ENN584 Robot Specification

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Abstract

In this paper, a specification for a robot capable of dealing with cane toads is proposed. The ethics of dealing with biological organisms has been considered, and a low-cost Spray devised to mitigate the impact within a small area, such as a lawn or backyard.

1 Introduction

The problem of the introduction of the cane toad to Australia impacting native wildlife is well known by locals, however, "it is not a prohibited or restricted invasive animal under the Biosecurity Act 2014" [1]. Still, their presence poses a threat to native predators and domestic animals alike, and should be dealt with per local government defined controls.
To address the problem of cane toads, this document has been created to outline the specifications of a robot capable of autonomously controlling cane toad population in a target area.

1.1 Operating Conditions

The robot system is to be designed for application in well-maintained suburban garden lawns, with minimal slope. An assumption is made that the system is not to perform under severe adverse weather, though will be required to operate in the aftermath of such events (ie. potentially muddy terrain).
Due to the specific issue of cane toads, operations are confined to within Australia, and to simplify varying local government control measures, another assumption is made that operations are specifically within the Brisbane region.

1.2 Project Requirements

1.2.1 Constraints

- The system must be portable. One person should be able to carry it.
- The system must be self-propelled. The operator should be able to set it up from a position of safety and the robot then proceeds to its goal.
- The system must be able to operate in a variety of lawns, although these can be considered as well-maintained and not steep.
- The system's overall costs should total less than US$5,000.
- The system should be able to operate for at least 2 hours.

1.2.2 System Requirements

- The system must be able to detect and navigate to cane toads
- The system must be able to apply control measures on cane toads
- The system should be able to dispose of, or at least notify, euthanised toads.

1.3 Ethical Considerations

When dealing with a biological organism, the ethics of the Spray should be considered, especially in the case of termination. The harm of any biological organism should be kept to a minimum, and ethical practices administered. The RSPCA provides humane techniques for euthanasia of cane toads [2].
The autonomous nature of the system also raises some pertinent concerns. Firstly, misidentifying other creatures as cane toads could result in the misapplication of the euthanising spray, potentially bringing harm. Therefore, in the development of any detection algorithms, heavy emphasis should be placed on precision, as allowing cane toads to roam freely is less problematic than inducing harm on other life.
The second aspect of autonomy is the development of technology around terminating life. While contextually euthanising cane toads is an approved control measure, the appropriation of algorithms around targeting, signs of life analysis, etc. could be particularly harmful in its modification.
As many of the ethical considerations surround the software implementation, this specification of the hardware and operation will progress, with proceeding key decision points reviewing the ethics involved for an unmanned euthanasing system.

2 Robot System Overview

A robot system has been devised that breaks down the problem into two parts: detection of cane toad presence and cane toad control. A robot is designated to each of the primary tasks, identified as Sentry and Spray. The Sentry robot will survey the area of interest for the presence of cane toads, streaming data to an external base station host. Upon the successful detection and localisation of a cane toad, Spray will be deployed to apply the Hopstop aerosol spray, with Sentry monitoring the cane toad for up to 2 hours after, per RSPCA guidelines[2]. This allows for a lightweight surveillance device, minimising the overall cost of operation by keeping power requirements to a minimum.
To limit the development requirement COTS parts will be used where possible, maintaining the budget of US$5000. Modified COTS systems are used for the Sentry and Spray platforms, with justification provided for each major subsystem in their respective specification section.

2.1 Sentry Robot

The Sentry robot must provide ongoing surveillance of the area of interest, and thus is required to operate for a minimum of 2 hours. To avoid the overhead of onboard computation, data will be streamed to an external host device for image processing and object detection.
For the base platform, an ARRMA Kraton RC vehicle valued at US$361.96 [3] has been selected.

Figure 1: ARRMA Kraton BLX 4WD

2.2 Spray Robot

Spray is only deployed on the successful detection of a cane toad, which may be an infrequent occurrence. As such, Spray's operating time is not required to meet the full 2 hours. This allows more flexibility in the operational aspects of Spray, such as enabling drones as an appropriate Spray, circumventing traversability issues.
With some of the best flight control on the market, a DJI drone makes for an ideal platform. The Mavic 3 series at USD$1,262.89 [4] provides an affordable but effective platform for Spray's tasks.

Figure 2: DJI Mavic 3 Classic

3 Locomotion

The robot's locomotion must be suitable to traverse a grassy area to fit the application within lawn environments. Most primary methods of robot locomotion are able to achieve this in some capacity: wheeled, tracked, legged, fixed wing or rotor platforms. Due to budgetary constraints and limited benefit, a legged platform is inappropriate for such a task, requiring many actuators for the various joints. Locomotion considerations for Sentry and Spray are provided separately.

3.1 Sentry Robot

Sentry is required to maintain operations for up to 2 hours. This rules out the use of rotors, as many craft are limited to roughly 20-30 minutes at best, with specialised craft being more capable of endurance, but more costly. Wheels have been selected over tracks, as they are just as capable of traversing in the target environment, while maintaining better reliability.
The Kraton platform contains a drive-train distributing the power of a 2050Kv brushless DC motor to the 4 wheels, with a servo motor providing Ackermann steering. The wheel size and tread pattern on the tires enable all-terrain traction, providing the capability to traverse lawns.

Figure 3: Kraton platform's 2050Kv BLDC

3.2 Spray Robot

Unlike Sentry, the Spray robot's locomotion is not as power-constrained, and can take some liberties to make it more effective. Many of the cane toads predators are airborne [5], as they are capable of catching them off-guard, and move quickly within their environment. Taking inspiration from nature, Spray has been designed as a rotor craft, for high maneuverability and relatively high speed. The DJI Mavic 3 applies 4 BLDC motors in a quadrotor configuration.

4 Electrical Systems

4.1 Power

4.1.1 Sentry Robot

Sentry's Kraton platform has compatibility for 2x 2S or 3S cells, with ARRMA's recommended battery specs being 50C, 5000mAH for either cell size[3].

4.1.2 Spray Robot

DJI provide proprietary batteries with their drones. The DJI Mavic 3 Classic specs show the battery is a 4S Li-ion with 5000mAH capacity at a nominal voltage of 15.4V[6]. This provides an absolute maximum flight time of 46 minutes[6] without payload.
Spray will also return to a docking station for charging, upon completion of its task. The docking station itself is considered beyond the scope of the system specification as it is non-critical to operations and many options exist, including simply hotswapping the battery manually.

4.2 Communications

In a suburban environment, range is not a significant problem for communications methods, however Sentry's requirements lead to high data transfer. Being an appropriate Spray in these conditions, and the added benefit of widespread adoption making it easy to interface with, WiFi has been chosen for Sentry's data transfer. To maintain a standard for communications, the same will be applied for Spray, where applicable.

4.3 Spray Robot

The Spray robot has its own communications requirement for interfacing with proprietary DJI hardware. DJI provide an E-port development kit (US$50.02 [7]) which enables communications over USB.

5 Compute

Compute for both Sentry and Spray will primarily be done externally, via some base station. This reduces the power and size requirements for each platform, ultimately extending the operating life of each. However, there is still some form of processing required for each unit, and considerations for each have been made.

5.1 Sentry Robot

5.2 Spray Robot

DJI's onboard compute is more than sufficient for general GNC tasks, however, being proprietary hardware, there is difficulty interfacing with task-specific sensors / actuators. Using a small form factor SBC, such as the Raspberry Pi Zero W (US$5.88 [8]), custom application software can be written and interfaced with the DJI Mavic 3 via the flight computer's E-port with the E-port development kit.

6 Sensors and Task Actuators

6.1 Perception

6.1.1 Sentry Robot

The Kraton platform does not come equippped with any autonomy functionality. As such, additional sensors are required. A ZED 2i Stereo camera (US$499 [9]) provides both RGB-D and IMU data for use in a SLAM application.

6.1.2 Spray Robot

The DJI Mavic 3 comes equipped with its own cameras for navigation. These can be interfaced over the E-port using the E-port development kit.

6.2 Task

The task payload consists of a container of the Hopstop aerosol spray and a spraying mechanism, to be equipped on the Spray robot.

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