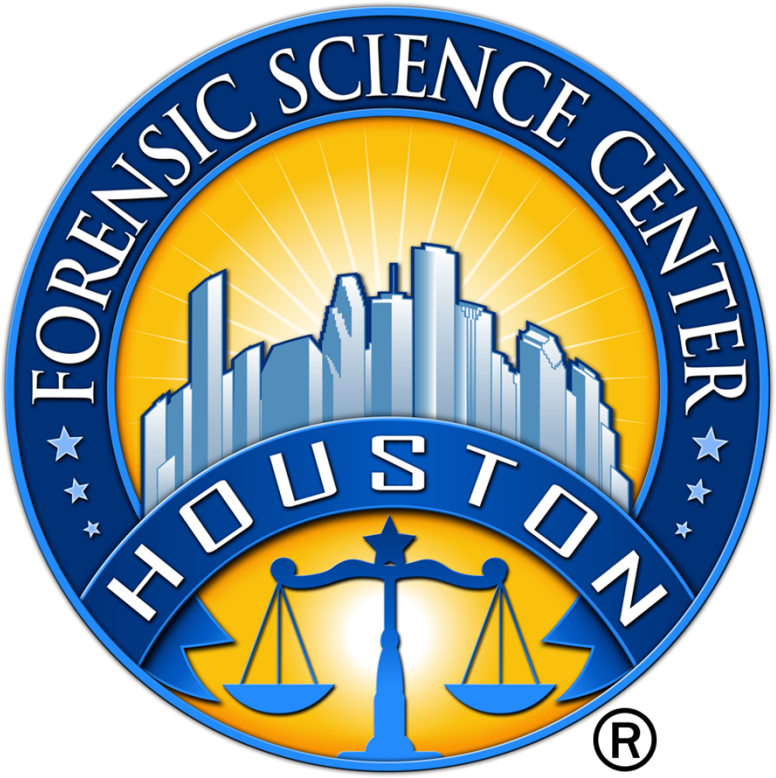

Crime Scene Unit

Photogrammetry Standard Operating Procedure

Crime Scene Division

Introduction

This SOP is intended for use during validation of collection and processing of data to produce maps of scenes. Until approved, scenes will be mapped consistent with established procedures and collection of data for validation will be done in parallel. For any scene where parallel data is collected for validation purposes, the report must contain an explanation making it clear that additional data on the scene was collected for validation and is available on request.

Photogrammetry tools are intended to provide more accurate and complete representations of scenes using photographic data from various sensor platforms such as UAS and handheld cameras. Photogrammetry operates on the principal of parallax which allows for the mathematical determination of points in space using different angles from overlapping photos of the same physical point. This is the same principal that the human brain uses information from both eyes to determine the depth and position of a visible object.

Pix4D is the specific software tool utilized by HFSC to construct 2D and 3D representations of scenes. This is a third party developed commercial software widely used in survey, mapping, and inspection applications. This software utilizes “multipoint” photogrammetry to make highly accurate and precise estimates of millions of points in 3-dimensional space (known as a point cloud) from an array of overlapping photos taken of the scene. The software calculations include the geometry of the camera optics and the geopositioning data from the image to determine both the relative position of points to each other and their absolution position of the points on the planet. The software also calculates color matching polygons between related points to construct a 3D textured mesh as part of the rendering of the 3D representation of an object or scene.

Because the software calculates the position of millions of points within the scene, highly accurate scale measurements can be made between any points within the model. HFSC has conducted validation studies to determine the reliability of these measurements in field conditions and reports an estimate of the resolution and measurement uncertainty associated with these measurements.

The mission of the photogrammetry tools is to take information gathered via UAS and other sensors to provide accurate models of crime scenes to assist CSU in rapidly and completely making accurate renderings of scenes. The program augments HFSC by providing the ability to digitally recreate scenes and capture information about scenes in the context in which they occurred.

However, the program is limited by the data available to it and the constraints of its algorithm. The quality of the input images is essential to the quality of the output representation. What is not in the underlying photographs cannot be represented. These limitations are included in the quality reports generated with calculated representations. Some artifacts and distortions are expected in models and are why traceable measurement references of multiple lengths and in the x, y and z axes are used to ensure specific scenes are appropriately accurate and precise. Photogrammetry analysis shall be

operated in a responsible manner consistent with CSU policy, Texas State laws, and federal rules and regulations; ensuring that the privacy rights of the people in the State of Texas are respected.

https://support.pix4d.com/hc/en-us/articles/202558679-Quality-report-specifications#label02

Terminology:

UAS: unmanned aerial system

GCP: ground control point

GSD: Ground sampling distance

MTP: manual tie point

Pix4DCatch: Software application for capturing images on an iPad or another mobile device

Pix4DCapture: software application for programming a UAS mission to collect images for processing in Pix4Dmapper

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1. Data collection:

1.1. Use of UAS platform for data collection

1.1.1. Ensure the UAS is operated in compliance with the Unmanned Aircraft System (UAS) for Multi-ray Photogrammetry Standard Operating Procedure

1.1.2. Pix4Dcapture set up (Capture is the software controlling the drone for image capture)

1.1.2.1. Place UAS home point near intended mission area.

1.1.2.2. Launch UAS via DJI app to establish position of mission, minimum usable flight heights, and optimizing camera.

1.1.2.3. Land UAS, launch Pix4Dcapture, and start mission.

1.1.2.4. UAS controls shall be manned at all time during the mission and visual contact will be maintained.

1.1.2.5. Mission can be paused via the pause button, changing flight modes, or moving controller's sticks.

1.1.3. Minimum data requirements

1.1.3.1. Between 35- and 60-feet elevation, or the lowest continuous height within that range.

1.1.3.2. At least 100 images, this is decided by the size of the grid.

1.1.3.3. Double grid pattern, this allows for the use of a 3D scene.

1.1.3.4. Minimal GSD of 0.8 inches per pixel but strive for lower.

1.1.4. Ensure all automated checklist requirements are "green check" prior to flight. Resolve any discrepancies prior to flight.

1.1.4.1. All checks are necessary, except for the multi-battery which may be necessary for larger scenes.

1.1.4.2. If a multi battery flight is planned, make sure there are sufficient charged batteries available.

1.1.5. Ensure adequate image quality and exposure before departing the scene

1.1.5.1. Use the DJI flight app to preform preflight camera optimization, Pix4D capture is unable to perform sufficient camera optimization.

1.1.5.2. Download images from the drone to the mobile device and visually check that images are of appropriate quality and exposure.

1.1.5.3. When stable high speed network connection is available, upload images to Pix4D cloud for processing. This process ensures that the project images are correctly organized in the cloud.

1.2. Use of pix4D catch.

1.2.1. For Pix4Dcatch, ensure at least 100 images are captured and adequate overlap and coverage is indicated by the viewer of the scene.

1.3. Included measurement references.

1.3.1. At least 3 approved GCP flags shall be included in the scene to be captured. No more than 8 are necessary.

1.3.2. Flags shall be placed near significant features in the scene and covering the extremes of the scene area.
1.3.3. Include at least 1 approved vertical reference board.
1.3.4. Include at least one 10–12-foot reference tape (yellow webbing) and ensure the tape identifier is visible.

2. Downloading images and storing images:

2.1. From UAS:
2.1.1. Download images from the SD card into a local directory labeled for the case.
2.1.2. Upload images to Dataworks consistent with CSU SOP section 22.1
2.1.3. Alternatively, images may be downloaded from Pix4Dcloud and then imported to Dataworks
2.2. From Pix4Dcapture:
2.2.1. Upload images from capture to Pix4Dcloud.
2.2.2. From pix4D cloud download images and import them into Dataworks consistent with CSU SOP section 22.1.

3. Processing data on Pix4Dcloud, is the primary means of processing data:

3.1. Once images are collected and checked, push up to cloud for processing.
3.2. Pix4Dcloud uses the latest stable version of Pix4Dmapper and is maintained by Pix4D. There are minimal settings that can be altered for this processing.
3.3. If the model is acceptable (see below for review and acceptance) this is all the processing necessary, and the final model can be delivered to end users via the web interface.
3.4. Once model has completed processing, name project for the case number and move the project to the parallel scene directory.

4. Processing data using Pix4D mapper (local processing):

4.1. Local processing is used for exceptional circumstances and to verify results if needed from cloud processing. The local version of mapper allows for greater control of settings and may provide a means of remediating data that could not be processed in the cloud. If cloud processing results in an acceptable model, no local processing is necessary.
4.2. Setting up a project:
4.2.1. Launch Pix4Dmapper.
4.2.2. Create New Project and name the project for the case number
4.2.3. Import images.
4.2.4. Select the output coordinate system and GCP coordinate system.
4.2.5. Select processing options template (default to 3D map).

4.2.6. Optional: Import GCP file GCP/MTP Manager.

4.3. Step 1 processing:

4.3.1. Start processing of step 1 in the software

4.3.2. Review Quality Report.

4.3.3. Optional: Mark GCPs in the rayCloud.

4.3.3.1. Mark GCPs via images, 10-12 images per GCP.

4.4. Step 2 processing

4.4.1. Start processing of step 2 in the software

4.4.2. Remove noise from point cloud.

4.4.2.1. Using the point cloud editor select points falling outside of the model to reduce extraneous contribution.

4.5. Step 3 processing:

4.5.1. Start processing step 3

4.5.2. Review full quality report.

5. Quality report and data acceptance criteria:

5.1. Items within the quality report

5.1.1. Quality Check

5.1.1.1. Images: the median number of key points per image shall be greater than 500 extracted key points per image. Typical results expected are more than 10,000 extracted key points per image.

5.1.1.2. Dataset: Percentage of images calibrated shall be more than 60% of images calibrated. Typically, more than 95% of images calibrate.

5.1.1.3. Camera Optimization: Difference between initial and optimized internal camera parameters. Shall be less than 20% difference between initial and optimized focal length for perspective lens Typically, less than 5% difference between initial and optimized focal length for perspective lens is calculated in models.

5.1.1.4. Matching: Median number of matched keypoints between images. There shall be more than 100 computed matches per calibrated image. Typically, more than 1,000 matches per calibrated.

5.1.1.5. Examine the image overlap graphic. Ensure that no areas of red or yellow are over essential elements of the scene. Red and yellow areas are expected at the fringes of the data. Red and yellow indicate low overlap of images and potential unreliability of data in these regions.

6. Model acceptance:

6.1. Measure 1 vertical and 1 horizontal side of reference flags included in the scene. Must be within 1.8-2.2ft

6.2. Measure long distance reference and compare with ground measurements. Must be within 0.5ft of expected measurement.

6.3. Measure inch reference and foot reference on the vertical reference. Must be within 10% of expected measurement. Note, the 2-inch reference squares may not be resolved in all models. Minimally, the 20-inch vertical height and 12-inch vertical height shall be compared.
6.4. Visually inspect that there is no obvious distortion of common objects.
6.5. Ensure there are minimal artifact in both 2D and 3D renderings.
6.6. Ensure the models are representative of the scene.

7. Remediation of failed quality report or measurements:

7.1. Re-upload original images and reprocess data. Reevaluate the quality report and measurement requirements. Ensure that reprocessing of data is indicated on the final report and retain all previous data attempts.
7.2. If data still fails, process locally with more MTP processing.
7.3. if measurements are not within limits, use internal referencing and ratio measurements to the known refences within the model. Ensure this is clear on the report.
7.4. Re-collect data if possible if all other remediation does not resolve the issues.