1. Intro
   1. Quick overview before digging into background and literature review
   2. State the goals and purpose of the paper
2. Photogrammetry -> Computer Vision -> SFM Background
   1. How has photogrammetry historically been used?
   2. How have DSMs and bundle adjustments been made using photogrammetry?
   3. How has Computer Vision community paralleled the Photogrammetry field?
   4. How have SIFT, SURF, Patch based reconstruction advanced the computer vision field?
   5. History of SFM usage for surveying
   6. Challenges in SFM usage
   7. Sentence or Two introducing what Computer Graphics is beneficial
3. Computer Graphics Background
   1. How Computer Graphics Began
   2. Two types of methods for rendering equations (radiosity and ray tracing)
   3. Textures using uv mapping
   4. Lighting equations
   5. Camera parameters (pinhole)
   6. Why using Blender
4. History Using Computer Graphics for Remote Sensing and SFM
   1. Dirsig
   2. Some paper doing almost similar things
5. Goal and Methods in more detail
   1. Describe why, how, advantages, disadvantages, goals, etc
6. Computer Graphics Validation
   1. ensures that any resultant error in an uncertainty analysis is due to SFM algorithm, not the rendering.
   2. Validate Interior/Exterior Orientation and Object Placement accuracy
      1. Cameras with various focal lengths placed in a cube with 10x10 checkerboards
      2. Corners detected with Harris corner, corners detected with photogrammetric eqn
      3. Compare differences and show accuracy at various fx, fy, cx, cy, Tx, Ty, Tz, Rx, Ry, Rz
   3. Validate That Point Spread Function is unit impulse
      1. Sphere placed at far distance
   4. Validate That Texture is accurate to the pixel
      1. Fly camera around checkerboard texture with 1 pixel checker size, ensure that you can see each pixel
   5. Final statement on why this validation is important, why it should be applied to any computer rendering of imagery to ensure accuracy
      1. Lighting is not validated as it is not the focus of this experiment
      2. Only care about the texture, not the radiosity of the object
7. Automated Workflow using Blender (internal renderer)
   1. Why Blender, advantages/disadvantages
   2. Blender API
   3. XML schema
      1. Goal to use photogrammetric terms and not computer graphics terms
      2. Default values allow for simple xml schema, or more complex for advanced use
8. Proof of Concept/Demo
   1. \*Here I want to show a basic experiment to explicitly spell out the advantages to the reader
   2. Experiment Design
      1. Simulate flight over a grasslike topography
   3. Results
      1. Process in Photoscan
      2. Compare Photoscan Pointcloud to true Model in Cloud Compare
      3. Compare Photoscan orthophoto to true orthophoto in Matlab
   4. Discussion of Results
      1. GCP error is on the order of mms, dense DSM error is higher than that
9. Conclusion
   1. Conclusion/Implications of Methodology
      1. Repeatable, Controlled experiments to test various SFM algorithms and accuracy
   2. Future Work
      1. Make software open source
      2. Experiment to determine sensitivity analysis to various parameters
      3. GPS accuracy effect on pointcloud accuracy, etc

**Abstract**

Structure from Motion (SfM) and MultiView Stereo (MVS) algorithms are increasingly being used to generate pointcloud data for various surveying applications, however the accuracy and sources of error in the resultant pointcloud across various use cases are difficult to realize without thorough experimentation. The acquisition of imagery and rigorous ground control data at field sites required for this experimentation is a time consuming and sometimes expensive endeavor. These experiments are also almost always unable to be perfectly replicated due to the numerous uncontrollable independent variables, such as solar radiation and angle, cloud cover, wind, objects in the scene moving, exterior orientation of cameras, and camera dark noise to name a few. The large number of independent variables creates a scenario where robust, repeatable experiments are cost prohibitive and the results are frequently site specific. Here, we present a workflow to render computer generated imagery using a virtual environment which can mimic all the independent variables that would be experienced in a real-world data acquisition scenario. The resultant modular workflow utilizes the open source software Blender for the generation of photogrammetrically accurate imagery suitable for SfM processing, with tight control on camera interior orientation, exterior orientation, texture of objects in the scene, placement of objects in the scene, and Ground Control Point (GCP) accuracy. The challenges and steps required to validate the photogrammetric accuracy of computer generated imagery are discussed, and an example experiment assessing accuracy of an SFM derived pointcloud from imagery rendered using a computer graphics workflow is presented.

The photogrammetric accuracy of the rendering methodology must first be validated to ensure that the interior and exterior orientation are set correctly. An assessment is performed by rendering a scene consisting of photo identifiable targets at known coordinates using a simulated camera with user defined interior and exterior orientations. The coordinates of the photo identifiable targets as calculated using Harris feature detection are compared with the expected coordinates of these targets based on the photogrammetric projection equation.

Before rendering more realistic scenes, it is advantageous to start with idealized scenes consisting of regular geometric shapes and patterns. If photogrammetric techniques and the known interior and exterior orientation parameters of the modeled camera can be used to measure coordinates of points in the imagery that agree closely with their known coordinates, this provides confirmation that the methods work in the simplest test cases. It is then possible to move onto more challenging test cases by introducing lens and motion blur, noise, vignetting, and more realistic objects, since degraded accuracy in the photogrammetrically-derived coordinates will then be attributable to these factors, rather than to underlying issues with the methods. To this end, the following section describes tests conducted using a simple scene consisting of a 1000 m^3 cube with a 10x10 checkerboard on each wall.