Robotic DGM Tow Vehicle
Project Overview

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Motivation

According to a 2003 report by the Department of Defense (DoD), there are currently more than 10 million acres of land on around 1400 DoD sites that are thought to contain unexploded ordnance (UXO). Clearing this land of unsafe materials is currently a very time consuming and expensive task. It is estimated that it would cost tens of billions of dollars to check and clear all of the possibly affected land. The DoD currently spends more than $200 million a year on UXO related problems.

Figure 1 - Segway Tow Vehicle towing two EM61-Mk2 sensors at Great Salt Plains, OK – Photo Courtesy of Nathan Harrison, Parsons Corporation

Auburn University in partnership with the Army Corp of Engineers Huntsville Center with initial funding from the Environmental Security Technology Certification Program (ESTCP) and with continued funding from the Huntsville Center's Innovative Technology Program have developed a robotic digital geophysical mapping (DGM) tow vehicle. The goal of the project is to increase safety, productivity, and accuracy of the geophysical survey process by using autonomous vehicle technologies. The platform is capable of towing an array of industry standard DGM sensors in either tele-operated or semi-autonomous modes. It has been used to collect geophysical data with Geonics EM61-Mk2 time domain metal detectors and Geometrics G-858 magnetometers, but is capable of towing most any sensor package.

System Description

The tow vehicle, shown in Figure 2, is a modified Segway RMP 400 (http://rmp.segway.com/). A custom fiberglass chassis was built to provide a water resistant enclosure for the electronics. The Segway's built-in charging system was also removed to minimize its effect on the towed sensors. The chassis contains an onboard computer, a Novatel SPAN® GPS/INS system (global positioning system/inertial navigation system) for position information, communications equipment including a 900MHz Ethernet radio modem, and space for various geophysical sensor electronics. A camera is also mounted on the front of the vehicle to allow for tele-operation and remote monitoring. An adjustable height arm is mounted to a roller bearing supported shaft on top of the chassis to provide an attachment point for a trailer. An optical encoder is attached to the bottom of the shaft to measure the angle between the trailer and vehicle. Trailer position can be determined from the combination of GPS/INS data and encoder measurements.

Figure 2 - Modified Segway RMP400 Tow Vehicle

Mission planning software has been developed that allows paths to be specified by either entering waypoints, polygonal grids, or a combination of both. The planner then generates a path that passes through the given waypoints and completely covers the given grids. The current vehicle cannot detect obstacles in real-time, but paths can be planned around polygonal obstacles if their locations are known. The path planner and real time path viewer allow files in many common GIS (geographic information system) formats to be imported, allowing aerial photography and other useful information to be displayed with the path. A screen shot of the planning software is shown in Figure 3.

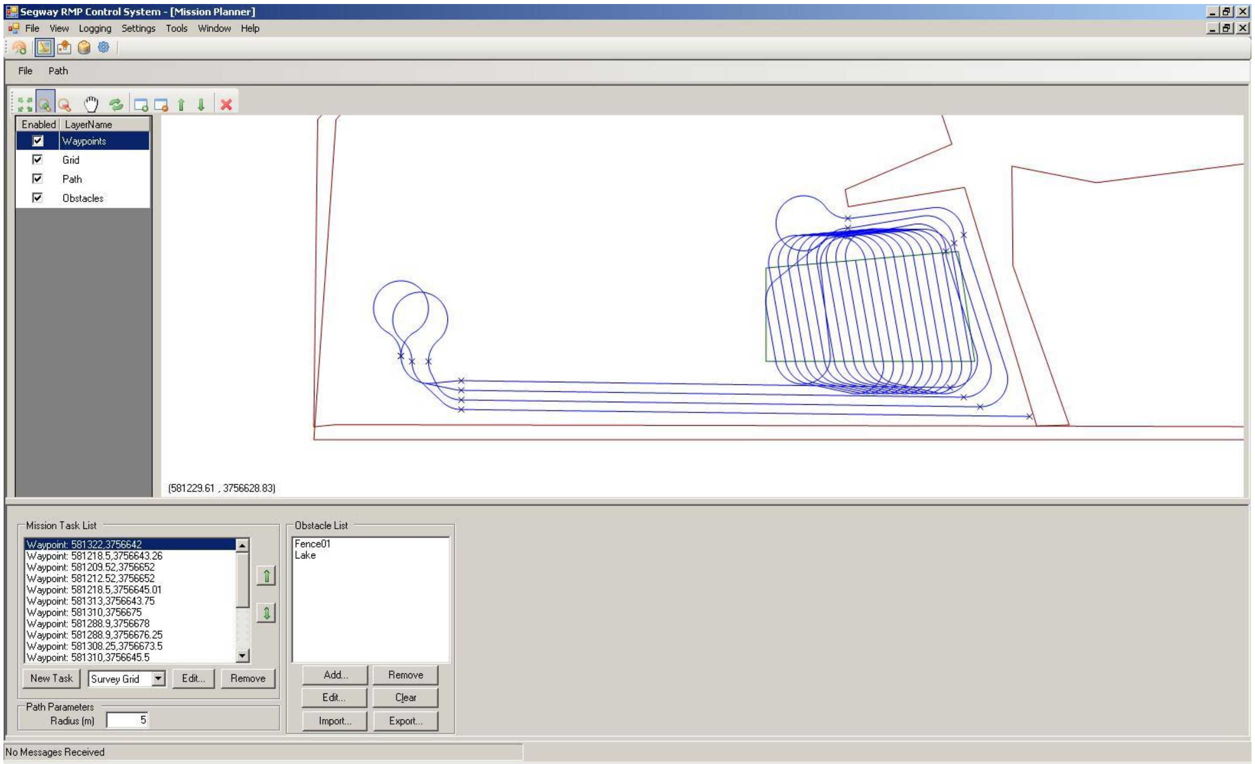

Figure 3 - Mission planning software. Obstacles are shown in red, grids to survey in green, and desired waypoints with black X's. The path generated is shown in blue. Image courtesy of Nathan Harrison, Parsons Corporation

The system is controlled using software running on a remote laptop, connected to the onboard computer via a wireless Ethernet link. A screenshot is shown in Figure 4. The control software allows the robot to be operated both autonomously and driven manually using an attached joystick. The remote interface allows the vehicle's status to be monitored and also displays the desired and actual traveled paths. Data from two towed EM61-Mk2's is also displayed in the graphics in the screenshot.

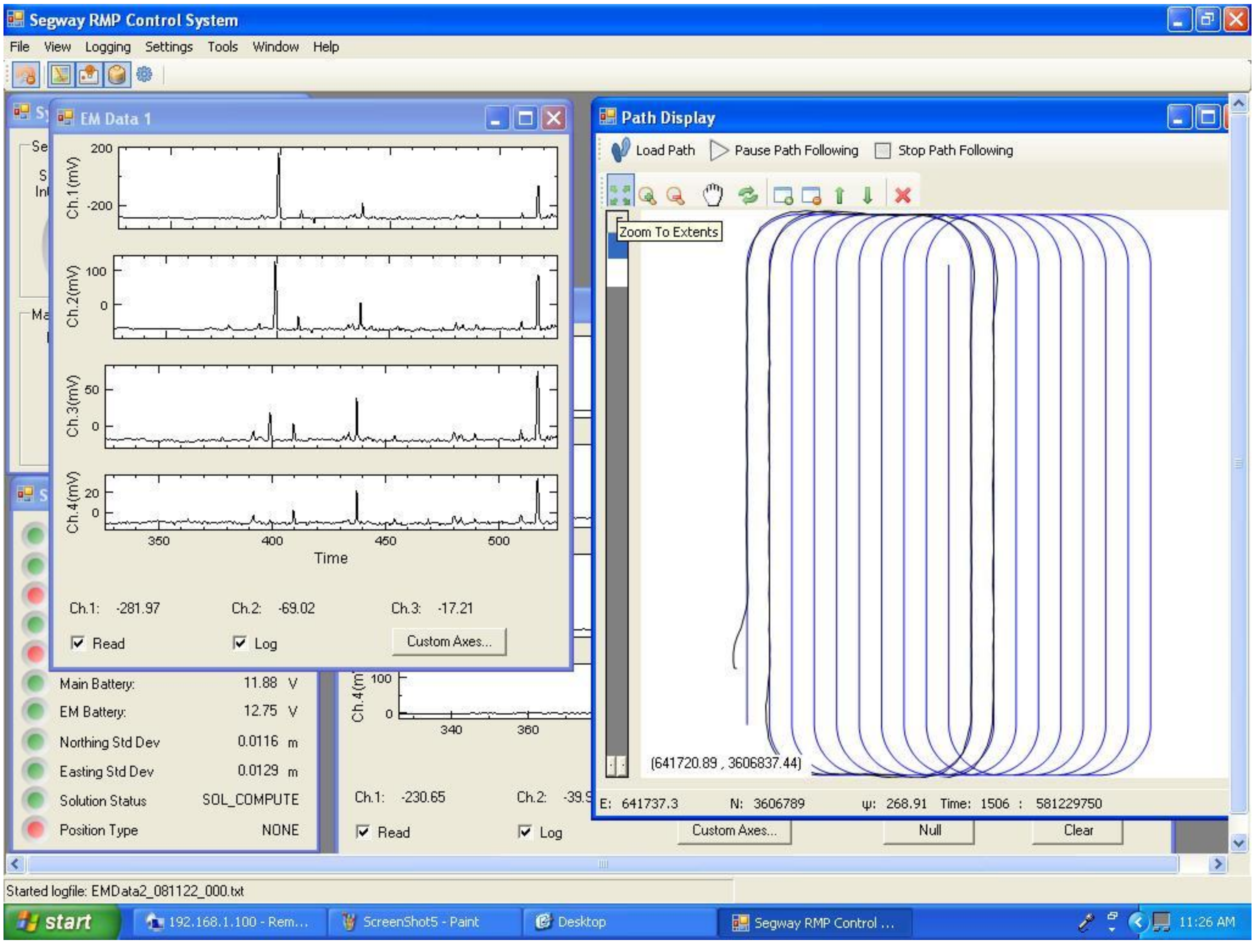

Figure 4 - Segway control software screenshot.

Demonstrations

An initial demonstration of the system to the Corp of Engineers was performed in May of 2007 at the standardized UXO test site at Aberdeen Proving Ground (APG) (http://aec.army.mil/usaec/technology/uxo01.html) in Aberdeen, MD. Two areas of the site were mapped, the calibration lanes and portions of the open field area. Both areas are seeded with various inert ordnance items. A 2.8 acre portion of that field was broken into 4 grids and surveyed autonomously towing a single Geonics EM61-Mk2. The resulting maps are shown in Figure 5. Several open areas can be seen in the survey where deep water or holes made it impossible to survey. The brightly colored regions indicate the presence of a metallic material, which could be a UXO item.

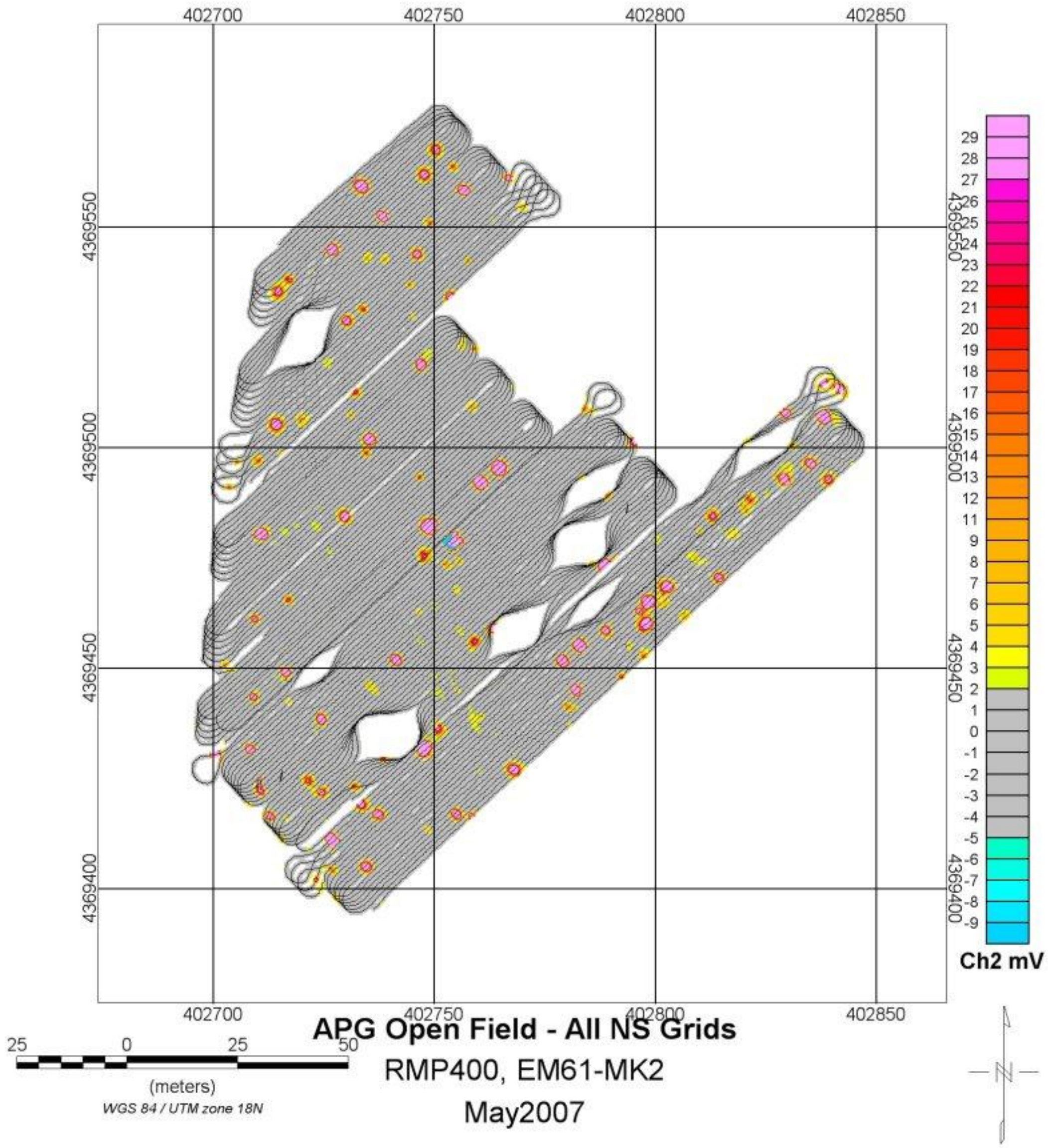

Figure 5 - Survey of a 2.8 acre field at APG

A Geometric G-858 Cesium vapor magnetometer was also used to survey the calibration lanes at the site. An early version of the vehicle with the original Segway chassis towing an array of two G-858 magnetometers is shown in Figure 6.

Figure 6 - Segway with pair of G-858 magnetometers

The first technology transfer of the system to a contractor for use on a real-world project site was performed with Parsons Corporation in December of 2009 at the former Great Salt Plains Bombing Range in Oklahoma (http://www.fws.gov/southwest/refuges/oklahoma/saltplains/) and at a portion of Camp Sibert near Gadsden, AL. The system was used to tow a custom fiberglass trailer built by the Corp of Engineers carrying two EM61-Mk2 sensors. The robot and trailer at the GSP site are shown in Figure 1. A portable office was set up on site and the robot was operated and monitored remotely at distances of up to 1.5 miles. A Parsons geophysicist tele-operating the vehicle on the range is shown in Figure 7. The Segway system surveyed on average over 2 acres per day at both sites. Areas at both sites were surveyed with both the Segway system and traditional methods to compare their performance. The results showed that while problems still exist, the system has potential for commercial use on UXO project sites. An analysis of those results has been submitted by Parsons for presentation at the upcoming 2010 Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP).

Figure 7 - Nathan Harrison of Parsons Corporation remotely operating the vehicle at Great Salt Plains, OK. The vehicle's current position, status information, and geophysical sensor output are displayed on the laptop screen on the left. Video from the robot is displayed on the small screen on the right.

Current Work

Several improvements and modifications are currently in progress on the system. The main thrust of the current work is to modify the system to collect grid node data. This will allow the vehicle to travel to a given point, stop, collect and filter geophysical data while stationary to reduce noise, and then move to the next point and repeat the process. This data collection method will provide an automated method for collecting high density discrimination level data with accuracy levels that far exceed man portable operations.

Hardware improvements are also being made and tested. The RMP400 has been modified by Segway to invert the gearboxes, increasing the ground clearance of the vehicle and allowing it to tackle more difficult terrain. Several modifications are being made to the chassis to make it more robust and watertight in order to reduce system downtime due to environmental conditions. The various computer and communication electronics needed to remotely operate the vehicle are being packaged into a single operator control unit (OCU) to reduce the system setup time. The modifications are expected to be completed by the summer of 2010 and demonstrated at a DoD site that is to be determined at a later date.

Project Publications

1. D. W. Hodo, J.Y. Hung, D.M. Bevly, S. Millhouse, “Linear Analysis of Trailer Lateral Error with Sensor Noise for a Mobile Robot-Trailer System.” Proceedings of the 2007 International Symposium on Industrial Electronics. Vigo, Spain.
2. D. W. Hodo, J.Y. Hung, D.M. Bevly, S. Millhouse. "Effects of sensor placement and errors on path following control of a mobile robot-trailer system." Proceedings of the 2007 American Control Conference (ACC), New York, NY, July 2007.
3. D. W. Hodo, “Development of an autonomous mobile robot-trailer system for UXO detection,” Master’s thesis, Auburn University, August 2007.
4. W. Travis, D. W. Hodo, D. M. Bevly, and J. Y. Hung, "UGV trailer position estimation using a dynamic base RTK system," Proceedings of the *2008 AIAA Guidance, Navigation and Control Conference*, Honolulu, HI, Aug 2008.
5. N. Harrison, B. Selfridge, C. Murray, and D. Hodo, “Self-guiding robotic geophysical surveying for shallow objects in comparison to traditional survey methods,” Presented at the Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP), Keystone, Colorado. April 2010.

Links

1. ESTCP Robotic DGM project fact sheet: http://www.estcp.org/Technology/MM-0608-FS.cfm
2. Article in Auburn Engineering’s 2006-2007Annual Report: http://www.estcp.org/Technology/MM-0608-FS.cfm (pg 22-23)
3. Auburn University GPS and Vehicle Dynamics Laboratory (GAVLAB): http://gavlab.auburn.edu