Hive Bots: Self-Reconfigurable Modules for Urban Search and Rescue

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OUR SOLUTION

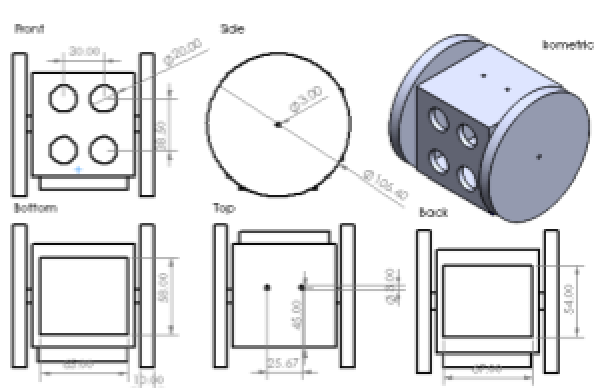
Our robotic solution is a cross between swarm robots and self-reconfigurable robots, having the ability to move and accomplish tasks independently, as well as connect to each other to achieve complex movements. The system will use centralized communication to assign tasks and use decentralized communication to execute pre-programmed algorithms and make autonomous decisions. The modules will consist of wheels with electromagnets that allow for reconfiguration. Each module would have a thermal camera that could send video footage back to humans who are not inside the building. Because of the system's wide range of capabilities, it will be adaptable and able to perform tasks in different environments. Because of the modular approach, it will be robust and able to continue tasks even if certain aspects malfunction.

I. Mechanical Components

a. *Structure of Central Cube*

A basic module contains a central cube with side lengths of 77mm and has a weight of about 3lbs with all of the hardware components inside [Figure 2]. The front face of the cube contains 4 holes for the eyes of the two ultrasonic sensors with the upper ultrasonic sensor at 30 degree angle pointing upwards while the bottom ultrasonic sensor is parallel to the ground. The bottom face of the cube will contain an extrusion of a rectangle (65mm x

Figure 2 - Module dimensions

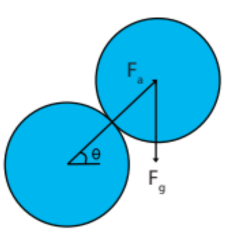


56mm x 10mm) where the battery holder will be, with a removable cover for easy access to replace the batteries. The backwards face of the cube will also contain a rectangular extrusion (69mm x 54mm x 10mm) to house the Arduino Leonardo. The top face of the cube will have two holes of 3mm diameter to allow for the antennas of the GPS module and WiFi module to protrude from the cube. Finally, the faces with the wheels will contain one hole with a 3mm diameter to allow for the axle of the motors to make contact with the wheels.

b. Wheels and Vertical Stacking

A unique component of the design are the magnetic rimmed wheels that allow for reconfiguration. One wheel of the module will contain a magnetic rim made out of neodymium, a strong compact magnet we specifically choose for this role. The other wheel will contain an circular electromagnet embedded inside of it to control the connection of the wheel to other modules' wheel and allow for easy separation after the vertical stack has been completed. Modules connect to each other with a fixed central module or fixed system of modules and an outer module rotates its wheels around the edge of the central modules' wheels to stack [Figure 3, Figure 4].

In order to determine the necessary magnetic strength to carry the 3lb module, we assumed a magnetic pull strength of 25lbs, and calculated the minimum angle that could support the outer module.



$$\Sigma Fy = 0 = -F_g + F_a sin(\theta)$$
$$F_g = 3lbs$$
$$F_a \leq 25lbs$$
$$\Sigma Fy = 0 = -3lbs + 25lbs\,(sin(\theta))$$
$$\Sigma Fy = 3/25lbs = sin(\theta)$$
$$\theta = 6.89°$$

From these calculations, we were able to conclude that a magnet with a 25lb pull strength was ideal for our purposes. It will be uncommon that an outer module will be at an angle of 6.89° or less in relation to a central module, because it will reconfigure to a higher position and therefore larger angle (θ) quickly. The magnet material best suited for this application then will be neodymium magnets which have a stronger pull force for less volume of magnet allowing for it to be compact.

Figure 3 - Stacking with one central module

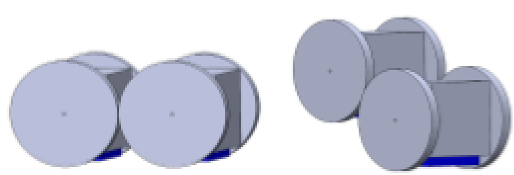
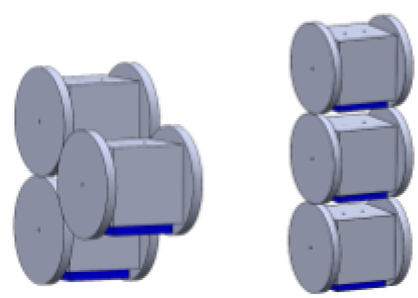


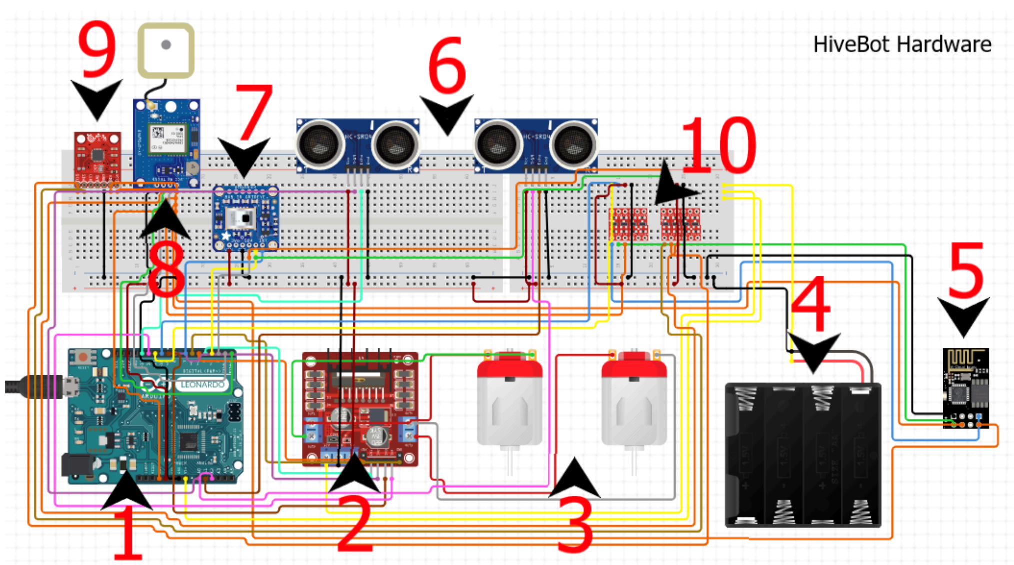
Figure 4 - Stacking with two central modules



II. Hardware

The neodymium permanent electromagnet (80mm diameter and 10mm thickness) embedded into the wheels will be controlled with a transistor switch circuit with the base of the transistor connected to the A3 pin of the Arduino Leonardo an analog output pin.

Hardware Schematic:



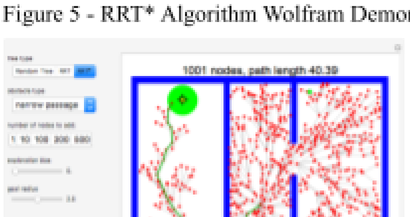
Hardware Table (associated with the schematic):

	Part:	Specifications:
1	Microcontroller: Arduino Leonardo	• Compact dimensions: 68.6mm x 53.3mm • 20 I/O pins allowing for a larger number of device connection capabilities • ESP8266 wifi module to allow for a wireless connection
2	Motor Adaptor for Arduino: L298N driver DC motor driver module	• Beneficial Features: control two motors simultaneously, control the speed of motors and rotation direction of the motors individually ◦ Gives capability to spin or turn the module • Compact dimensions: 34mm x 43mm x 27mm
3	Motor: 298:1 Micro Metal Gearmotor HP 6V	• Provides torque of 4 kgcm and has a no load speed of 100 RPM which is enough for search and rescue purposes • Compact dimensions: 10 × 12 × 26 mm with a 9mm axle shaft extending out
4	Battery Holder: 4xAA (6v)	• Entire module excluding electromagnet requires maximum of 6 volts • Compact dimensions: 58 × 63 × 16 mm
5	Wifi compatibility extension: ESP8266 Arduino compatible wifi module	• Allows Arduino Leonardo to connect to the internet and transceive data with the central control device. • Range of 90 meters which can be extended to 150 meters with an antennae[10] (enough range for searching a building) • Compact dimensions: 14.3 x 24.8 mm
6	Ultrasonic sensor model: HC-SR04	• Necessary for detecting obstacles in front of the modules • Range of 2 cm to 400 cm with an error margin of 3mm • Compact dimensions: 45mm x 20mm x 15mm
7	Thermal Camera: Adafruit AMG8833	• Easy to identify humans in collapsed buildings with their heat signatures ◦ Measure temperatures 0-80° C, detect human from 7 meters away • Compact dimensions: 25.8mm x 25.5mm x 6.0mm.
8	GPS Locator: Ublox Neo 6M GPS module	• Provides the longitude, latitude and time of measurement of the module allowing the person in control to track and know the location of a survivor • Works in extreme environments because of anti-jamming technology • Compact dimensions: 16 x 12.2 x 2.4 mm.
9	Gyroscope sensor: SparkFun ITG-3200 - Triple-Axis Gyroscope	• 3D gyroscope sensor that detects change on the x-axis, y-axis, and z-axis • Allows module to reorient itself if it falls and locate its ultrasonic sensors • Compact dimensions: 22.22 x 18.48 mm
10	Logic Level Controller: Bi-directional	• Allows the sensors to communicate with the Arduino Leonardo • Steps up or steps down signals to allow for communication • Compact dimensions: 16.05 x 13.33 mm

III. Computing and Algorithms

An important step in understanding the algorithm's requirements is determining whether the modules should use local or global communication techniques to receive and send

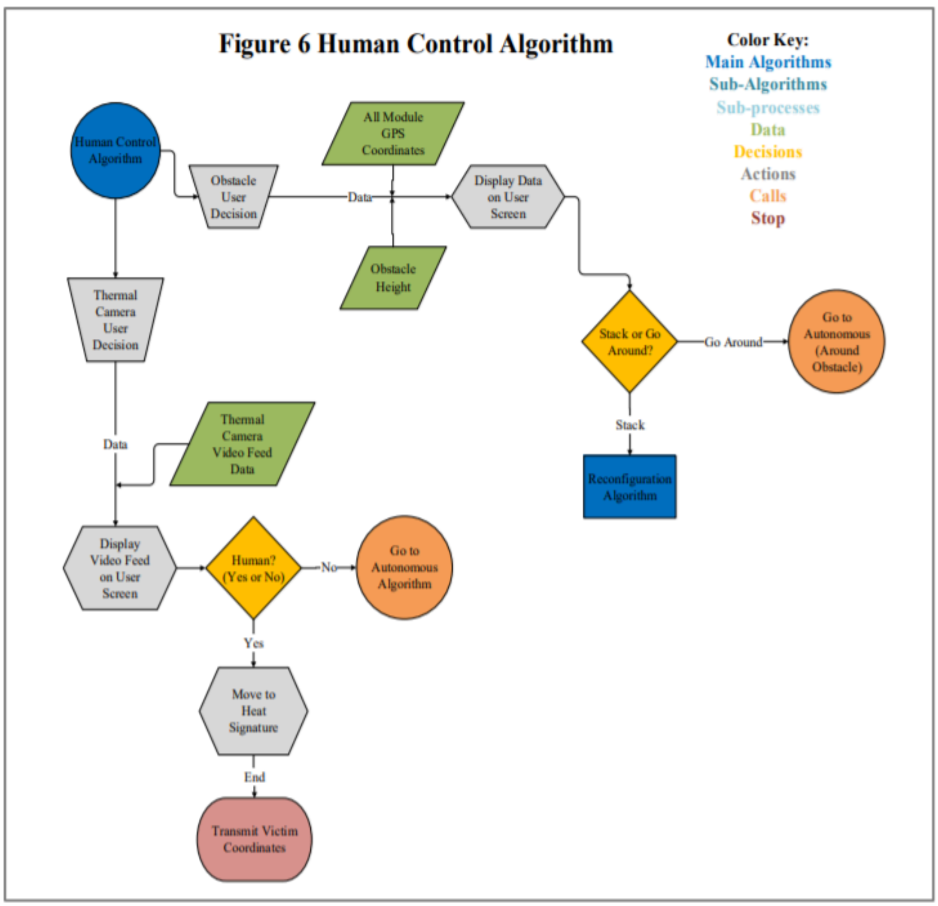
Figure 5 - RRT* Algorithm Wolfram Demonstration



information. With this in mind we decided that a central computer, such as a tablet, would be the best approach for storing pre-programmed algorithms and specifying what actions modules should take in order to reconfigure and work together.

Modules will still autonomously move around when independent, using the Rapidly-exploring random-tree* (RRT) motion planning algorithm [Figure 5] as a guide. RRT* generates a tree that expands outwards from a starting configuration, or a "start node", using random samples from the search space, and every new node randomly created becomes the new start node. By creating these nodes, the shortest possible path is generated for reaching a goal location while avoiding obstacles.

Although the algorithm avoids walls and obstacles, there are circumstances where the only option to maneuver is to climb over the obstacles. For these circumstances, the user will then specify whether the module should continue to map out its path or if it should work with other modules to climb. GPS trackers within each module will allow the central system to decide which modules are in the best location to help, and the central system will notify the individual modules of their new target location. Modules will then connect and reconfigure as necessary using a pre-programmed algorithm.



Architecture [Figure 6,7]:

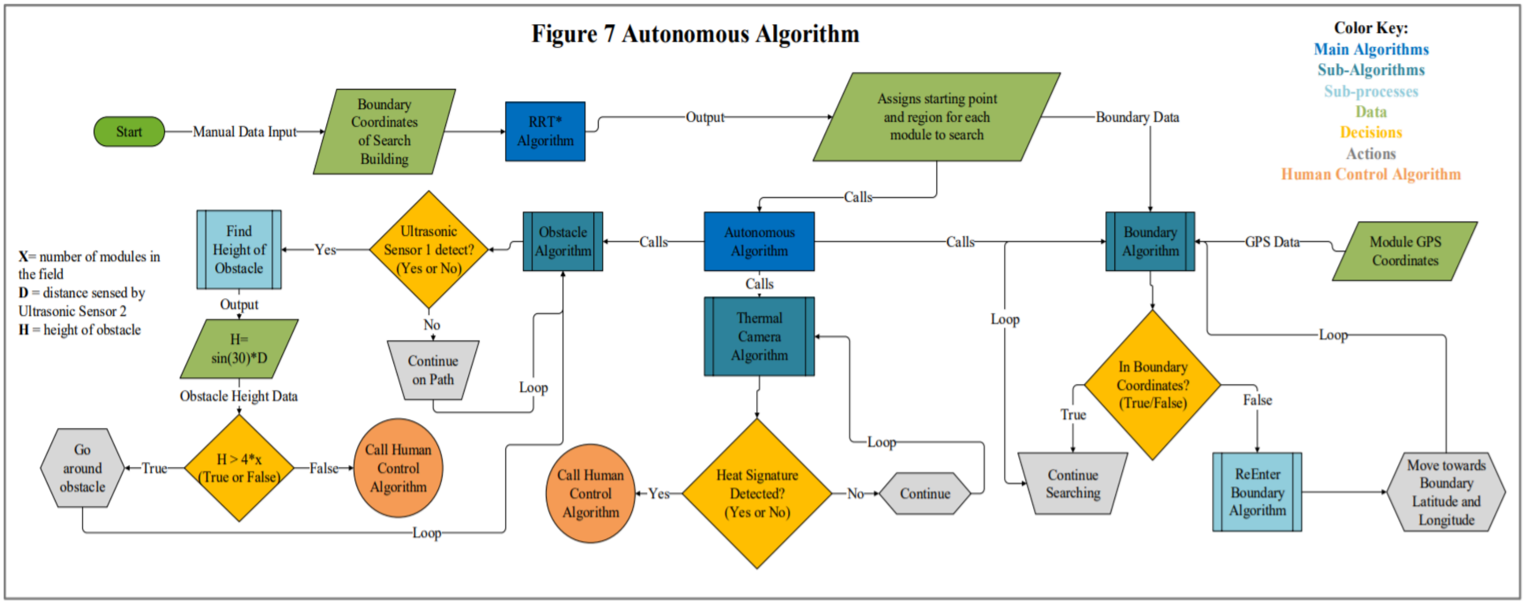


Figure 7 Autonomous Algorithm

PERSONAL INTEREST

Every individual bee in a honey bee colony has a simple task to perform, but together, they are able to accomplish complicated tasks such as building nests and collecting food. The dynamics of this hive inspired us to explore the concept of self-reconfigurable robots which are made up of simple individual modules but are able to accomplish complex tasks when working together. We noticed that this idea would be most beneficial for purposes that relied on adaptation to unknown environments. As a result, we thought to take nature as our inspiration in the creation of this idea.