Project DIAS: Drexel's Integrated ATV System

Keith W. Sevcik, Shreyansh Shah, Jason Collins, Andrew Moran
Robert Ellenberg, Michael Perreca and **Paul Y. Oh***
kws23@drexel.edu, sks39@drexel.edu, jc359@drexel.edu, atm28@drexel.edu
rwe24@drexel.edu, mgp27@drexel.edu, paul.yu.oh@drexel.edu
Drexel University, Philadelphia, PA

Abstract

Recent disaster scenarios and military operations have underscored the need for robotic ground vehicles that can navigate harsh terrain that is too dangerous for humans to enter. Such vehicles could be used to extract injured people, deliver supplies, or provide reconnaissance. The goal of project DIAS is to produce a group of robotic all-terrain vehicles (ATVs) that can still be operated as off-the-shelf ATVs. This paper describes the design and construction of a robotic retrofit for an ATV. The realization is a vehicle that can be remote controlled, navigate GPS waypoints, or be driven by a person.

Introduction

Disaster scenarios and military operations often involve rough terrain that is difficult and dangerous for a human to traverse. Missions executed in these environments such as search and rescue, supply delivery and reconnaissance demand assets on the ground that can be quickly and effectively deployed. All terrain vehicles (ATV's) have proven themselves as reliable platforms for conducting such mission. However, a person must put their self in harms way to drive the ATV. A robotic retrofit for the ATV offers a means to achieve the same goals without risking the life of an individual.

The design and construction of unmanned ground vehicles (UGV's) is thoroughly studied field in the realm of robotics. UGV's such as those presented in (Trebi-Ollennu & Dolan 1999) and (DARPA 2006) have demonstrated the ability to construct a sturdy platform capable of traversing harsh terrain without a driver. Other vehicles such as Stanford's Stanley (Thrun 2006) and Carnegie Melon's Sandstorm and Highlander (Whittaker 2006) have solved the problem of autonomous navigation through such environments. However, all of these vehicles are heavily modified from the stock version and in some cases can no longer be driven by a person.

*Address all correspondence to this author. The U.S. Army Medical Research Acquisition Activity, 820 Chandler Street, Fort Detrick, MD 21702-5014 is the awarding and administering acquisition office. This investigation was funded under a U.S. Army Medical Research Acquisition Activity; Cooperative Agreement W81XWH 04-1-0419. The content of the information herein does not necessarily reflect the position or the policy of the U.S. Government or the U.S. Army and no of£cial endorsement should be inferred.

Figure 1: Drexel's Integrated ATV System (DIAS). Project DIAS is a robotic retro£t for a stock ATV. Pictured here is DIAS-2, a converted Polaris Sportsman 90cc with electronics bay on the back rack.

This paper outlines the design and construction of a robotic retrofit for a stock ATV, shown in Figure 1. The following section outlines the design requirements and methodology. The Hardware section describes the hardware implementation. Next, the electrical system and the robot's controller are explained followed by and explanation of the software. The results are then presented with suggestions for future work and applications.

Design Criteria

The missions and operating environments proposed demand specific criteria of the robotic vehicle. Disaster scenarios and military missions are often executed in rough terrain. The environment could vary in elevation, ruggedness, obstacle density and obstacle size. ATV's are designed to be versatile and durable, allowing them to be utilized in a wide range of missions. For ease of transportation and storage, we chose to work with a Polaris Sportsman 90cc ATV.

The Sportsman 90cc has a 2-stroke engine which burns a mixture of gasoline and oil (these are mixed inside the combustion chamber). The 2-stroke engine presents a unique challenge in that the throttle position does not linearly effect engine speed. However, the Sportsman does have cable actuated brakes, which are much easier to interface with than the typical hydraulic brakes. The shifting mechanism is a lever that connects directly to the transmission. The Sportsman shifts between forward, neutral and reverse, a feature not common among 90cc ATV's. Another attractive feature of the Sportsman is a built in kill switch which turns off the engine when activated.

For this design iteration, the goal was to achieve GPS waypoint following in a flat, open field. Based on the available GPS technologies, DIAS was required to come within $1m$ of the speci£ed waypoint. We also wished to retain the ability of a person to drive the vehicle. For this reason, DIAS had to maintain 75% of the stock capability. These criteria drove the design of the hardware and software systems that controlled DIAS.

Hardware

To achieve basic control of the vehicle, four axes need to be actuated: steering, throttle, brake, and shifting. These axes are actuated using a variety of motors connected to a central processing unit. The design and implementation of these systems is outlined in the following sections.

Steering

Preliminary load tests were conducted to determine the amount of force required to steer the ATV. It was determined that an electric motor capable of producing 10 to 13 ft.-lbs. of force would be required to turn the steering shaft. The motor that was picked is an AME 12VDC gear head motor capable of producing 17.67 ft.-lbs of force.

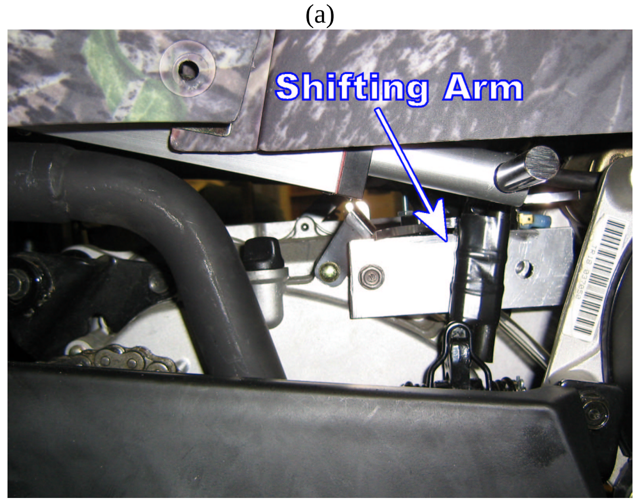
The torque is delivered through a magnetic clutch. This clutch is set to disengage the steering motor from the steering shaft if a load over 17.67 ft.-lbs of force is applied, thus preventing the motor from being overloaded. The clutch also allows the drive motor to be disconnected when the ATV is set to manual mode, allowing a person to operate the vehicle in a normal fashion. To provide steering angle feedback, a potentiometer was attached to the steering column.

Shifting

The shifting on the ATV is actuated via a linear actuator. This replaces the hand shifter creating an electronic shifting system. Limit switches are used to sense the position of the shifter arm and to act as the feedback of the system. The fixed end is mounted to a pivot point while the piston is connected to the shifter arm itself, as shown in Figure b. Manual shifting is actuated with a three way switch mounted on the dash of the ATV, shown in Figure a. Using this switch, the operator can manipulate the gearing of the transmission.

This design depicts a "shift-by-wire" system where the shifter does not mechanically shift the vehicle into gear but rather sends a signal to the central controller. The central

(a)



(b)

Figure 2: DIAS implemented a "shift-by-wire" system in which shifting was controlled by a switch mounted in the dash, shown in (a). This switch controlled the linear actuator pictured in (b) which moved the shifting arm.

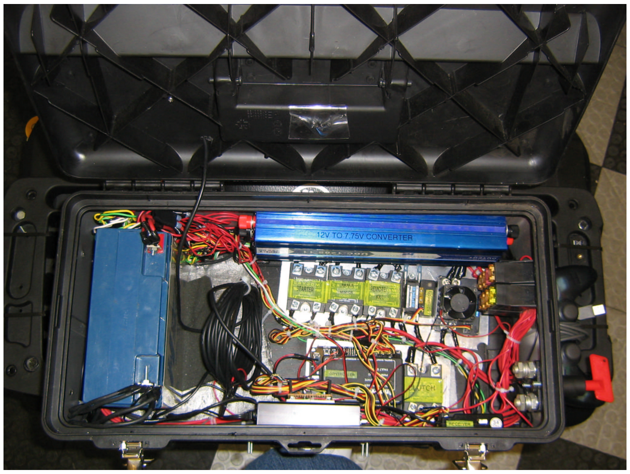


Figure 3: A look inside the electronics bay for DIAS-2. The 12V battery on the left provides all power for the robotic retrofit. The controller is located at the bottom. Mounted at the top, the 12VDC to 7.75VDC converter powers the lower level electrical system.

controller then controls the linear actuator to shift the vehicle into gear. Reed switches mounted near the shifting arm indicate when the vehicle is in forward, reverse or neutral.

Braking and Throttle

The braking and throttle systems on the Polaris are both operated by cables connected to switches on the handle bars. To automate these degrees of freedom, Hitec HSR5995 servo motors were used. The HSR5995 is rated at 2.2 ft-lbs. torque at 7.2VDC, which proved suf£cient to actuate these systems. Both servos were connected in parallel to the the stock systems. This allowed the brakes and throttle to be controlled by a person or by the central processor.

The servo has 8-bit resolution, allowing for over 50 throttle positions in the range of motion used. Limits were placed in both hardware and software to prevent the throttle from being fully actuated. This limited the top speed of the ATV.

Electronics

The electrical system for DIAS shown in Figure 3 involved both the low power control system and the high power system for driving motors and other actuators. The following sections describe the individual subsystems that compose the electronics.

Control System

All of the actuation on the robot feeds into a central processing unit. The central component is the Mini Robot Controller (Mini RC) from Innovation First, Incorporated (IFI). The Mini RC provides 16 channels of digital or analog I/O's, 8 PWM outputs, 6 solenoid outputs, a TTL serial port, and DB-9 serial port.

The servo motors actuating the throttle and brakes are capable of being controlled directly from the Mini RC outputs. To control the steering motor, pwm outputs are sent to a Victor 883 speed controller. The speed controller sources the power necessary to drive the motor. The shifting actuator is driven by a Spike H-Bridge Relay. Both of these components are available from IFI Robotics.

The controller also handles all data input. Feedback such as limit switches on the shifting system and the potentiometer on the steering are read into the controller and processed. The controller also communicates with three different peripherals: the GPS sensor, the wireless modem and the Futaba receiver.

Wireless and GPS Solution

To link the ATV to the base station computer, two Maxstream 9XStream 900MHz wireless radio modems were used. These transceivers offer full duplex asynchronous serial communication with miles of range outdoors and a bit rate of up to 19200 bps. Information sent from the base station to the IFI controller is typically commands for the various axes of the robot. Information sent from the controller to the base station is predominately GPS data.

The Garmin GPS 18 5Hz provides GPS position readings at a rate of 5Hz. With a diameter of 3 in and a height of under 1 in, the sensor fit neatly on the top of the electronics box. As a standard GPS sensor it has an accuracy of 15m. However, it is DGPS enabled, permitting accuracies of under 3m.

Power

To provide power to the entire autonomous system, an external 12 volt DC electrical system was implemented. This system includes two 12VDC sealed lead acid batteries from Power Sonic. These two batteries were wired in parallel to give a run time of over an hour under full load.

The 12 VDC system is then used in conjunction with a 12V to 8.5 V step down converter to create an electrical system for the IFI Controller and the steering and braking servos. To reach the operating voltage of these components, the step down converter was adjusted to create an output of 7.76 volts DC. As an added safety feature, all components were individually fused. An external kill switch cuts power to the entire robot when removed.

Software

To control DIAS, the base station application pictured in Figure 4 was created in Visual Basic 6. When the ATV was switched into autonomous mode, the base station could be set to three different modes of operation: Futaba control, joystick control, or GPS waypoint navigation. In all modes of operation, the base station can kill or start the ATV's engine remotely.

The base station utilizes GPS information to plot the position of DIAS on a map. Under GPS waypoint navigation, waypoints can be added by clicking on the desired position on the map. Once a waypoint queue exists and the "Engage Waypoint Following" button is clicked, the base station will issue commands to the subsystems. The distance from a waypoint and the required heading to approach a waypoint

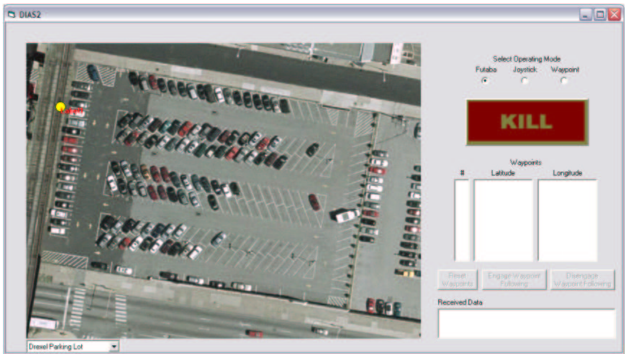


Figure 4: The base station application used to control DIAS-2. The user can select between radio control, joystick control, and GPS waypoint navigation. A map allows the user set GPS waypoints.

are then calculated. Distance from a waypoint in¤uences throttle and the error in waypoint heading and true heading influences steering (each utilize a form of proportional control).

Results

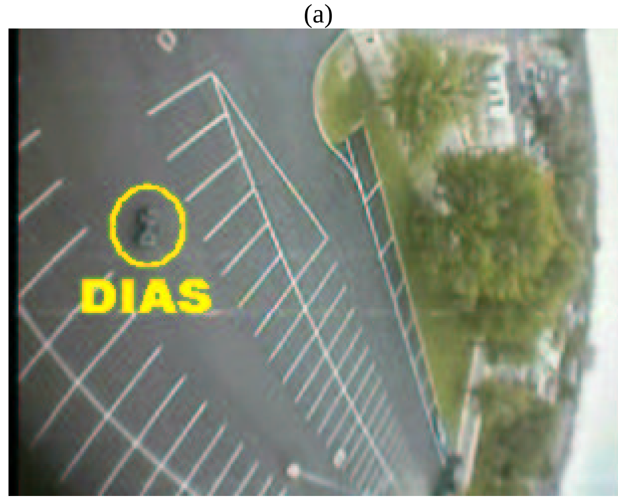
The £nished product was tested outdoors under all operating modes. DIAS performed well, successfully navigating waypoints mapped in an empty parking lot. The finished product met the threshold requirements set out at the beginning of the project. The only change to the stock ATV was the shift-by-wire system. The design still maintained the threshold 70% stock capability. The vehicle was shown to operate in grassy fields with navigation within 2m accuracy. The accuracy of the system was entirely dependent upon the GPS receiver. Greater accuracy could be attained if a more expensive GPS sensor was utilized.

A couple of design issues were encountered during testing. The IFI controller proved to be very sensitive to heat, and would often shut itself down in environments with temperatures exceeding $90^{\circ}F$. The next deisgn iteration should include a cooling system or investigate new controllers. It was also dif£cult to consistently regulate the speed of the two stroke engine. Future design iterations should include closed loop control of the speed.

Future Work

Currently two DIAS vehicles have been constructed, DIAS-1 and DIAS-2. A third vehicle has been purchased and is awaiting robotic retrofit. We have also acquired two robotic helicopter platforms from Rotomotion, Inc shown in Figure 5.This infrastructure paves the way for investigating higher level problems in heterogeneous robotic teaming. Missions such as cooperated search and rescue, convoys, and terrain mapping can all be executed with this group of aerial and ground assets.

(a)



(b)

Figure 5: (a) The SR100 from Rotomotion, Inc. can be used in conjunction with the DIAS vehicles to investigate robotic teaming. (b) The helicopter flying above provides aerial surveillance for DIAS driving below.

Acknowledgments

We would like to acknowledge Matthew Hardy, Colin Graham, Jacob Warren and Chris Crudele for their work in designing and constructing DIAS-1.

References

DARPA. 2006. Crusher unmanned ground combat vehicle unveiled. Technical report, Defense Advanced Research Projects Agency.

Thrun, S. e. a. 2006. Stanley, the robot that won the Darpa grand challenge. *Journal of Field Robotics* 23(9):661–692.

Trebi-Ollennu, A., and Dolan, J. M. 1999. An autonomous ground vehicle for distributed surveillance: Cyberscout. Technical report, Institute for Complex Engineered Systems, Carnegie Mellon University.

Whittaker, W. e. a. 2006. A robust approach to high-speed navigation for unrehearsed desert terrain. *Journal of Field Robotics* 23(8):467–508.