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Mobility Enhancements to the Scout Robot Platform

Andrew Drenner[2], Ian Burt[3], Tom Dahlin[8], Bradley Kratochvil[2],
Colin McMillen[2], Brad Nelson[3], Nikolaos Papanikolopoulos[2 7],
Paul E. Rybski[2], Kristen Stubbs[2], David Waletzko[3], Kemal Berk Yesin[3]

Center for Distributed Robotics, Department of Computer Science and Engineering
University of Minnesota, Minneapolis, MN 55455

Abstract

When a distributed robotic system is assigned to perform reconnaissance or surveillance, restrictions inherent to the design of an individual robot limit the system's performance in certain environments. Finding an ideal portable robotic platform capable of deploying and returning information in spatially restrictive areas is not a simple task. The Scout robot, developed at the University of Minnesota, is a viable robotic platform for these types of missions. The small form factor of the Scout allows for deployment, placement, and concealment of a team of robots equipped with a variety of sensory packages.

However, the design of the Scout requires a compromise in power, sensor types, locomotion, and size; together these factors prevent an individual Scout from operating ideally in some environments. Several novel attempts to address these deficiencies have been implemented and will be discussed. Among the prototype solutions are actuating wheels, allowing the Scout to increase ground clearance in varying terrains, a grappling hook enabling the Scout to obtain a position of elevated observation, and infrared emitters to facilitate low light operation. By diversifying the Scout configurations, selected specialized Scouts can be used in conjunction with one another to complete situation-specific applications.

1 Introduction

The task of semi-autonomous surveillance or reconnaissance requires that a small robotic sensor package position itself discreetly, either autonomously or through teleoperation, into an area of interest. The usage of a team of small, nearly disposable robots provides the potential for continuous, overlapping coverage of an area even if a single member of the robotic team is compromised.

Relying on a small form factor allows the robot to position itself in hard-to-reach areas which, in turn, provides a method of concealment. Small robots also have the advantage that they can operate in size- and weight-restricted areas. This allows reconnaissance into environments that larger robots may not be able to traverse, either for fear of damaging the environment further (e.g., searching for survivors in a damaged building), or for searching through space-restricted areas such as small passageways (e.g., inspecting for possible micro-fractures in the hulls of ships or in aircraft). The small form factor also allows for easier transportation to the area of interest and allows a greater variety of deployment methods.

However, the advantages of the small form factor can also create limitations in the available sensors, quality of communication, and the robot's mobility, as well as increasing the cost of per unit production. This paper presents the existing hardware in use by the Scout robot, followed by some unique approaches to solving problems in the areas of limited mobility and sensor deficiency in certain environments while maintaining a small form factor. The capabilities of new hardware are presented along with results of experimentation demonstrating the usefulness of the prototype hardware in situation-specific environments.

2 Hardware

The Scout robot currently in its second redesign, shown in Figure , is a cylindrical, two-wheeled robot that is 40 mm in diameter and 110 mm in length. The general-purpose Scout has two forms of locomotion: primarily its wheels, which can be used for rolling along relatively even surfaces; and also a spring foot, which enables the robot to overcome obstacles that would otherwise stop it.

Each Scout contains a variety of sensors, such as video cameras, accelerometers, tiltometers, and wheel encoders. For more information on the capabilities of the general

[2]Center for Distributed Robotics and Dept. of Computer Science and Engineering, University of Minnesota.
[3]Dept. of Mechanical Engineering, University of Minnesota.
[8]*Dahlin Consulting.*
[9]MTS Systems Corporation.
[7]Corresponding Author.

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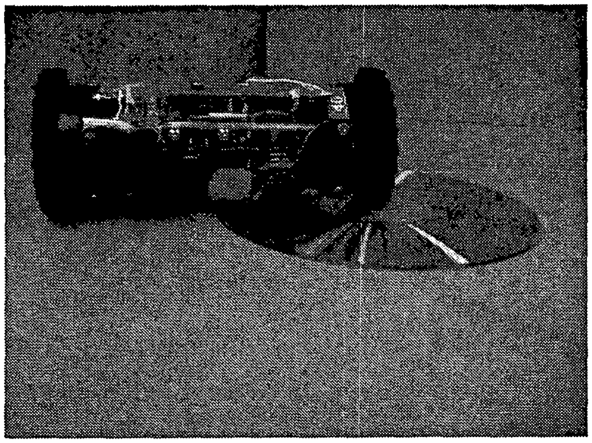

Figure 1: The Scout shown next to a compact disc for scale.

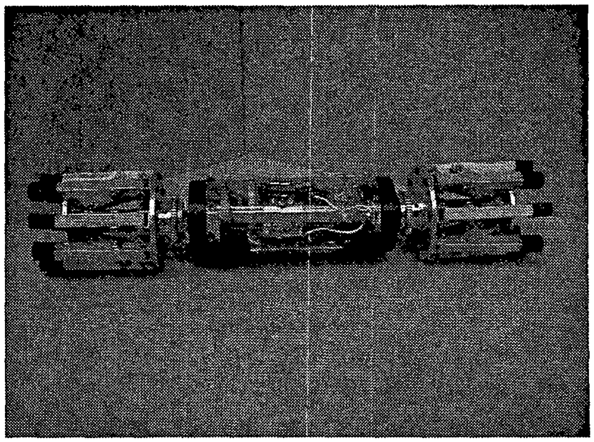

Figure 2: The actuated-wheel Scout shown with its wheels retracted.

Scout platform one may see [0].

Specialized Scouts have been developed to improve upon the sensory and locomotive capabilities of the general Scout platform. Several problems result from the small size of the Scout, including its low ground clearance and difficulty in surmounting obstacles. One approach to solving these problems has been the development of wheels that can actuate, changing size while the robot is in use. Another enhancement in the area of locomotion is demonstrated by the grappling hook. The grappling hook enables the Scout robot to overcome much larger obstacles, or position itself in hard-to-reach areas for the purposes of surveillance or reconnaissance. Finally, a vital aspect of reconnaissance is to attempt to observe a situation undetected, oftentimes using covert actions and operating in low- to no-light situations. To facilitate operations in these conditions, one Scout has been outfitted with a prototype infrared emitter pack, which enables the robot to flood a room with light in the IR spectrum.

2.1 Actuating Wheel Scout

The Scout robots operate in an urban environment. Mechanical systems for locomotion need to accommodate different urban environments in order to be successful. The actuating wheel design facilitates this additional translational freedom, while maintaining required design parameters. A Scout outfitted with the actuated wheel design is shown in Figures and . When the wheels are fully extended, the ground clearance of the Actuating Wheel Scout is increased from approximately 3 mm to slightly over 40 mm. The geared down motors which help to drive the larger wheel system reduce the speed of the Scout from .31 m/s to .2 m/s. While this seems like a large loss in speed, a normal Scout does not have the ability to traverse debris covered terrain without constantly hopping at a slower pace.

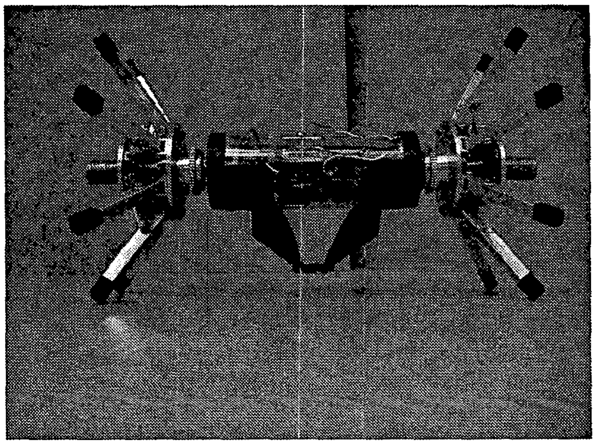

Figure 3: The actuated-wheel Scout shown with its wheels expanded.

The actuated wheel design had to follow several criteria. The major requirements were to fit into a small cylindrical form factor, to use the current drive motors to provide primary actuation power, to vary wheel size by at least twice the retracted size, and to maintain light weight while retaining strength.

Of the designs that were available, the current design was chosen to closely match the above specifications. The novel use of a small latching solenoid to selectively couple the center wheel shaft to the body of the Scout was implemented. In addition, the gear driven wheel components are allowed rotational freedom. The additional gear reduction is accomplished through a linear actuator built into the wheel and powered by the drive motor. This allows two plates, the inner one driven by the motor and the outer one affixed to the linear actuator, to be moved axially with respect to each other. Linkage between them actuates the umbrella-like structure of the wheel. This accomplished the goal of maintaining high torque and a high mechanical advantage at the linkage end plates, while still allowing a low torque high-speed drive for wheel rotation. The wheel linkage arms run parallel to the axis of rotation, allowing the wheel to expand further than if the linkage was limited in length to the diameter of the wheel in its retracted state.

There are several disadvantages of the wheel design, as well as future improvements that can be implemented. The wheel linkage arms run parallel to the axis of rotation, allowing greater range in size, but lengthening the wheel as well. This currently is acceptable in light of other design benefits. The linear actuator is susceptible to fouling in actual urban environments. This can be overcome by hardening and sealing bearing surfaces. The latching solenoid accounts for 10 mm of extra length on each side. Changing the form factor of printed circuit boards to accommodate the solenoid can solve this. The current design is not optimized. Subsequent designs will incorporate design improvements based on the testing of the current design. The improvements include linkage with better bearings, higher mechanical advantages in the actuator and linkages, reduced weight, width and length.

In the future, the actuated wheel design will allow the Scout robots improved mobility while maintaining standard deployment methods and form factors. The actuated wheel design will continue to evolve to suit the needs of an urban environment.

2.2 Grappling Hook Scout

The grappling hook Scout is designed to give the Scout yet another way to navigate difficult terrain. With the grappling hook, a Scout can raise itself into the air using a desk, chair, log, ceiling, or any other large object as an anchoring point. From its elevated vantage point, the Scout will not only benefit from improved range of vision, but also facilitates a more concealed observation point. The improved height will also reduce the effects of ground signal propagation and result in longer transmission distances.

Several design considerations were concieved of for the launching mechanism. An external spring launched mechanism was determined to be the most feasible. This device has two degrees of freedom in which to aim the mechanism. A pivot at the base of the device allows for angular elevation correction, while a pivot at the base of the motor determines the height of the launcher from the Scout frame. This freedom of motion, combined with the agility of the Scout, allows for the mechanism to be aimed with reasonable accuracy.

The hook is loaded before the Scout is sent on its mission. This is done using a simple loading device and takes approximately one to two minutes. Once loaded, the Scout

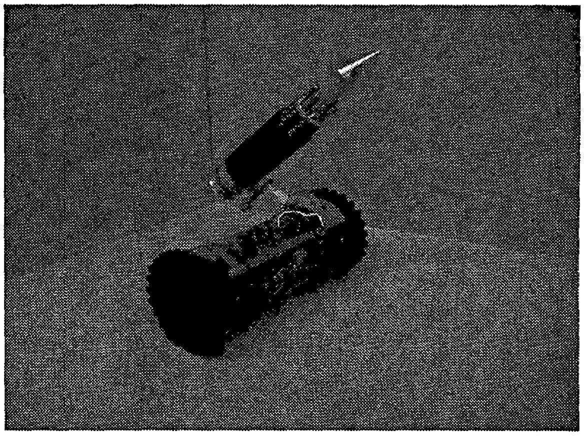

Figure 4: The grappling hook Scout.

is driven normally. When commanded to fire, a signal is sent to the motor which turns a gear and releases the shaft of the hook. The hook launches, grabbing onto a stationary target. Once hooked, the motor continues to turn, pulling the Scout up to its new location. The hook can fire up to 7 m, or up to the maximum amount of wire used to connect the hook to the Scout. Figure illustrates the Grappling Hook Scout climbing onto a desk to survey above the debris.

Future versions of the grappling hook should feature quicker loading times, the ability to get on top of desks and other objects, and a more compact and lighter shape with the ultimate goal of a self-loading mechanism. This design will allow for multiple launches per mission permitting a greater flexibility in vertical locomotion while still maintaining the rolling ability of the Scout.

2.3 Infrared Scout

The infrared Scout, shown in Figure has four modifications over the traditional Scout robot. First, the addition of a pair of IR emitters, each consisting of an array of 36 IR diodes, provides infrared illumination capabilities. A supplemental battery pack power supply required by the emitters is mounted near the Scout's spring foot. Due to the increased weight from the battery pack, stronger, larger wheels replace the small foam wheels associated with a generic Scout. In addition, the motors have been geared down to provide more power for hauling the additional weight.

The preliminary design of the IR addition to the Scout appears to be very promising. Early tests show that the cameras currently in the Scout robot can be used to identify features within a 2 m radius as well as illuminating the area of interest for other Scouts.

One advantage of the Scout robots is their ability to work as a group and perform autonomous behaviors [0] through

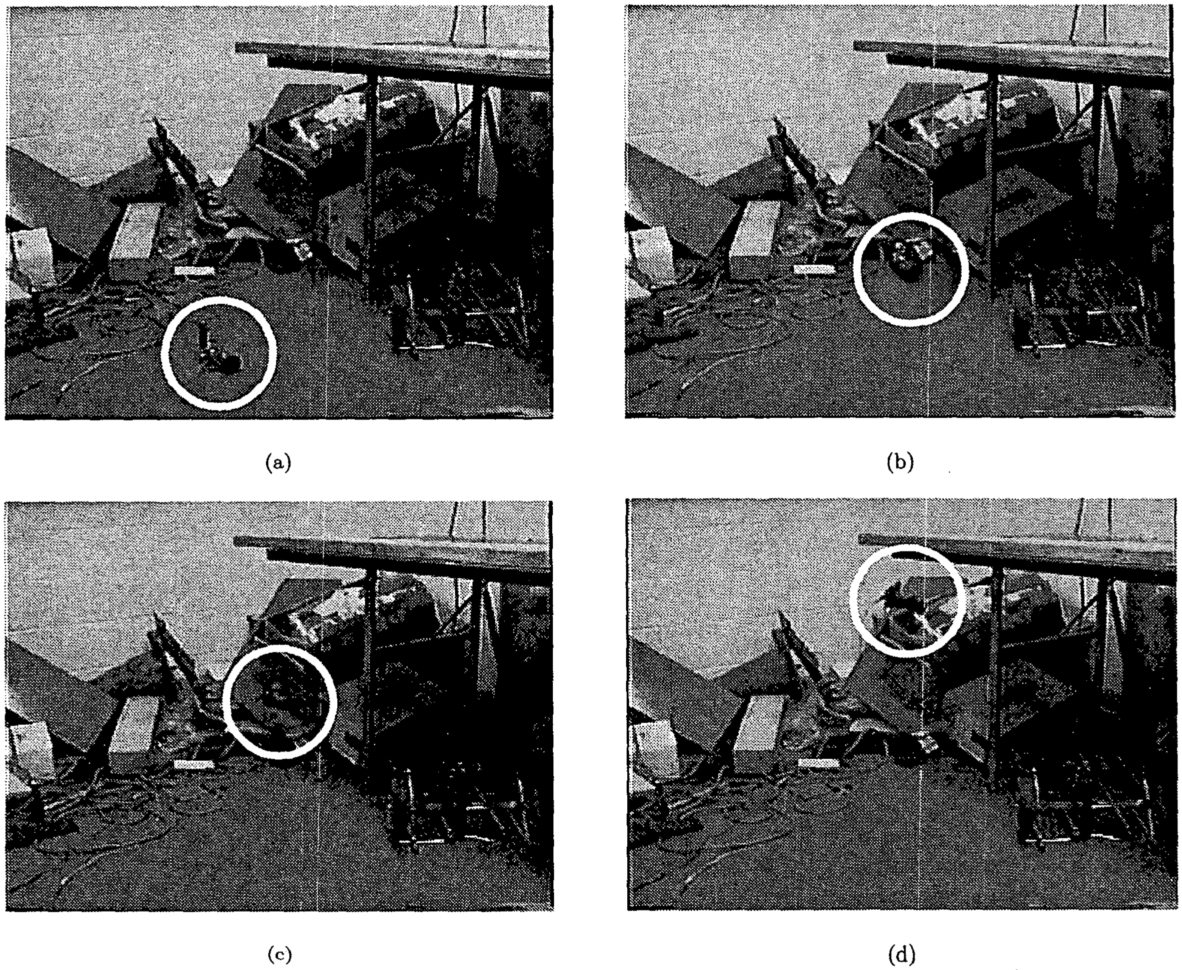

Figure 5: The grappling hook Scout (circled) using its hook to scale a table. The Scout launched the hook (a) and caught it around the wooden beam on top of the table. The Scout reeled in the cable (b)-(d) to lift itself up to the top.

a software architecture [0]. One of the autonomous behaviors developed involves a team of Scouts deploying a sensor net. In this behavior, the Scouts find dark places to hide in a room, move to the dark places, then rotate to face the light and observe motion. In rooms without adequate light, the motion observation behavior is not very effective.

Experiments demonstrating the usefulness of the IR capability in detecting motion are outlined as follows. In the first experiment, depicted in Figure , a Scout equipped with IR emitters is positioned within line of sight of an ordinary Scout in a darkened room. In this configuration, the Scout was able to detect motion at ranges over 5 m.

In a second experiment, an ordinary Scout is placed perpendicular to the IR equipped Scout. The goal of this test was to see what distances the ambient illumination was effective. In this scenario, the ordinary Scout was able to detect motion at a range of over 1 m when the IR equipped Scout was positioned 1.5 m.

Future improvements to the design of the IR Scout include reducing the size of the battery pack such that batteries can be stored internally. This would reduce the overall weight of the Scout and restore its ability to jump. Work is currently being done to add Fresnel lenses to the emitters to improve the amount of illumination.

3 Related Work

The field of mobile robotics is composed of several aspects consisting of locomotion, reconfigurability, and sensing and how they interact with the restrictions in available size, shapes, and power. Miniaturization makes optimizing these design issues in a single robot a difficult and

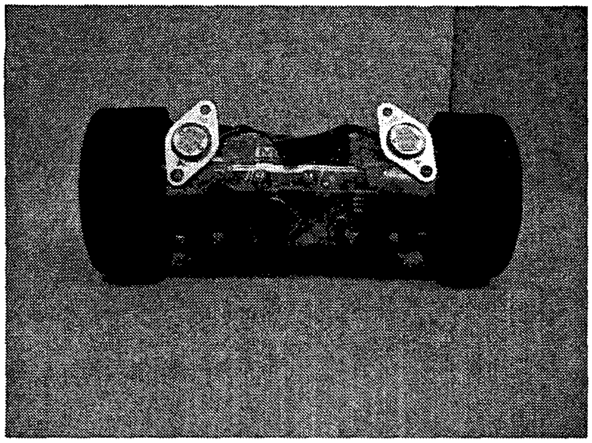

Figure 6: The infrared Scout.

expensive process.

Several interesting forms of miniature locomotion have been developed. Basing locomotion on insects has resulted in the cricket bot, which is designed to simulate the walking and jumping capability of a cricket [0]. Using a single leg for hopping has shown to be another form of locomotion [0].

Improved locomotion and sensing can be accomplished by implementing reconfigurable designs which consist of interchangeable modules allowing the robot to be modified for different situations. Reconfigurable sensing packages can be placed onto a common platform enabling a team of small robots to complete a task such as mapping of a large area [0]. A self-reconfigurable robot has been developed that is capable of modifying the configuration of modules to choose one of several variants of locomotion, dependant upon the current environment [0].

An area of particular interest in terms of small robots with locomotion is the task of Urban Search and Rescue. Researchers [0] hope that the number of victims of a catastrophe can be reduced by sending robots in first rather than risk more lives. Specific projects utilize reconfigurability and unique forms of locomotion such as CONRO [0] and the marsupial approach [0]. Both approaches allow for larger robotic systems to decompose into smaller systems that may be more capable for specific movements inside the search area.

4 Conclusions and Future Work

The next generation of the Scout robot will incorporate refined versions of the prototype designs presented in this paper. The incorporation of new sensing devices for application specific missions is something in the near horizon for the Scouts as well. Devices such as color cameras and improved transmitters will enable the Scouts to perform different varieties of reconnaissance tasks. The color camera will allow for the Scout to recognize skin tones which will improve the searching capabilities in debris filled areas.

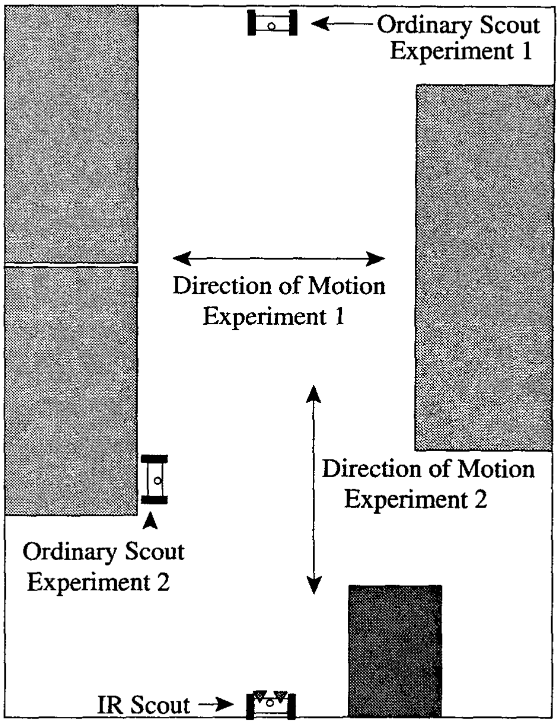

Figure 7: A diagram of the IR Scout testing environment with shaded regions representing office furniture.

The next Scout variant in the works will be a Repeater Scout. Due to the small size of the Scout robot, communication is hindered by the lack of a large powerful transmitter. With the use of a Scout that is dedicated to relaying messages, the effective range of the Scouts should increase indefinitely to a level which allows for operation in real world situations where the RF landscape is not as ideal as in a laboratory. The goal will be to deploy a network of Repeater Scouts which allows for Scouts that trade transmission capability for sensing capability to be able to complete the mission of remote reconnaissance or surveillance and truly allow remote operation.

Future work on the prototype locomotion and sensor improvements will be geared towards reducing the size to fit into the same form factor as the original Scout. To accomplish this some tradeoffs will inevitably be made, which may result in trading one form of locomotion for another, i.e., replacing the jumping capability of a Scout with an embedded grappling hook. However, the overall goal is to create a heterogeneous team of Scouts capable of working together in a variety of situations. By diversifying the available configurations of the Scouts, the idea of a distributed robotic system capable of performing in unique situations is strengthened.

Acknowledgements

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