Canadian Board of Examiners for Professional Surveyors
Core Syllabus Item
E 5: ADVANCED PHOTOGRAMMETRY

Study Guide:

Numerical answers and specific references to the Essential Reference Materials to assist in non-numerical answers are provided for each section of this study guide.

1. With reference to quality assurance and quality control of photogrammetric mapping:
   - Quality Assurance (QA): definition and procedures
   - Quality Control (QC): definition and procedures
   - Camera calibration: Analog and digital cameras, metric and non-metric cameras, and stability analysis
   - System calibration
   - Precision and accuracy evaluation of the outcome from photogrammetric mapping

Sample Questions:

Q1.1. What is meant by Quality Assurance (QA) and Quality Control (QC)?

Q1.2. What are the factors that should be considered in the QA for a mapping mission?

Q1.3. What are the QC measures for evaluating the outcome from a photogrammetric mapping mission?

Q1.4. What is the target function of the Interior Orientation procedure?

Q1.5. What are the parameters defining the Interior Orientation of a given camera?

Q1.6. What are the alternative methodologies for estimating the Interior Orientation Parameters of a given camera? Which methodology would you prefer? Why?

Q1.7. What are the factors affecting the precision of the outcome from a photogrammetric bundle adjustment procedure?

Q1.8. What are the factors affecting the accuracy of the outcome from a photogrammetric bundle adjustment procedure?

Q1.9. How would you evaluate the precision and the accuracy of the outcome from a photogrammetric bundle adjustment procedure?

Q1.10. How would you classify the following cameras in terms of being normal, wide, or super-wide angle cameras (explain your answers):

a. 9" × 9" format size with 30 cm focal length,

b. 9" × 9" format size with 15 cm focal length, and

c. 9" × 9" format size with 8 cm focal length.

Answer:

Normal angle (56.62º), wide angle (94.26º), super wide angel (127.32º)

Q1.11. Which of the following cameras:

- Normal angle camera, or

- Super-wide angle camera

  Would give better height accuracy? Why? (Assume that the same scale and overlap ratio are maintained for both cameras.)

See Essential Reference Materials ENGO 431 Chapters 1 – 8; ENGO 531, Chapters 1, 3, 4, and 5; ENGO 667, Chapters 1 and 2

2. With reference to digital imaging systems:

- Frame cameras: Large format and medium-format digital cameras
- Multi-head frame cameras
- Line cameras: data acquisition and stereo-coverage
- High resolution imaging satellites
- Perspective geometry of line cameras: Orientation Images (OI) and polynomial representation of the system trajectory
- Multi-sensor photogrammetric triangulation

Sample Questions:

Q2.1. What is the main limitation of a digital frame camera when compared with an analogue one?

Q2.2. How are the limitations of a digital frame camera compensated for by the introduction of line cameras?

Q2.3. For a push-broom scanner, what is the preferred methodology for stereo-coverage? Why?

Q2.4. How would the stereo-coverage alternatives associated with line cameras affect the Ground Sampling Distance (GSD) in the acquired scenes?

Q2.5. What is the main advantage of satellite imaging platforms when compared with aerial ones?

Q2.6. What are the main differences between the collinearity equations for frame and line cameras?

Q2.7. For a line camera, whose trajectory is represented by four Orientation Images (OI), what is the number of involved Exterior Orientation Parameters (EOP) per scene in the bundle adjustment procedure?

Answer:

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Q2.8. For a line camera, whose trajectory is represented by a second-order polynomial for the position component and zero-order polynomial for the orientation component, what is the number of involved Exterior Orientation Parameters (EOP) per scene in the bundle adjustment procedure?

Answer:

12

Q2.9. Do you expect any contribution by incorporating sparse frame imagery in a bundle adjustment procedure involving scenes captured by a line camera? If you do, what would such a contribution be?

Q2.10. What is the fundamental challenge in multi-sensor photogrammetric triangulation involving imagery captured by frame and line cameras onboard aerial and satellite imaging systems? Why? How would you mitigate such a challenge?

See Essential Reference Materials ENGO 431, Chapter 4; ENGO 435, Chapters 1 and 3; ENGO 531, Chapter 2

3. With reference to sensor modeling:

- Relating image and ground coordinates: objectives and alternatives
- Collinearity equations:
  - Rotation matrices: characteristics and derivation
  - Collinearity equations for frame cameras
  - Collinearity equations for line cameras
- Projective transformation
- Direct Linear Transformation (DLT)
- Rational Functional Model (RFM)

Sample Questions:

Q3.1. What is the objective of the mathematical model in photogrammetry?

Q3.2. What is the conceptual basis of the Collinearity equations?

Q3.3. What is meant by the orthogonality conditions of a rotation matrix?

Q3.4. Discuss the differences between 2D and 3D rotation matrices in terms of:

a. Number of elements in the matrix,

b. Number of independent parameters required to describe the corresponding rotation matrix, and

c. Number of orthogonality conditions that should be satisfied.

Answer:

4/9, 1/3, 3/6

Q3.5. What are the utilized rotation angles and rotation sequence in photogrammetry? Is it important to follow a certain order while applying these rotations? Why?

Q3.6. In a photogrammetric procedure that exploits the collinearity model, list possible unknown parameters that can be involved.

Q3.7. In a photogrammetric procedure that exploits the collinearity model, list possible observables that can be involved. Quote an example on how each quantity can be observed.

Q3.8. What is the underlying assumption for using a projective transformation to relate the image and object space coordinates?

Q3.9. Briefly explain the conceptual basis for using the Rational Functional Model to relate the image and object space coordinates?

Q3.10. What are the main differences between the collinearity equation and Direct Linear Transformation models?

See Essential Reference Materials ENGO 431, Chapters 7 and 8; ENGO 435, Chapter 5; ENGO 531, Chapters 1 and 2; ENGO 667, Chapters 1 and 2

4. With reference to image geo-referencing:

- Image geo-referencing: Definition and alternatives
- Indirect geo-referencing: concept and implementation
- Integrated sensor orientation: concept and implementation
- Direct geo-referencing: concept and implementation
- System calibration: lever arm and boresight calibration
- Mobile mapping systems
- Comparative analysis of the different geo-referencing techniques

Sample Questions:

Q4.1. What is the role of the Interior Orientation (IO) in the photogrammetric reconstruction procedure?

Q4.2. What is the role of the geo-referencing in the photogrammetric reconstruction procedure?

Q4.3. What are the main differences between the following bundle adjustment procedures:

a. Photogrammetric triangulation through indirect geo-referencing,

b. GPS-controlled photogrammetric triangulation, and

c. GPS/INS-controlled photogrammetric triangulation?

Q4.4. Is it possible to incorporate a GPS/INS system onboard the imaging platform to facilitate object space reconstruction from a single image? Why?

Q4.5. What are the quantities measured by a GPS/INS system onboard an imaging platform? What are the main requirements for relating these measurements to the exterior orientation of the exposure stations?

Q4.6. Considering the spatial and rotational offsets between the GPS/INS unit and the imaging sensor, which offset has a more significant effect on the quality of the reconstruction procedure? Why?

Q4.7. Can you carry out a photogrammetric reconstruction of a GPS-aided photogrammetric triangulation of an image block without any ground control points? Why?

Q4.8. Can you carry out a photogrammetric reconstruction of a GPS-aided photogrammetric triangulation of a single flight line without any ground control points? Why?

Q4.9. What would be the contribution magnitude (i.e., significant versus insignificant) of an INS in the following situations (explain why):

a. GPS/INS-controlled photogrammetric triangulation of an image block captured by wide-angle frame camera?

b. GPS/INS-controlled photogrammetric triangulation of an image block captured by a narrow-angle line camera?

Q4.10. What is the impact of biases in the Interior Orientation Parameters (IOP) on the reconstruction outcome from photogrammetric triangulation aided by GPS/INS observations or GCP? Why?

Q4.11. What would you expect from a GPS/INS-controlled triangulation and intersection procedures in terms of the quality of the reconstructed object space? Why?

See Essential Reference Materials ENGO 431, Chapter 8; ENGO 531, Chapters 1, 2 and 3

5. With reference to image matching:

- Automated matching of conjugate features in overlapping imagery: objective, terminology, and applications
- Interest operators for point feature extraction
- Cross correlation: concept, procedure, evaluation of matching results
- Least squares matching: concept, procedure, evaluation of matching results
- Epipolar geometry: concept and image resampling
- Edge detection: first derivative and second derivative operators
- Feature-based matching

Sample Questions:

Q5.1. What is the objective of image matching?

Q5.2. What are the main applications that would benefit from automated identification of conjugate points in overlapping images?

Q5.3. What is meant by the following terms: template, matching window, search window, similarity measure, and matching strategy?

Q5.4. What is the conceptual basis of the cross-correlation matching?

Q5.5. What is the conceptual basis of the least squares matching?

Q5.6. What is meant by image resampling according to epipolar geometry?

Q5.7. Explain how the image matching is simplified by working with resampled imagery according to epipolar geometry.

Q5.8. What is the conceptual basis of feature-based matching?

Q5.9. Which one of the following points (i.e., the center of the given windows) can be considered as an interest point? Why?

95	94	84		23	94	84
86	27	96	or	34	27	96
100	97	87		36	22	25

Answer:

The first window.

Q5.10. What are the two main categories of edge detection techniques? Discuss the advantages and disadvantages of these categories.

Q5.11. To output a thin edge using first derivative edge detection operator, non-maximal suppression is needed. What is meant by non-maximal suppression? (Explain your answer with the help of a sketch)

See Essential Reference Materials ENGO 435, Chapters 4 and 5; ENGO 531, Chapter 3, ENGO 667, Chapter 4

6. With reference to orthophoto generation:

- Registration, geo-coding, and ortho-rectification
- Necessary tools:
    - Image-to-image transformation (direct and indirect transformation)
    - Image resampling
- Polynomial rectification
- Rigorous/differential rectification
- True orthophoto generation
    - Double mapping problem
    - Visibility analysis
    - True orthophoto generation: Z-buffer method

Sample Questions:

Q6.1. What is meant by data registration? Why is it an important issue?

Q6.2. What are the characteristics and possible applications of an orthophoto?

Q6.3. What are the different strategies of rectifying images? Tabulate the advantages and disadvantages of each method?

Q6.4. What are the differences between direct and indirect transformation during image rectification? Tabulate the advantages and disadvantages of each method?

Q6.5. What is the required input for orthophoto generation using polynomial rectification?

Q6.6. What is the required input for orthophoto generation using differential rectification?

Q6.7. List all the necessary steps required to produce an orthophoto using differential rectification?

Q6.8. What is meant by the double mapping problem when generating orthophotos from large scale imagery over urban areas?

Q6.9. Explain the conceptual basis of the z-buffer method for true orthophoto generation.

See Essential Reference Materials ENGO 435, Chapter 5; ENGO 531, Chapter 5; ENGO 667, Chapter 4

7. With reference to LiDAR mapping:

- LASER principles

- LiDAR principles
- LiDAR equation
- Error sources (systematic and random errors)
- Quality assurance for LiDAR mapping
- Quality control of LiDAR data
- LiDAR data segmentation and feature extraction
- LiDAR versus photogrammetric systems

Sample Questions:

Q7.1. What are the main components of a LiDAR system?

Q7.2. What are the main factors affecting the size of the laser footprint?

Q7.3. What is meant by the following specifications and their typical values for commercial LiDAR systems:

a. Scan rate/frequency,

b. Pulse rate/frequency,

c. Ground spacing,

d. Wavelength,

e. Scan pattern, and

f. Beam divergence?

Q7.4. What are the systematic errors that might be present in a LiDAR system? How can you mitigate the impact of these errors?

Q7.5. What is the conceptual basis of point positioning using a LiDAR system?

Q7.6. What is the main objective of LiDAR data segmentation?

Q7.7. What are the alternative segmentation approaches of LiDAR data? Comment on the advantages and disadvantages of these approaches.

Q7.8. How would you compare the intensity image generated from a LiDAR system to an optical image?

Q7.9. What are the main differences between photogrammetric and LiDAR systems?

Q7.10. What are the main advantages of LiDAR when compared to a photogrammetric system?

Q7.11. What are the main advantages of a photogrammetric system when compared to LiDAR?

Q7.12. For a photogrammetric system, the horizontal accuracy is superior to the vertical accuracy. Do you agree with this statement? Why?

Q7.13. For a LiDAR system, the vertical accuracy is superior to the horizontal accuracy. Do you agree with this statement? Why?

See Essential Reference Materials ENGO 435, Chapter 3; ENGO 531, Chapters 4 and 5; ENGO 667, Chapter 4