3D Road Surface Reconstruction summary

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Version 2.4.1

Artificial Intelligence & Information Analysis Lab

3D Road Surface Reconstruction

- Road Surface Reconstruction
  - **Active-sensing-based methods**
    - Laser scanning-based methods
    - Microsoft Kinect
  - Passive sensing-based methods
    - Shape from Shading
    - Stereo vision
- Road Infrastructure reconstruction
  - SfM for cliff surface reconstruction

3D Road Surface Reconstruction

- Road Surface Reconstruction

Introduction

- Road damage is 3D in nature.
- As discussed in lecture 2, road inspection is currently still performed by either certified inspectors or structural engineers [1].
- The detection results are objective and qualitative [2].
- Road surface 3D reconstruction technology is commonly used for road anomaly/damage detection [3].
- The state-of-the-art road surface modeling algorithms can be categorized as either active sensing-based and passive sensing-based.
- Active sensing-based technologies (e.g., laser scanning) are mainly used for road surface 3D reconstruction and other technologies are largely neglected.

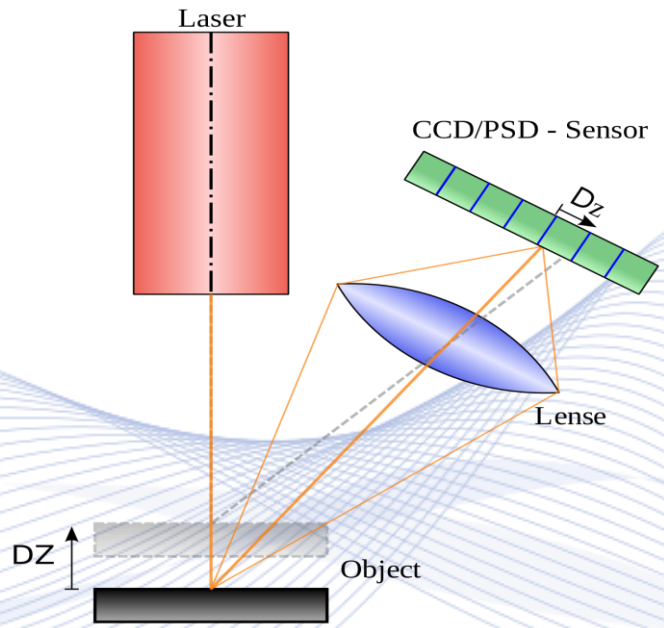
Laser scanning-based methods

Over past decade, many researchers [4, 5, 6] have used laser scanners to acquire 3D road surface.

Georgia Institute of Technology sensing vehicle [2].

Laser scanning-based methods

The 3D laser scanner uses a technique that employs reflected laser pulses to create accurate digital models of existing objects.



Principle of a laser triangulation sensor 1.

Active sensing-based methods

- The 3D point clouds provided by laser scanners/lidars are very accurate (much more precise than cameras).
- laser pulses may be affected by heavy rains or low hanging clouds because of the effects of refraction. However the data collected can still be used for analysis.
- Laser scanning technology does not work well in areas or situations where there are high sun angles or huge reflections since the laser pulses depend on the principle of reflection.
- Laser is a technology that collects very huge datasets that require high level of analysis and interpretation. For this reason, it may take a lot of time to analyze the data.
- The Laser beams used by LiDAR pulses are usually powerful in some instances and these may affect the human eye.

Microsoft Kinect

Some researchers also utilized Microsoft Kinect [8, 9, 10] sensors to reconstruct the 3D road geometry.

- Microsoft Kinect is a cheap 3D road reconstruction alternative.
- Kinect is equipped with an RGB camera, an IR sensor or camera, microphones, accelerometer, and a tilt motor for motion tracking facility.
- The IR camera of the Kinect sensor provides depth images at a resolution of 640 × 480 pixels/30 Hz.
- Alternatively, the IR camera of the Kinect sensor can provide depth images at a resolution of 1280 × 1024 pixels/10 Hz.
- The working range of Kinect is between 800 mm and 4000 mm, making it suitable for road imaging when mounted on a vehicle.

Microsoft Kinect

Microsoft Kinect drawbacks:

- However, a comprehensive study on reporting its accuracy for various technical surfaces has not been found as of yet [2].
- On the negative side of using Kinect, it is reported to suffer from infrared saturation in direct sunlight in outdoor conditions [11].

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Passive sensing-based methods

Passive sensing-based road surface 3D reconstruction technologies mainly include:

- Shape from Shading [12]
- Structure from Motion (SfM) [13]
- Stereo Vision [14]

Shape from Shading

Shape from shading works by establishing a relationship between image brightness and object shape.

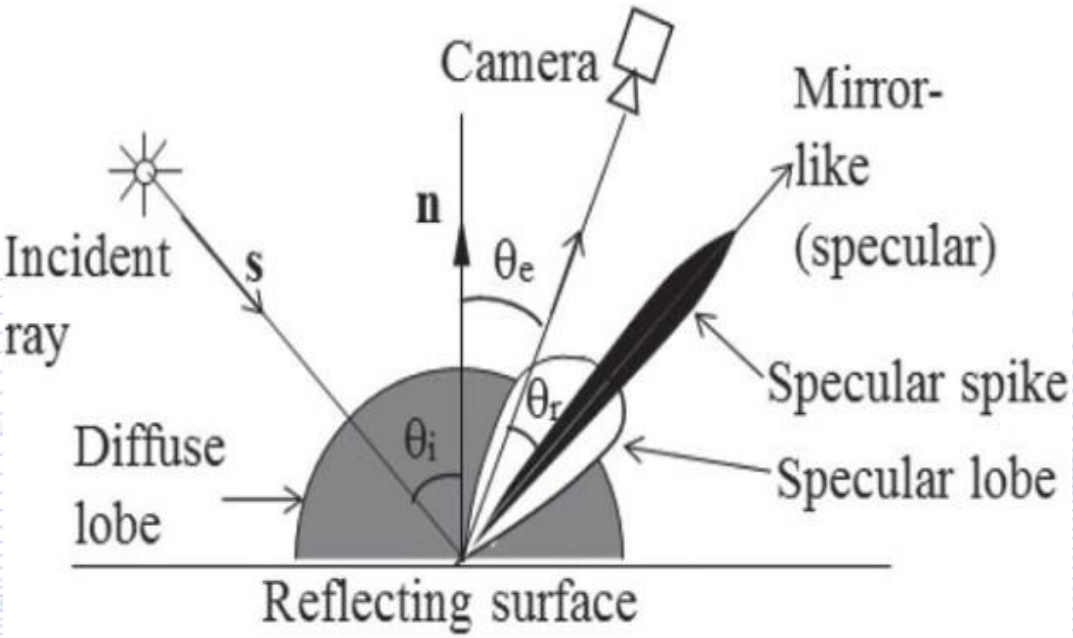


Figure:Principle of shape from shading [12].

Structure from Motion (SfM)

Structure from motion (SfM) is a technique where the 3D/range information of a scene is obtained by a single moving camera. By using multiple 2D images obtained from the same camera, point correspondences are established leading to the 3D depth reconstruction of the scene.

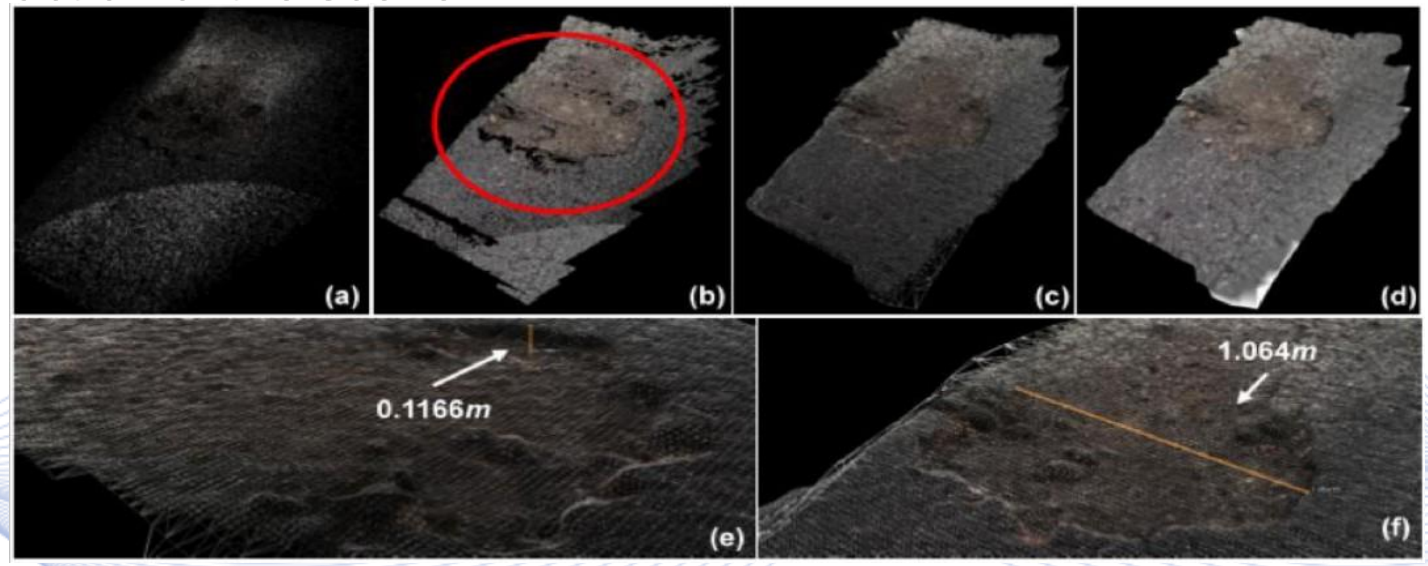


Figure:An example of road surface 3D reconstruction using SfM [12].

Stereo vision-based methods

Stereo vision has been prevalently used for road surface 3D reconstruction [14].

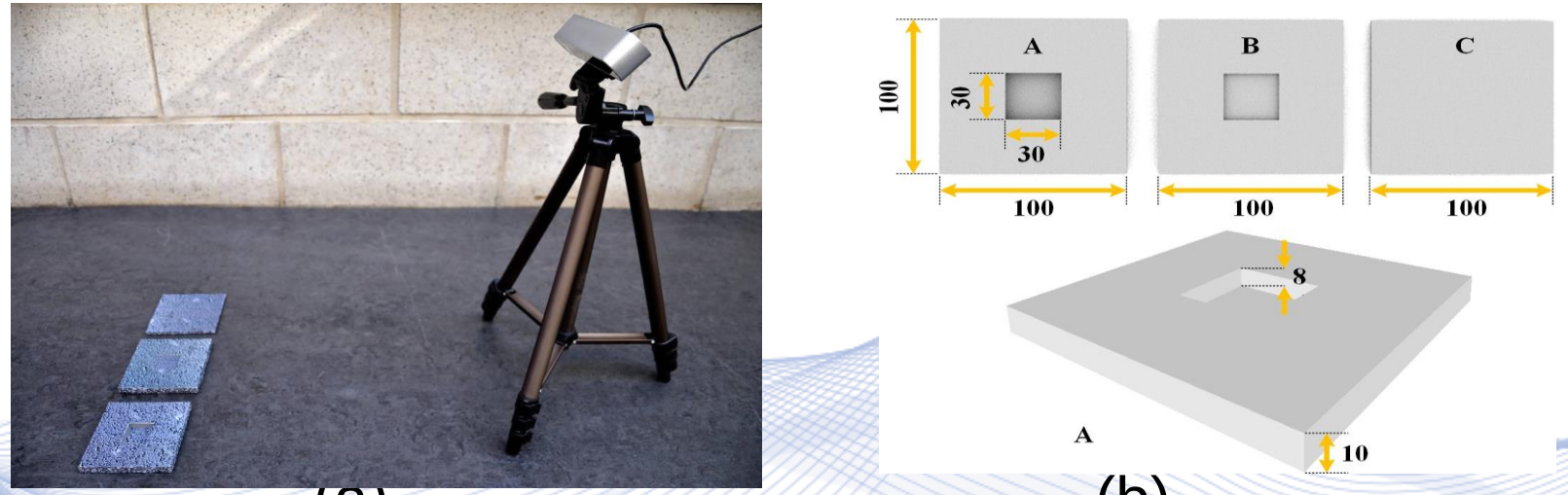
A demo video can be found:

https://www.youtube.com/watch?v=pypPI7fsctg

Stereo vision-based methods

Experimental set-up [14] is shown below.

Three models were 3D-printed.



(a) (b)

Experimental set-up [14].

SRP+PT

Some estimated disparity maps:

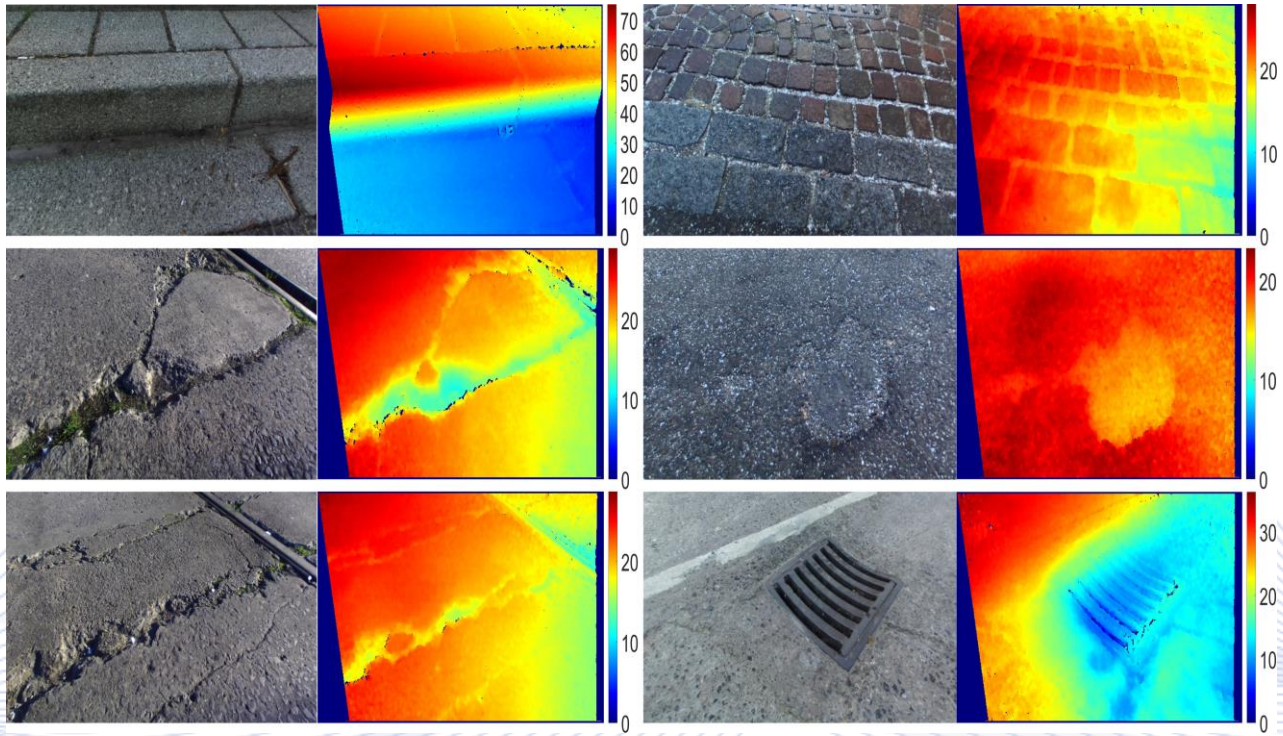
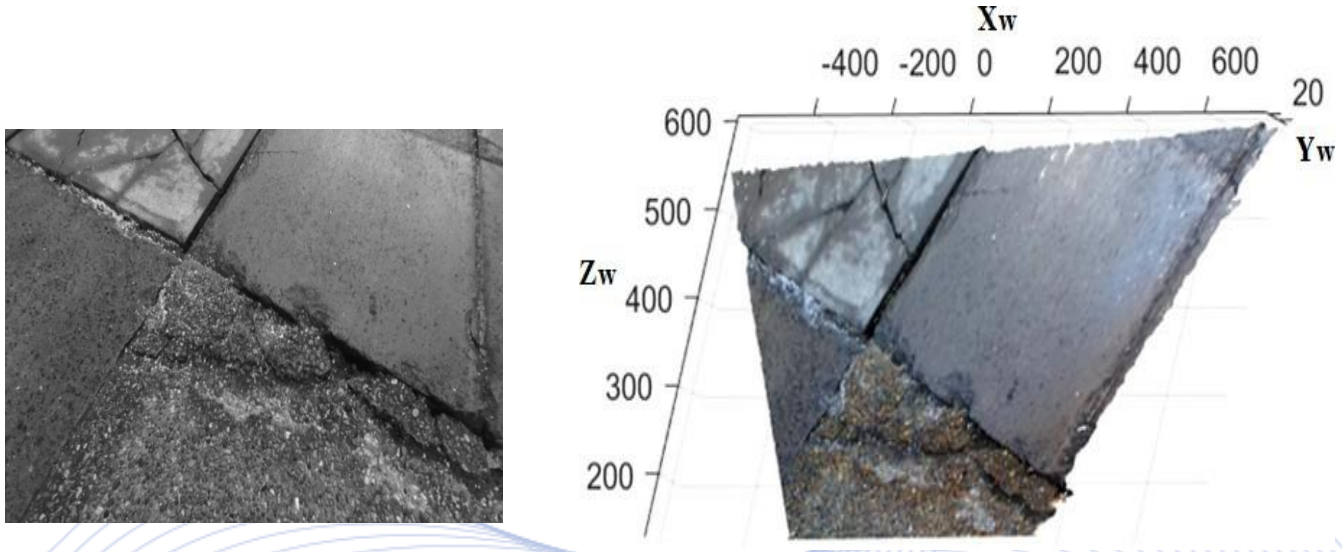


Figure:Disparity maps [14].

SRP+PT

Road surface 3D reconstruction result:



(a) (b)

Figure:Road surface 3D reconstruction result; (a) original left image; (b) reconstructed road surface.

PT+FBS

- FBS refers to fast bilateral stereo.
- FBS utilizes bilateral filters to process the 3D cost volumes. This process can be considered as a global optimization process (realized using a local filter).
- FBS is very parallel-efficient, and it can be easily implemented on some state-of-the-art GPUs.

PT+FBS

A demo video can be found:
https://www.youtube.com/watch?v= -YmlxojVMI.

Our experimental set-up:

Figure:Experimental set-up [3].

PT+FBS

Some experimental results:

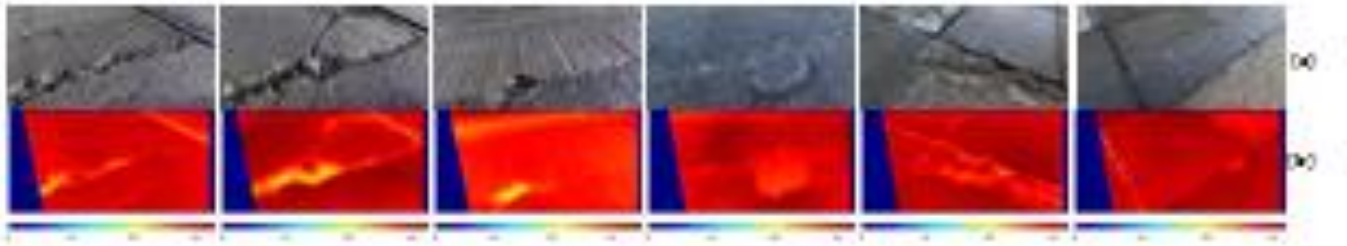


Figure:Experimental results I[3].

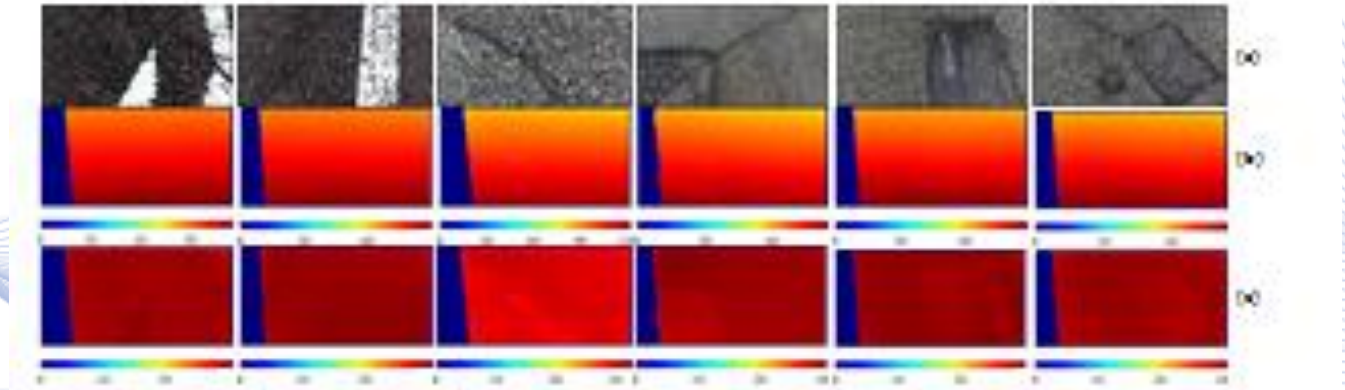


Figure:Experimental results II[3].

Structure from Motion (SfM)

- Structure from Motion (SfM) perfoms two tasks simultaneously:
  - 3D scene geometry reconstruction from a set of camera images and
  - Camera calibration.
- Images can be cquired by:
  - multiple synchronized cameras or
- one moving camera, or unsyncroniz3ed multiple cameras, if the scene and illumination are static.

Structure from Motion (SfM)

- Initial SfM stages end up providing an accurate initial guess to non-linear re-projection error optimization (Bundle Adjustment):

$$\underset{\mathbf{T}_{iw},\mathbf{X}_{wj}}{\operatorname{argmin}} \sum_{i,j} \rho\left(\left\|\mathbf{x}_{ij} - \pi_i\left(\mathbf{T}_{iw},\mathbf{X}_{wj}\right)\right\|^2\right)$$

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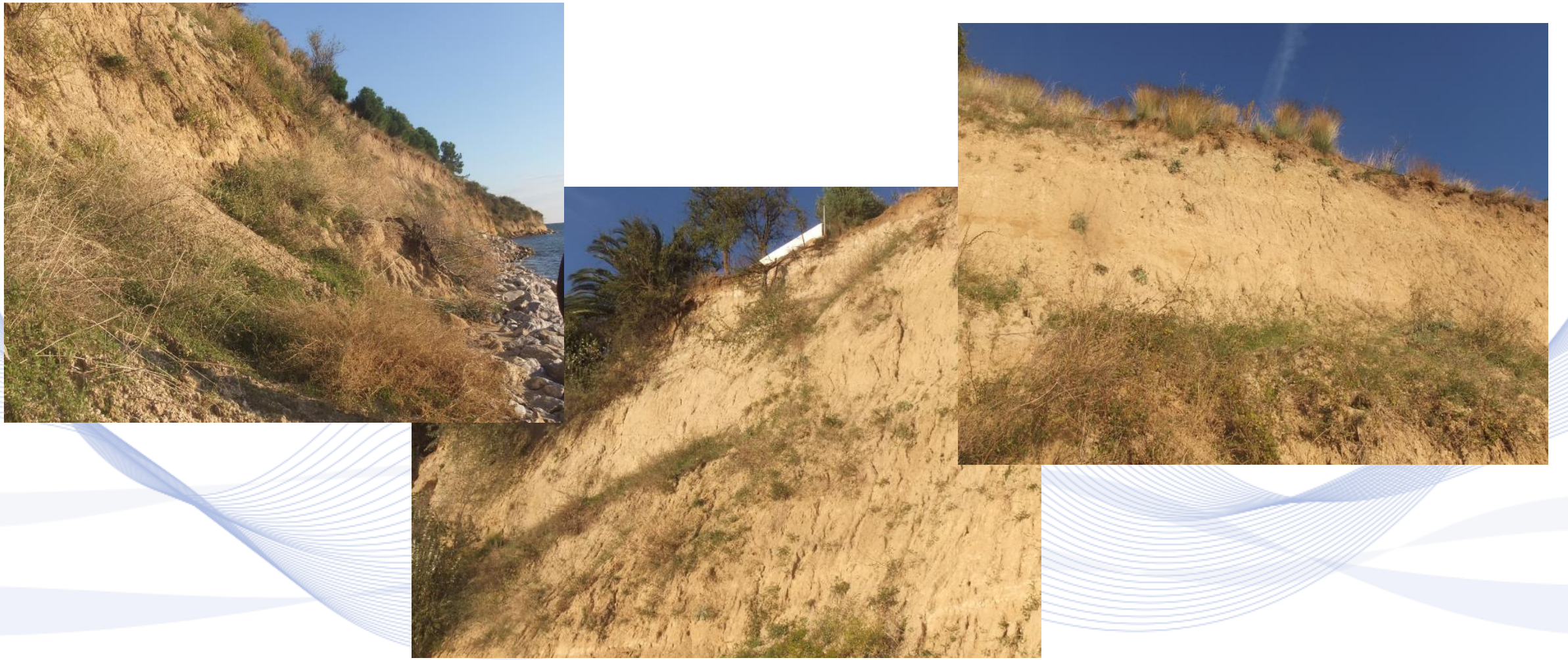
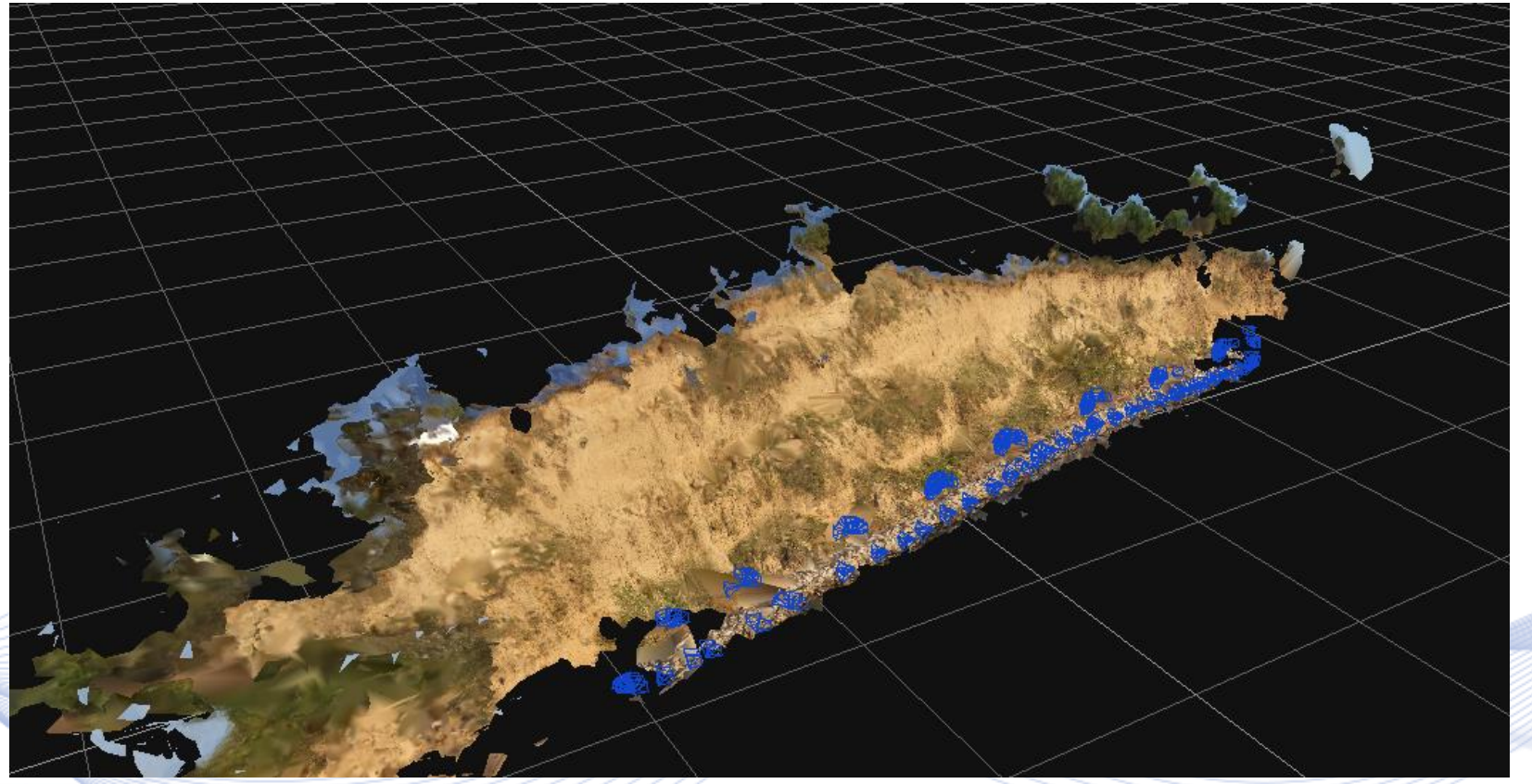
SfM for cliff surface reconstruction



SfM for cliff surface reconstruction



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Q & A

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