UAV Photogrammetric Thermography  
For Building Performance

A Prototype

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***Abstract*— The following paper presents a prototype utilizing the theoretical concept of drone image acquisition of visual spectrum energy (RGB images) and Infrared spectrum energy (IR; thermal images) for the purpose of producing 3D thermographic models in modern photogrammetry software. Preliminary findings indicate %%%%%.**

***Keywords—*** *UAV, drone, photogrammetry, thermal, thermography, IR, structure-from-motion, model, infrared, unmanned aerial vehicle.*

# I. INTRODUCTION

Population growth, resource depletion, climate change, and technological advancements have begun to move the public general consus toward consideration and the advancement of conservation. The United States of America's Environmental Protection Agency (EPA) defines sustainability as “creat[ing] and maintain[ing] the conditions under which humans and nature can exist in productive harmony to support present and future generations” [EPA 1]. The EPA has four focus areas for improving sustainability: (a) energy efficiency, (b) green infrastructure, (c) sustainable materials management, (d) sustainable purchasing and products [EPA 2]. Resource efficiency is becoming a desirable trait for architects in proposing new or renovating existing structures. To ensure transparency and legitimacy, several organizations have been founded to certify the quality of building efficiency (e.g., Energy Star, Leadership in Energy and Environmental Design, Green Globes and, Living Building Challenge). The present research focuses on green infrastructure and improving the rate of examining existing structures for energy loss. A quadcopter is a four propeller based helicopter and we consider it a type of unmanned aerial vehicle (UAV) and when it is autonomous classify it as a drone. We evaluated the use of a semi-autonomous quadcopter outfitted with a radiometric thermal camera, to photogrammetrically construct a three-dimensional model of a target building for heat transmission evaluation.

# II. RELATED WORK

## A. Photogrammetry / Structure-from-Motion

Photogrammetry is the use of multiple photographs to extrapolate distances between corresponding points. Photogrammetry has been identified as a reliable source of creating three-dimensional geometry of structures, even in recent research (2016) with the use of crowd sourced photographs on the world wide web [Pejic].

Criss, South, and Levy [Criss] theorised the use of photogrammetry to extrapolate coordinates with UAVs, using an example of the General Atomics MQ-1 Predator. This theory of using UAVs to collect photos for analysis has been identified as an accurate means of deriving dimensional coordinates and creating three-dimensional geometric models [Jizhou] [Remondino] [Eisenbeiss] [Zongjian].

## B. Thermography

Thermography has two primary camera types related to examining thermal transmission, radiometric and non-radiometric. Radiometric cameras are used to measure the temperature of the whole image, whereas non-radiometric measures the temperature of a single predetermined point of the image.

## C. Photogrammetric Thermography

Mohammed Hafez...

Geography paper...

HeatWave…

Analyst Group...

# III. BACKGROUND

## A. UAVs

During the 90s and the 00s, UAVs were prohibitively expensive and, in the United States, were the strict domain of the military. Hobby grade UAVs during this time were comprised of airplanes and traditional helicopters. It was in the years of 2008 and 2009 that there was a surge of interest in the quadcopter due to the appearance of hobby grade products at hobbyist prices [Drone Report 2016]. The rise in hobbyist purchases, increased production of quadcopters and over a few years reduced the retail price of commercial drones.

The history of UAVs, drones, and quadcopters is important for illustrating why research utilizing such products is limited to the last decade.

## B. Thermographic Cameras

# IV. METHOD

## A. Equipment

Two drones were used during this project, each with their own digital camera to capture visible energy: a Parrot.AR Drone 2.0 with a Canon EOS 7D, and a DJI Phantom 2 Vision+ with OEM camera. A single FLiR Dev Kit breakout board with Lepton LWIR Imager connected to an Arduino microcontroller was shared between the drones to capture IR energy. Both drones were mounted with the cameras and used to acquire video footage of the target structure. The video footage was stored on a micro SD card and then transferred to our computer. A %%%%% laptop computer with Universal Ground Control Software (UgCS; SPH Engineering) was used to design the navigation path of the drones.

Video footage was processed using ffmpeg and stills extracted using a Python script at a rate of %%%% images per second. Once the video has been discretized into a set of stills images they are subsequently imported into Agisoft PhotoScan. PHOTO SCAN METHOD.

## B. Project Timeline

Prototyping was divided into milestones as a check and balance system to help keep the project on task and reduce any potential for error or bias in the data collection phase. Prototyping milestones were based on standard software development lifecycle (SDLC) project milestones.

Alpha Milestone:

* Visible energy infrastructure established
* Drones used to capture visible energy videos
* Select frames stripped from same videos
* Frames passed to photogrammetry programs
* Photogrammetry programs evaluated with multiple datasets
* Crude 3D models viewable
* Upscaling image experiment performed to test viability of upscaling IR (thermal) images
* Presentation of current status
* Formal research paper 40% complete

Beta Milestone

* Thermal energy infrastructure established
* Thermal camera breakout board connected to parent controller, tested, and configured
* Thermal videos extracted
* Thermal camera radiometric calibration experiment and verification
* Automated process for upscaling of both visible and thermal images
* Drone path programmable or specified
* 3D models of visible energy
* 3D models of thermal energy
* Presentation of current status
* Formal research paper 80% complete

Gold Milestone

* Automated/smooth pipeline from capture to 3D model of both visible and thermal
* Final 3D models of visible energy
* Final 3D models of thermal energy
* Demo video of visible to thermal transition
* Final presentation
* Formal research paper complete
* Representative Images Document

# V. EXPERIMENTS

Given that %%%%%%% drones have a limited flight time (approximately %% minutes) due to the limitations of its battery, several surveys were collected over a period of days to complete the photogrammetric set. Images of a single planar surface were collected during the same survey to reduce distortion and error.

# VI. RESULTS

Begin

# VII. CONCLUSION

Begin

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