Enhancing Ambulance Accessibility in Deprived Regions: A Drone-Based Spatial Data Solution for Ashaiman, Greater Accra

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SUMMARY

Accessibility to emergency medical services is a critical factor in saving lives, particularly in deprived regions like Ashaiman in Greater Accra, Ghana. The existing open-source ambulance management system may have its challenges. This is due to the lack of sufficient and up-to-date spatial data. The continuously changing urban structure within the study region poses a significant problem. This is one of the reasons ambulances may miss their way while not using optimal routes. This results in a delay in response times.

The objective of this project is to provide an efficient and up-to-date spatial dataset for Ashaiman. This will in turn facilitate accurate navigation for ambulances within the project area. Value-added spatial data can be extracted from processed aerial imagery. The availability of a drone platform is leveraged in line with our goal. Through the use of drone photogrammetry techniques, stereoscopic coverage of the study region is obtained. This subsequently ensures the generation of precise and high-resolution imagery. Digital orientation processes are used to produce orthomosaics, which serve as a foundational dataset. Furthermore, generation of a DEM from stereophotos is explored. A point cloud was created as a by-product for subsequent classification of pot-holes - this is required to assess road quality.

The flight parameters were carefully determined to optimize data collection. A front overlap of 80% and a side overlap of 75% were chosen to ensure total coverage and minimal information loss. A flying height of 90 meters was selected, striking a balance between two criteria - achieving a ground sampling rate between 2 and 5 cm/pixel and saving time during data acquisition.

This project seeks to contribute to the improvement of the current state of the ambulance management system in Ashaiman. The outcome of the improved navigation capabilities will contribute to saving lives in this deprived region. An added result of this improvement is the reduction in response times. These results, which are the products and resultant maps provide knowledge that is needed for addressing accessibility issues.

Keywords: drone photogrammetry, photomosaic, point clouds, accessibility, spatial dataset

1 Introduction

A well-implemented ambulance service would ensure patients have good chances of survival if it provides the functions to find a suitable facility as quickly as possible. The EAMS is designed as an open-source project to make this possible, making use of open-source GIS "QGIS" as the basis for the system development (Okyere et al., 2022). It provides a solid foundation and easy ways to add features. This is important to ensure connections to databases and to create an interface for the allocation of ambulances. An initial attempt to analyse the data from the current system recommends that more data on the road infrastructure and real-time traffic volume data be incorporated (Okyere et al., 2023).

1.1 Approaches to improvement

To enhance ambulance routes in the operational area of Ashaiman, additional data on road conditions is crucial. Integrating this data into the Emergency Ambulance Management System (EAMS) could establish a reliable routing system, ensuring avoidance of built-up or poor-quality roads. The analysis of implementation data as discussed in Okyere et al., 2023, is only as effective as the data used. One proposed solution involves a web application allowing ambulance drivers to report route details, including speed, road conditions, and encountered obstacles. However, this approach raises concerns as it may impact the drivers' regular tasks, and the accuracy of travel time predictions can be compromised by unpredictable factors such as traffic volumes.

Another consideration is using traffic data to generate routes, but this approach presents challenges. An approach that optimizes travel time and minimizes congestion is crucial (Lanka & Jena, 2014). This information can be obtained through various sources such as GPS data, traffic cameras, and crowd-sourced data from mobile apps. By utilizing these sources and implementing effective data management strategies, transportation professionals can gain valuable insights into traffic patterns and develop innovative strategies for managing the large amounts of data that result from the operation of GPS receivers, thus improving overall transportation efficiency and reducing congestion on roadways (Ziarmand et al., 2016). Traffic information may lead to unreliable duration assessments due to the random nature of traffic incidents. Distinguishing between road quality and traffic density becomes difficult, making the evaluation process complicated.

An alternative approach suggests tracking ambulance speeds on all trips to automatically gather information about road quality. While this gets rid of the need for manual data entry, similar challenges in evaluating datasets exist. This makes classifying information retrospectively based on road quality challenging.

A different strategy proposes employing camera drones to fly over the urban area, generating orthophotos for road condition classification. This method offers uniform results for all streets in Ashaiman, but limitations include a lack of real-time traffic information and the inability to account for future infrastructure changes.

Before implementing the project in Ghana, detailed information gathering and organizational steps are crucial. The planning phases are essential to ensure a smooth and successful implementation process.

2 Methods

2.1 Planning the implementation

A suitable drone with enough batteries must be organized for the flight. All remote pilots should have a valid license and receive permission to fly over the whole of Ashaiman from the responsible authorities. A flight plan was also drawn up in advance. Various influencing factors play a role in planning, such as battery life, satellite errors and weather conditions. The project requires a suitable drone for aerial photogrammetry, emphasizing quality recordings, portability, and extended battery life. Due to budget constraints, a DJI Mavic 2 Pro is used, prioritizing its availability and acceptable specifications for the project's needs.

Table 0-1 Drone Model, characteristics and availability

Drone Model	Characteristics	Availability
DJI Mini	Small and handy (249g), shorter flight time, smaller camera sensor	Owned by THWS
DJI Mavic 2 Pro	Portable, 31 minutes flight time per battery, larger camera sensor	Available during implementation
DJI Mavic 3	Longer battery life (46 minutes), larger camera sensor	Not available during implementation

2.1.1 Batteries

After selecting a suitable drone, it's crucial to plan the flight details, including the number of batteries, their runtime, and charging times. Each battery provides a 25-minute flight time with a 15% emergency reserve. Charging takes 90 minutes per battery, but the existing station can't charge all simultaneously, extending the process to six hours for four batteries. Optimizing battery use involves choosing smaller flight areas, minimizing travel distance between take-off/landing sites for battery changes, and maximizing capacity for actual flight.

2.1.2 Creation of the flight plan

When flying a UAV, choosing the right control method is crucial. The options include manual, stabilized, pre-programmed automatic, and autonomous modes. The next step is to create the automatic flight plan and calculate the duration of a UAV flight over the whole of Ashaiman. Different parameters and external influences play a major role. When planning the flight, it is important to adhere to the regulations and restrictions set by the Ghana Civil Aviation Authority(GCAA). The battery life and the influence of satellite errors must also be taken into account. The weather conditions that come with the rainy season in Ghana are to be considered. Finally, the flight altitude of the drone and the overlap parameters play a role timing plays a major role.

2.1.3 Classification of flight areas

To comply with licensing restrictions and aviation regulations, drone flights over Ashaiman, covering approximately 10 km2 of the 45 km2 area, must adhere to visual line of sight (VLOS) limitations and remain within a designated flight area. Flight durations are restricted to a day due to satellite signal errors, necessitating careful planning to avoid discrepancies, and ensuring an overlap of 20-30 meters between flight areas for seamless orthophoto stitching (LBA, 2023; GCAA, 2023; Manortey et al., 2018). It should be noted that in Germany, flying outside VLOS is prohibited under both the A1/A3 basic license and the A2 specialization, aiming to minimize risks associated with airspace not visible for obstacle checks.

2.1.4 Ground resolution

Other important factors when planning the flight are the height above the area at which the drone is flying and the overlap between the individual aerial images. The ground resolution should be approx. 2 to 5 cm/px on the orthophotos from Ashaiman, that is, one pixel in the orthophoto represents two to five centimetres of the actual area. After the evaluation, the structures of the streets and the outlines of potholes can be seen.
The desired ground resolution is 2cm/px. The image width of 5742 pixels, focal length of 10.26 millimetres and sensor size of 13.2 millimetres are characteristic of the DJI Mavic 2 Pro (Mavic 2 Pro, 2018). The optimal flight altitude using the second formula is therefore 90 meters.

$$H[m] = \frac{(5742px \times 2px/cm \times 10.26mm)}{(13.2mm \times 100)} = 89.26 \text{ m}$$

In practical implementation, the ground resolution could deteriorate again due to influences such as the air quality in Ashaiman or occasional gusts of wind that briefly divert the drone's course, resulting in images becoming blurry and no longer usable. Nevertheless, the resolution should be sufficient for the project. Striving for a higher ground resolution would take more time; disproportionate to that merely there is little improvement in the result.

2.1.5 Control points

When planning drone flights over Ashaiman, the use of control points, such as target plates, is essential for accurate georeferencing of aerial images. However, due to the time-consuming distribution and measurement of control points in the large Ashaiman area, Google Earth coordinates are employed for control point creation, providing rough guidelines for evaluation based on overlap. The accuracy of these coordinates is in the lower meter range, but depending on the region it can vary between approx. one and 15 meters, with an average of 4.38 meters (Wang & Wang, 2020).

2.1.6 Obstacles in the flight area

To carry out a smooth drone flight, the surrounding area should be checked beforehand and observed. Obstacles in the flight area could get in the way of the drone during the flight. A sufficient flight altitude is then selected at which the drone is not in danger of collision with obstacles from the floor space.

2.1.7 **Prior Test Projects**

Due to its easy accessibility by public transport, a test site was selected in Germany for that purpose. The site is behind the sports centre of the University of Würzburg on Hubland, in which no airspace restrictions exist. The area is mainly made up of fields and bushes. There is hardly any traffic and sandy dirt roads run between the fields, which, due to their nature, are comparable to undeveloped roads in Ashaiman. Before each test flight, meticulous preparations are crucial for safety, following checklists recommended by (LBA, 2023). Pre-flight checks, including weather assessment and battery verification, occur the day before. Basic prerequisites, such as registration, licensing, insurance, regular maintenance, and software updates, must be met (LBA, 2023). The conceptual framework for the test and actual photogrammetric evaluation is shown in Figure 2-1.

2.2 Evaluation workflow

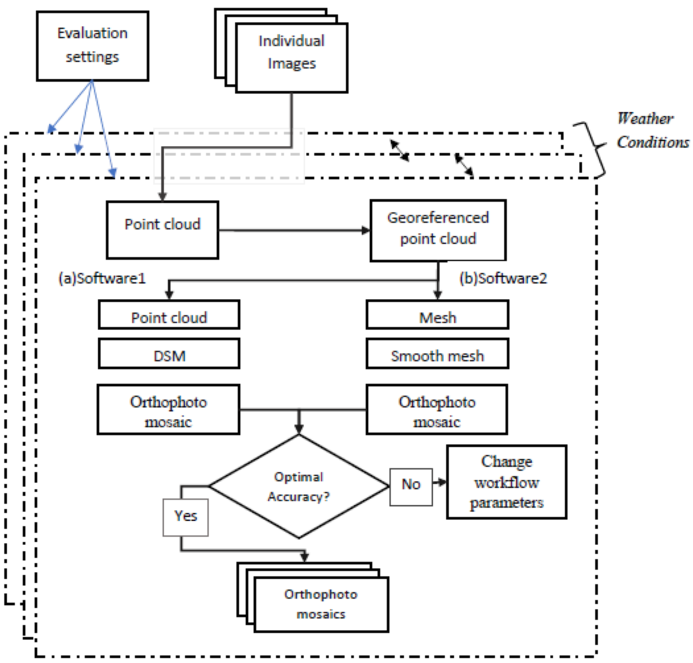

Figure 2-1 Conceptual framework of photogrammetric evaluation based on tested parameters

Photogrammetric evaluations are conducted in Agisoft Metashape software using standard settings to maintain consistency across aerial image processing. The project involves six "chunks" controlled through batch processing, with orthomosaics exported in the GeoTiff format for visual comparison, considered a quasi-standard in photogrammetry (cf. Mahammad and Ramakrishnan, 2003). Point clouds are exported in the binary "LAS" format due to their superior performance and smaller file size compared to ASCII formats like "OBJ" (Eltner et al., 2022). While binary formats have disadvantages in long-term storage, the evaluation, occurring shortly after the flight, renders this issue insignificant. The 3D point cloud comparison is carried out using the open-source software Cloud Compare (Thiele et al., 2017).

2.2.1 **Orthomosaic and Digital Elevation Model (DEM)**

The visual comparison of exported orthomosaics from different test flights reveals no significant differences in flat and unchanging areas but notable variations in vegetation, attributed partly to the time separation of flights. The evaluation using Metashape software indicates significant resolution differences, particularly evident during altitude changes from 90 m to 100 m, resulting in sudden increases in resolution. Flights three and four exhibit the lowest quality, with average deteriorations of approximately 3.1 mm in DEM and 1.5 mm in the orthomosaic. Despite a 7.5% time saving when changing the flight altitude to 100 m, the proportional loss in quality makes it irrelevant, suggesting that optimizing other flight parameters, such as overlap, may offer greater time savings with minimal soil resolution loss.

2.2.2 **Point cloud**

The visual analysis of point clouds from previous test flights revealed distribution differences, notably in green areas and trees, due to tree movements not considered in algorithms accounting only for camera movement. This leads to reconstructed points of objects found at multiple coordinates, reducing reliability and excluding them from the final point cloud (Dandois et al., 2015). Increasing side overlap to 70% (flight two) and 80% (flight three) condensed the point cloud.

The flight in Ashaiman aims to show streets and houses. These non-moving objects are less affected than areas of vegetation and are recognizable. This means that it is not necessary to fly with particularly high overlaps to ensure that the overlaps are important for the project to display features correctly and comprehensively.

The potential for time savings comes into play on flights with smaller overlaps. In the “DroneDeploy” mapping app, the number of images, batteries and the expected flight duration are specified before each flight. During the test flights, it is noticeable that the... Estimates made by the software are accurate and meaningful forecasts can be made from the calculated values. Simply reducing the front and side overlap from 90:80 to 80:75 results in a time saving of around 18.6%. In addition, it is halved

Number of images, which results in a reduction in the amount of data. This allows an increase in the flight speed from 3m/s to 6m/s. This results in a reduction in flight duration of 55.5% compared to a flight with 90:80 overlaps and a
Speed of 3m/s.

2.2.3 **Final parameters**

From six test flights in Ashaiman, parameter values for covering the entire area were determined. To achieve a ground sample distance (GSD) of 2cm/px, a maximum flight altitude of 90 meters is considered, ensuring better resolution and maintaining a safe distance from high-voltage lines. Front and side overlaps should be set between 70% and 90%, with the front overlap equal to or greater than the side overlap. After planning and executing the test flights, 31 flight areas can be covered in approximately 40 to 120 minutes each, totalling a maximum of 31 days of flying within three months, considering battery charging constraints.

2.2.4 **Evaluation Software**

The raw image data must first be processed using evaluation software. The choice of software has a direct influence on the quality and processing time of the final results. In the course of this chapter, different software will be examined in terms of their performance to find the balance between quality and time required.

The result of the evaluation is an orthomosaic and a 3D point cloud. To ensure unproblematic integration into the EAMS system, the data must be georeferenced and fit perfectly into the WGS84 coordinate system.

In addition, in later evaluations providing these results, the surface condition of the roads is expected to be classified. To enable complicated classification, the quality must be so high that details such as road surfaces or potholes can be recognized. However, this desire for the highest possible accuracy is offset by the processing time. As the accuracy of the evaluation parameters increases, the evaluation time also increases. This is how the duration of dense point cloud creation differs with the different settings “high”, “medium” and “low” from 84 s/image to 17 s/image to 4 s/image (Benjamin et al., 2017). Extrapolated, this time difference in the evaluation parameters would mean a computing time of around 60 hours, 12 hours or 2 hours for large flights with 2600 images. Since the data from the flights are processed immediately afterwards, the calculation time from the raw data should not be more than 24 hours. This prevents any accumulation of data.

2.2.5 **Options**

Two evaluation software options for the project are "Dmapper" by Pix4D and "Metashape Professional" by Agisoft (Pix4D, 2019, Logan et al., 2022). These state-of-the-art software packages, based on Structure-from-Motion (SfM), provide an alternative solution to LIDAR recording (Biçici & Zeybek, 2021, p. 97; Forsmoo et al., 2019). The workflow involves eight main steps, including cropping images, orientation, point cloud calculation, georeferencing, improving orientation, considering model uncertainty, condensed point cloud calculation, and creating orthomosaic, DTM, and 3D models (Ewertowski et al., 2019). Not all steps are mandatory, with some aimed at improvement and others at removing unnecessary data from results.

2.2.6 Choice of software

Small projects were created and evaluated to test the software. The processing time, the setting options and the quality of the results in both software are considered. In the Metashape software, it is noticeable that there are more different types. Because of the more diverse setting options and the better edge representation of roofs and walls (Tyagi et al., 2022; Agisoft, 2021), the decision was made against Pix4D and in favour of Agisoft Metashape.

2.2.7 Agisoft Metashape Professional

This section introduces features of Agisoft Metashape Software V. 2.02 that have a positive impact on the evaluation workflow and reduce the time from importing the data to shorten and simplify finished processing.

Due to the high degree of automation in the software, a long evaluation over several hours or days is possible without further user input. This supports the workflow in the project, as flights can be flown during the day and the evaluation can be initiated in the evenings. The processed results are available the next day.

2.2.8 Evaluation settings

After selecting the software for the project, the next step is it Investigation of the best evaluation parameters for the raw data. For everyone, The main evaluation steps are created with different settings. The main evaluation steps include orienting the images to each other (alignment), generating a point cloud and creating the digital terrain model (DGM/DEM). In the last step, all images become an orthomosaic merged (stitching). Because the steps build on each other and the results are directly correlated, the alignment is started and the best result is in the next related step. This procedure is repeated for all experiments. The goal is the highest possible quality with the least amount of time.

2.2.9 Test data

The test data from a previous student project by Joshua Aicon Oddoye, KAAF University College campus drone flight is comparable with the flight over Ashaiman. The parameters there were used for the testing of the evaluation set for the study area.

2.2.10 Alignment

(Agisoft, 2021; Benjamin et al., 2017) recommend key and tie point limits of 4,000 and 2,500 for accuracy. Three experiments show significant variations in evaluation times and point cloud sizes based on quality settings. The software measures alignment accuracy through Root Mean Square (RMS) values, with minimized errors at higher settings, and a Python script is suggested for automated error minimization (Hartley & Zisserman, 2003; Mavic 2 Pro, 2018). Using the "Medium" test setting achieves comparable results to the "High" setting with significant time savings and negligible impact on final results.

3 Results

3.1 Point cloud

From the work already used by Benjamin et al., 2017, a recommendation for the creation of a point cloud can be inferred. It should be noted that the goal of this work is the study of the accuracy of fit and not the resolution and dot density of the point cloud. The recommended accuracy setting is “High”. Depth Maps is set to Mildness. Tinkham and Swayze, (2021) also come to similar results. Swayze in her article “Influence of Agisoft Metashape Parameters on UAS Structure from Motion Individual Tree Detection from Canopy Height Models”, also refers to the level of detail of the results for further processing.

One influencing factor when creating the point cloud is “depth filtering”. Become there the depth maps, which are generated as an intermediate step to create the point cloud, used. Depth maps are a 2D representation of the distance of an object, based on the intensity of the pixels, from the viewing point. The further away a point is, the higher the intensity and vice versa. Since the depth maps are based on image data and there can be blurriness or image noise, the errors are incorporated directly into the depth maps. The “Depth filtering” function can be used to control the influence on the removal of points that are considered image noise (Mavic 2 Pro, 2018). The more aggressive the attitude is selected, the more detail loss occurs in the resulting point cloud. However, the reliability of the accuracy of the point cloud increases. Using the setting parameters just mentioned (accuracy and depth filtering), three possible evaluation scenarios are created and then compared (Table 3-1).

Table 3-1 Evaluation parameters for creating the point cloud

Name	High	Medium	Deep
Depth Filtering	Mild	Moderate	Aggressive
Accuracy	High	Medium	Low

Table 3-2: Comparison of the computing time in the Metashape software for the three evaluations

Name	High	Medium	Deep
Time in Depth Map	56	19	8
Time Point cloud[min]	96	23	5
Combined[Hours]	2.53	0.70	0.22
Number of Points	102475709	24943437	6082068
File Size[GB]	1.310	0.326	0.079

The increase in the number of points is approximately linear to the increase in processing time as the setting is increased from "Low" to "Medium" to "High". The number of points quadrupled when increasing the setting parameters. The time increases by a factor of around 3.5 (Table 3-2). The large differences in the density of the point clouds are serious.

As shown in Figure 3-1, buildings are only dimly visible at the Low setting. By increasing it to "Medium", the structure of the building becomes visible. When you increase it again to "High", details such as roof overhangs or window openings are clearly shown.

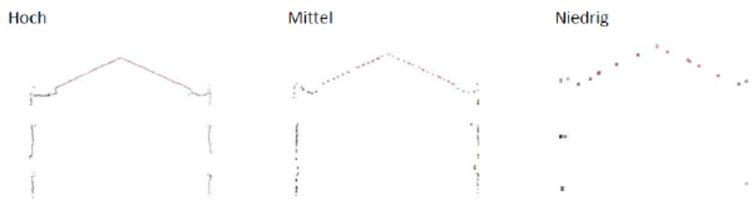

Figure 3-1 : 10cm thick section through a house from the point cloud of the test data with different Settings

These differences can also be seen in flat surfaces such as streets. When set to Low, there are distances of up to 1.6 m between two adjacent points. With such a resolution the road could not continue. Evaluations are used because potholes are not depicted or only partially in the point cloud. At the "High" setting, the surface of the road can be seen and the maximum distance between adjacent points is nine cm. However, the distance is smaller at around 5 cm on average. There can be potholes here to be recognized by the viewer. This provides a good basis for further developments

3.2 Evaluation of the data.

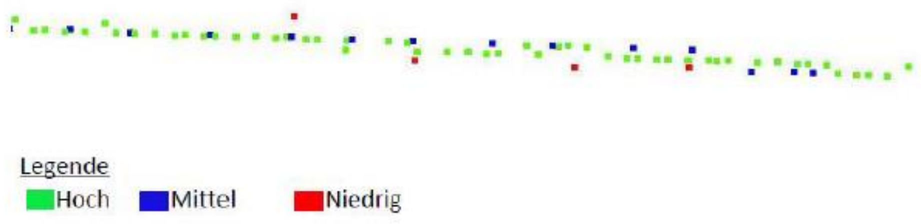

Figure 3-2: 10cm section through a section of road with different coloured point clouds depending on setting parameters for the evaluation

For the further course of the evaluation, the decision is made to use the "High" setting. Although the time increase between the different tests is significant, a significantly higher level of detail can be achieved. With the "Medium" and "Low" settings, the loss of resolution is so high that no certainty as to the accuracy.

The quality of the roads can be drawn. Since this is a mainstay for the creation of the point cloud, the settings “Low” and “Medium” must be avoided.

3.3 Digital Elevation Model

Creating a Digital Elevation Model (DEM) is cost-effective compared to generating a point cloud and has minimal impact on total processing time. The choice of a geographical projection ensures alignment with QGIS layers, facilitating undistorted image loading, while adhering to the recommended interpolation settings in Metashape's user manual (Agisoft, 2021). The decision to use "Depth Maps" as the data basis for DEM creation allows for selective classification, offering advantages such as creating DEMs from specific point cloud classes, rendering irrelevant evaluations obsolete. Despite the longer evaluation time associated with the "Ultra High" accuracy setting, the resulting DEM resolution does not significantly improve the orthomosaic resolution, leading to the pragmatic choice of the "High" setting.

3.4 Orthomosaic

The final step in the evaluation is creating the orthomosaic. That's what the pictures are for projected onto a 3D surface by the drone. Projecting allows the image data from folding effects can be adjusted. The more accurate the projection surface is, the more the calculated mosaic is more qualitative. In the Metashape software, there are two possible options; surfaces or DEM. On the one hand, the pre-calculated DEM or a mesh surface can be used. Using the mesh provides a more accurate resolution noticeable from building edges. When using the DEM, fringes are created. On edges and faulty artefacts can be seen at corners of buildings.

Unfortunately, serious errors occur when using the mesh even though not normal. However, according to Ludwig et al., 2020 the mesh is considered superior since it leads to better reproducibility in canopy areas.

3.4.1 **Stitching (putting the images together)**

The edges of the house roofs are partly offset meter-wide. However, not all roof areas in the test area are affected equally. There are some like that too

Roofs that are depicted without errors. Overall, however, no reliable information can be drawn from the mesh-generated orthomosaic. Without further research, no statement can be made about the exact reason for the incorrect stitching.
Therefore, the decision is made to use the DEM and therefore against its use of the mesh.

The last setting that can be influenced by the user is “ghosting filtering”. Using this setting, the software tries to detect moving objects such as cars or trains the images. This means that someone travelling doesn't appear twice. Since heavy traffic is expected in Ashaiman, this setting is activated.

3.5 Final parameters of the evaluation workflow

After carrying out all test attempts and assessing all results, a table of parameters for the evaluation of the flight was compiled (see table 9). These parameters offer a good balance between quality and time investment Processing.

Table 3-3: Final parameters for evaluation in Agisoft Metashape

Alignment	
Accuracy	Medium
Key Point Limit	20000
Tie Point Limit	5000
Reference Preselection	Source
Point cloud	
Accuracy	High
Depth Filtering	Mild
DEM	
Interpolation	Enabled
Data Basis	Depth Maps
Accuracy	High
Orthomosaic	
Data Basis	DEM
Ghosting Filtering	Enabled

In addition to the tabulated individual parameters, a corresponding "XML file" was generated for specific evaluations in Agisoft Metashape. This helps to loadng of data into "batch processing" without requiring the manual setting of individual parameters. Also, independent testing with customized test data is recommended. It is important that the test data reasonably aligns with the later flight data, considering variations like the flight area and, consequently, in the flight data.

There are also differences in the camera selection, the drone selection or the version of the Agisoft Metashape software. All of this leads to a greatly changed evaluation situation, which, with its peculiarities, requires the evaluation parameters to be reconsidered. Nevertheless, the parameters developed here should be used for initial tests to obtain an initial, comparable basis for the evaluation.

4 Conclusion

By planning the UAV flight for the study area and creating an evaluation workflow, the first step has been taken to generate routable data for ambulance management. Subsequently, the UAV project can be carried out based on the previously carried out planning. The development of the project planning and the compilation of the evaluation workflow were developed in theory and were not tested on-site. It is possible that in the course of implementation, new insights will be gained to improve implementation, based on which the developed process will be developed of the project can be optimized.

Due to the new and unknown situation in the project area, unforeseeable events may occur. To ensure that the project does not fail due to such incidents. There is an alternative variant of flight parameters to shorten the time implementation time provided. In the event of delays, a new one can be created. The results that emerge at the end of the implementation phase and evaluation are 31 Orthophotos and point clouds. At the end of the project in Ghana, this data is valid to prepare the actual usage to incorporate routable road data into the EAMS. Against this background, there are various options for further processing of the orthophotos. First, the orthophotos should fit precisely and georeferenced. An obvious approach would encompass a GIS program such as ArcGIS or QGIS to create coherent orthophotos.

To extract the quality of the streets shown, there is one option Classification that distinguishes paved roads from unpaved roads and Potholes detected. A road network will then be built to incorporate the classified road data into the EAMS. Taking road quality into account A navigation solution can be created for ambulance routes.
This new data, which is based on the UAV flight in Ashaiman is a primary source of more reliable and timeous data for a more efficient routing. Roads whose quality impedes the ambulance movement can be factored into decision-making by the health authorities in the future.

Overall, UAV aerial data offers the opportunity to provide up-to-date road information for the EAMS. This supports routing optimization and allows ambulances to travel more quickly and the timely transportation of patients to the nearest medical facility.

5 References

Agisoft. (2021). Agisoft Metashape User Manual: Professional Edition, Version 1.7. *Agisoft Metashape*, *September*, 160. https://www.agisoft.com/pdf/metashape-pro_1_5_en.pdf

Benjamin, A., Specialist, G., Geomatics, F., C, F. L. R. E., Brien, D. O., Barnes, G., & Wilkinson, B. (2017). Unmanned Peer-Reviewed Article (Sfm) Processing Parameters on Processing Time , Spatial Accuracy , and Geometric Quality of Unmanned Aerial System Derived Mapping Products Unmanned. *Journal of Unmanned Aerial Systems*, *3*(1), 73–99.

Biçici, S., & Zeybek, M. (2021). An approach for the automated extraction of road surface distress from a UAV-derived point cloud. *Automation in Construction*, *122*(May 2020), 103475. https://doi.org/10.1016/j.autcon.2020.103475

Dandois, J. P., Olano, M., & Ellis, E. C. (2015). Optimal altitude, overlap, and weather conditions for computer vision uav estimates of forest structure. *Remote Sensing*, *7*(10), 13895–13920. https://doi.org/10.3390/rs71013895

Eltner, A., Hoffmeiste, D., Kaiser, A., Karrasch, P., Klingbeil, L., Stöcker, C., & Rovere, A. (2022). *UAVs for the Environmental Sciences*.

Ewertowski, M. W., Tomczyk, A. M., Evans, D. J. A., Roberts, D. H., & Ewertowski, W. (2019). Operational framework for rapid, very-high resolution mapping of glacial geomorphology using low-cost Unmanned Aerial Vehicles and structure-from-motion approach. *Remote Sensing*, *11*(1). https://doi.org/10.3390/rs11010065

Forsmoo, J., Anderson, K., Macleod, C. J. A., Wilkinson, M. E., DeBell, L., & Brazier, R. E. (2019). Structure from motion photogrammetry in ecology: Does the choice of software matter? *Ecology and Evolution*, *9*(23), 12964–12979. https://doi.org/10.1002/ece3.5443

GCAA. (2023). *REMOTELY PILOTED AIRCRAFT SYSTEMS / DRONES – GHANA CIVIL AVIATION AUTHORITY*. https://www.gcaa.com.gh/web/?p=894

Hartley, R., & Zisserman, A. (2003). *Multiple View Geometry in Computer Vision, Second Edition*.

Lanka, S., & Jena, S. K. (2014). Analysis of GPS based vehicle trajectory data for road traffic congestion learning. *Advanced Computing, Networking and Informatics - Volume 2 Wireless Networks and Security Proceedings of the Second International Conference on Advanced Computing, Networking and Informatics (ICACNI-2014)*, *28*(VOLUME 2), 233–240. http://www.scopus.com/inward/record.url?eid=2-s2.0-84905403063&partnerID=tZOtx3y1

LBA. (2023). *Educational material – LBA – OpenUAV*. https://lba-openuav.de/onlinekurs/lehrmaterial/

Logan, J., Wernette, P. A., & Ritchie, A. C. (2022). *Agisoft Metashape/Photoscan Automated Image Alignment and Error Reduction version 2.0 | U.S. Geological Survey*. https://www.usgs.gov/software/agisoft-metashapephotoscan-automated-image-alignment-and-error-reduction-version-20

Ludwig, M., Runge, C. M., Friess, N., Koch, T. L., Richter, S., Seyfried, S., Wraase, L., Lobo, A., Sebastià, M. T., Reudenbach, C., & Nauss, T. (2020). Quality assessment of photogrammetric methods— a workflow for reproducible UAS orthomosaics. *Remote Sensing*, *12*(22), 1–18. https://doi.org/10.3390/rs12223831

Manortey, S., Mensah, P. A., & Acheampong, G. K. (2018). Evaluating Factors Associated with the Use of Aphrodisiacs among Adult Male Residents in Ashaiman Municipality, Ghana. *OALib*, *05*(09), 1–13. https://doi.org/10.4236/oalib.1104876

Mavic 2 Pro. (2018). *User Manual 2 Using This Manual Legend Warning Important Hints and Tips Reference*. http://www.dji.com/mavic-2/info#downloads.

Okyere, F., Minnich, T., & Brunn, A. (2023). Analyses of Implementation Data from a Low-Cost Ambulance Service in Ghana (11912) Franz Okyere (Ghana), Thea Minnich and Ansgar Brunn (Germany) FIG Working Week 2023 Protecting Our World , Conquering New Frontiers Orlando , Florida , USA , 28 May –. *Protecting Our World, Conquering New Frontiers, June*.

Okyere, F., Minnich, T., Sproll, M., Mensah, E., Amartey, L., Otoo-Kwofie, C., & Brunn, A. (2022). Implementation of a low-cost Ambulance Management System. *Dgpf*, *30*, 220–236. https://doi.org/10.24407/KXP

Pix4D. (2019). *Was bedeutet Genauigkeit bei Luftbildvermessungen? | Pix4D*. https://www.pix4d.com/de/blog/genauigkeit-luftbildvermessungen/

Thiele, S. T., Grose, L., Samsu, A., Micklethwaite, S., Vollgger, S. A., & Cruden, A. R. (2017). Rapid, semi-automatic fracture and contact mapping for point clouds, images and geophysical data. *Solid Earth*, *8*(6), 1241–1253. https://doi.org/10.5194/se-8-1241-2017

Tinkham, W. T., & Swayze, N. C. (2021). Influence of agisoft metashape parameters on uas structure from motion individual tree detection from canopy height models. *Forests*, *12*(2), 1–14. https://doi.org/10.3390/f12020250

Tyagi, D., Mishra, V., & Verma, H. (2022). Elevation Data Acquisition Accuracy Assessment for ESRI Drone2Map, Agisoft Metashape, and Pix4Dmapper UAV Photogrammetry Software. *Springer Proceedings in Mathematics and Statistics*, *404*, 121–131. https://doi.org/10.1007/978-3-031-19309-5_9

Wang, X. W., & Wang, F. (2020). THE PRECISION of GOOGLE EARTH MAP ANALYSIS with the COORDINATES of IGS STATIONS. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *42*(3/W10), 1053–1056. https://doi.org/10.5194/isprs-archives-XLII-3-W10-1053-2020

Ziarmand, A., Kucherenko, D., & Soklakova, T. (2016). Transport monitoring and control systems. *Proceedings of 2016 IEEE East-West Design and Test Symposium, EWDTS 2016*, 1–4. https://doi.org/10.1109/EWDTS.2016.7807662

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