THE ADVANTAGES AND LIMITATIONS OF UAVS FOR EXTERNAL THERMOGRAPHIC BUILDING FAÇADE INSPECTIONS IN CANADA

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ABSTRACT

Regular building inspections and retrofits ensure continued thermal performance of building envelopes. Thermographic imaging equipment, also known as infrared cameras, has established an important role within these processes. Current practices for thermographic building envelope inspections, involving both internal and external surveys, are time consuming. Traditional means of collecting external imagery often provide only an overview of each façade, missing smaller details and defects which require higher resolution imagery that cannot be taken by unaided ground crew or traditional lift equipment in most cases. Depending on the size and height of a structure, a comprehensive thermographic inspection of all façade elements becomes a tedious and disruptive process.

Small unmanned aerial vehicles (UAVs) stand to provide a cost effective solution for the capture of comprehensive external building façade imagery. However, the use of thermographic imaging sensors for external façade surveys requires special consideration for environmental parameters and the subject's surroundings, and the use of a UAV requires compliance with Canadian Aviation Regulations.

This paper showcases the utilization of a UAV carrying a thermographic sensor for qualitative external thermographic building envelope inspections and energy auditing purposes. Current methodologies will be discussed and compared to initial field results. The impacts and benefits, current limitations, and regulatory requirements surrounding UAV deployment in Canadian airspace will also be discussed.

INTRODUCTION

Space heating and cooling in residential, commercial, and institutional buildings accounted for roughly 20% of Canada's overall energy use in 2010 [1]. Energy audits and regular building envelope inspections help to ensure defects and anomalies within the envelope are identified and retrofitted or repaired quickly, helping to maintain the overall thermal performance of the envelope for the duration of the structure's lifespan.

External passive thermography surveys have become a popular method in this regard. Unlike other methods, little to no access inside the structure is necessary, and a thermal stimulus, such as a heat lamp is not required. As a result, these surveys can be performed frequently, with little impact on building occupants [2,3,4].

Commonly misunderstood, thermographic sensors, also known as infrared cameras, do not provide direct surface temperature measurements, but rather, based on the infrared radiation sensed, an approximated temperature based on black body radiation theory and Plank's law. The sensitivity of today's infrared cameras is as low as 20 mK, providing a very detailed thermograph; a 2D image representing the apparent temperature gradient of the subject, highlighting minute thermal anomalies [5].

Unmanned aerial vehicles, UAVs, also known as drones, are remotely operated aircraft providing researchers with a unique opportunity to collect aerial imagery for a fraction of the cost of traditional methods, and with much greater operational flexibility at a local scale. In particular, small multi-rotor UAVs, capable of vertical take-off and landing and the ability to hover in midair, are rapidly being explored as a platform for affordable, flexible, and timely aerial imagery.

CURRENT IN-SITU THERMOGRAPHIC SURVEY PRACTICES

Although some energy audit methodologies use theoretical building construction properties such as nominal U-Values in their evaluation of a building, it is commonly accepted in literature that these values often differ greatly from the measured in-situ values of a built structure. Likewise, the emissivity of façade materials, a property which describes the ratio of infrared radiation emission and reflection, also changes over time due to wear and exposure to the elements. As a result, it's imperative that energy audits be performed in-situ to ensure the most accurate representation of the buildings performance [6].

Current standards for thermographic study of structures instruct the thermographer to conduct a preliminary investigation into the building's construction, noting expected defects for a given construction type. An initial sweep of the structure can then be completed with a thermal imaging system to locate any thermal anomalies which may warrant further investigation [7]. Each type of defect, whether delamination of cladding, damaged or missing insulation, or moisture penetration, may only be visible under certain heat transfer regimes, or at specific points within a regime, thus the thermographer must also consider the heat transfer regimes of the structure and each façade to appropriately time thermographic surveys [8, 9].

The thermographer must also determine the most appropriate positions from which to capture the thermographic imagery. The sensor must be positioned close enough to the subject to observe the expected size of defects, too far from the subject and the thermograph will lack the resolution necessary to discriminate the defect from its surroundings. Images must be taken from a viewing angle that make the defect visible, often this is perpendicular to the surface under study. The surroundings of the subject must be considered, as no subject will be a perfect black body. Some portion of the sensed radiation will be reflected radiations from nearby surfaces and the sources of these reflections must be identified to minimize the potential for false positives in the interpretation of the final thermographs [10].

IMPACTS OF UAV TECHNOLOGY ON EXTERNAL SURVEY METHODOLOGIES

Small UAVs, particularly those capable of vertical take-off and landing, VTOL, known commonly as multi-rotor aircraft, have the ability to fly to and persist at viewpoints not previously reachable by traditional ground crews and equipment. This gives the operator unprecedented flexibility, when conducting thermographic surveys, to position the camera to overcome obstructions and reflections from

nearby buildings and other radiative sources. As shown in Figure 1, a traditional survey from ground level is unable to capture a recessed third floor façade element due to an obstruction from another building section. Figure 2 shows the subject element as viewed from the UAV hovering ten meters above the ground crew's position. In each figure the same concrete member of the structure is marked with a black line.

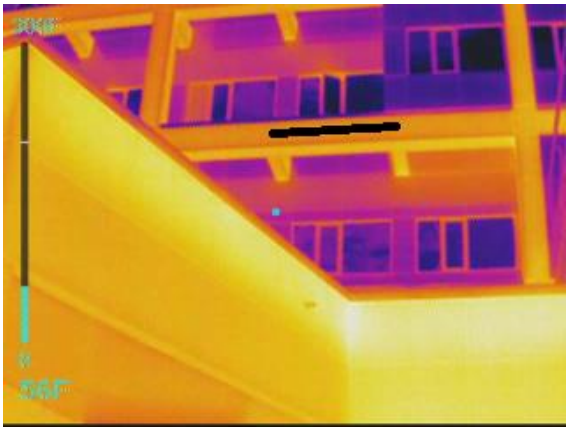

Figure 1: Thermograph captured by traditional ground crew

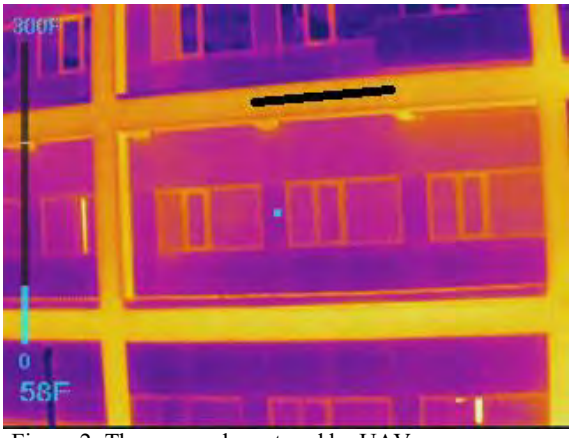

Figure 2: Thermograph captured by UAV

When conducting audits of taller structures, where only internal surveys were possible for the upper floor façade elements, a UAV can collect comprehensive imagery of most, if not all external surfaces. In addition, when thermal anomalies are found, the UAV can be maneuvered closer to the subject to verify the anomaly and document it with greater resolution, or identify a false positive created by reflections.

Today's flight controllers, the small onboard computer controlling the aircraft, offer powerful automation features, which can further minimize the time required to conduct a survey. Automation allows for collection of data in a repeatable and consistent manner, ensuring survey parameters such as viewing angle and distance from subject façade, are kept near constant while surveying both flat and curved building elements.

REGULATORY CONSIDERATIONS AND LIMITATIONS

All transportation activities in Canada, whether by ground, air, or sea, are overseen by Transport Canada, a federal body mandated to create policies, standards, and regulations to ensure public safety and mitigate risk. To address the recent rapid expansion of the consumer UAV market, a number of regulations and policies regarding the commercial and research application and deployment of UAVs within Canadian Airspace have been developed in the interest of public safety.

As an initial proof of competence, UAV operators are to apply for and secure a Special Flight Operations Certificate, or SFOC. This legal agreement between the operator and Transport Canada will stipulate a number of conditions and procedural requirements of the operator prior to flight to help ensure a safe operation. In addition, operators must know and comply with other applicable laws, including but not limited to the Canadian Aviation Regulations (CARs), BC Trespass Act, and the Canadian Privacy Act.

For novice operators without a proven record with Transport Canada, these conditions can be quite

restrictive in comparison to the true capabilities of today's UAVs. This may include restrictions to Visual Line-of-Sight operations only (VLOS), in which the operator must maintain un-aided direct line of sight to the aircraft at all times during the operation, potentially preventing a complete external survey from a single launch point as discussed previously, and lengthening the overall survey time, and complexity of flight plans.

Additionally, all operators are required to have a working knowledge of the management of Canada's National Airspace, a fundamental understanding of the principles of flight and the operation of their aircraft. They will be required to create and use checklists, placards, and standardized and documented operating procedures to ensure consistent execution of risk mitigation activities, while integrating themselves into Canadian airspace through collaboration and authorization with local air traffic controllers and other aviation authorities. The operator is also required by law to acquire and maintain a liability insurance policy for their flight operations, in the event of injury or damage to property.

CONCLUSIONS

With the rapid development of unmanned aerial vehicle technology, UAVs are proving to be a reliable, cost effective platform for the collection of aerial imagery. The maneuverability of multi-rotor UAVs and the ability to hover in place give thermographers and building inspectors a powerful new tool for the external inspection of building facades. Utilizing UAVs, inspectors can now survey external elements previously out of reach of traditional ground crews and equipment, reduce the impact to building occupants, and pave the way to automated, repeatable external building inspections in the future. However, inspection teams will first need to tackle the requirements of Canadian UAV Regulations before being able to utilize these machines.

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