UTILISING UAVs AND AI SOFTWARE FOR DATA COLLECTION AT ROUNDABOUTS

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ABSTRACT

The use of Unmanned Aerial Vehicles (UAVs) for traffic observation has increased with advances in both drone technologies and video analytics. Improvements in video analytics for identifying and tracking vehicles in two dimensions means that it is now possible to collect and analyse vehicle paths and traffic movement dynamics. This is useful for understanding vehicle movements through roundabouts. This paper will report on a large study using UAVs to collect data at over 100 roundabouts across four regions in South Africa, specifically considering the process of data collection using drones and the software requirements for data extraction. Vehicle operations at roundabouts were recorded by UAV-mounted cameras during peak traffic hours from optimal vantage points. The footage was then uploaded to a cloud-based video analytics platform for processing and scaled to the relevant coordinate system. The video analytics platform was found to provide accurate measurements and movement dynamics of vehicles as they travel through the camera view. Analytics that are directly available from the platform include point speeds at specific locations, acceleration, deceleration, and gap acceptance. Traffic counts and turning movements are also identified because every vehicle traversing the roundabout is tracked. This paper will further report on the post-analysis techniques that were followed to analyse the data and extract the relevant performance measures required for further research.

1. INTRODUCTION

1.1 Background

The use of Unmanned Aerial Vehicles (UAVs), also referred to as drones, has become more in demand with the advances in drone technologies for the use of collecting simultaneous traffic data. The simultaneous improvement of artificial intelligence (AI) in the field of traffic video analysis has made analysis of vehicle paths and traffic movement dynamics more readily available.

Previously, video data collection was undertaken using “permanent” (pole-mounted) and “temporary” (tripod-mounted) cameras. The video footage was then analysed manually to count vehicles or record the position of vehicles and their arrival time at certain points. This process was susceptible to human error, took large amounts of time and was very labour-intensive. Some of the procedures that were used for this purpose are described by Rodgers et al. (2021).

With the use of stabilized airborne drones, data collection in the transportation field advanced significantly. Some advantages drones offer are the expanded field of view of the drone camera and the higher resolution of the cameras that allows higher quality videos (Rodgers et al., 2021). Drones are now being used for purposes such as traffic surveillance (Barmpounakis & Geroliminis, 2020) as well as traffic network analysis and traffic safety monitoring (Outay et al., 2020).

The use of drones and AI software has now created a platform to allow observation of traffic movements, especially useful for vehicle movements through roundabouts. Several studies have recently been undertaken at roundabouts. Chun et al. (2022) and Shoaib Samandar et al. (2022) used drones to collect video footage at a roundabout. The image processing software that was used for data processing and extraction was DataFromSky, the same platform that will be described in this paper. In these two studies, the use of drones and post-processing software aided in the validation and calibration of simulation models of roundabouts (Chun et al., 2022). Another study was also undertaken by Gbologah et al. (2022) of 12 roundabouts in Atlanta, Georgia. The study also utilised the DataFromSky platform for the analysis of the videos.

1.2 Purpose of Paper

The purpose of this paper is to report on a large study using UAVs and AI software to collect data at over 100 roundabouts across South Africa. The study forms part of a research project of the South African National Roads Agency (SANRAL) to research roundabout operations and performances across South Africa.

The paper will report on the process of data collection using drones as well as the software requirements for the extraction of the data. This paper will further report on the analytics available from the cloud based DataFromSky AI platform and on the post-analytical techniques that were followed to make the data available for further research.

2. DATA COLLECTION

2.1 UAVs Used in the Study

The use of UAVs are regulated in South Africa by Part 101 of the regulations of the Civil Aviation Act No 13 of 2009. The legal term used in the regulations for a UAV is a “remotely piloted aircraft system” or RPAS. The use of these systems for non-private purposes are subject to various requirements, one of which is that the systems may only be operated by a licensed pilot.

Use was therefore made during the study of commercial companies that offer professional UAV services. Minimum requirements for the UAVs and the quality of cameras were specified. Videos were recorded at 4K resolution and stored on an SD card. Test flights were undertaken to ensure the cameras did provide the high-quality video footage that was required.

The UAVs pose no safety risks. They make little sound and appear very small to the human eye when they are flying at a height of 100-120 meters. Motorists looking in front of them won’t be able to see the UAVs except when they are explicitly looking up while driving through a roundabout. It was noted that the UAVs doesn’t affect the behaviour of the motorists.

2.2 UAV Surveys

Various tests were undertaken during the project to determine the most appropriate vantage point and height of the UAVs for the video recordings. The regulations do not allow the operation of a UAV nearer than 50m from a public road. This meant that the videos could not be recorded from directly above the roundabouts, all recordings had to be captured at an angle. Such recordings lead to distortions in the video image and could increase the incidence of occlusion of vehicles that may be travelling behind large heavy vehicles. Therefore, the UAVs had to be operated from a height of not less than 100 m to 120 m above the roundabouts to minimise the effects of the distortions due to the angle of the video image, anything lower than that showed the distortion effect in the video image. The distortion effect only comes in at the edge of the video frame. With the height requirements of the footage, the distortion effect was minimised and did not significantly impact the tracking of the vehicles as most of the vehicle measurements were taken at the roundabout centre where no distortion happens.

Another requirement is that the DataFromSky AI software requires that the video cameras have a minimum pixel resolution of 3840 x 2160. A vehicle needs to be presented by a minimum of 20x20 pixels to be successfully captured by the DataFromSky software. This meant that the height of the UAVs had to be restricted even if use was made of 4K resolution cameras.

A further issue that had to be addressed is that the battery of a UAV only lasts about 20-30 minutes. Multiple batteries were used at a site, and it was necessary to land the UAVs to replace the batteries. Time on the ground was minimal and only a few minutes of footage were missed. The UAVs, however, have the capability to return to a specific position and this capability was used to ensure that multiple successive recordings were made from the same location and height using the same drone.

One of the use-cases of the data collected was to investigate the capacity of roundabouts. The video recordings were therefore mostly undertaken during peak traffic periods. An example of an image extracted from one of the video recordings is provided in Figure 1, the intersection of Merriman Avenue and Cluver Street in Stellenbosch. This image illustrates the details that can be recorded using the UAVs, including number of vehicles queued, vehicle following distances in the circulating lanes and the vehicle trajectories.

Figure 1: Typical drone view – roundabout in Stellenbosch on Merriman Avenue

Another component of the SANRAL research project conducted an analysis of the DataFromSky software's level of accuracy, and determined that the speed data was highly accurate, with a difference of only 0,2 km/h compared to GPS observed speeds.

2.3 Study Area

Roundabouts were selected from various locations and regions throughout South Africa. A map showing the locations of the roundabouts is provided in Figure 2. The roundabouts were selected in the following regions:

- Western Cape: Cape Town, Stellenbosch, Paarl, Saldanha Bay, Wilderness, Plettenberg Bay, and George.
- KwaZulu-Natal: Durban, Empangeni, Eshowe, and Pietermaritzburg.
- Free State: Welkom and Bloemfontein.
- Gauteng: Soweto, Pretoria, and Molotto Corridor.

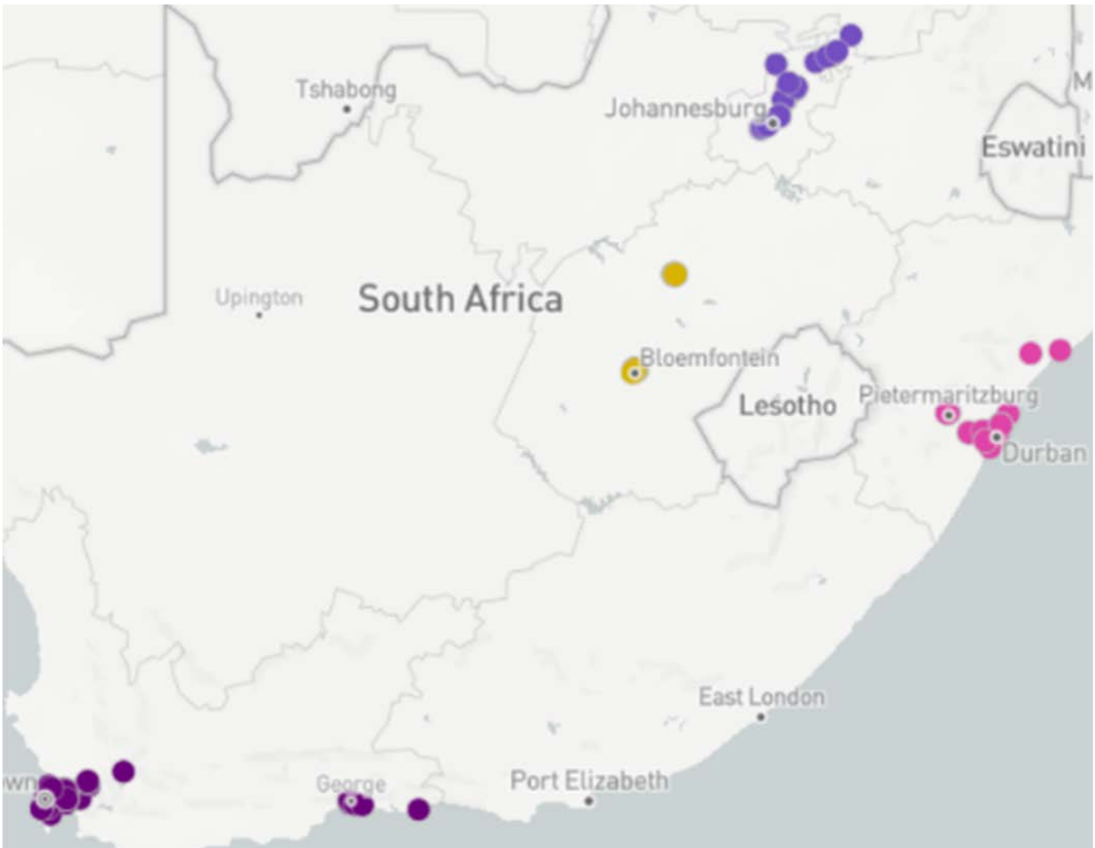

Figure 2: Location of roundabouts surveyed

3. DATA PROCESSING

3.1 Geometric Definition of Roundabouts

It was necessary for the purposes of the SANRAL research programme to obtain data on the geometry of the roundabouts. For this purpose, a scaled and ortho-rectified aerial photograph was obtained from various sources to ensure optimal quality and accuracy. Wherever a quality aerial photograph was not available, a photograph taken by the UAV was used.

The Autodesk AutoCAD drawing software package was used to obtain the geometric dimensions. An overlay drawing was made from the aerial photograph of all the various geometries and dimensions required at roundabouts. Tags were used to label each of the elements. These tags together with the properties of the various elements were exported to a file in a format that could be used in other software programmes. The geometric elements included, for example, the splitter island width, approach road width, centre island radius, truck apron width and circulating lane width.

3.2 Video Analysis

DataFromSky (DFS) was used to analyse the UAV obtained video footage to capture vehicular data. DataFromSky has several platforms for video processing, one of which is the TrafficSurvey platform. This platform uses AI and machine learning methods to capture traffic data (*Traffic Survey - DataFromSky*, 2021). The TrafficSurvey platform makes specific provision for capturing data from drone videos.

The video recordings were processed by first uploading the recordings to the platform. The processed vehicle tracking data then becomes available and can be downloaded from the website. The data are downloaded in a specific format that can be viewed using the DataFromSky Viewer software that is made available by DataFromSky (*DataFromSky Viewer*, 2019).

An example of the vehicle tracking data is shown in Figure 3. The DataFromSky Viewer allows viewing of the data against the background of the video recording. Figure 3 indicates how vehicle trajectories are labelled by a tag showing a unique ID number allocated to each vehicle that is recorded. Provision is made for either a frame-by-frame viewing of the tracking data, or the video can be played back showing how the vehicles are tracked through the roundabout.

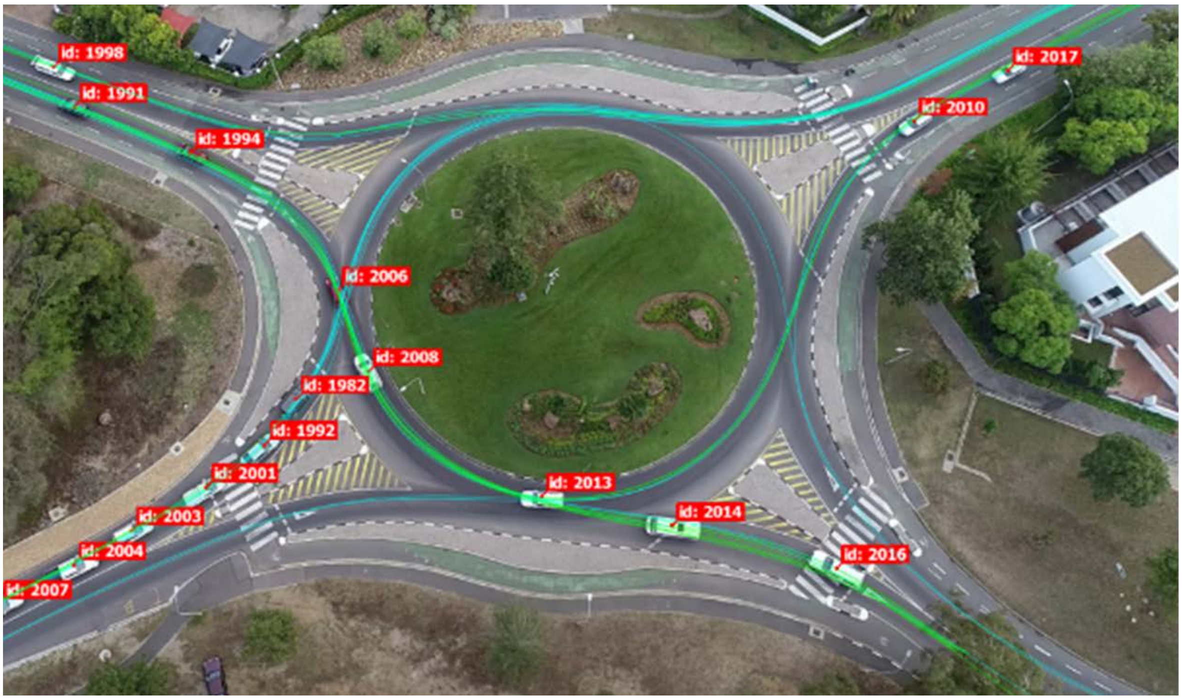

Figure 3: Compressed tracking log file

The DataFromSky software tracks a vehicle using the centroid of that vehicle. The software identifies the different vehicle types and therefore adjusts the position of the centroid according to type of vehicle. For example, a truck/trailer combination vehicle is tracked as a single vehicle, and the software identifies a centroid based on the combination. Each vehicle's path is extracted separately, and provision is made to analyse heavy vehicles separately from passenger cars.

3.3 Geo-Referencing of Video Recordings

The DataFromSky software captures all data measurements in units of pixels. For example, speeds are recorded in units of pixels per second. A process called geo-referencing is then applied to convert the pixel measurements to units of metres. This conversion is undertaken by providing the Universal Transverse Mercator (UTM) x- and y-coordinates of fixed points in the video image which is then transformed by the software to metre units. An example of a geo-referenced video is shown in Figure 4. The points given in Figure 4 are randomly selected points on the video image viewed within the DataFromSky software. The software requires a minimum of 4 points to geo-reference the video, however, more accuracy can be achieved by choosing up to 20 points on the image. These points are then given corresponding x- and y-coordinates of that position in space. It was found that using about 20 points reduced the deviation between the entered coordinates and the selected points to less than 0.4 m. These points have no relation to the path that vehicles drive, but rather ensure that the measurements obtained for the vehicles from this software are as accurate as possible.

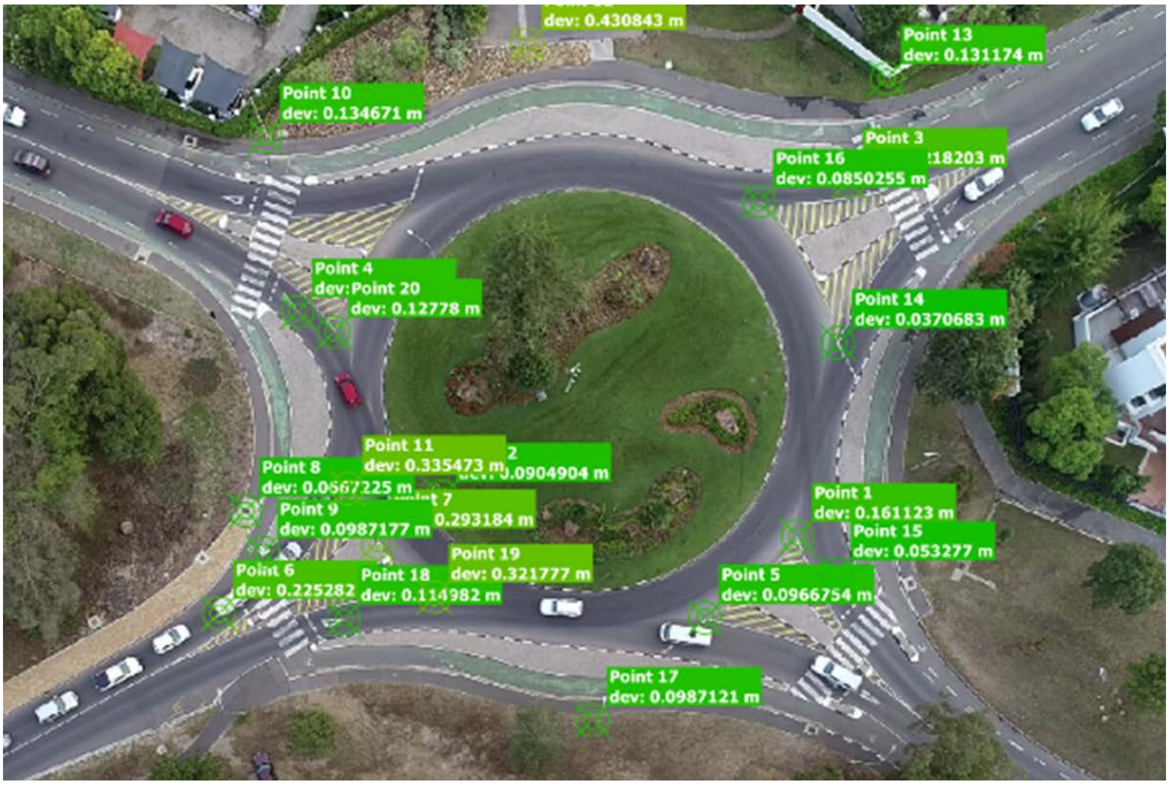

Figure 4: Geo-referenced video

3.3.1 Vehicle Trajectories

DataFromSky provides data measurements for the trajectories of all vehicles traversing through the video frame, from the time of entering until exiting the frame. The data include the vehicle category (light vehicle, bus or heavy vehicle), distance travelled, x- and y-coordinates, speed as well as the tangential and lateral acceleration at each point on the trajectory of a vehicle. The data are captured every 0,4 seconds (for a recorded frame rate of 25 frames per second).

The DataFromSky software makes provision for exporting the data in a format that can be used by other software. For example, the data can be imported into AutoCAD and overlayed on an aerial photograph of the roundabout. An example of the process is illustrated in Figure 5 which shows the vehicle trajectories that were captured from one video recording. The geo-referencing process allows for the accurate positioning of the vehicle trajectories on the aerial photograph. It is observed from Figure 5 that the trajectory information can be used to identify vehicular traffic and non-motorised traffic.

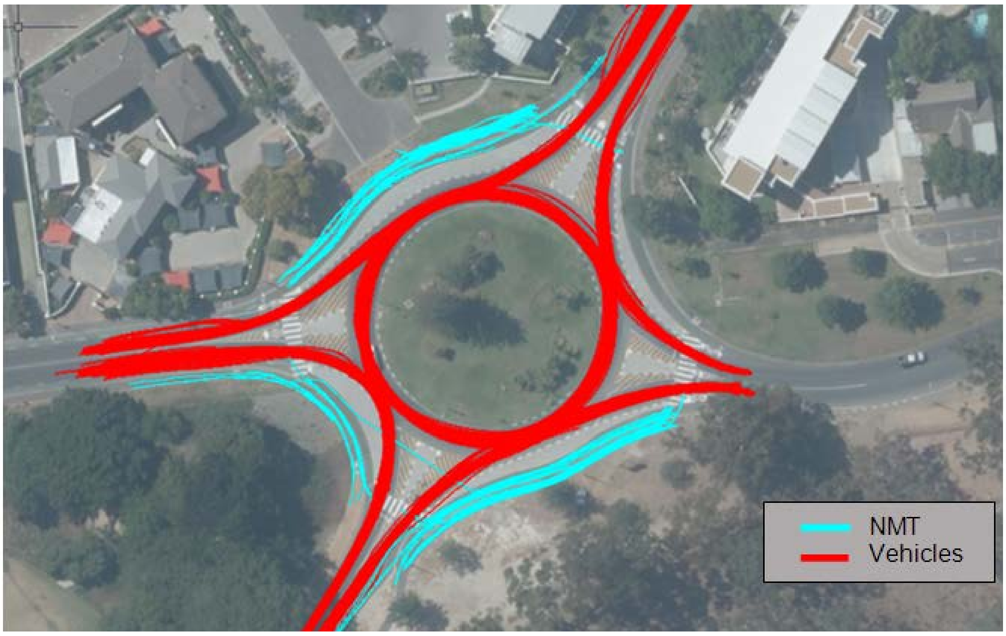

Figure 5: Trajectories imported to AutoCAD

3.3.2 Traffic Counts

The DataFromSky viewer provides a function called "gates" which are defined as line detectors. These gates are lines that are drawn onto the aerial photograph of the roundabout. The viewer can then provide a report on all the vehicles that have crossed these lines. The crossing events over these "gates" can also be exported. The "gates" can be drawn anywhere and can be defined as an entering, exiting gate or neutral gate, as illustrated in Figure 6.

Figure 6: Position of gates for entering and exiting vehicles

The software makes provision for capturing various attributes of vehicles crossing a gate. These attributes include the vehicle ID, speed, acceleration, position (UTM x- and y-coordinates) and the time the vehicle crossed each gate. For the study, gates were defined on the approaches and exits to and from the roundabout.

The traffic counts were generated from gate counts, which also define traffic according to vehicle type. The vehicle types that are identified by the DataFromSky software include: pedestrian, cyclist, motorcycle, car, van, bus, light truck, medium vehicle, and heavy vehicle.

3.3.3 Other DFS Functions

In addition to the line detectors, it is possible to define "traffic regions" that are equivalent to area detectors as shown in Figure 7a. There was no need for data recorded over these regions and this function was therefore not used.

DataFromSky can also provide information on locations where heavy braking occurred as well as so-called "time to collision". Examples of the locations where braking and possible collisions occur are shown in Figure 7b.

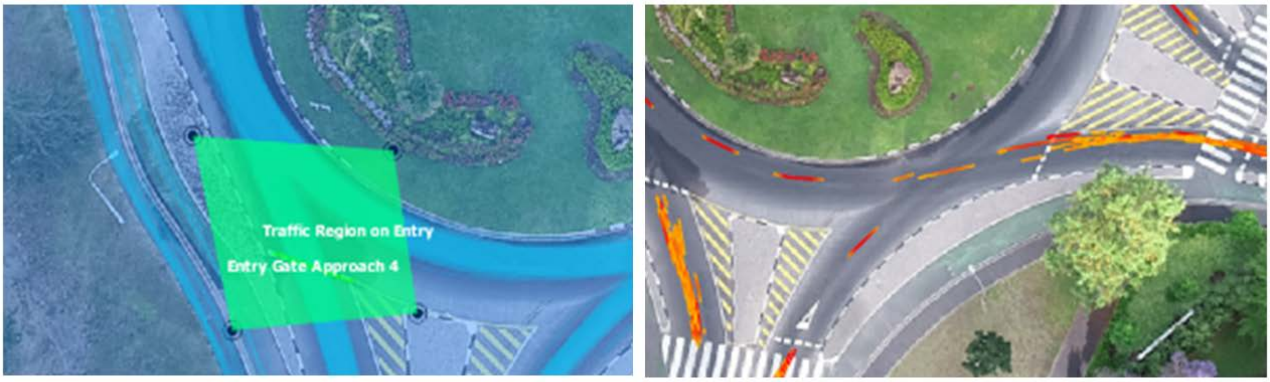

Figure 7: Traffic region on entry (a) and heavy breaking positions (b)

3.4 Summary of Extracted Data

The data processing and extraction steps described above produced the following for each roundabout that was surveyed:

- The trajectory paths for every vehicle travelling through the roundabout.
- Measurements of the speed, acceleration, and coordinates of the vehicle at each point on the trajectory followed through the roundabout.
- AutoCAD drawings of geometric dimensions of each roundabout.
- Typical vehicle path through the roundabout, conflict points and angles of the vehicle paths and approaches on the AutoCAD drawing.
- Traffic counts and turning movements of each roundabout.

These data were used as input for further analysis. The data will assist in determining performance measurements at roundabouts that are required as part of the SANRAL research project.

4. DATA ANALYSIS

4.1 Typical Vehicle Paths

After the trajectories are imported to AutoCAD, a typical or representative vehicle path through the roundabout was generated to represent all trajectories. Examples of these typical paths are shown in Figure 8. The individual vehicle trajectories are shown as red lines in the figure while the typical path is shown in yellow in Figure 8a.

The typical vehicle trajectories were used for establishing an approach angle as well as a conflict point for each approach to the roundabout. The approach angle is measured between the typical approach and circulating vehicle trajectories as illustrated in Figure 8b. A point of conflict was determined on the circulating trajectory opposite the position where a vehicle would stop at the yield line on the approach to the roundabout (also shown in Figure 8b).

Figure 8: Typical vehicle paths in yellow (a), entry angles in red (b)

4.2 Analysis Software

The DataFromSky software can only be used for the capturing of data on the vehicle trajectory as well as a limited analysis of the data, detailed in the previous sections. Additional software was therefore developed as part of the SANRAL research project for the analysis of traffic at roundabouts required for evaluating the performance of roundabouts. The additional software makes provision for various functions such as plotting the typical vehicle paths through the roundabout. These plots are used to assist in visualizing and validation purposes. An example of such a plot is shown in Figure 9.

The software also makes provision for an algorithm that “snaps” points on individual trajectories to the nearest point on the typical vehicle path as shown in Figure 10. These snapped position makes provision for linking the individual measurements to the geometry of the roundabout and for determining various performance measurements that are required for the research project.

The data extracted for the roundabout research include critical time and distance gap acceptance, follow-up headways between vehicles, conflicting headway distributions, approach speeds, exiting speeds, circulating speeds, accelerations, and decelerations.

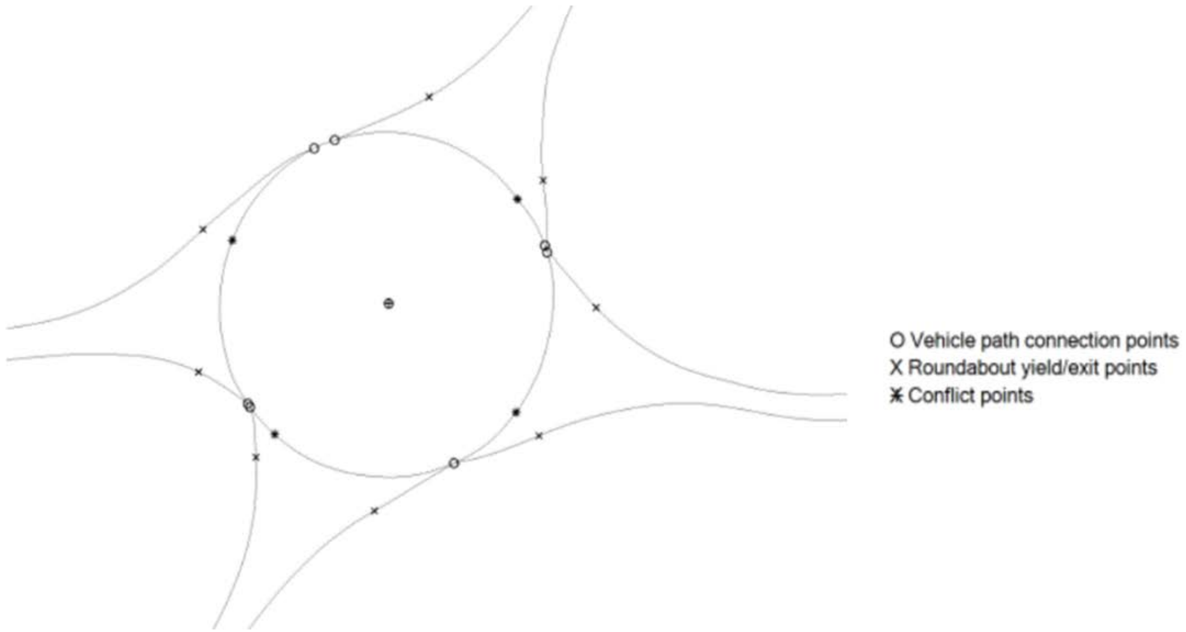

Figure 9: Plot of typical vehicle path

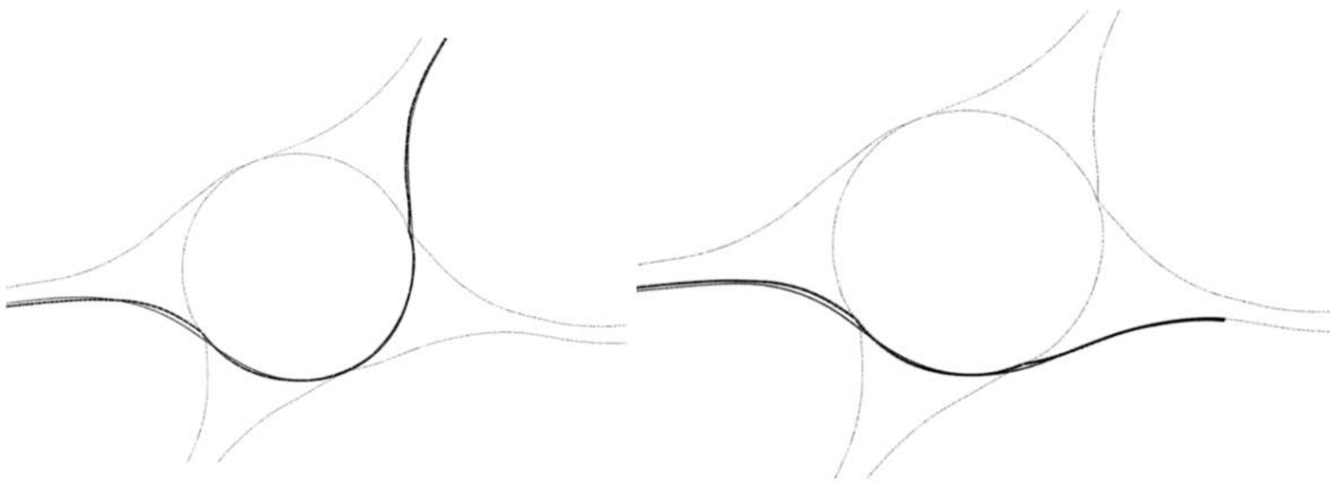

Figure 10: "Snapping" of vehicle path to typical path

These measurements are determined by the developed software and are given for each roundabout that was included in the research. An example of one of the functions of the developed software is to visually plot the positions of the circulating vehicles when a gap was accepted or rejected by a vehicle on the approach to the roundabout. Figure 11 provides an example plot for accepted gaps.

The approach number 1 referred to in Figure 11 are the bottom approach. The cross refers to the position of the yield line on that approach. The dots on the figure shows the positions of the conflicting vehicles, on the typical path, when a vehicle accepted a gap, while waiting at the position indicated by the cross.

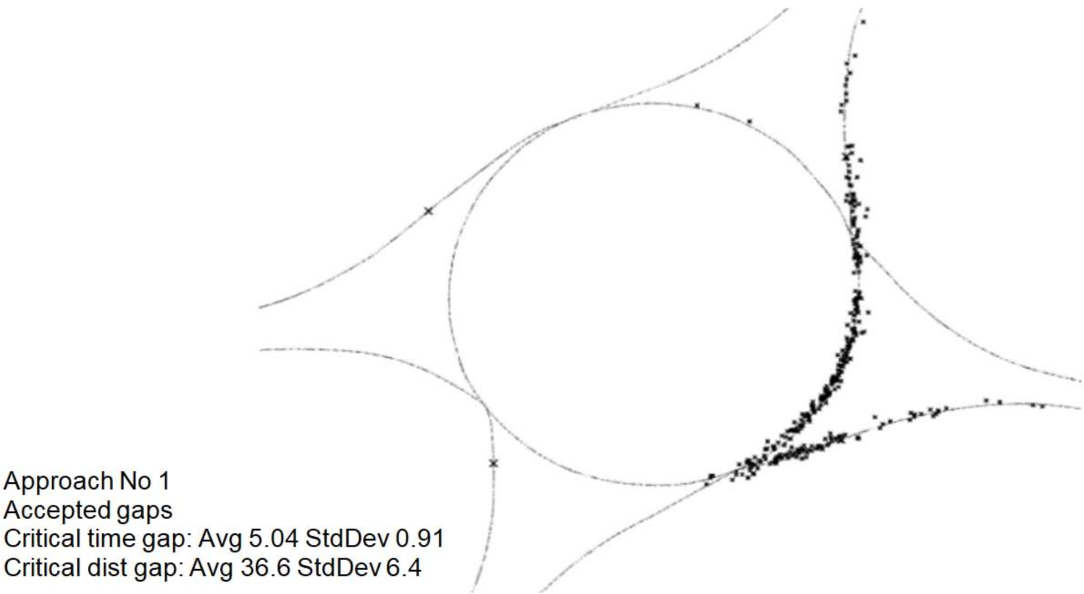

Figure 11: Position of vehicles when gaps were accepted

5. SUMMARY

This paper provided information on the use of UAVs and AI software in collecting data at 100 roundabouts across four regions of South Africa. An overview was given of the data collection process followed during the larger SANRAL roundabout research study. The processing steps resulted in data items such as roundabout geometry, conflict points and angles, vehicle paths and measurements for each vehicle driving through the roundabout e.g., speeds, accelerations, and coordinates. Traffic counts and turning movements were also obtained from the software.

Software was also developed during the project for further analysis of the captured data. This software has been used to extract data on circulating and exiting vehicle speeds, critical time and distance gaps and follow-up headway for each roundabout surveyed. These measurements will assist further research on the performance and operations at roundabouts.

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