Colony Scout: A Low-Cost, Versatile Platform for Autonomous Systems in Collaborative Robotics

Principal Investigators: Alex Zirbel and Benjamin Wasserman
Colony Members: James Carroll, Willis Chang, Jeff Cooper, Priyanka Deo, Lalitha Ganesan, Devendra Gurjar, Dan Jacobs, Alexander Lam, Abraham Levkoy, Matthew McKay, Alex Munoz, Nico Paris, Prashant Sridhar, Vinay Vemuri, Asia Wolf
Advisor: George Kantor

Abstract

Cooperative robotics is the concept that a group of robots working as a team can solve problems faster and more efficiently than a single robot. In the past, the Colony Project has explored numerous applications of group robotics, from mapping to formation control to cooperative manipulation. As is the case with a group whose stated goal is to be low-cost, past projects have always been hindered by imprecise sensors, faulty hardware components, and limited mobility. We propose to design and develop a new generation of Colony robots, the Colony Scout, to overcome these obstacles and increase performance, consistency, and robustness. Scout will dramatically improve upon the current generation of robots, Colony 3.0, with an innovative design that includes a more powerful drive system, more capable processing, and more reliable sensors. The main innovations of the Colony Scout will be capability to handle rough terrain and the ability to add new components (for example, a forklift) on an enhancement bay at the back of the robot. With more reliable and capable hardware, the Colony Project hopes to embark on more ambitious projects than in the past and to contribute in a more significant way to swarm robotics research.

Research Question and Significance

The Colony Project's main goal has always been to explore the field of group robotics with a fleet of extremely low-cost robots. We have attempted to make research into swarm robotics more accessible by lowering the entry cost unlike projects that require fleets of robots costing tens of thousands of dollars. The Colony Project itself has been able to maintain a team of 10 - 15 working robots costing $300 each. The challenge of a low-cost robot is that sensors can be less accurate and reliable; low expense comes at the risk of a loss of robustness and versatility. Our semesters of work with the current platform and research into newer low cost sensors have revealed opportunities for a modern platform that maintains the inexpensive appeal, but increases usability. By creating a more reliable and capable platform, we hope to enable behavior research on a high level without the limitations currently present which require significant maintenance just getting low-level behaviors to work on the hardware.

The Colony Scout is the next generation of the Colony Project's robot design. The main features that set Scout above the project's current robots are its enhancement bay, increased robustness, and improved motion capacities. Scout's enhancement bay is a dock on the back of the robot where new parts can be easily attached to add features to the robot - for example, a forklift could be added to allow Scout to move small boxes from one location to another. Scout also includes a faster processor and better sensors to improve the overall quality of the robot. The drive system has been completely redesigned, featuring four-wheel-drive, skid steering, and a flexible base to allow the Scout to drive over rocky environments.

Swarm robotics has numerous applications, from search-and-rescue to quick exploration of new territory to agriculture and transportation. In the areas of exploration and search-and-rescue, small groups of robots which are able to autonomously organize themselves and explore a building have huge advantages over human operators: they can navigate dangerous environments, fit through tight spaces, and split up to explore large areas very quickly. Autonomous vehicles are increasingly found in agriculture, from harvesting to transportation of crops and soil. Previous Colony work has been limited to flat environments and structured environments, which is well suited for research in structured urban environments, but falls short of the requirements for operating outdoors or in a field scenario. The Colony Scout will allow new research into the issues of safety, control, and collaboration as related to the agriculture industry by developing hauling and digging attachments.

Our goal with the Colony Scout project is to develop such a robot for use in our research, while maintaining the requirements that the robot be low-cost, robust, and versatile enough to navigate on rough terrain and to support later additions. As well as benefiting the Colony Project itself, we hope to contribute to the field of swarm robotics by demonstrating complex behaviors on a low-cost platform and releasing our work as discussed in "Dissemination of Knowledge."

Project Design and Feasibility

Robots

The general design of the Colony Scout is a four-wheel drive on a tractor-like base, as shown in Fig. 1. The front of the robot contains the processing hardware inside a protective hood, while the back of the robot features an expansion bay with free space. A rotating joint between the front and back halves of the robot allows the robot to maintain contact with the ground as it moves over obstacles and rough terrain. Batteries are mounted in the middle of the robot, and a panning sonar array extends above the robot.

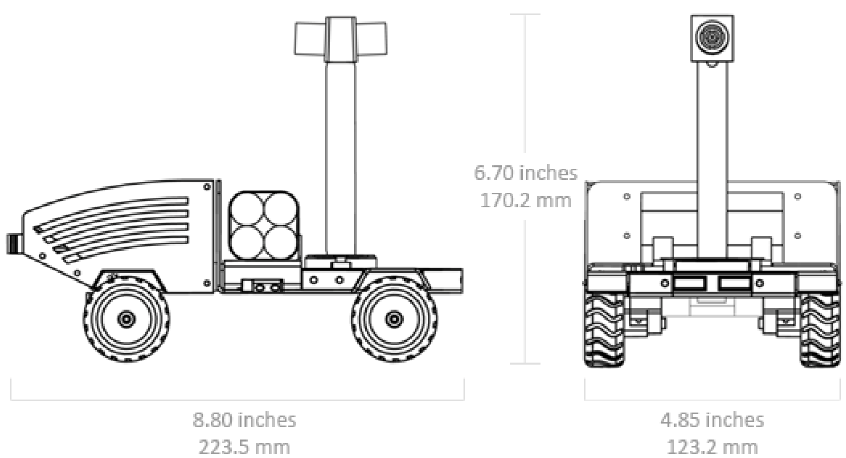

Fig. 1: Computer models of the proposed Colony Scout design

Sensors

We plan to utilize a narrow-beam ultrasonic rangefinder mounted on a stepper motor as Scout's primary distance sensor. This design resolves many of the distance sensing issues from the previous Colony robots. The panning design achieves full 360-degree visibility, which in theory allows this single sensor to create a full map of the environment around the robot in the horizontal plane. The ultrasonic sensor is more reliable and provides more accurate information valuable to our research.

Colony 3.0 is restricted to flat contiguous surfaces because its sensors do not provide any information about terrain, thus it cannot avoid obstacles such as cliffs. In order to increase Scout's versatility, the robot will have cliff sensors along its front and sides. The cliff sensor is a shorter-range range sensor that is oriented downward, allowing the robot to detect sudden drops in height in front of and beside the robot.

In order to enact many complex behaviors with swarm robots, the robots need to know their positions and pose relative to each other. With Colony Scout, we use four emitter-detector pairs; each emitter encodes data identifying the robot and the corner on the robot it is sending from, communicating pose data.

Computer Systems

The Scout robots feature two processing units: a Gumstix microcomputer running GNU/Linux on an OMAP3 processor and an AVR microcontroller running custom code to provide a level of hardware abstraction and safety. The AVR chip will handle low-level tasks such as polling sensors, sending and receiving data on short-range wireless with other robots, and performing sanity checks on the cliff sensors, encoders, and other critical sensors. The Gumstix computer will run Linux, which will provide a familiar Unix-like environment to the users of Scout robots. This will allow users to program the robots in multiple languages, including high-level languages. ROS, an industry standard for high-level robotics programming, will allow Scout robots to interface seamlessly with data from other, non-sensor sources as well as run code originally designed for other platforms with few modifications. SSH will allow remote access to the robots in real time over a standard TCP/IP connection, which the Gumstix hardware supports. With this access, users of Scout robots will be able to update code, read debug output, and process data remotely using a nearly universal protocol.

Accessories

Modularity and room for growth are both important parts of the Scout project. One feature of the robots that will advance these goals is the expansion bay, which features hard mounts for accessory attachment, and power and data connectors, including general-purpose digital and analog I/O and an I2C bus. Accessories will be able to deliver data and accept information from the robot. Potential accessories include manipulating arms, forklifts, sensors, turrets, or a towing hitch for cooperating robots. The bay is meant to allow open-ended accessory design: accessories can be "dumb" constructions that provide simple functionality to the robot or "smart" designs that include their own microcontrollers and processing to interact with the Scout more intelligently.

End Goal and Demonstration

The final goal of this research is to demonstrate simple behaviors on a working Scout prototype. The robot should be able to drive in simple patterns, collect sensor data, and respond to its environment as necessary. Reaching this goal involves both mechanical design and software. The Colony Project has a detailed plan for development of the Scout robot, including SolidWorks computer models and prototype testing procedures. Our immediate goals are ambitious but feasible within the scope of a semester's research project and will form a solid basis for future research.

Project Background and Organization

The Colony team is a group of hardworking and dedicated students, consisting of Robotics Club members, and continuing to grow in size and experience. The Colony Project makes a special effort to recruit and educate new members every year so we can take the greatest advantage of fresh ideas and veteran knowledge. Project members have a broad spectrum of previous knowledge and come from different fields of engineering, computer science, and design. The project is also able to draw on the collective knowledge of the Robotics Club for experience or resources, as well as the experience of past members and advice from our advisor, George Kantor.

Feedback and Evaluation

Colony project members attend a weekly status meeting to share the progress of sub-projects, discuss the overall status of Colony, and decide on short and long term goals. These meetings keep members and project leaders up-to-date, providing a forum for brainstorming and steering the general course of the Colony project. Professor George Kantor, our advisor and a primary source of feedback, meets regularly with the project leaders, attends review meetings, and offers helpful insights and a professional perspective on the project.

Dissemination of Knowledge

All source code and documentation will be published and made freely available on our website, www.robotcolony.org. Through our site we give other groups and individuals the opportunity to take advantage of the years of research and development already invested in the Colony project. We hope that by providing both knowledge and a technological base, we will assist other groups in their own investigations and expand upon our research in emergent behaviors in a robot colony.

The Colony project has previously presented at the National Conferences on Undergraduate Research (NCUR), as well as the "Regarding the 'Intelligence' in Distributed Intelligent Systems" symposium hosted by the Association for the Advancement of Artificial Intelligence (AAAI). We will present all of our findings and developments at the Meeting of the Minds Undergraduate Research Symposium in May 2012.

Budget

Parts for (1) functional prototype and bench top testing/prototyping units

Part	**Cost**	**Units**	**Total**
Sensors			
Maxbotix EZ-4 Sonar Rangefinder	$27.95	4	$111.80
Quadrature Encoder, Wheel, Bracket Set	$35.95	4	$143.80
Sharp GP2Y0D810Z0F Cliff Sensor	$6.95	6	$41.70
38kHz IR Emitter TSAL6200	$0.30	12	$3.60
38kHz IR Receiver TSOP1138	$0.94	12	$11.28
7.4V Li Ion Battery (4000mAh)	$19.95	3	$59.85
LISY300AL MEMS Gyroscope	$11.95	2	$23.90
Actuators			
7.5deg Unipolar Stepper (Sonar Turret)	$2.95	2	$5.90
150:1 Micro Metal Gear Motor (Drivetrain)	$15.95	8	$127.60
TB6612FNG Dual Motor Driver	$9.95	4	$39.80
A4988 Stepper Controller	$12.95	2	$25.90
Chassis			
0.063” THK 5052 Aluminum (24x24)	$16.39	1	$16.39
0.050” THK 5052 Aluminum (24x24)	$13.01	1	$13.01
1” x 0.5” 5052 Aluminum (24”)	$5.39	1	$5.39
0.125”x0.375” Copper C110 H04	$2.37	1	$2.37
1/4” ID Thrust Bearing	$2.06	4	$8.24
3D Printing for Prototype Components (CFA)	$50	1	$50
Computing			
Gumstix Overo Earth (ARM Development Platform)	$149.00	1	$149.00
Gumstix Tobi Expansion Board	$69.00	1	$69.00
Arduino Uno (AVR Protoyping Platform)	$30	2	$60
2 Layer PCB Prototype	$33	1	$33
Subtotal			**$1001.53**