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# Infrared drones in the construction industry: designing a protocol for building thermography procedures

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**Abstract**

While a number of domains readily employ Unmanned Aerial Vehicles with infrared cameras (IR-UAVs), the IR and UAV research directions still need to be bridged in the construction domain. Our research aims to develop a protocol for IR-UAV flights to survey building thermography. Through a series of test flights and a literature study, the protocol was developed. The protocol was verified during a final test flight surveying PV-panels and the thermal shell of a building. By outlining the system, designing a protocol, and reflecting on our experiences, we contribute to the discussion to use IR-UAVs in the construction domain.


*Keywords:* unmanned aerial vehicle, drone, thermography, infrared inspection, protocol, zero energy building

## 1. Introduction

Recent advances in infrared (IR) thermal sensing and Unmanned Aerial Vehicles (UAVs) technologies makes them disruptive for existing businesses. Multiple industries, such as the agriculture and mining industry, already realized potential benefits of such solutions. However, the construction industry appears to be less aware of the possible advantages of combining UAVs and IR technologies.

By itself, the application of thermography on buildings is already a well-known practice, as thermography enables us to distinguish surfaces with different temperatures. Temperature data from handheld IR cameras can, for instance, pinpoint flaws in the thermal shell of buildings or electric problems in the meter cup board. IR cameras located on

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planes can be used for large-scale airborne temperature mapping to document temperature signatures on the scale of whole suburbs at once. Compared to the former approach, the latter is more encompassing, but it is also more expensive and less controllable. Yet, the logic how to use a combination of IR and UAV technologies as an IR survey solution is not clear. Developing a protocol how to perform thermography surveys is therefore needed.

Our paper provides analysis that offer input for this task. We operate under assumption that external conditions (including weather) allow to perform the survey. Methodologically, we performed a sequence of generic research steps, which are reported in the following sections. The next section outlines the theoretical background. Section 3 reports on applying system thinking to the system in which a drone is an integral part and presents the protocol. Section 4 reports on the flight performed according to the protocol. Finally, in Section 5 and 6 we analyse data, draw conclusions, and suggest future research.

## 2. Background literature study

Even though thermography and drones are well-known topics, they are not commonly considered together. Inferring benefits related to these two topics motivates combining their functionalities to obtain joined benefits.

The applications of *thermography* in civil engineering include the identification of heat losses [1] or water leakages [2] in buildings. For instance, cooling down thermography can help in identifying subsurface structural deficiencies. With the help of an IR-camera, Clark et al. [3] were able to identify delamination in a concrete bridge structure in the UK. Furthermore, it was possible to investigate the internal structure of a masonry bridge. Experimental evidence can suggest that some sub-surface cracks are not detectable to the naked eye and thermographic analysis can better represent the baselines of the damages produced by an earthquake [4]. As a consequence, Bisegna et al. [5] developed and tested a method to use IR-thermography to spot weak points in ancient wall structures. In this way, the thermography serves a range of applications from identifying heat losses up to the non-destructive testing of structures.

Noticeably, IR surveying is a complex process, as there are three modes in which the energy is transferred to the inspected object or is generated from it [6]: 1) reflection, in which energy is delivered to an object from the same side from which data are recorded; 2) transmission, in which energy is delivered to one side of an object while observing from the opposite side and; 3) internal, in which thermal energy is generated or converted internally while data are collected from either side of the object. Therefore, it is not an easy task to make sure that material-related parameters (like emissivity, color, temperature difference, and thermal reflection) do not unintentionally influence thermographic testing, as noted by Barreira and De Freitas [7].

Moving to the second topic, there is a range of *drones* that can be described, for example, in connection to the altitude they fly at or the endurance of their flight [8]. Liu et al. [9] studied the potential of UAVs to facilitate applications in the field of civil engineering. They concluded that the advantage of UAVs in comparison to traditional data acquisition methods is the timely, versatility and flexibility to collect detailed imagery data in a wide geospatial extent. In a relatively rare example of applying IR-UAVs, Lega et al. [10] demonstrated contamination monitoring in the surface waters. Regarding PV-systems or so called 'solar parks', IR-UAVs can help to identify malfunctioning cells or broken electric circuits that show anomalous thermal behaviour [11].

Altogether, while a number of UAVs and IR procedures are already available for their use, IR-UAVs make only initial steps in the construction domain. It is therefore important to account how to employ IR-UAVs in the future. It is possible that applications can be found on the intersection of IR and UAV use cases described in this section. A protocol how to fly IR-UAVs safely, effectively, and efficiently can help designing procedures to use such drones.

## 3. Designing a protocol

To construct a protocol for IR-UAVs, we scheduled a number of field activities. The main focus of these activities was to become familiar with specifics how a drone equipped with a camera should be controlled. For this, we observed how skilled pilots operated their drones and visited several UAV manufacturers. In particular, a video production company, skilled in shooting movies using an UAV, performed a flight in a residential area (see Fig. 1). The utilized UAV system, a DJI Phantom 2 with a Go Pro 4 camera, is a solution affordable to a large audience. Besides, two manufacturers kindly demonstrated the use of their professional drones: at an abandoned airport and at an industrial area. These initial flights, performed in the beginning of this research project, provided multiple insights in the behaviour of a drone and a number of important elements to devise drone surveys were noted.

Figure 1 shows what forms of dynamic interaction can be observed, when flying a camera equipped drone. As