Introduction to SfM for a geology field course – Student Exercise

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In this introductory unit you will learn how to design and conduct a Structure from Motion (SfM) photogrammetry survey. SfM method involves taking overlapping photographs of the same area or object. The processing software then creates a 3D model from changing position of the same points. SfM requires less expensive equipment and less field time but more processing time than TLS. In low-vegetation field areas, it can yield a similarly valuable high-resolution topographic model applicable to a variety of geologic research questions. Unit 1-SfM may be used alone or concurrently with Unit 1-TLS.

Introduction:

This unit introduces Structure from Motion (SfM), a photogrammetric technique that uses overlapping images to construct 3D models with widespread research applications in geodesy, geomorphology, structural geology, and other sub-fields of geology. SfM can be collected from a handheld camera or an airborne platform such as an aircraft, tethered balloon, kite, or UAS (unmanned aerial system). In this exercise you will receive an introduction to the basics of SfM, then you will design and conduct a survey of a geologic feature. After completing the survey, you will use the photos you collected to learn the basics of SfM model generation, data exploration, and data visualization to answer questions about the geologic feature and your survey design.

Project Description:

Below is a description of the workflow to follow while doing this project. This exercise is expected to take four to six hours, with additional time needed to learn to generate an SfM model, visualize the data, and explore the data.

Field Notes and Metadata Collection:

While in the field, record notes as you would on any other field day (weather—especially wind or other weather that will affect the stability of the collection platform—rock type(s), measurements of strike and dip or other features, and a sketch of the outcrop or landform) as well as detailed metadata related to the survey workflow. You will also need to make a list of equipment needed for an SfM survey (worksheet attached below). Metadata includes a sketch of the study area with camera locations / collection path, and target locations. Include justification (including the limitations) of the selection of these locations; file naming conventions and locations; the surface texture, color, and condition; survey team; and the objective of the project. You want to capture enough information about the survey and the field site and conditions that you can clearly recall what was done when you are working to process the data in the lab, days to weeks after the data collection.

Make measurements of three prominent geologic features in the survey area. Your instructor will give you specific instruction, but examples include a bed thickness, distance between two large clasts, distance between two trees, distance between offset beds, or any other clearly identifiable feature. These will be used in your final write-up for the unit.

One of your objectives for the unit is to write step-by-step instructions for designing and executing an SfM survey, so also take notes on this process.

Data Exploration:

In addition to the *SfM Field Methods Manual*, the *SfM Data Processing and Exploration Manual* has been handed out. The *Data Processing* manual has sections on SfM model generation, including how to georeference the model; data visualization; data selection and cleaning; and exporting the data. The *Data Processing* manual is for the module as a whole, so not all sections are relevant to this unit.

Write-up:

After collecting and exploring the SfM survey data, create a write-up detailed below about workflow, metadata collection, and results of data exploration.

Project Report:

Part A: Workflow

The first section of the write-up for the unit should be step-by-step instructions for designing and executing an SfM survey with your collection platform of choice. Use details like sketches of the collection path and target locations from field notes. Remember to include:

1. A list of the equipment needed
2. A map of the camera locations/collection path, the target locations, and the GPS locations
3. A summary of the necessary metadata
4. Operational procedures for setting up a survey (like general considerations for camera locations / collection path, target location, GPS location, setting up the collection platform, any weather (windy, etc.) that affected the collection process, the number of photos, and time)
5. General steps for model generation and visualizing the data.

Part B: Why SfM?

In this section, detail the societal impetus for using SfM for research, including the importance of this technology to society. Many examples of the wide range of applications of SfM were given in the introductory lecture. Consider the commonalities between these examples to demonstrate why SfM is useful in a general sense, not just in a sub-field of geoscience or in geoscience. Recall the objective of the project at the field site and summarize why SfM was the best method—or not—to accomplish that objective. If you think another method would be comparable or better, explain.

Part C: Data Summary

Summarize the data collected by the class.

1. How many photos were collected? Were they all collected using the same platform? Multiple platforms? Multiple types of platforms?
2. Was the platform you used the best option for the feature of interest? If yes, justify why. If no, what might have worked better?
3. What are the files called? Where are they stored?
4. Are there blurry photos in the data set that were not included in the model generation?
5. How many photos were used in the model?

6. Provide a map of the camera locations / collection path.
7. Based on this map, would you assess that the survey covered the entire area of interest? Which areas were not well covered or missed entirely?
8. Use the function in the SfM software to generate a map of photo density. Does this map show that you successfully surveyed the area of interest? Why or why not?

Part D: Data Exploration and Analysis

Finally, identify occluded (or shadowed) portions of the model.

1. How do these occluded portions affect or not affect your ability to study that feature?
2. Demonstrate the resolution of the model versus reality by comparing the difference between measurements of geologic features in the model and those same measurements you collected in the field.

After completing these portions of the write-up, briefly answer the following question:

1. What surprised you the most about using SfM?

SfM Survey Equipment List:

Principal Investigators: ____

Project Site: ____ *Date:* ____________

Items	Quantity	Notes

Field Sketch:

Notes: atmospheric conditions, file names, number of photos, other metadata

Structure-from-Motion (SfM) Calculations Worksheet

This worksheet will guide you through estimating the distance from the feature and number of photos you will need to characterize a feature. FOR LATER UNITS: it may be helpful to measure things about the feature in Google Earth prior to going into the field and completing this worksheet, so you can know the exact length of what you are surveying prior to completing the sheet.

Part 1: Variables for calculations

Data from the manufacturer – get this from the camera's manual or your instructor (example values are common)	
Real focal length (use the minimum value listed, as photos will not be zoomed) in **mm** (fl)	28 mm for DSLR; 5.5 mm for point and shoot
Sensor width and height dimensions in **mm** (sw, sh)	22.2 mm x 14.8 mm; 6.17 x 4.55 mm for point and shoot
Aspect ratio of photograph (ar)	
Effective pixels (ep) Get this number by multiplying the megapixels by one million	

Field distances (replace these example distances with ones from your field site)	
Distance between the end of the camera lens and the ground/outcrop in **m** (d)	10 m, 25 m, 50 m
Horizontal length of interest in **m** (l)	100 m

Part 2: Calculate image dimensions for your camera in pixels

<u>*Calculate the horizontal-to-vertical aspect ratio (hvar)*</u>

Example with ar = 5:2; hvar = 5/2 = ______

hvar: ____

<u>*Calculate the vertical-to-horizontal aspect ratio (vhar)*</u>

Example with ar = 5:2; vhar = 2/5 = ______

vhar: ____

Find the horizontal image dimension in pixels

$$iw = \sqrt{ep * hvar}$$

iw: _____

Find the vertical image dimension in pixels

$$ih = \sqrt{ep * vhar}$$

ih: _____

Part 3: Calculate pixel size

$$ps = \sqrt{\frac{sw * sh}{iw * ih}}$$

ps: _____

Part 4: Calculate ground sample distance

The ground sample distance is the distance between the center of a pixel and the center of an adjacent pixel. This varies based on how far the camera is from the feature of interest.

Use the example distances below or replace with distances (d) that you put in Part 1.

$$gsd = \left(\frac{ps * d}{fl}\right)$$

gsd (10m): ____ **gsd(25m): ____** **gsd(50m): ____**

What is a good ground sampling distance to accomplish your accuracy goals? A reasonable rule of thumb would be ~10 pixels within your desired accuracy range. For example if you wanted 5-cm accuracy, you would want your pixel size on the ground to be about 5 mm. Justify your accuracy goal and calculate a reasonable gsd to accomplish that.

Part 5: Calculate photo dimensions

$$\boldsymbol{w = iw * gsd} \qquad \boldsymbol{h = ih * gsd}$$

For d = 10 m

w(10): ____ **h(10): ____**

For d = 25 m

w(25):____ **h(25):____**

For d = 50 m

w(50):____ **h(50):____**

Part 6: Calculate the number of images needed to survey

Use the image dimensions in meters you calculated in the previous step and the given feature lengths to calculate the number of photos you would need to take to survey that object. Assume that each photograph needs to overlap the previous photograph by 70% to ensure successful model production. Also assume this feature can be characterized by a single row of photos.

For a feature length of 100 m (or whatever length of interest you put in Part 1):

Number of photos (d = 10):_____ Number of photos (d = 25):_____

Number of photos (d = 50):_____

Unit 1 SfM Rubric - Introduction to SfM for a geology field program

This rubric covers the material handed in for Unit 1 student exercise and is the summative assessment for the unit.

Component	Exemplary	Basic	Nonperformance
General Considerations	Exemplary work will not just answer all components of the given question but also answer correctly, completely, and thoughtfully. Attention to detail, as well as answers that are logical and make sense, is an important piece of this.	Basic work may answer all components of the given question, but answers are incorrect, ill-considered, or difficult to interpret given the context of the question. Basic work may also be missing components of a given question.	Nonperformance occurs when students are missing large portions of the assignment, or when the answers simply do not make sense and are incorrect.
Part A: Workflow (7 points)	7 points: Workflow as a whole is detailed and makes sense; someone who has not used SfM could follow along. Includes the filled-in (and correct) equipment sheet, sketches of a setup in the field explaining camera locations / collection path and target and GPS location, a list of required metadata, operational procedures, and general steps for data visualization.	3–6 points: Characteristics of an 8-point response but missing 1–2 of the pieces listed AND/OR Workflow is not logical and is difficult to follow, but is still usable.	0–3 points: Missing 3–5 of the pieces listed for the workflow AND/OR The workflow is unusable.
Part B: Why SfM? (4 points)	4 points: Detailed and thoughtful answer about why to use SfM for research; includes examples and a discussion of the importance (3 points); Research objective of the project/why use SfM for this objective (1 point)	2–3 points: 1–2 of the three listed for an exemplary example; judge based on the number of points assigned to each factor.	0–1 point: 0–1 of the factors listed for an exemplary example.

Part C: Data Summary **(4 points)**	4 points: Includes a list of data collected, including number of photos, platform(s), justification of platform choice, filenames, photos included in the model, collection path map, and photo overlap map with explanation of survey success.	2–3 points: Missing details of the survey (3–4 of the six listed characteristics) AND/OR lack of detail in student response in 2–3 so they are unusable answers.	0–1 point: Includes only 1–2 complete and detailed characteristics listed for an exemplary answer.
Part D: Data Exploration and Analysis **(4 points)**	4 points: Identifies occluded portions of the survey, and the difference between the measurements done by hand or done on the model. Also, all calculations must be correct (3 points); Reflective and complete answer about what surprised them about working with SfM (1 point)	2–3 points: Includes all of the characteristics listed for an exemplary answer but I listed characteristic is incorrect or missing (1–2 points); Answers question about positive and negative aspects of working with SfM, but answer is not thoughtful or reflective (0.5 points)	0–1 point: One listed characteristic that is correct; all listed characteristics but none were calculated correctly (0–1 point); Does not answer reflective question (0 points)