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Mobile Robot Vehicles for Physical Security

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MOBILE ROBOT VEHICLES FOR PHYSICAL SECURITY *

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ABSTRACT

A fleet of vehicles is being developed and maintained by Sandia National Labs for studies in remote control and autonomous operation. These vehicles range from modified commercial vehicles to specially constructed mobile platforms and are utilized as test beds for developing concepts in the application of robotics to interior and exterior physical security. Actuators control the vehicle speed, brakes, and steering through manual input from a remote driving station or through some level of digital computer control. On-board processing may include simple vehicle control functions or may allow for unmanned, autonomous operation. Communication links are provided for digital communication between control computers, television transmission for vehicle vision, and voice for local control. With these vehicles, SNL can develop, test, and evaluate sensors, processing requirements, various methods of actuator implementation, operator controlled feedback requirements, and vehicle operations. A description of the major features and uses for each of the vehicles in the fleet is provided.

INTRODUCTION

Sandia National Laboratories (SNL) is engaged in developing mobile robotic systems for application to interior and exterior physical security systems. These applications place differing requirements on vehicle size, control capabilities, mobility and payload. As a result, a fleet of vehicles is being developed and maintained for concept development, test and evaluation. This fleet, illustrated in Figure 1, consists of specially developed vehicles and modified military and commercial platforms.

Control modes range from on-board manual control to fully computer controlled navigation. Intermediate modes allow remote control of the vehicle through teleoperation, either by an operator watching the vehicle or from the perspective of the vehicle through vision and sensor systems mounted on the vehicle. Mechanical actuators control the vehicle's speed, brakes, and steering. Input to the actuators may come from direct manual control provided by a human "driver" at a remote driving station or through some level of digital computer control. Digital processing may include simple vehicle control functions, or may allow for unmanned, autonomous operation. Communication links are provided for transfer of commands and status between the vehicles and the control station. Television transmission for vehicle vision and voice for local control are also available.

Table 1 describes the major features of each member of the vehicle fleet. The following sections describe each vehicle in greater detail.

MEMBERS OF THE VEHICLE FLEET

Sandia Interior Robot (SIR)

SIR, shown in Figure 1 as the third from the left in the front row, is a robot used for investigating autonomous vehicle operation. It is equipped with an on-board 6805 microprocessor, an odometer, an optically encoded magnetic compass, and a small CCTV camera. Thirty ultrasonic transceivers, mounted around the periphery of the robot, allow the system to locate walls or obstacles. Two drive wheels provide motive power, and a single front wheel provides steering. A modem provides a means for communicating between SIR and an auxiliary desk top type computer. This computer has allowed easy development of control algorithms without restricting the size or mobility of the robot.

SIR is primarily dedicated to algorithm development in the areas of room mapping, navigation, and path following, but has been used as a programmable sensor target for testing interior sensor systems and as a vehicle for developing concepts in interior security systems. For additional information see References 1 and 2.

Jeep Cherokee

A Jeep Cherokee, shown in the center rear of Figure 1, has been modified to provide a concept development test bed. Electric actuators control the throttle, brake, gear shift, and steering. Actuator control is through an on-board 68000 microprocessor. Sensors provide feedback on velocity, distance traveled, actuator positions,

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Figure 1

Table 1. Mobile Robotics Vehicle Fleet

Vehicle	Description	Application
Sandia Interior Robot	Special design	Autonomy development. Interior physical security.
Jeep Cherokee	Modified commercial Cherokee	Autonomy development. Mobile test bed.
Navair Mobile Land Target	Modified dune buggy	Driving studies.
Honda Fourtrax	Modified off-road vehicle	Exterior physical security.
Tamiya Mobile Platform	Radio controlled model truck	Driving studies.
Sandia Test Bed Vehicle	Special design	Mobile test bed
HMMWV	Modified military vehicle	Driving studies. Military use.
Suzuki LT50	Modified off-road vehicle	Exterior physical security. Driving studies.

state of health (such as water temperature and oil pressure), inclinometers (to measure pitch and roll), and heading. A modem allows communications between the on-board system and a remote control station. The initial control station utilizes an IBM PC as host computer.

The Jeep Cherokee has been configured as a multi-purpose test bed with power, cabling, communications and multiple mounting points sufficient to support all presently envisioned test requirements. Development, testing and evaluation can be performed on sensors (including vision and range finding), control modes (including teleoperation, telepresence and semiautonomous operation), and processing requirements (including self-contained and large scale remote facilities). Additional information on the design and operation of the Jeep Cherokee is available in Reference 3.

Navair Mobile Land Target

The Mobile Land Target, shown to the left of the Jeep Cherokee in Figure 1, is an expendable target for aircraft gunnery and missile practice, available through the US Navy. The basic vehicle is a Chenowth racing dune buggy. It has been modified for remote operation through installation of actuators and a radio circuit for control of throttle, brake, steering, and gear shift.

The Mobile Land Target can be operated manually or by remote control and can carry a moderate payload of sensors. The vehicle has been used as a test bed for evaluating teleoperation and telepresence requirements in on- and off-road environments. Additional controllers, sensors and operator vision capabilities are presently being developed.

Honda Fourtrax

A commercially available Honda four-wheel drive, all terrain vehicle is being modified for remote operation. This vehicle was initially used in driver vision studies using direct manual control. Figure 1 shows the vehicle in this configuration (in the front row at the far right). SNL is in the process of equipping the Honda with electric actuators for steering, throttle, brake and gear shift. Control is through an on-board 6805 microprocessor.

The Honda is dedicated to development of unmanned, exterior vehicles for teleoperation and limited autonomy. It has been identified as a vehicle for developing a remote exterior security patrol and observation vehicle.

Tamiya Mobile Platform

This vehicle is produced by Tamiya as a radio-controlled, electric-powered model car. It is shown in Figure 1 as the small vehicle at the far left of the front row. The vehicle can be fitted with up to three small CCTV cameras, RF television transmitters and an auxiliary battery pack. The system can be operated for up to several hours before requiring recharge.

The Tamiya platform is dedicated to developing teleoperated vehicle control and vision systems. Operating the vehicle by direct viewing and by using the on-board CCTV cameras allows a

comparison of driving capability in a variety of situations without significant hazard to vehicle or operator. After proof-of-principle testing, systems can be safely scaled up to one of the larger vehicles in the vehicle fleet.

Sandia Test Bed Vehicle

The Sandia Test bed Vehicle was developed and produced by Robot Defense Systems for Sandia National Labs. The test bed platform, shown in Figure 1 in the back row to the right of the Jeep Cherokee, is a rugged, all-terrain vehicle based on a commercial six-wheel chassis. Steering is by skid-steer operation. Control can be provided through a combination of on-board and remote capabilities. The on-board computer system consists of two 68000 microprocessors and a 68020 microprocessor. Two vehicle-mounted CCTV cameras provide visual feedback to the vehicle operator. One of the cameras is mounted on an extendable mast.

The test bed vehicle is designed as a platform for advanced, autonomous, vehicle-development work. With a payload of 4,000 lbs, many different types of sensors, processors and control equipment can be tested and evaluated.

HMMWV

The HMMWV (High Mobility Multipurpose Wheeled Vehicle or "humvee") is entering the military inventory as the replacement for the capabilities provided by the "Jeep" and the 1 1/4 ton truck. One of the HMMWVs shown is being used for developing concepts in actuator installation and control, vehicle control studies, and roadability measurements. Characterization of vehicle performance for a variety of command inputs and terrain types has been performed. For additional information, see Reference 4.

Suzuki LT50

A Suzuki LT50 all terrain vehicle is being modified for teleoperation. The basic vehicle, shown as the second vehicle from the left in the front row in Figure 1, is a small, four-wheel off-road vehicle configured for use by children. Electric actuators for steering, brake and throttle have been added to the LT50.

Evaluating control and communcations requirements for small vehicles has been the initial application for the LT50. The LT50 is being proposed as a candidate vehicle for reconnaissance and weapons carriage for short range security and military applications.

CONCLUSIONS

Sandia National Labs has a variety of robot vehicle development capabilities in the areas of vehicle control, operator-interface requirements, communications security applications and security missions. A large base of experience has been established for support of the mobile-robotics user community.

REFERENCES

1. P. R. Klarer and J. J. Harrington, "Development of a Self-Navigating Mobile Interior Robot Application as a Security Guard/Sentry," SAND86-0653 (Albuquerque: Sandia National Laboratories, 1986).

2. J. J. Harrington and P. R. Klarer, "SIR-1, An Autonomous Mobile Sentry Robot," SAND87-0226 (Albuquerque: Sandia National Laboratories, 1987).

3. D. P. Jones, "Jeep Cherokee Mobile Robotics Testbed Vehicle," SAND87-0394 (Albuquerque: Sandia National Laboratories, 1987).

4. J. B. Pletta, "Driver Feedback and Performance Characteristics of the High Mobility Multipurpose Wheeled Vehicle," SAND87-1178 (Albuquerque: Sandia National Laboratories, 1987).

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