

Analyzing Cultural Heritage by unmanned flights: new strategies researching rural and urban spaces.

Analizando el Patrimonio Cultural a través de vuelos no tripulados: nuevas estrategias de investigación de espacios rurales y urbanos

Emilio J. Mascort-Albea¹, Jonathan Ruiz-Jaramillo², Rocío Romero-Hernández¹

¹ Department of Building Structures and Geotechnical Engineering, University of Seville, Spain.

² Department of Architectural Constructions, University of Málaga, Spain

Abstract

Unmanned flight systems, better known as “drones”, are being progressively introduced in professional and research works. Nowadays, we are assisting a period where the advantages implied by the use of such technical means in different fields are demanded by society. It is clear to verify the power of images taken by unmanned equipment which incorporate tools for filming and photography. These systems allow to reduce costs on in-situ surveys of heritage, becoming into a key tool to understand the territory physical nature, both at a macroscopic level (urban and natural spaces), as a level of proximity unknown before (material nature of plots and buildings).

Key words: UNMANNED FLIGHT, DRONE, SURVEY OF HERITAGE

Resumen

Los sistemas de vuelo no tripulados, conocidos coloquialmente como “drones”, están introduciéndose progresivamente en trabajos profesionales y de investigación a través de la experimentación de las ventajas que implica su utilización. Resulta evidente comprobar la potencia de las imágenes obtenidas por equipos no tripulados que incorporan herramientas de filmación y fotografía, así como la reducción de costes económicos en trabajos para la documentación de bienes patrimoniales. Destaca así, su potencial para erigirse en una herramienta clave para el conocimiento de la naturaleza física del territorio, tanto a nivel macroscópico (tejido urbano y espacios naturales), como a niveles de proximidad inéditos (naturaleza material de solares e inmuebles).

Palabras Clave: VUELO NO TRIPULADO, DRONE, PROTECCIÓN DEL PATRIMONIO

1. INTRODUCTION

The interest of human being to get unprecedented views of known reality has always been linked to technical progress in each historical period (Fig.1). Optical devices developed during the Modern Age provided landscapers and artists the possibility of creating

new panoramic visions of known environments. The invention of the photographic technique and the use of a hot air balloon in the nineteenth century, made possible the first aerial images by pioneers like Alfred Guesdon, Felix "Nadar" or Wallace Black (GÁMIZ-GORDO, 2004: 110-117).

The technological developments during the XX century, in particular the possibility of getting an unlimited amount of aerial views, provided useful information to technicians of different disciplines and the general public. In the XXI century, the proliferation of unmanned flying devices provided with embedded media film, introduces a new horizon in capturing videos and aerial images. Nowadays, we are checking the advantages of using “drones” in different professional fields: multiple perspectives, powerful images, reduced economic costs proximity to the studied object and versatility of movements.

From the point of view of knowledge of the surrounding physical environment, filming by unmanned flights can be establish itself as a key tool for understanding the physical nature of the territory, both macroscopic (urban fabric and natural areas) and to an unprecedented level of proximity (characteristics of plots and buildings). In this paper we examine the usefulness of these devices, in order to be able to document, protect and interpret Cultural Heritage.

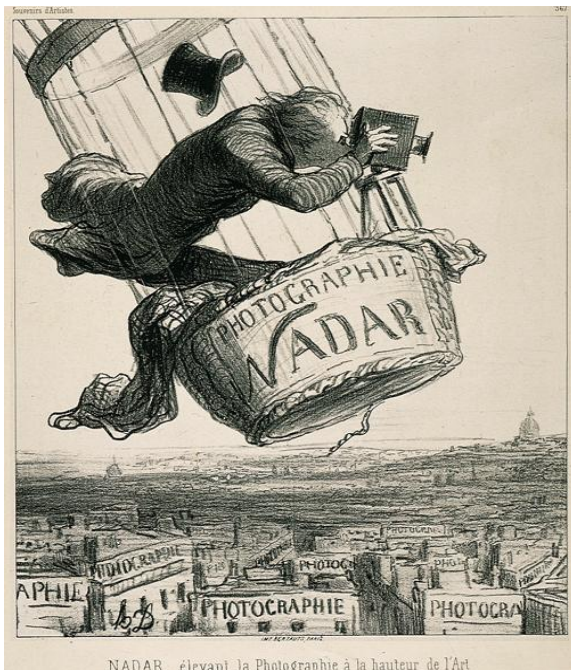


Figure 1: Cartoon representing french photographer Gaspard-Félix Tournachon's, better known as "Nadar", performing aerial photos from a hot air globo. Posted in "Le Boulevard", May 25, 1862

According to this, the present paper introduces a brief look at the art discussed, showing some field work in the city of Sevilla (Spain) and a multiscale analysis of the resources that these flights can provide to Cultural Heritage professionals and researchers.

2. LEGISLATIVE FRAMEWORK

Unmanned Arial Vehicles (UAV), commonly known as “drones” are aerial systems that can be remotely controlled for short and long range military and civilian purposes. Drones are usually equipped with a camera and can also be armed with missiles (SOUTHWORTH, 2012: 1).

However, using drones involves a number of risks, which have to be assumed and controlled. Today, the standards on using such devices are more developed in United States than Europe or Spain.

The indefinición in Spanish law for the use of drones in recent years has come to an end with the recent approval of Royal Decree-Law 8/2014, of 4 July. This document established the gear features, training of its users and also the conditions in which they can be used (Ministerio de Fomento del Gobierno de España, 2014).

This regulation distinguishes between light and heavy equipment, which is related to their scope and range. At the same time, it is not allowed using them in town, except special circumstances and in order to control the flights, licenses and certificates will be required. Therefore, it is checked the new document logically solves generic problems, without addressing specific issues related to the use of UAV for the documentation and study of architectural heritage.

3. OBJECTIVES, RESOURCES AND METHODOLOGY

In order to develop the advantages that this type of system can provide in architectural research, we have checked how it works in a case study conducted during 2013. Unmanned Aerial Vehicles have been used to the study of some of the heritage property in the city of Sevilla,

specifically, Gothic-Mudejar churches. For the purposes of this paper, the aim of using this technology to film these medieval temples is to put together new information with historical documents held about them.

Within the general characteristics set out above, the work developed in this research field have been performed with the following resources:

- Lightweight 4-rotor helicopter DJI Phantom 2 F330
- Two axis camera stabilizer with control angle
- GO-PRO Hero 3 Black Edition Camera
- Real-time video transmitter and receiver
- Set of batteries
- Portable power generator

The graphics and audio-visual information has been taken with photography services and ground flights conducted under the "Vistaerea" platform (Sanchez, 2013). As we can see in next chapter, the methodology used by the operator consists on displaying the frame of the camera via a video monitor in real time, and controlling the device helped by its GPS tracking (Fig.2).



Figure 2: Equipment and employee. From "Vistaerea" low-rise flight video and photography platform.

4. USING UNMANNED AERIAL VEHICLES TO STUDY ARCHITECTURAL HERITAGE: GOTHIC-MUDEJAR CHURCHES, SEVILLA (SPAIN)

From the University of Sevilla, works have been done related with the incorporation of new Information and Communication Technology (ICT) in preservation, interpretation and diffusion of the buildings, in the context of "smart city" paradigms. In this way, a research work finished during 2013 and named: *Aplicación de las infraestructuras de datos espaciales a la gestión del Patrimonio Cultural en la ciudad de Sevilla*, was developed with the collaboration of researcher from two centers which belong to University of Sevilla: *Higher Technical School of Architecture* and *Faculty of History and Geography*. The mentioned paper analyzes new Information and Communication Technology (ICT), according to mudéjar heritage of Sevilla (MASCORT-ALBEA, 2013).

In this context, some churches as *Omnium Sanctorum*, *San Esteban*, *San Gil*, *San Isidoro*, *San Julián*, *San Román*, *Santa Lucía y Santa Marina*, all of them in the historical and monumental center of Sevilla, have been recorded. The films were made during the months of April, May and December 2013, prior to the approval of the current law. Following results have been obtained:

1. - *Audiovisual recordings*: the designed tours allowed us to record approximately two minute videos. In order to get similar sequences, the flights took off a few yards from the main facade of the church and followed an upward trajectory to fly up to the bell, get overviews of other fronts of the building and landed.

The recordings allowed a gradual approaching to the building from the outside. At the same time, further processing of audiovisual material, provides the possibility of selecting the most representative sequences and adjust the speed of the movements of the camera to the needs of the final production (Fig.3).



Figure 3: At the top, flight team performing environmental surveys of the church of San Isidoro. Below, sequence of frames recorded by "Vistaerea".

2.- *Photographs*: To this end, the camera is programmed, in an automatic mode, to take a photo by second. Thus, each flight provided around a hundred images that in many cases achieve greater precision and expressiveness than the "bird view" reached by manned flights currently. (Fig. 4).

Once you know the main proceeds from the flights, and based on the work performed, we can describe the main developments that may involve the use of such systems for the study of heritage buildings in urban areas:

1.- *Unseen views*: The multiplicity of new perspectives give us unseen views of the building. As in the previous case, selecting and producing all the digital pictures and filtering out all data is essential, in order to obtain efficient information.

2.- *Approaching*: Collected information shown us that proximity to the building reached with the drone provides high detailed images. This question is quite useful when checking the physical state of the building, in usually inaccessible sites, allowing the characterization of formal, constructive and material aspects.



Figure 4: From top to bottom, aerial reconnaissance of the church of San Esteban: (1) Image courtesy of "Vistaerea "; (2) bird eye view "Bing, 2014"; (3) 45 degree aerial view from "Google maps, 2014."

This is particularly clear in the study of the least accessible parts of the exterior of the analyzed churches: the roof and the steeple (Fig. 5). Through the images from the unmanned flights, its elements are detailed with great accuracy, and provide useful data for future work and graphic survey of virtual reconstructions.

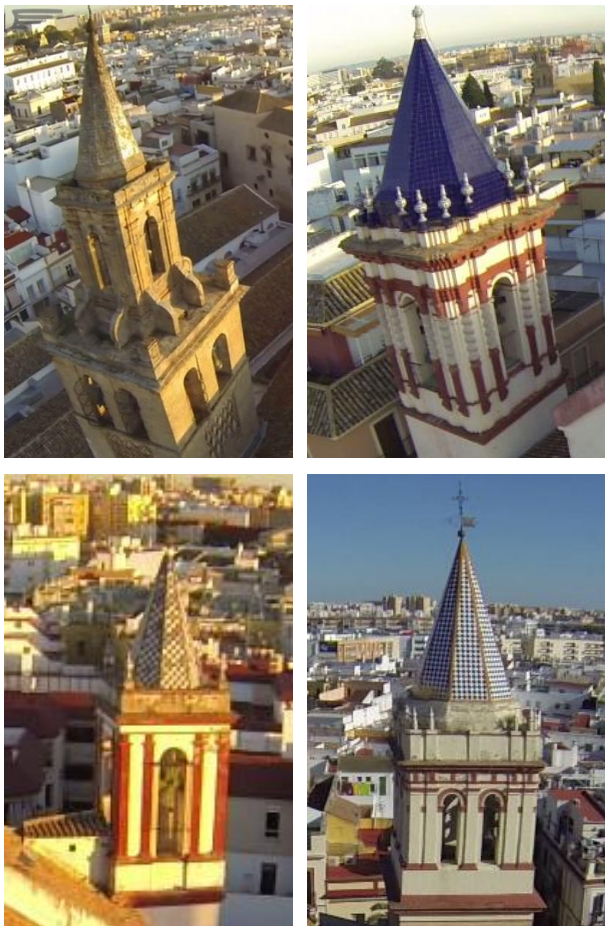


Figure 5: Aerial images of the following churches steeples of the city of Seville: Up, Omnimium Sanctorum (left) and San Román (right); down, San Julián (left) and San Gil (right). Images from "Vistaerea".

In this sense, it can be concluded that due to the distance from building provided by images taken by the drones, the information obtained by this new method is useful for architectural restoration works. In addition, the images obtained, in many cases, may become even more relevant than the information that could be achieved by visiting the same elements.

3. *Expressiveness*: As shown in figure 5, regarding the lighting conditions, it is considered that the most expressive images are obtained with oblique lights, that is: sunrise and sunset. It is therefore important to consider the orientation of the building itself. In this sense, the analyzed churches are east-west.

On the other hand, it is easily checked that using fisheye lens with 170 degree opening, at certain distances and positions, make us perceive the filmed object as bended. This circumstance has been considered a new way for the experimental design of logos and iconique images (Fig.6).



Figure 6: Logo for the church of Santa Marina from fisheye perspective taken through UAV. Design by architect Manuel Martín Vega.

4.- *Courtyard flights*: Another significant point, analyzing the use of drones in open spaces, is if they can be used in urban sites with safety. On this point, it is understood that there may be certain loopholes in the law regarding the possibility of low grade flights in private courtyards plots located in urban soils. This case was experienced in Sevilla Mudejar Art Center, located in the old Palace of the Marqueses de la Algaba, for which the necessary permits were obtained. During the flights inside the courtyard, was verified the usefulness of the recordings obtained, although the maximum height of the building wasn't exceeded. Also, the board was very interested in the videos and pictures taken, in order to be used as promotional material (Fig 7).



Figure 7: Courtyard sight of the Palace of the Marquesses de la Algaba, Mudejar Art Center of Seville. Images from "Vistaerea".

Once shown the main advantages and possibilities of using UAV detected during the field work carried out, the main problems, constraints and inconvenients encountered are listed below:

- 1.- *Environment*: During the several operations, some problems have been detected flying in densified urban areas, where fully manual operations were required, which involves the risk of loss of the device, because they lost reference for landing. However, this has not happened in testing in the open places, where the obstacles are fewer. Therefore, it is recommended taking off from non-visited open spaces near the building or roofs.
- 2.- *Liability insurance*: As with other vehicles, a liability insurance is required to take over the potential risks that may arise in case of accident.
- 3.- *Flight range*: Another major constraint is the device autonomy, or the battery life, whose performance depends on its weight. Different flights show that long tours are not necessary to get a large volume of information to analyze, short flights are recommended, shorter than the theoretical battery life.
- 4.- *Night use*: The device movement makes it impossible to get night time images, due to the blurring of them caused by the lack of light.

As a result from all stated above, and in order to minimize unexpected setbacks, it is essential the development of a preliminary protocol. At least, a path design should be included, avoiding navigation problems as a result of the urban layout (obstacles, narrow streets, etc.) in which these buildings are usually inserted.

The experience gained in this work, allows us to propose a series of systematic strategies, which can be applied in the future, to study the heritage building. These criteria are provided in the following paragraphs of this paper.

5. RURAL AREAS. NATURAL HAZARDS: LANDSLIDES.

Many monumental assets are located in rural or unconsolidated areas, which make it easier to follow the the new rules about flights of drones. This allows greater freedom of movement trajectories and better images when working with estates in rural environments (Fig 8.)

At the same time, many of these states are natural areas, and often they are also protected. Therefore, and as in urban areas, it is logical to think that the work of filming also contribute to its protection.



Figure 8: Trafalgar lighthouse in Barbate, Cadiz. Images courtesy of "Vistaerea".

Finally, it is noted that many of these assets are located in areas that may be affected by natural

hazards such as floods, earthquakes or landslides.

In this sense, it is understood that the use of unmanned systems can optimize costs and efficiency, studying how a landslide risk slope would damage the buildings built on it. Regarding that, the Research Group "TEP-018. Geotechnical Engineering" at the Higher Technical School of Architecture of Seville, is working on some research projects related to this subject.

6. URBAN AREAS. DIFFUSION PLAN.

In recent months experiences in recording videos UAV within metropolitan areas have increased. Video recordings of cities like Madrid (STEGMANN, 2014), o New York (GROSSMAN, 2014) have become news and consolidate the use of UAV like diffusion tools.

That is why in this line of research, is committed to implement in future projects of urban diffusion methodology and knowledge gained in previous studies. In order to offer new perspectives to understand the urban structure and the possibility of future film projects, this paper presents a proposal based on four different phases:

Phase 1. Strategic Planning. All the work done should be included in a "Final paper" including a detailed analysis of each of the aspects of future field work.

1.1.- Conceptual statements and thematic approaches development. It is proposed the development of a first section including the main strategic points that should be reflected in the final paper. To do this, it will take into account the main values considered to be representative of current strategies for the enhancement of the different municipal institution: heritage areas, facilities and neighborhoods, tourism, etc.

1.2.- Selecting filming scenarios. Field visits and inspection of proposed workspaces will be required, based on the following criteria: morphology, accessibility, representativeness and significance of the locations, functionality and viability of the unmanned flight equipment maneuvers. The final result of this phase will be

implemented in a set of records which should include the most important parameters to be taken into account: type of traffic, availability of the roofs, degree of complexity in takeoffs and landings, etc.

1.3.- Proposed flights. A technical working script is considered necessary in the project report in order to provide flight schedules as well as a series of preliminary diagrams to illustrate the most representative views to be obtained from each of them. Also, this script will include an estimate of the resources that should be brought into play to make the flight, avoiding possible risks and technical problems.

1.4.-Final Product definition: The "final paper" will specificate the main characteristics of images and videos. This chapter will include the amount of pictures and the time of footage and filming. Other aspects like music or sound effects must be considered.

1.5.- Institutional coordination. In order to keep safety, as refered in previous sections, different meetings with the all institutional actors involved in the project will be developed.

Regarding that there should be different meetings to define work priorities, discusse preliminary work and clarify issues and relevant details not done previously.

Phase 2.- Filming scenes. All work of Phase 2 will involve the application of a work methodology: simulation scenes, duration and resources consumed each shot, approximate number of shots per scene.

2.1.- Shooting scenes. Standardization of filming 600 minutes of video quality 2.7K 30 fps (Ultra Wide Angle 2716 x 1524, 16) is proposed. 120 shots. All the criteria written above will be applied for the realization of filming.

2.2.- Professional qualified team. It should be mainly composed of a specialized operator, in charge of the management and take off and landing of the unmanned vehicle. In addition, two operators are required the displacements, assembly/disassembly operations and transport of the equipment, etc.

Phase 3. Production and postproduction activities. All work of this phase will involve the final selection of videos, as well as post production work of the recorded material.

The progress of the work should be tracked through several meetings, where the different drafts with the details of the final product will be discussed.

3.1- Final selection of videos. The structure and the final script of the final product are defined, including the type (main video, video theme, individuals) as well as the viewing format (single, split-screen, multiscreen).

3.2.- Production. This section includes shot selection and approximate final duration and the choice of the final product format (2.7 K, Full HD, etc.).

3.3.- Selected material postproduction . In this chapter, effects, speed adjustments, credits, music, imaging, graphic schemes or virtual images are included. Main video composition with a volume of 50 shots, approximately 4 minutes in a presentation format Full HD (1920x1080, 30 fps) is estimated.

Phase 4-Delivery and dissemination of product. All works of Phase 4 will involve designing promotional graphic panels, creating channels of access to the product and general or particular maps with the itineraries of the flights.

4.1.- Design of strategic promotion panels. From an initial survey, a proposal for possible virtual physical spaces (buildings and institutional facilities) and dissemination (web links, digital) is performed.

4.2.- Building channels of access to the product: Broadcast channels arise through institutional web portals and tourist offices, including the possibility of creating an application for mobile devices.

4.3.- Map of urban flight itineraries. The paths followed by the drone in the different flights will be presented.

7. INDOORS INSPECTION OF MONUMENTAL BUILDINGS

The possibility of using unmanned flight for inside inspection of heritage buildings enables detailed data collection of elements and areas that otherwise would not be accessible, except being placed a scaffolding system. That is why it can reduce costs regarding the inspection of the property, in addition to significantly minimize the risks of people working at height.

Certain types of historical architectural usually have large volumes and spaces that enable these flights, which can mean a decrease of the risks to both, the building and the team itself. As a drawback, as cited above, it is estimated that the indoor lighting conditions, would force to use more lights as a reinforcement to enable imaging quality (either attached to the drone or controlled by the support staff).

All this highlights the possibility of applying the advantages of this technology in the field of conservation of cultural property. The use of this works, combined with other, currently used in the inspection of buildings, such as thermography in walls or detecting underlying structures in archaeological surveys, among other technique makes it possible to integrate this technology routinely in preservation heritage techniques.

In this regard, the development of this research arises from the use of UAV for inspecting structures in real estate, both exterior and interior; detection of underlying structures in archaeological surveys by uneven terrain mapping or thermography inspection of buildings or altarpieces.

Therefore, the main objective of this proposal consist to develop a basic material to make easier the inspection of the cultural property and, where appropriate, contribute to the drafting of conservation and development of cultural diffusion material.

8. CONCLUSIONS

The incorporation of new technologies to the practice of conservation of Cultural Heritage is a field that is undergoing rapid development at present. Using unmanned flight, the experience described in this paper shows us the usefulness of the images obtained for the documentation of heritage buildings, not only through perspectives and unpublished frames, but also by obtaining undeniable data that can be applied in conducting virtual reconstructions.

The main purpose of using UAV is to generate a chart (picture or video), during the inspection work of a building, which can be viewed from any simply electronic device. This resource allows detecting possible damages, generating a report from the data saving unnecessary risks and costs.

This is made possible by the fast speed use of instruments that, by their small size and easy use, do not need much preparation or complicated movements. Also, material can be produced almost instantly, so emergency measures can be adopted in the case of needed.

The experiment conducted has also shown the validity and usefulness of the method of images for the planning discipline as well as for the analysis of (urban or natural) environment in which the buildings studied are inserted.

REFERENCES

GÁMIZ-GORDO, Antonio (2004): "Paisajes Urbanos vistos desde globo: Dibujos de Guesdon sobre fotos de Clifford hacia 1853-55", in *EGA. Revista de Expresión Gráfica Arquitectónica*, nº 9, pp. 110-117. Departamento de Expresión Gráfica Arquitectónica de la Universidad Politécnica de Valencia. Valencia.

GROSSMAN, Samantha (2014): *Drone Footage Captures Stunning Aerial Views of New York City* [online] <http://time.com/63793/drone-video-new-york-city-aerial-views/>

MASCORT-ALBEA, Emilio J. (2013): *Aplicación de las infraestructuras de datos espaciales a la Gestión del Patrimonio Cultural en la ciudad de Sevilla*. [No publicado] Trabajo Final del Master de Ordenación y Gestión del Desarrollo Territorial y Local, defendido el 10 de diciembre de 2013 en la Facultad de Geografía e Historia de la Universidad de Sevilla. Sevilla.

Concerning the cost, this technique requires a logistics and personnel reduced, resulting in significant cost savings compared to using other means. Suffice it to recall such simplification in case of hiring and dismantling of scaffolding, hiring support staff, moving the staff for several days to the place of study

In turn, we have detected numerous open lines of research, and activities such as indoor flights from low altitude still lacking a specific regulation.

From the point of view of the law, it is seen as the new Spanish regulation has controlled many issues that were previously in the air. Nevertheless, today there still are unattended issues like its use in certain heritage researches or the possibility of flying in private, open or closed spaces.

ACKNOWLEDGEMENTS

The preparation of this article could not have been done without the collaboration of the architects Juan Luis Sánchez Aragon and Manuel Martín Vega, who through the platform of low grade flights, "Vistaerea" developed fieldwork described above. In turn, some of the ideas of Chapter 6 are from José María Calderón Llamas (degree in Art History).

Ministerio de Fomento del Gobierno de España (2014): “Real Decreto-Ley 8/2014, de 4 de julio, de aprobación de medidas urgentes para el crecimiento, la competitividad y la eficiencia”, in *Boletín Oficial del Estado*, nº 163, Sec. I. Madrid, [online] https://www.boe.es/diario_boe/txt.php?id=BOE-A-2014-7064 [Consult: 21/07/2014].

SÁNCHEZ-ARAGÓN, Juan Luis. (2013): *Servicios de fotografía y vídeo aéreo de baja altura*. [online] www.vistaerea.com.

SOUTHWORTH, Matt (2012): Drones. *Questions and answers. Legislative action message (202) 547-4343*. Friends Committee on National Legislation. Washington, [online] http://fcnl.org/images/issues/afghanistan/Drones_Questions_and_Answers.pdf [Consult: 10/07/2014]

STEGMANN, Josefina G. (2014): *Un “drone” graba el vídeo más espectacular del centro de Madrid*. [online] www.abc.es/viajar/20140209/abci-video-madrid-cielo-drones-201402071940.html