The implementation of surveying data obtained by Remotely Piloted Aircraft Systems in traffic engineering

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The current master thesis aimed at developing a total package in which video images obtained through Remotely Piloted Aircraft Systems (RPAS) are used to analyze traffic flows. This is realised by means of object recognition and tracking software, including the use of mapping software to display the results. The research was conducted in collaboration with Orbit GeoSpatial Technologies and KeenVision Wireless Solutions .

Unmanned vehicles, their applications and the applicable legislation are assessed in a theoretical chapter based on internal company documents, international literature and oral sources. In addition, traditional traffic survey solutions are discussed and compared with the currently used research methods and recording techniques.

Subsequently, in a practical chapter, a survey to examine the interest in and the need for RPAS is described. Furthermore, a case study carried out based on both photographic and video images obtained by means of RPAS is illustrated. The traffic, as perceived in the video, was analyzed using object recognition and tracking software. The photographs were used to map the area by means of photogrammetric software.

The survey confirmed the growing interest in and the demand for the application of RPAS in traffic research. The case study was successfully completed by means of an RPAS md4-1000 from the German company Microdrones GmbH with Sony cameras, Orbit UAS Mapping software from Orbit GeoSpatial Technologies and object recognition software from KeenVision Wireless Solutions. The use of video images produced through by means of an RPAS proved to be a valid and efficient alternative for the visualization and analysis of dynamic traffic flows.

__Keywords__: **unmanned aerial systems, UAS, unmanned aerial vehicles, UAV, Remotely Piloted Aircraft, Systems, RPAS, drones, traffic engineering, traffic analysis, traffic research, traffic flows, traffic counts, mapping, photogrammetry, image recognition, recognition software**

I. INTRODUCTION

During the last couple of years, interest in civil applications of Remotely Piloted Aircraft Systems (RPAS) has increased, not in the least in the surveying industry. Moreover, mapping traffic flows using the traditional methods is expensive, time-consuming and laborious. The research at hand examines to what extent images from an RPAS can provide a valid and efficient alternative to the classic methods used in traffic analysis. The package includes an unmanned aircraft, mapping software and recognition software.

The theoretical part of this thesis includes a detailed theoretical study on RPAS, the applicable legislation and traffic research. The interest in and the necessity of the application are examined by means of a survey in the practical part of this research. Furthermore, a case study is performed in order to understand the capabilities and potential bottlenecks of the assembled package.

II. THEORETICAL PROGRAM

A. Remotely Piloted Aircraft Systems

Scientists believe RPAS hold many new opportunities and therefore conduct extensive research on the subject. Aircrafts come in all shapes and sizes, making them suitable for numerous projects in various sectors. They are used in the surveying industry for collecting aerial images by which surveying products, such as maps and elevation models, are generated. Consequently, they provide an alternative to, for instance, terrestrial topographical measurements and aerial photogrammetry from manned aircraft systems. In addition to surveying purposes, RPAS are also used for structural inspections, agriculture, traffic research, law enforcement, rescue, nature and environmental and cultural purposes. The aircrafts are able to fly close to specific objects, are suitable in hazardous areas and quickly gather aerial images of relatively large areas. Beside many advantages, several challenges in terms of safety, protection, privacy, reliability, civil rights and legislation are posed by the use of drones.

The term Unmanned Aerial System (UAS) is used as a collective name for all unmanned aircraft and related systems. Remotely controlled unmanned aircraft systems form the subgroup Remotely Piloted Aircraft Systems (RPAS). The systems differ, among other things, in terms of maximum flight time, control system, load capacity and shaping. Classification is possible in several ways: based on their autonomy, autonomous (fully pre-programmed), semi-autonomous (with the opportunity to intervene) and manual (fully controlled by a pilot) aircrafts can be distinguished. According to shape, unmanned aircrafts can be divided into fixed wings and rotary wings. The latter can hoover and therefore doesn't have to fly continuously forward. In addition, rotary wings can fly vertical and execute a vertical take-off and landing (VTOL).

Unmanned Aerial Vehicles (UAVs) are used in isolated, dangerous and inaccessible environments to collect cheap and detailed information on relative large areas. Safety risks are limited due to low speed, low altitude and the fact that no lives are at stake. Along with their low weather dependency and their great compatibility, this ensures high usability. However, the UAV's low energy leads to a small load capacity and a short flight time. The most important technological disadvantage is the lack of a reliable and cost-effective Detect and Avoid system (D&A), which is why worldwide research on the development of this system is conducted.

When RPAS demonstrate that they are more cost-effective than other solutions and better at performing specific tasks, and they prove to gain an Equivalent Level Of Safety (ELOS) as current aircraft systems, it is most likely that the civilian market will be bigger than the military market.

B. Legislation

The absence of clear and international, European and national harmonized legislation creates major problems, confusion and frustration. Many people find the regulations too restrictive, others call the current situation a threat to the growth and still others think no legislation concerning RPAS is enacted.

The development of legislation is a need for countries all over the world. However, this development remains primarily a national jurisdiction. At international and European level, working groups try to obtain a certain level of harmony in RPAS legislation. Therefore, partnerships are set up to create harmonized legislation where possible. This harmonized legislation is extremely important in order to provide certainty for researchers, operators and manufacturers, and should support the growth of this market and stimulate investments.

Unfortunately, within the current market, not all necessary technology is available to ensure a safe integration of RPAS in the airspace. The biggest challenge is replacing the human ability to see and to be seen. Most of all, it must be avoided that the economic and social benefits of Remotely Piloted Aircraft Systems are realised at the expense of general safety and efficiency.

At international level, civil aviation is regulated by the convention on International Civil Aviation (1944). To make an integration of RPAS in legislation possible, each annex of the Chicago Convention is reviewed to determine the impact on existing standards. The ultimate purpose is the development of international standards and recommendations. According to the International Civil Aviation Organisation (ICAO), the most important integration principle is the fact that the new regulations should fit into the current Air Traffic Management- (ATM-) system instead of adapting the current system to the use of RPAS.

Initiative is also taken by the European Aviation Safety Agency (EASA), the national Civil Aviation Authorities (CAAs), the European Organisation for Civil Aviation Equipment, EUROCONTROL, the European Defence Agency and the European Space Agency. Beside these organisations, the Joint Authorities for Rulemaking on Unmanned Systems Group (JARUS), the Single European Sky ATM Research project (SESAR) and the industry also make efforts.

According to the European Regular 216/2008, EASA is responsible for the development of regulations for RPAS with a *Maximum Take-Off Mass* (MTOM) bigger than 150 kg. RPAS with a lower MTOM are under the jurisdiction of the national CAAs. Because many aspects are not affected by the MTOM, it is generally recognized that this distinction by weight is not relevant for the regulation of this aviation component. Therefore, it is considered to abolish this distinction by 2016. When this happens, only regulations based on territorial issues will fall under national jurisdiction.

The European vision defines conditions for each certified RPAS to be operated. These conditions include a certified pilot and a licensed operator. Furthermore, the European Commission notes that RPAS operations should have an equal level of safety as manned aircraft operations. For the purpose of an initial integration of RPAS by 2016, the *European RPAS Steering Group* (ERSG) published a roadmap in 2013 about several issues to be handled and identified: legislation, research and social impact. This document suggests a phased introduction of the aircraft systems over fifteen years, based on five different classes and several levels of integration. The ultimate goal is to make legal flights of certified and approved RPAS possible across borders, in a non-separated airspace and above urban areas. This roadmap is not recognized, but yet supported by the European Commission.

Next to international and European efforts, national initiatives are undertaken as well. The *Belgian Civil Aviation Autority* (BCAA), known as 'Directoraat-Generaal Luchtvaart (DGLV)', had cooperated with Belgocontrol, Defense and the professional association *Belgian Unmanned Aircraft System Association* (BeUAS) to develop a Royal Decree concerning RPAS. The objective is to enact a practical, comprehensive and clear legislation for the application of UAVs. This framework should include both aviation safety rules and safety requirements. Furthermore, legislation should foresee conditions concerning the aircraft system, the pilot, the procedures and the radiofrequencies.

The first Royal Decree on RPAS legislation will only permit flights within Visual Line-Of-Sight (VLOS) with a maximum height of 200 feet (60 m). At European level, however, a maximum height of 500 feet (150 m) is maintained. According to the sector, this restriction will lead to undesirable delays. Moreover, an RPAS at an altitude of less than 200 feet is more affected by ground turbulence than above this altitude. It is clear that this reduction is not a positive given for economical and safety reasons. The first phase of the legislation does not authorize flights in controlled airspace, although exceptions remain possible. After obtaining a licence for a particular application, a report obligation will be sufficient when conducting flights. The publication of this first part of the legislation in the Belgian Bulletin is foreseen by the summer of 2014.

In anticipation of European and national legislation, exceptions are made for registration of the aircraft systems. Because Belgian government does not want to stop the development of unmanned aerial vehicles, permissions are given for research and testing flights, demonstrations and trainings. These permissions are restricted in time and are granted on a case-by-case basis. The biggest problem is the total prohibition for commercial flights. The new legislation should offer an answer to these problems.

Countries all over the world develop rules for the integration of RPAS in their airspace. Almost all countries share the same opinion about RPAS applications. Nevertheless, the current procedures and classifications differ for each country.

C. Traffic research

Traffic is of high importance to society and the economy. Therefore, it needs to be monitored at all times so that its evolution can be guided. The information needed is gathered by means of traffic research. Traditional traffic registration techniques are human observation, inductive loops, pneumatic road tubes, radars and cameras. The techniques are applied in research methods at sections of roadways, intersections and roundabouts, licence plate research and measurement of speed, lengths of queues, waiting times and travel times.

Traditional registration techniques both have advantages as well as disadvantages, depending on the situation. Human observation for example is clear and easy to use, but a large quantity of observers is needed at complex traffic points, which implies more labour and higher costs. Inductive loops and pneumatic road tubes are mechanical research systems which possess the ability to register information in a continuous manner, but these can only be used for single section counts. Radars and cameras, used for optical registration techniques are often mounted on stable poles or present constructions. Radars are solely used for single section counts and speed measurements. Cameras, on the other hand, can be used for a large variety of applications, depending on the position of the camera. Examples of such are licence plate registration and full intersection or roundabout research. This usually implies a higher cost. The use of object recognition software lowers the amount of labour in processing the gathered video images.

The disadvantages connected to traditional registration techniques induce demand for optimisation from the relevant sector. Furthermore, the development of technologies opens new perspectives on the implementation of traffic research. The use of RPAS can offer a valid and efficient alternative.

III. PRACTICAL PROGRAM

A. Interest and necessity

Interest in and need for development and use of RPAS in the civil sector was investigated by means of a survey of people, companies and agencies who were related to traffic research, such as governments, traffic researchers, police and surveyors.

The overall objective of the survey was to acquire insight in the interest in and the need for development and use of RPAS in the civil sector. This objective was pursued by acquiring insights in the knowledge and experience of the respondents with RPAS, the sector's opinion concerning the development, the use of and the impact from the aircraft systems, the current traffic issues and traditional traffic research methods, and the interest in the use of RPAS, more specifically for traffic research.

The response percentage was 7.5%. 181 respondents answered the survey, which was enough for a confidence level of 80.0%. The results of the survey were considered to be an indication for the opinion of the surveyed group.

The results show that the majority of the respondents had some knowledge about RPAS, but only a small minority was well familiar with the matter. It was notable that respondents with knowledge about RPAS assigned more possible applications to the systems than others. The respondents expected the systems to be applied for military and safety applications and photogrammetry. Those who had experience with the use of RPAS for the gathering of information used the systems mainly for photogrammetry and mapping purposes.

The majority of the respondents considered the development of RPAS as a positive evolution and the systems are expected to play an important role in future land surveying. Furthermore, it was expected that several activities could be executed more efficiently using RPAS, that not all possibilities were being used and that the use of the systems could be cost-effective in specific cases. A large majority agreed that clear legislation is needed considering RPAS, that only trained pilots should be using the systems in public areas and that the development of RPAS implies risks to the privacy law.

The most used traffic registration methods were manual counts, counts using cameras, inductive loops, processing video images and pressure sensors according to respondents active in terms of traffic research. The biggest difficulties with these methods were the amount of labour, the employability, costs, accuracy and efficiency.

According to the respondents, the use of RPAS could offer most value in safety applications, photogrammetry and military applications. In this regard, it is notable that respondents with knowledge about RPAS saw more value in the use of the systems for photogrammetry, while the others saw more value in the use of the systems for military purposes.

The majority of the respondents who were active in terms of traffic research agreed that the use of RPAS could be of value for traffic research purposes. These respondents expected that the systems could be applied best for mapping dynamic traffic streams.

B. Case study

The application of RPAS for traffic research was already explored by several universities and other research facilities. However, a total package for the gathering of aerial images and processing those images with software is not yet available. In the case study, the following combination was tested: a Microdrones GmbH RPAS md4-1000 with Sony cameras, Orbit UAS mapping software (Orbit GeoSpatial Technologies) and object recognition software (KeenVision Wireless Solutions). During the flight of the md4-1000, both photographic and video images were gathered and post processed with object recognition software. The traffic research was performed on the video images.The mapping of the photographed area was fulfilled by means of photogrammetric mapping software. A Sony Camcorder was used to gather the video images. The photographs were taken with a Sony NEX-7, equipped with a fixed-focus 24mm lens. The necessary ground control points were materialized using cardboard tags and nails, measured with a Trimble R8 GNSS. With the use of mapping software, the following products were generated: a digital elevation model, an orthophoto, a dense point cloud and a stereographic image by means of anaglyphs. The comparison of different mapping campaigns showed that the results were independant of the flight direction and the number of ground control points.

The processed video images provided an insight into the feasibility of the different possibilities of object recognition software. Counting and tracing the vehicles on the roundabout proceeded without any problems. By adjusting the existing algorithms, it will be possible to perform traffic research using video images gathered with an RPAS. It appears that classification of traffic will probably be implemented best, based on pixel size of the object in the video.

In comparison with traditional methods, such as license-plate research by means of observers or cameras, the use of video images gathered by RPAS reduces the risk for humans, materials and vandalism. Furthermore, RPAS can be implied in risky and inaccessible areas. The use of unmanned aircraft systems implies lower costs concerning labour and consumption. However, the data acquisition cost is high and a well trained pilot is necessary. The aircraft always needs to be in sight of the pilots and a take-off and landing place is required. Yet, the use of a helicopter-type aircraft limits the needed space.

When using a camera in combination with an RPAS, it is possible to obtain a top view of an area. The images produced can be used for traffic counting and the analysis of road usage. Furthermore, the aircraft can be used for multiple missions, such as mapping the area or gathering information using specific sensors. The combination of mapping and traffic analysis of an aerial view offers more information than manual traffic counts or traffic analysis on images taken form fixed cameras. Using intelligent software can drastically reduce labour costs. The obtained traffic information can be visualized on top of geographic and thematic layers, which results in valuable information for policy makers and safety services. The subsequent geographical traffic information can be used to support policies and investigate problematic situations.

V. CONCLUSION

RPAS can be used in a large range of applications, yet this needs to be accompanied by a clear and harmonized integration of unmanned aerial vehicles in the existing legislation. High demand for traffic research, possible optimization of current research methods and registration techniques, and the advantages of RPAS indicate the possibility that these aircrafts can be used for traffic research.

Analysing video images obtained by RPAS with object recognition software is possible by adjusting existing algorithms. The visualization of the traffic counting results on a geographic underlay offers valuable information to governments.

This research shows that the combination of photographic and video images obtained by RPAS, object recognition and mapping software can offer a valid and efficient alternative for expensive, traditional traffic research methods for the evaluation and analysis of dynamic traffic flows.

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