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Combined Use of Aerial Remote Sensing and Terrestrial Survey in ICAO eTOD's Electronic Terrain- and Obstacle Data Collection

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Abstract

Maintaining and enhancing aviation safety at all times is an essential factor at various airports around the world. It is not enough to keep it at that level, as we also see from history that the volume of air traffic doubles almost every 15 years. The number of aircraft in traffic is constantly increasing, and airport infrastructure needs to be developed. Consequently, the challenges for aviation are also greater. Electronic Terrain- and Obstacle Data Collection (eTOD) at airports and their surroundings are an essential procedure for aviation safety that aims to organize databases of potentially dangerous flight obstacles. The process is based on passive optical aerial remote sensing from a fixed-wing aircraft. With the help of point cloud and geoinformatics software created during the processing of in-flight recordings and additional data, strictly defined terrain- and obstacle data can be organized into databases, the format of which is regulated by international standards and documents, according to which the obstacle database can be used internationally. These data sets are needed not only because they are required by law, but also because they form the basis for the design of various aircraft procedures and make a major contribution to safe aviation.

Keywords

eTOD, obstacle, photogrammetry, airport, ICAO, AIP, OLS

1 Introduction

All airports in ICAO (International Civil Aviation Organization) member states have to comply with a large number of regulations. It means, for example, the existence of physical equipment, the quality and painting of taxiways and runways and, last but not least, the handling of obstacles in and around the airport (ICAO, 2010; ICAO, 2018a; ICAO, 2018b; ICAO, 2018c). Obstacles can be trees, buildings, chimneys, antennas, terrain or even moving objects such as a railway train passing by (ICAO, 2002; ICAO, 2003; ICAO, 2004).

In the present research, the databases resulting from the survey of Szeged Airport provide a research topic. During the work, we have collected flight obstacles within a 10 km radius of the Airport Reference Point (ARP). The parallel application of the generated point cloud and field geodesy in the area resulted in a database of about 230 obstacles, which provided orders of magnitude more accurate data to the Aeronautical Information Services compared to the previous databases. We were able to collect a number of obstacles that would not have been possible with terrestrial survey alone. In such an area, there are a large number of obscured obstacles that are not visible from the ground. The optimal solution is the combined use of aerial remote sensing and terrestrial geodetic surveys.

2 Methodology

The field of research was the above mentioned Szeged Airport. The airport is located in the western part of the city (ARP WGS 84 coordinate: 461503N 0200521E). The point cloud was formed in an area with a radius of 10 km from the ARP point.

Integrity, accuracy, and resolution requirements had to be met during the collection process as shown in Table 1 (EUROCONTROL, 2015). The area can be divided into several smaller components where the numerical requirements differ. This is highly dependent on their position

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Table 1 Numerical requirements for terrain obstacle data in each area (ICAO©, 2018c)

Post spacing	Area 1 3 arc seconds (approx. 90 m)	Area 2 1 arc second (approx. 30 m)	Area 3 0.6 arc seconds (approx. 20 m)	Area 4 0.3 arc seconds (approx. 9 m)
Vertical accuracy	30 m	3 m	0.5 m	1 m
Vertical resolution	1 m	0.1 m	0.01 m	0.1 m
Horizontal accuracy	50 m	5 m	0.5 m	2.5 m
Confidence level	90%	90%	90%	90%
Integrity classification	Routine	Essential	Essential	Essential
Maintenance period	As required	As required	As required	As required

relative to the runway at the airport. Areas in the direction of the approach, i.e. the extension of the runway centreline, require much stricter regulations (Fig. 1). The "areas" perpendicular to the center line of the runway, hence located laterally, allow for much more lenient collection. Towards this approach, the criteria are orders of magnitude stricter, as aircraft fly over these areas on a regular basis. A beneficial factor is that the terrain around the airport does not rise adversely. The collection and Obstacle Limitation Surfaces of the designated obstacles above the areas do not follow the level of the terrain, so much more obstacles can be added to a database when there is strong elevation as presented in Fig. 2. Previous research has shown that it is no more significant at larger airports that in case the topography only rises a few tens of meters per kilometer, there are much more obstacles. Individual surfaces - airport specific - can extend up to more than 10 kilometers and most of them continue to rise as the distance increases.

Today, with the development of technology, methods based on experiential cognition, such as using of digital sensors, have become available. They – i.e. the sensors

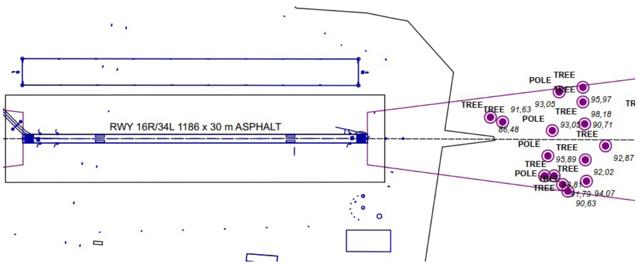

Fig. 1 Aerodrome Obstacle Chart (AOC) detail with obstacles around the runway

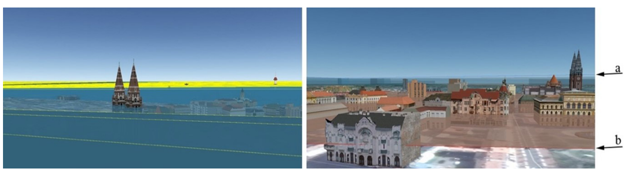

Fig. 2 Clearly visible that some obstacles exceeds the edited surfaces (Bakó et al.©, 2020)

– also became smaller, cheaper and more accurate over time (Zöldy and Baranyi, 2021). For aerial data collection, we used a fixed-wing aircraft to which the Interspect IS 5 high-resolution camera system was connected. The images and the point cloud were taken in the summer of 2017, when the level of irradiation was sufficient to apply high-speed aerial photogrammetry, as airport traffic could not be obstructed for days and more than forty flight lines were required to produce high-detail material. Through continuous airport and AFIS (Aerodrome Flight Information Service) consultations, we were able to fly over an area of just over 300 square kilometers in two days. The area with a radius of 10 km is actually an elongated circle shape. This is explained by the fact that the 10 km radius in practice does not start from the ARP point, but from the ends of the rectangular area around the runway, called Area 2a zone. The zones were flown by a professional pilot who had extensive experience in precision aerial photogrammetric flights. Photogrammetric processing of the images was performed with Agisoft Metashape and Global Mapper software. The software also used geodetic GNSS landmarks as well as GPS data.

In the vicinity of the airport, we edited more than 20 surfaces in GIS (Geographical Information System) software over more than 20 areas (Fig. 3). The result is 30 databases that contain the terrain- and obstacle data themselves, as well as their metadata (Fig. 4). The latter are needed due to the fact that Aeronautical Information Services and pilots need to get an accurate picture of the objects. One of the most important data is the coordinate pair, the definition of which is aided by rules and guidelines, as the main points of specially shaped objects, which are usually mapped from many points, are legally defined. Data were collected in an EOV projection system, but had to be transformed into a WGS-84 reference coordinate system according to ICAO regulations (ICAO, 2002). In addition, the type of obstacles had to be specified, which requires further detailed evaluation and, in many cases, terrestrial

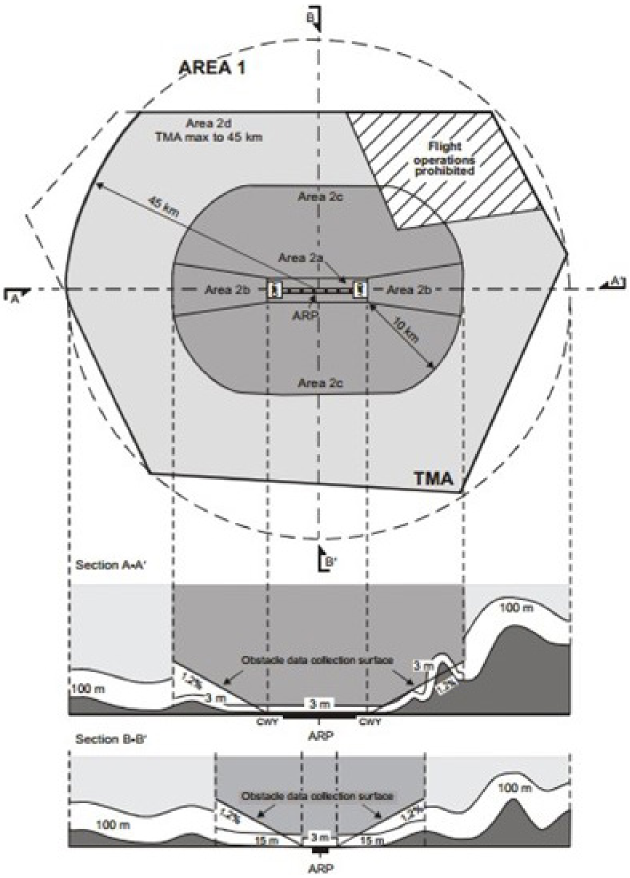

Fig. 3 Some obstacles clearly exceed the 10 and 45 km radius area (ICAO©, 2018c)

WGS-84 EAD format, longitude	WGS-84 EAD format, latitude	NAME / ID	Type
0200526.1879E	461519.4540N	LHUD_AREA2B_S_101_001	BUILDING

Defined area: Area 2b
Data source identifier: Remote Sensing – Terrestrial Survey

Group of obstacles	Lighted	Type and colour of lighting	Visual marking	Elevation (at top)	Elevation accuracy
N	N	NA/NA	NA	89.45	0.5

Height	x_EOV	y_EOV	x_WGS-84	y_WGS-84	x_WGS-84, Deg-Min-Sec	y_WGS-84, Deg-Min-Sec
8.46	730434.222	101743.569	20.0906077434388	46.2554038967594	020°05'26.1879"	46°15'19.4540"

Roof height	Building peak	Obstacle type-2
85.90	89.45	THUNDER ROD

Fig. 4 Obstacle metadata in the Terrain- and Obstacle Data identification report (figures are in meters)

surveys. We have indicated these using well-understood English words, that are also used in the official language of aviation. Such were BUILDING, TREE, or CHIMNEY without claiming completeness. This is the first piece of metadata that can be used to create an approximate image of an object. Basic data include heights: the height of a peak relative to mean sea level, the height of a structure relative to the base point on the ground, the height of prominent objects. The height of a chimney must be determined, however the height of the antenna on it must also be indicated separately (EUROCONTROL, 2015). There were many complex obstacles, the extent of which was significant in the lateral direction. In this case, it is not possible to define the object with a single coordinate and height data, but the height of the corners of the building and, if any, the height of the antenna must also be provided, as shown in Fig. 5.

It is very important whether the object is marked with visual markings such as painting or obstacle lighting. That being the case, it was necessary to use night vision examinations as well. In addition, resolution, accuracy, integrity and confidence level data were included. During the research and work, the data of the objects exceeding the defined surfaces had to be provided to the Aeronautical Information Services. Another very essential fact is that in the smaller area with a radius of 10 km it was not enough to survey an airport, but the city of Szeged has also to be included in the survey (Fig. 6). Szeged, with its almost entire area, belonged to the zone where we had to collect point cloud and then filter it professionally. Filtering resulted in points remaining above the surfaces, so we were able to work with them and evaluate terrain and obstacle objects. Here, we worked with appropriate tolerances

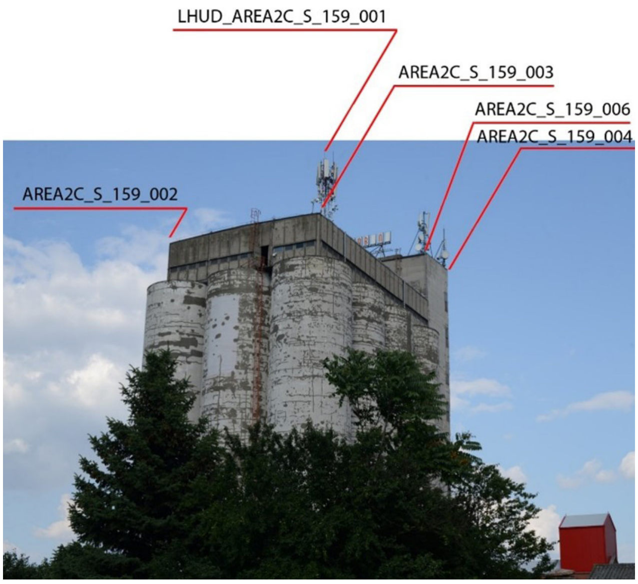

Fig. 5 Measurement locations for complex obstacle height points

Fig. 6 Point cloud urban detail – illustration

to avoid missing a pole or antenna due to the thinning of the object over the uppermost object points under the surface.

3 Results

The previous obstacle databases at the airport were retrieved for comparison. We have seen that the use of terrestrial survey alone does not guarantee the safe collection of obstacles. The work, which lasted more than four months, had resulted in hundreds of additional terrain- and obstacle objects being added to the database.

Managing these is a very responsible job, since these databases form the basis of the designed flight procedures. Compliance with accuracy, resolution, and other numerical requirements was also achieved with this technology.

Using 40% side overlap and 70–90% forward overlap and spatial resolution of 3, 5, 7.5, 10 cm, the applied technology was tested in a sample area of 0.5 km^2 and 0.4 km^2. The fixed-wing aircraft collected data in the speed range of 230–350 km/h and altitude range of 650–890 meters. The combined use of aerial photogrammetry and terrestrial survey is considered to be the most reliable method, in addition to the fact that at present the use of this technology can be considered economical in such areas.

4 Conclusions

Using a 10 cm GSD (Ground Sampling Distance) with a fixed-wing aircraft, we are now able to survey nearly 350 square kilometers in one day. With more powerful aircraft, this can rise to over 1,000 square kilometers (Bakó et al., 2014).

During the work, it was revealed that it is especially dangerous to perform electronic terrain- and obstacle data collection only with terrestrial survey, as we have also found that a large amount of additional obstacles are formed by using aerial remote sensing. This is due to the need for a high altitude view when surveying areas of this size and complexity, highlighting the fact that it is a matter of flight safety. Every single uncollected object poses a potential threat to aircraft.

In addition to the development of the aviation sector, the enhancement of aviation safety and sustainable mobility is a very important factor (Zoldy et al., 2022). Today's most economical aerial remote sensing method is flying of fixed-wing aircraft with piston engine, since over areas of this size, this solution makes it possible to efficiently collect data, taking into account regulations, traffic and other factors in the airport area. The aeronautical data collection technology of the future will be served by drones. Their use is already strongly perceived in aviation.

The article topics clarify that aerial remote sensing, terrestrial survey, sustainability co-application and integration in work required in the aerospace industry such as eTOD is the challenge of the future, the implementation of which has already begun.

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