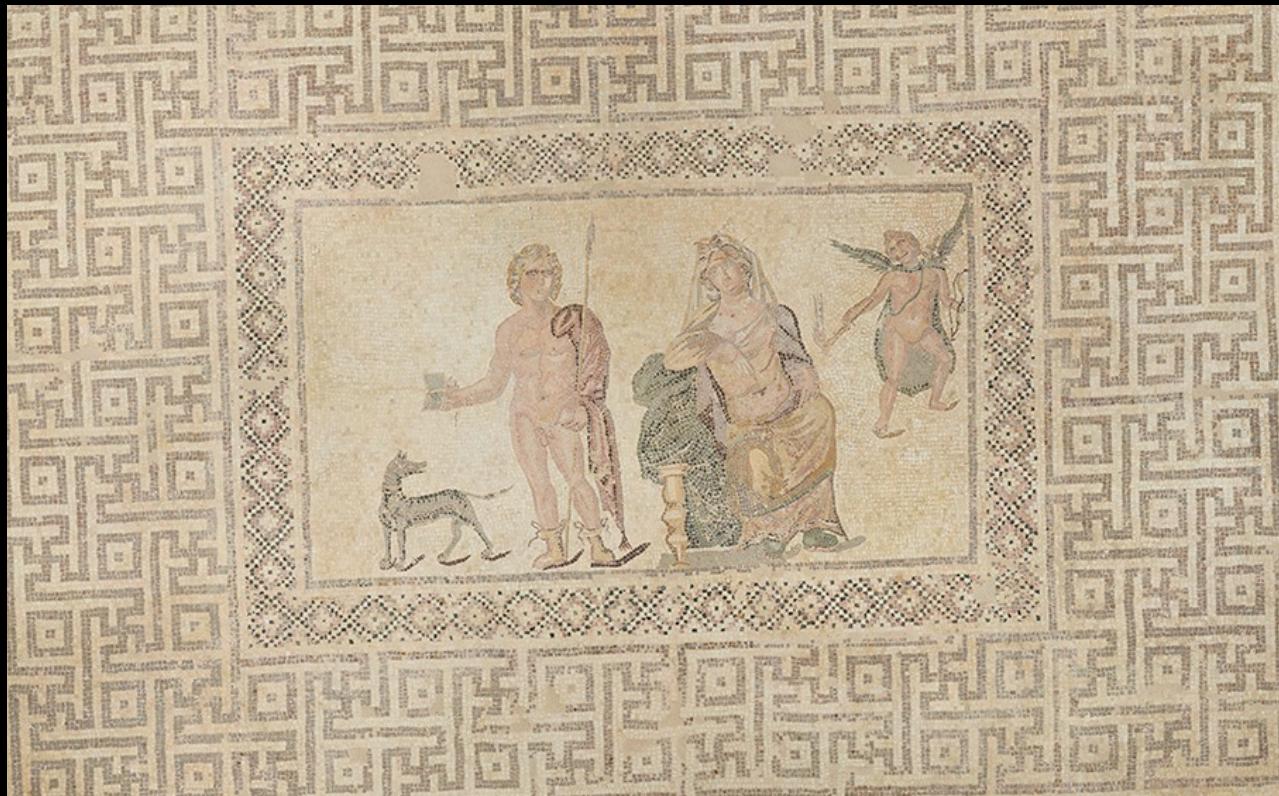


[Photogrammetry]



[Content]

[Content]

- **History of Photogrammetry**
- **Planning**
- **Data Acquisition**
- **Other Applications**
- **Examples**

[History of Photogrammetry]

[Beginnings]

-Photogrammetry = science of making measurements from photographs



Albrecht Meydenbauer

[1]



Cathedral of Wetzlar - 1858

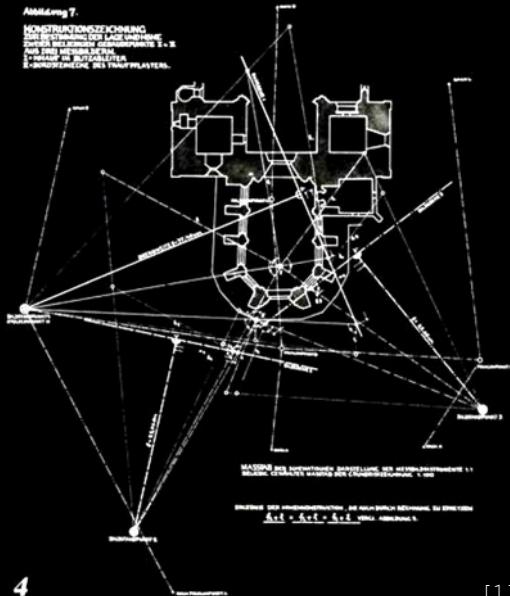
[1]

[Beginnings]

-Photogrammetry = science of making measurements from photographs



Photogrammetric Camera



Photogrammetry Network

[Beginnings]

-French Cathedral in Berlin, constructed in 1705



Original - Photograph 1882

[1]

[Beginnings]

-French Cathedral in Berlin, constructed in 1705



[2]

Damaged during WWII

[Beginnings]

-French Cathedral in Berlin, constructed in 1705

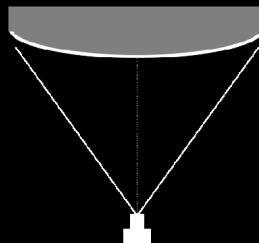


[3]

Reconstructed in 1981

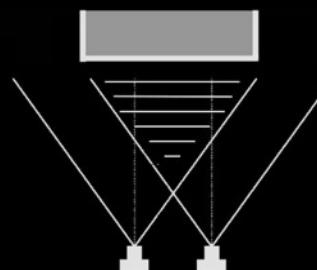
[Development]

Single Image Photogrammetry



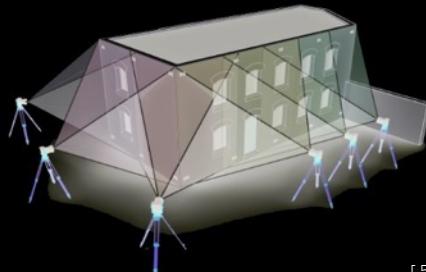
[4]

Stereo Photogrammetry



[4]

Structure from Motion Photogrammetry



[5]

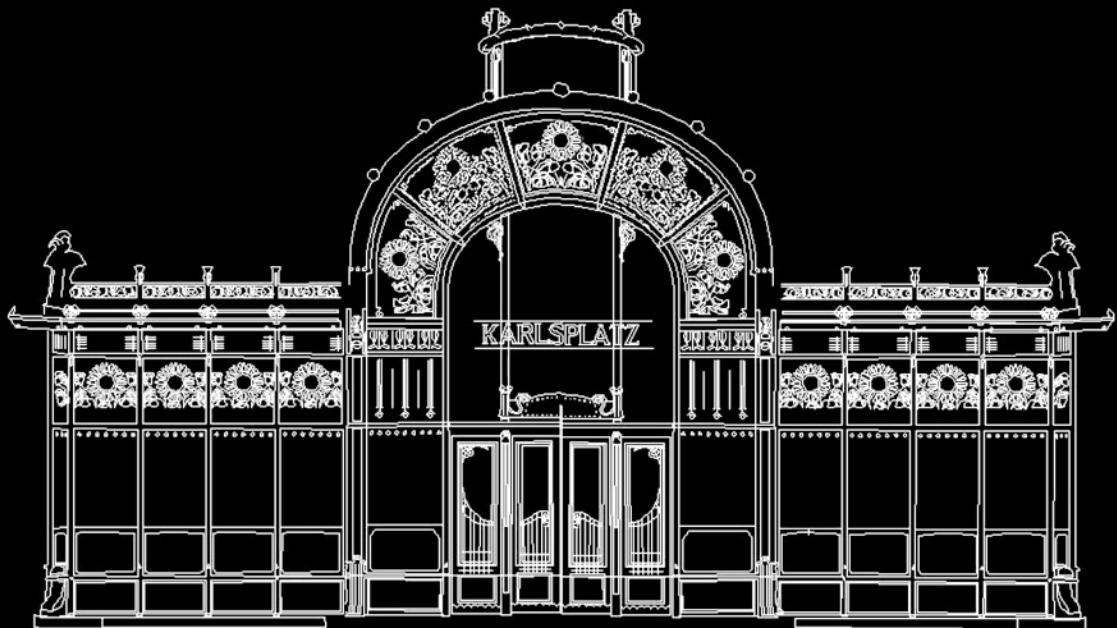
[Stereo Photogrammetry]



[4]

Stereo pair, Vienna

[Stereo Photogrammetry]

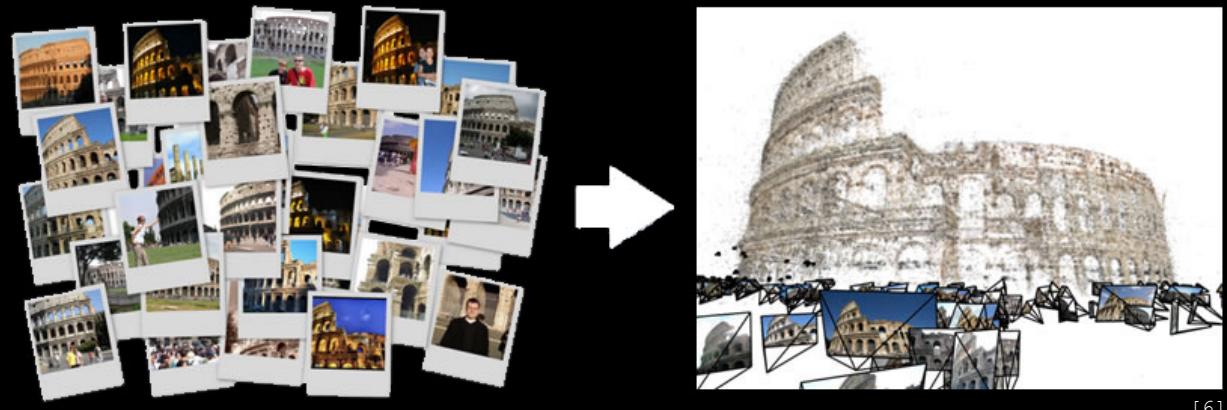


[4]

Drawing from stereo pair

[Structure from Motion (SfM) Photogrammetry]

- Developed for Computer Vision
- Now used for most modern photogrammetry



[6]

2106 Images

[Structure from Motion (SfM) Photogrammetry]

“Building Rome in a Day”



[Structure from Motion (SfM) Photogrammetry]

Basic steps:

- 1) Image capture



[Structure from Motion (SfM) Photogrammetry]

Basic steps:

- 1) Image capture
- 2) Image matching and bundle adjustment



[Structure from Motion (SfM) Photogrammetry]

Basic steps:

- 1) Image capture
- 2) Image matching and bundle adjustment



[Structure from Motion (SfM) Photogrammetry]

Basic steps:

- 1) Image capture
- 2) Image matching and bundle adjustment
- 3) Dense point cloud generation



[Structure from Motion (SfM) Photogrammetry]

Basic steps:

- 1) Image capture
- 2) Image matching and bundle adjustment
- 3) Dense point cloud generation
- 4) Outputs: textured model or orthophoto



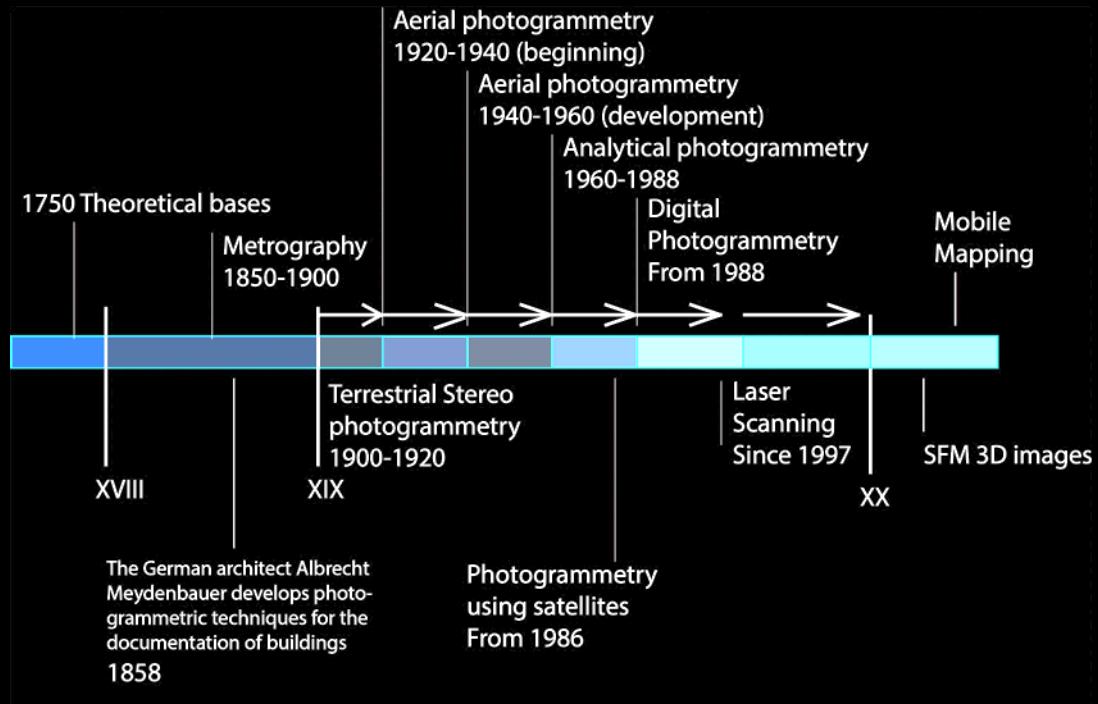
[Structure from Motion (SfM) Photogrammetry]

Basic steps:

- 1) Image capture
- 2) Image matching and bundle adjustment
- 3) Dense point cloud generation
- 4) Outputs: textured model or orthophoto



[Structure from Motion (SfM) Evolution]



[Types of Cameras]

Metric Camera

- Fixed lens and focal length
- Known interior parameters (calibrated)



[7]

Non-metric Camera

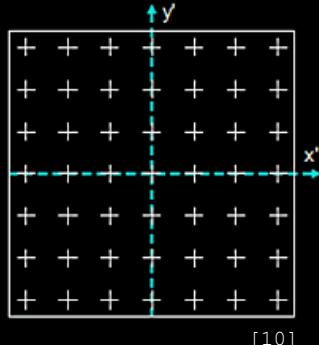
- Changeable lens and/or focal length
- Unknown relationship between sensor and lens (not calibrated)



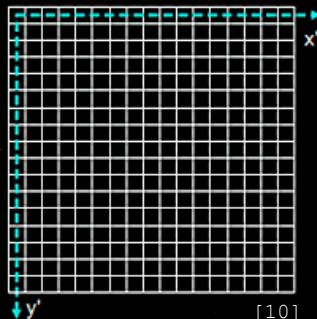
[8]



[9]



[10]



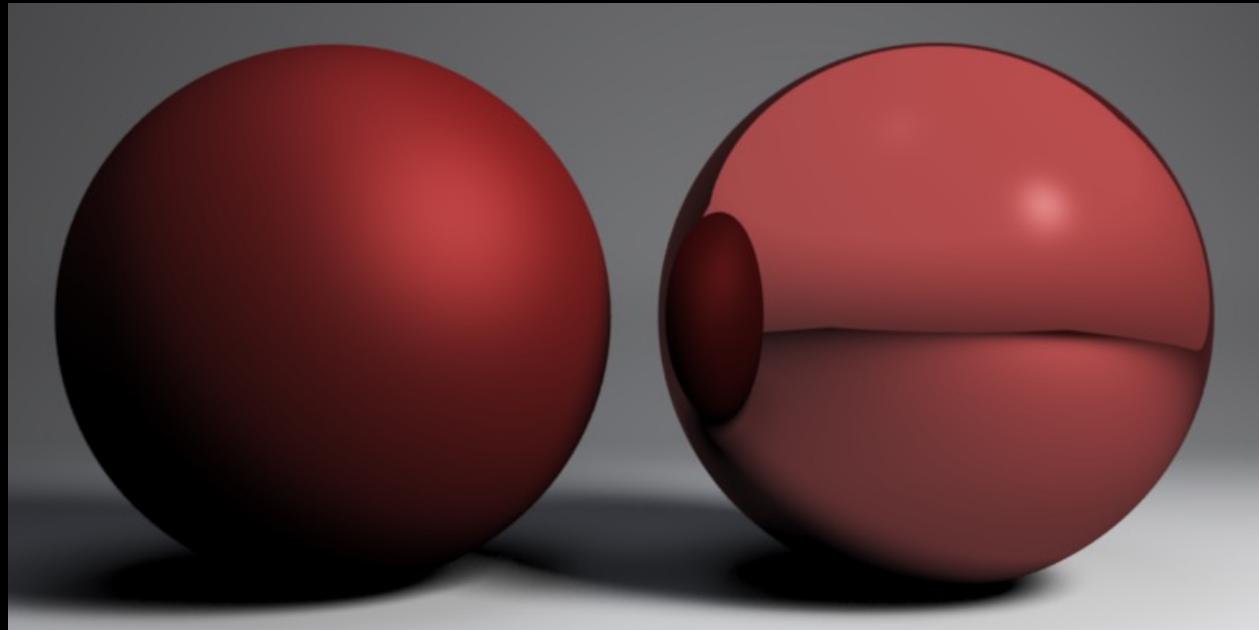
[10]

[Planning]

[Choosing Your Target]

Is it suitable for photogrammetry?:

- Specularity



[11]

Non-specular

Specular

[Choosing Your Target]

Is it suitable for photogrammetry?:

- Texture



[12]

Bad Texture



[13]

Good Texture

[Choosing Your Target]

Scale:

- Size of object



Micro



Macro

[Choosing Your Target]

Scale:

- What's around it?



[Choosing Your Target]

Scale:

- Access and time required



[Using Targets]

- We targets to scale and orient our model
- So we can combine other data sets in the same coordinate system



[Using Targets]

- We targets to scale and orient our model
- So we can combine other data sets in the same coordinate system



[Using Targets]

- Different types of targets
- What about natural targets?
- Diameter or length of target: $20 < \text{GSD} < 50$
- At least 3 targets that are each in 3 photos!



Square Targets



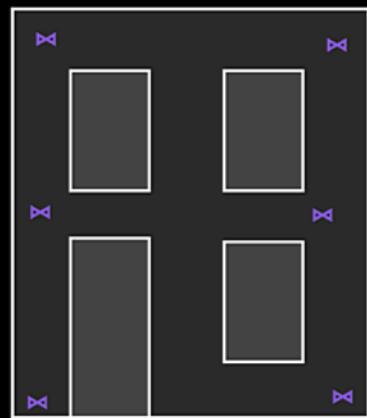
Circular Targets



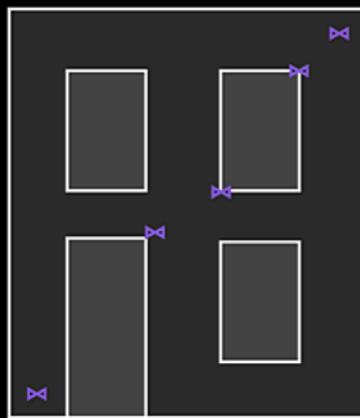
Circular Coded Targets

[Using Targets]

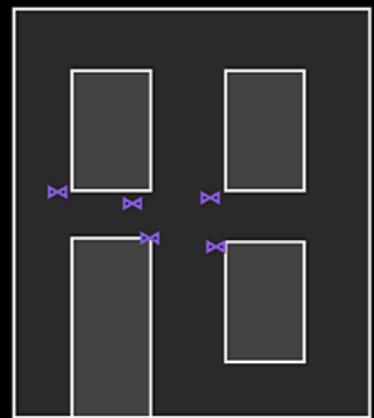
-How to arrange targets!



Good target
configuration



Bad target configuration



[17]

[Using Targets]

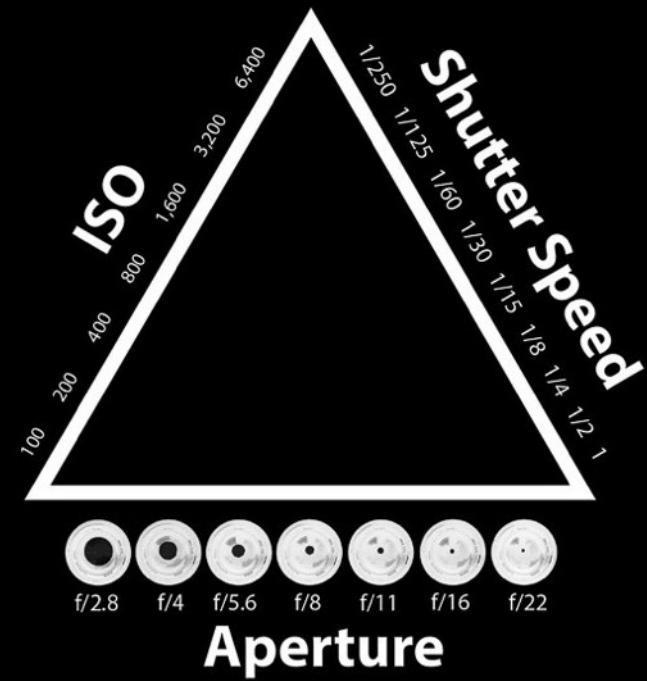
- Alternatively we can use a scale bar
- But it will NOT orient the model



[18]

[Data Acquisition]

[Photography for Photogrammetry]



[19]

[Photography for Photogrammetry]

Shutter speed:

- The shutter speed is the length of time that the cameras sensor receives light from the scene.
- The longer the shutter speed, the more light reaches the sensor.

Fast Shutter Speed



1/250th
of a second

Slow Shutter Speed



1/30th
of a second



1/2
a second

[Photography for Photogrammetry]

Shutter speed:

- No slower than 1/focal length
- Otherwise use a tripod!



Blurry

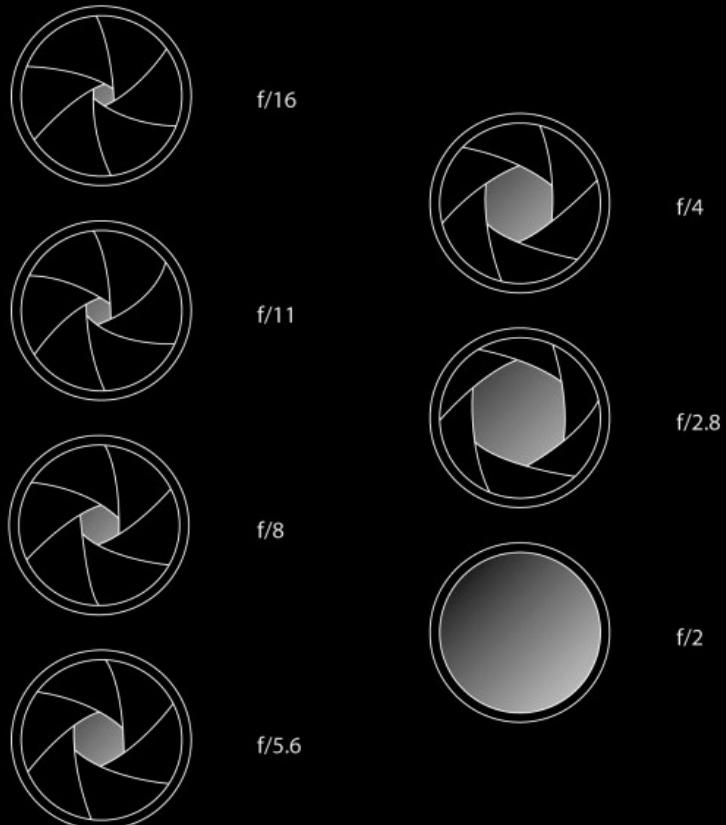


Sharp

[Photography for Photogrammetry]

Aperture:

- similar to your eye's iris



[Photography for Photogrammetry]

Aperture:

- Around f/8 to balance Depth of Field (DOF) and sharpness



[18]

[Photography for Photogrammetry]

Aperture:

- Around f/8 to balance Depth of Field (DOF) and sharpness



[18]

[Photography for Photogrammetry]

Aperture:

- Around f/8 to balance Depth of Field (DOF) and sharpness



[18]

[Photography for Photogrammetry]

Aperture:

- Around f/8 to balance Depth of Field (DOF) and sharpness



[18]

[Photography for Photogrammetry]

Aperture:

- Around f/8 to balance Depth of Field (DOF) and sharpness



[18]

[Photography for Photogrammetry]

Aperture:

- Around f/8 to balance Depth of Field (DOF) and sharpness

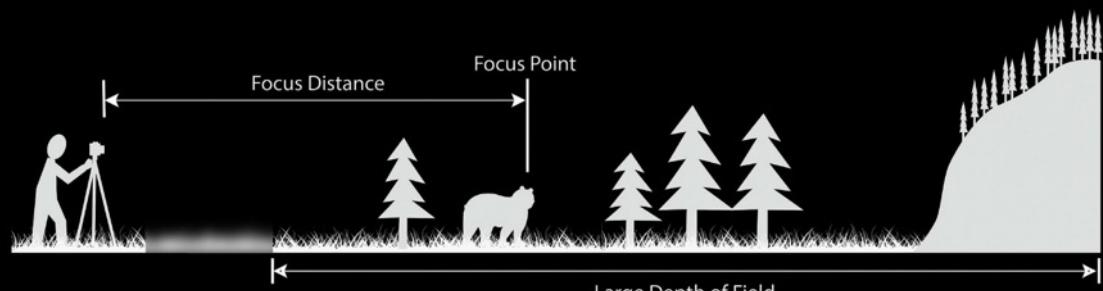
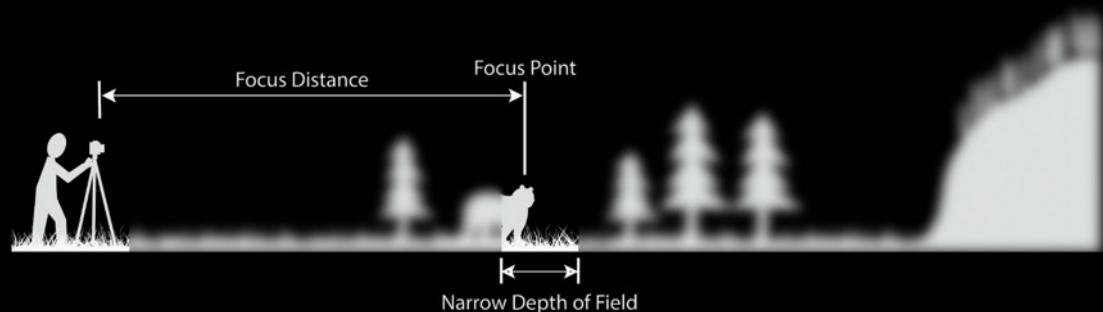


[18]

[Photography for Photogrammetry]

Aperture

- The closer you are the less DOF you get



[21]

[Photography for Photogrammetry]

Aperture

– DOF Calculators!

Online:

DOF Master: <http://www.dofmaster.com/dofjs.html>

Photo Pills: <https://www.photpills.com/calculators/dof>

Android:

HyperFocal Pro

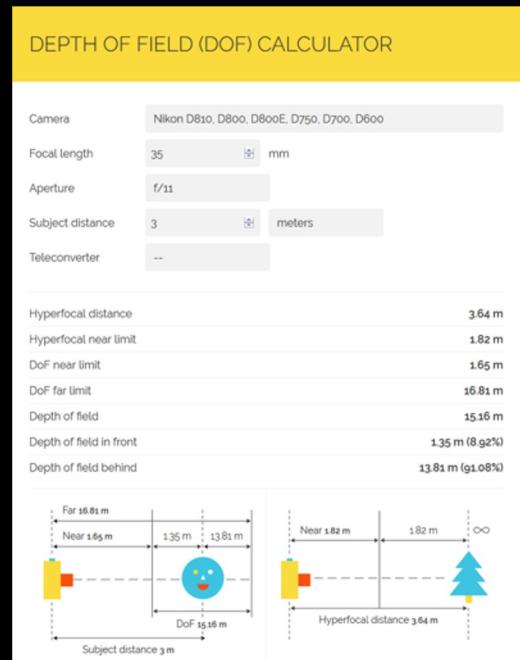
DOFDroid

iOS:

FDCalculator

F-stop

Digital DOF



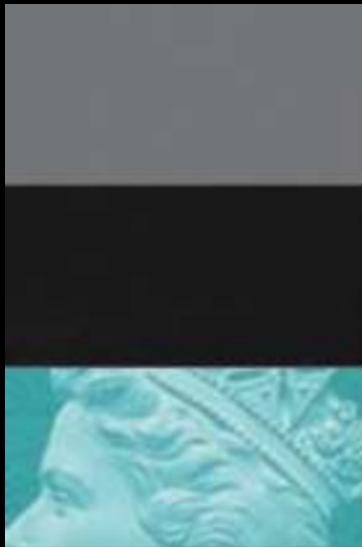
[Photography for Photogrammetry]

ISO

-Keep low

-But use if needed. A noisy picture is better than a blurry one!

ISO 100



ISO 25600



[18]

[Photography for Photogrammetry]

Camera Settings:

- RAW
- Turn off digital rotate
- Turn off live view



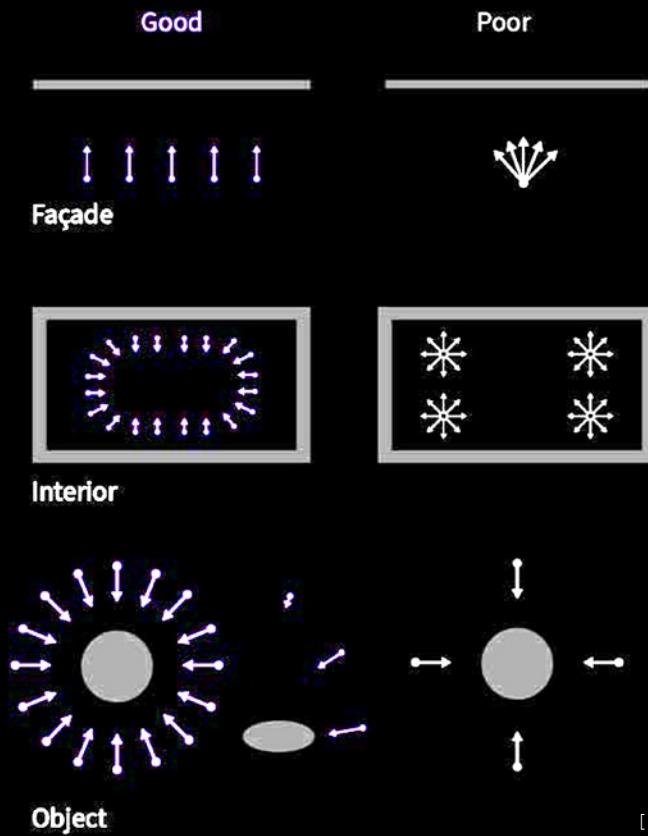
Bad



Good

[Camera Networks]

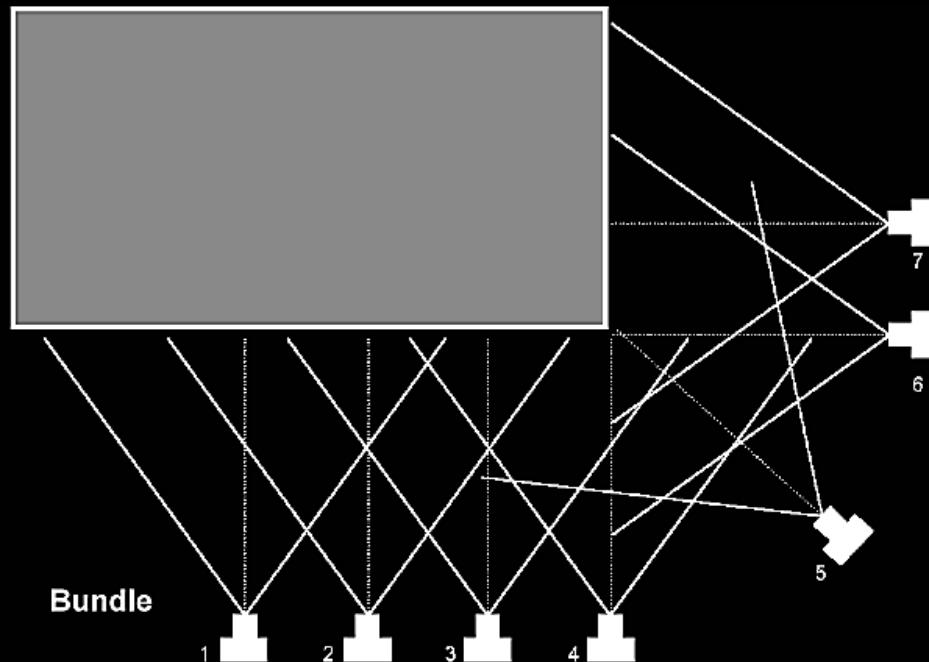
Overview:



[17]

[Camera Networks]

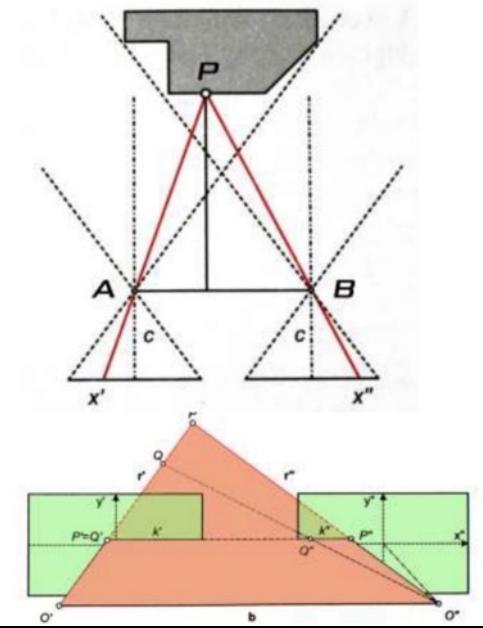
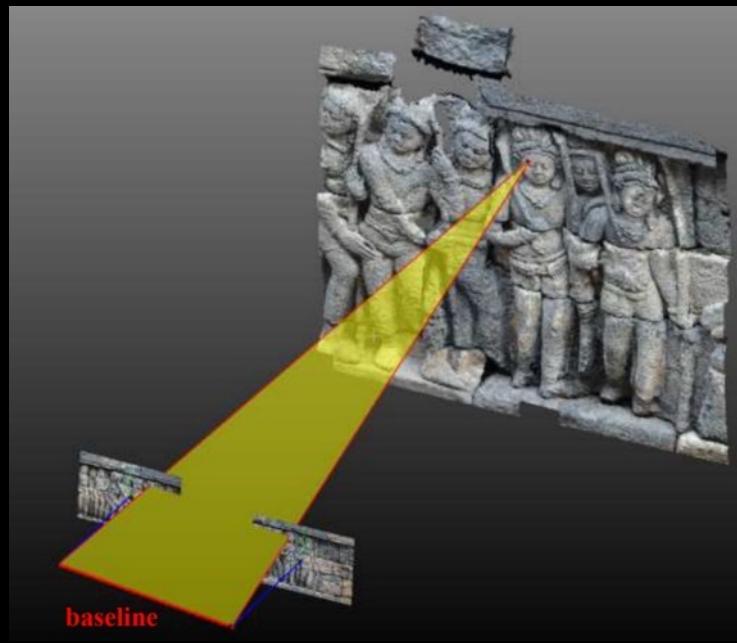
Strip based networks:



[4]

[Camera Networks]

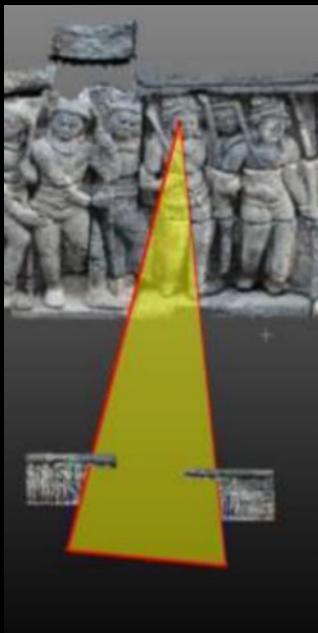
Strip based networks:



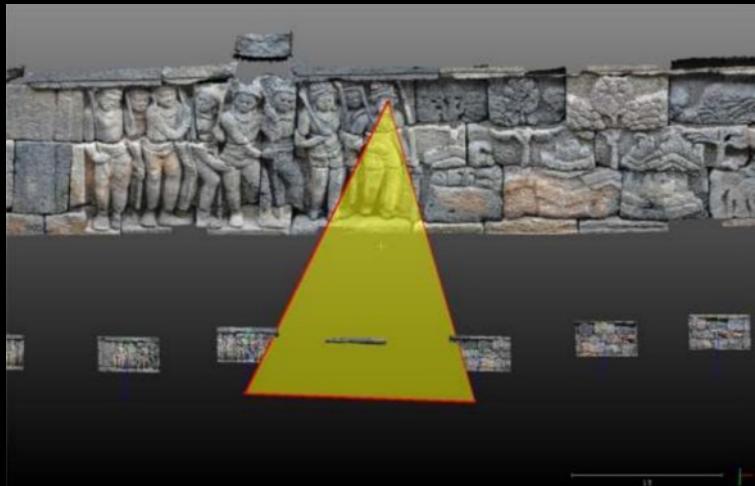
[18]

[Camera Networks]

Strip based networks:



Bad

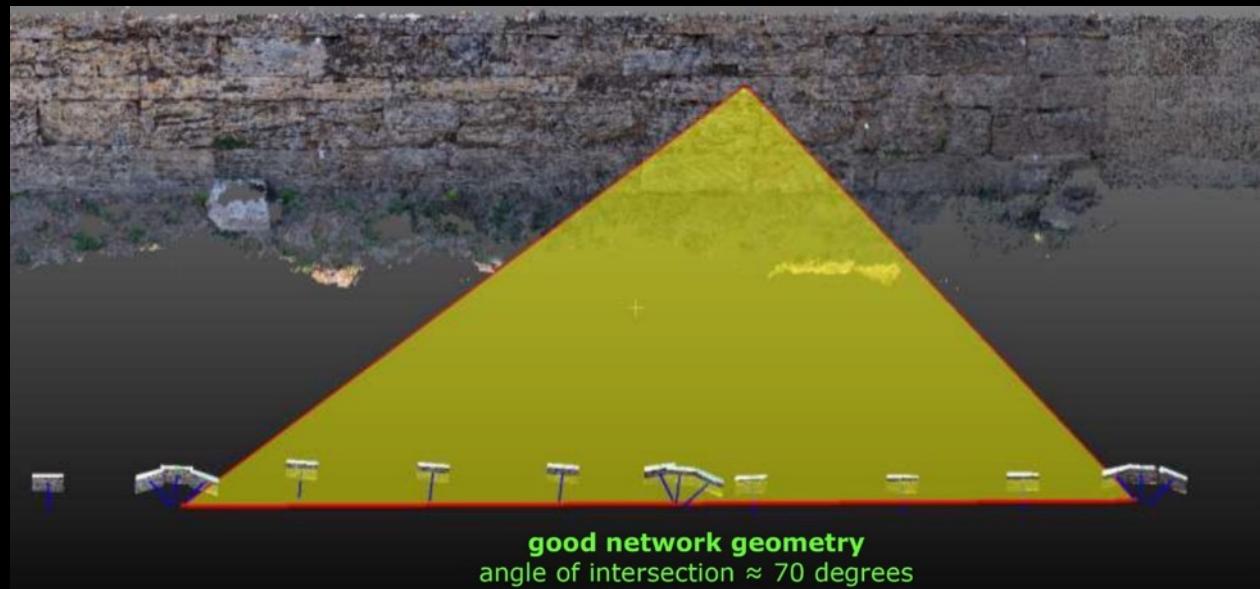


Okay

[Camera Networks]

Strip based networks:

- Convergent images



[18]

[Camera Networks]

A little deviation into camera calibration:

- Blue = interior parameters
- Orange = Exterior parameters

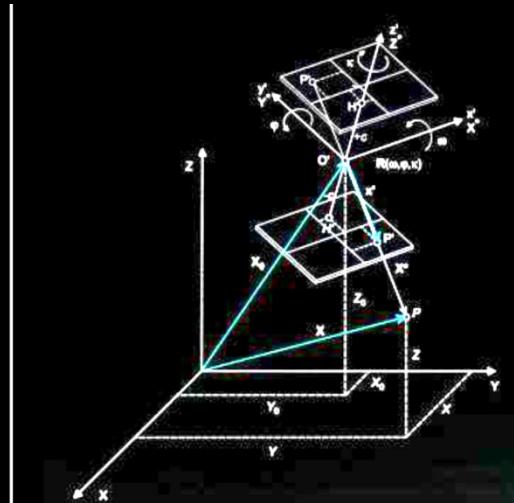
Collinearity equations

$$x - x_0 = -c \cdot \frac{r_{11}(X - X_0) + r_{21}(Y - Y_0) + r_{31}(Z - Z_0)}{r_{13}(X - X_0) + r_{23}(Y - Y_0) + r_{33}(Z - Z_0)} + \Delta x$$

$$y - y_0 = -c \cdot \frac{r_{12}(X - X_0) + r_{22}(Y - Y_0) + r_{32}(Z - Z_0)}{r_{13}(X - X_0) + r_{23}(Y - Y_0) + r_{33}(Z - Z_0)} + \Delta y$$

With:

x, y	... Image coordinates of the point P'
X, Y, Z	... Object coordinates of a point P
c	... Principal distance (\approx focal length)
X_0, Y_0	... Image coordinates of the principal point H'
$\Delta x, \Delta y$... Modelling of additional parameters (i.e. lens distortions)
X_0, Y_0, Z_0	... Coordinates of the projection centre O'
R_{11}, R_{12}, \dots	... Elements of the rotation matrix



[18]

[Camera Networks]

Strip based networks:

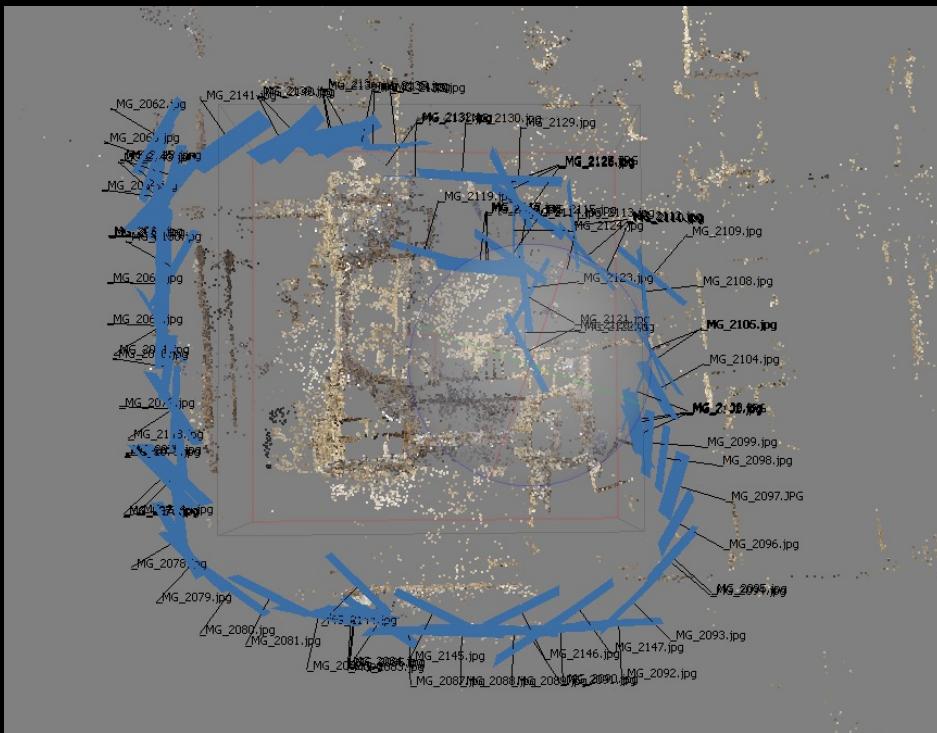
- Rotated images



[Camera Networks]

Strip based networks:

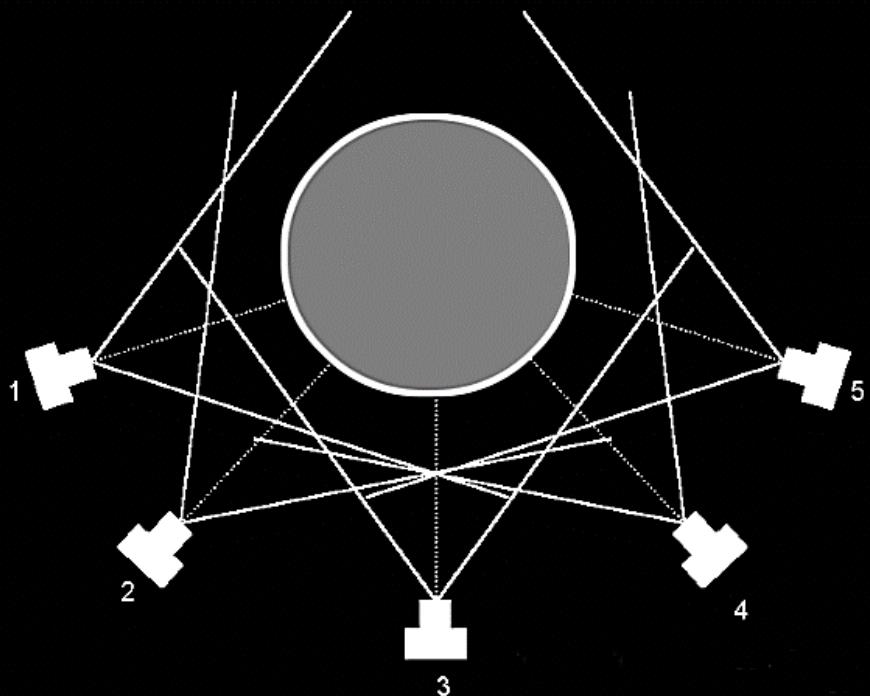
-Curved corners



[Camera Networks]

Circular networks:

- For smaller objects
- Images angled towards object in centre

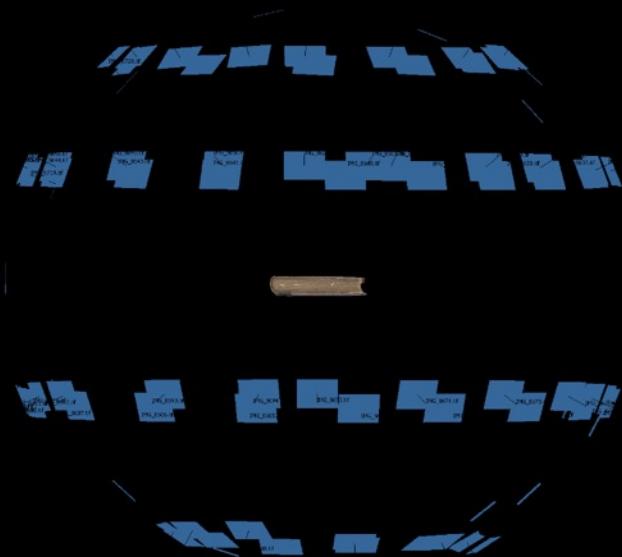
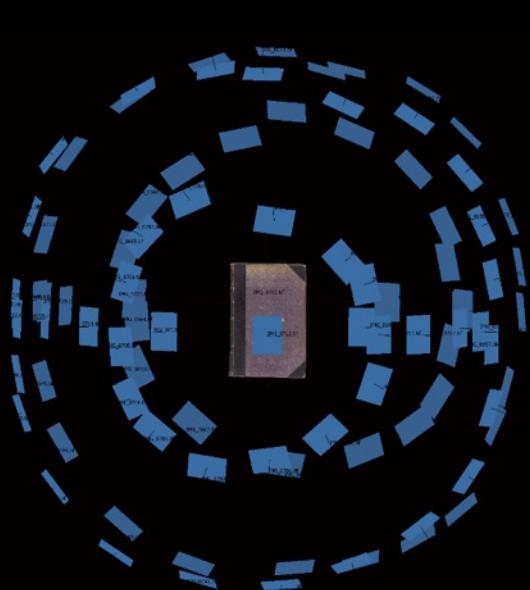


[4]

[Camera Networks]

Circular networks:

- For smaller objects
- Images angled towards object in centre



[Lighting]

General:

- As few shadows as possible
- Use colour card for white balance



[Lighting]

Outside:

- Diffuse cloudy day is best
- If not, around noon for constant lighting during acquisition (sun doesn't move quickly)



[Lighting]

Inside:

- Use diffuse lighting (softbox or flash with umbrella)
- Put perpendicular to the wall, or on either side of the camera



[18]

[Best Practices]

Taping:

- Zoom lens: tape focal length ring (but use prime lens if you can!)
- All lenses: tape focus ring (optional)

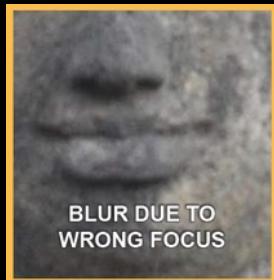


[17]

[Best Practices]

Common mistakes:

- Out of focus (autofocus)

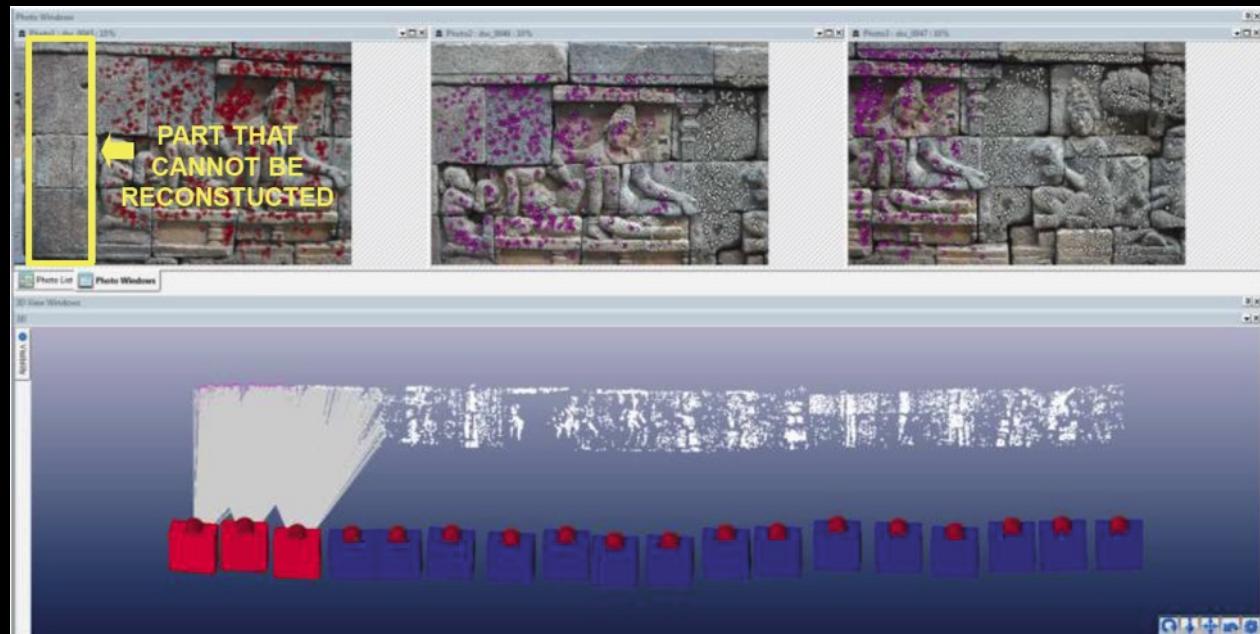


[18]

[Best Practices]

Common mistakes:

- Not enough overlap at beginning/end

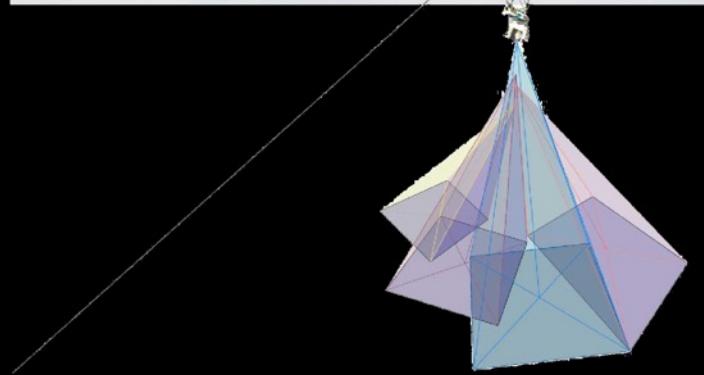


[18]

[Aerial Photogrammetry]

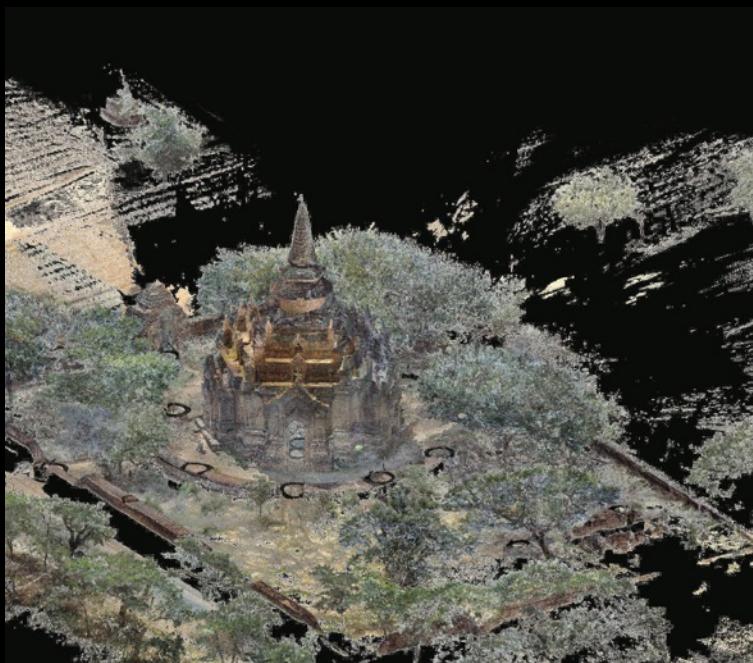
Low-cost Aerial Photogrammetry: kites

Bill Blake



[Aerial Photogrammetry]

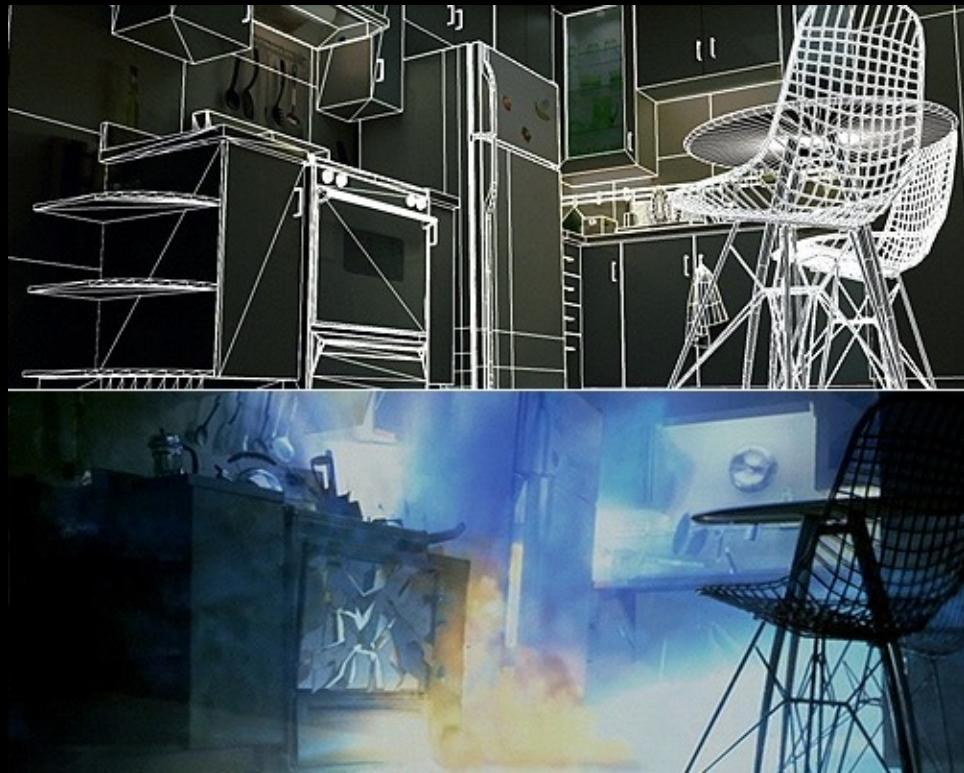
UAV: Unmanned Aerial vehicles



[Other Applications]

[Movies]

Fight Club (1999)



[22]

[Movies]

Fight Club (1999)



[Video Games]

Star Wars Battlefront



[23]

[Video Games]

Nefertari: Journey to Eternity



[Video Games]

Nefertari: Journey to Eternity



[CIMS Examples]

[Bagan, 2016]



[Bagan, 2016]



[Bagan, 2016]

Loka hteik pan ceiling



[Bagan, 2016]

Myin-pya-gu



[Bagan, 2016]

Myin-pya-gu



[Bagan, 2016]

Myin-pya-gu



[Henry IV Bas Relief]



[Tiny Face]



[Doric Column]



[Antler Sculpture]



[Coat of Arms]



[Queen Victoria]



[References]

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- [1] <http://www.hasler.net/meydalb.htm>
- [2] https://en.wikipedia.org/wiki/File:Bundesarchiv_Bild_183-12097-0007,_Berlin,_Platz_der_Akademie,_Schauspielhaus,_Franz%C3%B6sischer_Dom.jpg
- [3] https://commons.wikimedia.org/wiki/File:Gandarmenmarkt_franzoesischer_dom_ds_hochkant_wv_10_2007.jpg
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- [8] <https://www.cameralabs.com/best-dslr/>
- [9] <http://www.amateurphotographer.co.uk/buying-advice/best-compact-camera-105775>
- [10] Luhmann, et al., "Imaging Technology," in Close Range Photogrammetry: Principles, techniques and applications, 2nd ed. Dunbeath, Scotland: Whittles, 2011, pp. 97-135.
- [11] <https://bensimonds.com/2010/08/27/plausiblematerials/>
- [12] <https://www.housepaintinginc.com/duarte-painting-contractor.html>
- [13] <http://www.loversiq.com/o/217960126/wall-designs-exterior/217960/>
- [14] <https://www.e-education.psu.edu/geog892/node/657>
- [15] Courtesy Dr. Mario Santana Quintero
- [16] T. Luhmann, et al., "Imaging Technology," in Close Range Photogrammetry: Principles, techniques and applications, 2nd ed. Dunbeath, Scotland: Whittles, 2011, pp. 102.
- [17] <https://historicengland.org.uk/images-books/publications/photogrammetric-applications-for-cultural-heritage/>
- [18] Courtesy Dr. Fabio Menna, Fondazione Bruno Kessler (FBK)
- [19] <https://photographylife.com/what-is-exposure-triangle>
- [20] <https://www.dxomark.com/>
- [21] <https://photographylife.com/what-is-depth-of-field>
- [22] <http://www.listal.com/viewimage/1598859>
- [23] <http://starwars.ea.com/starwars/battlefront/news/how-we-used-photogrammetry>

[Questions & Comments]

Thanks for your
attention!

[Photogrammetry]

