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A Review on Potential Applications of Unmanned Aerial Vehicle for Construction Industry

Soroush Dastgheibifard[1], Mahsa Asnafi[1*]

1MSc. Graduated In Civil Engineering-Construction Management
**Corresponding E-mail: Mahsa.asnafi@outlook.com*

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ABSTRACT: *In the recent years, the Unmanned Aerial Vehicles (UAVs) have been greatly used for different construction and operation applications of various types of construction projects. The main purpose of this paper is briefly reviewing the UAVs in the construction industry. In the building and construction industry, sustainable construction involves different issues among them, the design and management of projects can be named. In recent years, different types of technologies helped improve the management of projects; one of them is the Unmanned Aerial Vehicle (UAV). As a real-time capturing data technology, UAV is used in the construction industry.*

Keyword: Unmanned Aerial Vehicle, Real-time Data, Data Capturing Technology, Construction Industry, Aerial Image

1. INTRODUCTION

According to the Cambridge English Dictionary, an unmanned aerial vehicle (UAV) is an aircraft operating under remote/autonomous control without a human pilot on board. These aerial vehicles do not carry a pilot; instead, they can fly autonomously or be remotely piloted. There is no unique word to name a pilot-less aircraft often called as UAS (Unmanned Aerial System), UAV (Unmanned Aerial Vehicle), RPAS (Remotely Piloted Aircraft System), RPA (Remotely Piloted Aircraft), UCAV (Unmanned Combat Aerial Vehicle), and Remote Controlled (RC) Helicopter. These days many of them are controlled by iPhone or tablet and equipped with camera and sensors such as a Global Position System (GPS). They are in a wide range of shapes and sizes with different functions. They are used for various goals and many areas. In recent years, the UAV technologies have been mainly used for military purposes. In today's world, the primary use of drones is in the military section. Drones have been part of the military forces all over the world used as target decoys for combat missions, research and development, and supervision. Nevertheless, UAVs have started to be developed beyond their military use. They have been also used for commercial purposes including mining, agriculture, forestry, archaeology, and architecture. In addition, they have been applied as innovation tools in the construction industry.

Figure 1 indicates the estimated process of the three areas of Military, Commerce, and Hobby. Although the military area is the main market in terms of value, the figure indicates that the other two areas will be expanded over the next few years (Figure 1).

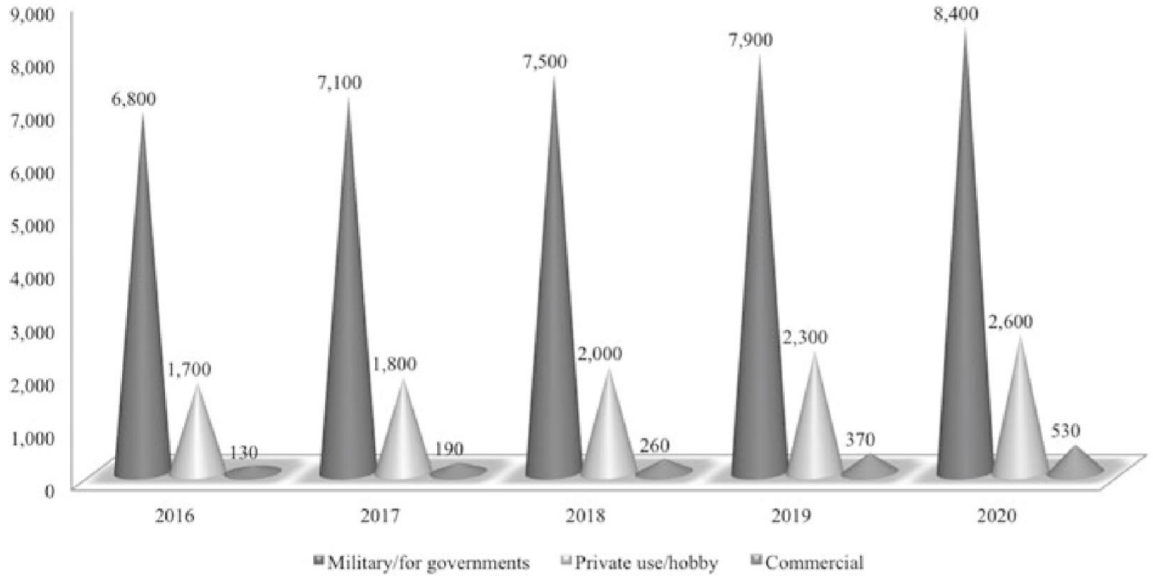

Fig. 1: The estimated value of drone market areas worldwide, 2010–2016 (mill. US $) [1].

In recent years, the variety of technologies has been developed to monitor the performance of construction site and each technology is capable of improving the construction industry. To improve our workplace, we require an innovation technology for collecting real-time images or videos from all part of the construction site. In recent years, a significant attention has been paid to the potential use of UAV in engineering environments. UAV has been used in different purposes in the context of construction, such as the monitoring and maintenance of pavements and highways, checking and monitoring of bridges; checking buildings, monitoring of damages and cracking, maintenance of facades and mapping of historical monuments, as well as 3D modeling for reconstruction of buildings, photogrammetric applications such as volume measurement using digital terrain model. UAVs are becoming more widespread since being able to be equipped with cameras, sensors, or other intelligent devices providing useful information for different applications. Due to the UAV's application and consequently drone characteristics, such as size, weight, engine power, range of the aircraft, etc., it can collect and process data through collecting images and videos along with methods that process the visual data into 3D models. These platforms frequently examine the construction sites, monitor work-in-progress, create safety documents, and inspect the existing structures and assess the seismic risk particularly for the hard to reach areas using traditional civil engineering tools, UAVs can be used to gather more accurate data during the construction project.

2. RESEARCH OVERVIEW

UAVs are being used in various industries all over the world. In addition, they are used in construction projects development. They provide accurate performance information on the construction state or the current conditions of construction. UAVs are needed for the projects in order to collect visual data in form of images, videos, as well as the 3D Models from the most relevant locations and views of a project site. Recently, many researchers have concentrated on applications of UAVs in different areas of construction industry. UAVs are innovation technologies that can help those in construction do their jobs better and faster over a number of applications [2]. This section provides a comprehensive overview of UAVs and the most important applications in the construction environment.

3. UAV IN CONSTRUCTION

With development of real-time monitoring technologies, UAVs provide many positive applications in civil engineering to control the construction process of the building, bridge, and any infrastructure system through capturing videos and images from parts of views of a project site as more as possible. Some studies have considered UAVs for checking the structures during maintenance. Moreover, they have been used in various transportation areas, such as traffic controlling and monitoring on roads during and after emergency incidents or severe weather conditions, road surface distress, repair and maintenance of streets activities and management of the work site to enhance the safety of workers. Compared to traditional control traffic systems, UAVs can fly over the work environment and they are able to cover a large area.

Table 1 indicates some applications and advantages of UAV technology utilized by civil engineering in the construction process. As shown in the table, since only three studies use UAVs as a damage assessment tools in the construction industry, it seems that more effort should be done to improve construction damage assessment in integration of UAV with the construction industry.

Table -1: Applications and Advantages of UAV in Construction

Numbers	Resources	Applications
1	Álvares et al. 2018 [3]	3D Modeling
2	Howard et al. 2018 [4]	Safety Monitoring
3	Moeini et al. 2017 [5]	Project Progress Control
4	De Melo et al. 2017 [6]	Safety Monitoring
5	Alizadehsalehi et al. 2017 [7]	Safety Monitoring
6	Freimuth & König 2016 [8]	Project Progress Control
7	Vacanas et al. 2015 [9]	Project Progress Control
8	Boqin Zhu 2015 [10]	Surveying
9	Fernandez Galarreta et al.2015 [11]	Damage Assessment
10	Lin et al. 2015 [12]	Project Progress Control
11	Zollmann et al. 2014 [13]	Project Progress Control
12	Siebert & Teizer 2014 [14]	Surveying/3D Modeling
13	Álvarez et al. 2014 [15]	Surveying
14	Yamamoto et al. 2014 [16]	Surveying/3D Modeling
15	Gheisari et al. 2014 [17]	Safety Monitoring
16	Rodriguez-Gonzalvez et al.2014 [18]	3D Modeling
17	Kerle et al. 2014 [19]	Damage Assessment
18	Eschmann et al. 2012 [20]	Damage Assessment
19	Feifei et al. 2012 [21]	3D Modeling
20	Irizarry et al. 2012 [22]	Safety Monitoring
21	Remondino et al. 2011[23]	3D Modeling

3.1 Project Progress Control

Project progress monitoring of construction site is one of the important tasks in the construction projects [24] [25]. The progress assessment provides the chance of recognizing the current as-built conditions of a project efficiently, to identify disparities between the as-built and as-planned progresses, and to aid in deciding on corrective actions, as well. Inspecting and monitoring of constructions are very important for the assessment of site conditions. Progress monitoring is considered as a critical success factor to timely deliver the construction projects, within budget, and in the needed quality [26] [27] [28], as well as being one of the most difficult tasks due to the complexity and interdependency of activities.

With the development of various technologies, UAVs are more useful than others. By increase in the use of UAVs in the construction industry, especially in monitoring the project, they are also capable of controlling the construction site. It is suggested by the Associated General Contractors of America (ACG)

that UAVs can document the projects' progress, providing a visual record being capable of reducing the later disputes between contractors and landowners; it can be eventually used to carry tools and equipment from one location to another, too. UAVs have the ability to cover a large area as well as collecting real-time images. As shown in Figure 2, they can capture data from various locations in a construction site. By using real-time images and videos, construction managers can create a relationship between pre-construction and construction phases.

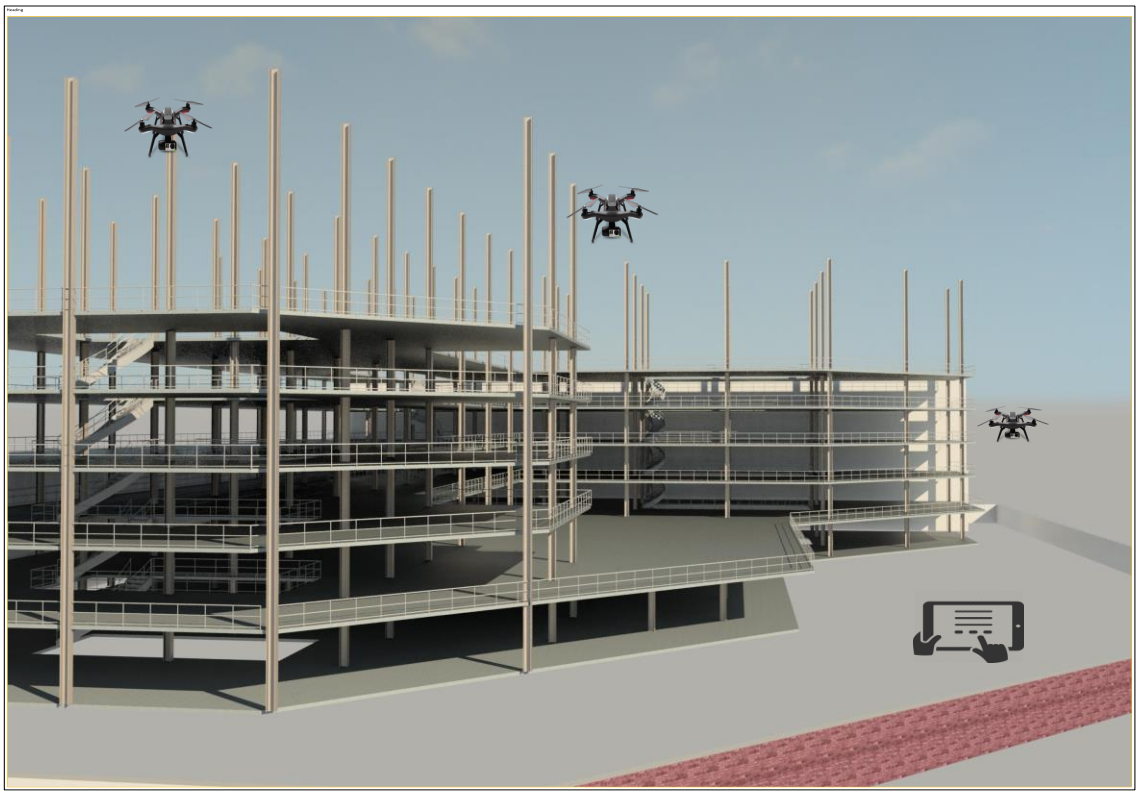

Fig. 2: UAV camera-based monitoring construction project

3.2 Damage Assessment

Detecting of damaged buildings quickly after natural disasters like earthquakes and hurricanes is an essential need for first response, rescue and recovery planning [29]. Remote sensing has been considered very useful for damage assessment, since it can cover large areas; moreover, the image-based assessments are understood faster than evaluation through ground-use of appropriately skilled surveyors [11]. UAVs have been used for inspection of damage on constructions because damage assessment in the construction is a significant factor. They can help engineers at the very beginning of the occurrence of damage. They can provide high-resolution imagery from various angles in an accurate and efficient way. As shown in Figure 3, Kerle et al. (2014) used UAV images for structural damage assessment.

Fig. 3: UAV-based Camera for Structural Damage Assessment [19].

3.3 Surveying

3D mapping is a very important aspect of geological surveying [30]. In recent years, the use of UAS for visual surveying as well as generation of 3D images of sites has steadily become relevant [8]. UAVs technologies can collect high-resolution images that are then transformed into 3D surface models and can be used for topographic mapping, volumetric calculations, or for showing the construction site in 3D form [31]. Many UAV systems finding application in the civil domain have already offered cost- and time-competitive alternatives to the conventional surveying applications [14]. At the construction phase, the same UAVs can be employed to provide a 3D bird eye view of the site, making efficient surface or volume measurements possible [32]. Since UAVs are equipped with video cameras, they can help engineers access images and videos from different locations of the construction site. They collect efficient images from large-scale site. The UAV is able to derive both geometry and texture data from UAV images [14]. Siebert and Teizer (2014) used UAV system to obtain 3D data for surveying earthwork projects. In addition, as shown in Figure 4, Boqin Zhu 2015 used UAV system to obtain aerial image from the site for surveying and mapping of the project.

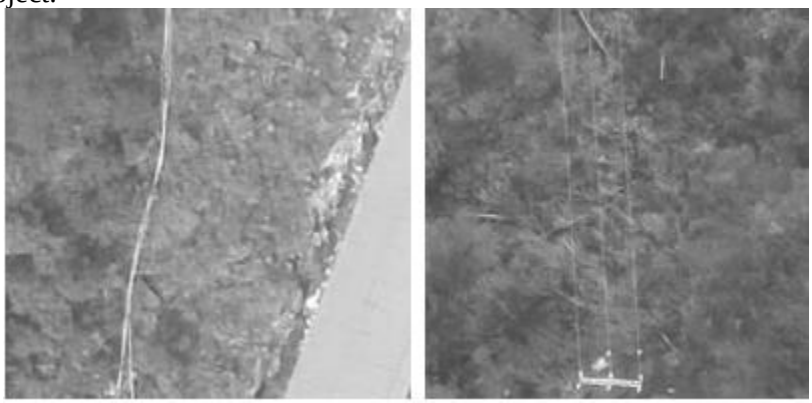

Fig. 4: Aerial images obtained from UAV [10].

3.4 Safety Monitoring

Research studies and statistics indicate that construction site is known as one of the most dangerous workplaces all over the world. The main concern in the construction industry is safety. Since there are high risks in construction and worker-hazard interactions are unavoidable, safety systems have been developed in order to prevent fatalities and accidents [33]. Nearly all accidents on work environment can be usually prevented through applying an efficient safety inception during the project. Worker safety would be enhanced through elimination of some of the high-elevation inspections now done with lift or scaffolding, such as inspecting caulking joints in a tall building's environment.

In recent years, a large number of articles have been published with a variety of technologies aimed to indicate the great potential for reduction of injuries on construction work site through reducing the unsafe situations in construction work. The construction site and worker/equipment safety has been monitored through using Radio Frequency Identification (RFID) technologies, Ultra-wide Band (UWB), Wireless Networks (WN), as well as BIM applications [34]. Furthermore, in recent years, UAVs technologies have been used in the construction site to collect real-time images and videos from different views and blind spots.

UAVs are very helpful to warn about the unsafe situations in large construction projects from site preparation to project completion. The new technology can fly over the construction environment collecting the real-time information from the location of personnel and equipment, hazards materials, moving equipment as well as the blind spots of the construction site in order to prevent unsafe conditions before happening of the accidents. In addition, it is especially useful to recognize the accident's location and injured workers in the project site for promoting safety. UAVs help safety managers become aware of the unsafe conditions or locations of the project existing in construction site. They are capable of presenting real-time feedback against hazards situations at any time. Irizarry et al. (2012) used an aerial drone flying all around the construction site and providing a safe management with real-time image and video about what is happening in the construction environment. Alizadesalehi et al. (2017) presented a safety-monitoring framework in the construction projects with using BIM and UAV technologies together [7].

As shown in Figure 5, in the construction part, the UAV technology is utilized to control safety rules. Following the construction's safety-rule checking during the construction process is helpful. By following these instructions in the construction stage, the safety of all stakeholders can be improved. This system has a potential to help designers, workers, as well as the safety managers decrease construction accidents and fatalities.

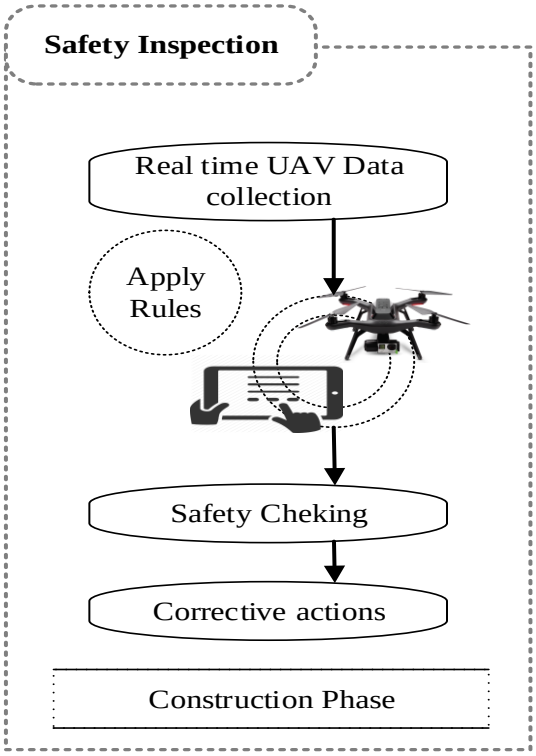

Fig. 5: Safety Inspection of Construction Projects

3.5. 3D Modeling

Three-dimensional (3D) models are essential tools for experts in different fields since they provide quality representations of as-built sites besides decreasing discrepancies between the design and construction phases [18]. Engineers need accurate data for generating 3D model. In recent years, the innovation technology of remote sensing and photographic measurement technology has played a significant role in 3D modeling [21]. UAVs are very helpful to collect image for preparing 3D building model. Due to UAVs' small size and maneuverability, they can collect data from very lower heights, starting from the surface of the ground, sweeping through the project at various heights and viewpoints, as well as fly-over views above the site [31]. As shown in Figure 6, Remondino et al. 2011 used UAV image for 3D reconstruction and modeling process.

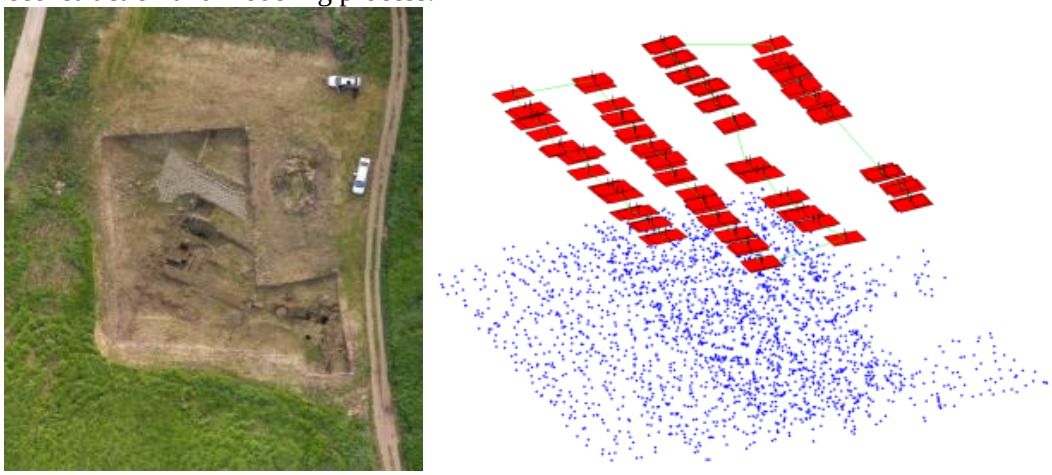

Fig. 6: Results of the automated image triangulation for the UAV block over the area of Veio, Italy (ca 35 x 20 m) [23]

4. CONCLUSION

In the building and construction industry, sustainable construction involves different issues including the design and management of projects [35] [36] [37]. In recent years, different types of technologies have contributed to improve the management of projects, which one of them is Unmanned Aerial Vehicle (UAV).

UAVs have been under development for years and now, their technology is becoming more mature. Civil engineering usually involves large-scale surveys to cope with uncertainties occurring before, during, and after construction. UAVs provide new opportunities for civil engineers to understand their projects or the problems they face. This paper summarizes state-of-art technologies related to UAVs, including control, navigation, power management, and image processing technologies.

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