Research Article

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Exploring conditions and usefulness of UAVs in the BRAIN Massive Inspections Protocol

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Abstract: In this paper authors conduct a case study analysis by implementing the use of UAVs in the data collection within the BRAIN framework for the failures diagnosis of facades. The main goal is to assess the conditions and usefulness of UAVs in the BRAIN protocol by analyzing the goodness of fit to the fundamental requirements that support this inspection methodology. This preliminary qualitative approach allows the authors to investigate the benefits and potential of this high performance technology as a complement or alternative tool to the initial method, which is based on visual inspections supported, as maximum, by high resolution digital camera images. For the study a sample of facades has been selected in Poland. A full equipped UAV has been collecting the images. Finally, full procedure, collected data and positive and negative issues has been assessed under the perspective of the requirements involved in a multiscale BRAIN inspection. Overall scoring conditions has been determined and, as a conclusion, it can be stated that the use of UAVs for technical inspections in a population based predictive approach is, and even more it will be in the future, an interesting complementary tool for the data collection.

Keywords: data collection, facades inspection, inspection methodology, Unmanned Aerial Vehicles

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1 Introduction

Lot of research has been developed exploring the use of digital images acquired through Unmanned Aerial Vehicles (UAVs) monitoring the technical condition of real estate and inventories of technical infrastructure. Within this perspective, Banaszek *et al.* (2017) [1] have proved the new opportunities that the use of UAVs offers in the area of technical inspection of buildings and constructions. New UAV data acquisition technologies offer new opportunities in this field. UAV case studies to monitor the technical condition of objects of different sizes (residential building, dam, retaining wall at the runway) have shown that high resolution image quality enables visual identification of cracks of 0.3 mm at approx. 10 m from the recorded surface [2, 3]. Recently, Serrat *et al.* (2018) [4] have described the benefits and disadvantages of this high performance technology and the authors have concluded that the use of UAVs for technical inspections of the facades in a building stock is an interesting alternative to the traditional visual inspections. In short, benefits come from the accuracy of the data, low operating costs, fast data acquisition time and variability reduction among inspectors.

The BRAIN (Building Research Analysis and Information Network) methodology was initially introduced by Serrat and Gibert (2011) [5] and lately developed in [6, 7]. BRAIN proposes, in a collaborative network of urban laboratories, a follow-up across time of the technical condition of the facades in a building stock, aiming to infer on the time to the ocurrence of potential failures or lesions in the existing facades. One of the most relevant issues in the methodology is the data colection procedure. Conventional inspections are primarily based on visual research methods. However, the data collection must be as exhaustive and accurate as possible, and a massive and periodic inspection should be efficient in terms of data quality versus time and cost resources.

In the present paper authors assess the conditions and usefulness of UAVs in the BRAIN protocol by analyzing the goodness of fit to the fundamental requirements that support the BRAIN methodology. On the basis of the same case study in [4] each one of the requirements will be discussed and compared with the current traditional criteria.

The paper is organized as follows. In Section 2 the Polish case study is discribed including characteristics of the sample under study and the flights. BRAIN inspection methodology, as well as requirements involved in it, are introduced in Section 3. Finally, a results and discussion section will end the paper with the resulting conclusions.

2 The case study

As mentioned, Serrat *et al.* (2018) [4] explored the emerging possibilities derived from capturing the information on the technical condition of the facades through UAV devices in the BRAIN context. In this paper we will consider the same dataset of images that they obtained in their experiment. To make the text more understandable and self-contained, we will reproduce in the next subsections the basic characteristics of the experiment.

2.1 Facades under inspection

The sample under study consists of six facades in Poland (four units in Warsaw and two units in Olsztyn). The sample was chosen based on criteria of morphology of the facade (*i.e.* flat facades, facades with balconies, facades with tribunes, and facades with balconies and tribunes) and deterioration level of the facade (*i.e.* no damaged, slightly damaged, medium damaged and heavy damaged). Figure 1 illustrates a general view as well as four particular images, of one of the units of the facades under inspection. More details of the sample can be found in [4].

2.2 Technical details of the UAV

The experiment uses the DJI Inspire One lightweight quadcopter with the following specifications: weight: 2,935g, vertical GPS accuracy: 0.5 m (accuracy determination), horizontal GPS accuracy: 2.5 m (accuracy of X, Y coordinates), climb speed: 5 m/s, max. drop speed: 4 m/s, max. cruising speed: 22 m/s (ATTI mode, no wind), max. flight height: 4,500 m ASL (Above Sea Level), max. wind force: 10 m/s, flight time: 18 minutes, operating temperature: −10°C to 40°C, size: 438×451×301 mm. To obtain digital images the UAV was equipped with a Digital camera (RGB sensor) with the following specifications: 12 Mpix resolution (4,000×3,000 pixels), physical size 6.170 mm × 4.628 mm, focal length: 3.55 mm.

Using UAV for commercial and scientific purposes requires in Poland a qualification certificate of UAVO unmanned aircraft operator. This requires Art. 95 of the Law of July 3, 2002, aviation law, and the detailed rules for obtaining the certificate are contained in the Regulation of the Minister of Transport, Construction and Maritime Economy of 3 June 2013 on certificates of qualification. Basic Visual Sight of Sight operation (VLOS) deals with the operation of UAV sightings. It is received by the operator after the completion of theoretical and practical training and passes the state examination, which is conducted by an examiner appointed by the Polish Civil Aviation Office.

Images were collected in three different days. Temperature, wind, humidity, precipitation and sun conditions were good enough for a successful data collection. Duration times of the flights per facade rang from 5 minutes to 29 minutes.

3 BRAIN inspection protocol

The inspection protocol is the practical part of the methodology to be applied in each urban laboratory. The protocol includes an inspection document that consists of two parts. Part a) allows the collection of field data, cartographic data, cadastral data as well as plot/building/facade data and architectural characteristics. Part b) covers the collecting of existing elements and materials and the state of any damage at the time of inspection. Extended details of the BRAIN methodology, as a predictive system, can be found in [6, 7].

3.1 Inspection methodology

The methodology focuses on a massive prospecting campaign of the facades at a multiscale level. Indeed, it concentrates on the concept of the urban laboratory that collects the envelope of the buildings and constitutes the urban front. The durability of each part of the facade and each one of the elements of the facade is assessed based on the facade characteristics, construction materials, injuries, extent and severity.

For inspections of facades, it was necessary to define a tool (assessment document) that allows to show the state of each element that composes the facade and to determine, in accurate manner, the magnitude and degree of severity of the lesion, in order to estimate a predictive control over it. In addition, it is necessary to achieve that the inspection is fast and with a minimum cost, since it will be

Figure 1: General view and four specific details of one of the facades in the sample.

applicable to a large stock of buildings. In the same way, it is necessary that the data extracted from the inspection can be managed and processed to perform studies on durability.

3.2 Fundamental requirements

The BRAIN methodology from its origins has been based on a series of general and specific requirements, which, duly weighted by a group of experts, drove the strategic guidelines to follow in the realization of inspections of facades on the urban front in a massive way [8]. So, the final protocol comes from a weighted criterion that combines issues like identifiability of the facades, classification of the facades, methodological issues themselves, resources needed, data collection, and analytical skills for the decision-making. Table 1 shows the general and specific requirements as well as the corresponding relative and overall weights. The interpretation and exact meaning of each field and each criterion is defined below.

Identification

The identification must allow the description of the general characteristics of the facade, being able to record the most relevant information (morphology, cadastral data, state of conservation, ...), besides being methodical, so that the inspection follows logical inspection guidelines going from the most general details to the most particular, and as universal as possible to allow the inspection of any type of facade.

Table 1: Weighted criteria and indicators for the inspection methodology.

General	Specific	Relative Weight	Overall Weight
Identification 17.5%	Descriptive	36.25%	6.34%
	Methodical	28.75%	5.03%
	Universal	35.00%	6.13%
Classification 16.25%	Sequential	36.25%	5.89%
	Detailed	35.00%	5.69%
	Ordered	28.75%	4.67%
Methodology 22.5%	Robust	35.00%	7.88%
	Standard	30.00%	6.75%
	Quick	35.00%	7.87%
Resources 11.25%	Technological	25.00%	2.81%
	Human	35.00%	3.94%
	Time	40.00%	4.50%
Data 21.25%	Reliable	42.50%	9.03%
	Quantifiable	31.25%	6.64%
	Verifiable	26.25%	5.58%
Analytical skills 11.25%	Multifunctional	26.25%	2.95%
	Processable	41.25%	4.64%
	Longitudinal	32.50%	3.66%

Classification

The classification of the information must sequentially respond to the constructive characteristics of the element, being as detailed as possible, specifying every minimum detail that may be relevant to the study, as well as ordered, for showing coherence within each area and not generate differences of interpretation.

Methodology

The methodology is the process to be used to obtain the information. Should be robust, presenting clearly the contents and avoiding differences in interpretation for the same situation; standard, using the same codes of identification for the same record; and fast, to minimize inspection times in the data collection.

Resources

Technological and human resources, and the data collection time that is required to perform the inspection should reduce the associated costs. For this you must have technological tools that facilitate the work in the field and determine the degree of specialization of the personnel carrying out the inspections, optimizing and adjusting the time of data collection, dump of information and extraction of results.

Quality of data

The quality of the data collected must provide credibility, therefore they must be reliable; they must also be quantifiable, allowing them to be processed analytically to extract numerical results; and testable, allowing to check the goodness of the data against the objective reality over time.

Analysis

It is important that the data extracted from the inspection have the capacity of being managed, processed and analyzed later, therefore, they must be multifunctional, to be used in different types of analysis, both qualitative and quantitative processable, being able to be systematically submitted to operations scheduled; and longitudinal, allowing a comparison over time in order to observe its evolution.

First column in Table 1 shows the percentages of each of the requirements, among which we can point out that Methodology (22.50%) and Data (21.25%) are those that require greater attention. Looking at the forth column we can see the overall impact of each indicator. As a consequence, all the efforts in the design of the inspection methodology must be focused on collecting reliable (9.03%) and quantifiable (6.64%) data, using a robust (7.88%), quick (7.87%) and standard (6.75%) methodology, and allowing a descriptive (6.34%) but universal (6.13%) identification of the facades.

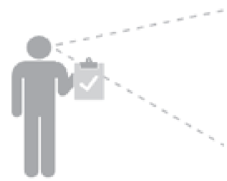
4 Results and discussion

Once the images were collected, the data were processed and analyzed with the aim of filling in the information in the BRAIN datasheet. This procedure gave the authors the opportunity of assessing each one of the general and specific requeriments above mentioned in Table 1 in order to compare the benefits of the UAV technology data collection versus traditional visual inspections and the support given by professional photo cameras. As a first step, given a specific requeriment the three inspection methodologies were ranked from 1 to 3 (1 = worst, 2 = medium, 3 = best) according to the goodness of fit to, or fulfillment of, the goals of the requeriment. This strategy allowed us a preliminary general comparison in absolute terms. As a second step, the scores in step one were weighted taking into account the relative weight of each one of the requeriments displayed in Table 1. Cumulative absolute and weighted scores are shown in Table 2 and discussed in what follows.

The factors that have been taken into consideration start from a first identification requirement that allows describing the general characteristics of the facades through their morphology, cadastral data and conservation status in order to arrive at a methodical and universal result. The assessment reached in this requirement has resulted in traditional visual inspections providing greater performance, although it is expected that UAVs flights with adjustments in the catchment methodology may achieve similar or better values.

The classification requirement allows to establish, in a sequential way, the construction characteristics with the maximum detail in an ordered manner throughout the inspection process, so as not to generate disparity of criteria in the data collection. Scorings are favorable to the UAV techniques in the level of detail criterion because they al-

Table 2: Scored (absolute / weighted) values for the specific requeriments according to visual, photo camera and UAV inspection methodologies.

GENERAL REQUERIMENT	SPECIFIC REQUERIMENT	INSPECTION METHOD		
		VISUAL	PHOTO CAMERA	UAV
FIELD	CRITERION			
IDENTIFICATION	Descriptive	3 / 19.02	1 / 6.34	2 / 12.68
	Methodic	3 / 15.09	1 / 5.03	2 / 10.06
	Universal	3 / 18.39	1 / 6.13	2 / 12.26
CLASSIFICATION	Sequential	3 / 17.67	1 / 5.89	2 / 11.78
	Datailed	2 / 11.38	1 / 5.69	3 / 17.07
	Ordered	3 / 14.01	1 / 4.67	2 / 9.34
METHODOLOGY	Robust	2 / 15.76	1 / 7.88	3 / 23.64
	Standard	3 / 20.25	1 / 6.75	2 / 13.5
	Quick	3 / 23.61	1 / 7.87	2 / 15.74
RESOURCES	Technological	3 / 8.43	2 / 5.62	1 / 2.81
	Human	3 / 11.82	2 / 7.88	1 / 3.94
	Time	3 / 13.5	2 / 9	1 / 4.5
DATA QUALITY	Reliable	2 / 18.06	1 / 9.03	3 / 27.09
	Quantifiable	2 / 13.28	1 / 6.64	3 / 19.92
	Verifiable	1 / 5.58	2 / 11.16	3 / 16.74
ANALYSIS	Multifunctional	2 / 5.9	1 / 2.95	3 / 8.85
	Processable	2 / 9.28	1 / 4.64	3 / 13.92
	Longitudinal	1 / 3.66	2 / 7.32	3 / 10.98
	Overall	**44 / 244.69**	**23 / 120.49**	**41 / 234.82**

low a better visualization of hidden areas to the human eye.

In the methodological field, issues like robustness in the interpretation of the observed data, standardization in the identification of the records and speed to optimize the inspection times must be considered. It is important to notice that the improvement factor comes from the robustness since the image allows verifications without the environmental pressure at the time of inspecting in situ.

When considering the resources that are necessary for the realization of an inspection, the hypothesis of the independence of the inspector and his own potential has been used. In this sense, aspects such as technology, human resources and time used for inspection are favorable to traditional inspections because in the case of UAV requires the involvement of other type of specialists in the management of the equipment and a greater time consuming resource.

UAV techniques are relevant and stands out from its competitors in two significant fields: data quality and analysis. It is quite straightforward and obvious that requirements like reliability and quantification of the collected information are better fulfilled and tested in a UAV approach. It is important to notice the UAV benefits from the analytical power perspective. As highlighted in [4], the most positive contribution of UAV data acquisition to the BRAIN platform is the reduction of the between and within variability among inspectors. This is one important issue in order to obtain more accurate confidence intervals in the prediction of the durability as a supporting tool for the decision making strategy across time.

As a summary, based on the data from this case study and from a qualitative approach, traditional inspections are nowdays slightly (4.2%) better scored than the UAV alternative. However, UAV scenario is quickly changing over time and the alternative is quite promising. On one hand, the advantage in the data quality and analysis requirements are not questionable at all. On the other hand, technological progress will move this UAV resource to a more standard, better well-known and cheaper technology. Within this perspective UAV-based inspections can really improve their compliance with the standards of the requirements for a large-scale inspection protocol. This is the reason why Society can not rule out the great potential that this form of inspection can offer in the near future.

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