3D from photos
Automatic dense photogrammetry

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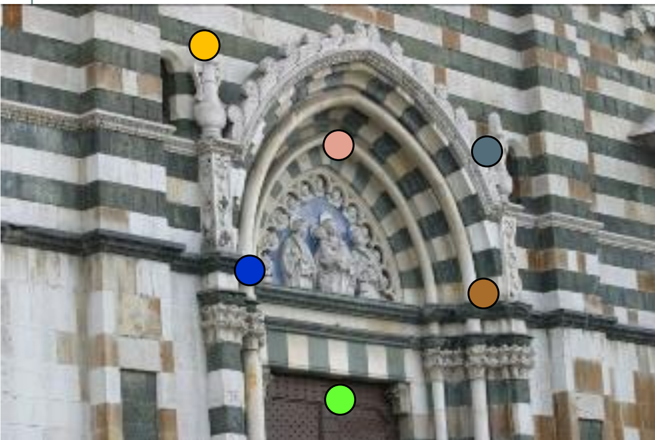
3D DIGITIZATION
FOR CULTURAL HERITAGE

3D from Images

Recap:

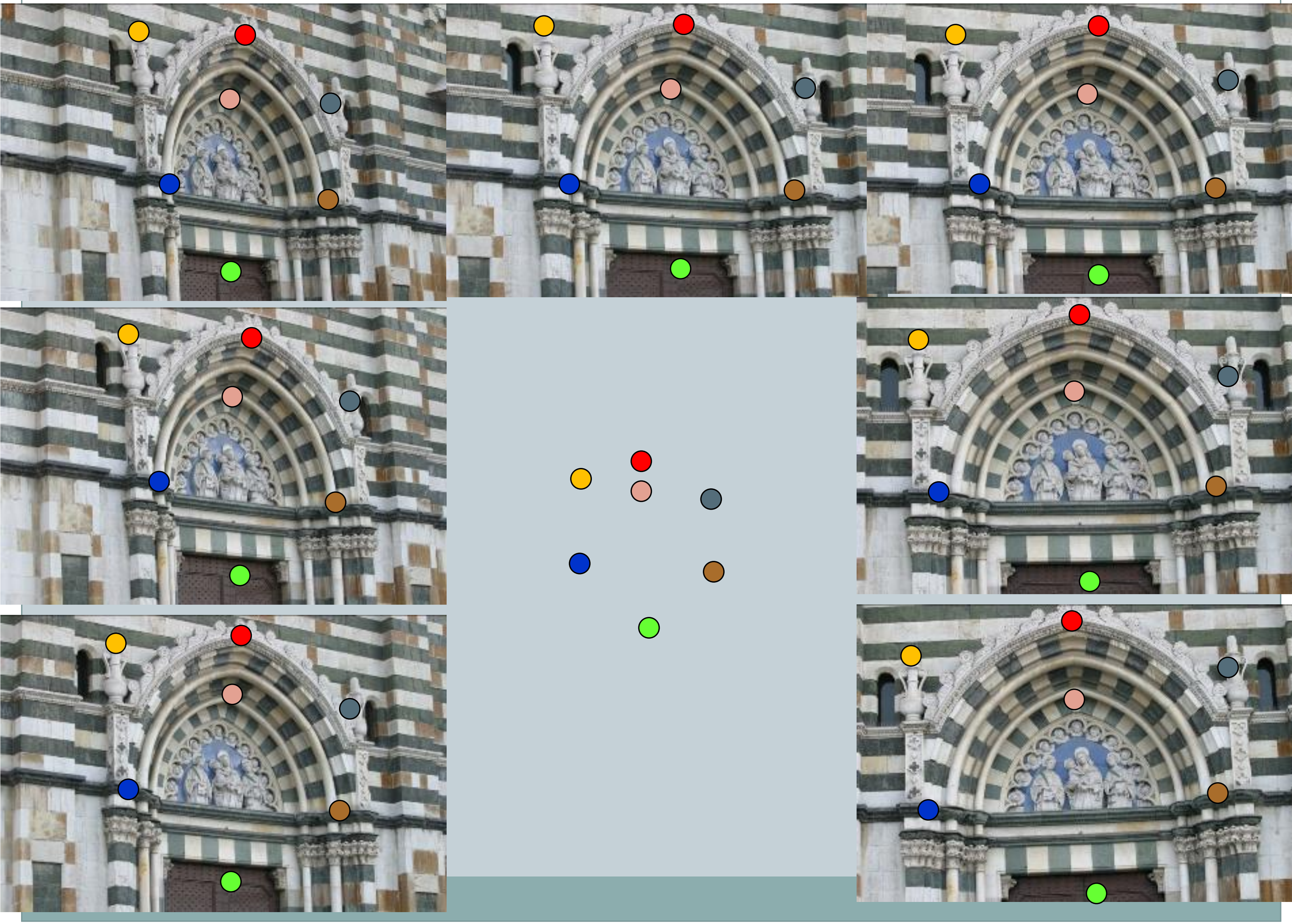
we want to have a fully automatic dense photogrammetry pipeline, starting from uncalibrated images to create a 3D model

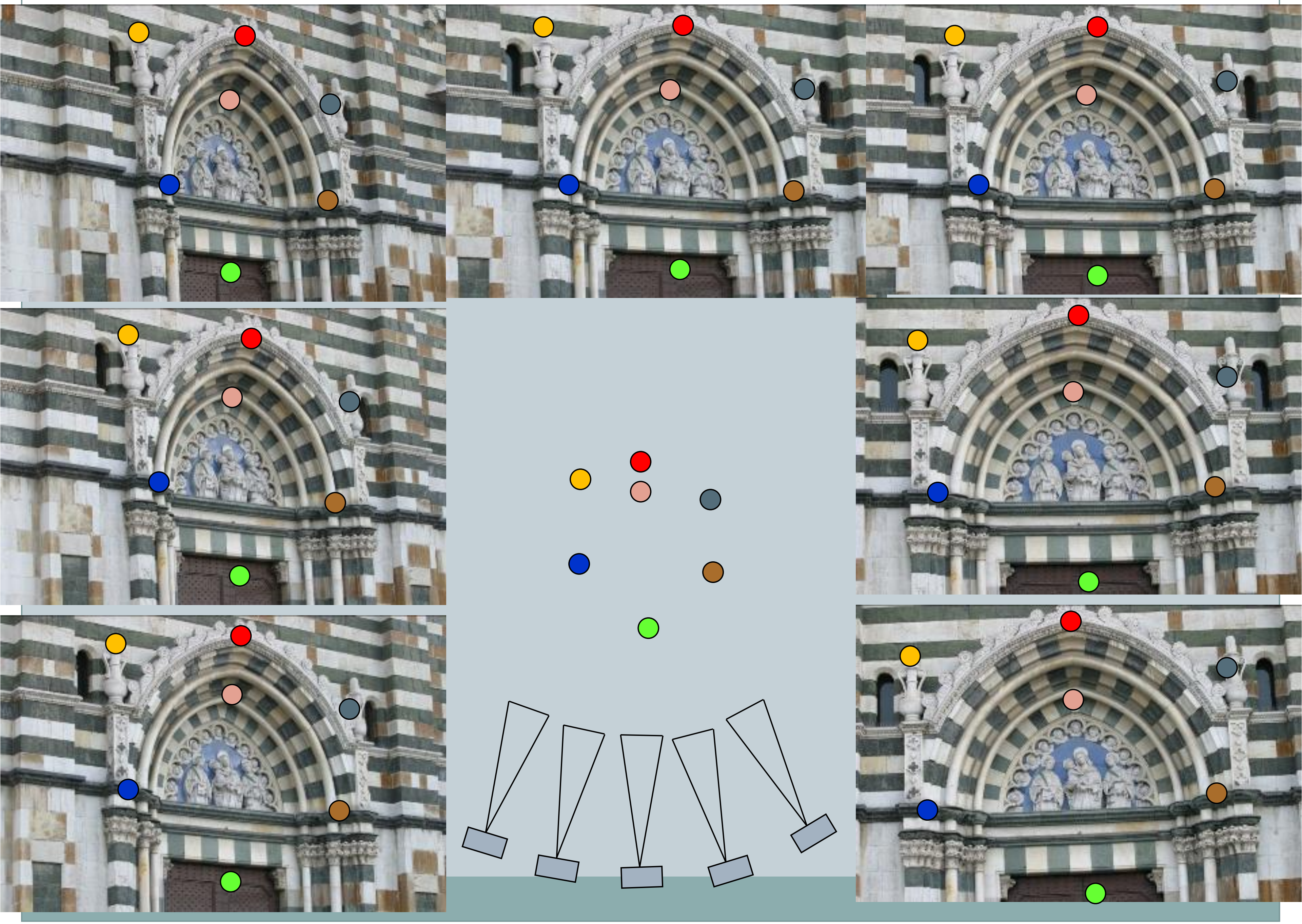
i.e. Having the PC doing automatically both processing steps: camera calibration&orientation and dense stereo match

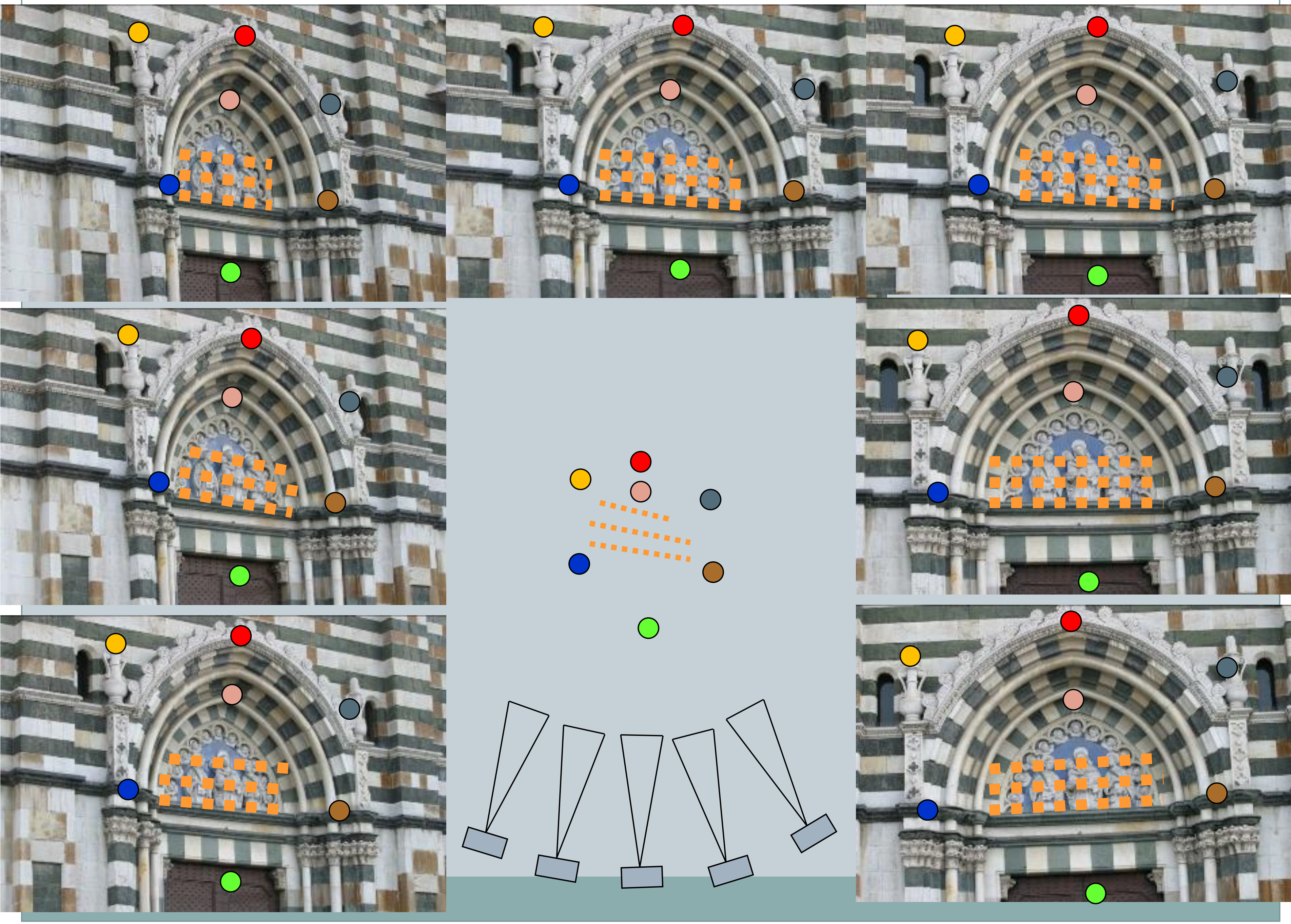












Calibration and Orientation step

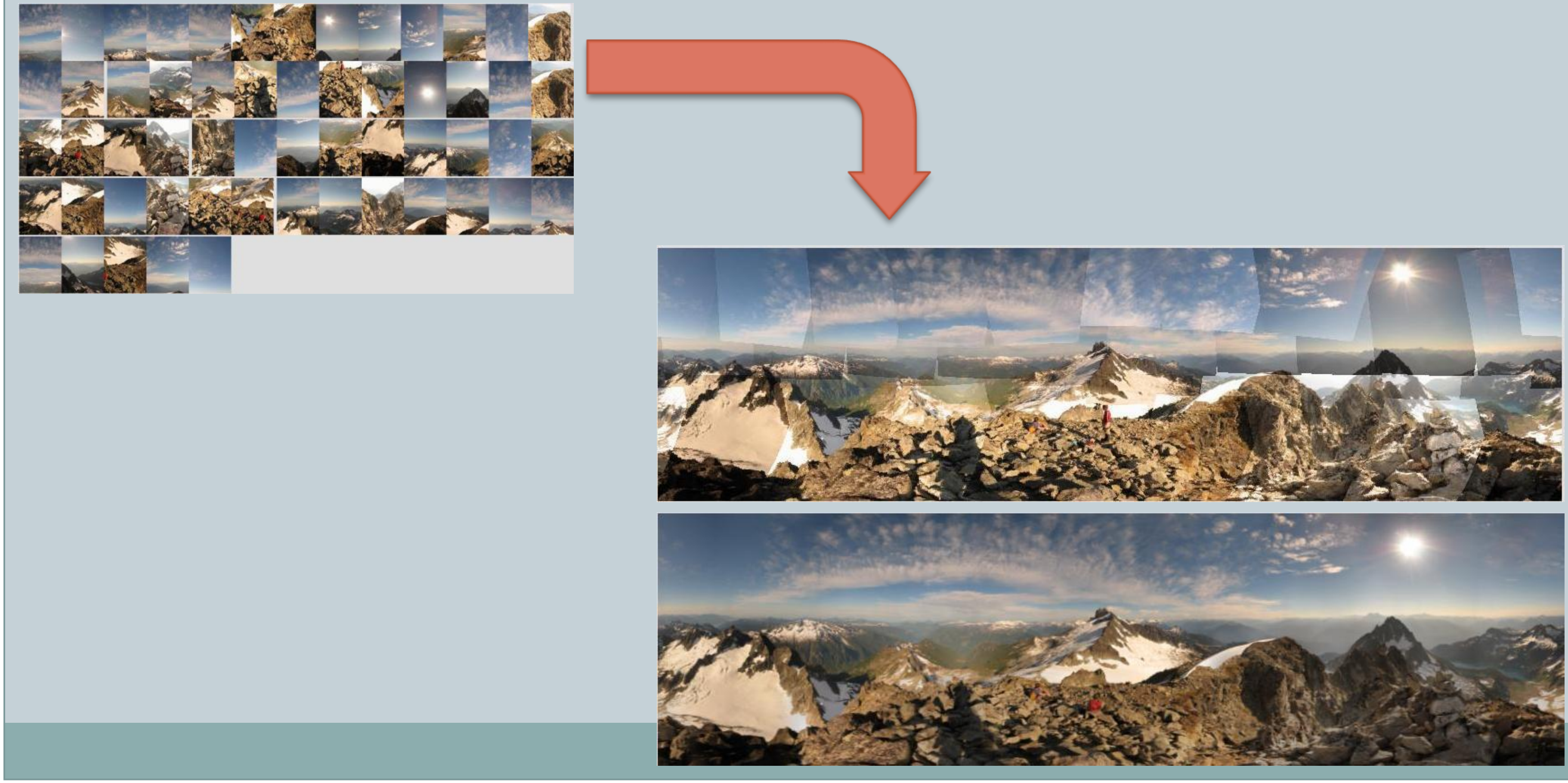
We know calibration and orientation can be obtained by having a set of photo-to-photo correspondences.

We do need a method to extract correspondences from photos, and possibly a method that scales well with the number of photos (remember we said the manual correspondence picking does not scale well)

Plese note: if the camera intrinsics are known (pre-calibration) or if the photos are undistorted, this steps works much better

Photo match & stitch

Maybe outside of 3D reconstruction, you have used similar methods



Working principle

All the existing tools follow the same scheme:

- Using euristincs and local analysis, find some *salient* points in the input images.
- Match the salient points across images, determining overlap between images (*bag of feature*).
- From the matched points, determine position, focal lenght and distortion of the camera at the time of the shot.
- Using the computed cameras, perform a *dense* match trying to determine 3D coordinates for all pixels.

SIFT - SURF

SIFT: Scale Invariant Feature Transform

SURF: Speeded Up Robust Feature

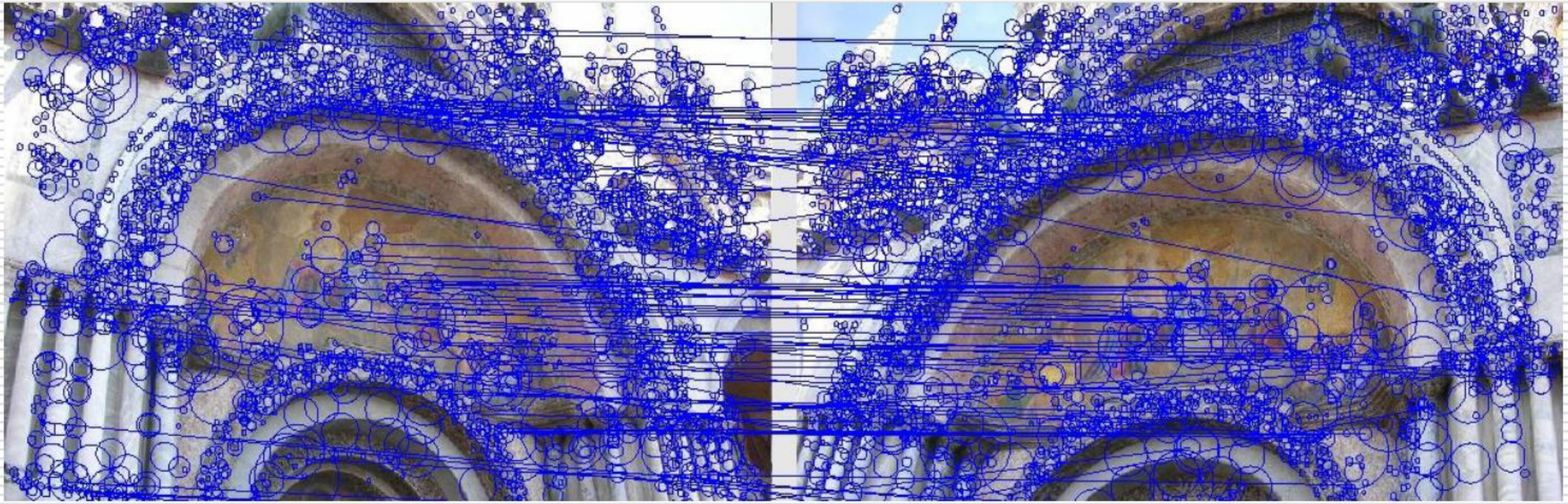
Local descriptors of an image “feature points”, they are used to efficiently determine salient points and match them across images.

Many variants, and really diverse is the scheme for multi-image matching from one software to another.

Bag of feature

A lot more correspondence points are used, with respect to manual photogrammetry…

Computer point match is less accurate than human, more points->error reduction. More points-> coherence check (ransac)



All for one, one for all

Another component used in these tools is:

Bundle Adjustement

Cameras are determined independently, using the detected corresponences, and a global optimization step is often necessary to ensure a good fitting.

Many ready-to-use libraries for bundle adjustement exists...

A problem of SCALE

All these tools have a problem in common: the returned geometry is at an unknown scale... every proportion is correct, it is only that the measure unit is unknown. This is because nothing is known about the scene and the camera (you may have been taken a photo of a car or of a car model).

How to solve this? You need a measurement taken on the real object and the corresponding measure from the computed 3D model to calculate the scale factor!

Most tools have a way to calculate/specify this scaling factor at the time of model creation... in any case, it will always be possible to apply a scaling factor to the whole result :).

A problem of SCALE

This issue is common also to pure Photogrammetry tools!

Photogrammetry software has inbuilt tools to apply scale, with multiple measurements and residual error calculation.

If you are using markers of known size/pattern size, or some metric details of the scene are known (like the offset of the camera in the MENCI tool), the scale is calculated automatically.

A plethora of tools

Using 3D from images is easy, you need a camera and one of the many software tools...

A lot of free tools, often a "toolchain" of existing tools.

Some semi-free or very cheap software.

Many commercial implementations, sometimes bundled to custom-made devices.

Online - Offline

Computing 3D reconstruction from photos is a cumbersome task, computationally. A reconstruction may take hours, or even more than one day...

For this reason some tools are implemented as web-services.

The data is sent to a remote server, ad you receive the results

- ☺ Good performances, remote code is regularly updated
- ☹ You need network access, you have to send away your data

Regard3D

Open Source tool.

Quite new, but is becoming widespread.

Completely local. Works on Windows and MacOS

http://www.regard3d.org/

VisualSFM

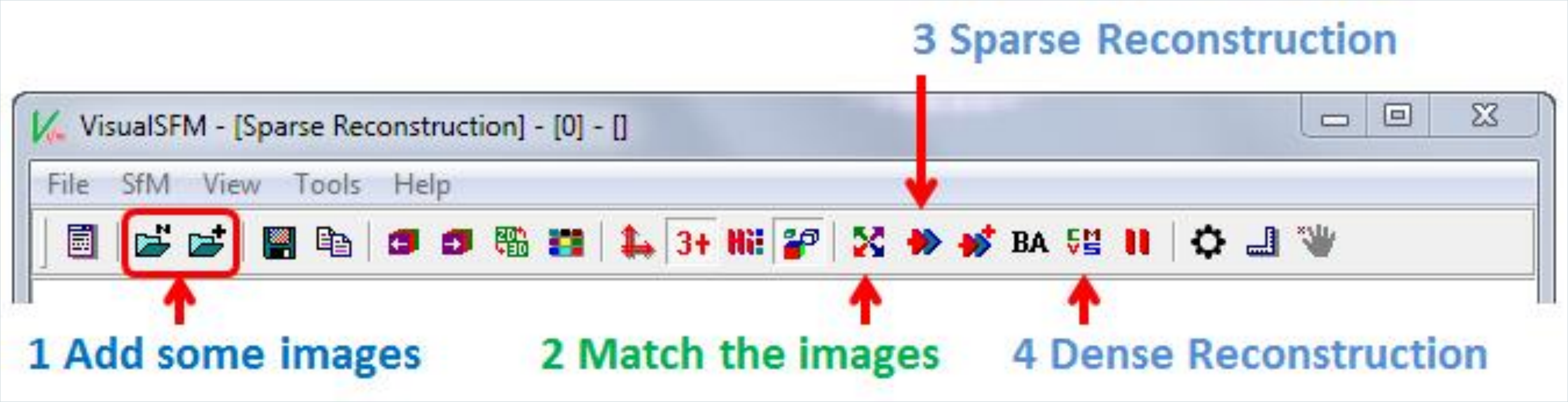
Free tool (not opesource, but some components are opensource).

Grown a lot in usability and performances...

Completely local. Easy to install (under windows) and use.

Good result at no cost... But has been abandoned

http://ccwu.me/vsfm/



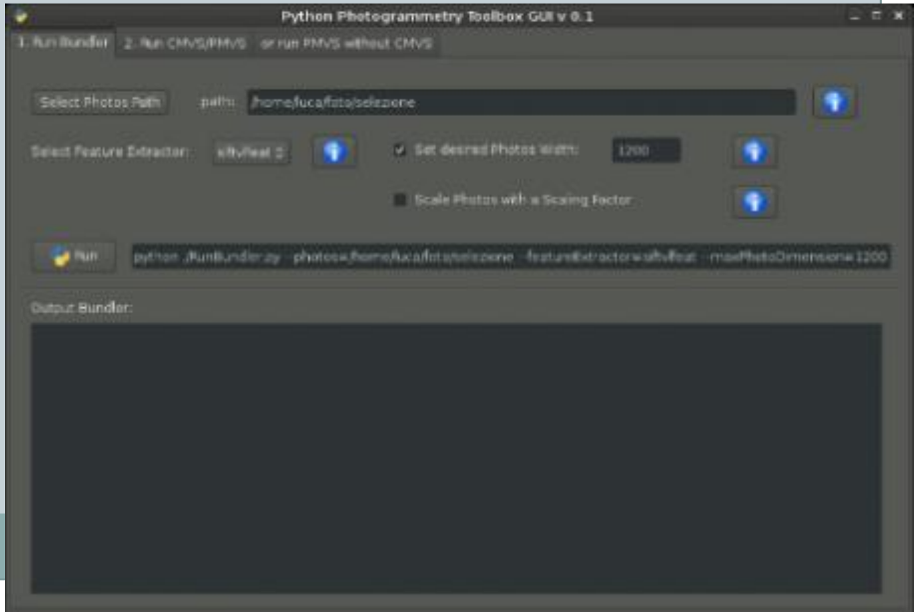
Python Photogrammetry Toolbox

Developed by Arc-Team, open source and free, for Debian and Win (32 and 64bit)

- http://www.arc-team.com/

Completely local, interface, control on parameters, video tutorial

But, a bit tricky to install on windows…



PMVS2

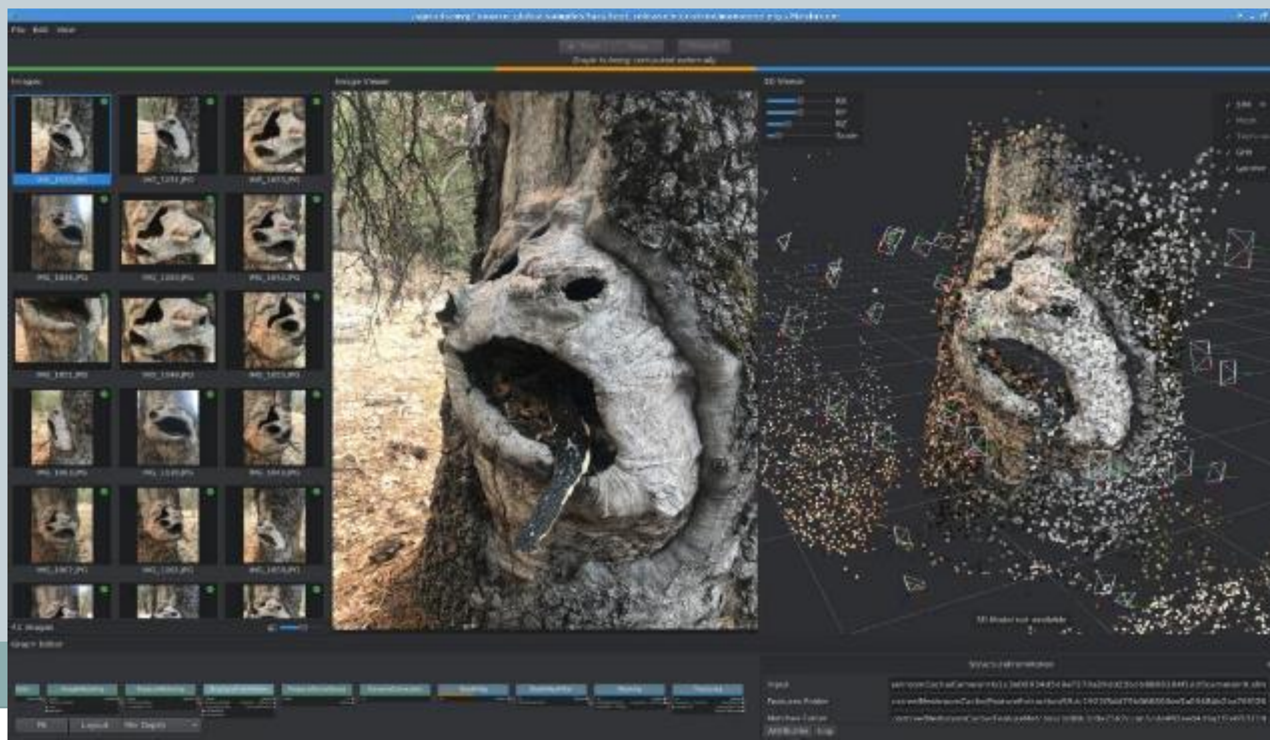
Most of these open/free tools, will use for the DENSE step the same tool… PMVS2. This is a research tool made by Yasutaka Furukawa (a major researcher in Computer Vision).

Beware of computation time... if you exaggerate with the extraction parameters, the machine can remain at work for hours (or days). The result is a colored point cloud with normals; with MeshLab it is possible to generate a surface.

MeshRoom

New kid on the block. Open source tool from a commercial Company: an open **professional** solution

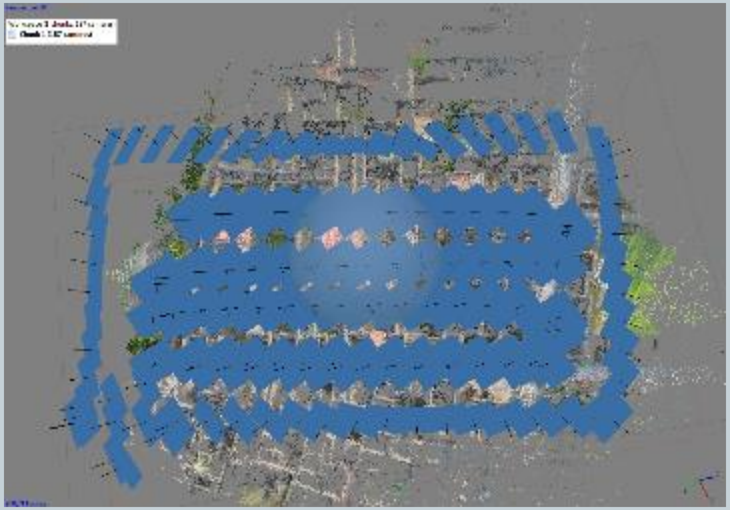
Powerful and configurable. A bit of a mess to install, and more complex to use w.r.t. the other free alternatives.

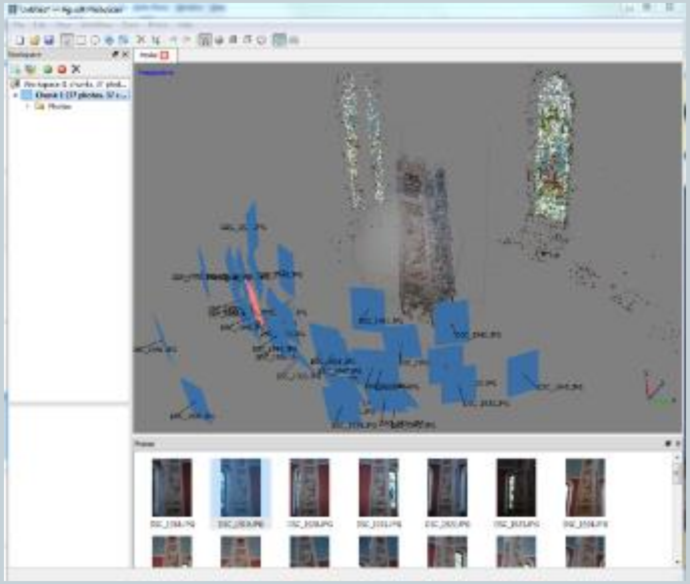


PhotoScan (now MetaShape)

Commercial, low cost tool: 59 € for educational license, 179€ standard license. (win, mac & linux)

Fast, work on **local** machine, directly produce textured model. Very robust and reliable... We have used it with good results on many diverse datasets.





They also have an integrated tool for camera calibration

PhotoScan (now MetaShape)

Photoscan is the **DE FACTO** standard tool in CH...

It's cheap, easy to use, and reliable.

It works incredibly well with DRONES

PRO version has a georeferencing tool, can use markers for automatic scaling, and has a lot of exporting features specific for survey, CAD and GIS tools.

Reality Capture

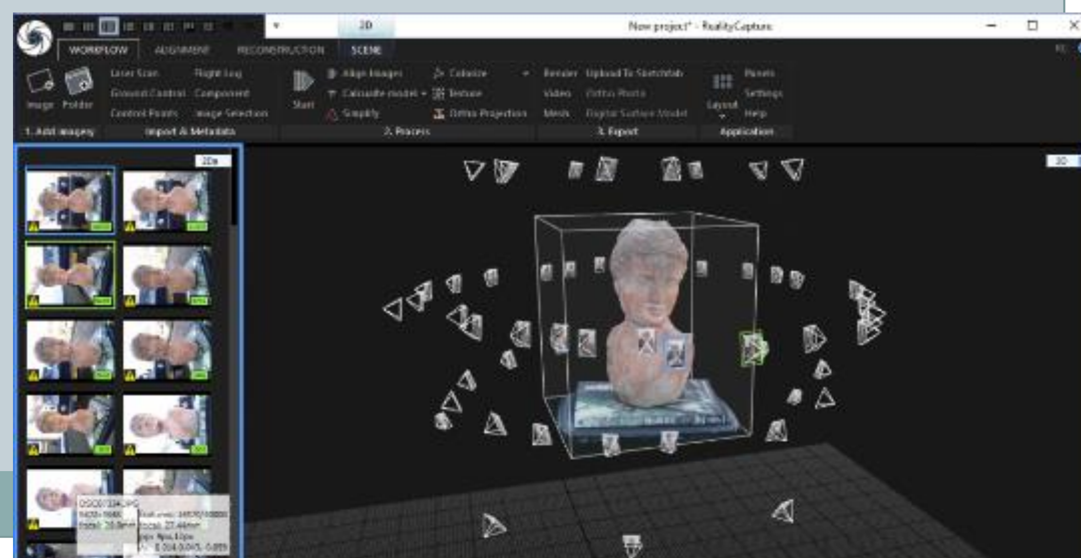
Quite recent, but already super-popular…

At the moment, the most compete and powerful tool

Works on really large datasets (1000+ images)

Can integrate photos + 3D scans. Works locally or on their cloud service.

☹ very high cost…



Autodesk ReCap

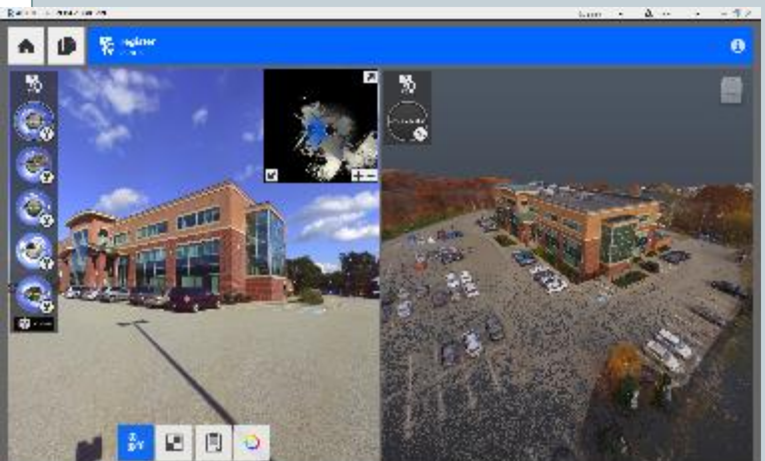
Previously known as, 123DCatch, Memento, ...

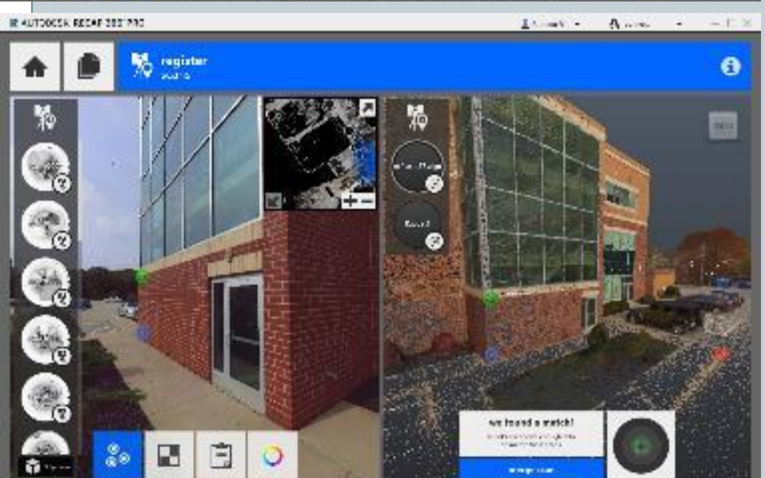
- Very well engineered tool...
- Works on a **remote server** or **locally**
- Produces a *complete*, *textured* model
- A full-fledged 3D digitization & processing tool, from scan/photo to CAD and printable models

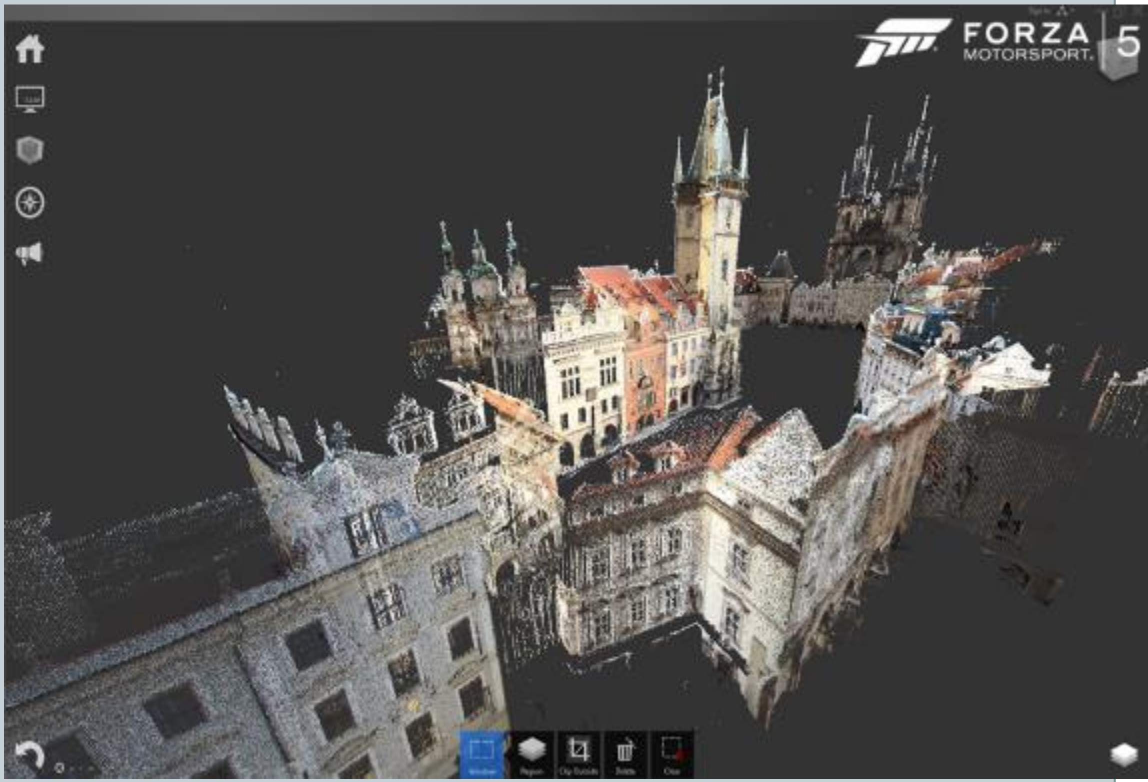
Has a limited free version...

It is fast, and works very well , is able to reconstruct difficult datasets and the results looks good.

Autodesk ReCap







Photos

And now, let us talk about the photos...

- Do not worry if your first set does not comes out, retry, trying to understand what went wrong.

We will give basic rules, try to follow them at the begin, and the more you got experienced, you will see some may be regarded only as «suggestions»

Equipment

What kind of camera should I use?

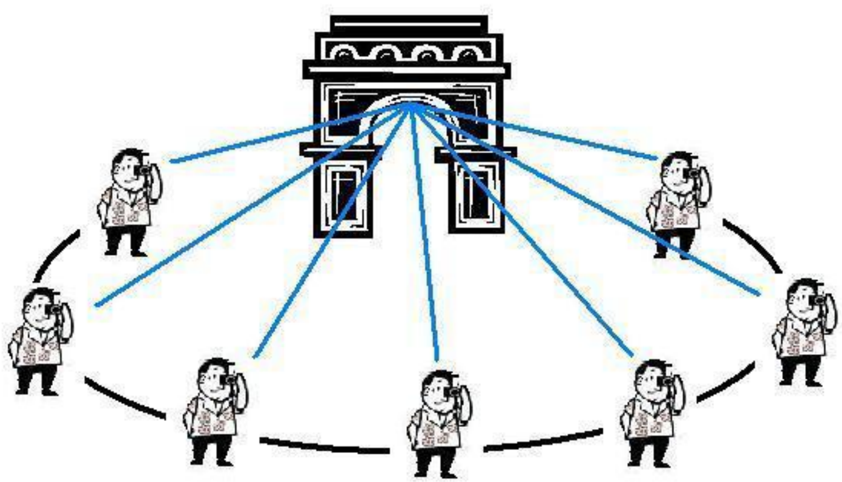
- More pixels = more 3D points = longer upload and processing time
- Using 20-30 Mpixel photos will probably crash the tools, 5-10 are ok, and the result will be better than expected
- Good lens → less distortion → better result
- Good lens → more light → better result

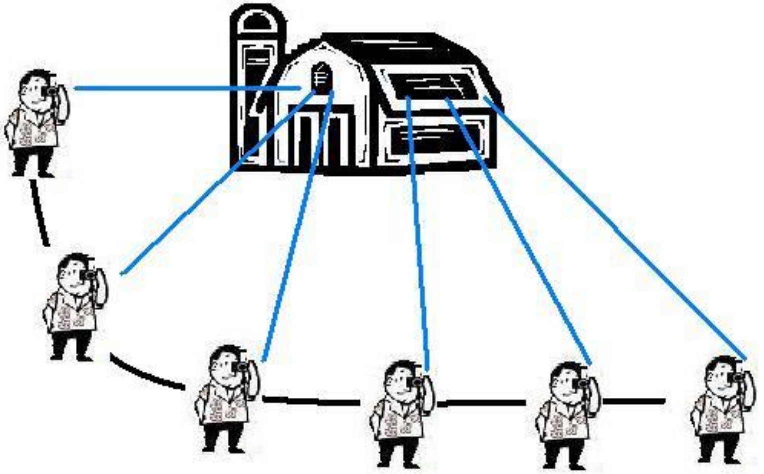
A good compact camera may be enough. DSLR have better lenses.

Mirrorless *may* distort too much (avoid pancake lenses).

Good sequence

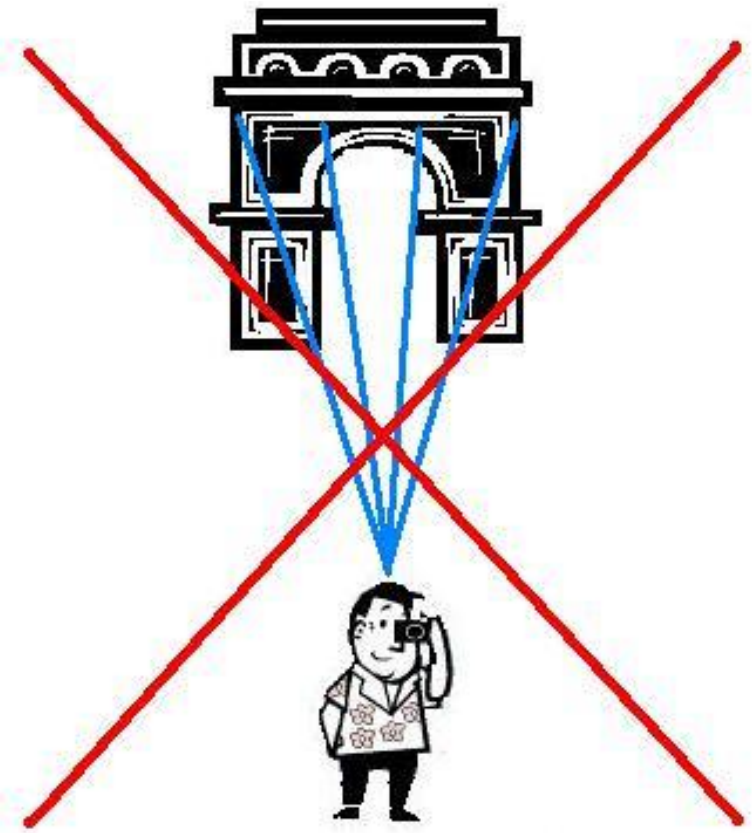
- ***Walk with the camera in an arc around the scene, while keeping the scene in frame at all times, shoot every few steps***
- ***Keep the zoom FIXED (not always true)***





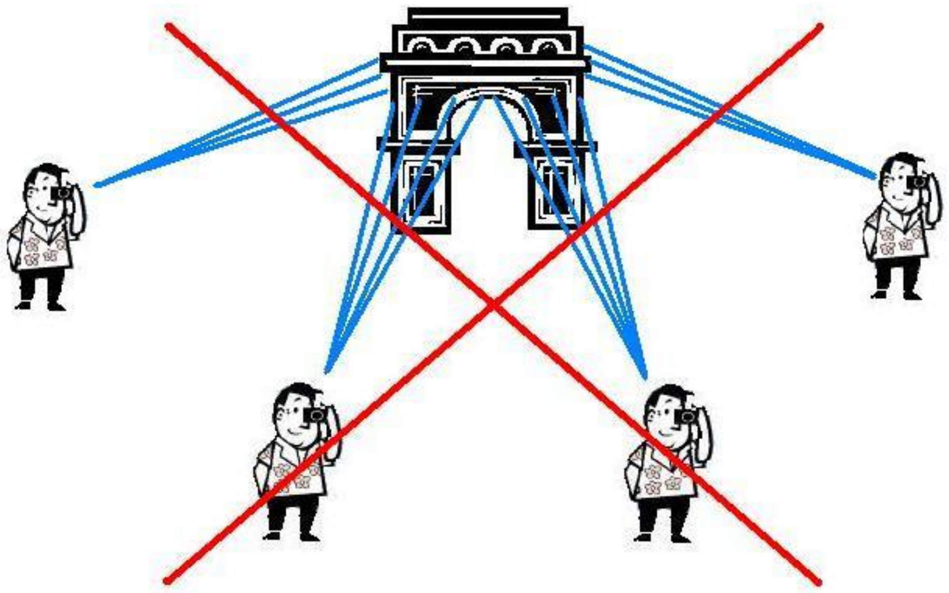
Bad sequences

- ***Do not pan from the same location***, as if you were recording a panorama. It is not possible to determine enough 3D information from such a sequence.



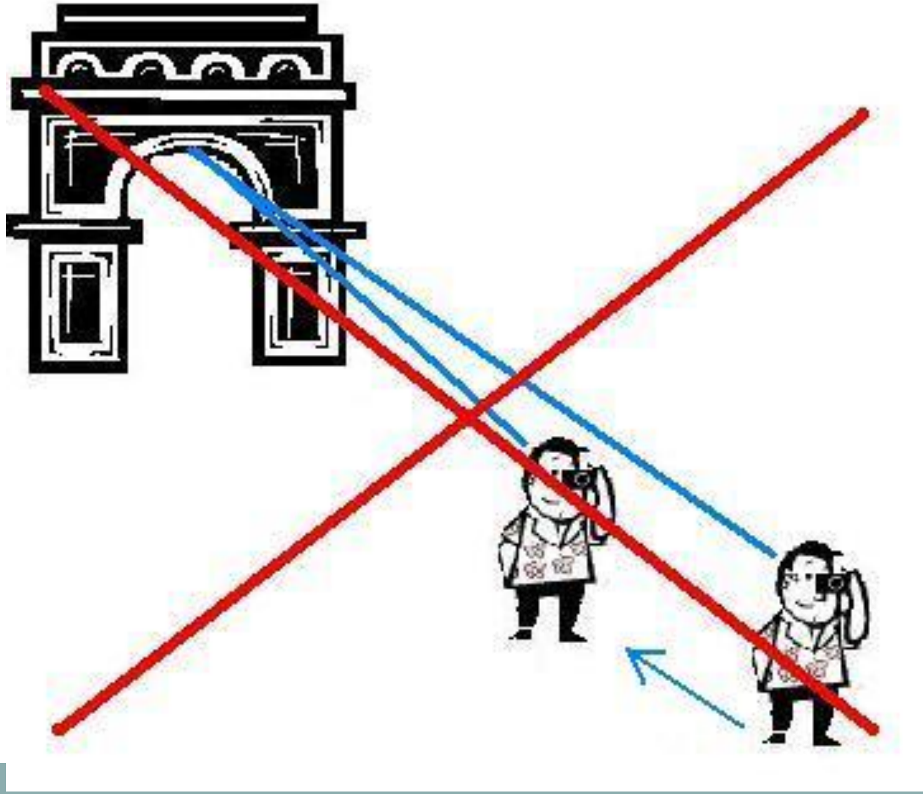
Bad sequences (2)

- Don’t shoot multiple panorama-like sub-sequences from different viewpoints



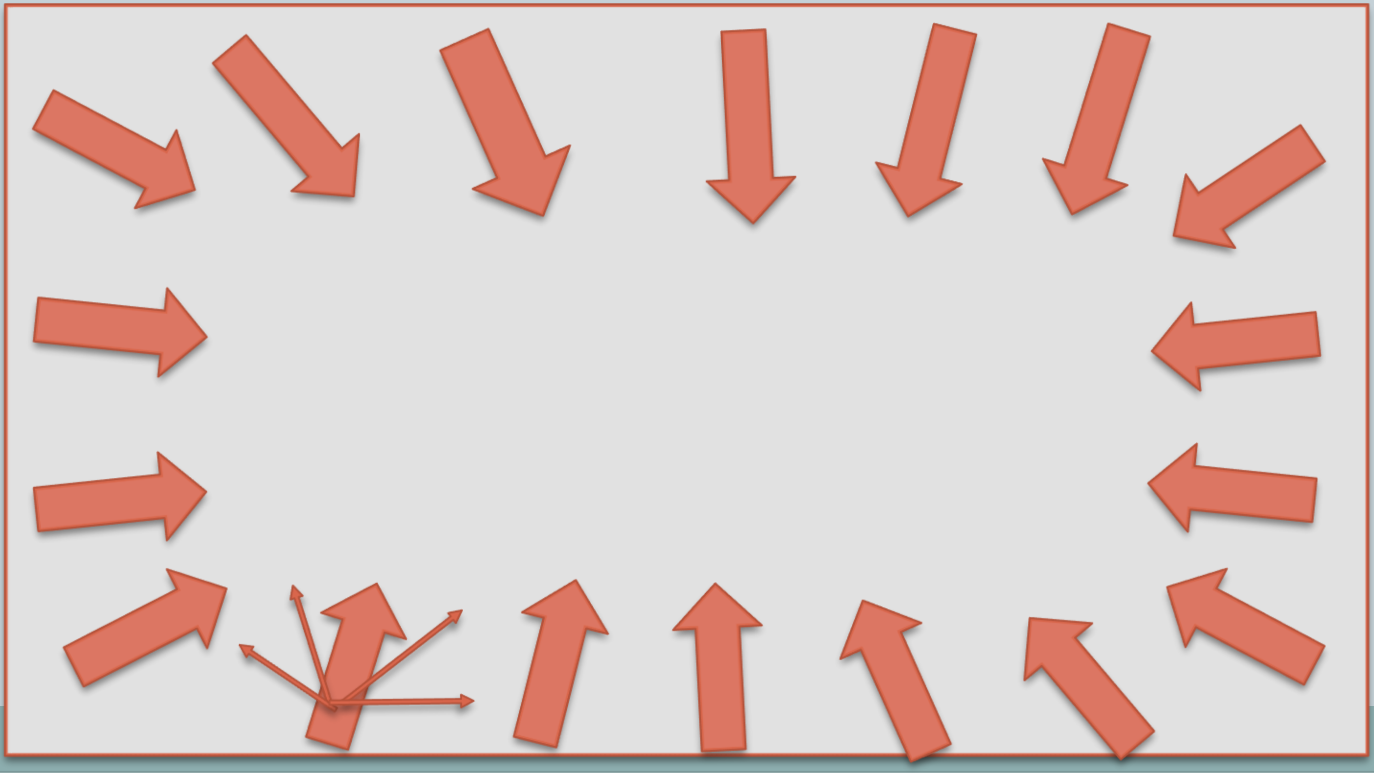
Bad sequences (3)

- Do not walk in an EXACTLY straight line towards or inside the scene you want to reconstruct



Good sequence

- ***If inside, walk the perimeter, looking at the opposite side***
- ***In this case you may take more photos for each point, but NOT like a panorama (small or no overlap)***

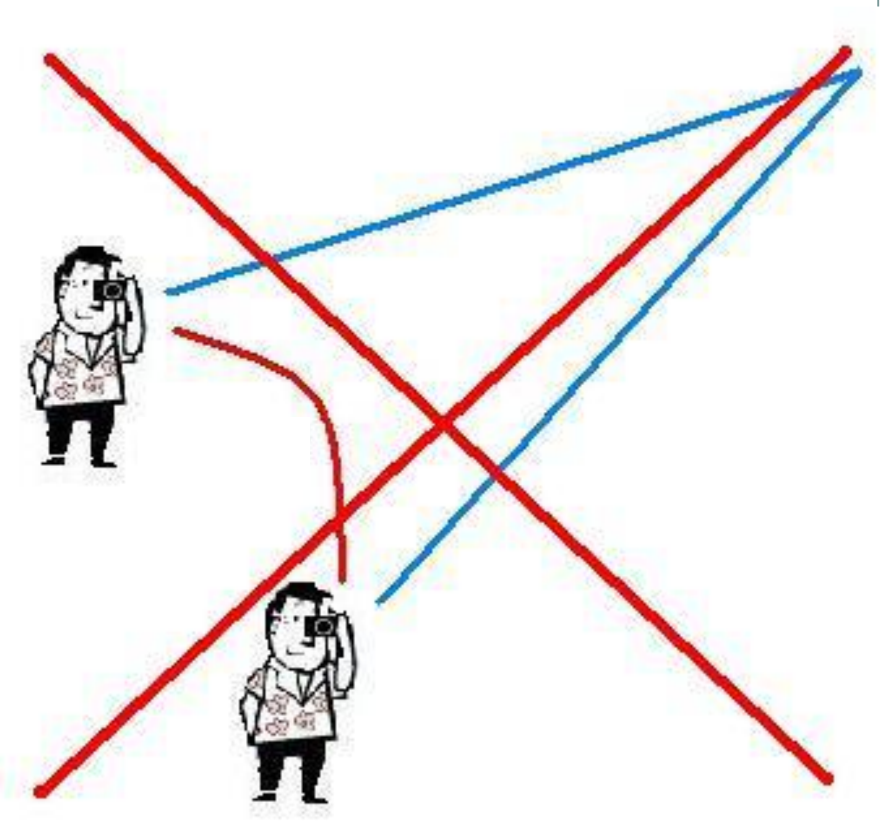


Good sequence

- ***Shoot from different heights... This helps a lot***
- ***You can mix photos taken at different distances: i.e. shoot the whole object going around, then get closer and cover the object again framing smaller areas, then get closer again and frame details***
- ***Background is important!!!!***

Bad sequences (4)

- It is better to shoot a lot of pictures than few ones.
- The viewing angle between images should not be too large, i.e. adjacent images should not be too far apart
- Consider 15-20 degree as a good step...



Bad sequences (5)

NO TURNTABLE

NO PLANAR SCENE

Practical Problems

All information is retrieved from the images, so take care when you shoot them!

The texture (color, intensity) of the scene/object is critical!

- Enough texture must be available on the object
- Appearance of object must stay the same!

Not Enough Texture

No Constant Appearance

No Constant Apperance

No Constant Apperance

No Static Scene

Dynamic Scene cannot be reconstructed

Don’t use blurry images

- Blurry images (due to movements or out-of-focus) must avoided
- This causes problems during the reconstruction process and/or degrades the final result

Self-Occlusions

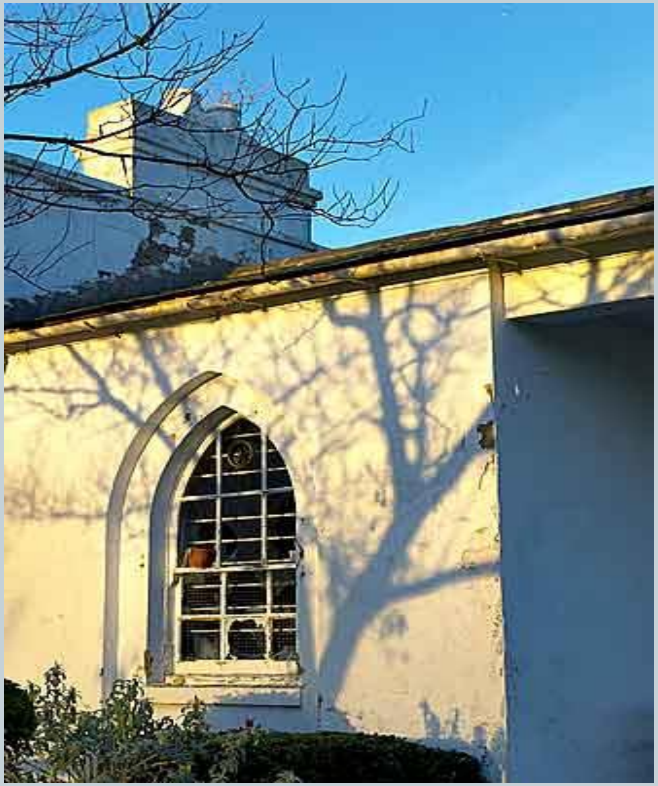
- Self-occlusions have to be treated with care (be sure that your photos cover all the self-occluded parts).

Lighting Conditions

Overcast sky is perfect due to uniform illumination.

In general changing conditions should be avoided...
NO FLASH (if possible)

Moving Shadows should be avoided...



Question Time

THANKS FOR YOUR ATTENTION

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