Automation in Construction 94 (2018) 458–480

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Review

Feasibility study for drone-based masonry construction of real-scale structures

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ARTICLE INFO

Keywords:
Drone
UAV
UAS
Flying robot
Construction
Building
Masonry
Drick
Droxel
Additive manufacturing
High tolerance
BIM

ABSTRACT

The additive manufacturing of real scale structures using UAVs (drones) is a new discipline with challenges as wide as the possibilities it opens up for the future. UAVs must not be seen as the only way of robotizing future construction sites, but in combination with other kinds of robots. This adequate combination is indeed likely to reduce the influence of factors that usually badly affect the quality and profitability of construction projects, such as human factors, execution slowness, insecurity, insufficient communication between the stakeholders, weather conditions, strikes, lack of skilled labor, etc. The aim of this research, carried out jointly by MIT and UCLouvain since 3 years, was to lay the necessary groundwork, still not explored elsewhere, in order to prove the feasibility of building real-scale structures, in particular masonry structures, with big custom-built drones. In particular, the objective was to investigate the drones precision, their behavior while transporting, handling and laying loads, but also to draw the first guidelines for the design of "Drone compatible" construction elements: their shape, the way they should be assembled together, how to minimize their weight, how to connect them together, how to ensure their stability. This publication summarizes the work carried out so far in this field, provides the results of the laboratory tests and proposes development and improvement paths for the future. In particular, lab tests with a big drone assembling different kinds of more and more complex construction elements are commented. Several conclusions can be drawn from the study, the first one being that the research is worth going beyond the step of proving the feasibility. Indeed, it shows that using UAVs for the construction of future real scale structures is certainly not a utopia and is very promising. However, it requires further developments, not only about the drone themselves (guiding systems, handling systems, robustness, power supply), but also about the way to pass from the laboratory stage to the construction of real structures with a complex geometry, composed of slabs, walls, connections and finishing.

1. Introduction and objectives

The steady rise in labor costs, crossed with the decreasing prices of technologies has encouraged in recent years the development of new automatization processes in the field of construction. Technologies related to UAV (Unmanned Aerial Vehicle), also called drone, flying robot or UAS (Unmanned Aerial System) have undergone an exponential growth and have become much more affordable. Furthermore, this growth is far from being done, and projections show a flourishing future for the UAV industry [1].

For all the construction projects and still today, workers still use paper plans, which leads to mistakes, a lack of quality and a loss of time. In 2014, a survey from the ADEB (Association of Belgian contractors for major works) showed that, on construction sites, the lack of knowledge, of communication, of (auto) control and rigor is usually responsible for 5 to 13% of the total cost of a building.

Assembling buildings on a fully or partly automated process using UAVs, eventually combined with other kinds of robots, should allow a better construction management as far as the automated process can be directly linked to BIM models (Building Information Modeling/Management: [2, 3]). BIM is about gathering around a shared 3D model all the information concerning a construction project, in order to ensure a better communication and sharing of information between the stakeholders (Architects, engineers, contractors, clients, …). Linking BIM models directly to UAVs (and other types of robots, Fig. 1) should thus allow to bring many benefits to the constructions projects, such as:

- The reduction in construction time, and a better CO_2 balance;

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https://doi.org/10.1016/j.autcon.2018.06.015
Received 27 February 2018; Received in revised form 28 May 2018; Accepted 25 June 2018

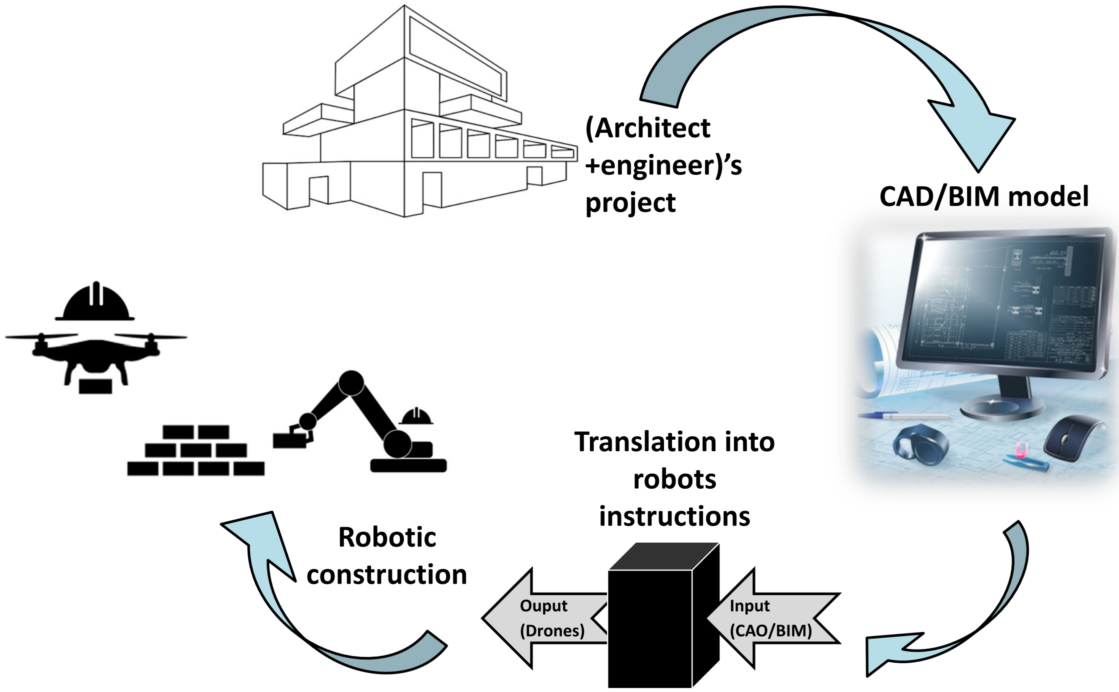

Fig. 1. BIM models could be directly translated into UAV flight (or other robots) instructions, allowing a fully automated construction process without the need to produce plans.

Fig. 2. Transportation of a long concrete beam by two synchronized UAVs.

- The reduction in the number of construction defects;
- The decrease of the impact of human factors;
- The futility of making paper plans;
- No use of cranes, which reduces the congestion inside and outside the worksite areas and facilitates construction in cities or in hard-to-reach places;
- The reduction of the painful work;
- The increase of the safety;
- A better profitability;
- A very fast construction process, combined with a quick access at any height, outside and inside the buildings, and to inaccessible areas;
- The possibility to link the automatic construction process with on-site computer vision-aided systems. This could allow the automated detection of components during the construction phase, and provide real time information about the quality of the construction by the means of a comparison with the BIM model [34].

UAV-based construction could be considered for many different types of buildings and different materials such as timber, concrete, steel or masonry. However, whatever the construction process, it must respect at least 2 constraints that leaded us to first consider masonry-based construction, which still remains today, in Europe and in many countries of the world, a widely spread construction process.

First, the mass of the construction elements should be limited to 100 kg, unless the drone become heavy and dangerous helicopters. The challenge is thus to succeed in building real scale buildings made out of a large amount of small and light elements. A combination with other non-flying robots should then be foreseen in all the cases where elements with a mass larger than 100 kg remain unavoidable. Secondly, the assembling process should take into account a position inaccuracy of the UAV of several centimeters, as a consequence of the wind or the imperfection of the guiding system. This inaccuracy is discussed further in this paper. The terms "UAV-compatible", "Drone compatible" or "DC" are thus used, in this study, to designate construction elements that respect these two limitations.

This article has not to be seen as an evolution where we would try to automate some existing construction processes. Conversely, it has to be