

3D from Photographs: Introduction

Francesco Banterle, Ph.D.
francesco.banterle@isti.cnr.it

3D from Photographs

- 3D from photographs is a technology that allows us to do a 3D reconstruction of a real-world scene starting from a set of photographs as input.
- We can see it as an alternative to 3D scanning but it has some important issues:
 - It is not MEASURING tool!
 - We cannot know the result of a 3D reconstruction beforehand.

3D from Photographs

- Advantages:
 - Fully automatic process.
 - Faster for creating models than modeling (e.g. AutoCAD, Rhinoceros, etc.).
 - Good scalability: from tiny (e.g., a toy) to large models (e.g., an entire city).
 - Unskilled users can create 3D models.
 - Economically cheap; i.e., a digital camera.

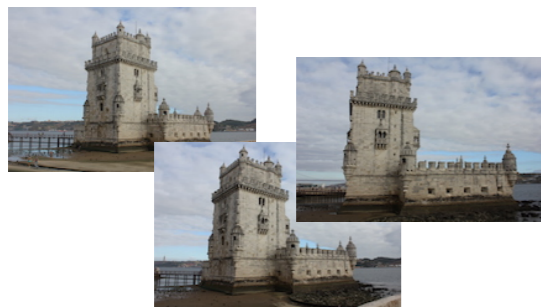
3D from Photographs

- Disadvantages:
 - Accuracy may be low; it can be improved with expensive set-ups.
 - Some real-world objects cannot be captured.
 - A generated 3D model may not match ground truth due to skew.

3D from Photographs

- The 3D model is generated using automatic Computer Vision techniques.
- The process has three main steps.

3D from Photographs



Photographs



Automatic
Matching of
Images



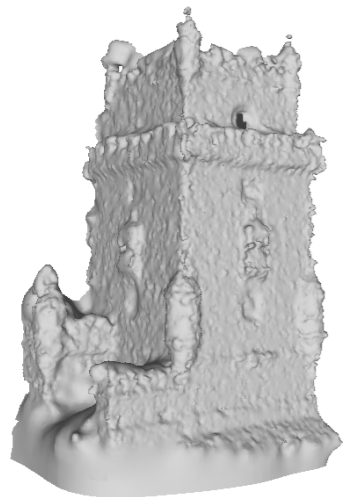
Camera
Calibration



Dense
Matching

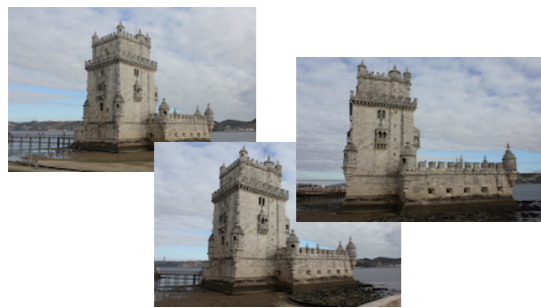


Surface
Reconstruction



3D model

3D from Photographs



Photographs



Automatic
Matching of
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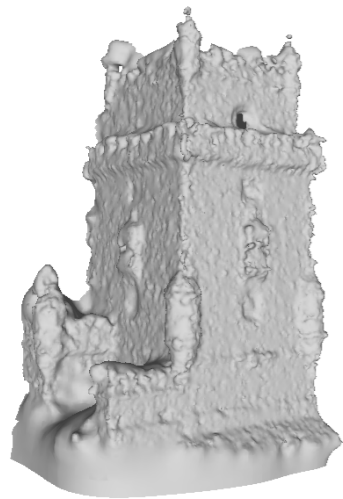
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Surface
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3D model

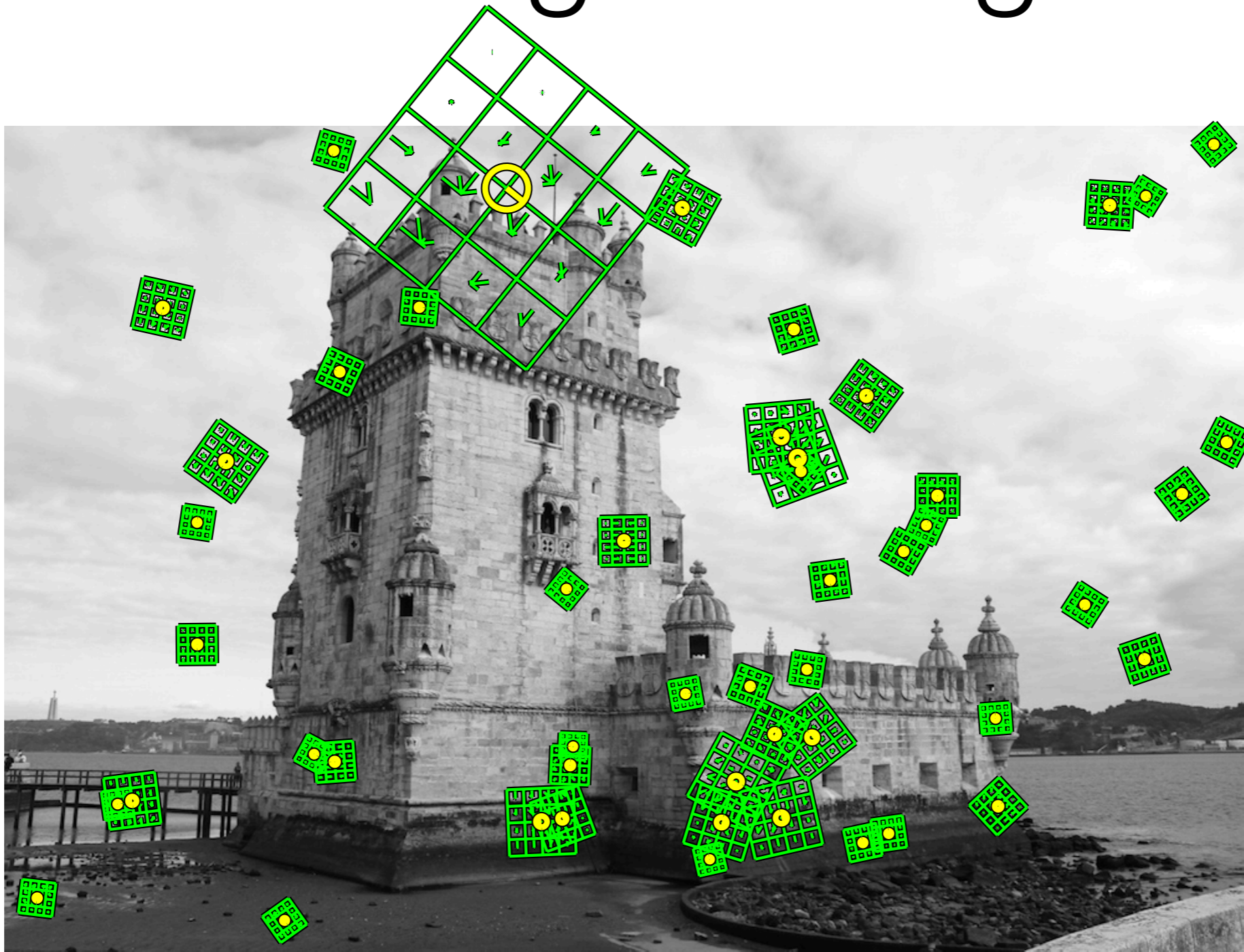
Automatic Matching of Images

- The entire process is based on finding matches between images.
- This means that you have to shoot pictures not too far apart, so that the algorithm can match them easily.

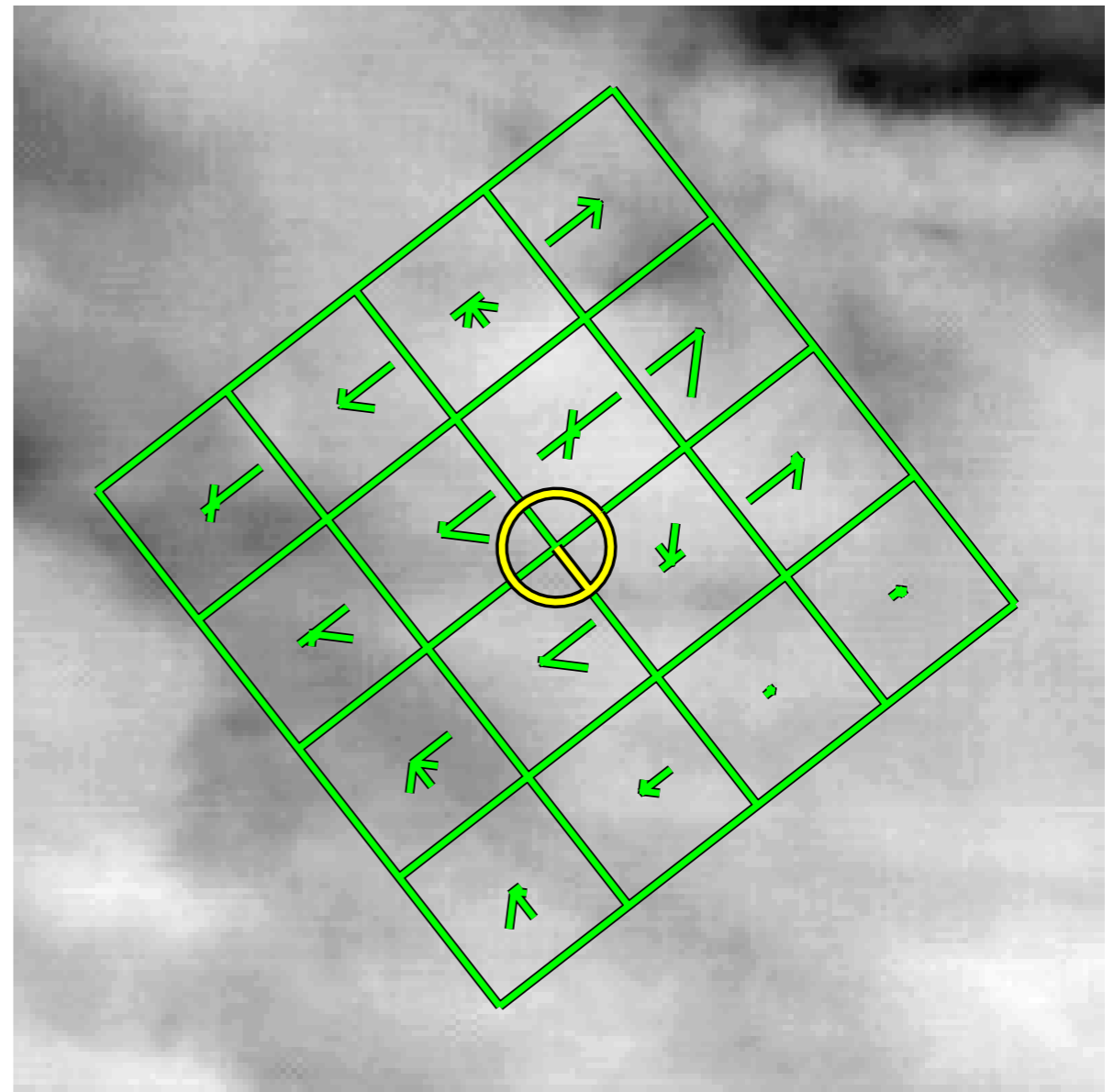
Automatic Matching of Images

- For any object in an image, “*interesting points*” (or **corners**) on the object can be extracted to provide a “*feature description*” (or **descriptor**) of the corner.
- A descriptor of an object corner (extracted from an image) can be employed to locate the object in another image containing many other objects.

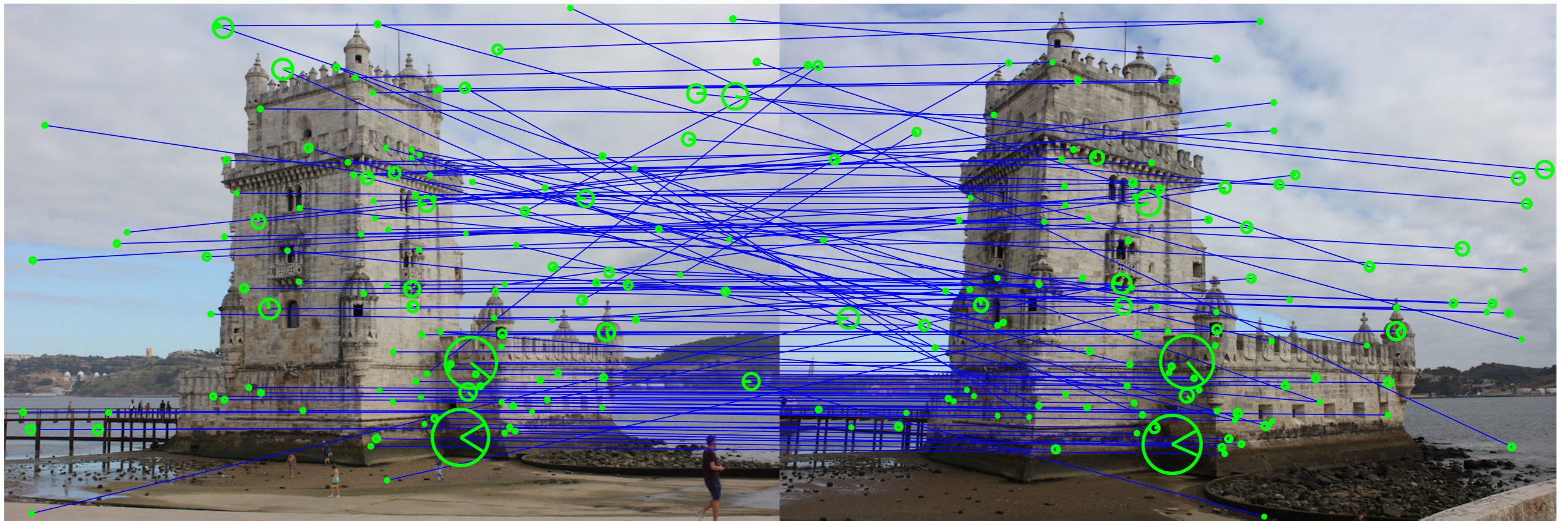
Automatic Matching of Images



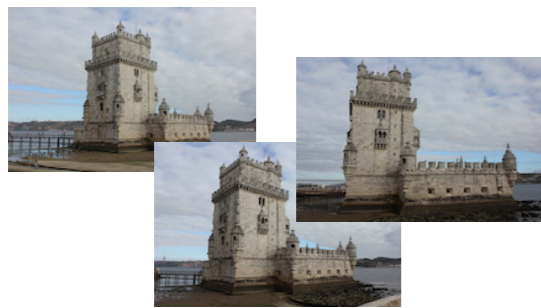
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Automatic Matching of Images



3D from Photographs



Photographs



Automatic
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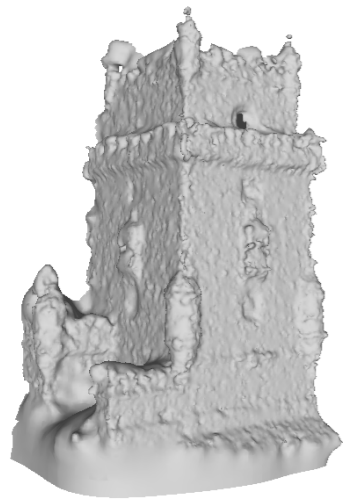
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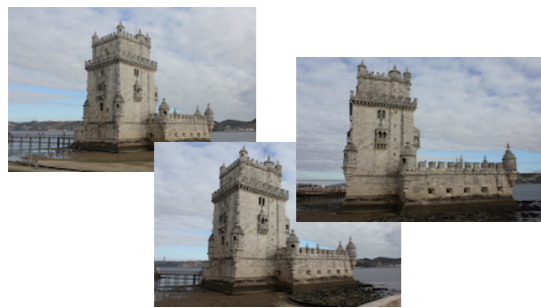


3D model

Camera Calibration

- No prior knowledge about camera calibration is available.
 - All information must be recovered from photographs.
- It is crucial that we have enough information in photographs.
- Important factors:
 - Motion of the camera
 - General structure of the scene
 - Enough overlap: only points that are visible in at least three images are useful.
 - **Note that** what you want reconstruct and how you get the photographs have great influence on the final reconstruction!

3D from Photographs



Photographs



Automatic
Matching of
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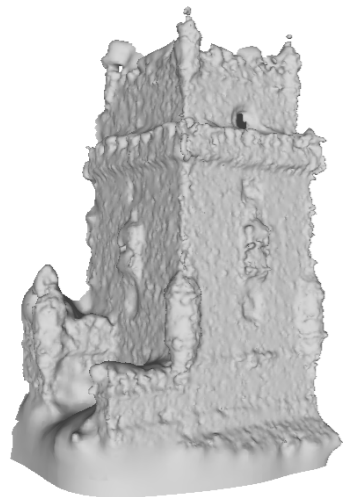
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3D model

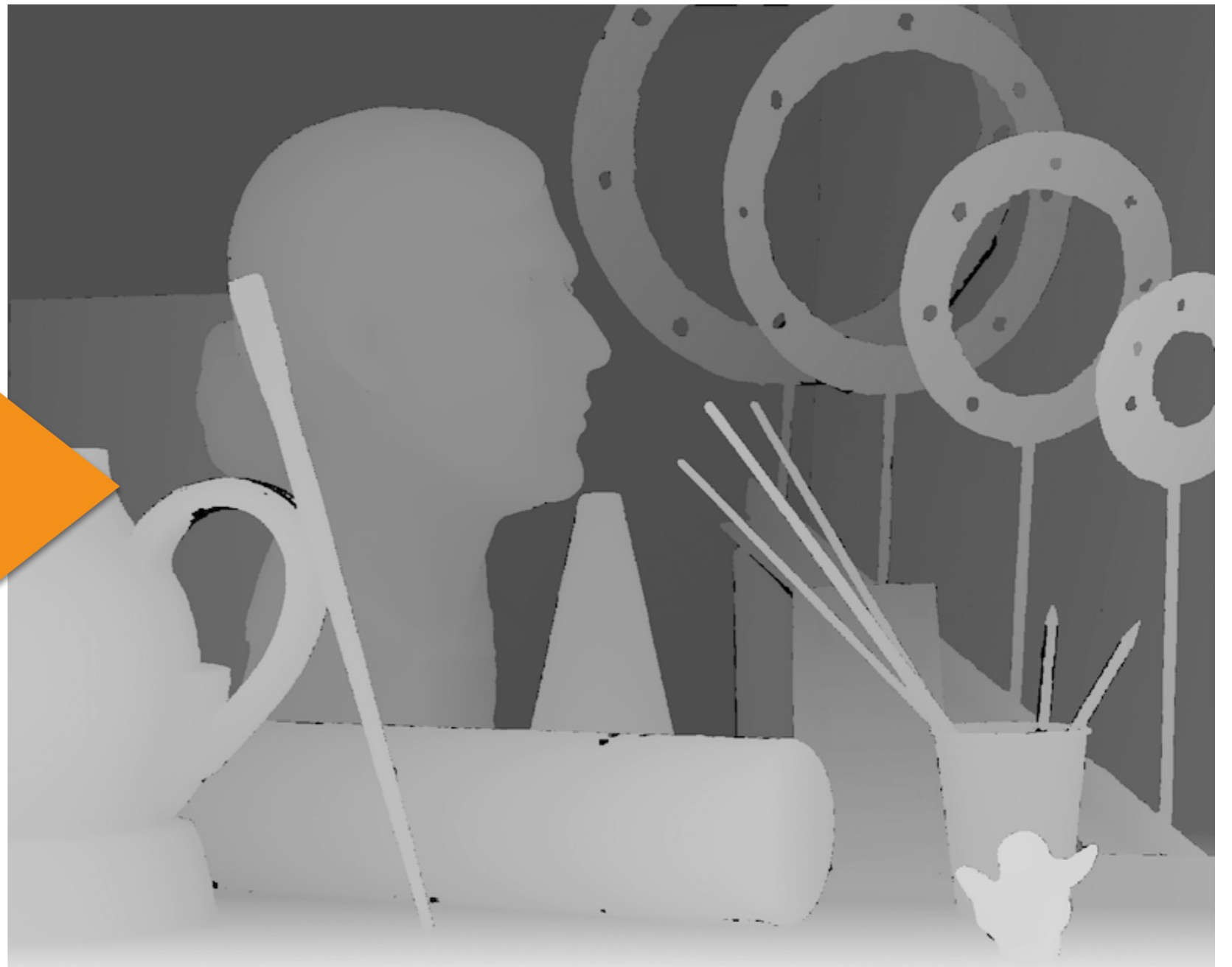
Dense Matching

- After recovery of the camera calibration, we can compute dense depth maps:
 - We need a pair of images for each depth map.
- These contain the depth of every pixel and a quality measure (how confident we are of each particular pixel).

Dense Matching

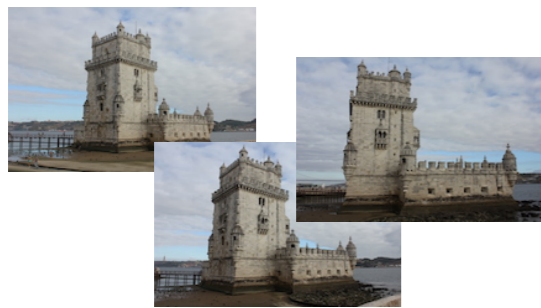


Input



Depth Map

3D from Photographs



Photographs



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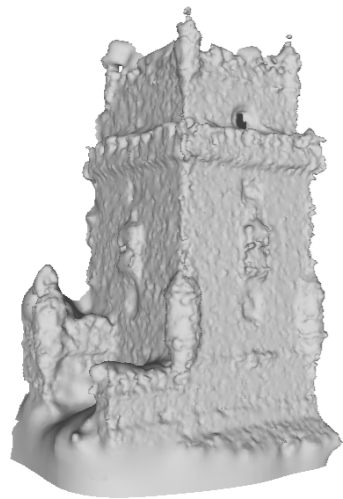
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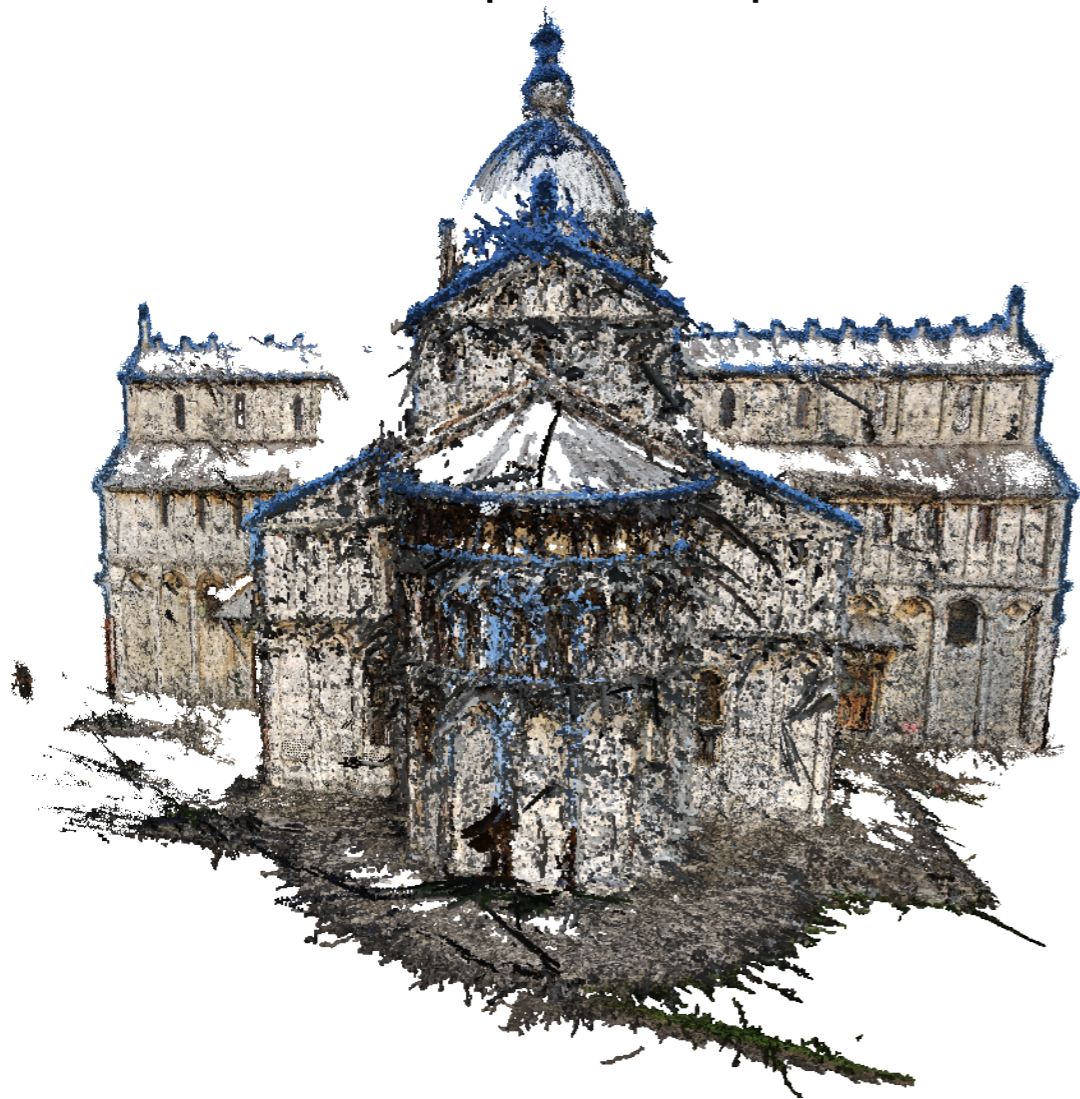
Surface
Reconstruction



3D model

Surface Reconstruction

- To compute an unique 3D surface by integration of the all the depth maps of each image:



Dense Point Cloud



Final 3D Model

Photographs Best Practice

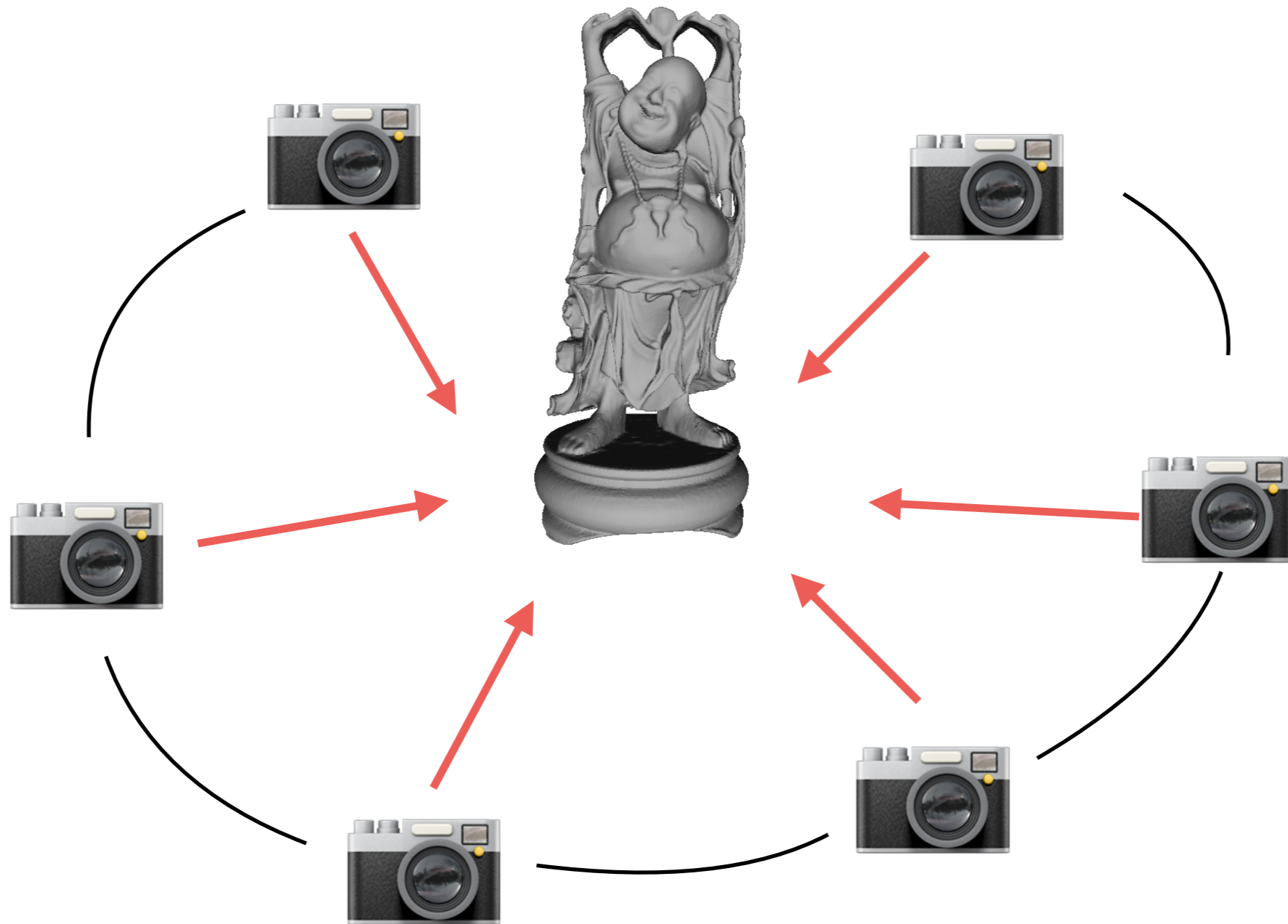
Best Practice

- How do we shoot pictures?
- Practical suggestions and limitations to avoid failures during reconstruction.

Best Practice: A Good Sequence

- We have to shoot a picture of the same location for every step made in the shooting sequence.
- Each picture needs to be of the same scene, but captured from a slightly different point of view.
- We have to walk with the camera in an arc around the scene and keeping the entire scene all times.
- We have to keep the same focal length; i.e., zoom!

Best Practice: A Good Sequence

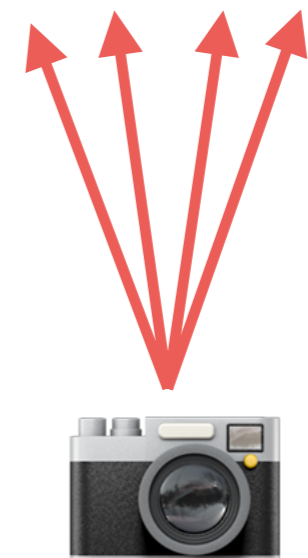


Best Practice: A Good Sequence

- We have to capture as many photographs as we can:
 - The more the better.
 - We need at least 5-6 photographs for a very basic reconstruction!
 - A reconstruction algorithm can fail if only four photographs or less are given as input!

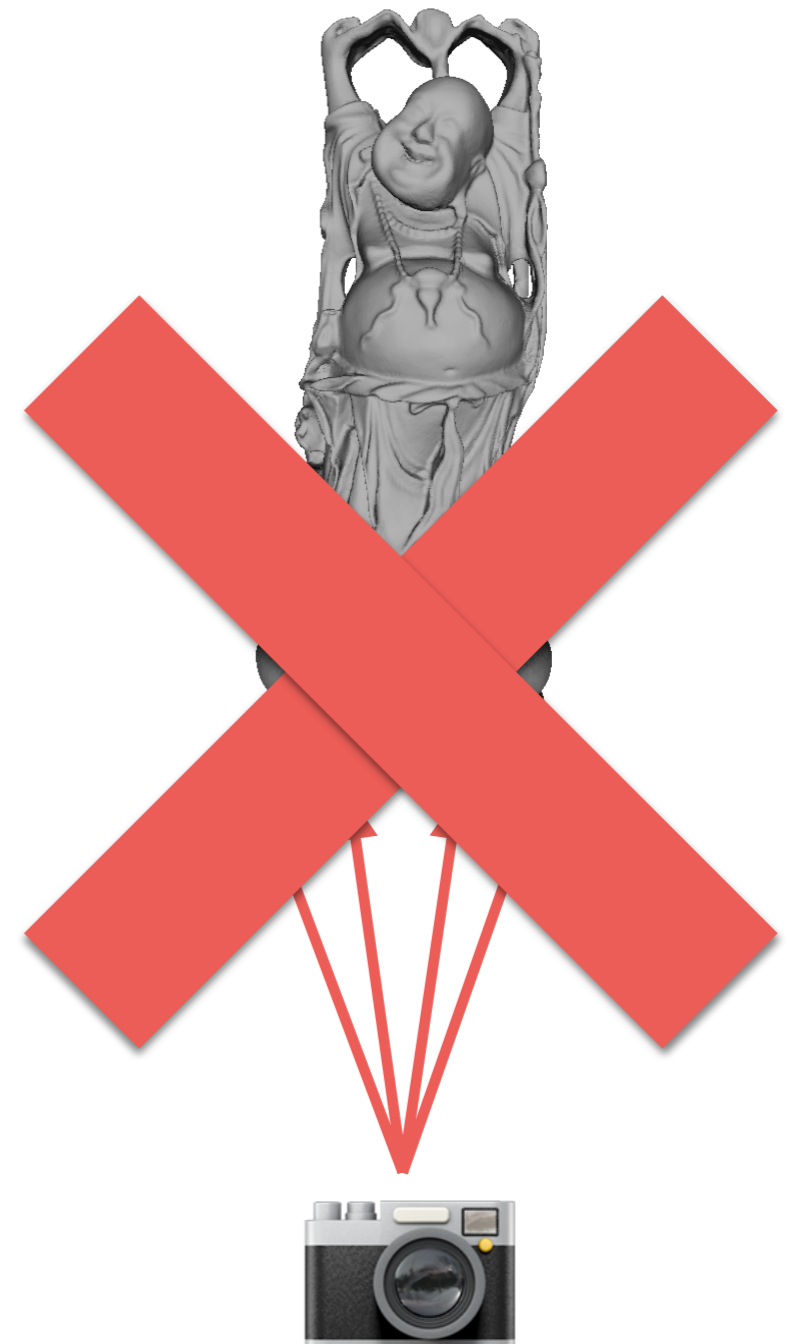
Best Practice: Bad Sequences

- We have to avoid “pan” sequences (panoramas sequences); i.e., capturing photographs on a plane.
- These sequences do not have 3D information.



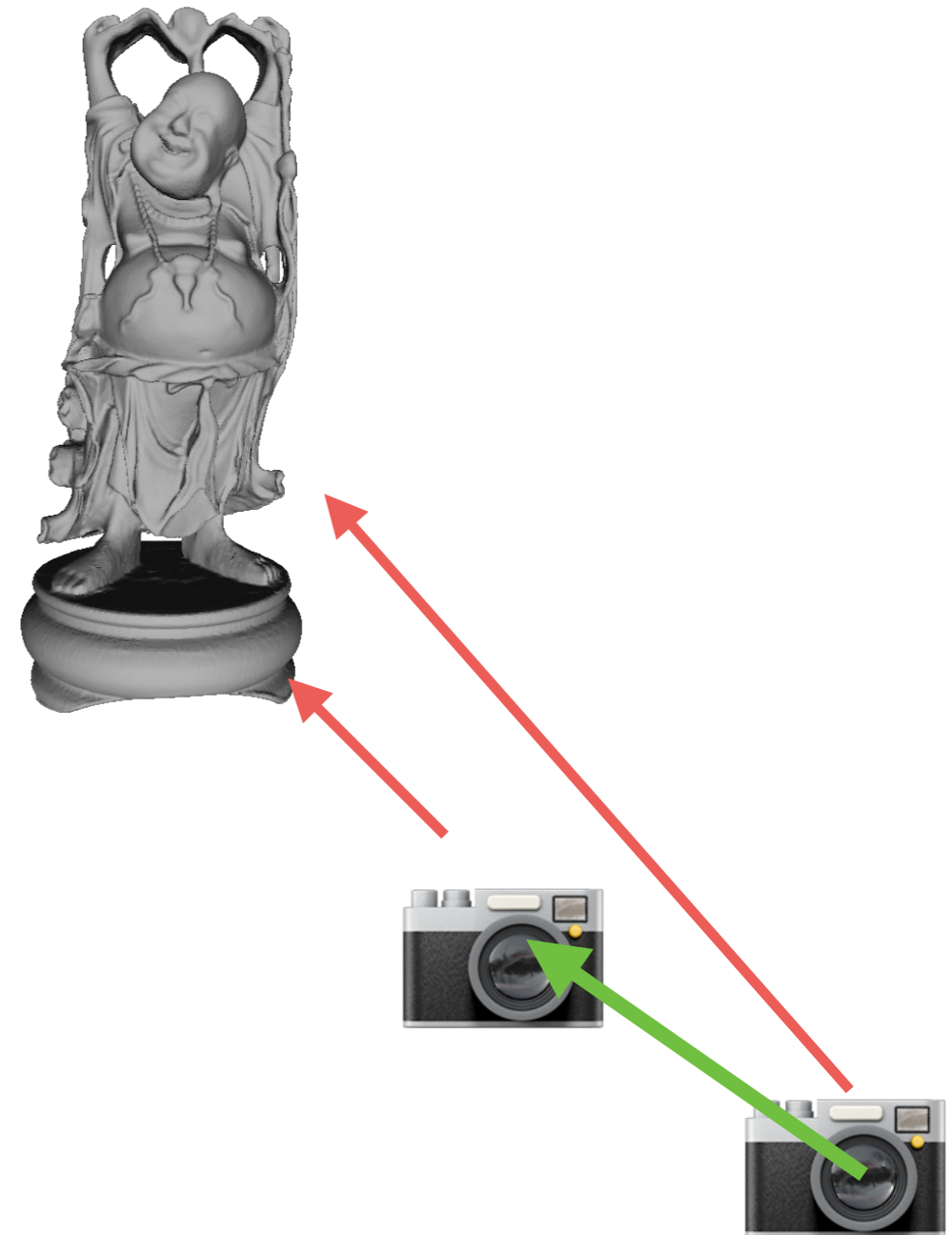
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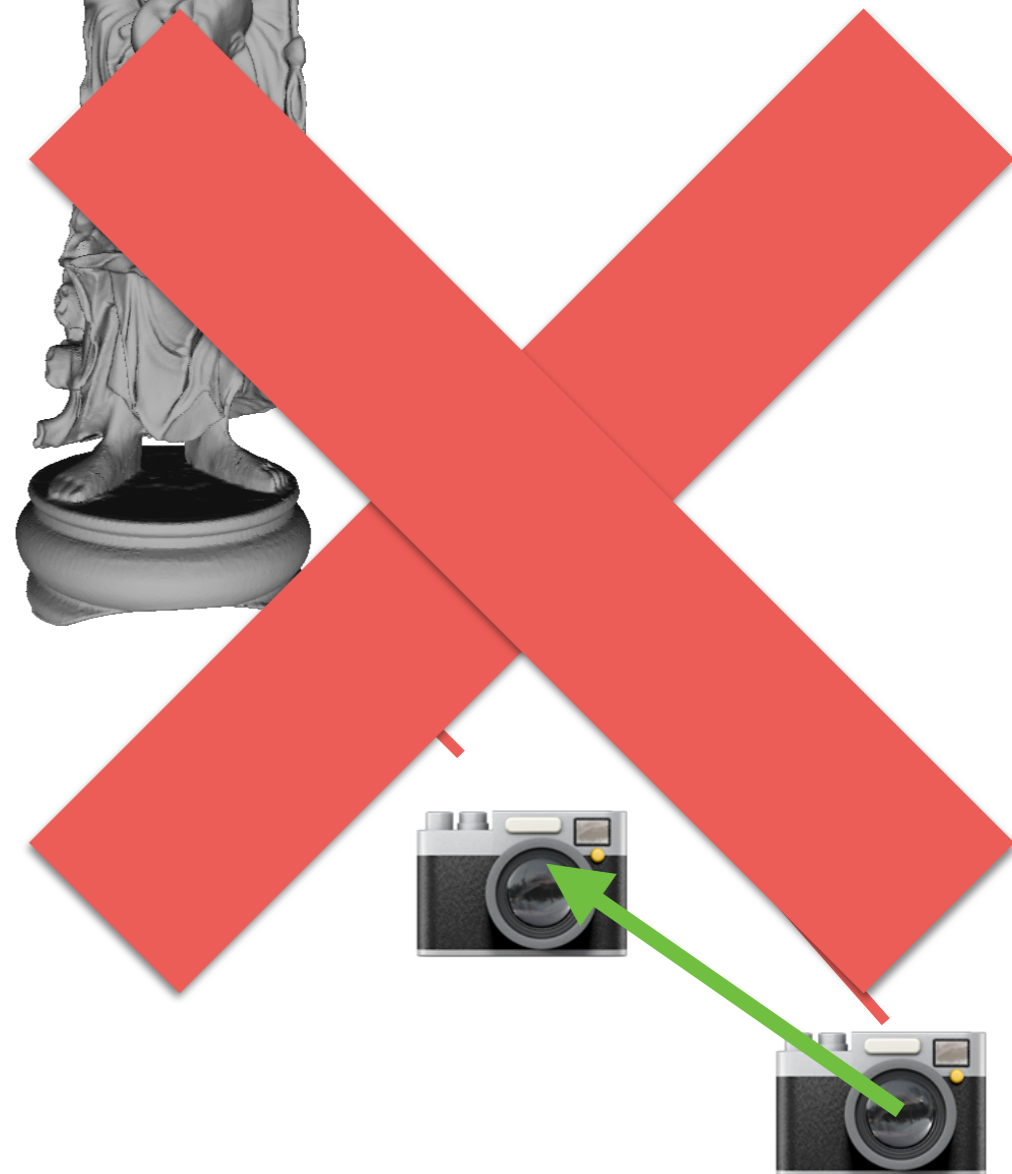
Best Practice: Bad Sequences

- We have to avoid photo sequences in which we shoot toward/outward the scene to capture!



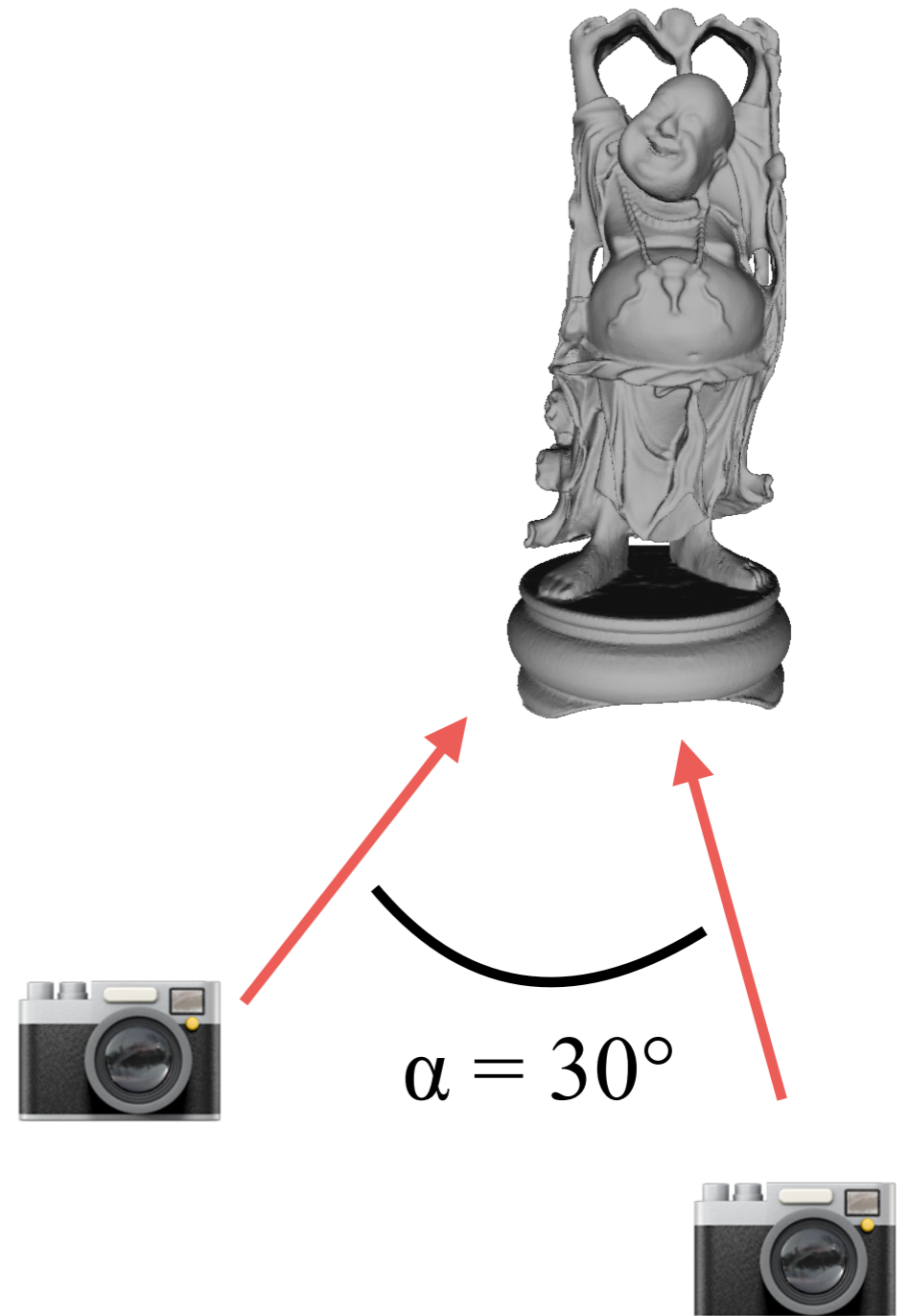
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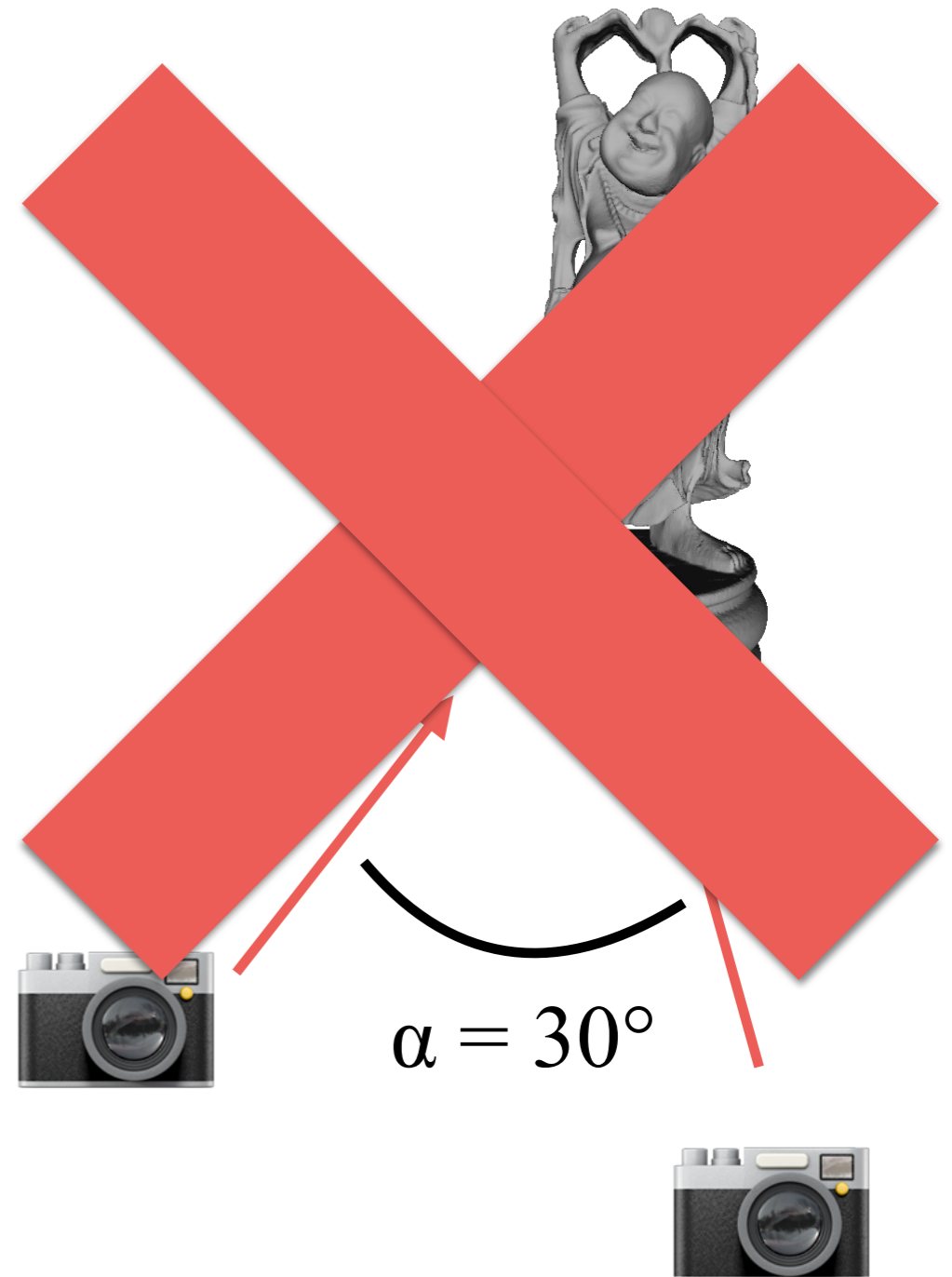
Best Practice: Bad Sequences

- If the angle between a photograph and another is too small, the reconstruction algorithm may fail or produce low quality reconstruction!



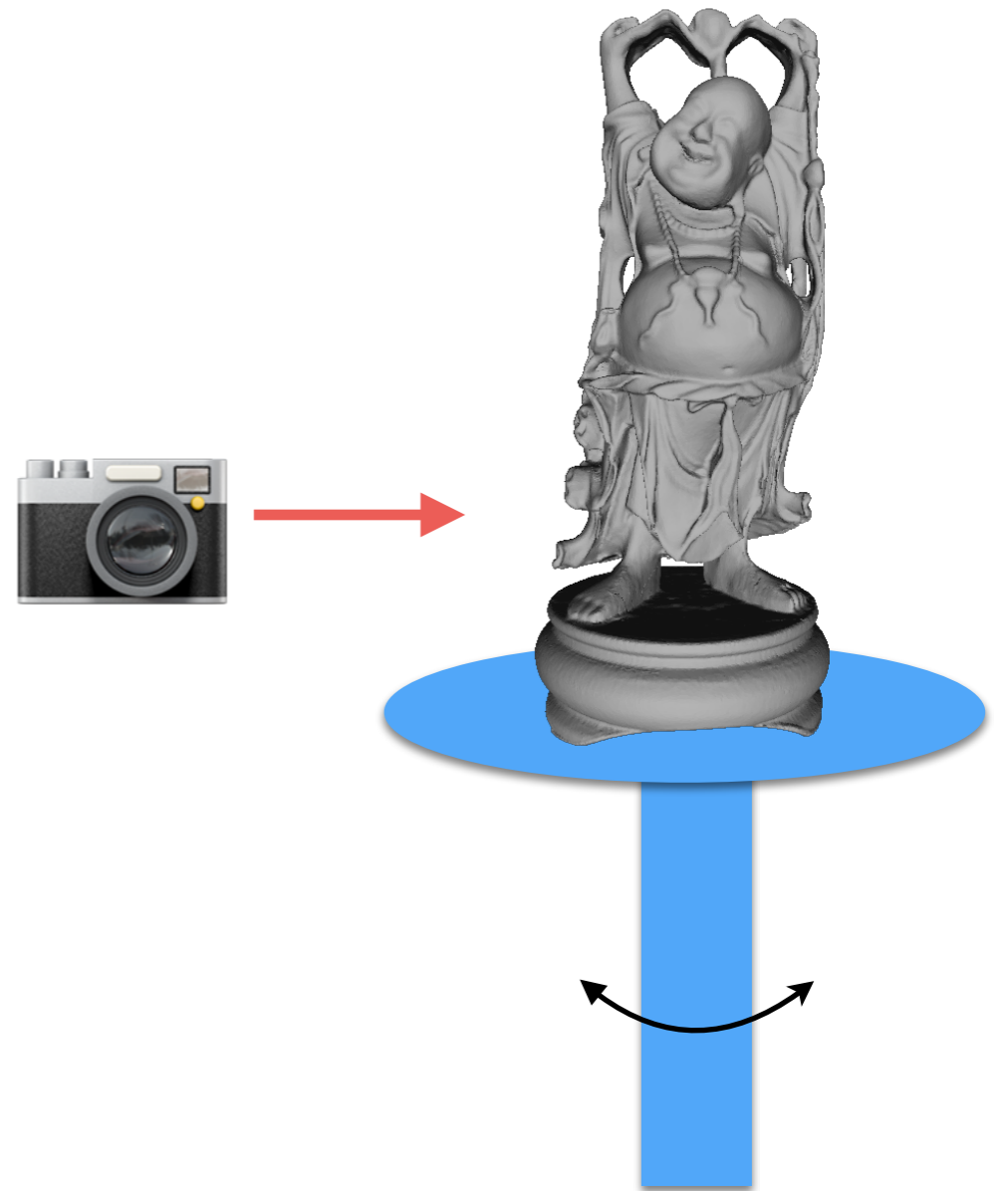
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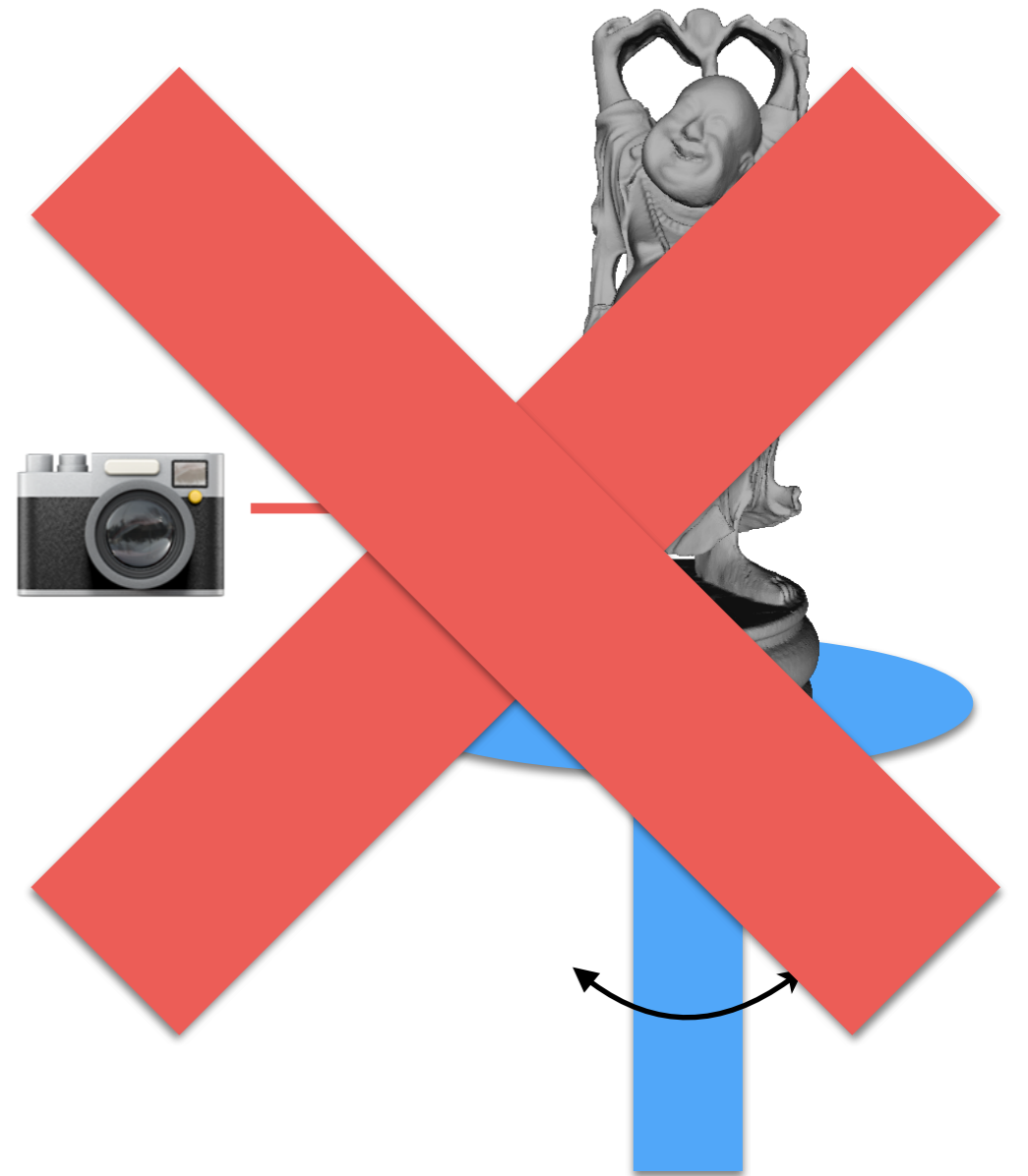
Best Practice: Bad Sequences

- We cannot take photographs by rotating the person/object using a turnable table!!



Best Practice: Bad Sequences

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Best Practice: Planar Objects

- We cannot take photographs of planar objects!



Best Practices: Not Enough Textures



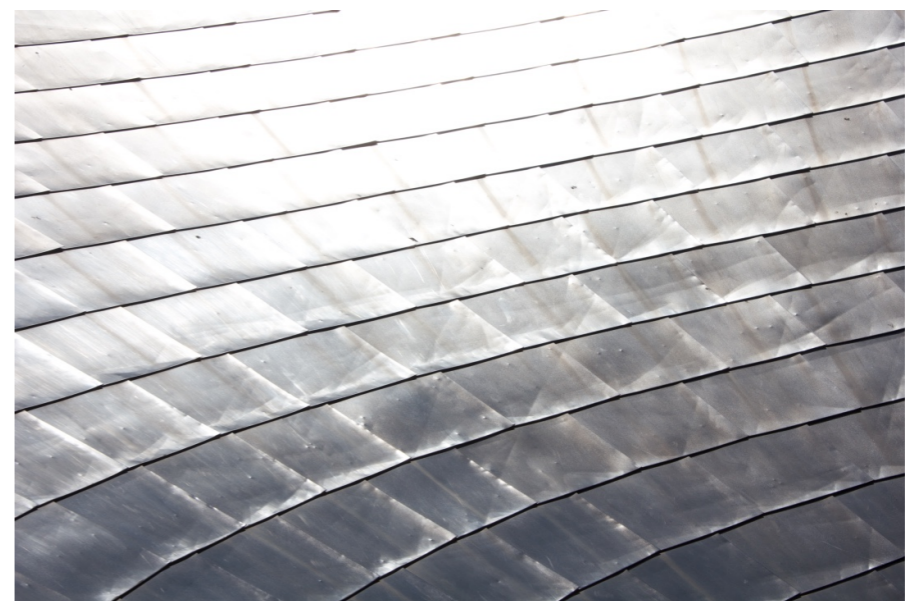
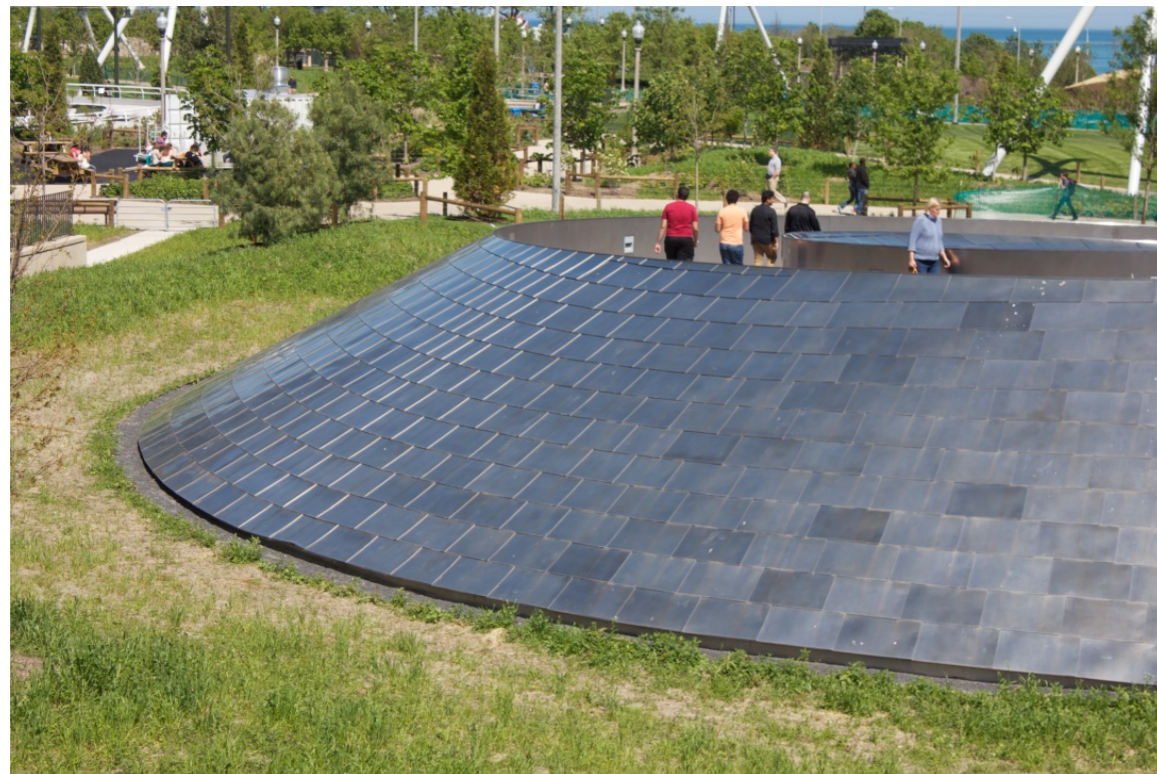
Best Practices: Non Constant Appearance



Best Practices: Non Constant Appearance



Best Practices: Non Constant Appearance

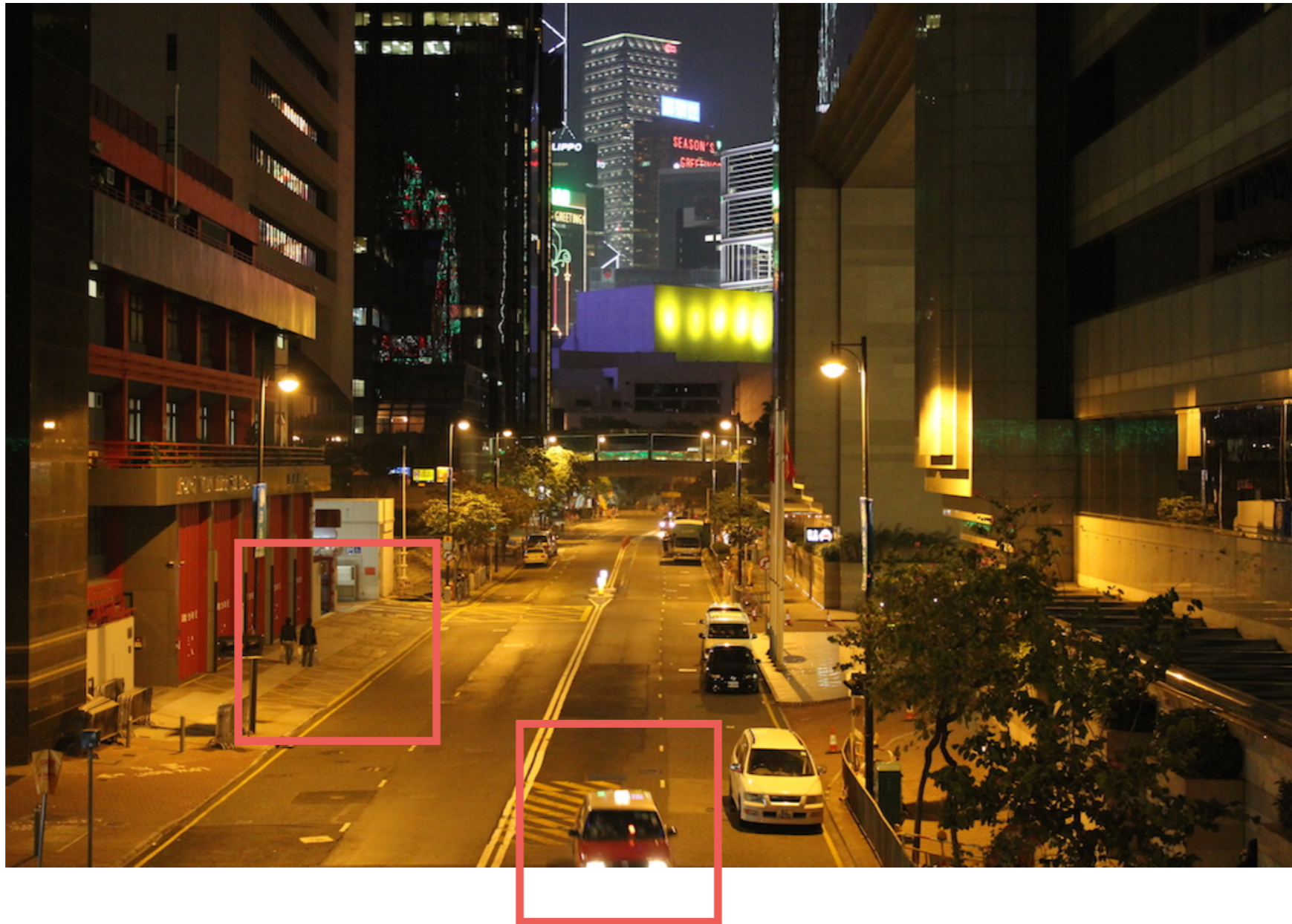


Best Practices: Dynamic Scenes



Moving people or objects appear/disappear!

Best Practices: Dynamic Scenes



Moving people or objects appear/disappear!

Best Practices: Blurry Photos

- Blurry photos are caused by:
 - Movements in the scenes or of the camera; i.e., motion blur.
 - Camera is out-of-focus
- These photos **MUST** be avoided!
- They cause issues during reconstruction and/or degrade the final result!

Blurry Photos



Blurry Photos



Best Practices: Self-Occlusions

- Self-occlusions have to be treated with care!
- We have to cover all self-occluded parts.



Best Practices: Lighting Conditions



Cloudy days are ideal because lighting is stable!

Best Practices: Lighting Conditions



Avoid moving shadows!

Capturing People

- To capture faces, hands, etc, we have to:
 - Make people to stay still; i.e., find a sit!
 - Use markers (e.g., checker boards) to increase features.
 - Make them wear patternful clothes.



Software

Software

Free Software:

- Regard 3D
- Multi-View Environment (MVE)
- COLMAP

Commercial Software:

- 3DZephyr
- Autodesk ReCap
- Agisoft Metashape
- RealityCapture

Software: Regard3D

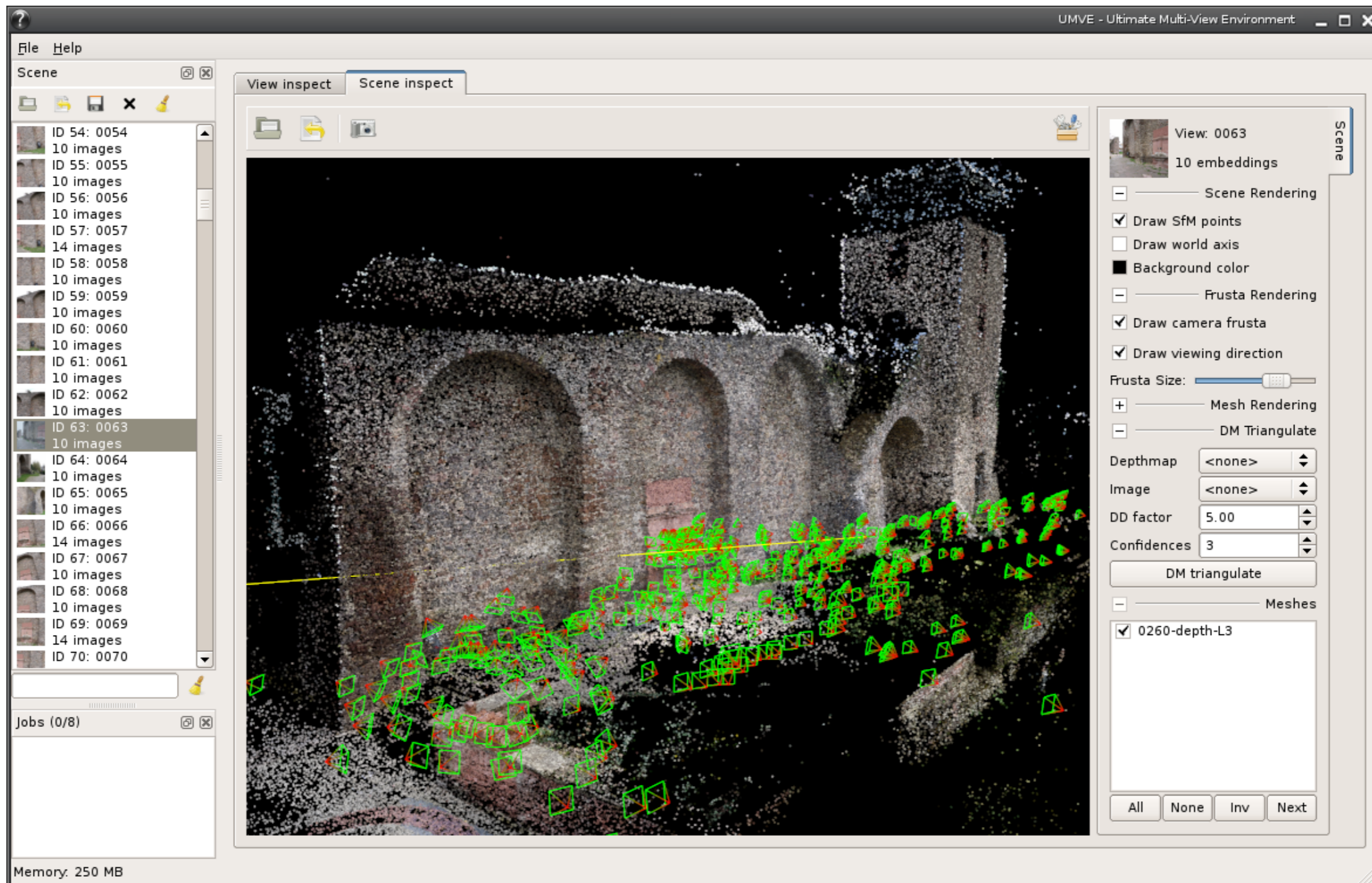
- GUI application that integrates different open-source libraries and tools (MVE, OpenMVG, and CMVS/PMVS).
- Complete pipeline; from the Structure-from-Motion to the Surface Reconstruction.
- Open-source (C++).
- This tool works locally.
- <http://www.regard3d.org/index.php>

Software:

Multi-View Environment

- End-to-end pipeline for image-based geometry reconstruction: Structure-from-Motion, Multi-View Stereo, and Surface Reconstruction.
- Command line applications, but most features are also available from our user interface UMVE.
- Open-source (C++).
- This tool works locally.
- External tool for high resolution texturing:
 - <https://github.com/simonfuhrmann/mve>

Software: Multi-View Environment



Software: COLMAP

- End-to-end pipeline for image-based geometry reconstruction:
 - Structure-from-Motion.
 - Multi-View Stereo.
- Command line and graphical user interface.
- Open-source (C++).
- This tool works locally.
- External tool for high resolution texturing:
 - <https://colmap.github.io/>

Software: 3DZephyr

- It is a local software that requires an one time fee:
 - Free version (50 photos limit).
 - \$149 Lite version.
 - \$3,900 Pro version.
- It creates high-quality 3d meshes.

Software: Autodesk ReCap

- It was a web service by Autodesk:
<https://www.autodesk.com/products/recap/overview>
- Main advantages:
 - It is robust; it works even with challenging photo sequences.
 - It creates high quality results.
- It requires a subscription per year; roughly \$360.
- It exports 3D models with color.

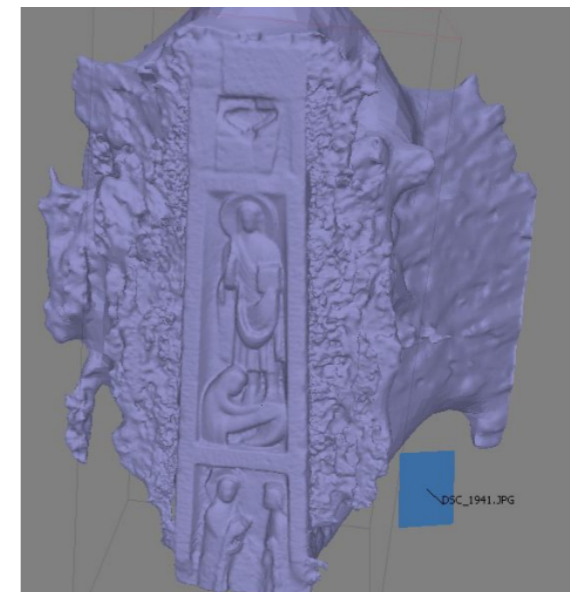
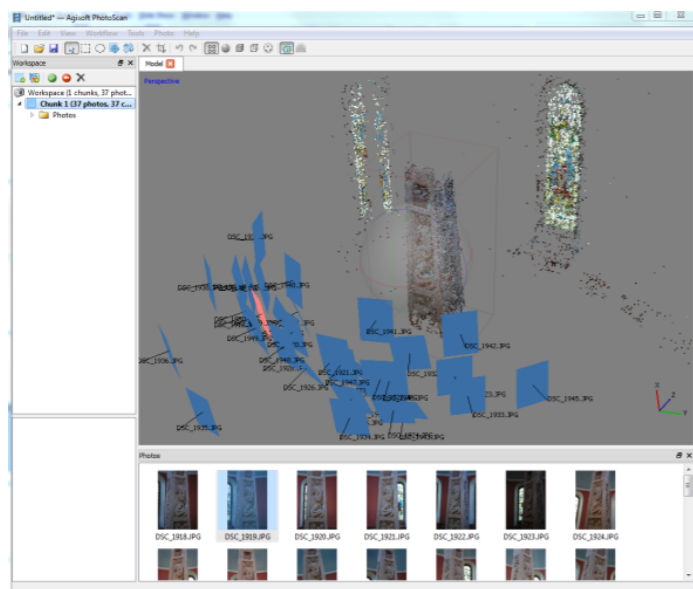
Software: Autodesk ReCap



An example generated using the previous iteration of the Software

Software: Agisoft Metashape

- It is a local software by Agisoft that requires an one time fee:
 - \$59 for students
 - \$179 standard version
- It is fast and creates high quality models with color.



Software: RealityCapture

- It is a local software by Capture Reality with a subscription fee:
 - \$10-20 subscriptions.
 - \$3,750 forever.
- The fastest software (recently a real-time capture and reconstruction inside Unity), but very expensive.

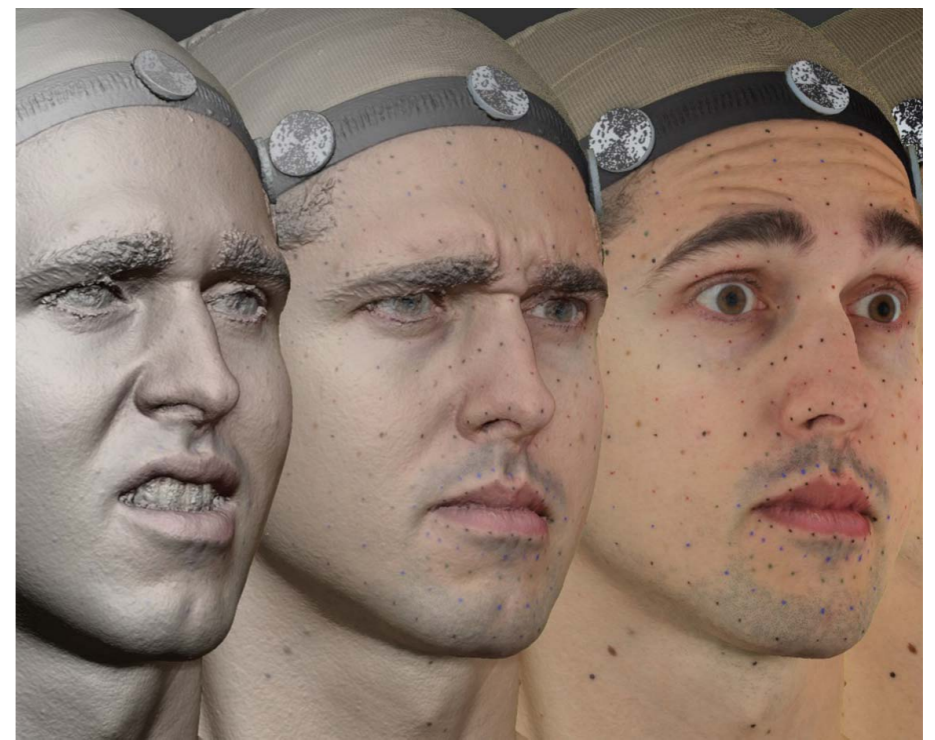
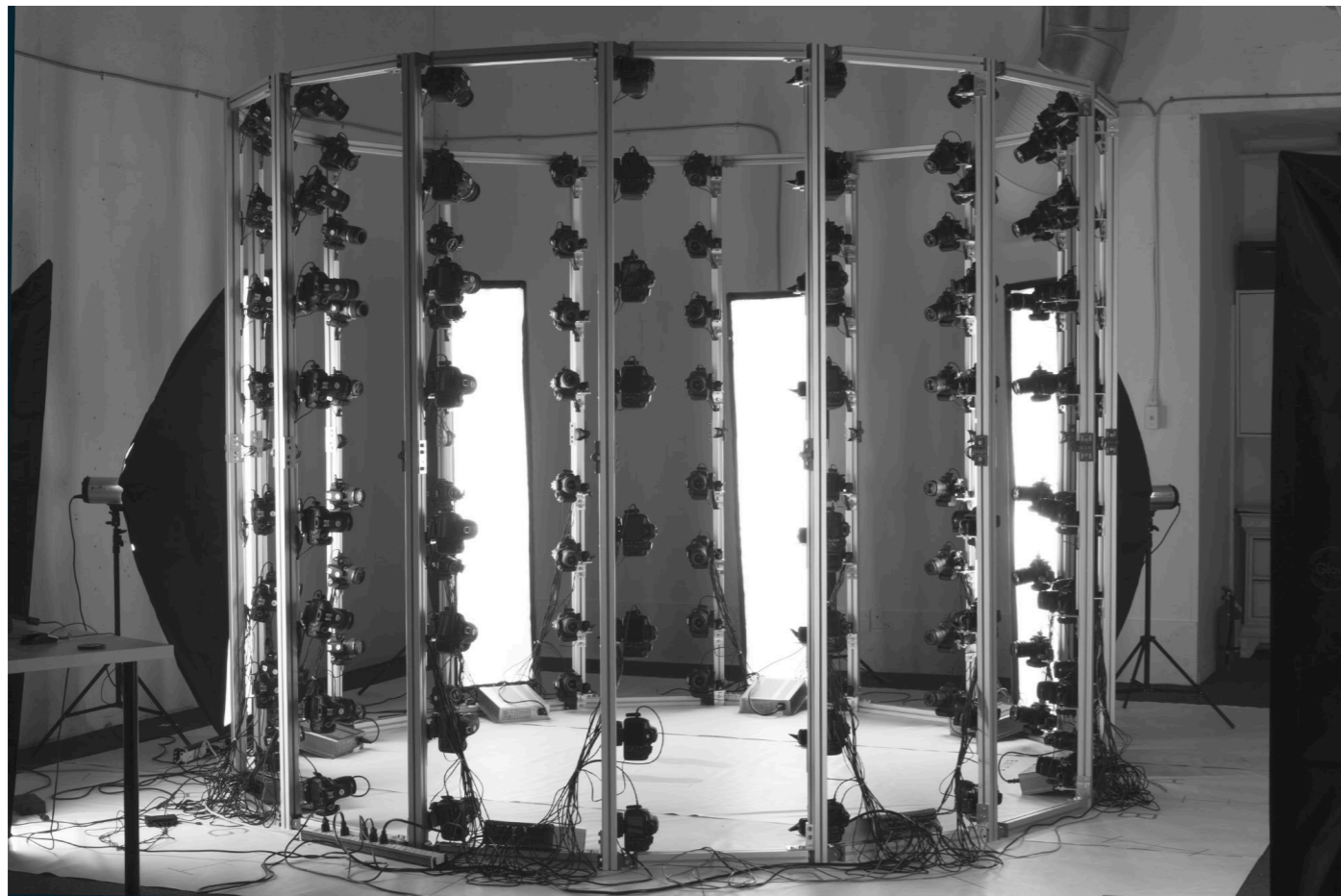
Why 3D from
Photographs in this
course?

Why?

- Fast and cheap acquisition of 3D model for 3D printing of replicas of anatomical parts.
- Full body 3D scanning
 - Healthcare
 - Research (ergonomic, biometrics, anthropology)
 - Size & Fit
 - 3D printed figurine

Full Body 3D Scanning

- 128X DSLR camera:
- <http://pixellighteffects.com/>



Full Body 3D Scanning

- Raspberry Pi with 100 camera module:
 - <http://www.pi3dscan.com>



that's all folks!

Acknowledgements

- Some images on work by:
 - Dr. Matteo Dellepiane:
 - <http://vcg.isti.cnr.it/~dellepiane/>