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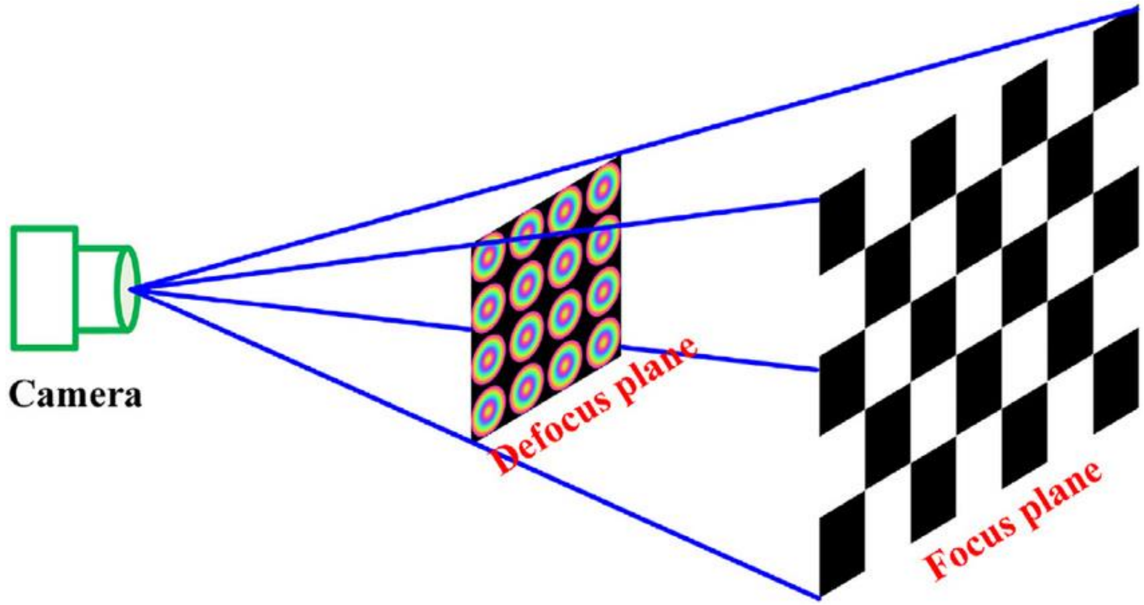

Close-Range Photogrammetry- Project Planning Tips & Camera Calibration

BSc - 4th Stage

2020-2021

Lecture 4

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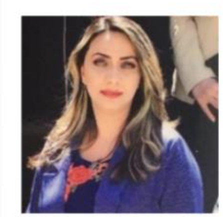


CRP Project!

Tips for first CRP project:

- Test-field calibration to derive an **approximate lens model**;
- Provide sufficient control for restitution and providing independent checks;
- Obtain images for object recording using a **convergent image pair configuration** with an overlap of 90-95%.

  If multiple image pairs are combined to mosaics, an appropriate overlap between adjacent convergent pairs can be 5-10%;
- Spatial measurement using digital photogrammetry, including automated DEM acquisition.

Which Camera to Use?

- Digital Single Lens Reflex (SLR) cameras tend to give better results than compact digital cameras.
- The number of megapixels is important with high resolutions providing more information, but if the lenses are of low quality, images will lack sharpness and clarity whatever the resolution.
- SLR cameras are generally equipped with higher quality lenses than compact cameras and therefore give better results.

Which Camera to Use?

- SLR cameras also offer the best high ISO performance - this allows controlling noise effects and working indoors without the need for a tripod or flash or to stop down aperture for increased depth of field.
- Higher ISO settings are generally used in darker situations to get faster shutter speeds.
- Distortions associated with fixed focal length lenses are easier to model than the more common, variable zoom lens. However, variable zoom lenses (e.g. 18-70mm on digital SLR's) cameras are more versatile and can, with care, be utilised for close range digital photogrammetry at medium accuracies

Which Camera to Use?

- Never purchase the "top of the range" digital camera, unless equipped with an **essential feature** that is necessary for the project.
- Although wide angle lenses typically allow for better triangulation results, avoid extremely wide angle lenses because radial lens distortion becomes excessive for these lenses, and could reduce the potential accuracy of a system.

Which Camera to Use?

- When choosing a camera, choose stability over anything else if accuracy is a major factor because CRP work often involves exposed conditions, heavy use & taking photos perhaps days apart, which emphasizes the need for a very stable camera system. Unlike aerial mapping where photos are taken in rapid succession.
- Only use cameras with fixed and stable sensors, it is not recommended to use those with anti-shake (image stabiliser) mechanisms or clip-on backs.

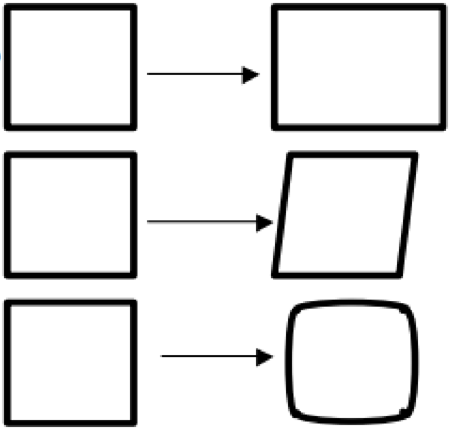
Which Camera to Use?

- Disable "automatic image orientation" in your camera. The photogrammetric image coordinate system assumes this to be fixed relative to the camera. If you cannot disable this feature, record the orientation of the camera manually for each image.

Camera calibration

What is Camera Calibration?

- Primarily, finding the quantities internal to the camera that affect the imaging process
  - Position of image center in the image
    - It is typically not at (width/2, height/2) of image
  - Focal length
  - Different scaling factors for row pixels and column pixels
  - Skew factor
  - Lens distortion (pin-cushion effect)



Camera calibration

- To derive accurate spatial data using consumer grade digital cameras, it is necessary to define several critical parameters which model distinct geometric characteristics of the imaging system. The prime parameters normally recognised include:
- camera focal length (f)
- principal point offset (x_P, y_P)
- radial lens distortion (K_1, K_2, K_3)
- tangential distortion (P_1, P_2)

Camera Calibration Models

- The selection of the proper Camera calibration model is technically based on camera lens types:

  - Frame camera
  - Frame camera -Fisheye lens
  - Spherical camera – equirectangular projection.
  - Spherical camera – cylindrical projection.
  - Others (e.g. RPC for satellite images), etc.!

Camera Calibration Models

- The camera calibration models are distinct in defining the distortion type and amount.
- Agisoft Metashape supports several parametric lens distortion models. Specific model which approximates best a real distortion field must be selected before processing. All models assume a central projection camera.
- A camera calibration model specifies the transformation from point coordinates in the local camera coordinate system to the pixel coordinates in the image frame.
- The local camera coordinate system has origin at the camera projection center. The Z axis points towards the viewing direction, X axis points to the right, Y axis points down.
- The image coordinate system has origin in the middle of the top-left pixel (with coordinates (0.5, 0.5)).
- The X axis in the image coordinate system points to the right, Y axis points down. Image coordinates are measured in pixels.

Camera Calibration Models

- Equations used to project a points in the local camera coordinate system to the image plane are provided below for each supported camera model.
- The following definitions are used in the equations:
  - (X, Y, Z) - point coordinates in the local camera coordinate system.
  - (u, v) - projected point coordinates in the image coordinate system (in pixels).
  - f - focal length (in pixels)
  - cx, cy - principal point offset (in pixels).
  - K1, K2, K3, K4 - radial distortion coefficients (dimensionless),
  - P1, P2 - tangential distortion coefficients (dimensionless),
  - B1, B2 - affinity and non-orthogonality (skew) coefficients (in pixels),
  - w, h - image width and height (in pixels).

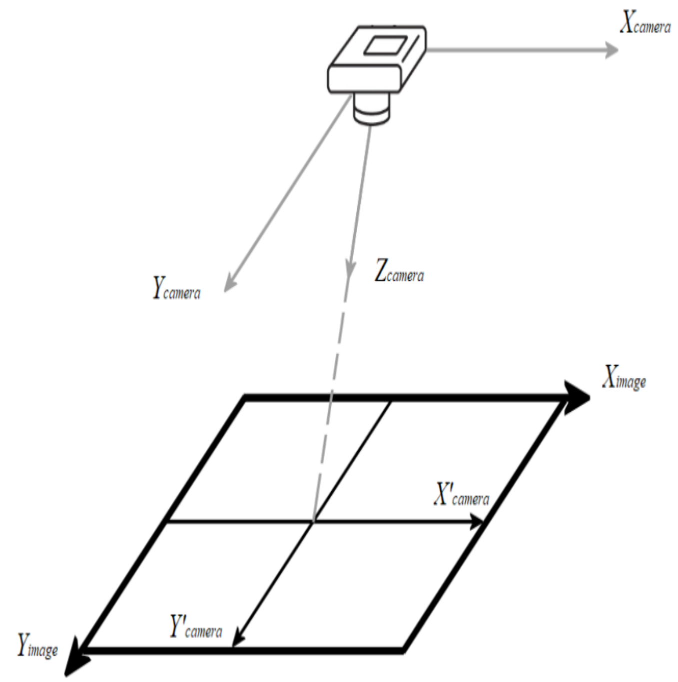


Image and camera coordinate systems

Camera calibration solution

Colliniarity condition equations – self calibration (metric camera).

$$x_a = x_o - \bar{x}_a(k_1 r_a^2 + k_2 r_a^4 + k_3 r_a^6) - (1 + p_3^2 r_a^2)\,[p_1(3\bar{x}_a^2 + \bar{y}_a^2) + 2p_2\bar{x}_a\bar{y}_a] - f\frac{r}{q}$$

$$y_a = y_o - \bar{y}_a(k_1 r_a^2 + k_2 r_a^4 + k_3 r_a^6) - (1 + p_3^2 r_a^2)\,[2p_1\bar{x}_a\bar{y}_a + p_2(\bar{x}_a^2 + 3\bar{y}_a^2)] - f\frac{s}{q} \tag{11-12}$$

where
x_a, y_a = measured photo coordinates related to fiducials
x_o, y_o = coordinates of the principal point
$\bar{x}_a = x_a - x_o$
$\bar{y}_a = y_a - y_o$
$r_a^2 = \bar{x}_a^2 + \bar{y}_a^2$
k_1, k_2, k_3 = symmetric radial lens distortion coefficients
p_1, p_2, p_3 = decentering distortion coefficients
f = calibrated focal length
r, s, q = collinearity equation terms as defined for Eqs. (D-7) and (D-8)

Camera calibration

- There are a variety of cheap/free calibration software tools available, including: Agisoft Metashape, Matlab, PhotoModeler, iWitness, Camera Calibrator, LISA-FOTO which provide the required capability.

Camera calibration tips!

The camera system should be re-calibrated at least every 12 months; or:

- If the camera is heavily handled or knocked, or has been unattended during major transit;
- If the lens has been moved, or removed (ie. to clean the sensor);
- If the initial photo orientations become unstable;
- During, or prior to carrying out a major or crucial project ;
- In case of deliberate changes to camera/lens setting, i.e. new focus position.

Fieldwork/Planning/preparation

- Where possible, visit the site or review the subject and take various test photos to study prior to planning.
- Spend time planning ALL photo locations & control points, estimate the time required for preparing the site (marking control targets etc.) taking photography & making field notes.
- Consider all possible working conditions & other site specifics: weather, visibility, sun/shadows, equipment, assistance, safety regulations & legal responsibilities.

Fieldwork/Planning/preparation

- Most; if not all planimetric measurements derived photogrammetrically require elevated photos in order to see enough detail that is common to & can be identified in at least 2 or 3 photos.
- Common methods of obtaining elevated photos include: tall tripods, masts, cranes or elevating platforms, UAVs & helicopters.

Photo acquisition

- Find the sharpest aperture setting for your lens (often f/8) and calibrate with this setting;
- for most projects infinity focus can be used; keep the lens fixed to this focus & calibrate with the true infinity setting;
- Use the fastest shutter speed applicable to the conditions & available light;
- Increase ISO as necessary if additional sensitivity is needed in lower lighting conditions;
- If necessary in very low light, use a tripod and mirror-lockup to avoid any camera movement;
- Take extra images to increase data redundancy.

Don't forget the photo control/check points!

Other points/comments

- A key source of systematic errors in the object space is caused by inaccurately estimated lens distortion parameters. Although deriving the perfect lens model through self-calibration can be difficult to achieve, it is worth establishing the most accurate lens model possible for a camera. Therefore, prior to their use for spatial measurement, digital cameras should be calibrated, ideally using the test-field calibration method.

Other points/comments

- Having derived an approximate lens model for the camera lens system, it is strongly recommended to acquire image pairs obtained using a convergent image configuration, rather than the “normal case” traditionally used for aerial photography.
- Critically, recent research demonstrated that a convergent image configuration minimises residual systematic error surfaces caused by slightly inaccurately estimated lens distortion parameters. There are other benefits. The convergent image configuration provides 100% overlap of image pairs and hence more efficient coverage of the object, compared to the traditional coverage methodologies used for aerial photogrammetry.

New Features in MetaShape 1.7

New Features in MetaShape 1.7

Acknowledgment Credits

- Agisoft MetaShape, https://www.agisoft.com/
- Photo Modeller, http://www.photomodeler.com/index.html
- **“Tips for the effective use of close range digital photogrammetry for the Earth sciences“,** ISPRS - Commission V - Close-Range Sensing: Analysis and Applications, **Working Group V / 6 - Close range morphological measurement for the earth sciences, 2008-2012**