LOW COST AERIAL IMAGES FOR HERITAGE 3D RENDERING

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ABSTRACT:

This paper reports the fundamentals, activity and results achieved by IMAP3D, and acronym for "Imágenes Aéreas para la Modelización 3D del Patrimonio" (Aerial Images for Heritage 3D Rendering). We are a group of teachers from the Universities of Salamanca, Valladolid, León and Santiago concerned on improving the protection of the Cultural Heritage of our community through accessible and reliable cartographic production.

Our work aims at taking advantage of the technological and educational possibilities available from the digital era in order to engage the society within protecting, recovering and enjoying the Cultural Heritage. Specifically, we intend to overcome the lack of a methodology to obtain rather easily aerial photogrammetric images, captured from a captive balloon, a microlight aircraft or a kite - both stereoscopic and oblique - which are important in order to improve the surveying of buildings and essential to render archaeological sites.

MOTIVATION AND BACKGROUND

We are working in a rising Knowledge (or Learning) Society in which Cartography leads to Geomatics, in which Analogic Photogrammetry has become Digital Photogrammetry and in which the motto "Photogrammetry for / by all" is increasingly meaningful.

Our work is supported by the following key features of this new paradigm:

1. Knowledge Society is qualitative beyond Information Society because it is quantitative less (lighter) than this. The new society relies on the ability to select available information, analyze it and generate knowledge under well defined and appropriate targets.

2. New information and communication technologies play an essential role in this situation by erasing borders among countries and among economic, social and cultural institutions. We live the "access era".

3. Knowledge moves from specialization to integration and multidisciplinarity.

4. Knowledge is linked to permanent change, to continuous updating and so, citizens become long life learners.

5. The Learning Society main professional profile is "monitoring and assessing own learning of knowledge and own acquisition of abilities".

6. Cartographic releases become digital (softcopies are an abstract model), and this empowers its distribution and use.

7. Cartographic generation becomes digital (software is an abstract tool), and this empowers cartographers both performance and creativity.

8. Cartography becomes a GIS, a geographical information system; a complex, versatile and coherent structure in which feedback (quality control) provides the essential data flow.

9. Some new cartographic relevant parameters appear: 3D visualization, reality vs virtuality, multimedia, linking, … Quality control must, therefore, spread its frame to cover these new issues.

ISBN:0-958-46093-0 Produced by Global Congresos

10. Cartography increases its communication capacity in a variety of fields: learning, cultural, heritage, management, leisure, sport, tourism, traditions, …

11. Photogrammetry becomes flexible on its instruments and its methods.

12. Photogrammetry meets and mixes with other disciplines: Remote Sensing, Image Processing, Robot Vision, Computer Graphics, …

13. Photogrammetry moves towards automatization

14 . Photogrammetry opens itself to society.

15. There is still a lack of means in Photogrammetry to acquire low cost aerial images.

Against this background, our aim is to contribute to close the gap between terrestrial and aeroplane image acquisition. We intend to investigate the "pros and cons" of a variety of devices that may be used by the "lay society" to obtain large scale and low cost aerial images. In this way, we may be able to empower our community capacity to render, preserve and enjoy its Cultural Heritage.

TYPES OF OBJECTS

Regarding Architectural and Archaeological Heritage, the objects to be rendered may be placed along an axis within two opposite cases.

<u>Regular object supported by vertical plans:</u>

The typical object of this case is an architectonical building composed by analytical surfaces, the most simple of which are vertical planes for the walls and sloping planes for the roofs. The basic methodology for this type of object is the shutting of oblique images arranged in a variety of angles and positions, including ground and air. The presence of well defined points will lead to a straightforward identification in several images and thus, to a sure determination of the correspondent object points. Besides this, the surface regularity will allow the establishment of a projective relation between the details of a chosen image zone and the correspondent zone on the object face.

In this approach, we need aerial images because:

- They improve object understanding, especially on oblique images. Images containing three vanishing points related to the three main object directions match easily with the perceptive human abilities.
- They provide access to usually impossible views such as roofs and inner yards.
- From a bird position, there are little obstacles that may lie between camera and object.
- They improve the network geometry as more and better viewpoints may be placed in a robust design.
- It is easier to enclose the whole object and to document its relations with its environment.

<u>Irregular object structured on an horizontal frame.</u>

The typical object of this case is an archaeological site exhibiting a certain demolition state. The object interpretation demands a datum definition in which the main plane is the horizontal one. It also needs to consider the existence of high relative relieves.

In this situation, it is not possible to apply geometrical constraints related to the object surface and it is not possible to identify singular issues within several images. The methodology will, therefore, rely on space exploration provided by stereoscopic images arranged in a horizontal fashion (floating mark moves in the vertical direction).

In this way the photographic configuration is much more restrictive than in the previous case: the twelve degrees of freedom related to this situation must be controlled very closely:

- Both points of view must be placed at the same height.
- Both points of view must be placed over predetermined terrain (X,Y) positions.
- Both camera axis must be vertical.
- The third angle (swing) must be the same in both images.

BALLOON PHOTOGRAPHY

We can place the origins of the balloon flights just before the French Revolution. On 1783, september 19 th., in the Gardens of Versalles, in the presence of Luis XVI, Montgolfier launched a hot air balloon carrying a lamb, a duck and a cock. Two months later, Jean-Francois Pilâtre de Rozier and Francois Laurente D´Arlandes became the first human beings flying on an aerial machine. Later that year, Jacques-Alexandre Cesar Charles performed another balloon flight, but in this case, filled with hydrogen.

In 1849, Laussedat, worldwide regarded as the father of Photogrammetry, tryed unsuccessfully to take photographs by means of balloons and kites. In the French – Piamonte war, Nadar also failed because the hydrogen in the balloon spoiled the chemical film components. Once he repaired this problem he is reputed of obtaining the first aerial photographs.

Balloons and blimps rely on aerostatic principles, opposite to kites, aeroplanes and microlight devices which are supported by aerodinamics. The bouyancy principle is its main rule. The target is to be lighter than air. Balloons with radial symmetry cannot be attitude controlled and so, they cannot travel along a flight line. They will be dragged by the wind unless they are earth controlled by a string. Blimps instead, exhibiting an axial symmetry will align themselves with the air flow and so they can accept a motor and travel along a predetermined air path.

There are two ways of floating a balloon.

<u>Heating the air inside (diminishing the air density)</u>:

The balloon will rise until the air inside will cool down to equal the surrounding air temperature. When the rising force and the gravity force come to a balance the device will stop but the cooling will continue until the inner temperature (density) will equal the outer temperature (density) and then, the balloon will come back to earth. If the balloon carries an air heater (with its fuel additional load) it may be able to rise again or to maintain a predetermined height.

<u>Filling with a lighter than air gas; Hydrogen at the beginnings, Helium nowadays</u>

Hydrogen and Helium are gases lighter than air. Hydrogen density is half the Helium density and 0.07 times the air density but while Hydrogen is the most inflammable (dangerous) chemical element, Helium is the most inercial (safer) one of them all. Helium balloons are used nowadays to carry meteorological instruments to the high atmosphere (20 km. height) where no wind blows.

A Helium or Hydrogen balloon or blimp will rise (float), searching for the lighter air layers and it will stop when it finds them. To make such a balloon come back to us there may be three ways:

- Allowing the inner gas to get out.
- Implementing closed bags inside the balloon, which can be filled or emptied with air, and so, increasing and decreasing the balloon weight.
- Implementing a closed bag at the balloon core, filled with Helium while the outer bag is filled with heated air. In this way one can profit the Helium tendency and so, save fuel and increase the flight time. One can also profit the heating and cooling air behaviour and thus, control better the device vertical movements.

PHOTOGRAPHS FROM KITES

Kites are supposed to be born in China more than 2.500 ago, maybe invented by philosopher Mozi. Initially, they were related to religious ceremonies but also exploited as a means of fishing. Soon later, Gonshu Pan proposed to use them to pass information between separated military troops; some chronicles speak also about a human observer being lifted in the air by the kite.

In the late XVIIth century kites became very trendy in Europe as a children (and adult) game. Its technological use can be spotted on the Franklin´s experience: he used a kite to proof the electric nature of rays.

In the XIXth century kites were commonly used to lift meteorological instruments and in the XX th century, when aeroplanes were already taking off, devices were implemented to lift observers above the battle fields.

Some references report Archibald as the first one to shut photographs from a kite as early as in 1882. He certainly achieved so in 1887 releasing the shutter by means of a delayed micro explosion.

From 1890 on, Batut and Wenz, following separate ways but maintaining a collaboration relationship, developed the systematic use of kites to obtain aerial images. Batut published the book *La photographie aérienne par cerf-volant.* Soon, they saw that it was better to keep the camera attached to the wire rather than fixed to the kite body. In this way the camera could be accessed while keeping the kite flying. In 1912, Picavet designed and built a pulley system for suspending the camera below the kite line. This device is currently used nowadays and referred by its creator name.

In the United States of America, Lawrence used a train of kites to lift a panoramic camera that weighted 50 pounds and Cody used the same system to lift the camera and himself or one of his sons to a 900 meter height.

Unlikely balloons, kites are not an aerostatic (lighter than air) device but an aerodynamic (heavier than air) one. It can fly, like aeroplanes, because of the irregular distribution of the air flow over and under it.

PHOTOGRAPHS FROM PARAMOTORS

Paragliders descend from parachutes and hang gliders, which themselves are an evolution product of kites. Parachutes goal is to diminish vertical speed. Hang gliders one is to glide, i.e. to travel while falling. We call glide ratio to the rate between the horizontal distance and the vertical distance In the case of paramotors this coefficient approaches nine.

Paragliders may be seen as the result of changing falling into gliding. It is reported that some parachutist - Bosson, Betemps, Bohn - tried in 1978 to avoid the dependence on an aeroplane by "jumping" from a hill. In a few years this challenge lead a complete and practiced sport.

In 1988 took place a successful trial to add a propeller to the pilot back. First motors were very heavy and the flights very short but again very rapidly the new technology evolved to a well established field.

Paramotors introduce an important novelty regarding Paragliders: any place with a 20 meters - free from obstacles - area and without strong winds fits enough for the taking off.

This advantage is also relevant concerning more sophisticated flying devices (such as microlight aeroplanes) which need a constructed track for the taking off. The force provided by the propeleler allows also to control the flying path and not just to sail the wind. Taking photographs from a paramotor is a simple action as soon as the pilot enjoys a little comfort (quiet atmosphere) while flying.

CARTOGRAPHIC VISUALIZATION: FROM 2D TO 3D THROUGH 2,5 D.

Cartographic evolution may be portrayed as a change from paper to computer screen. Even though both are bidimensional, this change is largely equivalent to the change from 2D to 3D. We will use Marr (1982) concepts on Artificial Vision to briefly describe cartography evolution from 2D to 2.5 D and to 3D.

2D, whether on paper or on screen, is constrained to rigidity and parciality. In case of the computer, rigidity is partial as diverse views may be easily added, side by side, or layer by layer, to extend the object surface or the thematic items rendered by the map. It is also flexible concerning the operations of editing, updating or generalizing. But it is rigid as far as visualization is concerned. User cannot get but a partial, unique view (as scaling, rotation and translation within a plane does not affect perspective).

2.5 D means a qualitative change: rendering surfaces with spatial parameters. Paper certainly allows this possibility by means of the so called perspective view. This technique includes simple models (wireframe) or complex ones (surface rendering considering illumination sources) through intermediate ones (occlusions representation or solid colours application). It is worthy to stress the role played by conic perspective with the point of view placed at a finite point and so, supporting the possibility of introducing the user inside the scene and linking him/her to the objects in the world. In any case, it means a qualitative change as the user accesses a concrete and real representation, which spontaneously appeals his / her imagination.

Here, an important difference becomes evident between paper and screen. While the former only provides frozen views, the latter is able to stitch them in a temporal sequence and so, it releases the most powerful feature of the user vision: his / her ability to perceive changes or movement. It also provides a tool to "dive" the scene and thus, to improve subjective identification with it. Note that the translation of the viewpoint generates paralax and, consequently, a certain level of stereoscopic visualization.

3D fosters an equivalent jump: object representation. From a continuous and undifferentiated surface, singular entities arise. Objects are splitted apart, each of them geometrically and radiometrically referenced by a proper frame which can be related to the other frames. These objects may be endowed with "life" and so, to move around and to react to user enquiries or actions.

Objects also may perceive, may have sensors to detect changes going on at their surroundings. They may be also capable of motion. And they may be able - between "stimulus and response" - to analyze and asses a variety of circumstances and to choose within a variety of adequate behaviours.

3D Cartography leads to Virtual Reality and to Augmented Reality. We can render - maintaining the classical metric and semantic demands - a complex world and even a fantastic world gathering reality and imagination, objectivity and subjectivity, technology and art.

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