Drogon, the Thermal-Sensing Drone: Exploring Aerial Imagery as a Tool for Citizen Science Research

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Abstract
New developments in low-cost and widely accessible drones have the potential to radically transform the existing mechanisms for citizen science data collection, scientific analysis of the gathered information, and the broader impacts of drone-based projects on science activism. In this paper, we present Drogon, a thermal-sensing drone, which was used in an initial data gathering and co-design workshop with a group of conservation researchers, policy makers, and citizen scientist volunteers. Our findings reveal three concrete directions for future thermal drone-based citizen science projects. In addition, we reflect on higher-level design opportunities and challenges for working with drones in a citizen science context, including systems for expertise sharing amongst citizen scientists and platforms for collecting, analyzing and sharing drone-based data.

Author Keywords
Drone; thermal sensing; citizen science; co-design

Introduction
Citizen science has a long history [1] and recent breakthroughs in DIY (do it yourself) methods, low-cost technologies, and social media platforms have led to new forms of scientific participation and civic engagement.

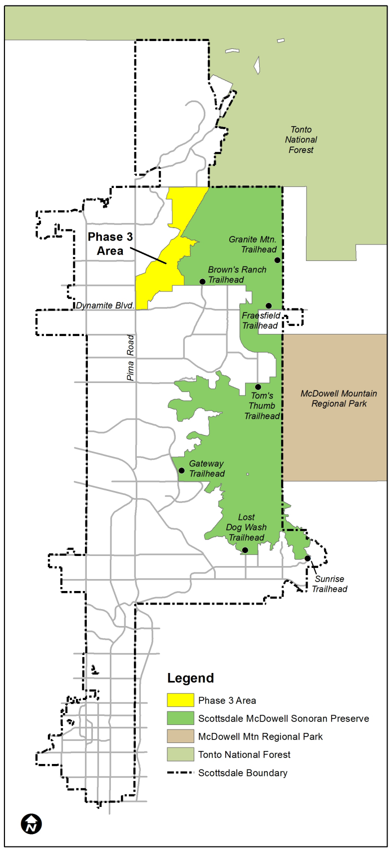

Figure 1: The 30,000 acre McDowell Sonoran Urban Preserve in Scottsdale, Arizona. This areas' ecological diversity is being threatened by intrusive developments and requires large-scale data collection methods for further preservation initiatives.

Within this domain, HCI research has focused on participatory sensing as well as the broader questions around expertise sharing and community activism that arise from public participation in science [e.g., 2, 4]. We contribute to this research by exploring the challenges and opportunities for incorporating drones into community-based citizen science initiatives.

Related Literature

Although most drones are not designed specifically for citizen science, communities have benefited from them as. For example, environmental groups have mapped rain forests for signs of deforestation [10], and drones have also been labelled as "game-changers" for wildlife population monitoring [9].

In addition, citizen scientists have created and modified drone data recognition programs for their specific applications, customizing and automating certain processes. Work by Jan Gemert presents an example of this, whereby an algorithm was designed to process data recorded by the drone and automatically pick out specific species of animals that have been captured by the camera. The automation of this process greatly increases the ability to capture large surveys of animal-populated land over time [7]. This same automation process has been seen in regards to studies of plant cover over large areas of land. While traditional methods of field research may require days of work to complete the surveying task, a drone is able to accurately scale these large areas in a much shorter amount of time [8].

Building on prior design research on community-based citizen science, [e.g., 3], our work leverages community-based envisioning activities to examine the challenges and opportunities for drone-based thermal sensing projects with a local nature conservation group.

The McDowell Sonoran Preserve

The Scottsdale McDowell Sonoran Preserve is the largest urban preserve in North America, located in a desert in the southwest (Fig. 1). With over 100 miles of accessible trails, this rich terrain also features many unique species of plants and animals which call this habitat their home. Over the last decade, a substantial increase in development around the preserve boundaries has caused an unwanted amount of noise and traffic negatively affecting these species that inhabit the area. The increasing traffic, road noise, and microclimate variations, and their effects on wildlife in the corridor have been a focus of many current citizen science projects.

Thanks to various field research endeavors partnering the conservancy at our University (Fig. 2), we have collected evidence that these man-made areas are having negative impacts on the local ecosystem. By placing camera traps and microphones in hotspot areas, we saw a that areas closer to the highway/urban developments yielded less variety of species. Another project, which involved placing 32 trackable collars on the local mule deer population displayed that only 1 of those 32 deer crossed the busy highway over the course of the month. Long-term effects of this refusal to cross the highway, which runs through the preserve, could lead to breeding issues of the mule deer population as they remain separated. We partnered with the preserve to explore how drone-based thermal sensing could improve current data collection and gather new information for existing and future citizen science projects.

Figure 2: Current conservation endeavors include microphone boxes collecting long term psychoacoustic data.

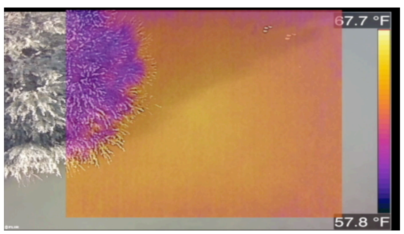

Figure 3: Thermal imaging overlays digital imaging from the FLIR Duo camera

Figure 4: First flight at the aerial imaging workshop held in the McDowell Sonoran Preserve

About Drogon

Drogon is a custom-built drone based on the DJI Matrice developer model [5] that utilizes a modular base system which allows the payload to be customized for the users specific application. The drone's capabilities currently include a gimbal stabilized 4K DJI Zenmuse camera while simultaneously running one of our two FLIR infrared cameras [6] hand-wired to receive power from Drogon's battery. The FLIR Duo Pro contains both a thermal lens as well as digital lens, blending the two for a "critical edge" overlay on thermal images and videos, allowing the observer to distinguish the smallest details from hundreds of feet in the air. The Duo comes with spot detection and records surface temperatures for each pixel captured in-flight in radiometric JPEG format. FLIR Tools, a free post-processing software, supports manipulation of radiometric JPEG images and videos. A temperature threshold may be set so that each image only displays areas of a certain temperature, all while selecting spot points to compare and contrast certain locations in that scene. If desired, this data list may be sent out in a CSV data file for other processing (e.g., using MatLab).

Community Design Workshop

To envision current and future conservation applications for aerial thermal sensing, a community-centered design workshop was held with 12 people (4 female, ages mid 30's-late 60's) who are either volunteers at the preserve or serve as Scottsdale city officials. This workshop (lasting 3 hours total) began with a hands-on setup and flight of Drogon to capture thermal imagery, which was then explored by participants using the FLIR Tools application. After guiding participants through the software and its capabilities, a structured individual brainstorm was held to ideate possible citizen science initiatives that could benefit from thermal aerial data. Individual ideas were organized into higher-level categories, and participants split up into groups to explore one of the higher-level project themes in detail. Participants developed a potential workflow for data gathering and analysis for each of their desired topics, as well as any future sensing or drone interface tools, which would help streamline their projects. Audio from the workshop was recorded, transcribed, and open-coded into themes. Our findings revolve around the three main drone-based citizen science project concepts from our workshop.

Findings: Drone-based Citizen Science Projects

Water was one of the key concerns shared by all participants during the workshop because of the preserve's fragile desert ecosystem. They emphasized applying the drone in exciting monitoring efforts in order to "*map what we would call ephemeral water...because wildlife in the desert is adapted to finding what water is available*." (P2) Participants proposed collecting survey images after periods of rainfall to monitor water retention and flow. In addition to the existing thermal camera, participants proposed also using regular aerial images to refine the data and obtaining software to create high-contrast color images of the target areas. They discussed processing the data alongside volunteer observations on the ground to gain deeper insights into their research questions around water and wildlife conservation.

Wildlife is a special concern in terms of conservation for the preserve due to its surrounding urban environment. Wildlife species co-exist with man-made objects and activities, and without careful planning for both, this can prove harmful. One example of how this issue was discussed in our workshop is: "*how does human use affect the deer movement through the area*?" (P7). Participants developed a project workflow around this question beginning with flying the drone over heavily-trafficked

Figure 5: Lush plants and wildlife cover the ground of the McDowell Sonoran Preserve [11]

trails to document the usage of that trail for humans versus deer. Following consistent flights and robust occupancy results, volunteers suggested, "*to have an algorithm that includes time of day, time of the season, and the actual weather responses, and then we can attach that traffic volume information to each deer location and do a bunch of analyses that we normally do for roads all the time*" (P4). The proposed drone in this instance would allow easy large-scale surveying. The collected data could be analyzed to develop new trail policies based on specific deer movement and to effectively answer the question, "*Where's the ideal place to put it [a human trail], and how much of a buffer [around it] do we need*?" (P5)

Plants are significant in this desert landscape, especially because of the wildlife and broader ecosystems they can sustain. In fact, our park volunteer participants reported that much of the current conservation work focuses on removing invasive species of plants before they can negatively impact the ecosystem. "*I think one of the things that we were discussing is, if it's a dense grass in a wash, it's probably fountain grass, with a little mixture of the buffelgrass…*" (P1). This variation in grasses could be easily visible during drone flyovers, along with suggestions from the participants such as "*multiple cameras so we can look at the different spectral signature or heat or standard color too*" (P2). With these combinations of sensors and proper flight planning for effective data collection, aerial imaging could greatly increase the rate of invasive plant removal from protected areas.

Design Implications and Future Work

Through a series of test flights and co-design workshop with scientists, policy makers, and volunteers in a local nature conservation group, our work explored the challenges and opportunities of using thermal-sensing drone technology in citizen science efforts. On a very practical level, our findings reveal three concrete directions for future projects to incorporate aerial imagery into existing citizen science monitoring projects at the preserve, focusing on water, wildlife, and invasive species monitoring. These areas present logistical challenges of obtaining flight permits and the non-trivial technical challenges of working with drones during remote fieldwork (e.g., battery life, operating flights at high temperatures in the desert, checking data quality in the field). At the same time, there are many new and exciting opportunities for design, including drone flight-planning software for specific types of data collecting, development kits for easier augmentation of drones with additional custom sensors, systems for analyzing and sharing hybrid data that incorporates aerial imagery with human observations and on-the-ground sensors, and the broader impacts of this work on policy (e.g. trail development in the preserve).

Moving forward, our work will implement citizen science projects across the three areas suggested by the stakeholder community. We will also explore the privacy issues and public concerns associated with aerial mapping of the Preserve. We expect to develop several new interfaces that will scale and generalize to other citizen science efforts beyond our work, including a plug-in for easier flight path planning to target data collection sites; data sharing applications that produce geo-referenced aerial images that could be superimposed over other GIS (map) data of the preserve; and mechanisms for more broadly sharing the findings with policy makers and the general public. Above all, our work presents a critical first step towards applying design research to envision drone-based citizen science data collection, scientific analysis of the gathered information, and the broader impacts of drone-based projects on science activism.

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