Summer Research Project – Mechanical Engineering - 2020

Design of Collection Systems and Semi-Autonomous Controls for a Tick Collection Robot

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Introduction / Background

Ticks are small parasitic arthropods that can be found in every state across the United States. Out of the approximately 878 species of ticks found worldwide, 22 of them are known to bite humans. These species are particularly important to study because they are all capable of transmitting serious diseases to humans such as lyme disease [1]. In order to study tick populations and the diseases they carry, researchers need to collect ticks from the wild. Some of the traditional methods of tick collection include dragging and flagging. Dragging is carried out by dragging a large cloth across the ground (see Figure 1). Ticks will attach to the cloth while attempting to feed. Although these collection methods work well overall, they are unable to effectively collect ticks from areas with a high number of obstacles, such as from underneath shrubbery. [2]

Figure 1: A researcher conducting dragging [3].

Figure 2: The previously developed robot and collector.

After analyzing the areas in which traditional tick collection methods are unable to collect ticks from, it was determined that a small radio-controlled robot should be able to collect ticks from these hard to reach areas. This robot would have to be small and robust enough to navigate through the challenging terrain. Additionally, the robot would need to carry a mechanism to allow it to collect ticks. Before now, a large amount of progress had previously been made towards building such a robot. Previous students of Union College constructed a radio-controlled robot that met the size and functionality requirements for the project [4,5]. Additionally, a single collection mechanism had been prototyped but not tested [6]. The robot and collection mechanism can be seen in Figure 2. The goal of this research is to develop a tick collection mechanism, and semi-autonomous controls for the robot.

Prototyping Methodology

To help drive the development of prototype concepts, a list of requirements was developed to ensure each tick collection mechanism would be as effective as possible. Some of the key aspects each concept was evaluated against are ease of manufacturing, impact on the maneuverability of the robot, size, weight, durability, tick collection efficiency, and ease of utilization. From these requirements, an initial group of 10 concept designs was developed and evaluated. During the evaluation process, several design features were selected that showed promise. Using the identified design features and the list of requirements, a final group of 7 concepts was created. Of these 7 concepts, 4 were selected as the final prototype designs to be fully developed. An additional 3 designs were also selected for full development. Due to the outbreak of COVID-19 the initial development and testing of the prototypes took place in central Minnesota without the use of the robot which remained in New York. To improve the reliability of initial testing results, a location was found in MN with similar features to the intended operational environment in NY. These testing locations can be seen in Figure 3 and Figure 4 respectively. After initial construction of the prototypes, they were tested using a stand in for the robot that had similar dimensions. These tests and subsequent modifications were focused on addressing functionality and reliability issues with the prototypes.

Figure 3: Testing site in MN

Figure 4: Testing site in NY

Figure 5: The buildup of small pieces of debris after a testing run.

Once the initial testing and development in MN was concluded, the prototypes were disassembled and shipped to NY where they were reassembled. Once reassembled in NY, the robot and prototypes were taken out to the Reist Nature Preserve in Niskayuna, NY and tested. These tests focused primarily on the impact of the collection mechanism on the maneuverability of the robot, and the ability of the collection mechanism to collect ticks. To measure the impact on the maneuverability of the robot, during each test the robot attempted multiple basic maneuvers such as driving forward, backing up, a sweeping turn, and a point turn. Since these tests were conducted in July when there are effectively no nymphs present, the overall contact with the ground and the ability to collect small pieces of debris from the forest floor, as seen in Figure 5, were used as metrics for the collection efficiency. Observations made during testing were recorded and a video was made of each trial to allow for more in-depth analysis. In some cases, based on the results of these tests, modifications were made to the prototype which was then retested.

Prototypes

Overall seven different prototypes that span a wide range of styles were developed and tested. Three of these seven can be seen in Figure 6. After carefully reviewing the recorded field observations and the videos of each trial, each prototype was given a score from 0 to 10 in three primary areas: maneuverability, collection, and ease of construction. The average rating across all three categories for all seven designs was 7.4/10. This signifies that overall the developed designs performed well in the field.

Figure 6: Three of the seven different prototypes that were fully developed and tested.
Left to right: Rope Ladder, Antennas, Turtle

Semi-Autonomous Controls

The dense vegetation that characterizes the environments in which the robot is designed to operate create a unique set of challenges to navigation. The first challenge is the inability to maintain a line of sight to the robot through the dense foliage. As seen in Figure 7, the dense leaf cover makes it nearly impossible to see the forest floor. The second major challenge is the chaotic placement of obstacles such as stems. The frequency and unpredictability of their placement combined with the inability to drive by sight mean that the robot must be able to navigate semi-autonomously. To achieve the goal of allowing the robot to operate autonomously, the onboard electronics package needs to be expanded. As a step towards achieving this goal, the wiring diagram shown in Figure 8 was developed. It includes an array of sensors that will allow the robot to function autonomously. The combination of an accelerometer and a compass will provide location and direction information. To navigate through the underbrush, an array of limit switch based whiskers will be used to allow the robot to navigate by feeling its way through the environment.

Figure 7: The dense foliage of the invasive lonicera

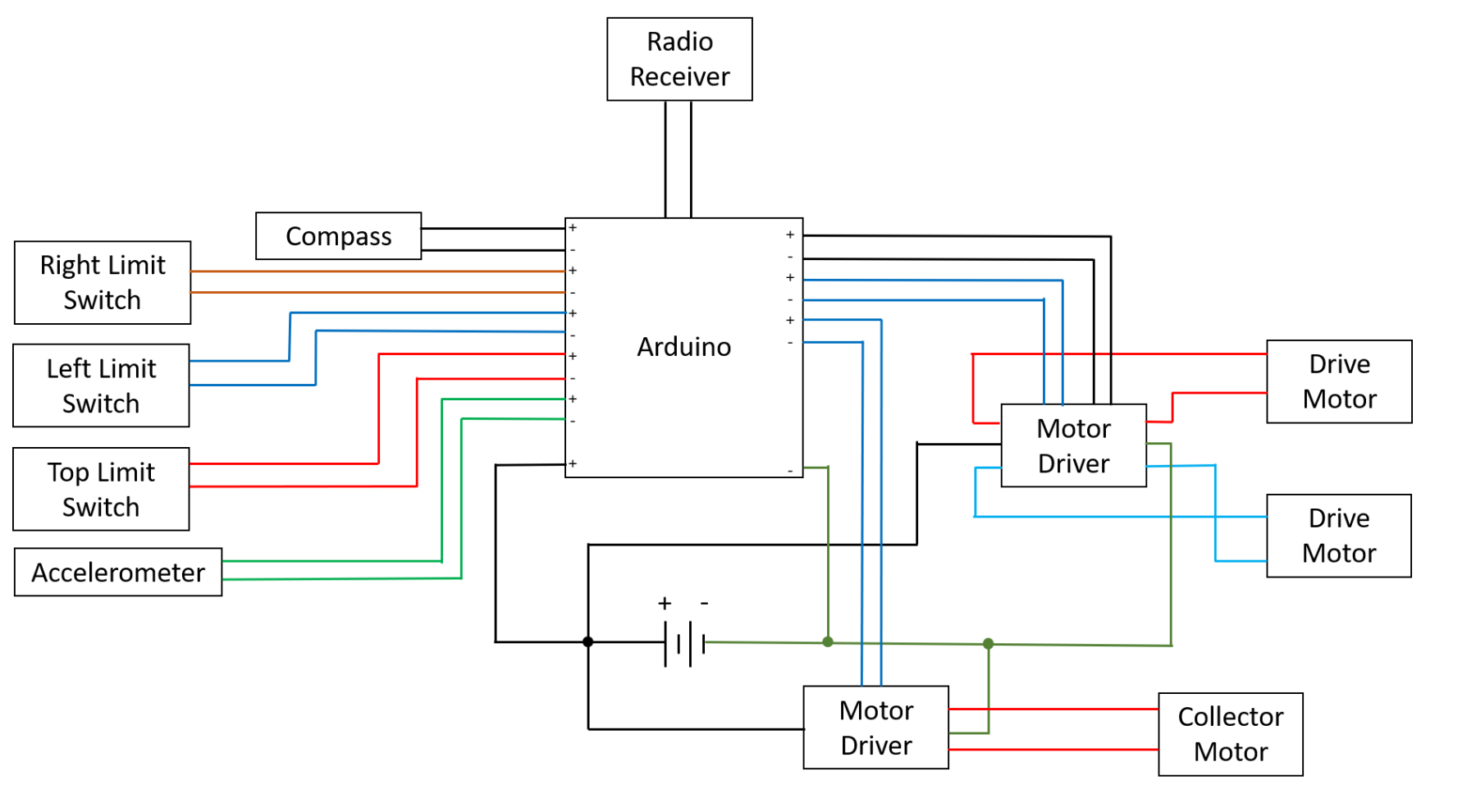

Figure 8: The electronics diagram for autonomous navigation

Conclusions and Future Steps

Performance metrics were recorded for each collection prototype throughout the testing process. These metrics can be seen in Table 1. Overall the designs performed well with the rope ladder, turtle, and doughnut coming out as the top designs. These are the three for which further development will be conducted. The next step in development is to enable the collectors to be retracted and deployed to allow for collection from specific locations. The next steps regarding enabling semi-autonomous function will be to fully develop the electronics package and write an algorithm to allow the robot to autonomously navigate the dense underbrush.

Table 1: The measured performance metrics as compared to the design requirements

Prototype Name	Maneuverability Rating	Collection Rating	Ease of Manufacturing	Average Rating
Rope Ladder	6	9	9	8
Antennas	6	6	5	5.7
Turtle	9	10	6	8.3
Doughnut	10	10	9	9.6
Treadmill	7	8	1	5.3
Mop	7	6	10	7.6
Apron	2	8	10	6.6

List of References

[1] https://www.cdc.gov/dpdx/ticks/index.html
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[6] Alexander Rothschild, “Design of a Tick Collection System”, Scholars Research Report, 2018.