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An Autonomous Robot for the Collection and Extermination of Ticks

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Abstract

Ticks are a heath hazard; they infest our pets and vector human diseases such as Rocky Mountain spotted fever and Lyme disease. We propose a robotics-based solution to reduce tick populations. The ecotone, a fifteen-foot wide swath defining the boundary between cultivated lawn and woods, is the ticks' natural habitat. A flexible perforated tube is routed around the ecotone that emits a chemoattractant such as carbon dioxide, drawing ticks from the ecotone into a narrowly-defined path. A robot is programmed to travel around this path collecting and exposing ticks to promethren, a common insecticide. The chemoattractant tube also houses a signal wire that the robot follows using inductive sensors to navigate the path, sweeping the entire ecotone. Sensor information is relayed to a microcontroller which, using a fuzzy logic algorithm, keeps the robot directly over the tube and the attracted ticks. The robot stops every lap in a specially designed shed to be recharged, cleaned, and UV sterilized. If continued for three months, the ticks' life cycle will be broken leaving the protected area tick-free for years.
Keywords: Robot, Collection, Ticks

1. Introduction

Ticks have become a major health concern across the country. People who live near wooded areas know that ticks are a nuisance and potentially dangerous. Besides infesting pets, ticks are a danger to humans as they carry diseases. The most common infection carried by ticks is Lyme disease, which struck nearly 17,000 Americans in 1998, the highest number of cases ever reported, according to the CDC[1]. Symptoms include fatigue, chills and fever, headache, muscle and joint pain, and a characteristic circular rash. Untreated, Lyme disease can lead to joint and nervous system damage including arthritis, numbness, chronic pain, and heart rhythm problems[2]. Another serious illness spread by ticks, Rocky Mountain spotted fever, annually strikes some 300 to 400 Americans according to the CDC. Symptoms include a spotted rash that spreads from the wrists and ankles, high fever, and muscle pain. Some years as many as 5% of victims have died[2]. Another, ehrlichiosis, was first discovered in the 1980s. In 1998, scientists reported on four people in Oklahoma who had been infected with a form of this disease long thought to afflict only dogs. Four more cases involved people in Missouri, Oklahoma, and Tennessee in 1999 according to a report in the September 15, 1999 issue of *The New England Journal of Medicine*[3]. Meanwhile, researchers have discovered other reasons to worry about ticks. On January 13, 2000, *The New England Journal of Medicine* reported the case of a 6-year-old girl who nearly died of tick paralysis, a rare condition caused by toxic substances produced by ticks themselves[4]. Ticks are so small that they can attach and feed unnoticed for hours and possibly days, increasing the risk of contracting disease. A team of four engineering students advised by two engineering professors and an entomologist sought to reduce tick-borne disease by designing a robot that traveled the perimeter of the yard, clearing the area of ticks.

2. Design

The ecotone, a fifteen-foot wide swath defining the boundary between cultivated lawn and woods, is the ticks' natural habitat (Figure. 1). Research shows that 80% ± 10% of ticks can be found in the ecotone[5]. By placing a small perforated tube around the yard that emits a chemoattractant such as carbon dioxide, ticks are drawn from surrounding areas in the ecotone into a narrowly-defined path. A small signal generator provides a 10 kHz sinusoidal signal through a wire placed inside the perforated tube. The rover (Figure. 2) uses inductive sensors tuned to the specific frequency of the magnetic field produced by the wire. The sensor signals are digitized by a microcontroller which, using a fuzzy logic control algorithm, keeps the rover directly over the tube and the ticks.

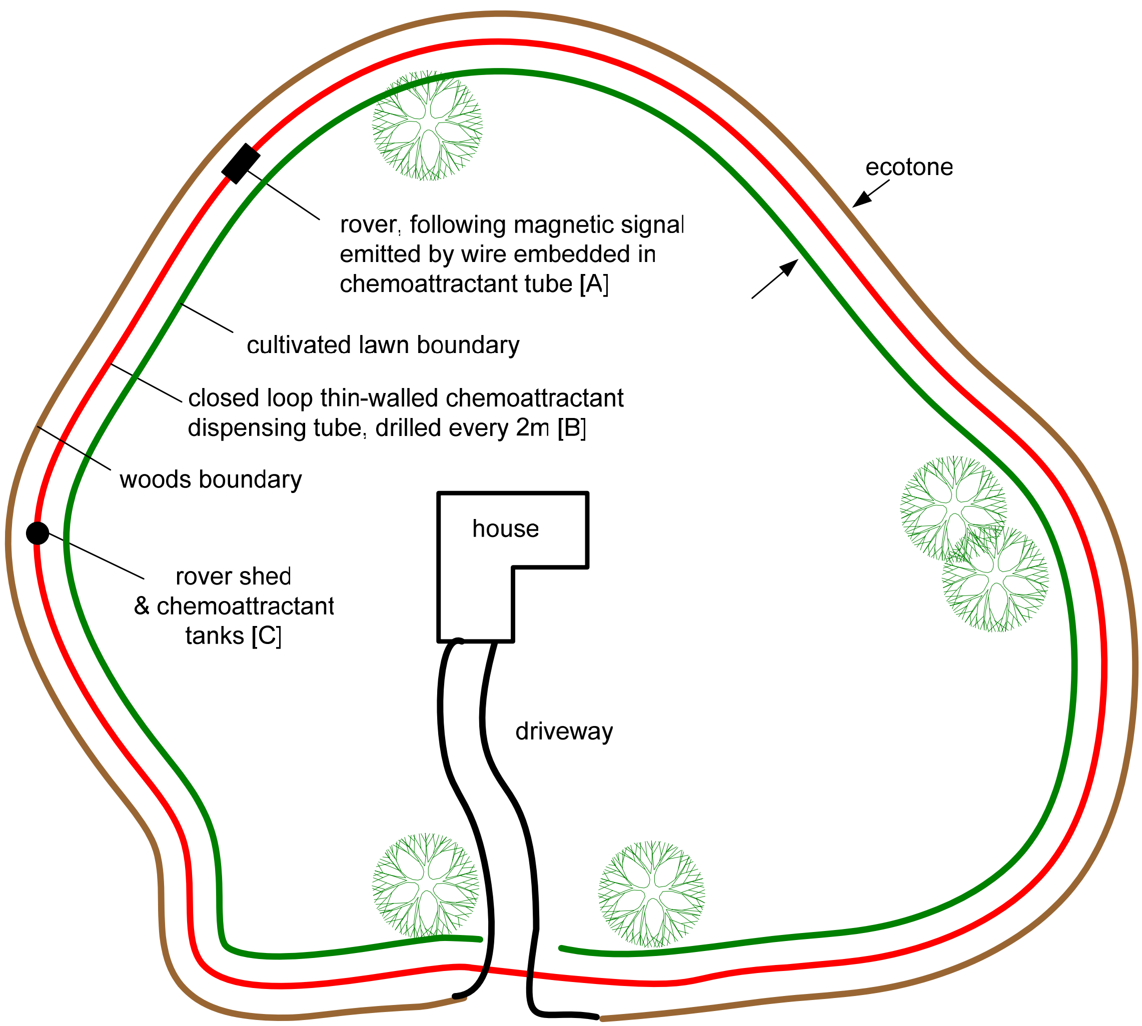

Figure 1: The tick rover (A) follows a signal from the wire (B) to follow the ecotone around a home's perimeter. Coaxial with the wire is a tube drilled to dispense a tick chemoattractant. The rover pauses in a shed (C) every lap to recharge and self-clean.

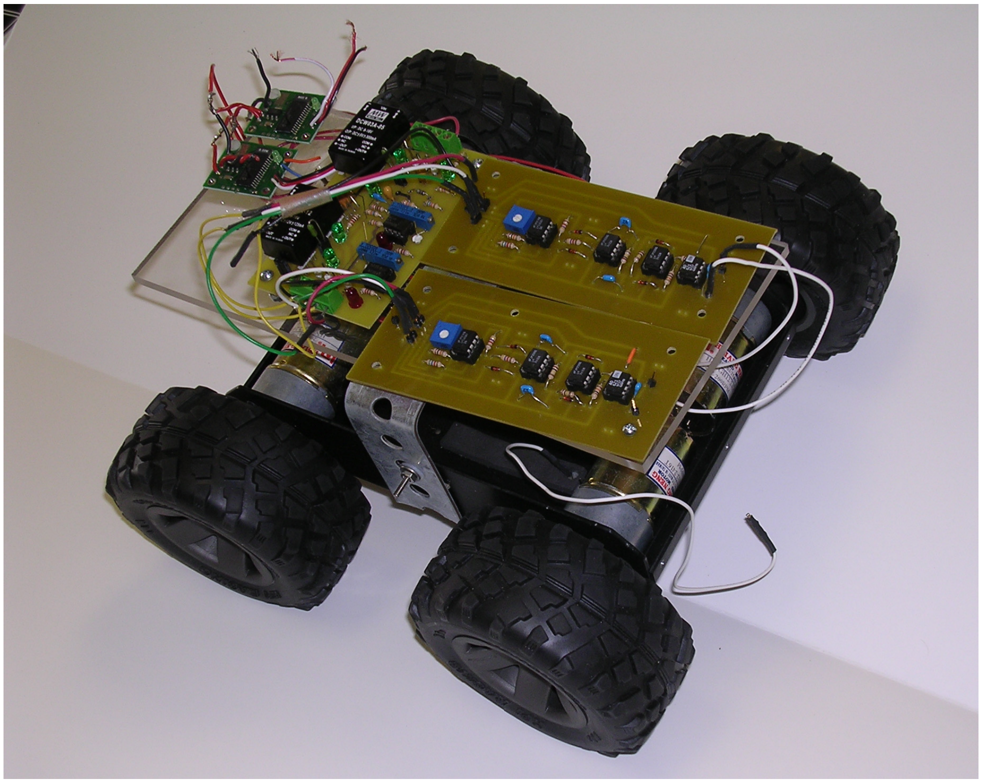

Figure 2: The Phase I prototype is shown. The two symmetric sensor boards are mounted in front of the power module. The motor controllers are mounted in the rear. All five units are secured on a clear piece of Plexiglas. The charging lead can be seen in the front of the rover

The robot's passive collection system consists of a denim skirt, a material to which ticks naturally attach. Denim has been found better in this regard than any other man-made or natural product[6]. The skirt is soaked in promethren, an effective acaricide with little or no harmful mammalian side effects. As ticks live primarily within 12" of the ground, the robot is designed to be low with a large contact area close to the chemoattractant tube[7].

After completing one lap of the yard, the robot returns to the specially designed shed that recharges and cleans the robot. Upon entering the shed, the robot skirt is cleaned of dead ticks and debris by a high power fan and brushes. While this occurs, contacts on the bottom of the rover touch points on the floor to recharge the batteries, a method similar to many desktop cell-phone chargers. After charging and being sprayed with a fresh coat of promethren, the robot will exit the shed. This process like the rover itself is fully automated. In addition, the shed will provide a weather-resistant storage area for the chemoattractant tanks.

The robot is designed be used during the late spring and summer months when it picks up both tick larvae and nymphs, as both stages of development are active during this time (Figure 3). Following treatment for the summer months, the life-cycle of tick growth will be broken and the area will remain relatively tick-free without further treatment for several years.

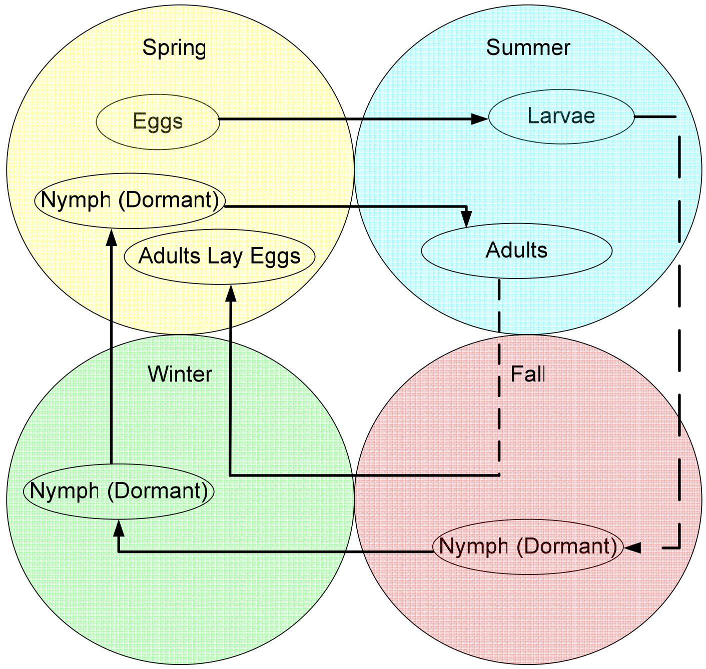

Figure 3: The life cycle of a tick begins when eggs are laid in the spring and ends two years later when the ticks become mature adults. The dotted lines indicate where the tick life cycle will be broken with use of the rover.

2.1. power supply

Figure 3 shows a block diagram of the robot. Powering the motors is one set of 8 NiMH batteries generating 12V. A second set of 8 NiMH batteries provides power to the microcontroller and sensor-conditioning circuitry. This voltage is processed by buck/boost DC-DC converters to provide regulated ±12V and +5V power supplies as long as the batteries are not discharged below 9V.

2.2. sensors

The robot follows a wire embedded in the chemoattractant tube using two inductive sensors. Detecting the sinusoidal signal from the wire is a 100mH inductor and a 22uF capacitor forming a tank circuit. The differential signal the tank circuit receives is converted into a ground-referenced signal and is amplified 40dB by an AD621 instrumentation amplifier. The dual-polarity signal is then rectified and passed through a low-pass filter that both removes high-frequency noise and converts the signal into a DC output with strength inversely proportional to the inductor's distance from the wire. The signal strength is displayed on a bar graph for debugging purposes.

2.3. algorithm: fuzzy logic controller

The signal from the sensor unit is digitized by the microcontroller for analysis. The signal from the rover sensors can be represented using fuzzy logic, a logic type which defines not only true and false but every value in between[8]. By processing the sensor data, the position of the robot relative to the wire and the rate at which that position is changing can be determined. Through fuzzy logic operations, position error (distance from the center of the robot to the wire) and error-rate (the rate at which the center of the robot is moving from the wire) the correct action can be taken to keep the robot near the wire as it traverses the course. If the robot is very far left of the wire and the error-rate is increasing to the left, moving the robot further away, then a strong corrective action to the right is necessary. If the robot is slightly to the right of the wire and the error-rate is strongly increasing to the left, meaning the robot is moving back toward the wire, then a small corrective action to the right needs to be taken to keep the robot from overshooting the wire.

A graph of the fuzzy sets used in the microcontroller can be seen in (Figure 4). Because of the imprecise nature of an individual's yard or campsite, the rover may go over rocks, sticks and other objects which would cause inaccurate sensor readings. Due to the imprecise nature of fuzzy programming compared to linear control, slight variations in sampling data will not adversely affect the movement to the extent as in other control systems[9].

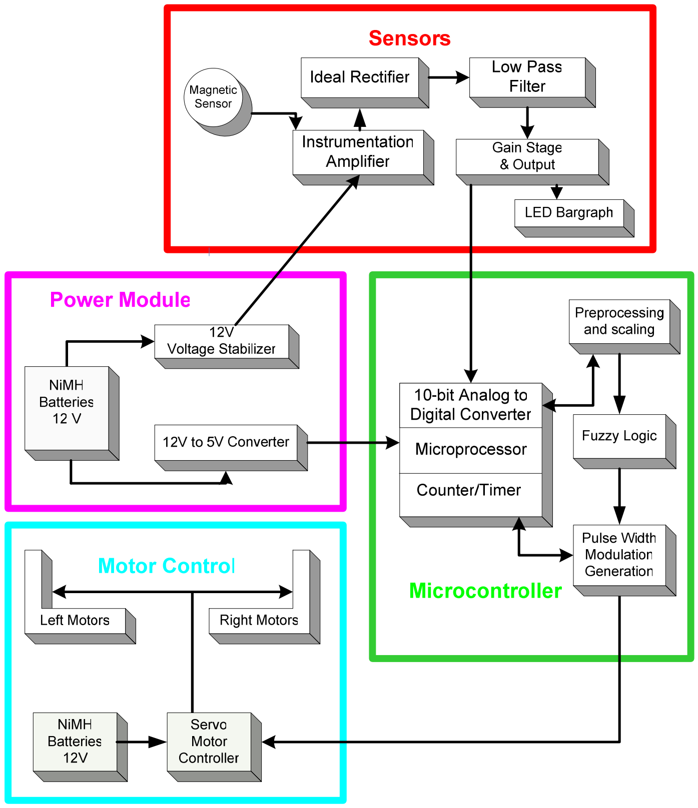

Figure 4: Block diagram of the high level design of the rover. The sensor data is processed by the microcontroller which instructs the motor controller to take the necessary corrective action to stay on track.

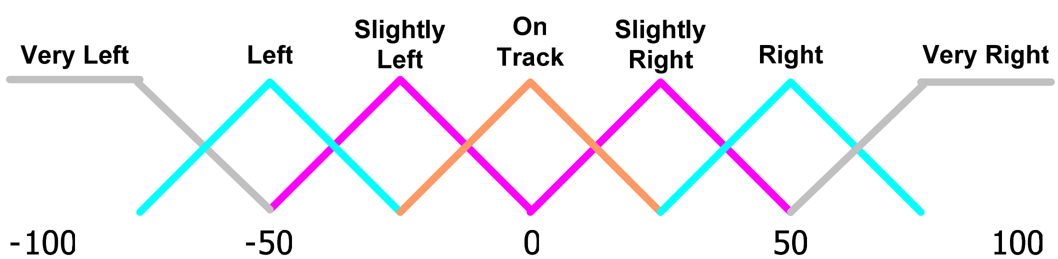

Figure 5: Fuzzy sets used in the robot controller which correspond to the distance of the wire from the center of the rover. The farther the distance from the center, the larger the corrective action instruction given by the controller.

2.4. microcontroller

The Atmel AVR ATmega8 microcontroller was chosen to implement the fuzzy logic controller. The ATmega8 is a RISC device using the Harvard Architecture. It contains 32 8-bit registers, 8 KB of flash memory, 2 KB of EEPROM memory, 512 bytes of SDRAM, and uses an 8 MHz clock. The program resides in flash memory, constants are stored in EEPROM and variables are stored in SDRAM.

2.4. software modules

The C programming language was used to write the control program which is broken into seven parts (Figure. 3). These include:

1. analog-to-digital conversion to a 10-bit digital signal,
    a. onboard the microcontroller,
2. preprocessing,
    a. scaling and adding appropriate offset values,
3. fuzzification,
    a. converting the “crisp” signal values to their fuzzy counterparts,
4. fuzzy inference,
    a. if error is X and error-rate is Y then turn Z,
5. defuzzification,
    a. find the centroid of the output fuzzy sets to get a “crisp” output value
6. post-processing,
    a. map the fuzzy result to the appropriate duty-cycle for the motor controller,
7. pulse-width modulation generation.
    a. motor speed and direction are controlled here

3. Discussion

The process of filing for patent protection has begun. The researchers are working with the licensing officers at two educational institutions. The robot will also undergo field testing to establish collector efficacy with the help of an entomology professor. This will be done using a current prototype designated Phase I. A larger prototype, Phase II, is in design. In addition, the team is researching its efficacy and marketing potential for not only ticks, but for other pests which could be eliminated in a similar manner.

A broad array of insects and rodents from mosquitoes to field mice can be found in the ecotone and elsewhere. The robot can easily be modified by simply changing the type of skirt, insecticide/pesticide and chemoattractant to attract and exterminate a wide variety of nuisances. Possible targets include field mice, mosquitoes and carpenter ants. For example, the robot could be employed in a lumber yard in early spring when carpenter ants swarm, using aerosized fructose as a chemoattractant and chlorpyrifos (Dursban) as the insecticide[10]. Field mice can simply be attracted to the rover by placing bait directly on the robot as it traverses the ecotone in a slow stop and go manner. Mosquitoes can be attracted to the tube using carbon dioxide as was used with ticks, and by coating the skirt of the rover with a mixture of lactic acid, a floral scent and an insecticide[11]. Other pests may also be targeted with similar modifications. One advantage of the robot over present pest-removal methods is its maneuverability and mobility, permitting a single device to autonomously traverse a large area.

There are many other applications for this device. Currently tick collection is done by a researcher dragging a sheet across the ground in a manner similar to the robot’s denim skirt[12]. The robot could automate this process, making tick collection cheaper and safer. Campsites may also benefit from this device. Campsites are primarily ecotone, filled with low brush, and are often not well-maintained. This device could provide protection to government-funded sites such as National Parks and Forests, military bivouac sites, and civilian campsites where a liability for public safety exists.

4. Conclusion

The autonomous rover constructed by the team should be capable of eradicating dangerous pests such as ticks not just temporarily but for several years. After the completion of field testing to be held during the summer of 2005, precise data will be available. The invention has potential to influence several aspects of society, including public health in residential and recreational sectors, and industries subject to loss of income by pests. The autonomous rover will effectively eliminate ticks and the deadly diseases they carry for nearly any application, from a tick infested backyard, to a large commercial area.

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