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Minesweepers: Towards a Landmine-Free Egypt, an Outdoor Humanitarian Demining Robotic Competition

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Minesweepers: Towards a Landmine-Free Egypt, a Humanitarian Demining Robotic Competition

Listed as one of the most contaminated countries in the world, Egypt has an estimated 22.7 million landmines and other explosive remnants of war.[1] In order to foster the research, development and application of robotics in humanitarian demining in Egypt, the Institute of Electrical and Electronics Engineers Robotics and Automation Society – Egypt Chapter organized **Minesweepers: Towards a Landmine-Free Egypt**, an outdoor robotic competition hosted by the German University in Cairo from 15–17 September 2012.[2]

by Dr. Alaa Khamis [IEEE Robotics and Automation Society – Egypt Chapter]

The majority of Egypt's landmine contamination is a result of military action during World War II, although ordnance remains from armed conflicts with Israel in 1956, 1967 and 1973.[3] Landmine contamination hinders the economic development of oil and agriculturally rich locations in the Gulf of Suez, North Coast and Red Sea areas. Furthermore, landmines emplaced in fields and around wells and water sources severely limit agricultural production, one of the mainstays of the economy, making these lands unusable and perilous. Egypt's current clearance methods, including conventional hand-held metal detectors, magnetometers and ground-penetrating radar, are slow and inefficient. It is unlikely these methods will ever achieve the required objectives that more advanced robotic solutions for minefield reconnaissance and mapping can meet.

Environmental Clearance Challenges

The extent of contamination is unknown, but the amount of affected land is estimated at nearly 25,000 sq km (9,653 sq mi) with areas between the Quattara depression and Alamein and near Marsa Matrough and Sallum being particularly affected.[1,3] Landmines and unexploded ordnance in the region are as much as 60 years old, and contamination involves hundreds of types of landmines. Mines can have metal, plastic,

Conventional manual landmine detection methods.
Executive Secretariat for the Demining and Development of the North West Coast.

Competition arena with buried and surface mines.
Photo courtesy of Minesweepers: Towards a Landmine-Free Egypt Organizing Committee.

wood or even football casings. Furthermore, casings and components degrade over time, altering their detection signature and creating uncertainty as to how mines will withstand clearance. Additionally, thick deposits of mud or sand cover many landmines and UXO, rendering conventional detection techniques mostly ineffective.

Egypt's various soil types contribute to clearance challenges. In sandy soil, the fine grit rapidly deteriorates equipment. Wind-blown sand buries mines and fragments up to 2 m (2.2 yd) below the surface. Conventional methods struggle to detect deeply buried mines (more than 30 cm/12 in), and mechanical clearance equipment may miss them. Moreover, excavating and sifting soil for mine-size objects is more difficult in hard clay soil or rocky areas found in Egypt. Some soils also have high mineral content, which interferes with standard detection equipment. In addition, muddy areas and marshes cause particular difficulties for deminers, as standing in the mud is often impossible. Many contaminated zones reside in areas of rough terrain with steep inclines, ditches and culverts, making the movement of individual deminers or mechanical equipment around sites difficult and even dangerous.

Additionally, the climate is extremely challenging for deminers. Common temperatures reach 55 C (131 F). The lack of consistently accurate maps means that the exact location of minefields and placement of specific mines are unavailable for deminers. Available maps are copies made by the British Defense Ministry from a few surviving historical documents and can only be relied upon with a limited level of confidence, because time and weather often shift the location of mines in the soil.

On the other hand, robotic systems can be designed to provide efficient, reliable, adaptive and cost-effective solutions for landmines and UXO contamination.[4] The robotics competition, **Minesweepers: Towards a Landmine-Free Egypt**, was created to foster the application of robotics in humanitarian demining and to raise public awareness of the role of science and technology in solving this problem.

Minesweepers Competition

Held in September 2012, **Minesweepers** is the first national robotic competition on humanitarian demining. Each participating team (maximum of 10 members) must construct a teleoperated or autonomous, unmanned, ground/aerial vehicle able to detect and map underground anti-personnel mines. The robot is required to navigate through rough terrain that mimics real minefields. The competition arena is an open, 20-by-20-m (22-by-22 yd) desert area surrounded by a 30-cm (12-in) wall. The landmine-contaminated zones in the arena start 50 cm (20 in) from each border. Most of the arena is composed of sandy soil or is rocky with obstacles, steep inclines and ditches.

This competition uses two different kinds of artificial mines.

Buried mines. Made from metallic cubes with approximate dimensions of 10-by-10-by-10 cm (4-by-4-by-4 in), these mines are completely buried to a depth of 10 cm (4 in). These buried metallic cubes mimic real AP blast mines. Real AP blast mines are designed to be small, typically 6–14 cm (2.4–5.5 in) in diameter, as this makes them cheap to produce and easy to store, carry and deploy.

Surface mines. Labeled in gray, surface mines are made from metallic cubes. These mines are visible, located on the surface of the competition area.

Any contact the robot has with these mines is penalized. The gray metallic cubes are used to simulate above-ground mines and UXO. Although UXO fail to function as intended, sometimes the slightest disturbance causes detonation. UXO vary greatly, ranging from the size of hand grenades to the size of large aircraft bombs.

For this first edition of the competition, only metal mines were considered because most mines in Egypt are encased in metal. Plans are underway to consider objects with plastic, glass or wooden casings for the next year's competition.

Some landmines are laid in a pattern so that they are easier to remove and account for; others are scattered randomly

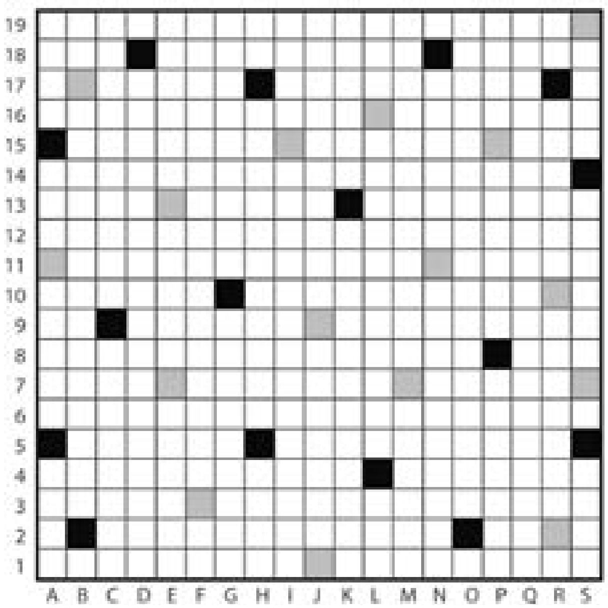

Figure 1: Graphical representation of the mine map (black = buried mine; gray = surface mine)
Figure courtesy of the author.

to reflect the various ways mines are found in real-world situations. Only the jury committee knows the locations of each landmine.

Each team must use a teleoperated or autonomous robot. Team members must create the robot and operate it remotely from a base station located outside the minefield. A wireless controller based on ZigBee, a set of communication protocols, is recommended for communication between the base station and the robot due to the field's large size. The robot locomotion systems require careful attention, as the terrain is particularly rough. Autonomous robots, which operate without any human intervention, receive a 40 percent bonus over teleoperated robots.

Each team can select its own set of sensors for locating mines. Although teams can install cameras on robots or on the sides of the field, no cameras or sensors are allowed to hang over the competition area. When a robot detects a mine, it must autonomously report this event using a blinking light signal and/or a warning siren for at least two seconds. The robot must also visualize and relay the type and position of the detected mine on the minefield map. Each demining robot has to provide a map of the detected mines when its competition time slot finishes.

The objective of the **Minesweepers** competition is twofold. The first objective is to create technical challenges that will generate new research and applications for robotics in the area of humanitarian demining. The second is to provide an educational forum to teach different aspects related to service robots and their application in humanitarian demining through a set of webinars and a free intensive course on how to build a real robot. Technical support is provided through a compilation of frequently asked questions, a resource page on the competition website, emails and social media network groups such as Facebook and Twitter.

The competition was judged by a committee made up of Dr. Salaheldin Omar, chair of Talent and Technology Creativity Unit at the University of Tabuk, Saudi Arabia; Dr. Hisham El-Sherif, head of the Industrial Automation Department at the German University in Cairo; Dr. Ahmed El-Mogy, an assistant professor at Tanta University, Egypt; and Marwa Soudi, Women and Junior Activities chair at IEEE Robotics and Automation Society, Egypt Chapter.

Results

Seventy teams began at the start of the competition, but only 24 could actually compete due to various issues that arose during robot construction. While some of the teams managed to build a working robot for the competition, some quit and could not complete their robot because of limited time, lack of necessary components or a last-minute technical difficulty with their robot. Each team had 10 members ranging in age from 14 to 28 years old. The first three winners received monetary prizes and certificates of honor. EMAR from Ain Shams University in Cairo, Egypt, won first place; Pegasus from the Arab Academy for Science, Technology and Maritime Transport in Cairo, Egypt won second place and third place went to Cateus from Mansoura University, Egypt.

The author created a comprehensive questionnaire and held discussions with participants to learn the most beneficial aspects of the competition. Some of the findings indicated that

- Creating a competitive technical challenge and raising awareness about humanitarian demining in Egypt were the most important reasons the teams gave for participating in the competition.
- The respondents believe robots will be widely used in humanitarian demining in the future.
- The majority of respondents found that the competition increased their interest in robotics and humanitarian demining.
- The respondents found that the competition helped them improve their practical skills and hands-on experience. Robot design is highly interdisciplinary, and necessary skills include engineering design, mechanical engineering, electrical engineering, computer science, sensor technology, systems engineering, project management, teamwork and creative problem-solving.
- The competition helped the participants practice

EMAR, a four-wheeled unmanned ground vehicle placed first in the competition.
Photo courtesy of EMAR.

challenging aspects of landmine and UXO detection and removal, such as difficult terrain that requires careful attention to the design of the robot's locomotion system. The harsh climate also requires the use of high tolerance and rigid electronic components. Many robots failed during the competition due to the use of traditional room-temperature electronics.

- The participants discovered that minefields are frequently strewn with small metal fragments, which can camouflage landmines and cause high rates of false positives. Therefore, participants had to put more emphasis on the ability of the detection system to differentiate subsurface mines, surface mines and randomly scattered metal fragments. The participants agreed that the competition's most challenging aspect was the mine mapping, as this process requires accurate localization of the robot in order to accurately visualize and report detected mines on the minefield map.
- The respondents expressed their interest in participating or recommending the competition to colleagues.

This year, the competition will be changed into an international competition under the title **Minesweepers: Towards a Landmine-Free World** where students/researchers from all over the world will be invited to participate. The ultimate goal of the **Minesweepers: Towards a Landmine-Free World** competition is to serve as an educational opportunity and research forum to provide efficient, reliable, adaptive and cost-effective solutions to help countries combat landmines and UXO contamination. The competition can also motivate the participants to create new companies and industries geared toward minefield reconnaissance and mapping technologies.

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The author wishes to express gratitude to the German University in Cairo for supporting and hosting the ***Minesweepers: Towards a Landmine-Free Egypt*** *competition. He also acknowledges the support and generous input of the Executive Secretariat for the Demining and Development of the North West Coast, the Ministry of International Cooperation, Mine Action and Human Rights Foundation, and Protection of Armaments and Consequences. Finally, the author would like to thank all members of the organizing and jury committee, supporting organizations and the international advisory board.*

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ENDNOTES

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1. "A paper on the problem of Landmines in Egypt." *Arab Republic of Egypt: Ministry of Foreign Affairs*. http://tinyurl.com/cg3wgjr. Accessed 10 December 2012.
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