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41014 Sensors and Control for Mechatronic Systems

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UNIVERSITY OF TECHNOLOGY SYDNEY

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41014 Sensors and Control for Mechatronic Systems

Lecture-3: RGB-D Cameras

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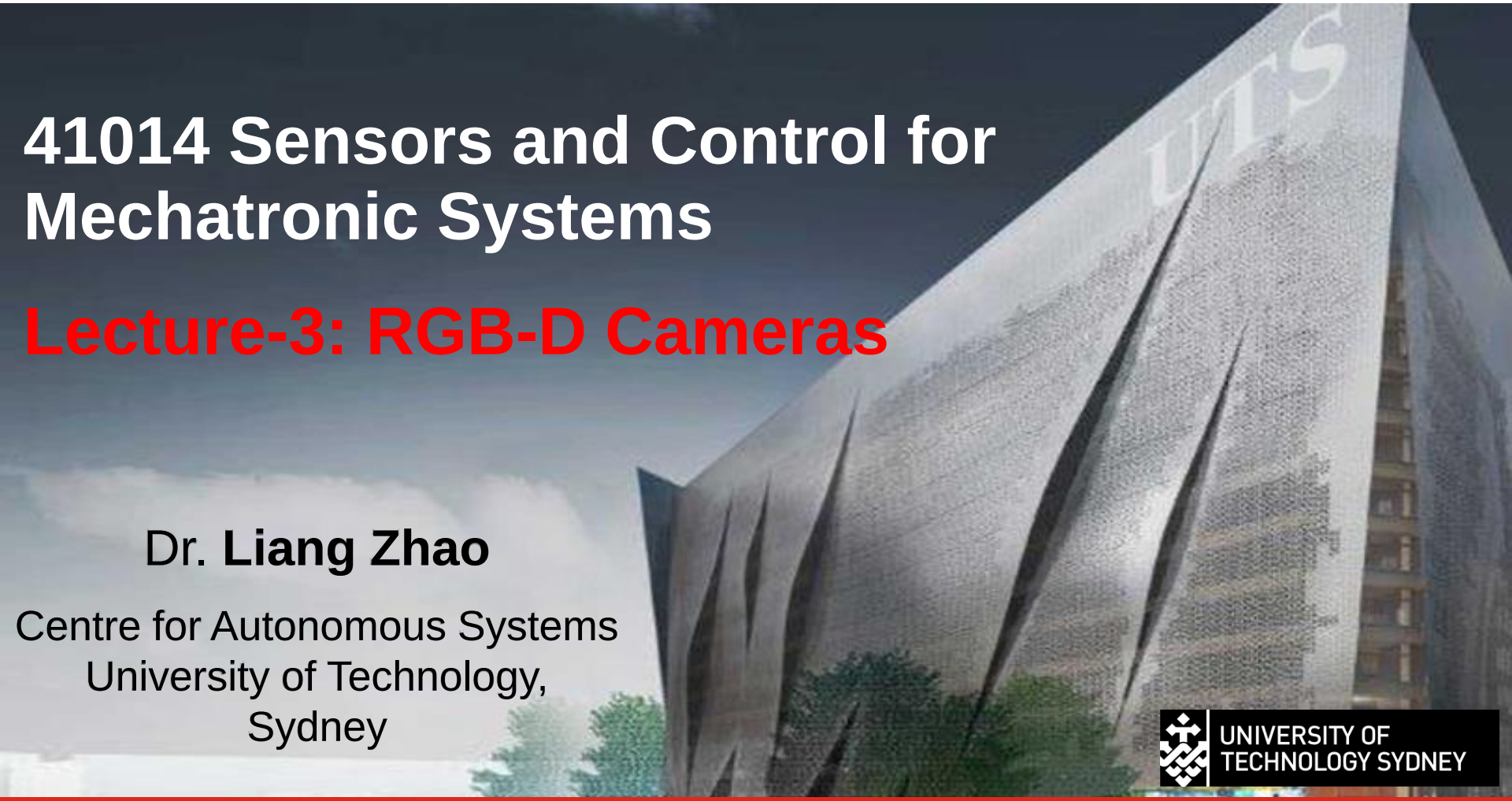

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1. Lecture-3

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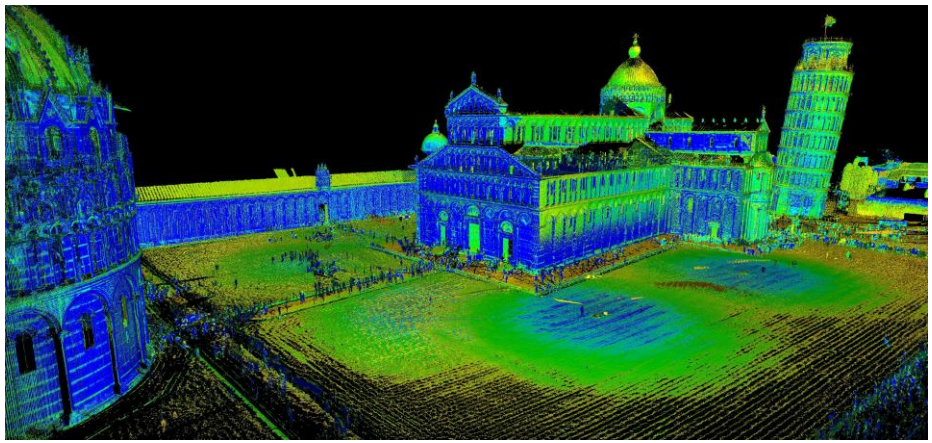
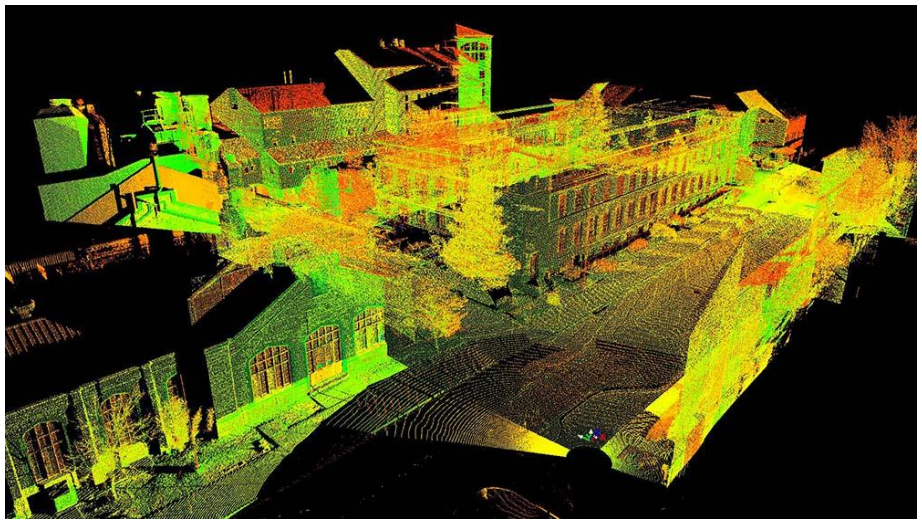
- **Sensors:**
  - **Cameras**
  - **RGB-D Cameras**
  - ToF sensors

- **In details of**
  - Fundamental
  - Data and Processing





1. Lecture-3

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❖ Lecture:

- Stereo Cameras
- RGB-D Cameras: principle and different models
- Applications of RGB-D Cameras

❖ Active hands on:

- Play with Different RGB-D Cameras
- Display of RGB/Depth images and point clouds
- Image processing on RGB-D images

2.1 Stereo Cameras

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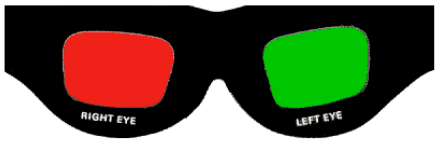
Human eyes

Stereo vision

Anaglyphs

- Two images of complementary color are overlaid to generate one image.
- Glasses required (e.g. red/green)
- Each eye gets one image => 3D impression



2.1 Stereo Cameras

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Shutter glasses

- Display flickers between left and right image (i.e. each even frame shows left image, each odd frame shows right image)
- Uses a timing signal to synchronize the glass and the display
- Requires new displays of high frame rate (120Hz).

Shutter glasses and 120Hz display

Autostereoscopic displays

- No glasses required!
- Matrix of many transparent lenses put on the display.
- Lenses distort pixels so that left eye gets a left image and right eye gets a right image (if you are standing in a proper spot) => 3D impression

Sharp 3D display

2.2 Stereo: Disparity

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- Disparity: the pixel difference in two images

Foreground disparity - large

Background disparity - small

2.2 Stereo: Disparity

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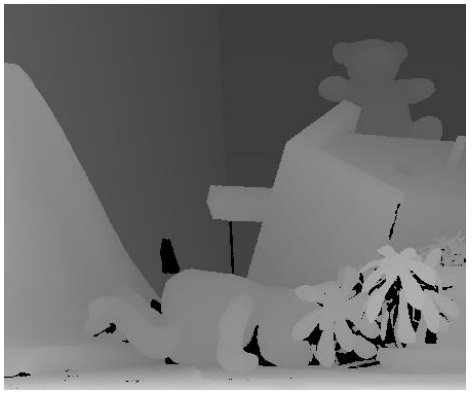
Disparity

- The disparity of each pixel is encoded by a grey value.
- High grey values represent high disparities (and low gray values small disparities).
- The resulting image is called disparity map.
- The disparity map contains sufficient information about the depth map



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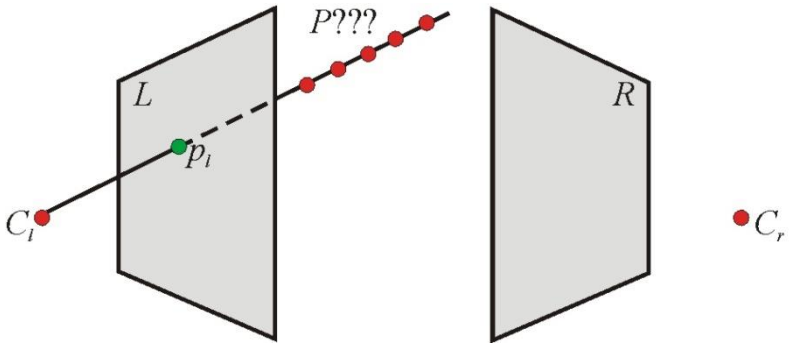
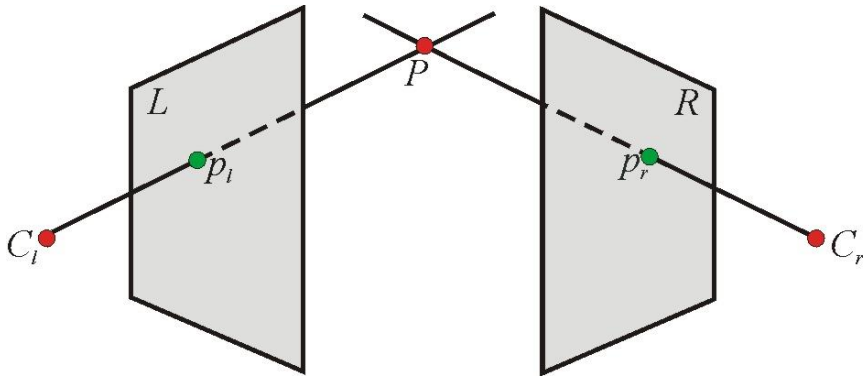
3D Reconstruction

- P can lie on anywhere along the C_l-p_l line.



- Let us assume we also know the 2D projection p_r of P onto the right image plane R. Can we now determine the pint P?

- The challenge is to find the matching p_l and p_r. It is called the stereo matching (correspondence) problem.



2.3 Stereo: 3D Reconstruction

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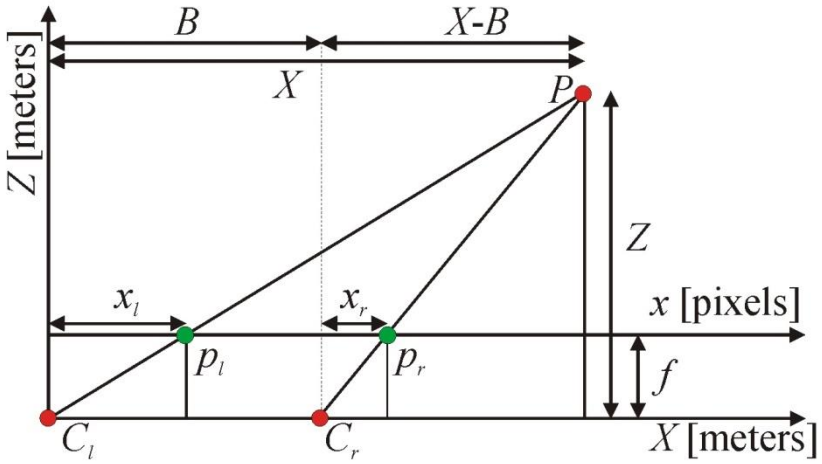
Triangulation

- X, Z : 3D space
- B – baseline of the cameras
- x_l, x_r : Image coordinates
- f : focal length



- Using similar triangles

$$\frac{X}{Z} = \frac{x_l}{f}$$

$$\frac{X - B}{Z} = \frac{x_r}{f}$$

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Triangulation

$$\frac{X}{Z} = \frac{x_l}{f} \qquad \frac{X-B}{Z} = \frac{x_r}{f}$$

$$X = \frac{Z.x_l}{f} \qquad X = \frac{Z.x_r}{f} + B$$

$$\frac{Z.x_l}{f} = \frac{Z.x_r}{f} + B$$

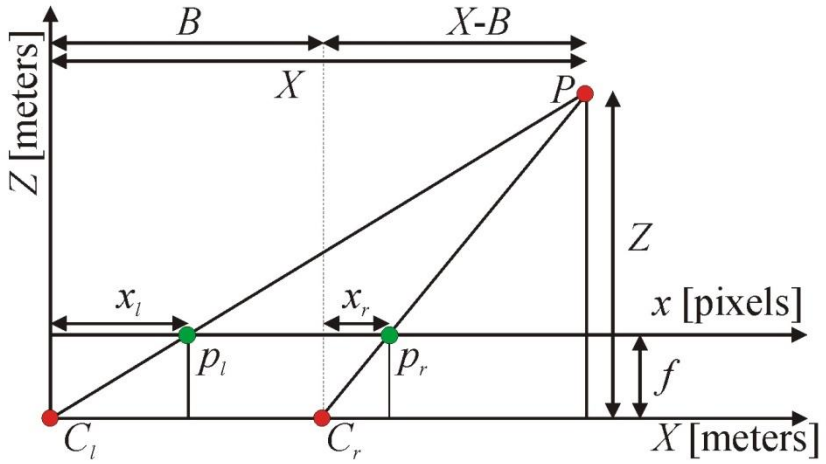
$$Z.x_l = Z.x_r + B.f$$

$$Z.(x_l - x_r) = B.f$$

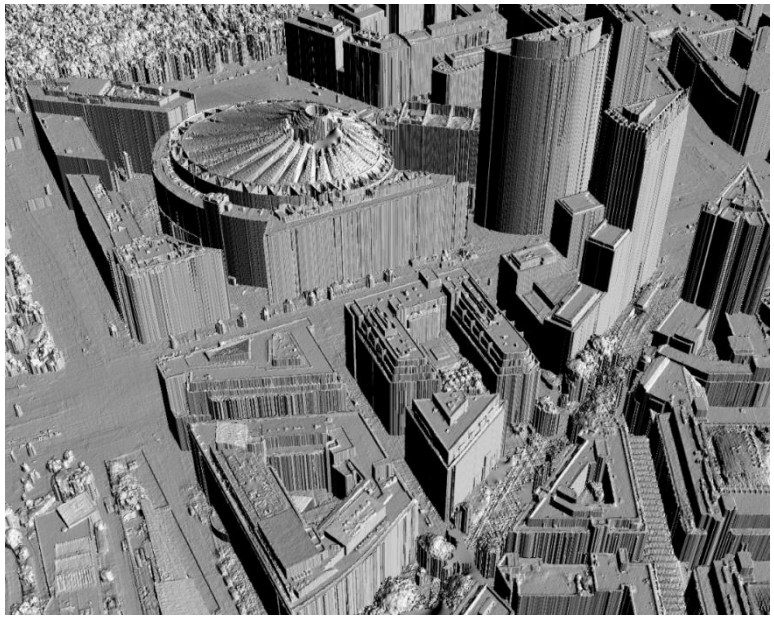
$$Z = \frac{B.f}{x_l - x_r} = \frac{B.f}{d}$$

Where *d* is the disparity

– It can be seen that the disparity is inversely proportional to the depth.



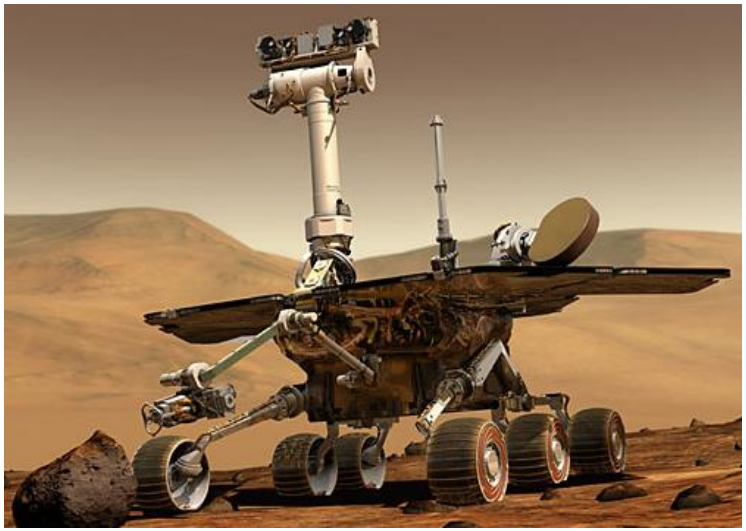
2.5 Stereo: Applications



- Stereo cameras are mounted on an airplane to obtain a terrain map.

http://www.robotic.de/Heiko.Hirschmueller/

2.5 Stereo: Applications



- Reconstruct the surface of Mars using stereo vision

2.4 Stereo: Challenges

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Stereo Correspondence - challenges

- **Color inconsistencies:**
- When solving the stereo matching problem, we typically assume that corresponding pixels have the same intensity/color (= Photo consistency assumption)
- It is not necessarily be always true:
  - Image noise
  - Different illumination conditions in left and right images
  - Different sensor characteristics of the two cameras.
  - Specula reflections (mirroring)
  - Sampling artifacts

2.4 Stereo: Challenges

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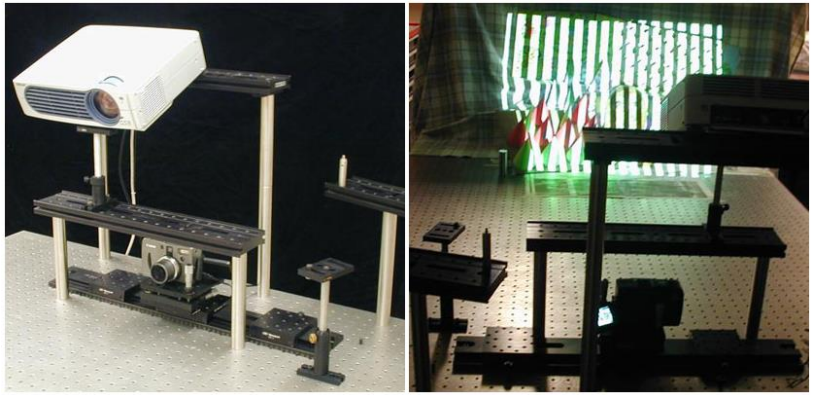
- **Stereo Correspondence - challenges**
  - Textureless regions

Left image

Right image

  - The corresponding is infeasible. So disparities can not be calculated.



Disparity image

2.4 Stereo: Challenges

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Stereo Correspondence - challenges

- **Occlusion Problem**
  - There are pixels that are only visible in exactly one view.
  - We call this pixels occluded (or half-occluded)
  - It is difficult to estimate depth for these pixels.
  - Occlusion problem makes stereo more challenging than a lot of other computer vision problems

Occluded pixels

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THANK YOU

Questions?

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