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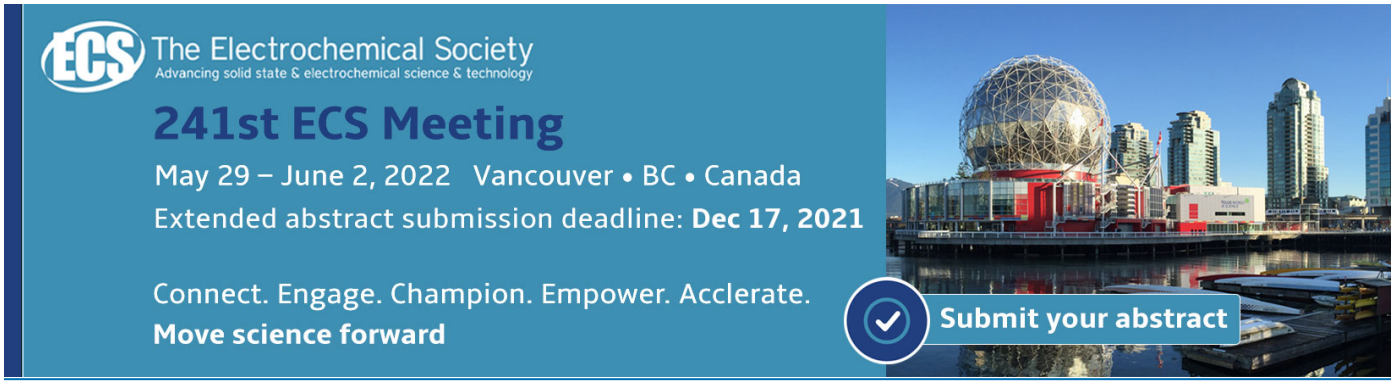

Results of a pilot experiment on monitoring the condition of buildings and structures using unmanned aerial vehicles

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Abstract. The purpose of the experimental study presented in the paper is to generate new knowledge about the possibility of using unmanned aerial vehicles to survey buildings and structures for subsequent extraction of information about their condition in hard-to-reach or remote places. As objects for the pilot experiment, the following were selected: a residential building in an urban environment that has been destroyed during operation; an object of unfinished construction; a roadway on the carriageway. An unmanned aerial vehicle of the model: DJI Mavic Air was used to survey the objects. The results of the study of objects are recorded in the form of photo and video streams for each object. Comparison of the results of the inspection of objects by experts and unmanned aerial vehicles showed the possibility and necessity of using new means to collect information about the condition of buildings and structures. The primary processing of the obtained images revealed their features: the effect of illumination on the color characteristics of the object of study; the presence of a textural component that complicates the process of separating the defect from the background; the presence of objects in the image that are not related to the elements of surface destruction; the change in the initial size of the object over time. The detected features of the images allow the use of standard algorithms and processing and require the synthesis of unique trajectories of their application.

1. Introduction

Building Information Modeling (BIM) is a process based on the construction and use of intelligent 3D models. The basis of intellectualization in BIM technologies is the experimental data obtained during the study of objects of reality. BIM technologies allow not only to design new construction projects, but also to form a picture of the resolution of buildings and structures. To form a picture of destruction, the results of continuous or discrete monitoring of the state of the construction site as a whole or its individual parts are necessary. Visual inspection is used as tools to collect information about surface destruction or

deviation from the normal state. Increasingly, it is proposed to use unmanned aerial vehicles to obtain information on inaccessible objects.

The empirical stage of scientific research is an integral part of the technological phase of design and the basis for assessing the compliance of the results obtained with the behavior of the real processes under study [1, 2].

A complete empirical study includes three types of experiments [3, 4], including:

– industrial aerobatic experiment-study or experiment-transformation, carried out for preliminary, relatively superficial orientation in the object under study;

– specialized laboratory experiment-study, conducted to study individual aspects, aspects of the object under study;

- Computational experiment-transformation, used for a comprehensive study of an object based on its electronic model.

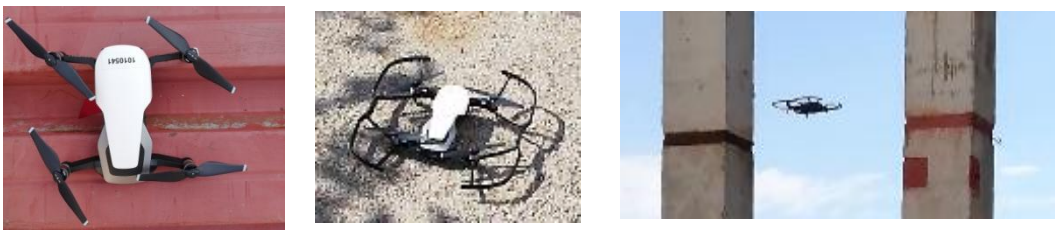
The availability of modern computer equipment and software currently allows us to form a new level of information support for experimental research. The expansion of information fields both in terms of quality and quantity of stored information makes it possible to implement one of the tasks of the national project "Science": an increase in the number of works on core activities "Knowledge Generation" by 20% in 2022 and by 40% in 2024. According to [5], knowledge generation is a scientific and technical activity that represents the process of creating new knowledge by processing information based on well-known knowledge. New aspects of the study using computational experiments make it possible to reveal the concealment of the property of the object, to assess the dynamics of transformation.

In this regard, *the purpose* of the experimental study presented in the work is to generate new knowledge about the *possibility of* using unmanned aerial vehicles to survey buildings and structures for the subsequent extraction of information about their condition in hard-to-reach or remote places.

2. Methods

a *b* *c*

Figure 1. Type of objects of inspection: a – view of a residential building from destruction on the outer wall; b – type of object of unfinished construction; c – type of roadway



a *b* *c*

Figure 2. Type of quadcopter: a – general view of the quadcopter; b – view in the mode of preparation for flight; c – view in survey mode

As objects for the pilot experiment were chosen: a residential building in an urban environment, which has destruction during operation; object of unfinished construction; roadway on the roadway (Figure 1). To inspect the objects, an unmanned aerial vehicle of the model was used: DJI Mavic Air (Figure 2). Technical characteristics of the unmanned aerial vehicle are given in the table 1.

Table 1. Technical characteristics of the unmanned aerial vehicle

Characteristic	Meaning
Country of origin	China
Type	Quadcopter
Approximate flight duration, min	21
Maximum horizontal speed, km/h	68,4
Maximum vertical speed, km/h	14,4
GPS	Yes I do
Flight on a given trajectory	Yes I do
Hold the height point	By GPS
Radius of action, m	4000
Camera included	Yes I do
Shooting mode	HD: 1280×720 24/25/30/48/50/60/120p, FHD: 1920×1080 24/25/30/48/50/60/120p, 4K: 3840x2160p 24/25/30fps, 2.7K: 2720×1530 24/25/30/48/50/60fps
Maximum viewing angle, deg	85
Video shooting speed, car/s	100
Max. allow. Photography, px	4048×3040

Quadcopter control: DJI Mavic Air was operated in manual mode. An experienced pilot licensed to fly was involved in controlling the spacecraft. The maximum altitude was no more than 40 m from ground level.

3. Results and Discussions

3.1. Evaluation of video materials obtained during the aerobatic flight of objects

The results of the pilot experiment in the study of selected objects is to determine the quality of information flows that can be observed by the expert when evaluating the object and fragments of images obtained using quadcopter cameras (Figures 3, 4 and 5).

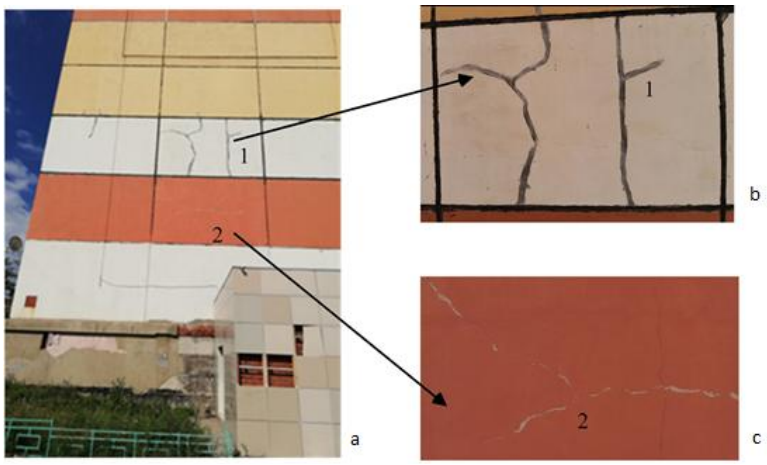


Figure 3. Areas of visibility of the destruction of a residential building: a – the area of visibility of the object by an expert from ground level; b – the area of visibility of object 1 from the quadcopter at the level of destruction; in – the area of visibility of the object 2 from the quadcopter at the level of destruction

Each of the figures shows a general view of the object, obtained either with the help of the expert's camera or with the help of a quadcopter camera. Additionally, photographs or fragments from the camera of an unmanned aerial vehicle are presented.

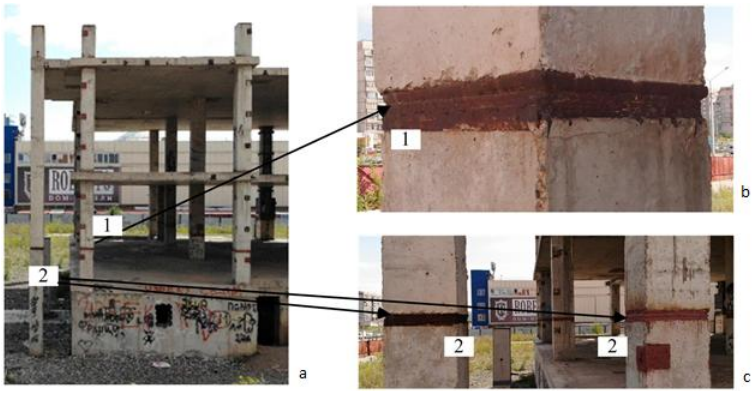


Figure 4. Areas of visibility of the unfinished construction project: a – general view of the object from the quadcopter at the level of the average height of the building; b, c – the type of fragments of the object at the level of the seams under study from a distance of 1 m and 3 m, respectively.

Figure 5. Areas of visibility in the study of the roadway: a - a fragment of the video frame during the examination: b - a fragment of the video frame of the roadway with mesh cracks; in – a fragment of a video clip with point destruction

3.2. Results of selection of objects of irregular shape and indefinite length on the image of objects

The video material obtained during the pilot experiment to study the destruction of the surface of buildings and structures was subjected to primary processing to clarify the possibility of using standard algorithms and building the trajectory of their application [6-8]. The authors of the study have extensive experience in the use of standard algorithms and the development of methods for deciding on violations of the continuity of metal surfaces [9-12].

A feature of the obtained images is:

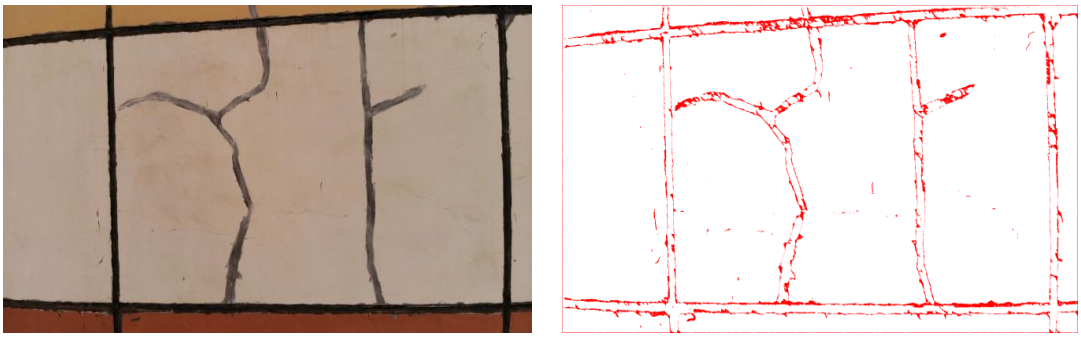
– the influence of illumination on the color characteristics of the object of study;

– the presence of a textural component that complicates the process of separating the defect from the background;

– the presence of objects in the image that do not belong to the elements of surface destruction;

– change in the initial size of the object over time.

The influence of the illumination of the object causes difficulties in comparing images that are obtained in different periods of time. The solution to the problem is possible when choosing weather conditions close to each other or building algorithms for processing and comparing images invariant to light sensitivity.
The influence on the results of processing texture components is eliminated by filtering algorithms or comparison with reference images of the object. Often it is not possible to obtain reference images, since the object is operated for a long time.
Changes in the initial size and shape of the object are associated with deformations of the load and lead to the synthesis of algorithms for transforming the image grid.
Figure 6 shows one of the examples of pre-processing of the image of cracks on the wall of a residential building. When processing the image, threshold binarization and a boundary closure algorithm are applied. The image remains small point objects and the boundaries of the connection of plates, which are not defects in the surface. Cracks appear as objects of non-regular shape and have a limited length.



a *b*

Figure 6. Image processing results to highlight solid lines

Based on the results of the pilot inspection of the building, structure and roadway, it can be argued that the use of an unmanned aerial vehicle allows you to obtain information about the condition of the object from areas that are difficult to access reinspection experts. The accumulation of information about the quality of the surface of buildings and structures allows you to assess the dynamics of the development of destruction and predict the possibility of an emergency situation. The results of pre-processing, the images obtained proved the possibility of using standard algorithms and forming the trajectory of image processing depending on the lighting [9-12] and the classification of the selected objects for research [13-16].

4. Conclusions

1. The use of an unmanned aerial vehicle for the inspection of construction sites is one means of obtaining information flow about their condition.
2. The most rational is the accumulation of information in dynamics for the subsequent construction of brightness maps of the image and analytical comparison of changes in the destruction of objects in time.
3. The quality of the received video and photo material about the state of objects is sufficient for subsequent automated and automatic processing.
4. The form of violations of the continuity of the surface of the object is both regular (Figure 5b) and irregular (Figure 3b, Figure 5b). To determine the degree of development of objects, algorithms given in the works [9-12] can be used.
5. The use of technologies to build the trajectory of the automatic flight of the quadcopter allows you to perform its positioning for the accumulation of data and analysis of changes in the quality of the surface of the object.
6. The applicability of standard algorithms for processing static images for the selection of objects of irregular shape corresponding to the elements of destruction of the surface of buildings and structures has been proved.

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