A New Protocol of CSI
For The Royal Canadian Mounted Police

I. Introduction

The Royal Canadian Mounted Police started using Unmanned Aerial Vehicles to help them with their work on collision and crime scene investigations. It allows the investigations to be conducted under all weather conditions and provides broader views than the traditional procedures.

This past September, an experimental project was organized by the Royal Canadian Mounted Police (RCMP) and Pix4D, using UAV models from Draganfly and Aeryon Labs to acquire images of a staged car accident scene from low altitude. The images were processed by Pix4Dmapper to reconstruct the three-dimensional scene. In this article, we compare the time spent and accuracy between UAV mapping and traditional procedures, including laser scanner.

The project aims to propose a solution protocol for accident scene investigations. Additionally, by including the accuracy and reliability of the output results, it ensures not only that the whole process is efficient and accurate but also that the reconstruction results can be eventually used as admitted evidence in court.

II. Presentation of the Project

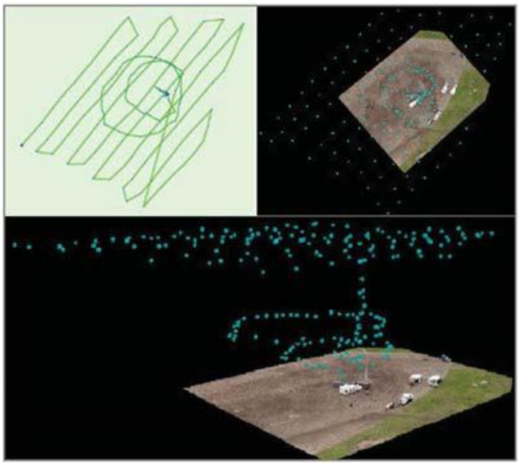
The project took place in Regina, Canada. A staged car accident scene was set up to reproduce a crash of two vehicles with a person fallen out of one of the vehicles. The RCMP took photographs and measurements before anything was moved. The yellow plastic evidence markers indicated where each piece of evidence was found.

Aeryon Labs and Draganfly rotary-wing UAVs were used to acquire images with very high overlap and ground sampling distances of 0.6 and 0.9 centimeters respectively. Both UAVs acquired oblique photos by flying a few circles around the scene as well as nadir photos with grid flight plans above the crime scene. Both flights lasted between ten and twenty minutes. A total of 225 images from Aeryon Labs and 212 images from Draganfly were obtained during the flights.

A few on-site measurements were made by the police. GPS measurements of the object corners and the evidence markers were used as ground control points, and tape measurements between the markers were recorded for further assessment of the final results.

Pix4Dmapper's total processing time was approximately two hours on a laptop with a core i7 and 8GB RAM. A densified point cloud, digital surface model (DSM) and orthomosaic were generated. Annotation and measurements were directly made in the software user interface.

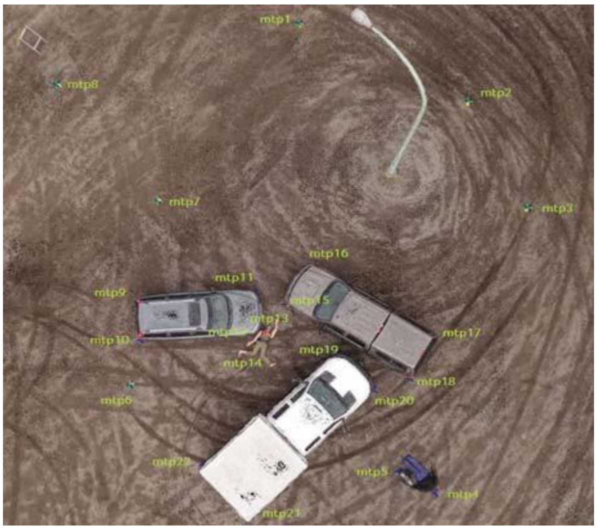
III. Data Acquisition



The total pre-flight preparation time was approximately ten minutes. Both UAV models weigh less than two kilograms and thus are light enough to be easily unpacked and operated by a single person. Once the flight plan set, it took less than twenty minutes to complete the designed flights. For the proposed protocol, the entire on-site process time is estimated within thirty minutes, excluding optional measurements.

Nadir images taken with grid flight plans achieved high overlaps and eliminated systematic errors. A few circular flights were performed to obtain oblique images of the most focused area in order to cover as many facades as possible. With a flying height of approximately forty meters above the ground, images with a ground sampling distance of less than one centimeter were collected. These images provided accurate and detailed information of the collision.

In order to improve the global accuracy of the final results (which is optional), several points were measured with kinetic GPS and total station. These points were picked from corners of the vehicles, the feature objects, and the evidence markers. They were imported into the software and used either as ground control points, manual tie points or check points.



In addition to the measurements mentioned above, a terrestrial laser scanner was set up in several locations to scan over the entire scene, to be used for quality assessment of the UAV results.

The laser-scanned point cloud was compared with the Pix4Dmapper point cloud in respect to their density, accuracy and how they fit the actual needs.

IV. Comparison with Traditional Procedures

Traditionally, the collision investigation workflow adapted by most police departments - including the RCMP - uses tapes, GPS and laser scanners. Tapes and GPS provide a limited number of measurements. They are written down in field books, and it is not easy to recall precisely where the measured spots were located. Plus, these measurements may easily contain manual mistakes and are not accessible in all situations.

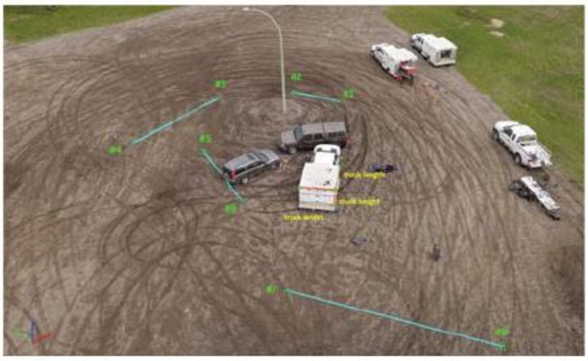
Usage of laser scanners is expensive and time consuming, and the delicate instruments need to be operated by trained professionals. Some other issues to take into consideration are the obstruction of laser beams and the difficulty of finding appropriate locations to set up the scanners, resulting in missing point cloud data of extremely important information in some hard-to-reach yet focused areas.

One or a combination of the three principal measuring methods are used depending on circumstances. Sometimes one method is enough to cover the whole scene while in other conditions the combination of two or more of them is required to complete the tasks.

<u>New UAV era</u>

UAVs provide more practical solutions as they respond faster to emergency cases. They are already broadly used for natural disaster monitoring, and can also serve as an ideal reconstruction workflow for accident investigations.

We propose the use of UAVs for several reasons - rather than choosing case-by-case from the measuring methods - as it is more likely to fit all solutions. For wide-coverage accident scenes, UAVs save hours or even days on the time spent gathering data and measurements.

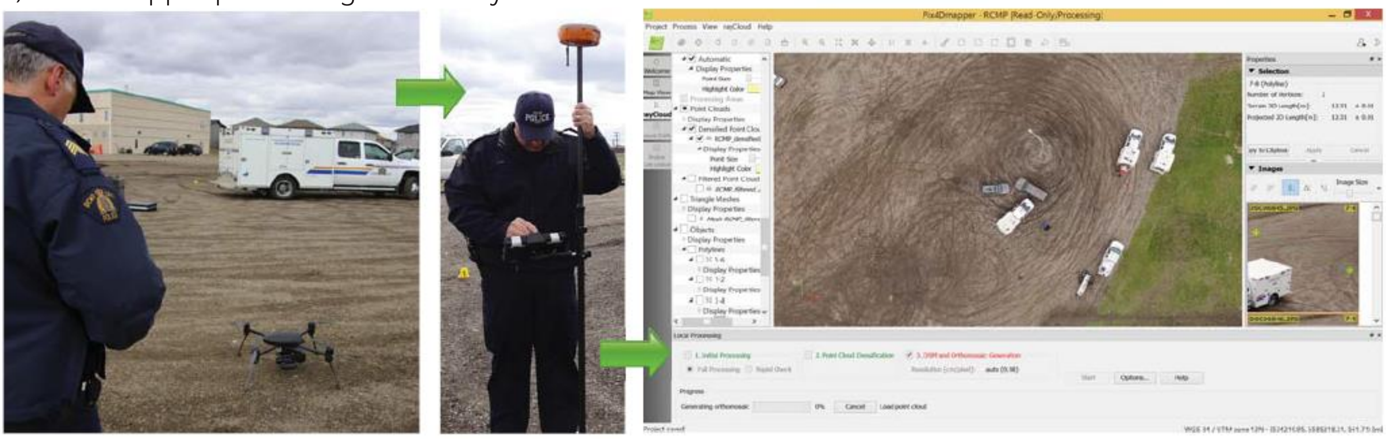


The proposed protocol contains three simple steps:

1) UAV preparation and data acquisition

2) 3 to 5 tape or GPS measurements for quality improvement and assessment

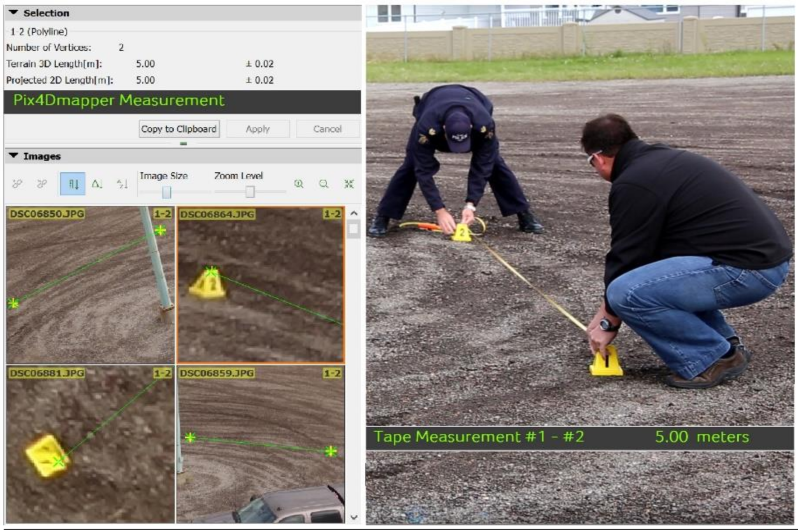
3) Pix4Dmapper processing with a fully automatic workflow



The whole procedure, including the on-site flight and an additional ten minutes of optional but recommended measurements for quality assessment, can be completed right after the accident occurred. For this project, the total processing time of Pix4Dmapper was approximately two hours. After processing, the whole scene was reconstructed and the terrain model, point clouds, and orthomosaic were exported. Annotation and measurement were then directly performed in the software.

V. Accuracy Assessment with On-site Measurement and Laser Scanner Result

a) Compare UAV+Pix4Dmapper results with tape measurements



Eight evidence markers, labeled with the numbers 1 to 8, had their positions surveyed by GPS and thus were with known coordinates. Tapes were used to measure the following distances between markers: 1-2, 3-4, 5-6, and 7-8.

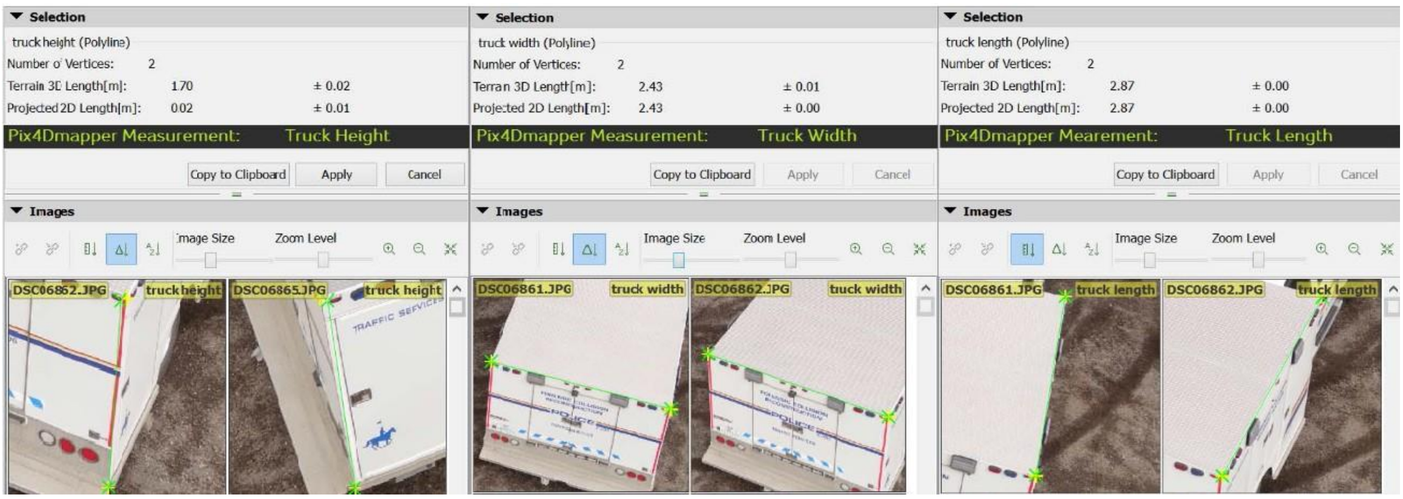
The same distances were also measured by the measuring tools in Pix4Dmapper. These two types of measurements were compared with the same distances calculated directly from the known coordinates of markers.

	#1 ~ #2	#3 ~ #4	#5 ~ #6	#7 ~ #8
Marker Corners (GCPs)	5.00 meters	9.99 meters	7.50 meters	12.32 meters
Tape Measurement	5.00 meters	10.00 meters	7.50 meters	12.34 meters
UAV+Pix4Dmapper	5.00 meters	9.98 meters	7.49 meters	12.31 meters

b) UAV+Pix4Dmapper results in RCMP Truck Dimensions

Images acquired by the UAVs were processed and the three-dimensional scene was reconstructed by Pix4Dmapper. As seen in the lower graphs, we measured the width, length, and height of the RCMP truck directly in the software, and the results exactly match the real RCMP truck dimensions.

These results confirm the high accuracy of Pix4Dmapper, both for its processing and measuring capabilities.

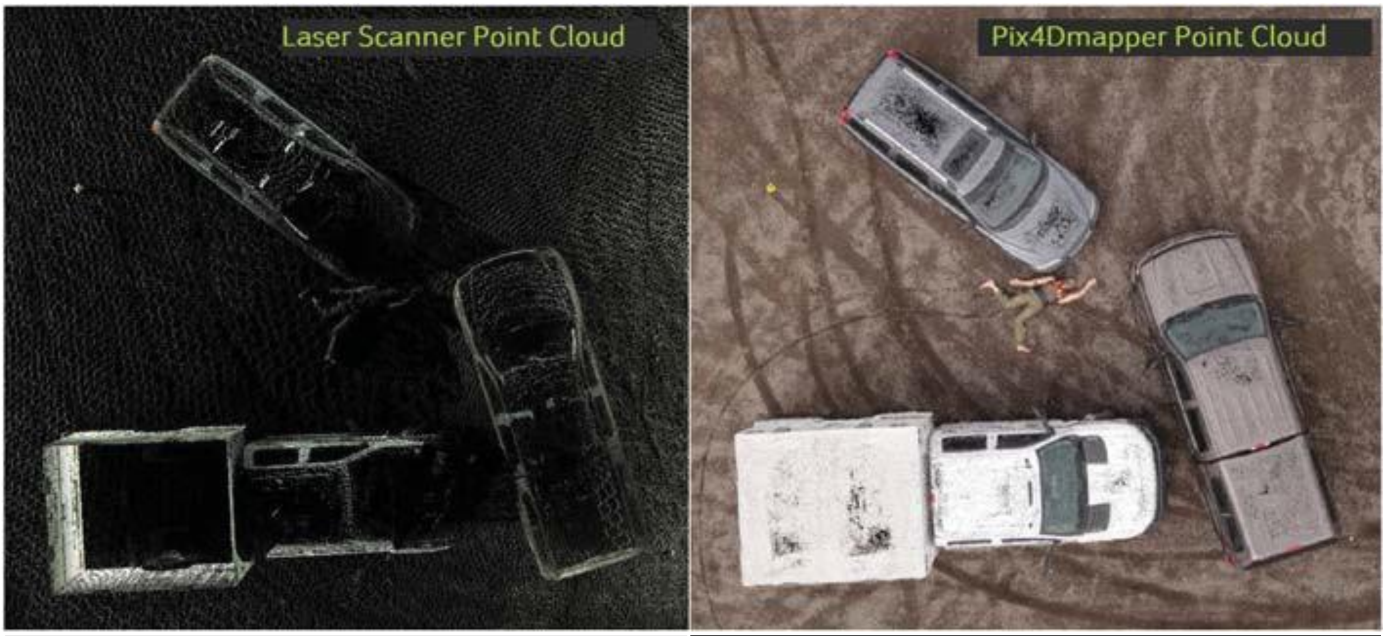


	Truck Height	Truck Length	Truck Width
RCMP Truck	1.70 meters	2.87 meters	2.43 meters
UAV+Pix4Dmapper	1.70 meters	2.87 meters	2.43 meters

c) Compare UAV+Pix4Dmapper results with laser scanner measurements

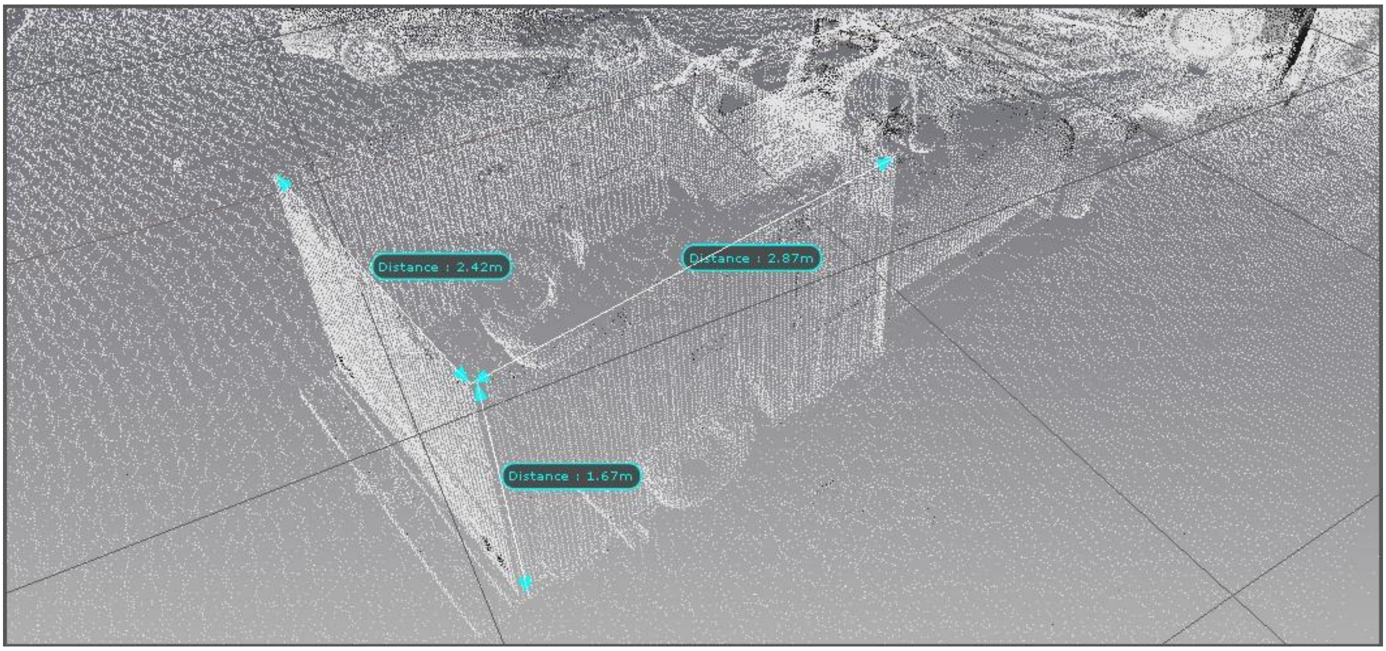
Laser scanner measurements are well-known to provide accurate point clouds and to have high penetration through objects. In this example, we could actually see some points inside the vehicles. However, it took more preparation time than the UAVs and the scanner's set-up position and scanning angles were not flexible. From the graphs below, we can observe that the scanner obtained much fewer points. Another difficult problem to solve was the obstruction of views, resulting in lack of details in the focused area around the body.

Rotary wing UAVs like the Draganfly and Aeryon Labs systems are capable of getting very close to the aim with good control. The number of points generated by Pix4Dmapper for the point cloud depends on the image resolution, image quality and the program settings. For a dataset of less than one centimeter GSD, Pix4Dmapper provides both high accuracy and fine details of the scene.



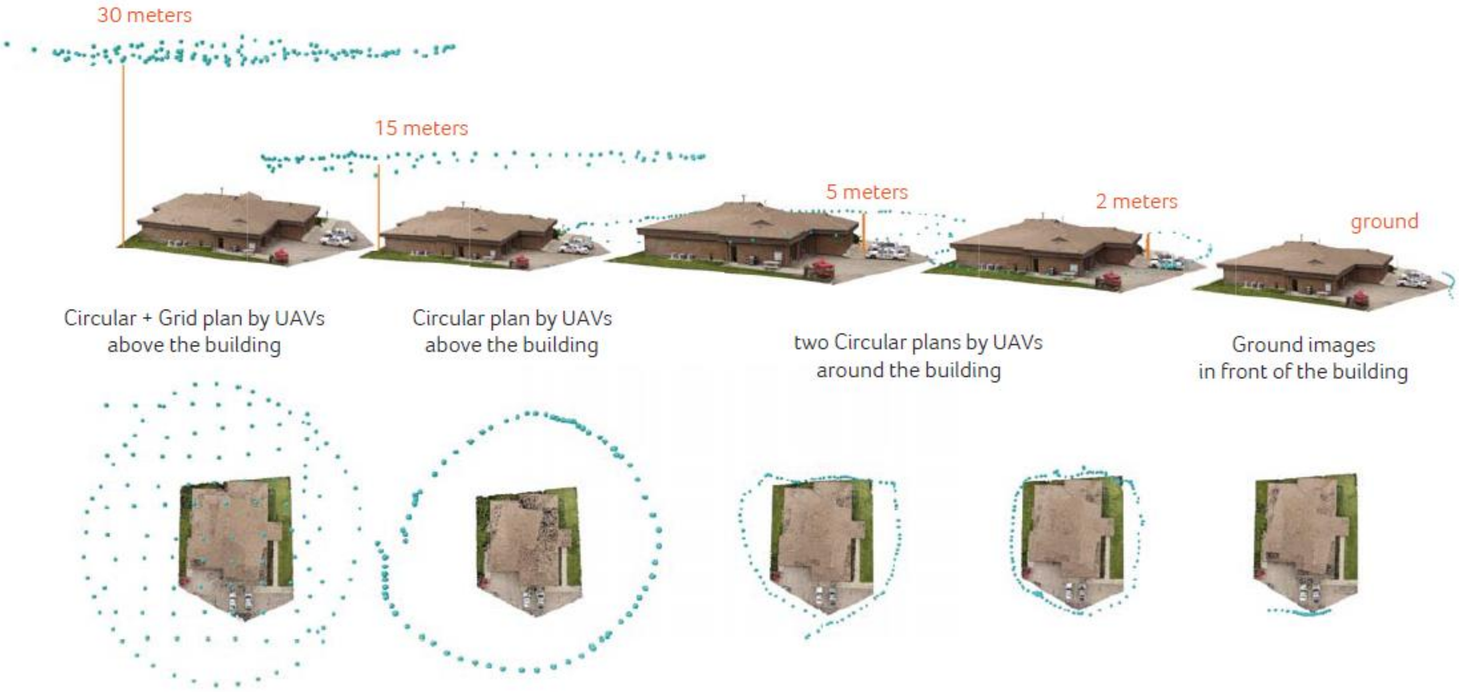
	Truck Height	Truck Length	Truck Width
RCMP Truck	1.70 meters	2.87 meters	2.43 meters
Laser Scanner	1.67 meters	2.87 meters	2.42 meters

	Truck Height	Truck Length	Truck Width
RCMP Truck	1.70 meters	2.87 meters	2.43 meters
UAV+Pix4Dmapper	1.70 meters	2.87 meters	2.43 meters

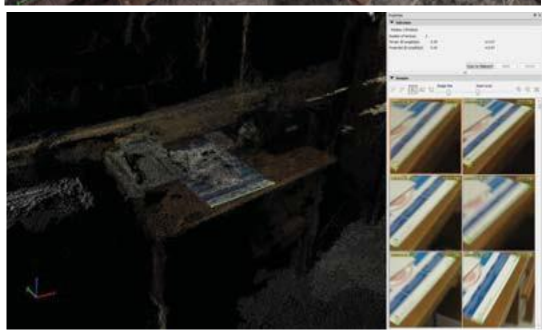


VI. Additional Showcase – RCMP Office Reconstruction

In addition to the collision scene project, two data sets from the RCMP office were acquired. The outdoor images were taken from various heights above and around the office building by UAVs and hand-held cameras (Canon 6D and GoPro); the indoor images were taken only by hand-held cameras (GoPro), collecting information from the corridors and from one office. Outdoor flight plans were following:



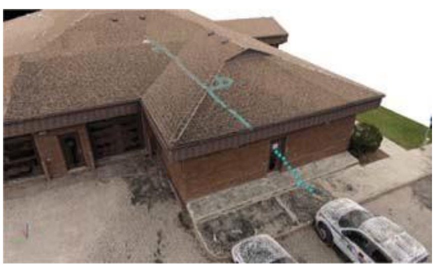
Indoor images were acquired while passing through the corridor and entering an office inside the building. The photographed office was located to the right of the corridor, as seen in the small circle on the image position path here under. Sub-projects of both the inside and outside of the building were processed separately and then merged into one project.

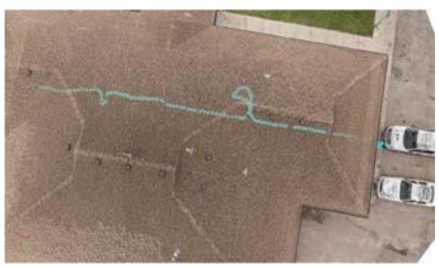


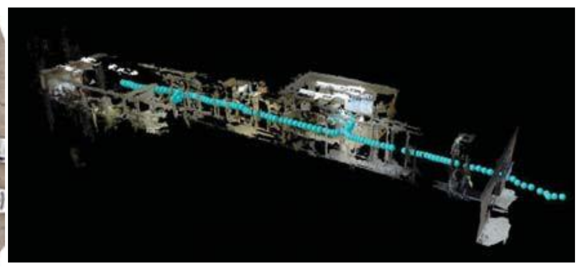
Processing with Pix4Dmapper required less than two hours for the outdoor data set containing 421 images. For the indoor data set of 139 images, it required only ten minutes to reconstruct and half an hour for point densification. Manual points were added in the projects and clicked manually to help with the merging process.

The two sub-projects were then merged successfully, as seen in the rayCloud editor of Pix4Dmapper and the windows and door shared by both data sets were perfectly matched. We also see from the graphs below that the image positions of the indoor data set correctly match the outdoor reconstruction.

The merged project kept the same accuracy as the individual projects and we were able to measure the indoor objects directly in the software, for example the magazine width displayed in the figure on the right.







VII. Conclusion

Unmanned Aerial Vehicles have become the most practical solution in many urgent cases. They can be used to search and save survivors in the wilderness, to collect updated photos or videos for monitoring natural disasters and to reconstruct traffic collision or crime scenes to be presented in court. These are only some examples of conditions where timeliness is the most critical concern.

The combination of UAVs for image acquisition and Pix4Dmapper for converting images into results provides a complete solution to reconstruct accident and crime scenes and solves vital issues not covered by traditional methods.

Why use UAVs+Pix4Dmapper?

They provide angles with multiple views from the ground as well as from the air. Obtaining information from a bird's-eye view is very helpful as it solves important issues when evidence is spread out and it is difficult to get a good perspective from ground level. Previously, helicopters were used to provide such complimentary information. However, organizing an available copter to cover the scene sometimes takes up to several days and by that time, outdoor evidence already might have been altered or washed out due to weather conditions (heavy rain or snow).

Compared to other precision instruments such as laser scanners, the cost of execution and maintenance of UAV mapping is much lower. Packed in an easily transportable case and a weight of under two kilograms, UAVs can be carried everywhere. And UAVs are ready to fly after some minutes of assembling only. Such small systems are also easier to use and maintain, saving expenses and time spent on training staff.

Using UAVs and Pix4Dmapper for reconstructing accident and crime scenes provides an immediate response, saves time and expenses and offers highly accurate outputs. Generated results are available permanently and the files and make measurements anytime he/she requires to. Actual scenes are preserved in 3D and with detailed information within centimeter accuracy.

- Applies to all conditions
- Efficient and time saving, immediate response
- High accuracy for measurements
- Views from all angles, no missing details
- Easy to operate and maintain, less training needed
- Both outdoor and indoor reconstruction, seamless merging
- Permanent preservation of data and reconstructed scene