PETALS: a visual interface for landmine detection

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ABSTRACT

Post-conflict landmines have serious humanitarian repercussions: landmines cost lives, limbs and land. The primary method used to locate these buried devices relies on the inherently dangerous and difficult task of a human listening to audio feedback from a metal detector. Researchers have previously hypothesized that expert operators respond to these challenges by building mental patterns with metal detectors through the identification of object-dependent spatially distributed metallic fields. This paper presents the preliminary stages of a novel interface – Pattern Enhancement Tool for Assisting Landmine Sensing (PETALS) – that aims to assist with building and visualizing these patterns, rather than relying on memory alone. Simulated demining experiments show that the experimental interface decreases classification error from 23% to 5% and reduces localization error by 54%, demonstrating the potential for PETALS to improve novice deminer safety and efficiency.

ACM Classification: D.2.2 [**Design Tools and Techniques**]: User Interfaces

General terms: Design, human factors

Keywords: Landmine detection, humanitarian demining, spatial patterns representation, assistive visual interface, PETALS

INTRODUCTION

Hidden beneath the ground, a landmine is a passive explosive device usually triggered by pressure and used to deny access to military positions or strategic resources. After wars, landmines remain hidden within communities, indiscriminately killing and maiming innocent civilians. As of 2009, landmines affected nearly 70 countries, and during 2008 alone, they were responsible for over 5000 casualties [2]. Landmines impose especially high economic costs on third world countries by increasing the number of disabled victims requiring medical care and government welfare, as well as rendering vast tracts of farmland unusable. Vietnam, for example, has an estimated 100,000 survivors, while nearly 13% of Cambodia's land mass is estimated to contain threats [2]. Furthermore, mines affect the economic strength of farm-based societies, where estimates from a decade ago indicate that financial costs on the order of \$6.5 million could arise due to livestock loss from landmines [1]. To prevent further loss of human life and livelihood and to promote economic prosperity in third-world countries there is an urgent humanitarian need to find and neutralize landmines.

Given the operational difficulties presented by typical minefields and resource constraints on most demining programs, a human listening to audio feedback from an affordable metal detector remains the primary method for finding landmines [2, 8]. With this technique, the proximity of the human to the explosive device means that mistakes are potentially fatal. Furthermore, the presence of metallic debris in former combat areas means that operators must discriminate landmine feedback from that induced by clutter in order to operate efficiently: in current practice, operators must stop and inspect every contact that could be a landmine, which slows down the demining process significantly [2]. Both these challenges are exacerbated by newer landmines with minimal metallic content. Any improvement in metal detector-based performance can therefore increase operator safety and also reduce the typical time and cost associated with the demining process. With these possible gains at heart, we explore the possibility of assisting current demining efforts by designing a visual interface to help deminers using metal detectors.

BACKGROUND AND PREVIOUS WORK

Efforts to improve performance in human-based landmine detection have focused on improving detection technology or on improving human performance with respect to existing devices. Improvements in the accuracy of metal detectors and the development of dual sensor systems represent significant technical advancements in this area [3]. Novel detection systems, such as the Advanced Landmine Detection System (ALIS), are also being developed, where signals from both a metal detector and ground penetrating radar are processed and visualized on a palmtop PC [6]. The sweep monitoring system—a training tool intended to improve operator sweeping technique during training—tracks the movement of a hand-held detector and provides training feedback on trainee performance [5].

Work in the area of cognitive engineering has suggested that expert deminers mentally construct spatial patterns to make detection decisions. These patterns are constructed by finding a point near a potential threat at which the metal detector responses start and stop. By systematically finding several such points, experts build spatial patterns (outline of the boundary points) of the metallic field belonging to the buried object or collection of objects (see Figure 1). If the encoun-

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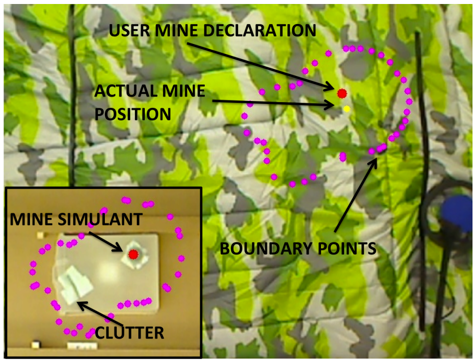

Figure 1: PETALS user interface (larger picture). Lower left hand corner shows underlying configuration of the detection task.

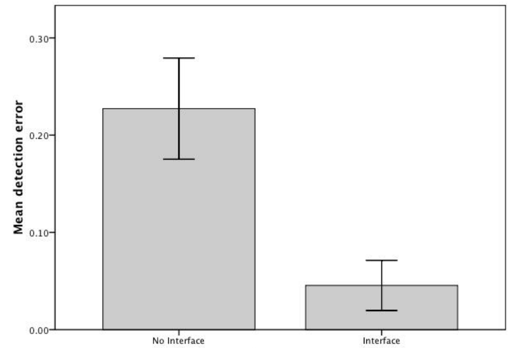

Figure 2: Probability of error (with standard error bars)

tered pattern is similar to one belonging to a landmine in past experience, then the probability of a threat is high. By incorporating such procedures into demining training programs, researchers have been able to improve performance of novice deminers [7]. This technique, however, relies on operators' creation and retention of mental models that are subject to cognitive limitations such as working memory capacity.

APPROACH

To circumvent cognitive limitations associated with internal representation we designed a preliminary experimental version of PETALS (Pattern Enhancement Tool for Assisting Landmine Sensing). This interface allows the operator to build and see these patterns on a display screen, helping them determine the presence and location of simulant mines on a detection test-bed. Our experimental interface consists of a three button controller, an overhead camera, and a monitor mounted at head height. The operator uses the three button controller to add or delete boundary points belonging to the pattern, and to declare the position of a suspected mine on a live video feed of the operator workspace. Figure 1 shows the user interface, where the user has collected a sufficient number of boundary points to see the pattern and to make a decision about mine position.

EXPERIMENTAL EVALUATION

To understand the effects of visualizing these spatial patterns in relation to the traditional method of internal representation we conducted a controlled laboratory experiment with 44 participants from an undergraduate population [4]. The participants were extensively trained (each training session lasted up to 90 minutes) to behave like novice deminers, after which they completed simulated mine detection tasks (see Figure 1). Each detection task required the novice deminer to i) discriminate between simulated mines and clutter and ii) localize potential mines as accurately as possible. Subjects were randomly assigned to perform these tasks either with or without the use of the experimental interface.

The experimental results demonstrate that visual assistance significantly improved the classification accuracy for novice deminers: with the interface, participants were much less likely to misclassify a simulated landmine as a piece of harmless clutter, decreasing error from 23% to 5% (see Figure 2). They were also significantly more accurate at estimating the location of the mines, reducing localization error by 54% [4].

CONCLUSION AND ONGOING WORK

Our findings suggest that an interface like PETALS that assists in visualizing spatial patterns has potential to improve both the safety and the efficiency of metal detector based landmine detection. Ongoing work is directed at validating the PETALS concept in more realistic environments with actual deminers.

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