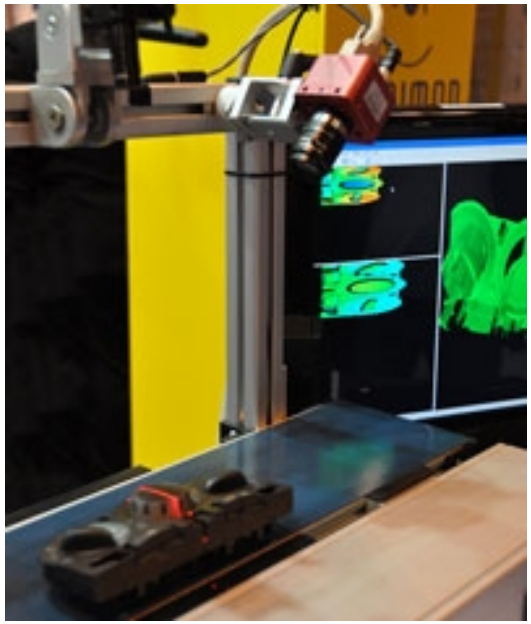
- Structured light projection
  - Perform spatial triangulation with an image sensor and a controlled direction light projector
  - High light power projector causes strong luminance gradients in arbitrary areas of the scene
  - Active method, uses triangulation





Infaimon Visión Artificial

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- Structured light projection
  - Advantages
    - Provides dense and accurate three-dimensional maps
    - Simple processing
    -
  - Disadvantages
    - Those inherent to triangulation, occlusions
    - High number of images required (high acquisition time)
    - Scanning mechanism to ensure sequential lighting
    - Distant scenes, luminous energy attenuation
    - Environments where high-energy employment is dangerous

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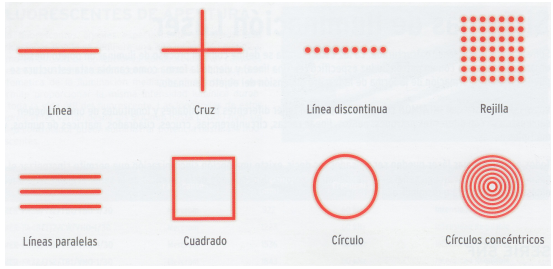
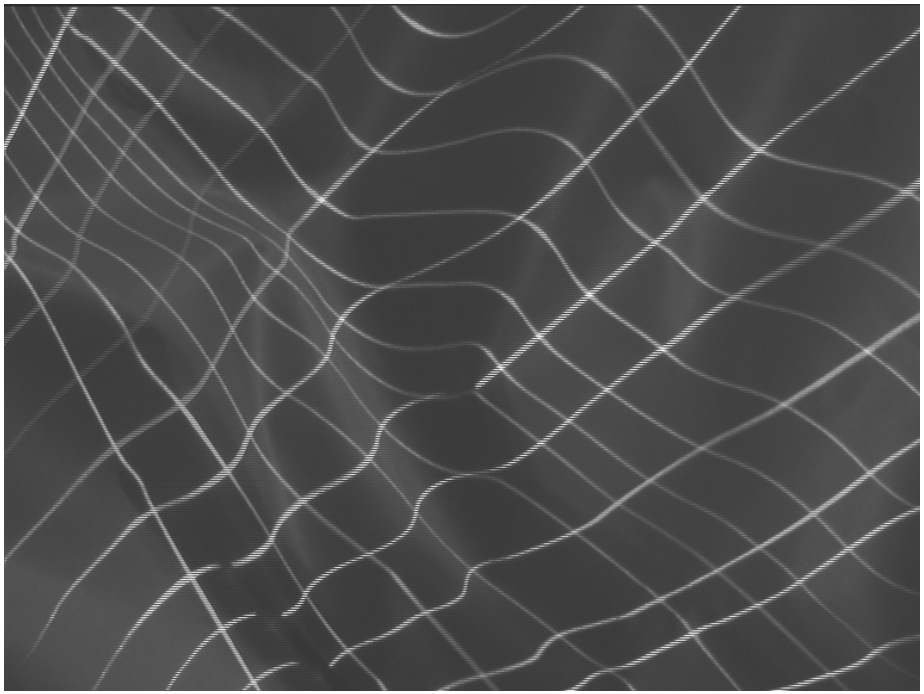
- Structured light projection: examples





Structured light grid projected onto an uneven surface

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- Structured light projection: example

Scanning with structured light

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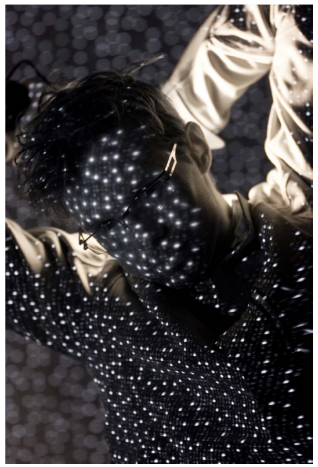
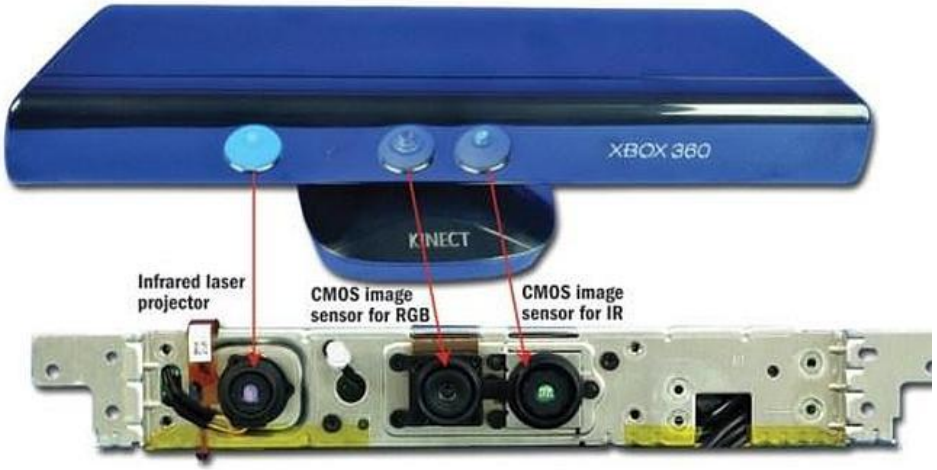
- Structured light projection: Integrated Systems
  - RULER SICK

  - Kinect Microsoft: proyector infrarrojos



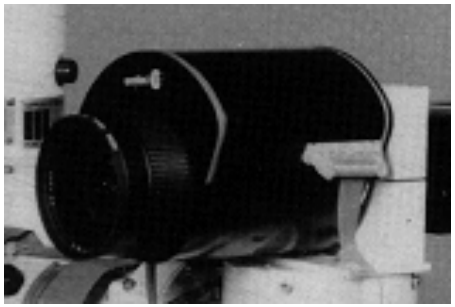


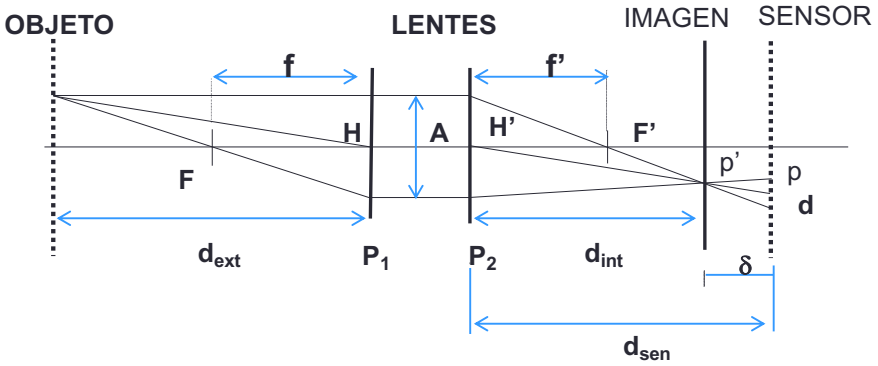
Introduction to 3D Computer Vision

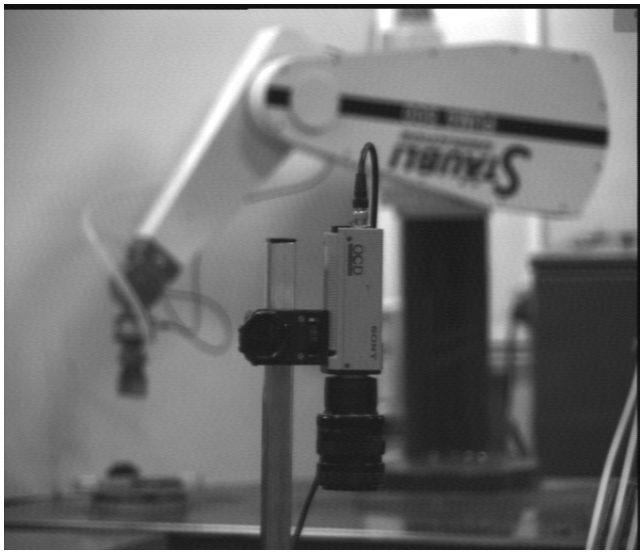
- Focus
  - Determines the distance between sensor and scene by looking for maximum contrast, by varying focus
  -
  - Advantages
    - It doesn’t use triangulation
    -
  - Disadvantages
    - Accuracy decreases with distance
    - Needs regions with high light contrast

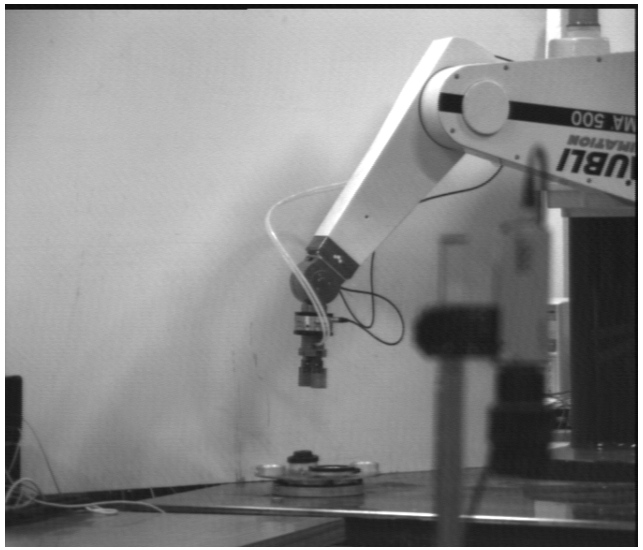
Introduction to 3D Computer Vision

- Focus









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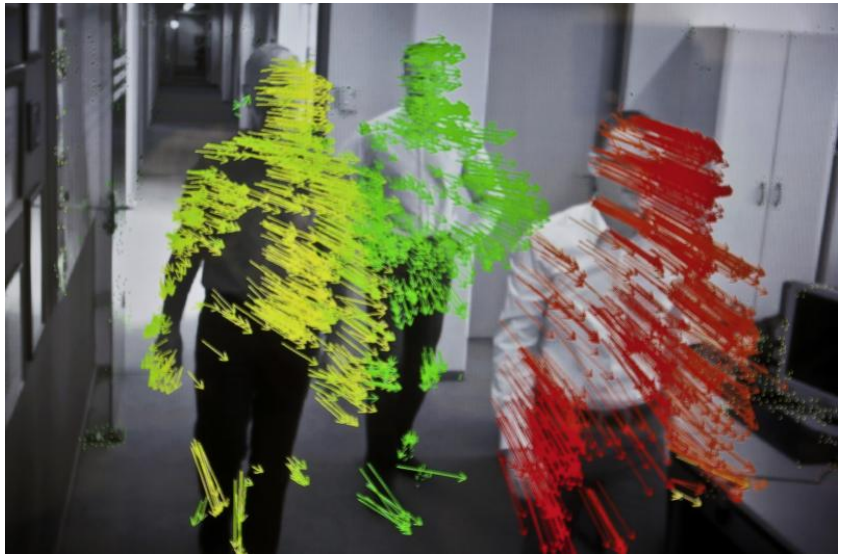
- Optical Flow
  - Determines the position of a point in space, based on an instantaneous motion field. A sequence of images is used to determine this field
  - *Sequence of images*, with different images taken in known time intervals, and with a known camera movement

Introduction to 3D Computer Vision

- Optical Flow



Introduction to 3D Computer Vision

- Optical Flow

(Penn Engineering Univ. Pennsylvania)

Introduction to 3D Computer Vision: Applications

- 3D Vision Applications:
  - Quality control
  - Moving robot guidance
  - Reverse Engineering. Fast prototyping
  - Cartography. Aerial observations
  - Control Visual
  - Photogrammetry
  - Motion Capture

Introduction to 3D Computer Vision: Applications

- Mobile Vehicle Guidance

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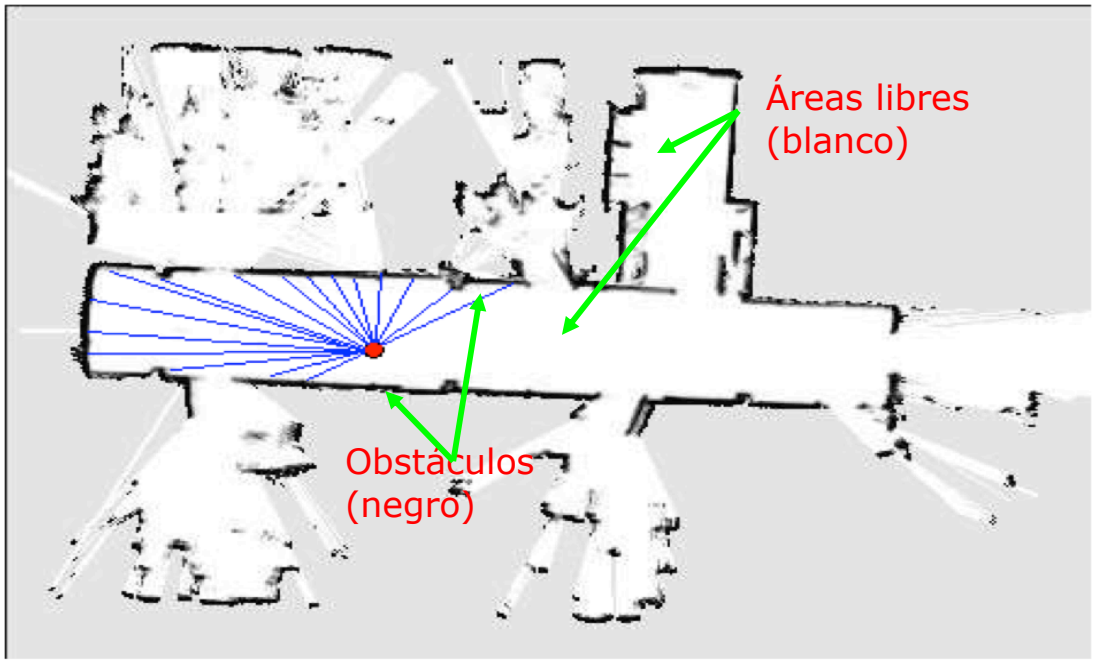
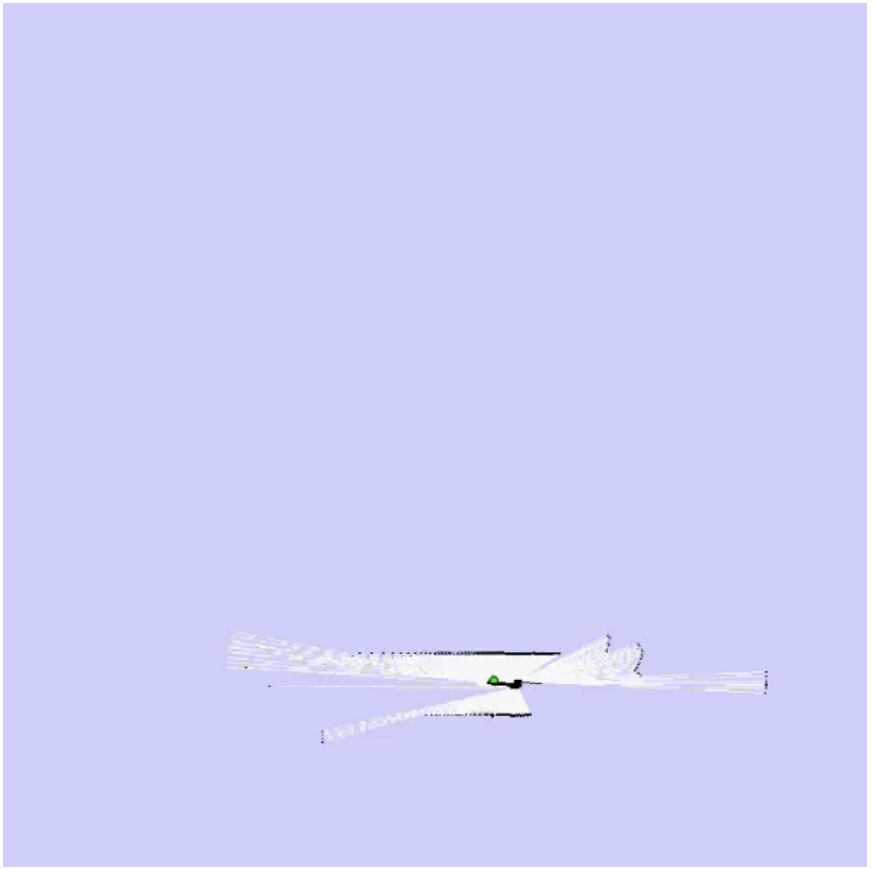
Introduction to 3D Computer Vision: Applications

- Mobile robotics: mapping



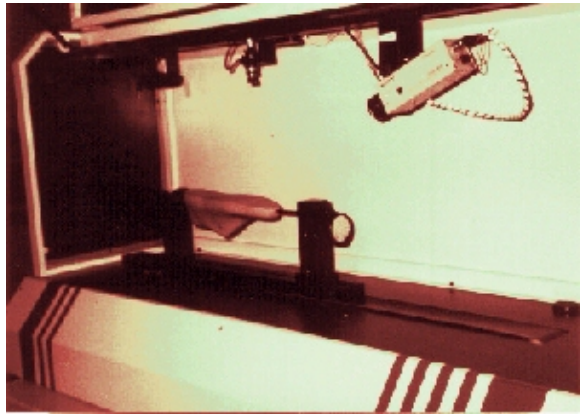


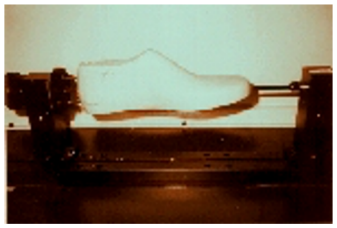
Video

Introduction to 3D Computer Vision: Applications

- Reverse Engineering

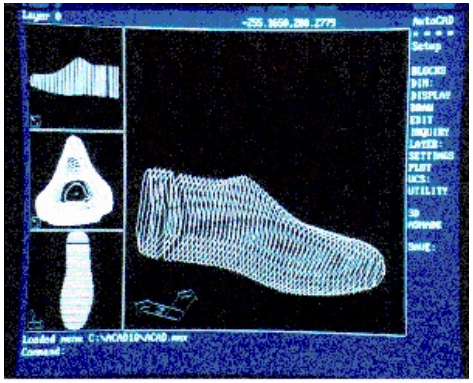
Starts from a handmade shoe model

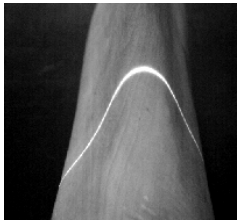




It is placed on the digitizer and a CAD model based on polylines is obtained

The model is scaled to manufacture shoes of different number, as well as a symmetry is applied to manufacture the left and right shoe





Detail of the polyline generated by the laser plane.

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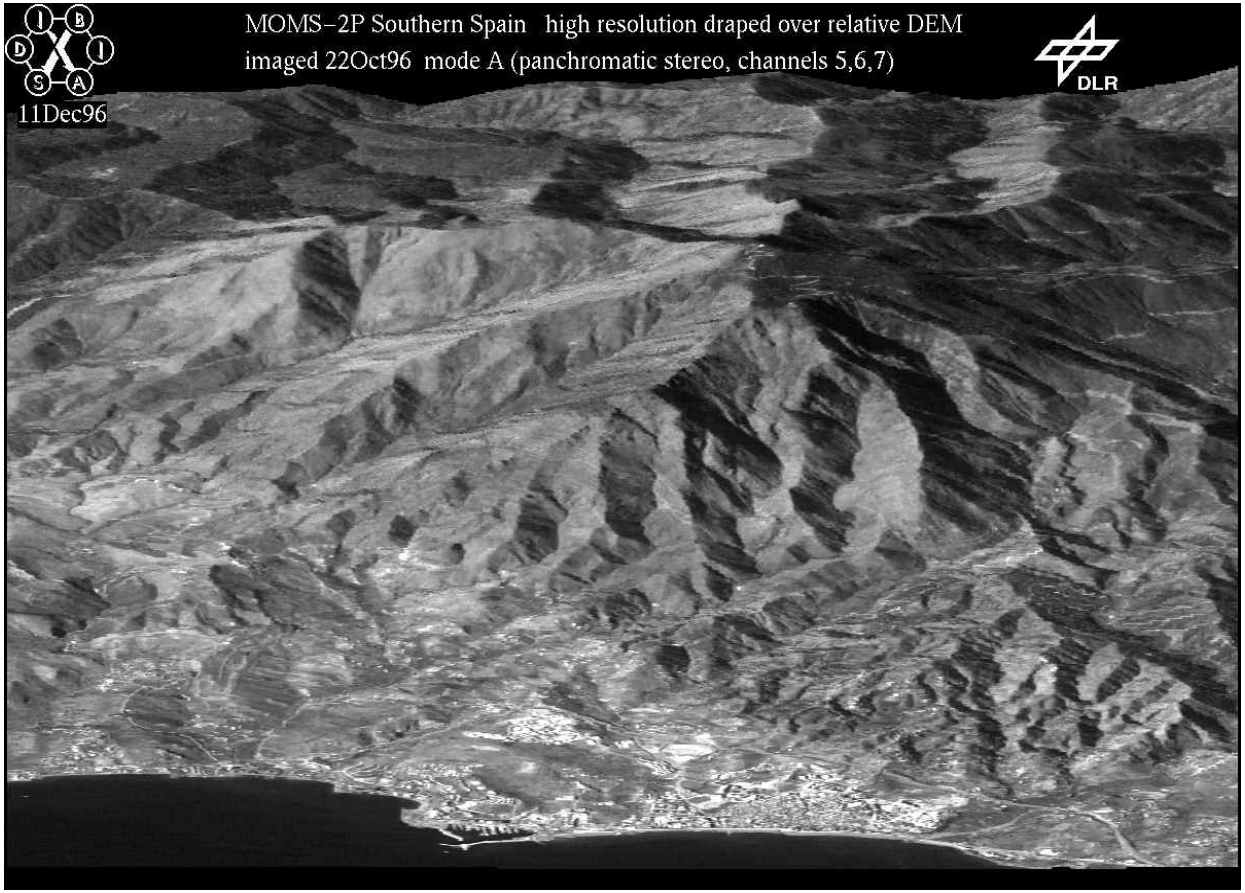
- Cartography. Aerial observations



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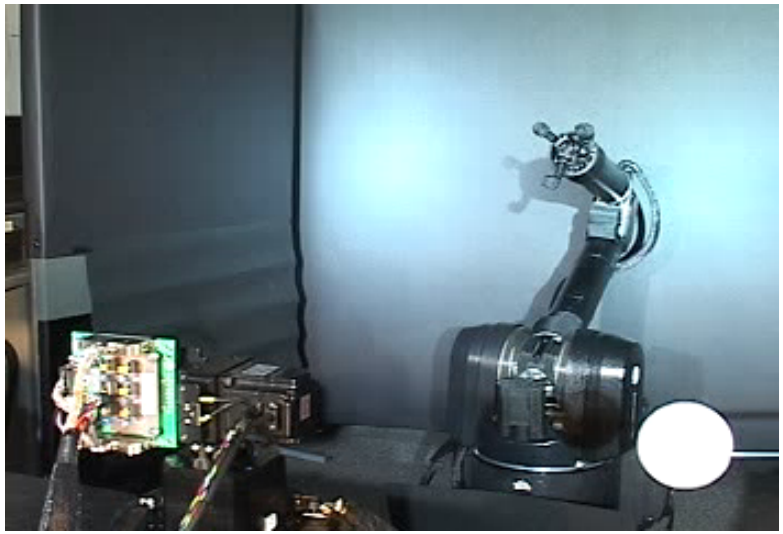
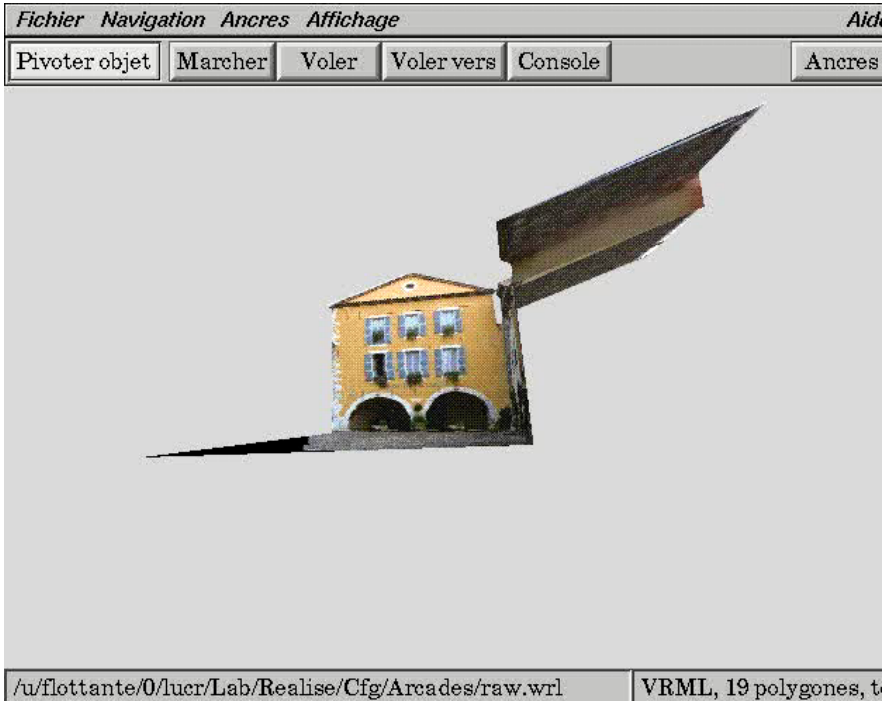
- Visual Control



Introduction to 3D Computer Vision: Applications

- Photogrammetry - 3D Modeling



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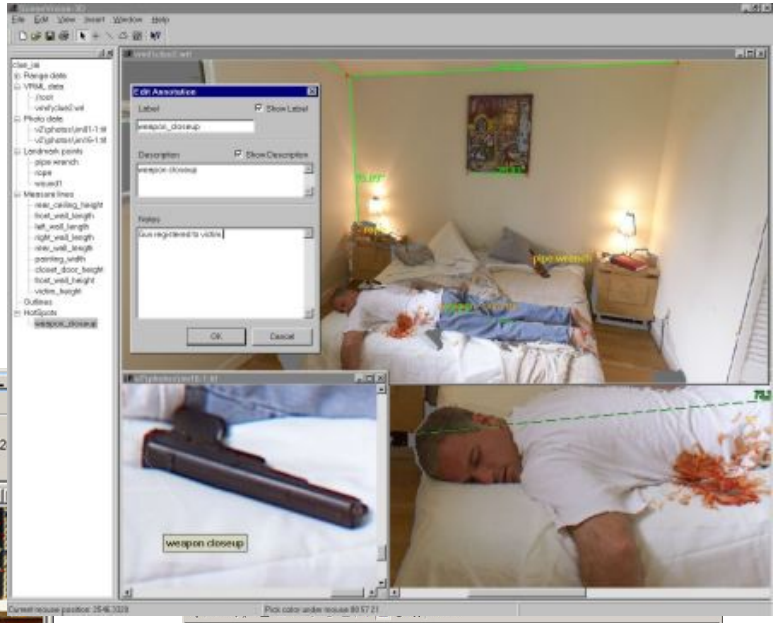
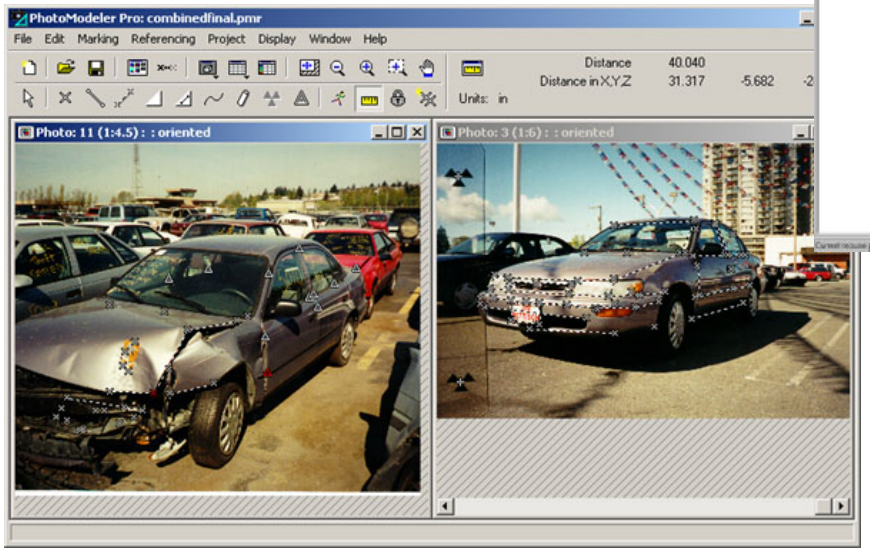
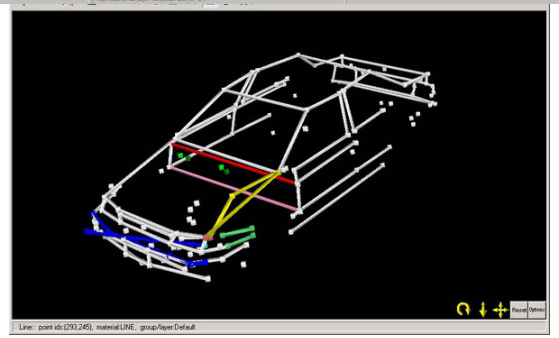
- Forensics: PhotoModeler Scanner







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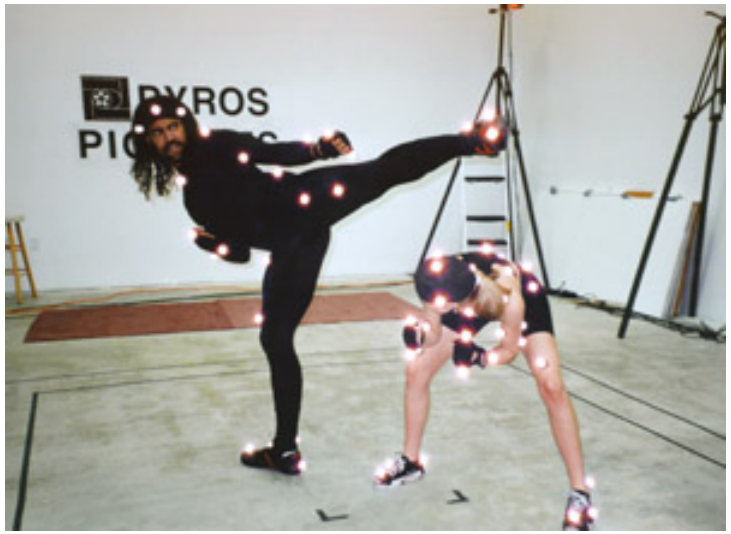
- Motion Capture



PYROS Pictures