USAGE OF INNOVATIVE AERIAL SENSORS FOR CONSERVATION PURPOSES

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Abstract: *Aerial sensors provide a unique view to the object from the top. Traditional aerial sensors look vertically down to the roofs of the objects and provide a good overview. The presented innovative aerial sensors also provide a view from the top, rather oblique, showing not only the roofs but also facades, basement doors, balcony floors and other elements which are neither visible from vertical aerial images nor from street level. The* ***Aerial Oblique System AOS*** *is a set of three medium format cameras assembled to a system continuously covering a wide opening angle in a rotating sensor head, mounted in a stabilized mount and equipped with a high precision DGPS/IMU system. The system is designed to cover systematically cities or expanse sites, linear structures or singular objects with a ground resolution of up to 5 cm from fixed wing aircraft. The whole system is designed as modular system fitting in the technical environment of standard photogrammetric flight procedures and also fits into the photogrammetric processing chain. The other presented system is the* ***scan2map****. This is a hand held sensor package consisting of a medium format digital camera, a laser scanner and DGPS/INS-system. The system is operated out of the open door of a helicopter. It is designed to acquire sensor data (geo referenced images and laser point clouds) on short notice with limited resources of sites with a size of up to ten square km. It is dedicated to be used on archeological sites, inaccessible sites and to evaluate and analyze technical or natural disasters.*

1. AERIAL SENSORS FOR CONSERVATION PURPOSES

Compared to terrestrial methods for conservation purposes [1] aerial systems cover larger areas in a short period of time and are better suited for whole sites. They don’t deliver the same amount of details but a good overview and allow the analysis of the whole site, the structural dependencies and can form the data base of a GIS system [2].

1.1 Established Aerial Sensors

Actual and established aerial sensors are vertical looking, large scale aerial cameras to cover the landscape with ground resolutions between 2 cm and 50 cm. The aircraft with the sensor covers the Area of Interest (AOI) by meander flying over the object with an overlap between 60% and 80% along track, and 20% to 80% cross track. This overlap guarantees the opportunity to stereo map the displayed object features in a high geometric quality and to generate Digital Terrain Models (DTM), Digital Surface Models (DSM) and Digital Orthophotos (DOP).

The other established aerial sensor system is the Airborne Laser Terrain Mapper (ALTM) – an active system emitting a laser beam and measuring the time necessary to return from the terrain surface to the system. In combination with high quality Differential GPS (DGPS) and Inertial Measuring Units (IMU) this system provide geo-referenced point clouds with a density of 1 point/m^2 up to 25 points / m^2.

Though both systems are designed to cover medium to large areas (from a few km^2 to complete federal states). They can be used to provide overview over complete conservation relevant sites and their environment. They are optimized to form the data base of any Geographic Information System (GIS) or 3D city model.

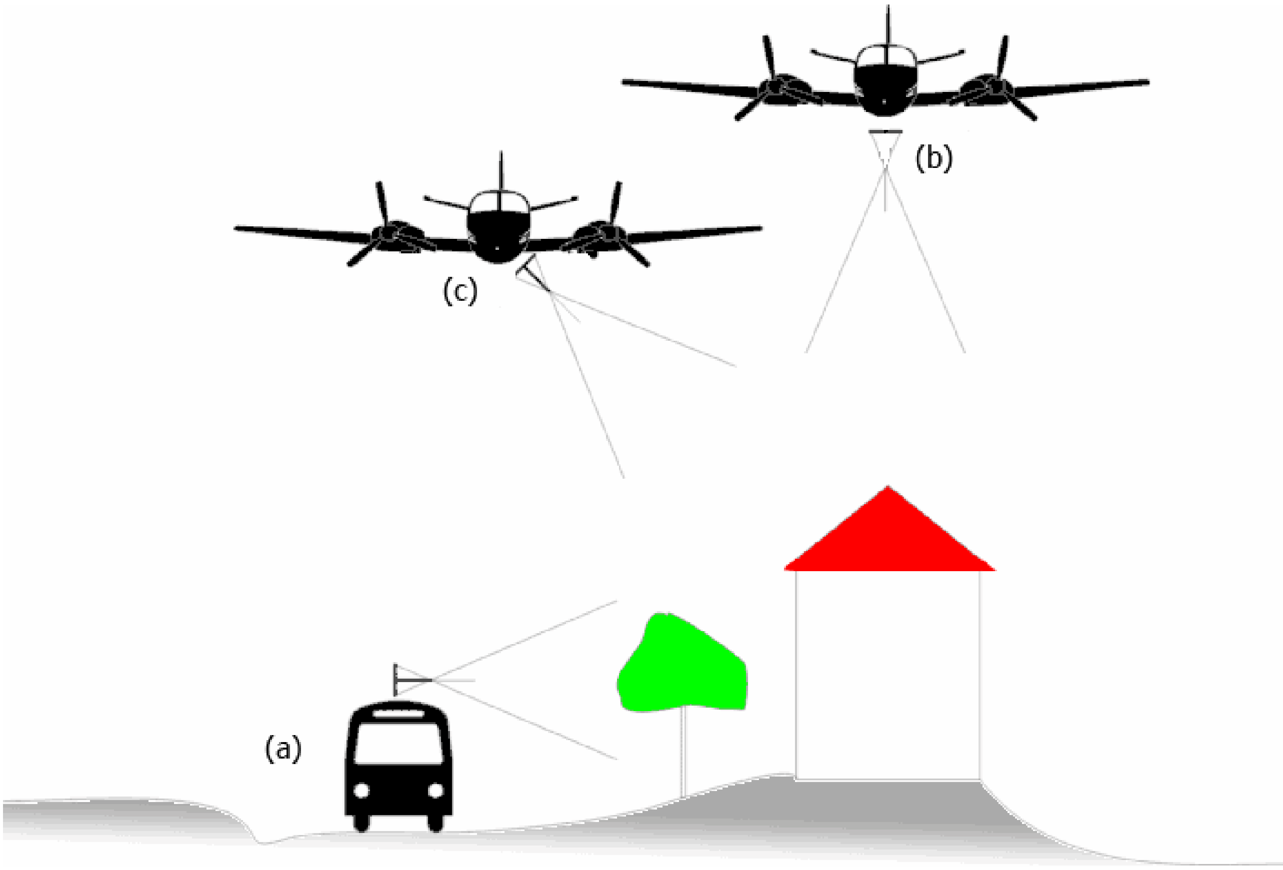

Figure 1: Coverage of terrestrial systems (a), vertical aerial systems (b) and oblique systems (c)

1.2 Innovative Aerial Sensors

To fill the gap between terrestrial applications and traditional airborne, vertical looking sensors BSF Swissphoto has developed in cooperation with partners two new airborne sensor packages: The **Aerial Oblique System (AOS)** consisting of three cameras covering objects from all sides, and the combined, hand-held camera-laser-scanner-combi pack *scan2map* to be used out of a helicopters door.

The AOS is designed to cover complete sites systematically in such a manner, that each object is displayed from at least four oblique points-of-view. The used cameras are three well calibrated Rollei/Trimble AIC cameras with 39 MPixel. The system is based in a gyro-stabilized mount and is combined with a high quality DGPS/INS-System. This allows precise aero triangulation and the direct usage of the oriented images for texturing of 3D city models, multi image and stereo 3D restitution in high precision. Based on these oriented image data the user can browse through the whole site without the artifacts resulting from incomplete and insufficient object modeling, he can measure in the data and compare multi-temporal data sets.

The AOS is designed for systematic and well prepared economic flights over dedicated and mid size areas; the other innovative system is designed also for highly flexible ad hoc missions, e.g. in the case of disaster management. The **scan2map** system acquires high resolution image data with directly acquired exterior orientation data combined with a set of high density laser scanner data in high precision in a short time. The scan2map system consists of a digital mid-format camera (Hasselblad H2 wit Imacon backplane 22 MPixel and 35 mm lens), a Riegl LMS-Q240 laser scanner and integrated DGPS/INS package. The system is usually used in horizontal, vertical or oblique direction held in the hand of an operator out of the door of a helicopter. This allows to scan and to photograph simultaneously buildings, architectural or archeological sites or endangered objects on short notice in a systematic manner. The delivered data cover the selected region in a short period of time, without endangering the crew and allow a detailed analysis of the object in the lab.

Figure 2: AOS in an fixed wing aircraft (Cessna 206) in a gyro stabilized mount over a standard camera bay (left), scan2map operated out of a helicopter door (right)

2. AERIAL OBLIQUE SYSTEM (AOS)

2.1 System Description

The AOS system is used in a process consisting of flight planning, flight conduction, post processing and image orientation. The following processes depend on the requested data usage.

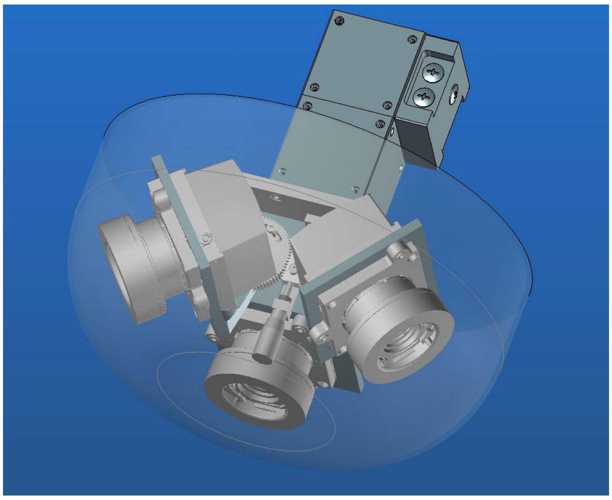

Figure 3: AOS Sensor Head Sheme

Due to the rotating sensor head (shown in figure 3), the flight planning is a challenge. Especially in hilly ground the planning of flight patches is complex. Therefore the design of the flights is done in a manner guaranteeing at least one view on each object from each direction and two from the top, but this leads usually to much more real view points, showing the object in different resolutions and aspects. Due to the wide opening angle of 114° the ground resolution is different – degrading from the nadir point below the sensor to the outer edge of the image triple. Due to the request to save the 117 MPixel in real time the image sequence is limited to 3 s. With a realistic airspeed of a fixed wing aircraft of 120 kts (220 km/h, 60 m/s) and a requested overlap of 20% of along track for each second image we get a optimized ground sampling distance in nadir point of about 8-10 cm.

Table 1: System parameters AOS

Digital Camera (Rollei AIC + Phase One P45)	**39 MPixel**
Focal length	47 mm
CCD Size	7228 × 5428 pixel @ 6.8 µm
Field of view	41° ×55°
Radiometric resolution	16 bit
GPS (Novatel OEM4)	
Measuremenrt rate	1 Hz
Frequencys	L1/L2
IMU (IGI Aerocontrol IId)	
IMU accuracy (roll / pitch / yaw)	0.004° / 0.004 ° / 0.010°
IMU sampling rate	64 Hz / 128 Hz

After the flight the images have to be developed from RAW to TIF with the opportunity for radiometric improvement according to the designated usage of the images. For some tasks it might be recommended to stitch the three images of a dedicated expose together (see figure 4), but in general we handle the images separate to avoid loss of quality during this process. Though the system has in integrated DGPS/IMU it is recommended to perform an aerotriangulation (AT) after the flight, to improve the geometric accuracy [3]. During this process we achieve in general an accuracy of better than 50 cm at the outer edges of the images of a flight with 10 cm GSD in the Nadir point, but there is still room for improvement.

Figure 4: Rectified image butterfly from three stitched images of a single expose

2.2 Application Examples in Conservation

First of all the AOS provides a new view to objects from several points of view. The observer can see a lot of details, as can be seen on figure 5, which does not show the full resolution but gives a good impression of achievable details..

Figure 5: Detail of an oblique AOS image

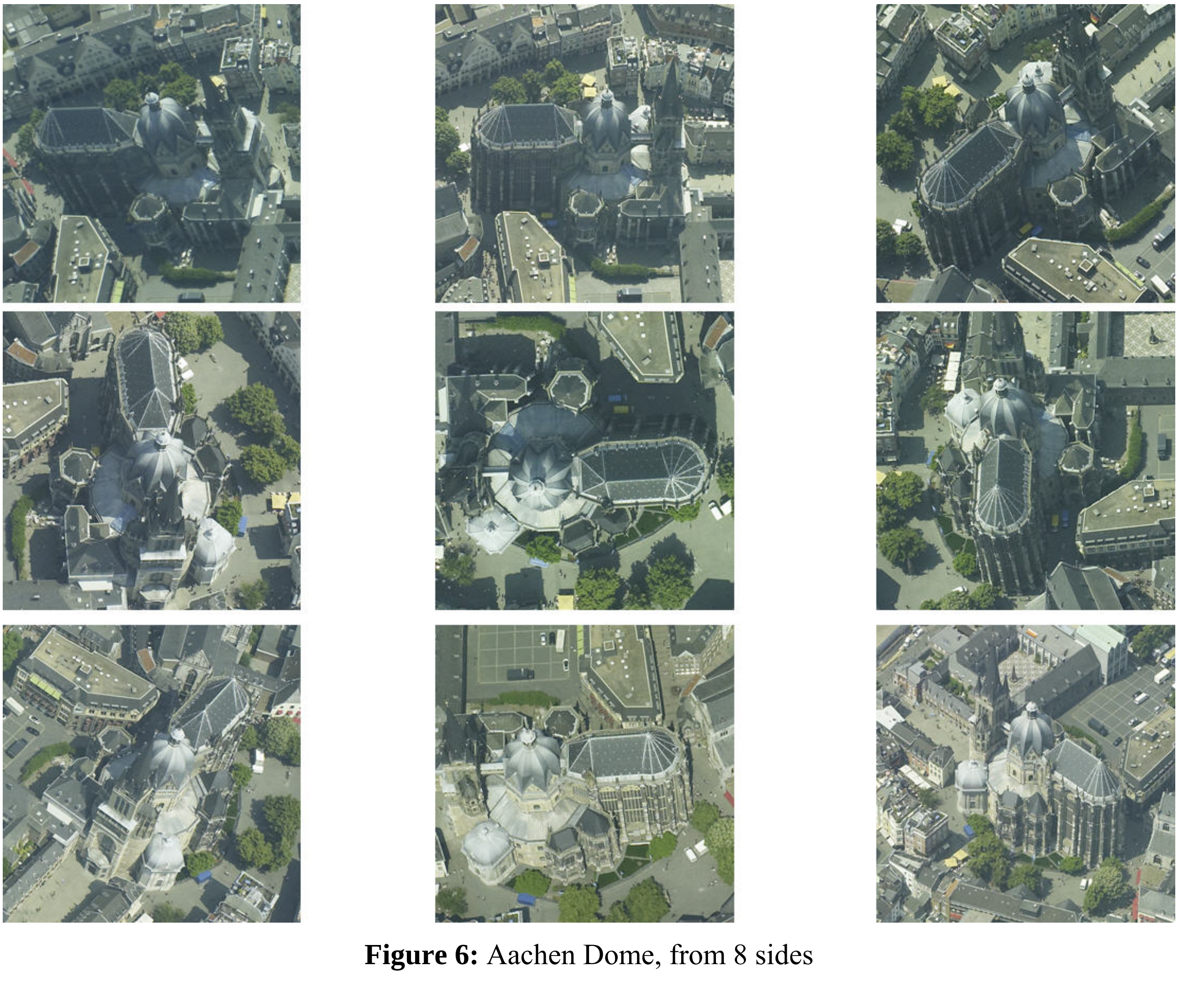

Figure 6: Aachen Dome, from 8 sides

The multiple views to objects from several points of view are systematically distributed. In Figure 6 you see 9 views from different points-of-view of the Dome of Aachen, flown with AOS twice, with lines intersecting with 45°.

Beside just images to view there is a wide variety of possible applications of the oblique images: from stereo or multi image mapping of roofs and facades, generation of Digital Terrain Models or Digital Surface Models to texture mapping of 3D city models (Figure 7).

Figure 7: Textures LoD2 3D city model

3. SCAN2MAP

3.1 System Description

The system scan2map delivers geo referenced images and laser scanner data on short notice after the flight request. Installation of the system in a helicopter takes only 30 min, a detailed flight plan is not necessary due to low flight levels. The components of the system are showed in figure 8 and the technical details in table 2. The system is well suited for up to 10 km^2, depending on requested ground sampling distance and point density [4].

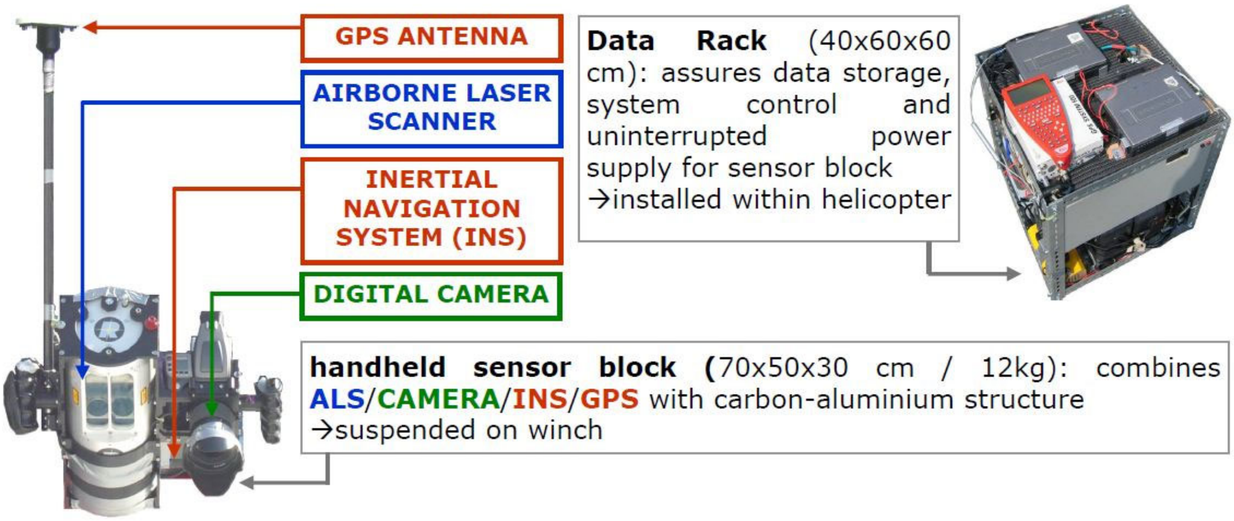

Figure 8: Components of scan2map system

Some of the advantages of the system are:

- No recalibration needed: all sensors are tightly fixed in one sensor block calibration values are installation independent

- Oblique and nadir surveying can be performed with little change in configuration possible tomap vertical rock faces with high accuracy
- Non-intrusive mapping method due to direct georeferencing: no ground control needed in the survey area

Table 2: System parameters scan2map

Digital Camera (Hasselblad H2 + Imacon Backplane)	
Focal length	35mm
CCD Size	4100 x 5400 pixel @ 9 µm
Field of view	56°
Radiometric resolution	16 bit
Filters	RGB and CIR
Ranging Unit (Riegl LMS-Q240)	
Maximum range	600 m
Minimum range	2 m
Range resolution	5 mm
Target detection modes	first or last return or alternating
Laser wave length	905 nm
Maximum Pulse repetition Frequency	(PRF) 10 KHz
Beam divergence	3 mrad
Scanner	cylindrical polygon mirror
Number of facets	4
Scan pattern	parallel scan lines
Scan angle	± 30° (60° total)
Angular resolution	0.005°
Scan frequency	6 - 80 scans/s
Scanner duty factor	33 %
Max. effective measurement rate	80 Hz
Swath width	1.15 x altitude
GPS (JAVAD Lexon-GGD)	
Measuremenrt rate	10 Hz
Frequencys	L1/L2
IMU (Litton LN-200)	
IMU accuracy (roll / pitch / yaw)	0.01° / 0.01 ° / 0.02°
IMU sampling rate	400 Hz

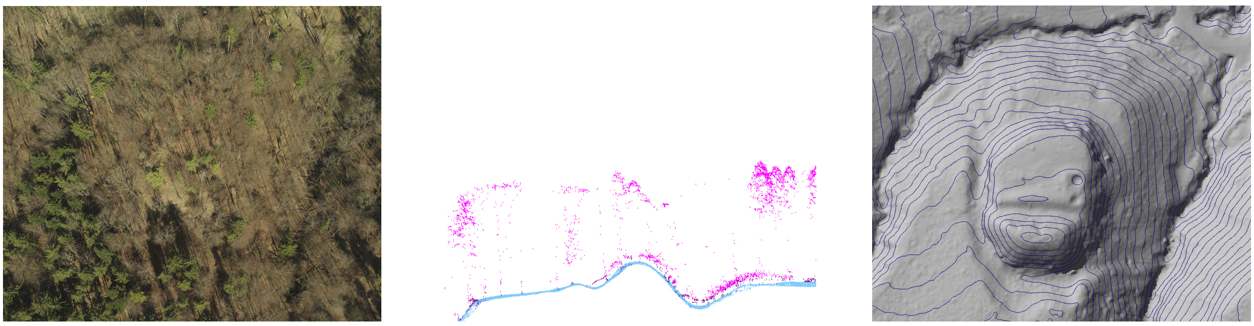

Figure 9: Detection of fortress traces in forest areas by scan2map (aerial image, profile in laser scanner point cloud and Digital Surface Model (DSM) with contour lines

3.2 Application Examples in Conservation

In conservation and archaeology the system can be used to map sites. The point clouds cover roofs, facades and ground, the sensors also penetrates vegetation and delivers points e.g. on the forest surface. It was used by the Kanton Zürich to detect the hidden traces of ancient fortresses in the dense forested areas by generating a dense Digital Terrain Model (DTM) derived from the last pulse signal of the laser scanner system.

An other data example shows an endangered building on a rock slide site. On short notice the slide area was analyzed to determine the mass of endangered soil and the location and size of endangered areas [5].

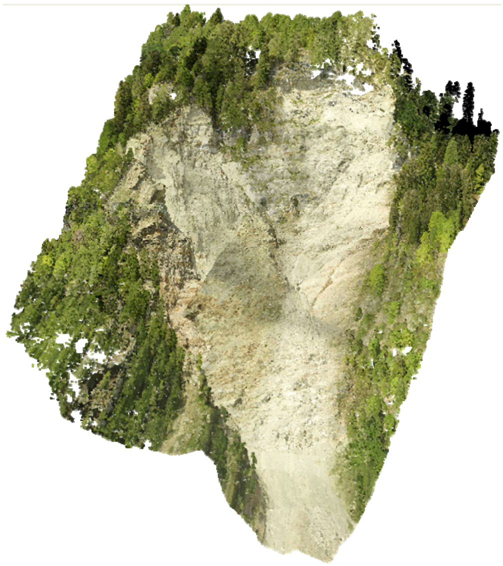

Figure 10: Endangered building a rock fall site and textured 3D view of a Dgital Surface Model (DSM)

4. CONCLUSIONS

Compared to terrestrial data acquisition technologies the data rate of both systems is much higher and not limited to access from street side. Both systems are not designed to replace terrestrial or vertical aerial data acquisition technologies but to complement these technologies. Moreover scan2map offers an economic technology for areas from 1 ha to 10 km^2 that could not be covered with terrestrial nor vertical sensors in the same cost effort ratio. Both systems are operational, but data fusion and integration with other technologies is here the main challenge.

5. ACKNOWLEDEMENTS

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