Journal of Conventional Weapons Destruction

Volume 11
Issue 2 *The Journal of Mine Action*

Article 41

April 2008

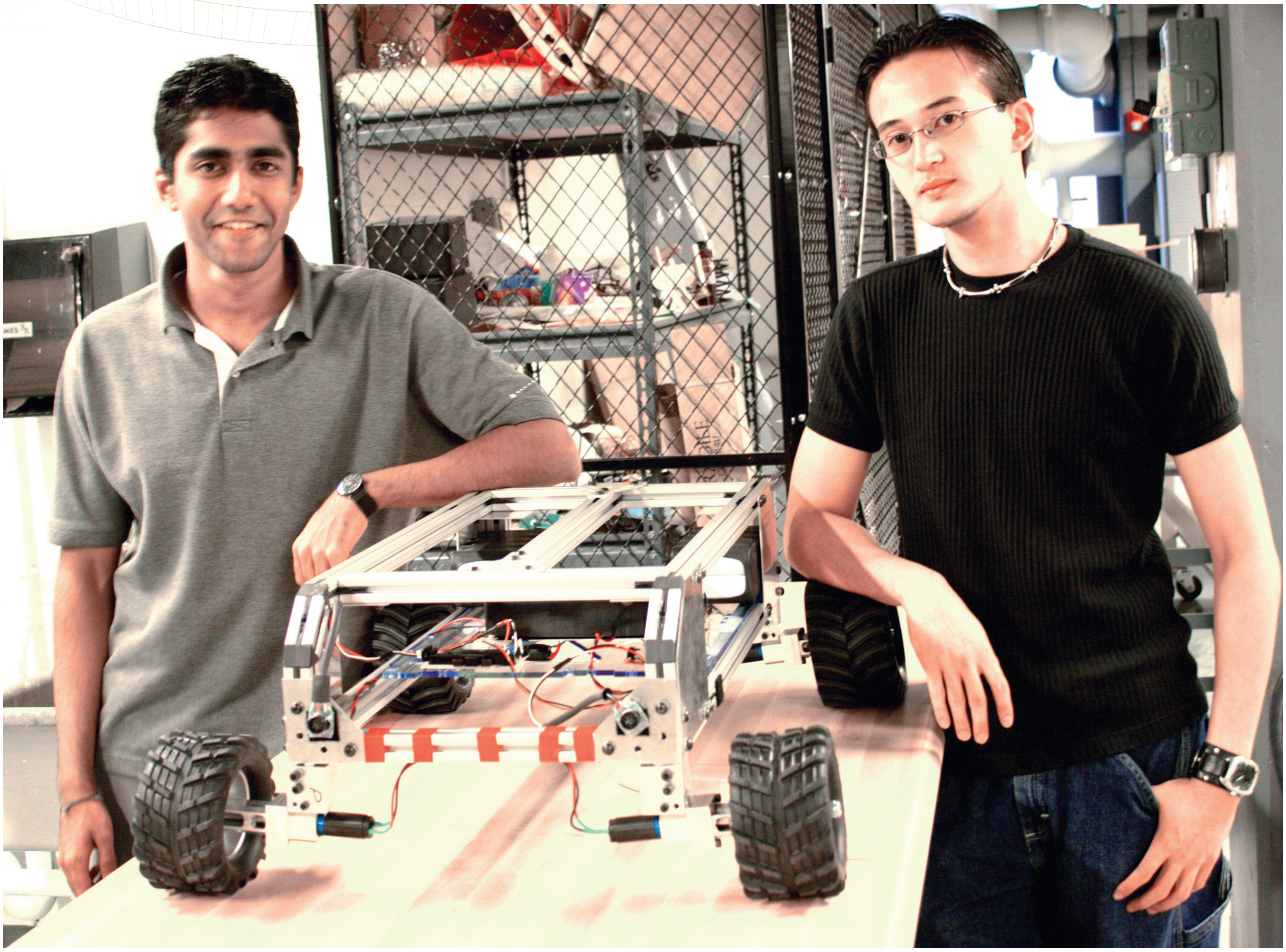
MineSweeper: Not Just a Game Anymore

Andres Mack
Cornell MineSweeper

MineSweeper: Not Just a Game Anymore

Cornell MineSweeper is a nonprofit student organization founded in 2006 by Cornell University engineering student Vikas Reddy that integrates robotics technology and humanitarian initiatives. The team, comprised of over 40 highly dedicated Cornell students, is designing practical robotic vehicles—still in the concept stage—to assist with demining efforts worldwide.

by Andres S. Mack [Cornell MineSweeper]



Saran Baskaran (left) and Daniel Wong working on the first design prototype of the robot.
ALL GRAPHICS COURTESY OF CORNELL MINESWEEPER

Deeply moved by the British film *The Killing Fields* (1984), a drama about the Khmer Rouge regime in Cambodia and its landmine fields, in 2006 Vikas Reddy and his fellow Cornell engineering students formed a new organization, Cornell MineSweeper, to develop a new type of demining machine. The organization is dedicated to the design and fabrication of cost-effective autonomous robotic vehicles capable of accurately detecting anti-personnel landmines and facilitating their clearance.

"That movie shocked me," says Reddy, who is currently a senior mechanical and aeronautical engineering student. "It made me want to do something about the landmine problem, so I started reading anything [I could] related to it." Finally, in the fall semester of his junior year, Reddy got together with other engineering students and formally started Cornell MineSweeper.

Initial Research

The team looked at the products already on the market before it began its work into small, inexpensive robots. The products they found were large and expensive—nothing like the robots they envisioned.

Current robotic clearance systems by companies such as MineWolf Systems use remotely operated, armored vehicles to clear landmines by direct detonation on contact using flails or tillers. Mine-detection robots such as Gryphon (see article on page 101) are again remotely operated vehicles. This means an operator must be present to direct the actions of the vehicles. Additionally, due to the size of these machines, they are expensive to buy and maintain.

MineSweeper's solution is different. Instead of building a large robot for demining, the team envisions a swarm of small, autonomous robots cooperating with each other and scanning minefields with minimal human intervention. The team's original idea was to create a small, inexpensive and autonomous robot that could detect AP landmines and then blow them up. After several discussions and designs, the team decided that this type of robot would not be cost-effective.

Design Overview

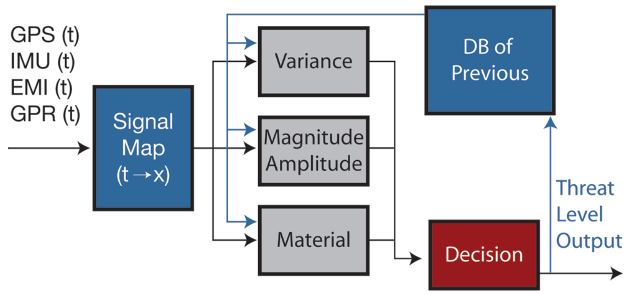
The best solution Cornell MineSweeper developed was a little more elaborate than originally expected, building on other available robotic solutions' pitfalls and experiences. The team is currently designing an inexpensive robot capable of working with multiple similar robots in a swarm. The team is focusing on using robots to detect mines to ensure the safety of human deminers; however, the robots are no longer being designed to explode the mines.

It must be noted that the MineSweeper robot is not meant to become a panacea for detecting and removing landmines. Much of the team's work is still in the design and development process and many modifications have been made to improve the robot. When the team finishes constructing the robot and testing it with positive results, they plan to offer this robot as an alternative solution for landmine marking and clearance.

Although the robot currently is designed to work as a stand-alone detecting tool for a human deminer, the Cornell MineSweeper team expects demining teams to combine the MineSweeper technology with other methods, such as mine-detecting dogs, to improve its success. That's why one of the most important features of this robot is its modular and highly customizable design. This will allow demining teams to implement other technologies simultaneously on the platform to autonomously accomplish an assigned task.

Research. According to the papers "Robots and Landmines"[1] and "Proceedings of International Symposium of Robotics Research"[2] by Professor James Trevelyan of the University of Western Australia, manual demining is still the most cost-effective way of clearing landmines; yet it is the most dangerous method due to the high rate of detection faults and false alarms in metal detectors.[3]

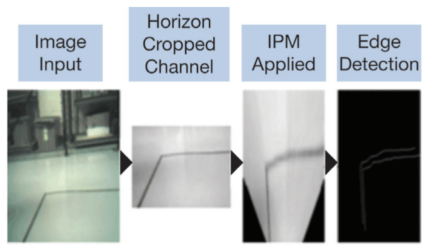
Trevelyan argues robots might be a safer way to detect and clear mines, but the costs and economic impact in the local economy are not realistic for war-torn countries like Afghanistan and Cambodia. One good reason for this is that if robots were successful at detecting and clearing landmines, hundreds of local human deminers would lose their jobs, and good jobs are hard to find in these economies.



Proposed mine-detection algorithm.

Cornell MineSweeper learned that its robot design had to be not only effective and inexpensive, but it must have a low social and economical impact. People would like to argue that manual deming is the most cost-effective way to clear minefields, but they overlook the difficult insurance policies, the cost of training individuals and equipment, and the unquantifiable cost of human life. By creating cost-effective autonomous robots that efficiently detect and mark mines for the human deminers to remove without the hazards of metal-detection faults, the team would protect the deminers' lives and protect their jobs in the end.

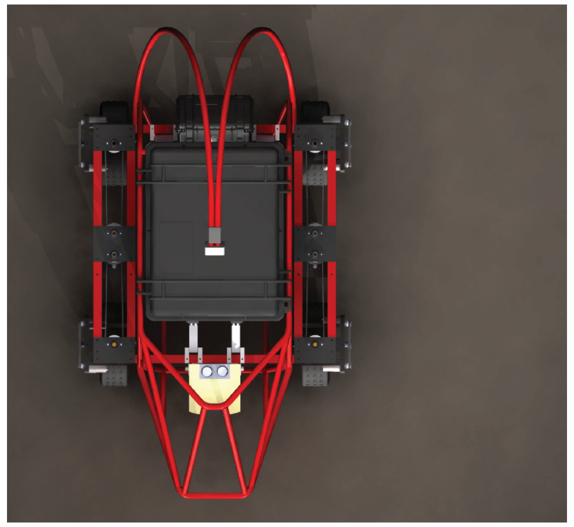
How it works. Although still experimental, the current concept of Cornell MineSweeper, also known as the Cornell Gladiator, consists of several low-cost, all-terrain robotic vehicles with on-board image processing, a global positioning system and an inertial measurement unit. These sensors would allow the robots to navigate and avoid obstacles autonomously. The robots communicate to a central field computer to receive scanning zone information so that all areas of the minefield are covered.



Block diagram of Cornell MineSweeper's robot's image processing algorithm.

The specifications. Each robot is a four-wheeled, all-terrain robotic vehicle, measuring 3 feet by 3 feet by 2 feet (91 centimeters by 91 centimeters by 60 centimeters) and weighing 30 kilograms (66 pounds), with an additional 10 kilogram (22 pounds) payload capacity. It utilizes an innovative steering mechanism which allows it to perform zero-point turns, making it highly maneuverable. The robot has four wheels that are 3-inches wide, each wheel exerting a ground pressure of 2.2 psi at nominal wheel deformation. Additionally, each wheel is moved by two motors. The platform can travel at a maximum speed of 1.5 meters-per-second (5.25 feet-per-second) and can traverse an incline of 20 percent. The robot utilizes a minicam to capture stereo images, which are immediately processed with edge-detection algorithms to watch for obstacles.

Each robot also uses a LIDAR sensor to scan for obstacles. The LIDAR has a maximum range of 30 meters (100 feet), giving the robot plenty of leeway to correct its trajectory. To determine the exact position of the unit, a GPS receiver and an inertial navigation system are used. Additionally, encoders have been implemented for dead reckoning. It should be noted that the LIDAR and INS sensors are advanced and expensive units included to accomplish complete autonomy but by no means are required to make the robot useful to deminers. Future generations of the robots will replace these sensors for less expensive SONARs and inertial measurement units.


Rendering of the team's Cornell Gladiator from the top.

Each robot has two core duo processors which communicate with all the sensors via its serial, firewire, and USB ports. The system is open source so any programmer can customize it. An ATMEL® microcontroller controls the motors, and the robot communicates with the ground station via a radio-frequency modem. All these devices are powered by an onboard, rechargeable lithium polymer battery pack, which provides a runtime of around two hours at maximum load. The robot scans for landmines using an electromagnetic induction array assisted by a ground penetrating radar, marks the threat spot with reflective spray paint, and maps the data using the INS. This information will provide the manual deminer with the necessary knowledge of the terrain to avoid any accidents.


Rendering of the team's Cornell Gladiator robot.

The EMI array is essentially a traditional metal detector but with a higher-resolution receiving end.[4] Instead of using the conventional two coils—one to emit the pulse, the other to receive it—the sensor has an array of receiving coils that are spaced close to each other. Each coil receives a pulse of different intensity based on the position of the metal content. By mapping the intensity all the coils receive, the robot can determine the size of the metallic object. With prior knowledge about the types of the landmines present in the local area, an educated guess can be made about the metallic object, thus giving the robot the ability to differentiate landmines from other metallic debris. This sensor is still in the design phase and no hard data has been established regarding scanning speed.

This prototype costs approximately US$5,000 and upon mass production is expected to cost as little as $1,000. This pricing structure becomes very realistic since the current cost of clearance is estimated at $300 to $1,200 per landmine.

This concept's primary limitation is its ability to scan only for metallic landmines; however, John Brooks' research shows that a large percentage of landmines in Cambodia are metallic, thus making the robot a very viable option for landmine detection in Cambodia.[5] There have been concerns about what happens if the robot triggers a landmine even though the ground pressure it exerts is minimal, thanks to its six wide tires. The robot has so-called "crumple zones," which take all the energy from the blast and split the wheels away from the body. This technique


Daniel Wong working on the first design prototype Spongebob.

should absorb most of the blast energy.6 Also, all the expensive sensors and computers are enclosed in a watertight, rugged box, which is being refined to meet military specifications for explosion proofing.

Good Support and Growth

Although completely student-led, Cornell MineSweeper has greatly benefited from the assistance of two professors in the robotics and sensors area at Cornell: Dr. Ephrahim Garcia and Dr. William Philpot. Garcia is currently the head of Cornell's Laboratory for Intelligent Machine Systems and contributed his many years of experience in the development of distributed intelligence in small robotic swarms and autonomous robots. His experience as a Defense Advanced Research Projects Agency Project Manager has also been an important asset to the team. Philpot is currently the Associate Director of the School of Civil & Environmental Engineering and the Program Leader for Remote Sensing at the Cornell Institute for Resource Information Systems. His research experience in the physics of optical remote sensing, spatial and spectral pattern recognition, and image processing has proven extremely helpful.

During a recent visit to Cornell University, Nobel Peace Prize Co-laureate Rae McGrath had the chance to meet with Cornell MineSweeper. "I really want to congratulate Cornell for allowing this young team the freedom to develop the idea. What excited me the most was that the team … hasn't made the mistake of so many other groups that set out to find the solution. They've really done their research and they're developing something that's very flexible. The next step for them is to go to somewhere with the problem of landmines," said McGrath.[7]

With its fresh design, quality of advisers and humanitarian mission, Cornell MineSweeper is starting to grow in the Cornell engineering community. Initially comprised of only six members, the team has expanded in only one semester to 41 committed students coming from all engineering fields and is still growing. In the beginning, people thought Cornell MineSweeper was a group of engineers that liked the computer game *Minesweeper* so much they gathered to play it; now students inquire about the robot. MineSweeper is neither a game nor an idea anymore; it will soon be ready to be field-tested.

See Endnotes, page 114

Andres Mack is a junior in the College of Engineering at Cornell University. He is also the Business Team Leader for Cornell MineSweeper. Cornell MineSweeper is a nonprofit student organization funded partially by Cornell University, Gladiator Technologies, Kionix, MaxBotix, Legend Technologies, Sunstone Circuits, Igus, Advanced Circuits and the Bartel family.

Andres S. Mack
Business Team Manager
Cornell MineSweeper
B62-P4 Upson Hall
Ithaca, NY 14853 / USA
E-mail: asm62@cornell.edu
Web site: http://minesweeper.engineering.cornell.edu/

News Brief

Cambodia Pushes Back Mine Clearance by 10 Years

The government of Cambodia announced in late 2007 that its mine clearance efforts would not be completed until at least 2020. Representing one of the world's most contaminated countries, Cambodian Prime Minister Hun Sen said that predictions made in 2000 for a 10-year window of clearance were overly optimistic.

Details or rationale for the extension were not given by Hun Sen at a meeting on Cambodian demining efforts, although the Prime Minister did say that the government expects the budget for landmine clearance to increase in coming years.

Every year, hundreds of Cambodians become casualties to landmines and other explosive remnants of war, which still litter the country after decades of conflicts. Demining groups from around the world have been collaborating with the government's own demining agency to clear the countryside since 1992. More than 2,900 square kilometers (1,120 square miles) remain contaminated, and progress in demining these areas has been slow.

Prime Minister Hun Sen cited a large number of U.S. landmines and unexploded ordnance items, left behind in Cambodia from massive bombing campaigns in the 1970s, as an enduring problem for the nation.