Lawrence Livermore National Laboratory

Thermal Detection/Infrared

Multi-Spectral Scanning/Imaging

Radar

Ground Penetrating Radar (GPR)

Micropower Impulse Radar (MIR)

Acoustic Mine Detection

Other Technologies (No Description Available)

Magnetometer Imaging of Land Mines - Phil Harben
Multi-Band Infrared Imaging of Land Mines - old
Wide Bandwidth Ground Penetrating Radar for Mine Detection - Steve Alvezdo
HyperSpectral Imaging for Mine Detection - Mike Carter
Micropower Impulse Radar (MIR) for Mine Detection - Steve Alvezdo
Ion Trap Mass Spectrometer for Mine Detection - Dave Chambers 925 422 5607
Fluorescent Taggants for Explosives - Bryan Andresen
Explosive Taggants for Enhanced Mine Detection - Bryan Andresen 925 422 0903
Surf Zone Mine Clearance - ?
Electromagnetic Detection and Clearance of Mines - Phil Harben
Synthetic Aperature Acoustic Mine Detection - Terry Donich 925 422 8637
A Mine Clearing Rake - Milt Finger
Autonomous Vehicles for Mine Clearance - Erna Grasz 925 423 6556
Bacteriological Destruction of Mines - ?
Thermoflux Materials for Mine, Chemical, and Biological Agent Destruction - ?
Shaped Charge Destruction of Mine Fields - old

Thermal Detection/Infrared

A buried mine acts as a impermeable barrier to the normal movement of soil moisture, preventing gravimetric flow downward during precipitation; and upward movement by capillary action during times of surface moisture depletion. As a consequence, the normal water distribution of soil is altered by the presence of the mine. In general, the soil above a mine is usually drier and more porous than homogeneous soil (at the same depth) surrounding the disturbed area where the mine was emplaced. This does not always hold true right after rainfall or when the soil is saturated.

Soil water content has marked effects on thermal properties to include heat capacity and conductivity, and electromagnetic reflection, transmission and emission characteristics. Infrared emissivity and reflectance are strongly affected by moisture content and hence are potentially useful phenomena for recognizing moisture and thermal anomaly patterns indicative of mined areas.

The disturbed soil over a mine cools faster (and more) as the sun retreats, and then heats faster than the surrounding undisturbed soil when the sun returns. There may be a difference of a few tenths of a degree, or several degrees depending on the moisture, solar load and soil composition. It is this difference in temperature which makes it possible to find buried mines in roads and non-foliated areas.

LLNL has been very active in electro-optical and (to a larger extent) infrared techniques for mine detection. Early work (1989-91) by Nancy Delgrande demonstrated the detection of mines by detecting the change in ground temperatures as a result of the placement of mines under the ground. The novel aspect of this work was the simultaneous use of mid-wavelength IR (MWIR, 3-5 µm) and long wavelength IR (LWIR, 8-12 µm). In a larger follow-on program supported by ARPA and U.S. Marine Corps, LLNL determined that this thermal technique would be limited to areas of low clutter. Since that time, the Army has used this type of system for the detection of mines in roads in Somalia. Other multispectral and multisensor experiments were conducted as part of this effort. A large test facility was established at the Nevada Test Site to support this experimental program. This work also emphasized the value of spectral analysis for mine detection.

Multi-Spectral Scanning/Imaging

Multispectral Scanners (MSS) obtain light energy measurements in the visible-near infrared and short wave infrared range, typically from 0.4 to 2.6 microns (also expressed as 400 to 2600 nanometers). Field scanners are able to measure the ultraviolet energy (.01 to .4 microns) but the MSS systems used from aircraft and satellite do not image the ultraviolet energy as too much of this energy is absorbed by the atmosphere. Most MSS systems collect data in broad band of about 100 nanometer width. New instruments called hyperspectral scanners (HSS) can collect data at 3-5 nanometer band widths which means that more distinct information can be collected about surface features that provides for the possibility of distinguishing pigments within a plant leaf or soil properties such as organic matter content or type of iron oxides.

LLNL is currently at work with ARPA on the detection of mines using infrared hyperspectral imagers. LLNL, using the LIFTIRS instruments, has provided important data for the development of a Hyperspectral Mine Detection system.

Thermal scanners operate on the same principle as MSS or HSS systems but the resultant images must be interpreted with due regard to the basic thermal radiation principles involved. LLNL has applied hyperspectral imaging to detect the disturbed soil above a buried mine.

LLNL has had at least two projects looking at the visible and near IR spectral regions. Measurements were made as part of the ARPA program, but no systems were developed. The CAMI program has developed a multispectral vis-near-IR camera system.

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Radar

Radar methods, particularly ground penetrating radar (GPR) were seen as very promising methods of detection, particularly if used in combination with other sensors. The main improvements that need to be made are feature extraction and target recognition. In addition, improvements to the hardware such as antenna design and bigger bandwidth are necessary. It is also necessary to develop the equipment into something that is lightweight (man-portable) and relatively inexpensive.

Developments Underway Include

- Algorithms and databases to enhance the reliable detection of mines by the identification of reliable features to yield a very high probability of detection with substantially-reduced false alarm rates.

- Fusion algorithms for arrays (e.g. as in synthetic aperture array - SAR - techniques) to enhance detection, identification and localization.

- Automated Target Recognition (ATR) algorithms to increase the detection rates, hence reducing costs, at a specified high probability of detection and low false alarm rate (these minimize the total costs by reducing unnecessary excavation).

Ground Penetrating Radar (GPR)

A ground penetrating radar transmitter focuses microwave impulses into the ground. Buried objects such as metallic land mines reflect the microwave impulses back toward the GPR receiver. A moving GPR system can map the location of buried objects. For detecting buried mines (metallic) the GPR system is normally swept along in contact with the ground and operates within a frequency range of approximately 200 MHz to 1 GHz. Plastic / non-metallic mines / object detection and identification is problematical. There are a number of GPR systems in prototype development, however, they consistently suffer from a high false positive detection rating. That is, they identify buried objects to be mines when in actuality they are various forms of metallic debris. Note that for every mine there may be as many as 2,000 metal fragments cluttering the area.

Ground Penetrating Radar - Standoff

As part of the ARPA mine detection effort described above, LLNL worked with SRI to investigate the detection of mines using ground penetrating radar (GPR). LLNL demonstrated the detection of metal mines in a cluttered environment (where the IR systems did not work) using an ultra-wideband impulse radar system.

Lawrence Livermore National Laboratory (LLNL) has developed a side-looking, ground-penetrating impulse radar system that can eventually be mounted on a robotic vehicle or an airborne platform to locate buried land mines. The radar system uses LLNL-developed monocycle pulse generators which have been tailored to be most efficient for this application. Extensive field tests have been conducted on a mine field consisting of real and surrogate mines buried in natural vegetation. Results indicate that the LLNL GPR system consistently detects buried metal mines, but does not reliably detect plastic mines.

Ground Penetrating Radar - Near field

While GPR systems operated in close contact with the ground have been operated for some time, LLNL has worked in two different areas to change the nature of these systems. Work in the Engineering Research Division has been conducted to develop a synthetic aperture radar system for the 3-D imaging of buried structures, originally developed for inspection of civil structures. This work has direct application to mine detection using a vehicle mounted system.

Micropower Impulse Radar (MIR)

The Micro Impulse Radar (MIR) is an LLNL technology development which is applicable in at least two types of mine detection systems. The MIR transceivers can be used as the detection elements in the 3-D system described above, probably reducing cost, size and mass. The MIR technology can also be applied to a hand held mine detection system analogous to the hand held metal detector.

LLNL has developed a new extremely small radar sensor, the micropower impulse radar, for short range motion sensing and imaging applications. The micropower impulse radar was developed at LLNL in 1993. The compact MIR circuit module is a complete impulse radar transceiver on a chip and is constructed using low cost, off-the-shelf components. A variety of antennas have been designed for various applications. The transmit and receive antennas used for mine detection are resistively loaded cavity backed dipoles measuring about 4 cm on a side. With the antennas connected to the radar module, the entire system fits in a 4 x 6 x 10 cm volume. The unit emits very low RF power in a broad RF band, resulting in low power consumption as well as making it difficult to detect in operation. The present unit has a 100 ps rise time pulse yielding a range resolution of about 2 cm in typical soils. The entire radar package-drive electronics, transmit / receive antennas, range sweeping circuitry, and 9V battery power for many hours of operation, fits in one hand, making it the smallest, lightest, and lowest cost radar known. Based on a pulser for emitting and detecting very low amplitude voltage impulses, the MIR has a sensitive detection window for accurate ranging that can be varied over time to provide the radar return information at different depths. Its ultra-wide band frequency range (1-4 GHz) is near optimal for short range ground penetration (<2 feet), and mine detection with reasonably high resolution (~1 cm in soil). It has been coupled with a laptop computer for completely portable image capture, processing, display, and analysis. This low cost opens up the possibility of using arrays of radar modules in a synthetic aperture mode or a diffraction-tomography based imaging mode. An array of radar units this small is consistent with implementation in a land robotic vehicle or a UAV. Input power requirement per unit is 6-12 volts at 8mA. Typical range in air is approximately 10 meters and range in soil is .2-.5 meters depending on soil conductivity and standoff range.

Acoustic Mine Detection

Advanced signal processing software is now available, which can be used with acoustic/seismic methods to produce tomographic images of mines and other objects several feet in front of the operator. This could distinguish a mine from other clutter and therefore reduce the false alarm rate. The hardware consists of an acoustic transducer array and a microprocessor. The returned acoustic signal is then interpreted in real time via a new calculational capability to reconstruct the three dimensional object causing the reflected acoustic signal.