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Unmanned Aerial vehicle (UAV) Based Traffic Monitoring and Management

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16. Abstract

With recent Federal Aviation Administration (FAA) policy changes and test site designations, Unmanned Aerial Vehicles (UAVs) or "Drones" have gained attention among the public and private sectors. Practical applications such as facility inspection, mapping, surveillance, delivery, etc. have been intensively tested. Overt the last decade, UAV applications in transportation engineering have included experiments with traffic surveillance, infrastructure monitoring, and roadway incident management. Most have focused on transmitting on-site video footage to traffic management centers so traffic operators can monitor congestion, coordinate incident response crews, or collect traffic data in areas without CCTV surveillance systems. In this study, the main focus is to explore the feasibility of using UAV to accelerate the site surveying at major traffic accidents, a major delaying event in incident management. We developed a prototype UAV system that can be rapidly deployed in the field for video-based site surveying and 3D reconstruction of accident sites. The hardware system includes UAVs equipped with high-frequency GPS sensor, high-resolution camera, HD transmitter and ground station for communication and data collection. The software components include the mission control, planning software, and photogrammetry 3D reconstruction tools. The prototype system was tested at an orchestrated accident site and the developed 3D models that yield promising potentials for further development. The test results reveal factors such as shooting altitude and angle, glares on smooth surfaces, Geo-tagging of photo snapshots, and GPS signals have major impacts on the scanning results. These impacts need to be addressed efficiently to ensure the quality of the constructed model.

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1. INTRODUCTION AND PROBLEM DEFINITION

Traffic incident management (TIM) is the core operational mission in most traffic management centers (TMCs). Reducing incident response delay, ensuring the safety of response crews, completing thorough site investigation, and accelerating the incident recovery have been the main objectives in TIM operational improvement. Thorough site surveys and medical examinations at major accidents are the most critical but also the most time-consuming steps in the TIM process, but are necessary to facilitate subsequent safety analysis, medical treatment, insurance requirements, and legal proceedings. Meanwhile, capacity-restricting traffic accidents can cause large-scale traffic jams even in non-peak hours. Conducting comprehensive and expeditious accident site investigations are crucial to accelerate the process and to reduce the overall impact on traffic flow. In the state of New Jersey, major improvements have reduced the incident management duration for major accidents from 2.5 hours in 1995 to 40 minutes in 2014*(1)*. However, the remaining road blocks to further reduce the duration is bounded by the time consumed on site through surveying by both law enforcement and medical crews as well as the clearance process. In this paper, the focus is to use Unmanned Aerial Vehicles (UAVs) to help reduce the duration of site surveying.

In recent years, UAVs have shown high potential in remote sensing in a wide variety of areas. Embedded new technologies in UAVs enable them to fly convenient, fast, precise, safe and economical compared to other modes of remote sensing. The latest technologies are 1) a fully automatic flight mission including the waypoint execution and landing, 2) GPS-based position hold, 3) long-range wireless communication, and 4) long range data transmission. There are two types of UAVs, fixed-wing and rotary-wing. The former type is more suitable for large-scale sensing and surveying mission; while the latter one is more efficient for monitoring, surveillance, and surveying work that requires waypoint holdings and camera repositioning. The rotary-wing UAVs such as quadcopters can perform vertical take-offs and landings and conduct GPS or altitude holding in the air. These type of UAVs are more suitable for accident site investigation due to the limited geographical area of an accident site and the requirement on positioned photo or video shooting.

Quadcopters are a type of UAVs with four rotary wings. Quadcopters are capable of Vertical Take-Off and Landing (VTOL), which gives more freedom for the pilot due to the fact that it requires much less space and time for landing and launching. Also, hovering capability of the Quadcopters provides an excellent condition for static remote sensing during flight. All these features could help the responders to 1) faster access to the accident site 2) prioritize the incident treatment 3) allocate fewer emergency resources, and 4) collect data faster which leads to faster site clearance.

In this study, we propose the development of a prototype multi-functional airborne traffic management system (Air-TMS) for non-recurrent traffic congestion. The system includes Quadcopters Unmanned Aerial Vehicle (QUAV) equipped with a high-resolution video camera and HD video transmission units and the software to conduct waypoint planning and photogrammetry 3D reconstruction. A completely scaled 3D model of an orchestrated accident site is created and evaluated. An algorithm has been developed to detect and track congestion using LiDAR Model and traffic video. The prototype system has the potential of significantly accelerating the accident site investigation, with the entire UAV surveying process takes less than 10 minutes.

2. LITERATURE REVIEW

Traffic Operation Studies Using UAV

Studies have been done to investigate the capabilities of UAVs compared to conventional methods and hardware for traffic operation. In a study conducted by Srinivasan et al.*(2)* with the collaboration of Florida DOT, Airborne Traffic Surveillance System (ATSS) was proposed to collect traffic data in real time. The integration of ATSS with the existing microwave network, Traffic Operation Centers (TOCs), and State Emergency Operation Centers (ESOCs) was investigated. Proof of study concept was conducted by Florida DOT. Four potential application for fixed-wing UAVs in traffic data collection has been proposed by Coifman et al.*(3)*. The first application includes Annual Average Daily Traffic (AADT) and level of service estimation. The second application calculated the arrival and departure rates of vehicles at signalized intersection. Platoon-based O-D estimation methodology was proposed as the third application. The fourth application involved parking lot utilization monitoring. In a study conducted by Ro et al.*(4)*, the applicability of traffic monitoring and emergency identification was examined by identifying the regulatory and safety concerns and developing a communication system to broadcast the recorded video to traffic management centers. Another study*(5)* in traffic monitoring using the UAV was focused on providing a guideline for UAV selection. The guideline was based on the critical factors affecting the performance such as flight time, speed, payload, power source, wind-resistance, and cost-effectiveness. In the latest study by Lee et al.*(6)*, the applicability of using small quadcopter UAV for traffic surveillance and roadway incident monitoring was investigated. In this study, two scenarios were tested for 1) traffic data collection such as queue length, total delay time, and traffic count at a particular intersection and 2) real-time incident report. In the first scenario traffic data such as queue length, total delay time and traffic count at the particular intersection was estimated. In second scenario broadcasting video recorded by UAV using the 4G/LTE signal strength was tested in terms of video streaming duration. An overview of existing UAV studies on transportation infrastructure is shown in Figure 1.

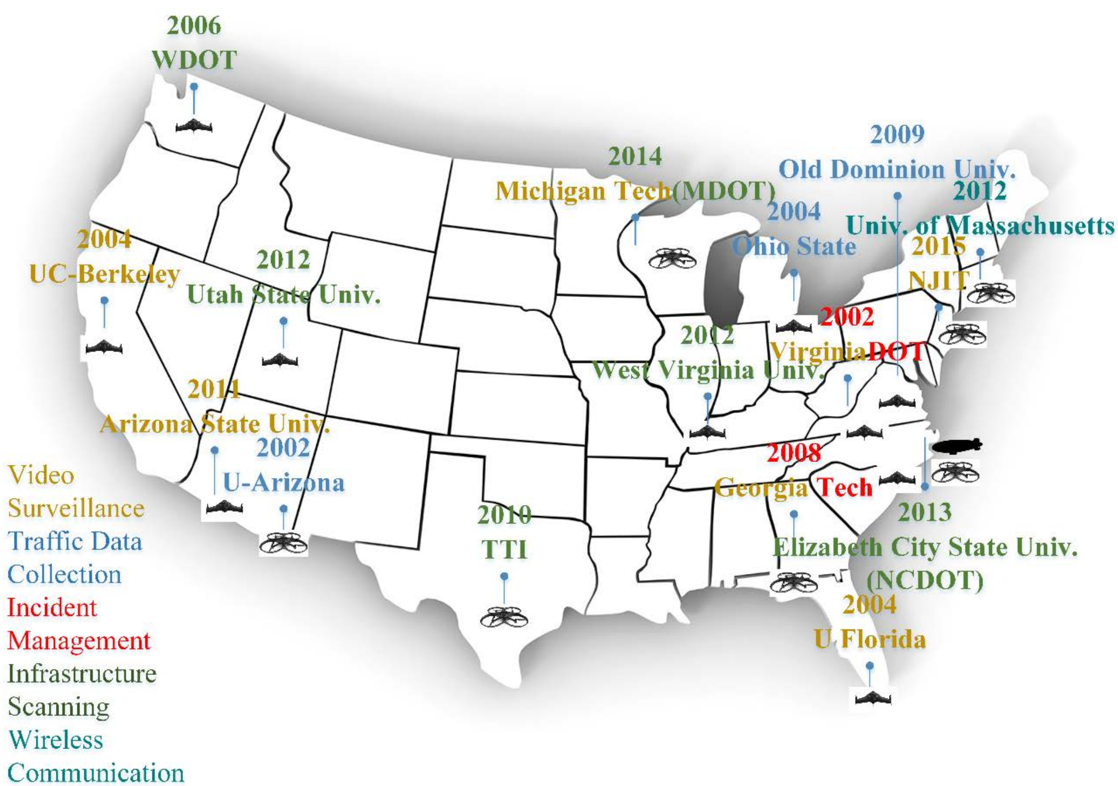


Figure 1 Locations of existing UAV studies on transportation infrastructure

3. CONCEPT OF OPERATION

3.1 System Description

The system is a prototype multi-functional airborne traffic incident management system (Air-TIMS) for investigation, management, and coordination during traffic incidents. We specifically design the system for incident management to develop an economically justifiable case for the use of UAVs in traffic management. The previous studies aiming at replacing the existing traffic surveillance system with UAVs are difficult to justify financially and technologically given the apparently fast development and sophistication in ground-based vehicle detection systems. One example fast-growing system includes the mobile sensor technologies such as GPS, Bluetooth, and cellphone based traffic detection. Traffic incidents are events such as traffic accidents, road spills, and vehicle breakdowns that occur at random locations and times. Such stochastic nature in space and time makes the existing fixed-location traffic surveillance systems insufficient sometimes in covering and observing traffic incidents. Furthermore, the strong need of information distribution especially related to traffic diversion and secondary incident prevention makes a temporary mobile multi-functional management system like Air-TIMS a suitable alternative. To justify the cost-effectiveness, evaluation indexes such as incident clearance time and traffic recovery time can be easily defined and evaluated.

3.2 System Components

Entire system contains three major components.

1) 3D LiDAR models of highway infrastructure:

This module prepares a 3D LiDAR model of highway infrastructure to reduce the computational load and complexity of real-time scanning and detection algorithms.

2) LiDAR-assisted incident site reconstruction module:

This module attempts to establish incident site 3D model through aerial scanning to assist the incident site investigators and medical examiners.

3) LiDAR-assisted congestion tracking and detection module:

This module matches aerial video with LiDAR model to identify vehicles and traffic congestion.

3.2.1 Required Devices

3.2.1.1 Hardware

The Air-TIMS system consists of four major hardware components: Aircraft unit, Camera and Gimbal Control, HD Transmitter and Receiver, and Ground Control Station.

- Aircraft Unit: In this study we acquired a mid-size quadcopter UAV, called QU4DX produced by STEDIDRONE company as shown in Figure 2. The UAV is designed with long propellers enabling it for higher payloads, as well as making the UAV more stable for video recording and image capturing. The UAV payloads is 20 pounds, consisting of the camera gimbal, the camera, theHD transmitter and the UAV power source including four 10000 mAh batteries . Batteries are two-by-two in parallel providing 20000 mAh capacity for 20 to 30 flight time in full payload condition. UAV is controlled by 2.4 GHz controller with a communication range of 2km. The UAV is equipped with GPS enabling it to communicate with available GPS satellite for precise flight. This UAV platform has the capability of performing full automatic flight plan using the built in GPS and Mission Planner Software*(7)*. The flight plan can be developed in the software using the GPS coordinates of desired locations for photography including latitude, longitude, and altitude and can be uploaded to UAV for automatic flight including the landing. UAV Flight mode can be switched between auto mode and manual during the flight with a click of a switch. The switch will assist the pilot to put the UAV in manual mode when UAV is not performing properly. The UAV communicates with the ground station via 915 MHz transceiver to send the real-time status of a flight to the Mission Planner software. The UAV is equipped with a transceiver enabling the UAV to send flight status information to the ground station for monitoring and receiving the flight plan for performing the auto flight.

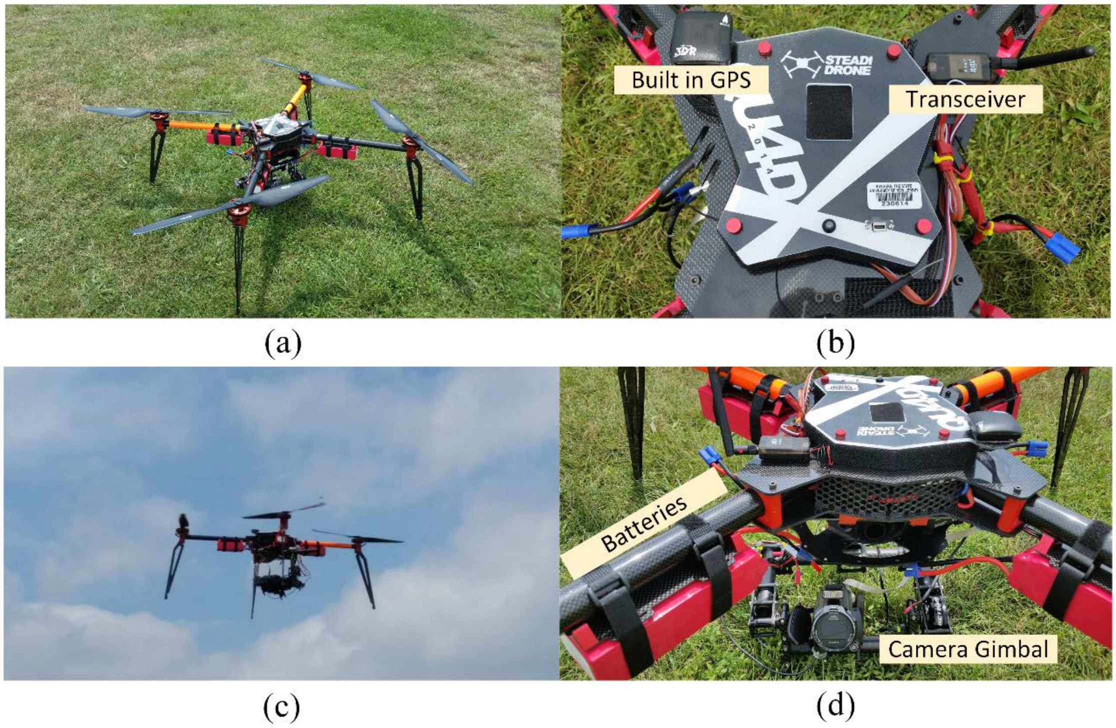
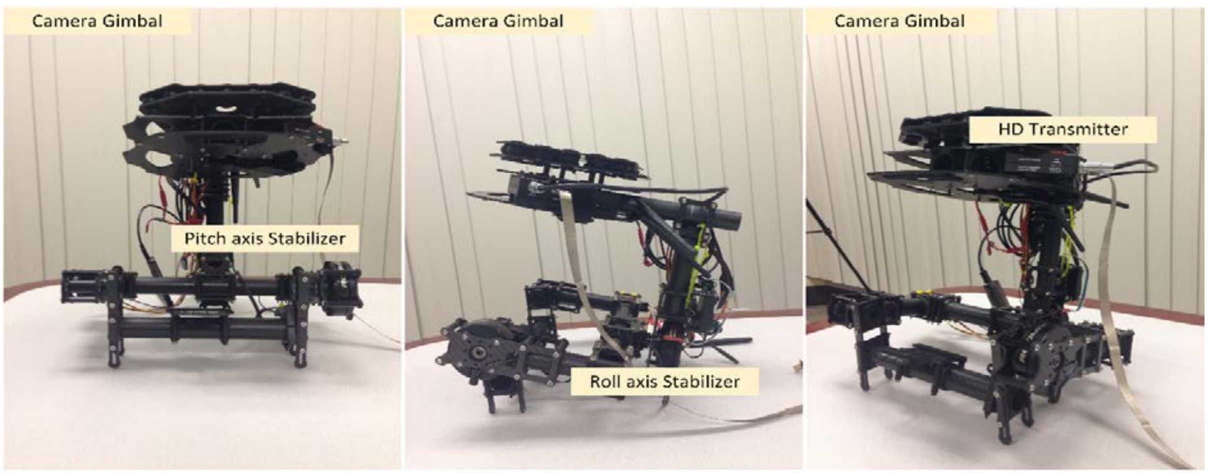


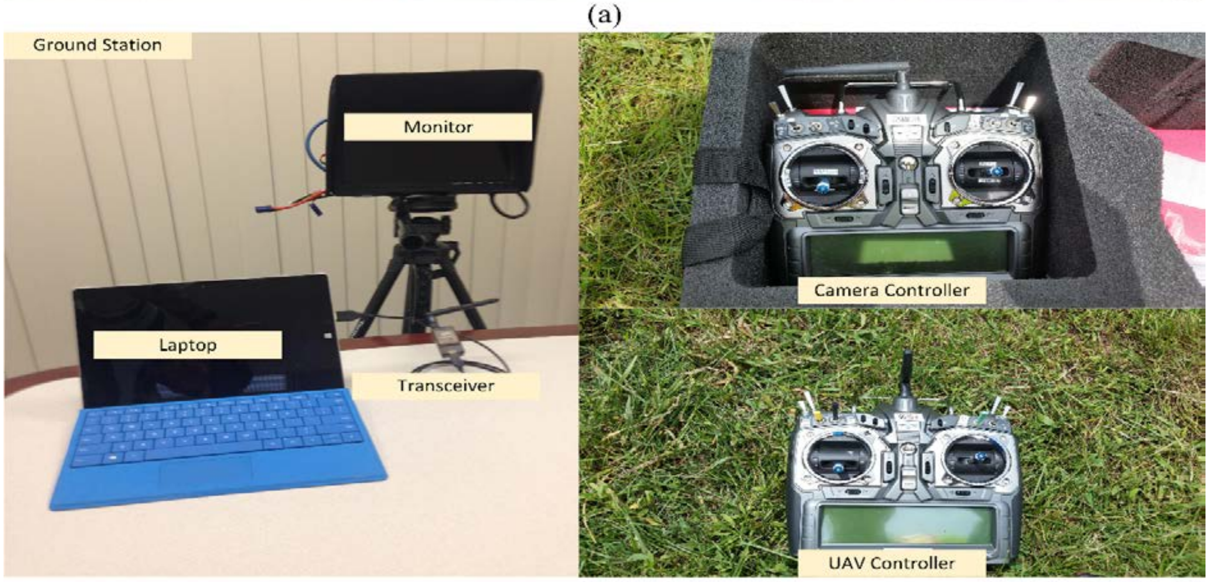
Figure 2 Aircraft unit: (a) UAV (b) built-in GPS and transceiver (c) UAV during flight (d) batteries and camera gimbal

- Camera and Gimbal Control: The camera gimbal was built in a way to stabilize the camera in both roll and pitch axis using the electronic stabilizers for better video and image recording as it shown in Figure 4(a). The camera gimbal can be either controlled manually via wireless communication for changing the pitch and roll angle (camera angle) or automatically with the UAV using the flight plan. The yaw dimension unit was removed to save the payload and increase the stability of the platform. The camera used in this study is SONY HXR-NX30U*(8)* which has the capability of HD video recording, image shooting, wireless control communication, built-in GPS, and lens stabilizer. The wire communication control includes zooming and recording and image shooting. Both camera and gimbal can be controlled using 2.4 GHZ controller.
- HD Transmitter and Receiver: HD transmitter and receiver was used in this study is Paralinx Tomahawk*(9)*. It has the ability to transmit HD video via 5.8 GHZ communication link up to 800 meters.
- Ground Station: Ground station units shown in Figure 4(b) includes the following: 1) laptop, 2) USB transceiver, 3) HD receiver and external monitor, 4) video image capture card, and 5) UAV and camera controllers. Mission planner was installed on the laptop for flight status monitoring, flight planning development and uploading the flight plan on the UAV using the transceiver on the UAV and laptop.
- Mobile LiDAR Scanner: Mobile Lidar scanner will scan corridor and recreate a 3D point cloud of existing infrastructure shown in Figure Below.

Figure 3 Mobile LiDAR Scanner and 3D points clouds infrastructure



(a)



(b)

Figure 4 Components: (a) camera gimbal components (b) Ground station components

3.2.1.2 Software

The software components of Air-TIMS for accident site reconstruction functionality include 1) mission planning, 2) Geo-tagging and referencing, 3) photogrammetric 3D reconstruction software, and 4) LiDAR scanning.

- Mission Planning Software: The open-source Mission Planner (Version 1.3.30) Software is used for monitoring the UAV status, compass calibration, waypoint planning for autonomous flight missions, and planning the positions and angles of photo or video shooting positions and angles.
- Image Processing and Geo-Tagging Script: A hybrid Matlab-Java program is developed to process photo and video footage from the UAV flight and to match photos or snapshots with UAV flight records which contain detailed 3D geographic location information. In the case study, since only photos are only taken and pre-planned waypoints, Geo-tagging can be automatic within the 3D reconstruction software.
- Photogrammetric 3D Reconstruction Software: Agisoft Photoscan is used to conduct the photogrammetric 3D reconstruction from accident site photographs. The key input for Agisoft include the photos or video snapshots with significant overlaps between consecutive images (e.g. 70% or more), Geo-coordination of photos, ground control points and their pixel location in each photograph. Either Geo-tags or ground control point is needed to ensure the scale of the 3D model is to the actual dimensions. The ground control points are needed to accurately calibrate the geo-positions of the accident sites with respect to earth coordinates.

3.3 Air-TIMS Operation

Prior to incident site investigation, corridors need to be reconstructed in 3D point clouds using the Mobile Lidar scan. The 3D model is required to speed up the process of real time incident site investigation and congestion detection and tracking. In this situation a database of 3D corridors model will be available for further investigation at incident sites.

In the next step, when an accident happens Highway patrol will receive the accident report. Highway patrol will reach the accident site and they will prepare the UAV to be deployed. Highway patrol will control the UAV to fly over the accident site, in this situation the UAV will be used as a live camera to broadcast the video of accident site to TMCs for further decision and instructions. Meanwhile the UAV will take pictures and video from different angles to reconstruct virtual 3D model of accident site for further investigation. Reconstruction of Accident site enables the Highway patrols to clear the accident site faster. In this following section, detailed system design and functionality of Air-TIMS (Air Traffic Incident Management System) system has been provided.

ISI (Incident Site Investigation) as the major task of Air-TIMS system will be executed after deploying Air-TIMS at incident sites. Upon arrival at the incident site, the UAV uses its onboard high-resolution video cameras to take several overview video or pictures of the incident sites to identify the scope, involved vehicles, impact locations, tire marks location and other site information. The flight path can be entered through MissionPlanner interface to define the optimal waypoint sequence and camera angles to take pictures of the incidents/accident sites for 3D accident reconstruction. Additional photos or video may be taken manually by on-site operators if needed. ISI is expected to be completed within 2-5 minutes.

3.3.1 Corridor 3D LiDAR Model

The first step in the proposed system is to create an archive of 3D LiDAR models of corridors. A mobile LiDAR truck will be deployed to drive along the highways and create the 3D LiDAR model. In a situation where an accident happens the incident site investigation and congestion tracking can be done much faster when 3D LiDAR models is available. Otherwise the LiDAR scan should be performed within the time of incident which contribute to higher site investigation incident site clearance.

3.3.2 Mission Planning, Pilot Flying, and Image Shooting

The flight plan will be created based on the accident site reconstruction needs. Therefore, defined number of points in a circle shape flight plan with defined diameter and altitude will be created. For better coverage of accident site and 3D reconstruction at least four more points on top of the accident will be assigned to flight plan in higher altitude than the base points. Figure 5(a) illustrates the mission plan on the software. Similarly Figure 5(b) and 7(c) depicts the flight plan from top and side view.

3.3.3 Assembly and Calibration

UAV was assembled by unfolding the UAV, attaching batteries to the arms, propellers, and camera mount installment. For an accurate flight, the UAV's campus was calibrated by connecting the UAV to Mission Planner software using the wireless transceiver on both the device and UAV.

3.3.4 3D Model and Image-based Geo Referencing

For Geo-tagging the pictures, the GPS coordinates of the pictures are required. Considering that the UAV was taking control of the camera for shooting the pictures, the GPS location of the UAV at the time of shooting images is recorded on the flight log files. Based on the GPS coordinates of the flight plan points and the accident site, the UAV stopped, turned towards the accident site and took a photo at each defined points. The photos were transmitted to the ground station receiver shown in Figure 6. Images were saved on the laptop using a video image capture card for further processing. Once the UAV passed, took, and transmitted the photos at each point, it landed automatically. The Mission Planner created all the steps which were then uploaded on the UAV.

All the collected images are processed by Agisoft Photoscan Professional*(10)* Version 1.1.6. Agisoft can generate independent depth maps out of images taken from multiple views of the accident site. Those depths maps are merged together by comparing common features in the overlapping areas of multiple pictures. Those common features are usually represented as vortex points and will be used to create dense point cloud and triangulated 3D meshes to create 3D model of accident site.

Meanwhile, Agisoft also allows user to input the geo-coordinates of each image recorded by UAV flight log or camera GPS. This can help geo-register and scale the image-based reconstructed model. The rescaled 3D model will facilitate the measurement of tire mark, vehicle damage, infrastructure damages, etc. To find the GPS coordinates the flight logs are downloaded from the UAV using the Mission Planner software. Agisoft also supports setting a coordinate system with ground control point (marker) coordinates. But in this study the reconstruction is based on image coordinates. The details of camera locations and constructed 3D model can be found in Figure 6. The blue images in Figure 6(a) depict the positions of the camera shooting locations and the directions of the pictures towards the accident site.

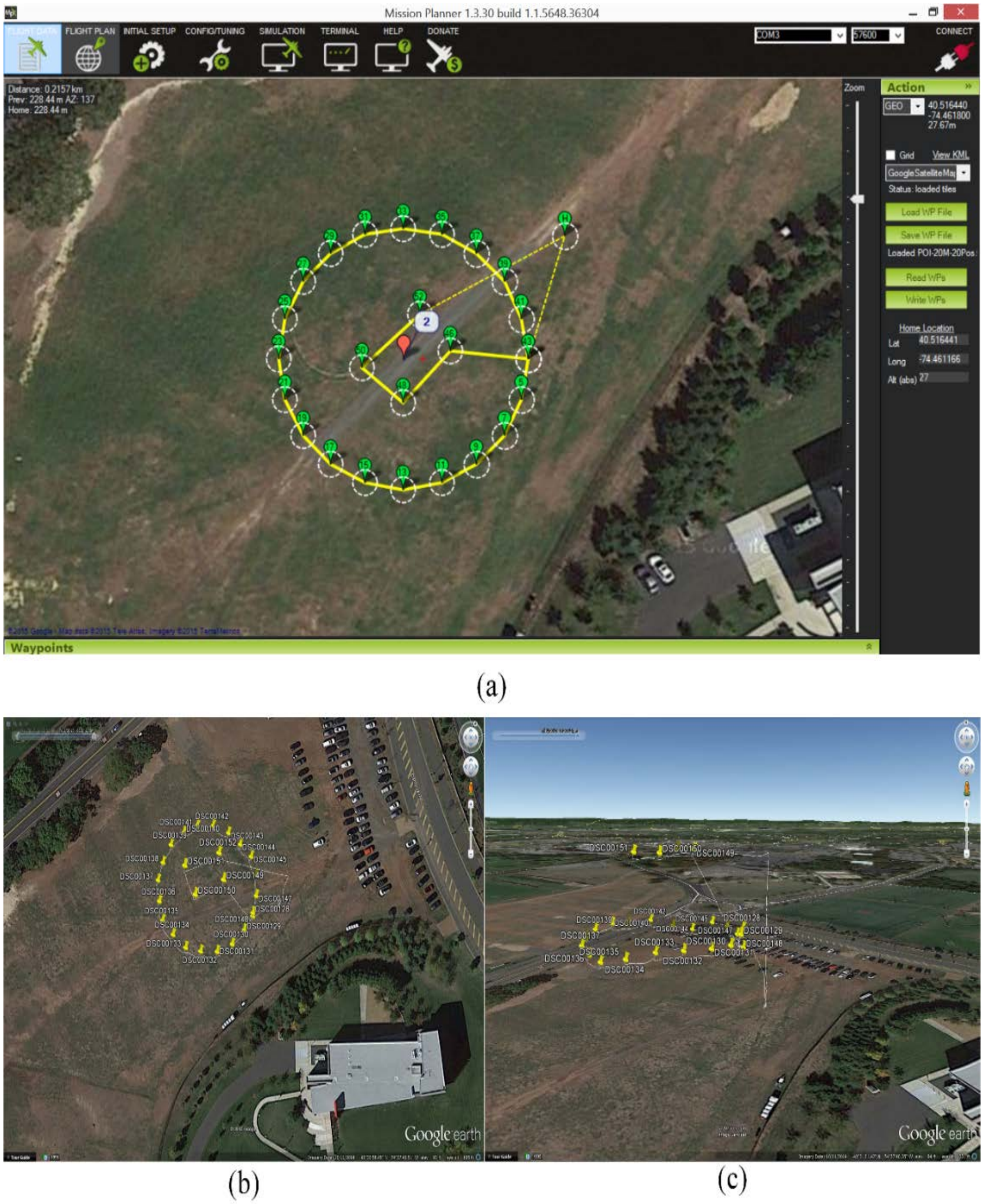
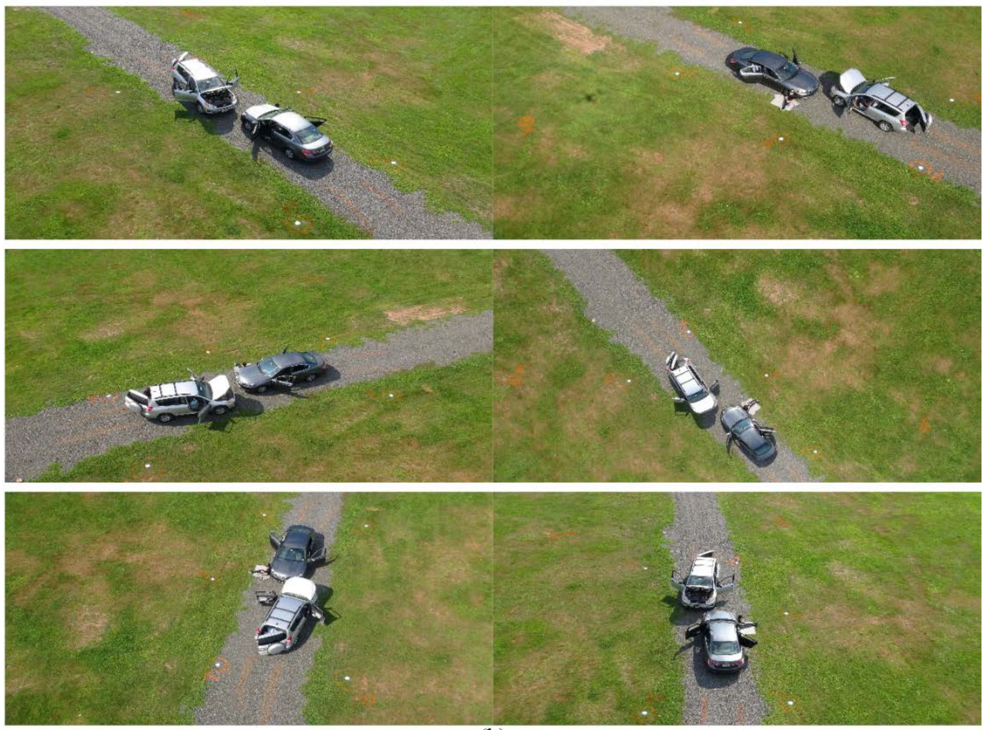


Figure 5 Flight mission: (a) flight mission in software (b) flight mission top view in Google Earth (c) flight mission side view Google Earth

(a)



(b)

Figure 6 Images taken by UAV: (a) image location on Google Earth (b) sample accident site images from different angles

3.4 LiDAR-assisted Congestion Tracking and Detection Module

The proposed system is a LiDAR-assisted video analytic system that can extract vehicle trajectories from regular traffic video. The vehicle trajectory extraction is based on the team's previous study on Spatial-Temporal Map processing method of traffic video *(11)*. The spatial-temporal map is created by stacking the pixels along a "scanline" along the centerline of a lane frame by frame to a simple image map (See Figure 7). Due to the local continuity between the neighboring pixel lines on the S-T map, vehicle trajectories can be extracted by using simple edge detection without the need of intensive background calibration**.**

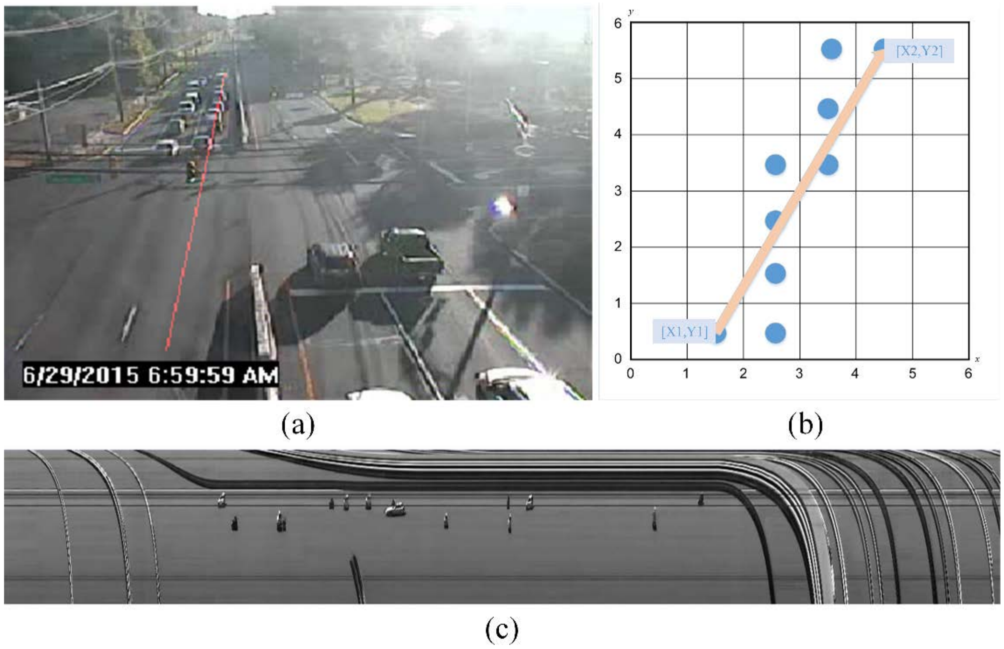


Figure 7 ST map generation

The extracted pixel trajectories can then be transformed into actual vehicle trajectories by converting the frame number into time on the horizontal direction and conducting coordinate transformation on the vertical direction. The calibration of the coordinate transformation parameters can be done in two ways. One way is to compare points on the scanline e.g. the start and end of nearby lane marks to create the full coordinate system similar to the method used in Autoscope systems. The other way, the proposed method in this study, is to directly match features point from the LiDAR model to the corresponding pixels in the video image. The latter one can be done automatically and more importantly can be used to geo-spatially video images in real-time. Figure 8 illustrates the system schematics how feature points extracted from LiDAR model are matched with pixel feature point. Once the feature points are matched, the coordinate system in the original images can be interpolated based on the matched feature points.

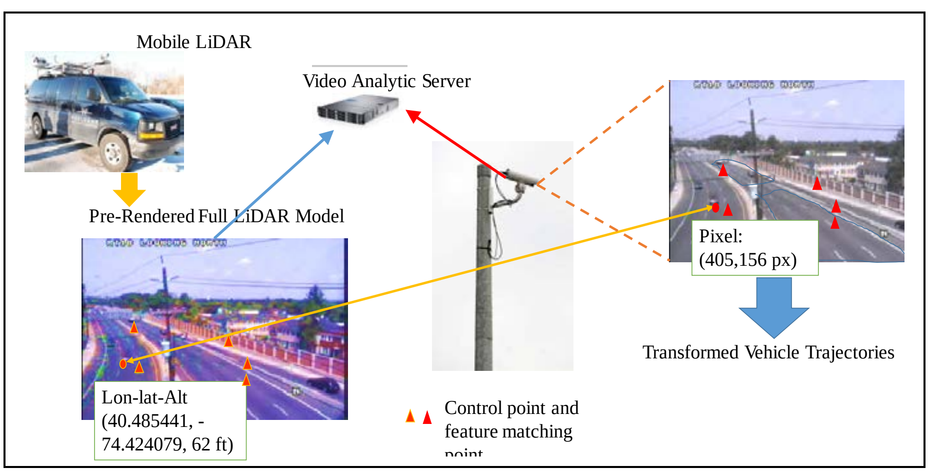


Figure 8 Schematics of LiDAR model Integration for Coordinate Transformation

3.4.1.1 LiDAR Mobile Scanning

The input data of the LiDAR modeling module is collected by an existing Mobile LiDAR scanning system. The LiDAR scan generates the 3D point cloud data for the experimental site. In addition, the system also takes 360-degree pictures of the scanned site which will be used to enrich the point cloud data with coloring for more efficient feature extraction.

3.4.1.2 Infrastructure 3D modeling and Feature Extraction

This step further processes the 3D point cloud and automatically identify infrastructure objects from the model. With the identified objects, an algorithm then extract features such as critical edge points, mileposts, roadway curvature, marking lines, pole and the CCTV camera locations. The selected points are matched to the feature pixels from video images. Figure 9 illustrates a sample infrastructure object segmentation results by the research team.

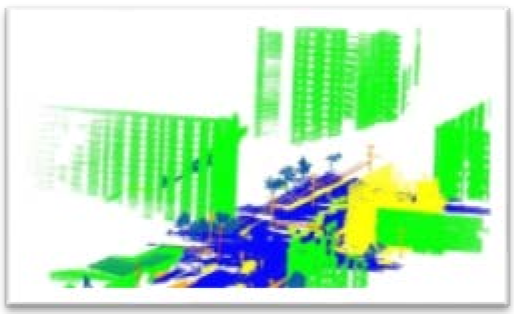


Figure 9. Infrastructure Object Segmentation

3.4.1.3 Video/image and Pixel Extraction

In the first step in video analytic, the video frames (image) are extracted. An automatic algorithm will be developed identify and extract feature pixels to be compared with LiDAR feature points. Those video image features will be extracted by using edge and corner detection, line detection, and object segmentation. Sufficient number of features will be extract in case some of feature points cannot be matched effectively with the LiDAR 3D models.

3.4.1.4 ST Diagram Processor

This step focuses on developing vehicle trajectories in pixel by
the implementing ST map algorithm. ST map demonstrates the time progression of a specific group of pixels. This group of pixels is located on a user-defined scanline. To create the ST (Spatial- Temporal) map first the pixel coordinates on a targeted scanline, e.g. the centerline of a lane, are defined and the ST map can be generated by stacking the pixel intensity along the scanline at every frame onto the time axis as shown in Figure 10. Every moving object passing through a scanline will leave a group of trace captured by scanline. This group of traces along the time axis will create the moving strands. These strands imply that each strand corresponds to a separate object, e.g. a moving vehicle, thus creating the “pseudo vehicle pixel trajectories”. The outcome of this step is ST diagram of vehicle passing through the intersection. The research team has successfully implemented this processor as part of research published in TRB Annual Meeting *(10)*. In this task, the major focus is to develop interfaces to allow automatic generation of scanlines based on the line features detected in the previous task.

Figure 10 Pixel Trajectory Generation (Dotted Lines are generated trajectories)

3.4.1.5 Vehicle Pixel Trajectory

This step mainly focuses on reconstructing full vehicle pixel trajectory from S-T diagrams. As illustrated in Figure 10, the direct edge detection results of the ST map may contain multiple strands from the same vehicle and the traces can have disconnection and noises. In this step, the pixel trajectory generator will use intelligent algorithm to search through the Pseudo vehicle pixel trajectories to detect and connect desired pixels from trace of front or rear part of the vehicle to established accurate pixel trajectories of vehicles. Figure 10 illustrates the preliminary results of two identified trajectories.

3.4.1.6 Feature Matching

This task implements the feature matching algorithms to correlate features from LiDAR model with the real-time video images. The matched point in both video frames and 3D LiDAR model will be used for pixel coordination establishment. The feature matching will be based on 1) rough alignment of video and LiDAR feature points based on their relative positions, and 2) accurate matching through coloring features.

3.4.1.7 Pixel Coordination Systems

Once the matched points are detected, real world coordination will be assigned to all pixels in video frames by interpolating the coordinates of the matched features from task 6. At each localized area, the interpolation is conducted by matrix transformation using the closest four matched feature points. In this situation a pixel coordination system will be established to be applied for calibrate the pixel trajectory by assigning real world coordinates to the entire frame pixels including scanline pixels. The outcome of this task will be frames with real world coordinates which will be used to calibrate the vehicle pixel trajectory from task 5.

3.4.1.8 Vehicle Trajectory

In this step by using the established pixel coordination system pixel trajectory will be calibrated to compensate the prospective effect and reconstruct the actual vehicle trajectories with accurate distance measurement. The generated vehicle trajectories will be stored and indexed in a trajectory database for further processing.

4. EXPERIMENTAL DESIGN AND FINDINGS

4.1 The Orchestrated Accident Site

An orchestrated accident site was created to test the proposed methodology shown in Figure 11. The accuracy of the model was evaluated by conducting measurements on both 3D model and orchestrated accident site. The 3D model will be constructed using the Agisoft software. The Agisoft creates a 3D model of the multiple pictures by creating a scaled 3D cloud of pixels from original pictures. More pictures from different angles will produce more accurate 3D models.

Figure 11 Orchestrated accident site

4.2 Results

Figure 12(b) shows the dense cloud of the 3D model. It can be observed that the general shape and key features of the accident site such as roof outline, open doors, open hood, tail lights, tires, car body, and the orchestrated injured personnel outside of the vehicle have been captured. However, due to the glare that leaves different colors on the smooth surface of the car such as windows and roof panels, are not fully captured causing missing points at the corresponding locations. To compensate, the missing points require more pictures from different angle can be taken to provide more overlaps between images. Another way of reducing the glares is to use the polarized filter on the camera lens. Those options are to be tested in future flights.

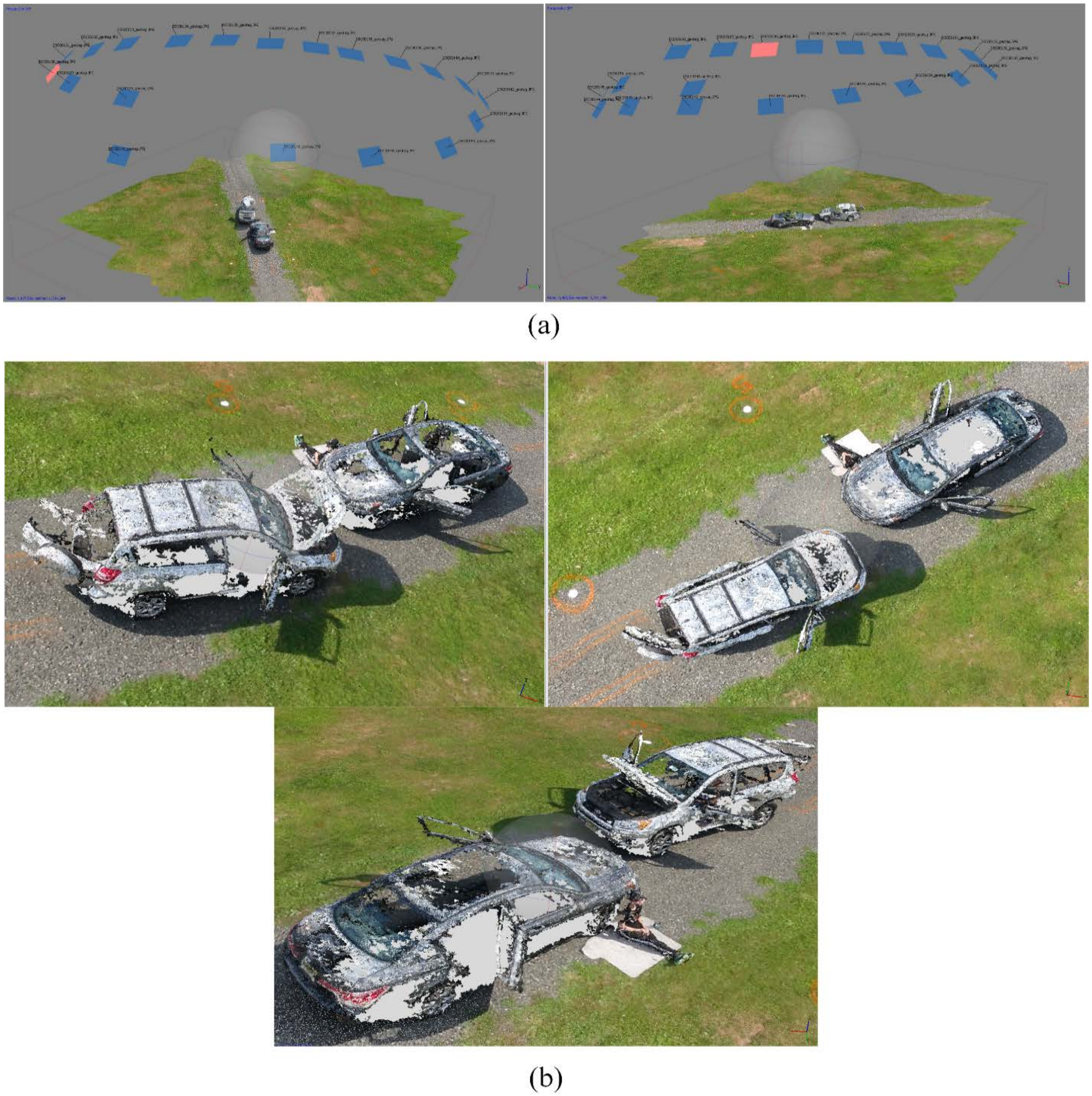


Figure 12 3D reconstruction results from Agisoft: (a) camera locations (b) close view 3D dense point clouds

TABLE 1 Image Coordinates

Image number	Longitude	Latitude	Altitude
DSC00128_geotag.JPG	-74.461222	40.516250	48.250000
DSC00129_geotag.JPG	-74.461222	40.516194	48.190000
DSC00130_geotag.JPG	-74.461278	40.516139	47.400000
DSC00131_geotag.JPG	-74.461306	40.516111	47.900000
DSC00132_geotag.JPG	-74.461389	40.516083	48.250000
DSC00133_geotag.JPG	-74.461472	40.516083	48.360000
DSC00134_geotag.JPG	-74.461528	40.516083	46.870000
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DSC00136_geotag.JPG	-74.461639	40.516167	46.000000
DSC00137_geotag.JPG	-74.461694	40.516194	46.310000
DSC00138_geotag.JPG	-74.461694	40.516250	46.720000
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DSC00142_geotag.JPG	-74.461528	40.516417	46.860000
DSC00143_geotag.JPG	-74.461444	40.516444	45.310000
DSC00144_geotag.JPG	-74.461389	40.516417	44.570000
DSC00145_geotag.JPG	-74.461306	40.516417	46.610000
DSC00146_geotag.JPG	-74.461278	40.516361	46.500000
DSC00148_geotag.JPG	-74.461222	40.516250	44.270000
DSC00149_geotag.JPG	-74.461361	40.516278	63.880000
DSC00150_geotag.JPG	-74.461472	40.516194	63.740000
DSC00151_geotag.JPG	-74.461556	40.516250	63.580000
DSC00152_geotag.JPG	-74.461417	40.516333	63.820000

4.2.1 Measurement Result Analysis

Measurement comparison was implemented to investigate the accuracy of proposed methodology. Two vehicles were used in this study, Toyota RAV 4 and Honda Accord. Measurements were conducted on these vehicles. Measurement comparisons have been summarized in Table 2.

TABLE 2 Measurement Results

Length(cm)	Toyota RAV 4 2010				Honda Accord 2011			
	Actual	Model	Error		Actual	Model	Error	
			Rel.	Abs.			Rel.	Abs.
Tire Diameter	70	69.16	1.20%	0.84	64	65.54	2.40%	1.54
Tire Center to Tire Center	268	273.18	1.93%	5.18	280	283.81	1.36%	3.81
Bumper to Bumper	447	461.27	3.19%	14.27	411	494.77	20.38%	83.77
Height	165	163.76	0.75%	1.24	142	138.4	2.54%	3.6
Taillight to Taillight	130	125.62	3.37%	4.38	155	159.21	2.72%	4.21
Roof Width	190	208.88	9.94%	18.88	125	140.14	12.11%	15.14

Results show high accuracy of the 3D model. Seventy-five (75) percent (9 out of 12) of measurements were within 5 percent error. However, the three measurements show significant error such as bumper to bumper length in Honda Accord. These errors derive from the missed matched pixels detected by the software due to illumination of the sun on the same surface from different angles. Sunlight reflection in few pictures created a glare that resulted in miss detection of matched pixels in software.

5 CONCLUSION AND RECOMMENDATION

Improvement in UAV technologies such as autonomous flight mode, GPS-based position holding make the technology more suitable for applications in traffic operations, especially for rotary-wing UAVs with the VTOL capabilities. Furthermore, mass production and civilian usage of UAVs have brought down the unit price significantly making it more and more affordable and cost-effective for transportation applications.

Existing studies on using UAV in traffic operations have focused on traffic surveillance. In this study, we developed and field tested a mid-size rotary-wing UAV system for traffic incident management, the Air-TIMS. The system is equipped with a high-resolution camera, stabilizing camera gimbal, HD video transmitter, and ground control station. Combined with software such as Mission Planner, Geo-tagging script, and Agisoft Photoscan, the proposed system can be used to reconstruct 3D models of accident sites. An orchestrated accident site is configured to evaluate the proposed system. Twenty-five (25) pictures had been taken from different angles by UAV cameras planned through a waypoint plan. Once the pictures were taken and transmitted to the ground station, the pictures were Geo-tagged using Agisoft. The Geo-tagged pictures were used in Agisoft software to create a correctly scaled 3D model of the accident site. To compensate the shift of model in the real world due to GPS errors in UAV, reference points were surveyed to find the correct relative location of the model with respect to earth coordinates. The measurements in the 3D model and model to real world measurements on the site shows promising accuracy illustrating the feasibility of the approach.

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