

Image-based, geometric sensing in unstructured environments

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Subterranean Robotics
RI Summer Scholars 2010

motivation

Unstructured environments

- ill-defined geometry, natural materials
- dark / no lighting
- 3D model necessary for mobility

Locations

- Caves
- Mines
- Volcanoes



motivation

LIDAR is the current standard

- sparse dataset
 - insufficient for close inspection
- requires actuation
- costly



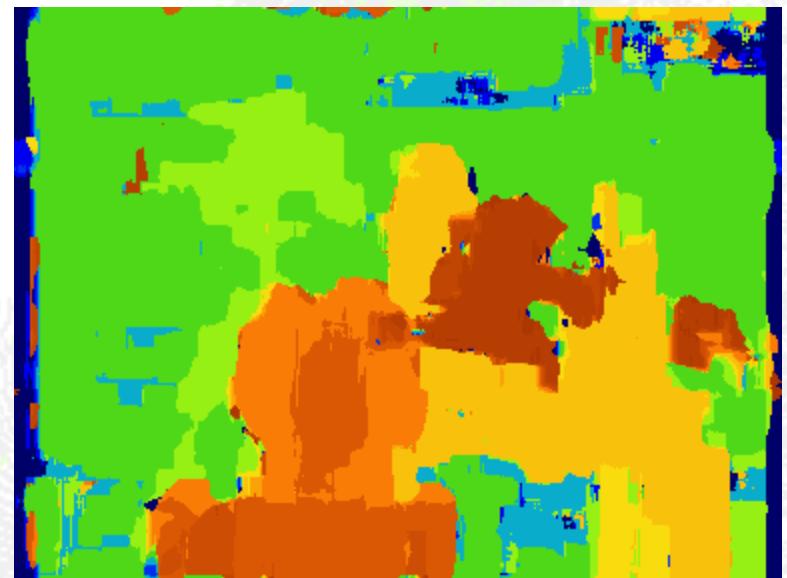
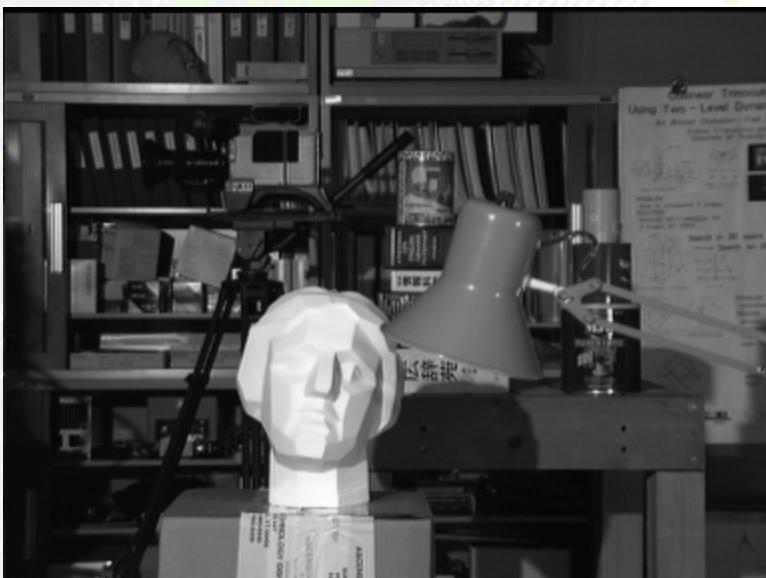
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motivation

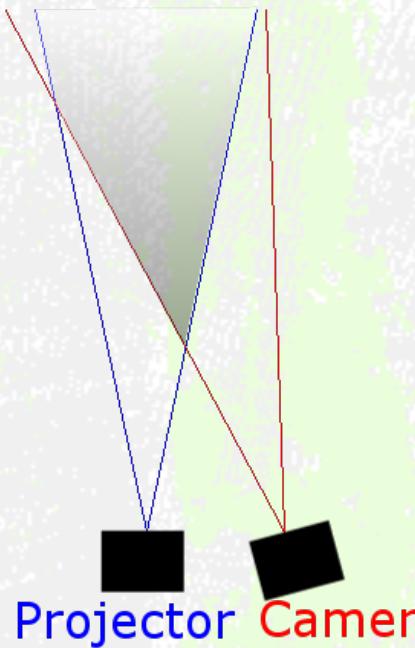
image based sensors

- promising results indoors
- dense data

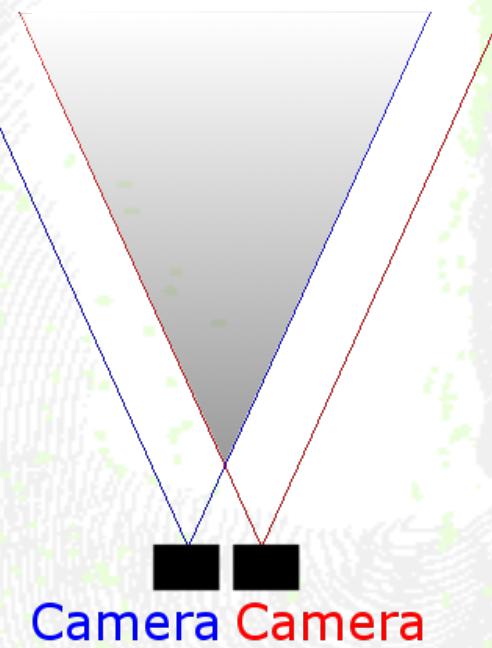


methods

Structured Light



Stereo Vision

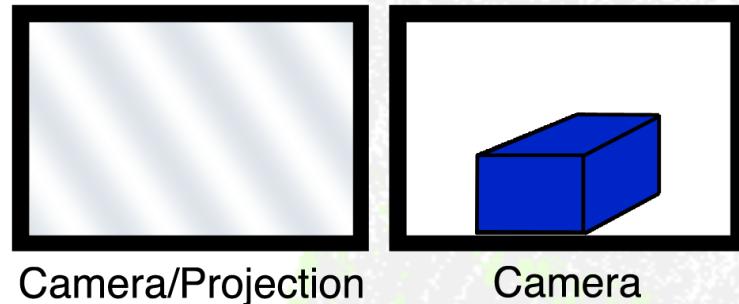


3D LIDAR

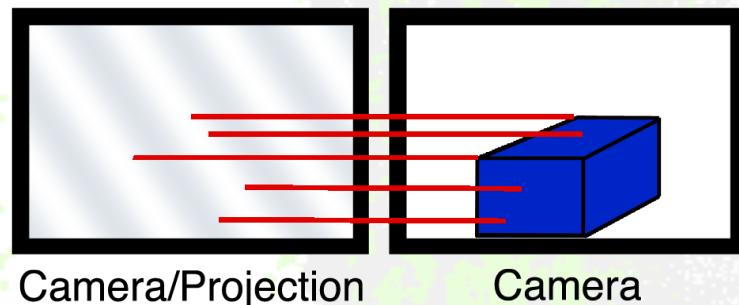


methods

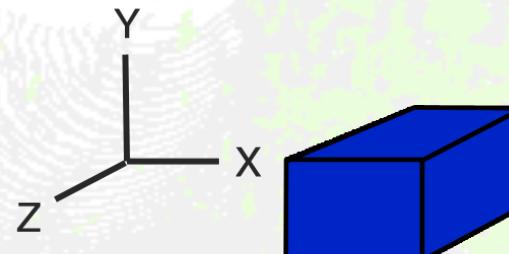
1. Capture imagery



2. Match features



3. Determine depth

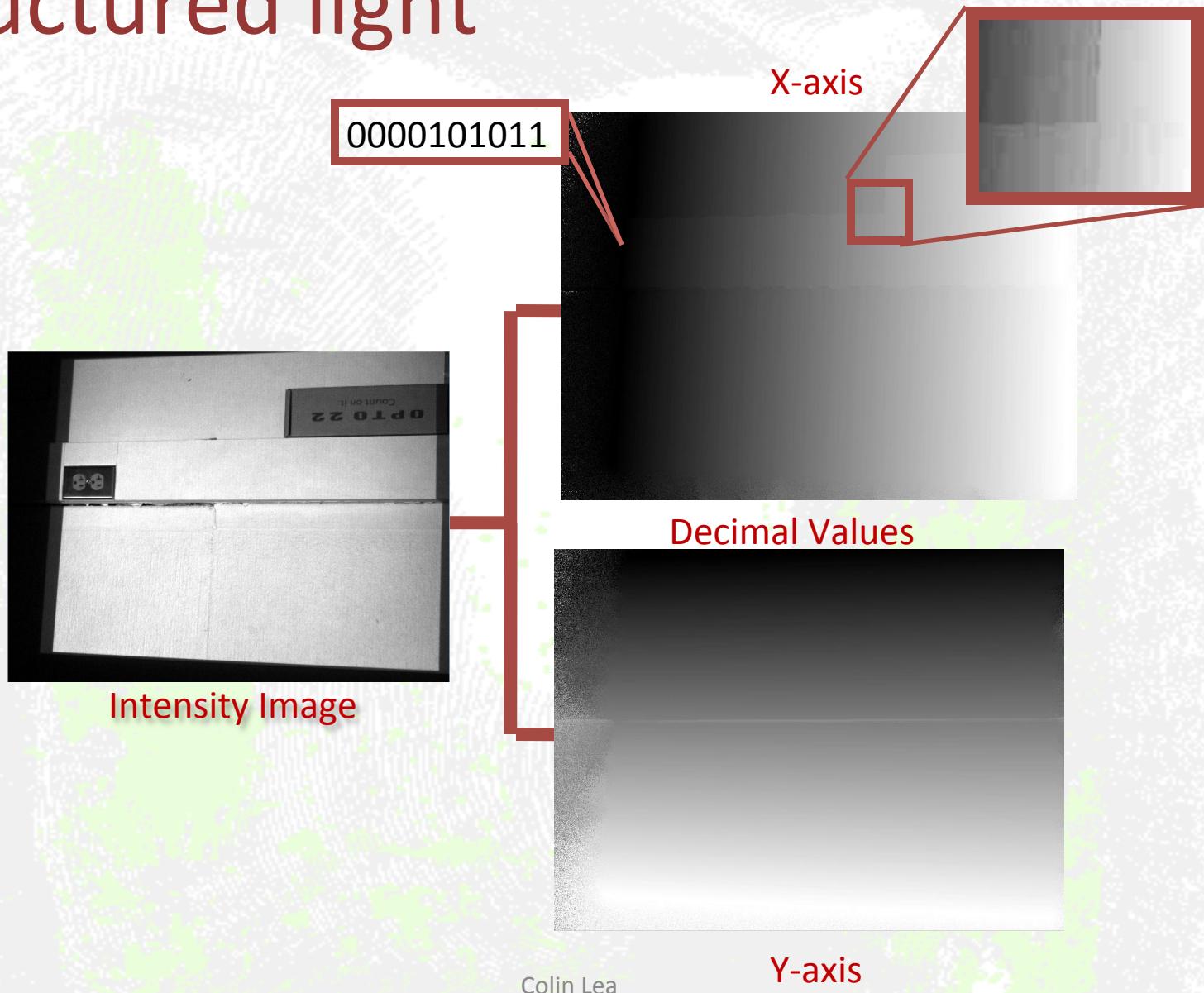


structured light

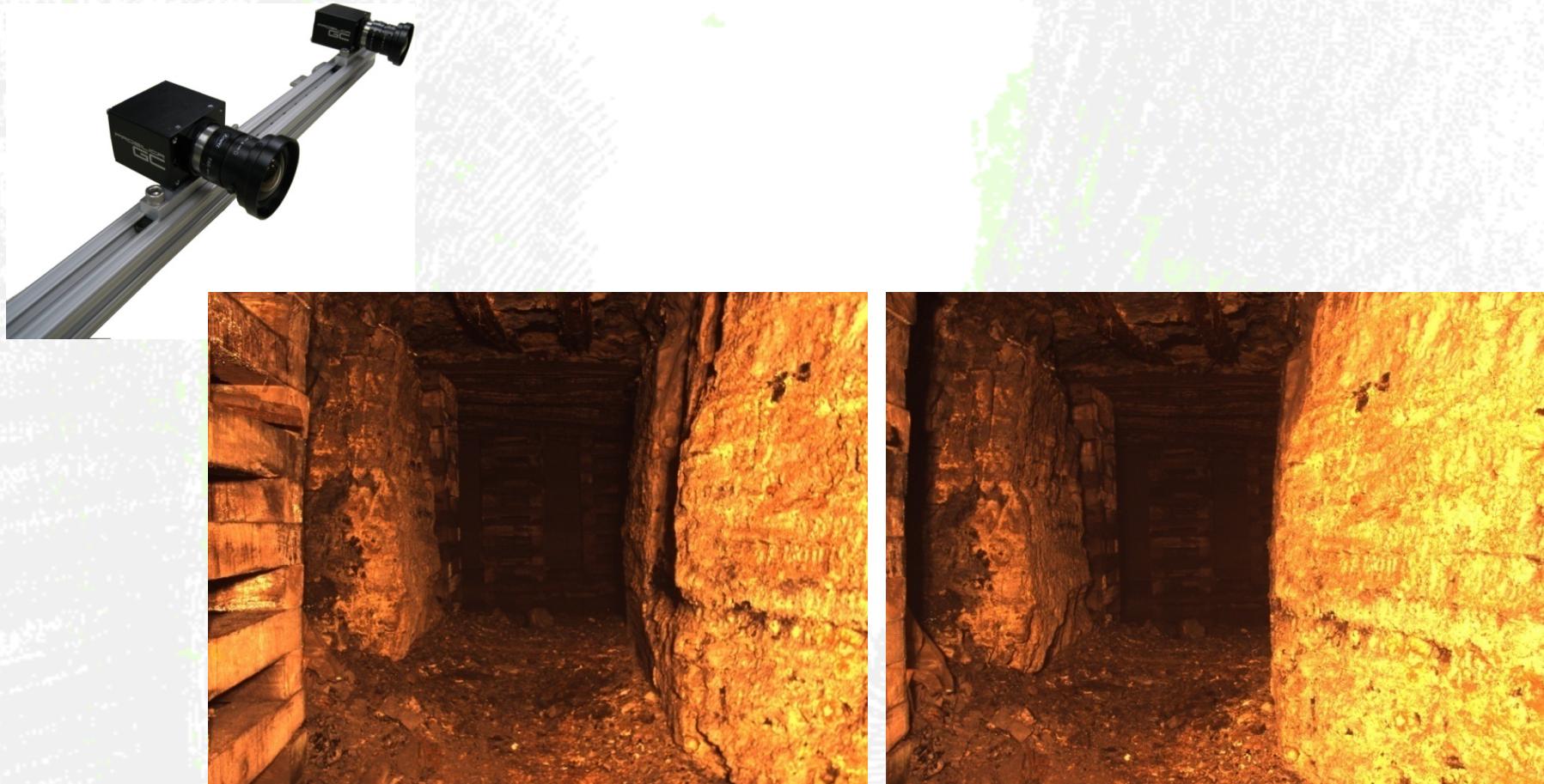


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structured light

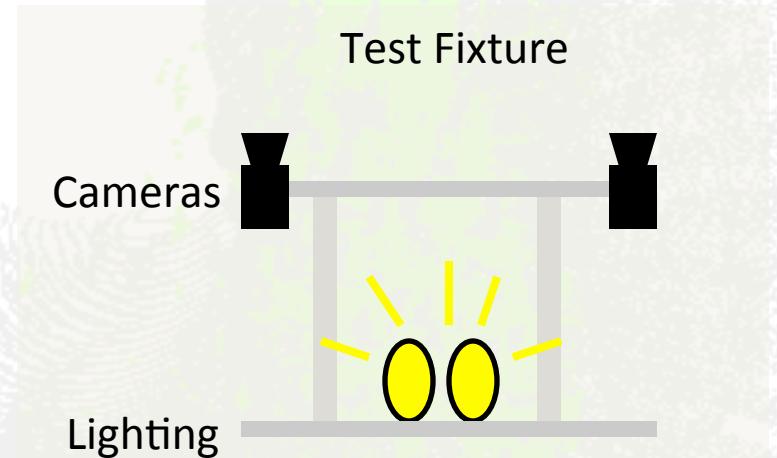
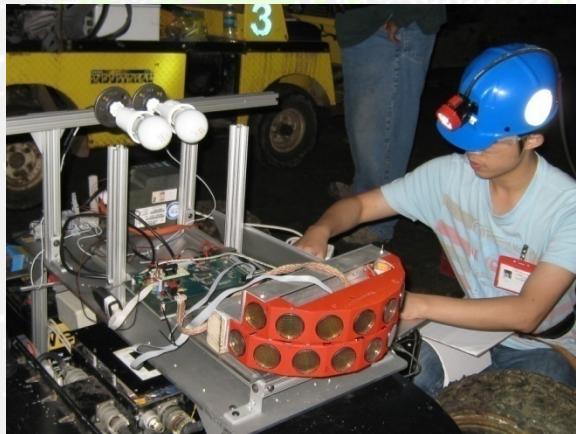
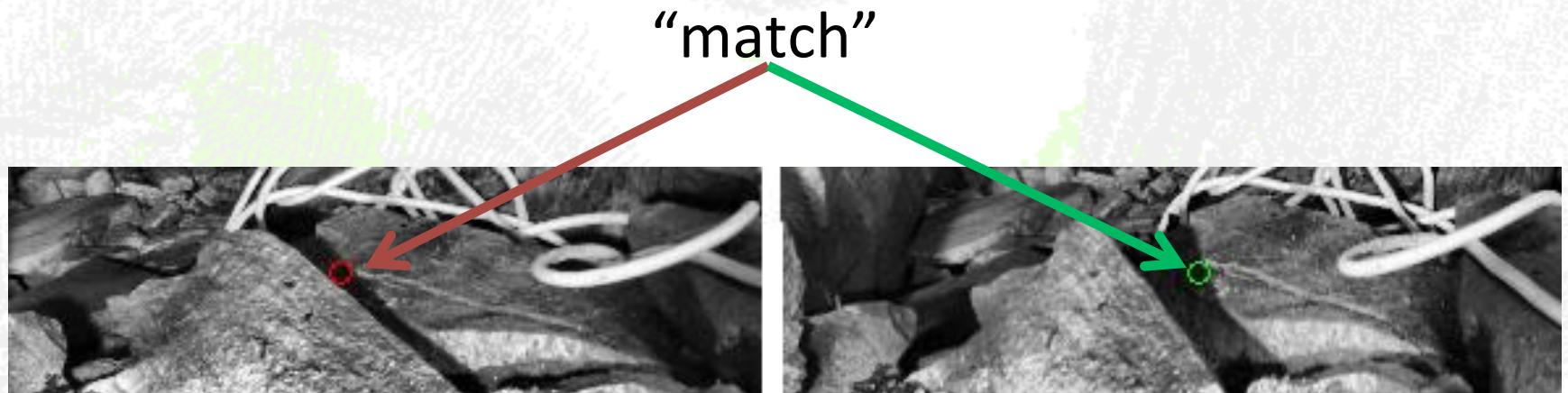


stereo vision



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stereo lighting



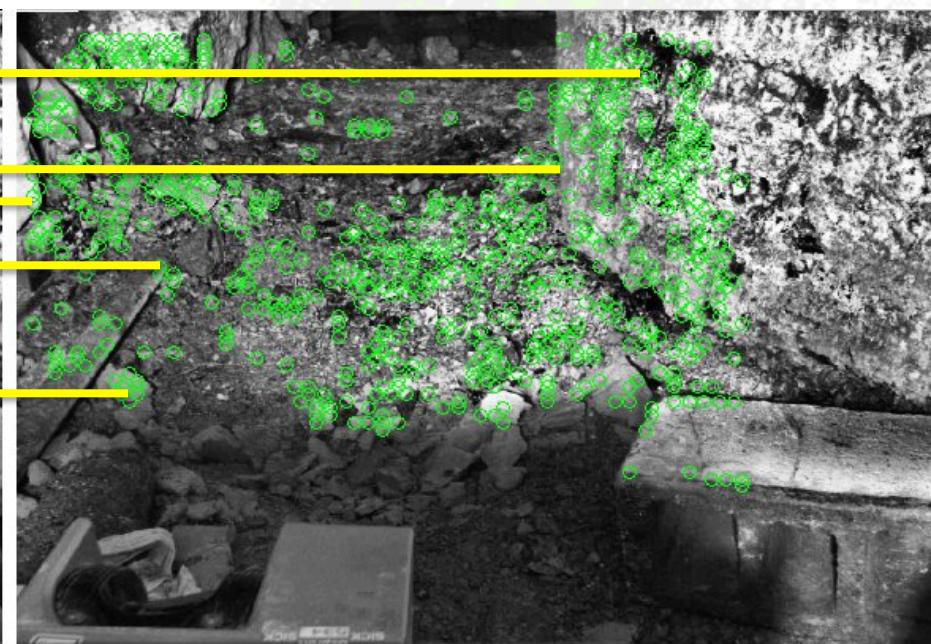
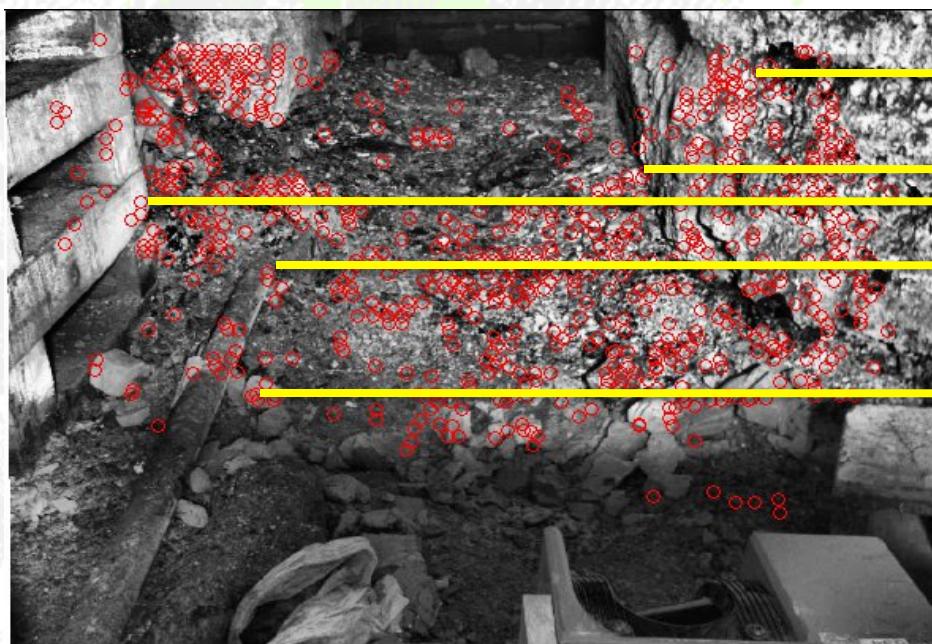
stereo vision

- Template matching

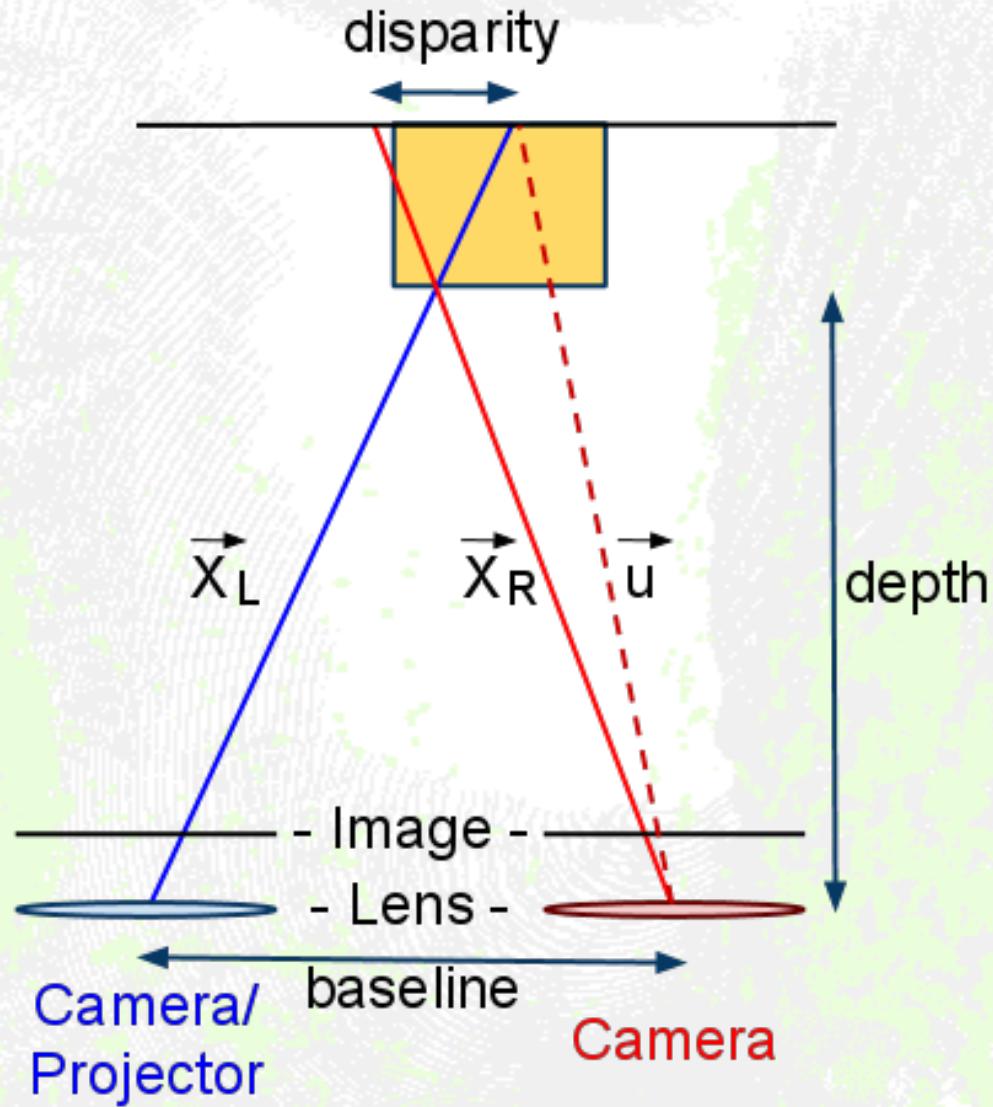
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<Template>



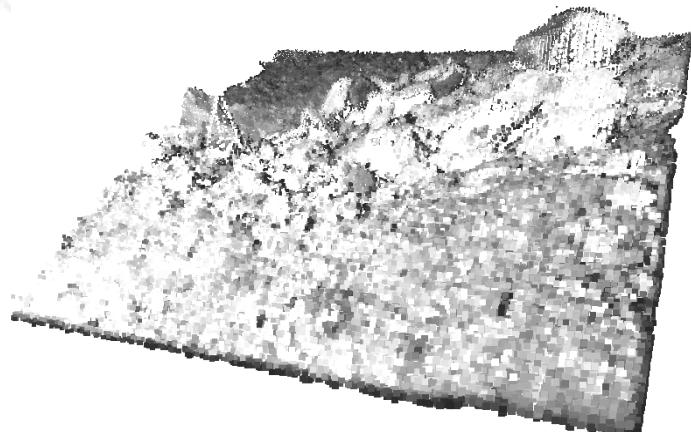
triangulation



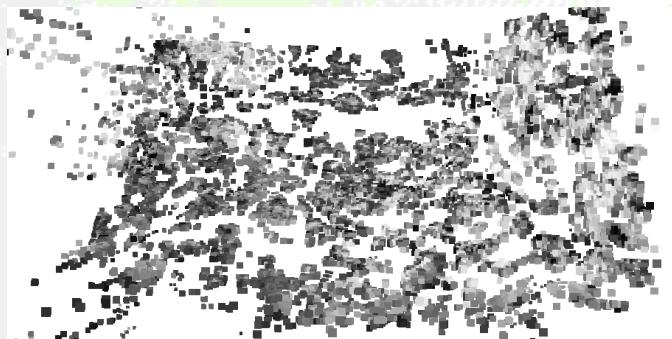
Bruceton Coal Mine



Image



Structured Light



Stereo Vision

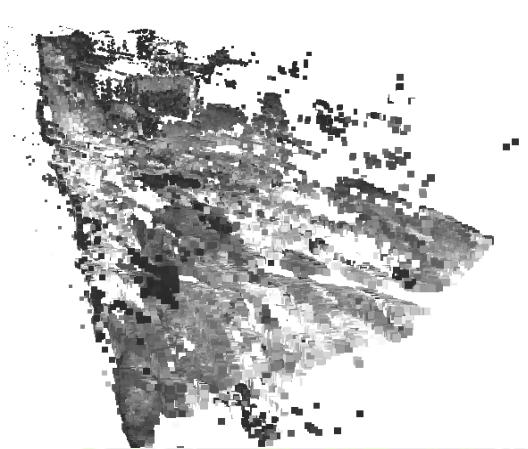


3D LIDAR

Walkers Mill Cave



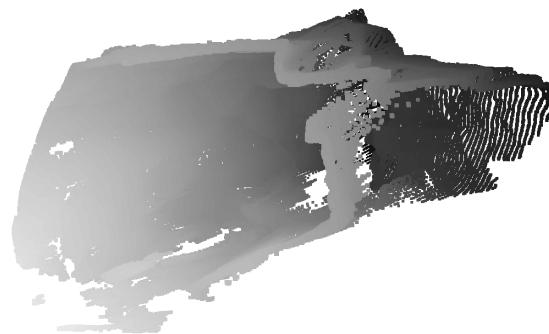
Image



Structured Light



Stereo Vision

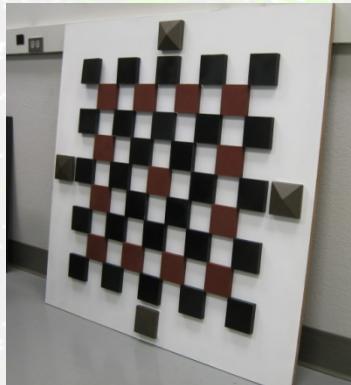


3D LIDAR

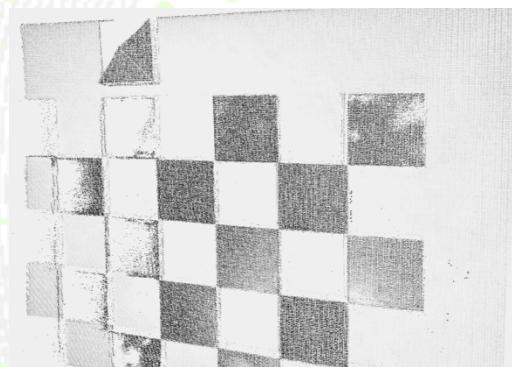
checkerboard analysis

- width = 102 mm
- height = 101 mm
- distance = 1.8 m

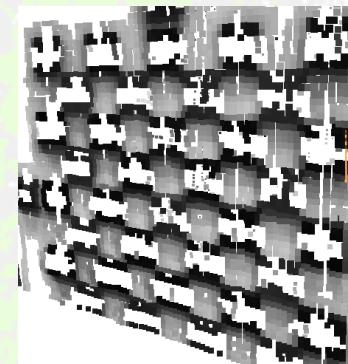
Setup	Error (mm)	Error (%)
SL (x)	3.5	0.19%
SL (y)	6.8	0.38%
SV (x)	11.5	0.64%
SV (y)	8.6	0.47%



Scene



Structured Light



Stereo Vision

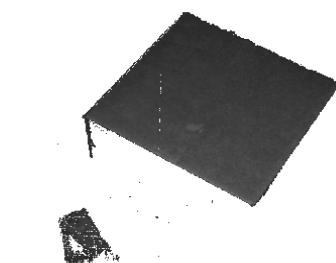
fiducial analysis

Cubic box:

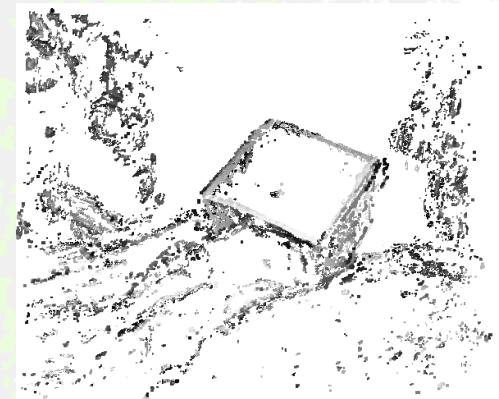
- lengths = 304.8 mm
- distance = 1525 mm



Scene



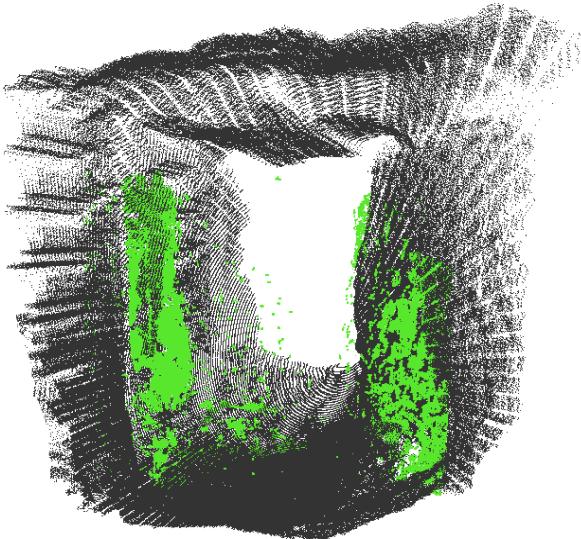
Structured Light



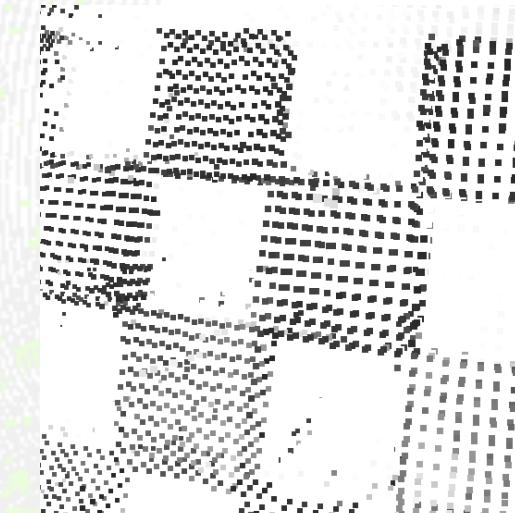
Stereo Vision

comparison tools

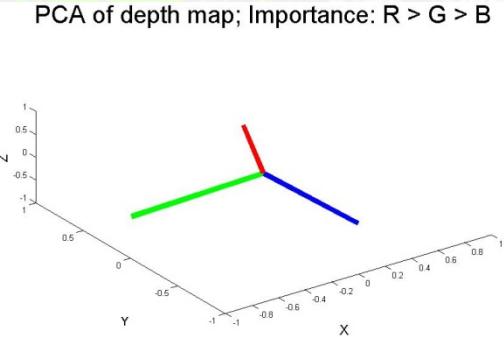
- Alignment with Iterative Closest Point (ICP)
- Point clouds converted to voxels
- Gradient point filtering
- Principle Component Analysis (PCA)



Stereo/LIDAR alignment



Voxels



PCA



Structured light generates a dense dataset with high accuracy, but is often limited by a relatively small field of view.

Stereo Vision models distinguishable features well but suffers from noise due to shadows and irregular surfaces.

future work

- Complete fusion and analysis of data
- Generate high dynamic resolution(HDR) images
- Improve stereo algorithm parameters
- Examine wide field of view lenses
- Investigate “structured light stereo”