Preliminary Evaluation of Dog-Drone Technological Interfaces: Challenges and Opportunities

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Abstract

In many of the applications involving working canines, such as search and rescue operations and agriculture, drones are increasing in ubiquity. There has been some recent focus on training dogs to follow or interact with drones in such applications. From the Animal Computer Interaction (ACI) perspective, drones have the potential to monitor the dog's welfare when handlers are not in close proximity in such harsh environments. Our on-going work has focused on canine welfare through the use of on-body sensors for monitoring behavior, physiology, and the *micro-environment* dogs are in. We have also used these technologies to explore computer-assisted training of canines and more recently included drones to complement these to assess the *macro-environment* dogs are working in. This work discusses the challenges and opportunities we learned during our efforts to include drones for computer-assisted interactions with working dogs. We focus on the enabling technology and its implications for ACI when dogs and drones work together.

Author Keywords

ACI, animal-computer interaction, dog-drone interaction, wearable EKG, activity level, computer vision

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H.5.m [Information interfaces and presentation]: Misc.

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Sensing Paradigms for canine-welfare

- Drone (remote-off-body)
 - Macro-environment
 - Movement
- Smart Harness (on-body)
 - Behavior
 - * Posture
 - * Movement
 - Micro-environment
 - Physiology

Introduction

Canine welfare while working is the responsibility of humans, and micro-air-vehicles (UAVs or commonly referred as “drones”) have a great potential to provide eyes in the sky to ensure their safety, security, and comfort. For example, drones and dogs are generally used for scent detection tasks in larger areas where drone-based macro-assessment of the environment can enable labeling the regions according to their hazard levels and relevance to the task to make the such detection tasks easier and safer for the dogs. Beyond monitoring, these remote controlled flying machines can also function as flying robots by incorporating necessary algorithms into their avionic systems and provide a new platform for animal-machine, animal-robot, or animal-computer interaction. For example, dogs can be trained to visually track automated drones to be led away from hazardous regions and into regions of interest when immediate human guidance is not available.

Given our prior work indicating the benefits and limitations of both on- and off-body sensing in ACI [4, 5, 6, 7, 9, 10, 12, 15, 16, 17, 18], we believe that the real benefits for “dog welfare” in dog-drone partnerships comes from the fusion of on-body monitoring with wearable sensors and remote monitoring with UAVs. While wearables monitor behavior, physiology, and the *micro-environment*, drones monitor *macro-environment* dogs are working in. The belief is rooted in the knowledge that behavioral and physiology sensing is not yet feasible from a distance, but is critical to characterize affect, temperament, and health. Further, monitoring of dogs’ interactions with the broader environment is challenging with wearables, but enables improved welfare and safety due to remote sensing capabilities of UAVs.

In this publication, our aim is to bring both an ACI perspective to technology development and technology perspective

to ACI exploration as we define our next generation dog-machine interfaces. To demonstrate our stance, we discuss what we learned from our recent exploration in this ACI space and highlight the barriers we identified on dog-machine interfaces that includes wearables for on-body sensing and drones for remote monitoring of the dogs.

Background and Previous Work

As noted in [21], the majority of the previous work concerning dog-drone or dog-robot interactions was focused on SAR scenarios. Drones have been integrated into canine search strategies and tactics to develop more effective and safer tracking solutions [2]. Dogs have also been trained to follow a drone or receive commands in such scenarios [21, 13, 20].

A notable computer-networking-focused project, based in Europe, was *Synergistic Interactions in Swarms of Heterogeneous Agents* (SWARMIX). It focused on the SAR application, using “swinglets” to automatically scan an area using computer vision where the software also tracks human-canine teams using drones and communicate areas of interest to the human handlers [3]. Previously, our team participated in the US-based *Smart America Challenge* in 2013, organized by the White House in which a *Smart Emergency Response System* (SERS) was developed connecting cyber-physical technologies (robots and drones) with humans and instrumented dogs to save lives in disaster areas [8, 15]. In this, we developed a canine harness with sensors to monitor the disaster area with cameras and gas detectors as well as vibration motors and micro-speakers to communicate sound and tactile signals to the SAR dog. Drones established a Wi-Fi network and provided an overhead view of the canine and disaster area. Command/control center software developed by MathWorks connected dogs, drones, and other ground robots [1, 19].

Figure 1: Two labrador retrievers wearing our custom harness awaiting command and watching a drone.

Figure 2: Custom software segmenting and classifying drone acquired movements of two labrador retrievers wearing the custom harness.

Technological Interface Challenges

Maintaining an *ACI* perspective requires that drones not only be used to achieve missions prescribed by human controllers, but that a focus on *the welfare of the canine using a dog-centric perspective on dog-drone interaction* is paramount to developing pragmatic and safe technologies [21]. As a result, the dog-drone technological interface we outline here also encompasses the physical on-body sensor suite worn by the dog to be aware of its behavior, physiology, and environment on a micro-level to enable welfare monitoring with high fidelity.

Drones

The commercially-available quadcopter products are the easiest solution to be used as UAVs due to easier lift off and landing, enhanced maneuvering capabilities, and slower operational speeds for close-proximity operations. It is important to ensure proper habituation in canines as well, in order to avoid (undue) stress [21]. Currently, drones are limited to short flight times due to power consumption and smaller light-weight batteries. The larger and increased number of rotors increase flight duration but may induce more stress due to the visual appearance and the auditory noise they generate. If the drone is used as a data collection and transfer hub for aggregation or relay, it would require a larger battery and decrease flight time due to increased weight. Such drone-dog missions should consider the flight time of the drones, the noise it generates, the size of the machine as well as the healthy working duration of dogs in the particular environment for the particular task.

Commercial UAV software is generally used to obtain visual images/videos of dogs for remote handlers. The UAV models currently available are not capable of both providing automated tracking of the dogs and collision avoidance capability simultaneously. Based on our evaluation,

the UAV models that use visual image processing (such as the Mavic Pro from DJI) come with better collision avoidance but fall short in tracking the dogs efficiently. If the dog disappears from the visual field, *e.g.*, when going under thick brush or tree canopies, the software ends up losing the track, and is unable to re-acquire it when the dogs return to view. The tracking algorithms also confuse the dog and human handler when they work closely, even if their images don't overlap. The devices that use radio or GPS transceivers worn by dogs (generally as a collar) do a better job of tracking the dogs, but fail in providing efficient collision avoidance (such as the ADII from Airdog). Manual performance of these tasks could overwhelm a drone pilot—the best implementation is through automation. Therefore, there is a need to develop application specific drone control software that automates collision avoidance *and* tracking capability, potentially customized to the operational environment (Fig. 2). As an eye in the sky monitoring dogs' working environments, these software solutions should also provide automated detection of the behavioral cues from the dogs that indicate degrading welfare and assess the regions that would be hazardous for dogs to work in.

Sensor-Equipped Canine Harness

On-body sensors give the most accurate and highest resolution data related to the micro-environment, physiology, and behavior of the dogs to support the drone-based macro-assessment for dog welfare. To begin, although the harness is a familiar form-factor to working dogs, a habituation period and process should be introduced. For safety, all electronics and wires should be hidden inside custom pockets and sleeves specifically designed to evenly distribute the weight across the median plane for comfort [9, 10, 12]. The harness would house an ultra-small computer, which collects and transfers data wirelessly to a central hub or the Cloud. Attached to the computer, a cus-

Figure 3: Custom PCB for behavioral, environmental, and physiological data acquisition.

Figure 4: 3D-printed canine-specific electrodes.

tom miniaturized circuit is needed to collect activity level data via an inertial measurement unit, environmental information including ambient temperature, relative humidity, barometric pressure, levels of dangerous gasses (such as methane or propane) via commercially of the shelf sensors, and electrocardiogram signals through contactless or skin-attached electrodes (Fig 3 and 4). The harness would carry a forward-looking camera to record the visual appearance of the environment. Based on our experience, less than half a kilogram of weight should be added to the commercially available harness to induce no observable adverse behavior with adult dog breeds used in SAR applications.

The battery selection to power electronics comes with a trade-off between power capacity and size. A larger battery can power a higher processing power with extended transmission range, but with increased size and weight. In addition to the payload weight, the ergonomics of on-body sensors should ensure not to restrict movement or overly increase body temperature. The harness pockets must be water insulated while providing airflow to the electronics to avoid overheating. The ergonomics of harness and the electronics need to withstand the harsh environmental conditions the dogs working in as well as its excessive motion.

Our earlier work indicated a particular emphasis is required for heart rate detection when skin contacting electrodes are used. Commercial wearable heart rate sensors using non-contact methods provide only heavily processed data and are difficult to integrate with the other sensors in hardware platforms [14]. Clinical heart rate or Holter monitors are accurate and provide beat-to-beat information; however, these devices are not practical for field work as they require shaving the fur at contact points and tape to affix the gel based sticky electrodes. We found out that 3D-printed conductive-polymer-based electrodes can be easily tailored

for canine size specific. Using three rounded protrusions provides optimum stability and penetrate the fur to provide a proper electrode-skin interface while maintaining comfort [10, 11, 12]. A consistent contact is required to ensure a low-impedance tissue-electrode interface especially when dogs are working at fast running speeds.

Wireless Network, Base Station, and Human Interface

Finally, there are many challenges with wireless networking in this application. Eventually, the network must be able to handle data streams from multiple drones and dogs alike. Large data transfer must be reliable and fast. Transferring real-time video is data-intensive and will consume many of the resources. The network also needs to cover a large range—potentially miles. All data packets must be transferred reliably in order to adequately monitor the canine's health and wellness in real-time. A robust base station is required in order to complete real-time processing. Tasks may include automated-behavioral annotation and real-time peak detection of an electrocardiogram signal for heart rate detection for welfare assessment. The user-interface must be intuitive and capable of performing machine learning algorithms to elucidate underlying insights. The user must be able to interpret the available data in a meaningful way to ensure the welfare of the working canine partner.

Summary

During the newly emerging dog-drone partnerships, the fusion of micro-assessment via on-body monitoring with macro-assessment via UAVs would provide real benefits for “dog welfare”. An ACI perspective is paramount in tackling the technological challenges presented by this dog-machine-human interface. Design of drones, on-body sensors, and human-computer interfaces need a dog-centered approach for reliable, safe and comfortable performance.

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