PARADIS: A Prototype for Assisting Rational Activities in Humanitarian Demining Using Images from Satellites

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PARADIS: A Prototype for Assisting Rational Activities in Humanitarian Demining Using Images from Satellites

The PARADIS project aims to improve the planning of humanitarian demining campaigns, with a software package working from the country scale to the field scale. A demining organization and an image interpretation team work together to put this system to use and benefit mine-affected areas.

by Vinciane Lacroix and Marc Acharya, Centre d'Information et de Traitement des Signaux de la Statistique (CITS), Royal Military Academy (RMA), Belgium, and Eleonore Wolff, Institut de Géographie et de Cartographie, Université Libre de Bruxelles

Introduction and Overview

The aim of the PARADIS project is to improve the planning of humanitarian demining (HD) campaigns using remote sensing data and Geographical Information System (GIS) techniques. In this context, a method and two software packages were built based on the needs expressed by the Bomb Disposal Unit of the Belgian Armed Forces. The main software package consists of management tools integrated in a common GIS platform, working from the country scale to the field scale. The planning method involves two main actors: a demining organization and an image interpretation team. A third actor is an image processing team for which the other software package was built. Applying image processing tools on satellite images and on scanned maps should speed up the extraction of objects of interest in an HD context. This aspect of the project is beyond the scope of this article.

The Belgian Armed Forces Bomb Disposal Unit, also known as SEDDEDOVO, is responsible for rendering safe and destroying all munitions found in Belgium. Apart from giving direct support to Belgian units when deployed abroad, the unit also contributes directly to HD all over the world. At the moment, the unit has teams of technical advisors deployed in Laos and Cambodia.

Some basic knowledge in remote sensing can be found in the TELSAT guide. Satellite sensors vary in spatial, spectral, temporal and radiometric resolution. In this document, we will often refer to the spatial resolution. Spatial resolution is related to the resolving power to distinguish image details. To remote sensing, it is common to specify the spatial resolution as the size each pixel represents in the real world. For example, the SPOT satellite has a spatial resolution in the panchromatic mode of 10 m, meaning that the image is composed of pixels with a ground diameter of 10 m. Also, a sensor may be active or passive. Optical sensors are passive, as they measure the reflected solar-radiance and radiation emitted by the observed objects. Radar sensors are active, as they emit a beam of electro-radiation and detect the wave that is reflected by objects.

GIF and Remote Sensing for HD

We made a review of existing GIS tools for HD in A Geographical Information System for Humanitarian Demining when proposing the design of PARADIS. The review included the project undertaken at James Madison University (JMUDIV), the Information Management System for Mine Action (IMMSA), developed by the Geneva International Centre for Humanitarian Demining (GICHD), MinedeXem developed at ITG; the Digital Mine Documentation System Prototype, developed by the Business for Industry Concern (BIBG); "FO-CUS HD," a Mapping Information system designed by Landair International Ltd.; and the integrative approach proposed by the Defense Evaluation and Research Agency. Those projects are described in more details in Demining Technologies, a publication from International Exhibition, Workshops and Training Courses. Also, some studies aimed at using remote sensing data in order to detect mine fields, as for example, the "airborne mine field detection" project. From the latter review, we conclude the following:

• The use of airborne or satellite images helps to detect hidden mines and general mine fields that have not yet been demonstrated.

• None of the GIS tools is oriented by the tasks assigned to deminers during a mission.

• BISMA is becoming the UN standard for collecting and managing mine field data. However, the tools provided were mainly developed to analyze spatial distributions and to centralize information about suspected areas and mine fields.

Therefore, we decided to build a tool based on IMMSA and ArcView in order to plan the humanitarian campaign, following the tasks of deminers during a demining mission.

Design of PARADIS

Identification of Spatial Data Needs

In order to identify the spatial data needs of deminers during an HD campaign, a collective work was started. As a starting point, a table of the needs established by Paddy Blagden, technical director of the GICHD, was used and expanded during meetings with the Belgian deminers.

A demining mission involves the following tasks:

• Collecting general data at mission

<table>
<thead>
<tr>
<th>Table 1: INFORMATION NEEDS FOR PLANNING HD CAMPAIGNS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Info</strong></td>
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<tr>
<td>----------</td>
</tr>
<tr>
<td>1. Mission announcement</td>
</tr>
<tr>
<td>Global topographical data</td>
</tr>
<tr>
<td>Hydrographic network</td>
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<tr>
<td>Inherited areas location and toponomy</td>
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<tr>
<td>Administrative limits</td>
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<tr>
<td>Local topographical data</td>
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<tr>
<td>Practicable roads and bridges</td>
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<tr>
<td>Hydrographic network</td>
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<tr>
<td>Inherited areas location and toponomy</td>
</tr>
<tr>
<td>Land use</td>
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<tr>
<td>Important infrastructures</td>
</tr>
<tr>
<td>Military buildings</td>
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<tr>
<td>Climate</td>
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<tr>
<td>Precipitation and wet/dry seasons</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Conflicts</td>
</tr>
<tr>
<td>Which were the parties (guerrilla or military)?</td>
</tr>
<tr>
<td>Where were the areas of conflicts/fighting?</td>
</tr>
<tr>
<td>Which were the ammunitions used?</td>
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<tr>
<td>How are the ammunitions placed?</td>
</tr>
<tr>
<td>(Pottens)?</td>
</tr>
<tr>
<td>Changes related to conflicts</td>
</tr>
<tr>
<td>Land use and roads</td>
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<tr>
<td>Where did they come from?</td>
</tr>
<tr>
<td>Where are they?</td>
</tr>
<tr>
<td>How many?</td>
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<tr>
<td>Evaluation from surface covered by cumes</td>
</tr>
<tr>
<td>Where do they have to go?</td>
</tr>
<tr>
<td>Relocation</td>
</tr>
</tbody>
</table>

DCW: Digital Chart of the World
TC = topographic maps
VRHSI = high-resolution satellite images
UDB = database
RP = resource person
### 2. Field Survey

**Level 1**
- **see phase 1. if level 1 exists, the information below will be obtained from the organization that made it.**
- **collateral information**
  - Government, population, hospitals, NGO, UNDP, BD, moga
- **overview of mine field location**
  - Information origin and reliability
  - 1:10,000, 1:50,000
- **Marking**
  - Map, mark in the field
  - Government, population, hospitals, NGO, UN, sketch
- **Comparison of mine field location**
  - Link to mine DB
  - Precise localization and nature: Hospitals, industries, military buildings, schools, villages, trenches, etc.
- **Communications roads level 2 already done and cleared areas**
- **3. Planning**
  - Desk work Duration: 1 week

### 4. Level 2: Demining

**Work field Duration:**
- 1:250,000

**Which detailed map available?**
- CARTOGRAPHIC INVENTORY, NATIONAL GEOGRAPHIC INSTITUTE, ETC.

**Precise mine field localization and extent**
- Areas to clear

**Nature of area to clear**
- AFR, work on the field

**Types of removed mines**
- Geographical (per mine field)

**Existence of traps**
- Geographical (per mine field)

**Clearing methods and techniques**
- Manual, automatic, dogs, etc.

**Personnel**
- Number of deminers and management

**Working pace of the clearing**
- Depends on surface type, season, munitions, traps

**Productivity**
- Number of cleared m²/deminer/month

**Security**
- Deminer accidents

**Planning update**
- Based on the surface cleared compared to the surface initially estimated. New map production

**Syntheses of demining results**
- 1:250,000

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**NOTES FROM THE FIELD**

[Journal of Conventional Weapons Destruction, Vol. 6, Iss. 1 (2002), Art. 21](https://commons.lib.jmu.edu/irar-journal/vol6/iss1/21)
4. Clearance: drawing the mine field (Field – team scale ≈ 1:5,000)

A. Overlaying the detailed topographic map or the space map and its interpretation
B. Overlaying geo-referenced UXO – suspected mine field selected into a DB
C. Filling/correcting/modifying a follow up form of clearance activities with information such as precise location (GPS points, reference of map, reference of image or photo), descriptive information of the mine problem coming from the Level 1 DB (injured person, etc.), vegetation cover
D. Drawing and/or updating a sketch of the mine field on a map (if available)
E. Printing and reporting

5. Clearance: follow up of each section (Field – section scale 1: 500)

A. Overlaying of a grid (size and orientation of the grid defined by the user) on the sketch
B. Printing the sketch with the grid
C. Encoding the number and the type of mine or UXO found in each cell of the grid
D. Filling the grid each week according to the cleared area
E. Printing and reporting

6. Updating the planning from the mine field to the region (1:5,000 to 1:50,000 to 1:1,000,000)

A. Computing the cleared area and the area to be cleared and updating the estimated time required to clear the area according to the demining means (number of detectors) and the time needed to clear a square meter (parameter to be fixed by the user according to the vegetation cover, the duration of a working day, the mine density.
B. Following up with indicators (to be determined) to be visualized and computed at several geographic scales (grouping and generalization procedures) for a feedback to the headquarters
C. Printing and reporting

Remarks:

It seems necessary to maintain an attribute related to the scale at which any information was collected. The follow-up of a mine field through time should be possible.

PARADIS Interface

We have identified the tasks to be performed in the interface according to the routines of a mission and the identified data needs previously described. A software package working at four scales embedded in an ArcView platform that is compatible with IMSMA and the Belgian EOD Champassak database has been produced. The global scale or Country Scale (1:1,000,000) may contain satellite images (SPOT, Landsat TM, ERS and RADSAT), topographic maps and information from field surveys. Based on this data, the user should see practical roads and bridges, village extensions, hydrographic networks, hospitals, military buildings, accident localization, campaign schedules, mine field locations and land cover. This overlay information comes from image interpretation and from the IMSMA database. At this scale, the demining staff has tools to plan its campaigns and organize its teams according to priorities, regional constraints and logistic facilities.

The Field Scale (1:10,000 to 1:5,000) may contain aerial photos, very high-resolution satellite images (IKONOS), statistics and sketches. Highly accurate maps of the suspected areas and cleared mine fields could be available as overlay. An Ad-
vancement Scale (1:500) is added in order to produce a detailed description of each mine field. The system was fed with data for test sites in Laos and Mozambique (see section entitled Test Sites). The design of the prototype was presented at the ISPRS 2000 conference in Amsterdam. A doubleface was set up, however, to use the system for the Laos and Mozambiquian test sites is available at the SIC website.

Table 2 describes the high-resolution data in the interface and their working stage.

Organization of a Campaign

The goal of the general planning method is providing a demining organization and an image interpretation team. Additional to the team forming the inspection team, an additional role is performed in the form of the interpretation team.

In the PARASID project, the SEDE-E DOVO played the role of the team forming the inspection team. The phase of the project, the interpretation team was distributed between the scientific partners of the project: the IGES and the SIC. The team must be performed in routine, an operational partner had to be found inside the Belgian mine-sweeping force. Gaspar Research and Security Service, Section Imagery (GSR-M) assumed this task. This role could be given to a well-chosen consultant in the case of non-Belgian missions.

Extracting information from satellite images and scanned maps could be tedious work. This routine was analyzed of if images are large semi-automatic feature extraction could be a precious help for image interpreters. This work is not mandatory, but it should speed up the interpreters' work.

The procedure of data collection goes as follows. It is summarized in Figure 1. At the mission announcement, the demining team contacts the interpretation team (SGRID) in order to identify the region and the best season for acquiring satellite data over the areas of interest, and to purchase them. This team is also responsible for collecting maps and performing a field mission. The following the hydrograph and road networks, identification of water areas and classification of the images. This information should be used to facilitate the image analysis which aim is to produce the vectorial overlays made of roads, inhabited and cultivated areas, infrastructure, etc., again performed by the interpretation team. The latter team will also produce composite colour images using all bands, and black and white images displaying the panchromatic data. Meanwhile, the deminer (SEDE-EDOVO) fills in the IMSMA database with the field information. When all these data has been collected, it is introduced in the prototype described in the "PARASID Interface".

Test Sites

The first test site chosen was in Mozambique because of the area available from the "airborne mine detection" project mentioned. In order to show the adaptability of the method in a different context, another test site was chosen in Laos, where the Belgian deminers are active. All missions involved data collection, data interpretation and ground survey, as well as work with local deminers, specifically Norwegian People's Aid (NPA) in Mozambique and UXO Lao in Laos.

Mozambique

The test sites were located in the province of Tete close to Songo and Mamane. A first mission on the site was conducted in order to obtain all the missing information. The field data were included in the PARASID interface and the use of them was used as a tool to realign the geometric correction. The survey and the mapping teams might also use the IKONOS panchromatic images, for example, in order to locate the UXO on the image instead of drawing schematic maps or locating the UXO in the right place. The assessment concerned for the SPOT image. Due to its lower resolution and maybe to the chosen color composition, the raw image is much more difficult to read. Thus, the visual interpretation was very helpful for the deminers. They could use it as a map, and this was also the case for the symbol with an object or an affection. A village had almost no difficulties reading the interpreted image, he could guide us along paths while showing his position on the document. Similar observations were obtained from the last mission in Mozambique.

Both types of satellite images need to be properly geo-referenced if they are used as reference images to locate mine fields or UXO. If topographic maps exist, the user has to identify points in the image and give their coordinates on the map. However, the map may not be precise enough to geometrically correct the satellite images. Therefore, a set of ground control points collected on the field with a GPS should be used for the geometric correction.

In conclusion, very high-resolution satellite images (resolution 1 m) are very useful in the mine fields since they do not require an interpretation. On the other hand, high-resolution images (resolution 10 m to 30 m) are useful as regional maps for planning the teams' work. However, they require an interpretation by an expert, and this interpretation could be sufficient for deminers.

PARASID Interface

The PARASID interface was not finished in time, so only part of it could be tested. However, it's philosophy has been explained to other end-users, and much appreciated. The presentations made to various people have sparked great interest and encouragement. Deminers showed their willingness to use it later, (among other things) it simplifies the representation of the clearance areas, and it optimizes—both in easiness and speed—the encoding of data in IMSMA.

Furthermore, we noted that specific tools (such as clearing the grid, automatically integrating GPS measure of coordinates and shifting the scanned images) might improve the deminers' work both for the everyday job and for the planning process at the office.

Conclusions and Further Work

As a general conclusion, we may say that PARASID was a successful project, thanks to a motivated multidisciplinary team and the motivated and cooperative end-users. This is one of the list of conclusions from this project.

The project has demonstrated the benefits of using remote sensing data in HD. The study of image sequence in high-resolution images provides relevant information and can be used as a basis for topographic maps. High-resolution images require interpretation by an expert, and this interpretation seems sufficient for deminers. Very high-resolution images are useful for the fieldwork and do not require any interpretation.

The team has set up an operational method involving two main actors: a demining team and an image interpretation team. The method has been elaborated on a mission in Laos thanks to field missions in Mozambique and Laos.

An interface answering the user needs has been produced.

Various Image Processing methods have been designed and tested. Their use as tools for image interpretation has been evaluated.

These conclusions should be validated by other field missions. Moreover, the table of spatial data needs could be expanded and enhanced by defining mission and their location (implicit in the scale) and the relevant attributes (e.g., for a road, its width) as well as their translation in terms of graphical symbols (different symbology for different activities) for each object. Last but not least, the symbology should be finalized and distributed as a complementary tool to the existing ones.

Acknowledgments

This project involved a multidisciplinary team. At the SIC, Dirk Bovy, Makarmul, Mireia and Vincenzo Locci are Image Processing researchers. Wim De Groodt is the electrical engineer and Michel Shimoni is the geologist. At the UCB, Richard Wold and Vincent Mayrl are deminers. In MUNCH (concerning the central SVM, the SVM were very helpful), we wish to thank Norwegian People's Aid and UXO Laos. Also, we wish to thank a lot of data collected in the previous project, "Ashore Mine Field Assessment", during which the SIC was involved. The PARASID project was supported by the TELSAT program of the Scientific Medical Affairs of the Prime Minister's Service (Belgian State).

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mine! What type? What depth? What condition?

TMAC operators were trained, test areas were selected and prepared, and the ROX498 was tested first with mechanical reproduction mines (to ensure continuity of results from the Canadian environments) and then with real mines. It was important to use TMAC personnel and TMAC procedures as much as possible to be sure that the system could be integrated into their processes. There is little benefit in a system that can only do the job when operated in a laboratory manner; it must be compatible with existing demining operations.

To assist with this integration, CCMAT developed a draft Standard Operating Procedure (SOP) that reflected the machine and the existing SOPs. Rather than simply dropping a piece of equipment in someone's lap, it is important to help make it a part of their overall operation.

Results were consistent with the earlier inert tests. The Canadian government was pleased to respond to TMAC's request, and they made a donation consisting of a complete system plus a spare working head. The system has been hard at work in the minefields along the Thai-Cambodian border ever since.

The key to ensuring that technology does get delivered is that you trust complete the loop. Find out what the users need. Decide what you (rationally) have the ability to do. Do the laboratory level testing and adequate "field" testing to make sure you have credible results. Make sure the data is not tainted by any real or perceived conflict of interest. Find the right place and the right context for real-world trials. Make sure the system and humans are properly protected from the hazards of mine fields. Make the connections with potential donors. All before you leave home. Once you arrive at the mine field, involve the Mine Action Center (MAC) people. Confirm your present data. Get controlled live data. Be sure the data is still unused. Complete the connection between the users and the donors. Technology delivered.

Demolition Material Technology

In situ demolition of landmines should be a relatively simple matter. Identify the mine. Place an explosive charge. Blow it up. Simple. What is there to improve about the technology? How about making it cheaper? How about making the charge easier to ship and store? How about making the charge less prone to disappearance and misfire?

After working on a research program for the Canadian government, MREL came up with FIXOM, a novel demolition explosive. They had a solution, but was there a problem? Along with MREL's own research, CCMAT helped to ensure that there was, in fact, a niche that FIXOM might fill for. For its own part, CCMAT could provide help with test and evaluation and with the development of SOFs (assuming successful test and evaluation). The technology, which will require further consideration for the successful delivery of the technology, identify user needs, develop through testing, escort into the field, and then do technical and finally link up with a donor.

After testing FIXOM against a variety of targets at MREL and CCMAT facilities, CCMAT made arrangements through its contacts in Kosovo to bring the product into the field for further testing. The labs and the manufacturer of the UN Mine Action Coordination Center ultimately resulted in a donation of several thousand charges. FIXOM has since been provided to demining operations in Congo, Ethiopia, Eritrea, Mozambique, Cambodia, Zambia and Thailand. Technology delivered.

Victim Assistance Technology

Finally, let us examine a work-in-progress. CCMAT is involved in the development, test and evaluation and delivery of a new prosthetic foot. We can point to the design being used, but it is following the same path described for the two previous examples. As with the other two technologies, CCMAT worked with the manufacturer—in this case, Niagra Prosthetics and Orthotics (NPO)—so that there was a need that would be met by this promising new development. Since many conventional prosthetic feet are awkward and lack the feel or action of a real foot, and since they are often too expensive, too complex and too short-lived for many mine-affected countries to bear, the need was clear.

With CCMAT's assistance, NPO has been developing and testing the Niagara Foot in controlled laboratory conditions. Clinical (field) trials started in September 2001 in a cooperative program involving NPO, CCMAT and TMAC with the generous participation of the Thai Royal Family. While not yet completely through the technology insertion cycle, the Niagara Foot is clearly following the same pattern as the two previous examples. Technology being delivered.

There are certainly other ways that technology can be successfully developed. The key to success, however, is the same:

- Get the user involved at the start—what do they want? Decide what you can do. Get potential donors involved. Do controlled testing. Do testing with the users. Complete the loop by connecting the users and the donors. Always make sure that your data is not contaminated by a real or perceived conflict of interest.

- There is one final failure in the successful insertion of technology into the mine fields: the failure of communication. The labs and the manufacturers often fail to get their message across and the end-user community remains unaware of what new or improved technology is out there. Just as importantly, the end-users often fail to communicate their needs except in general terms. The labs and the companies often cannot figure out what they are shooting for. In June 2001, CCMAT sponsored a conference that attempted to address this very issue.

- Improved mechanisms for information exchange are being developed but they will only work if both sides participate. The technology developers have to present their information and seek out the participation of suitable end-users. Meanwhile, the user community needs to present both its needs and the results of its real-world experience and tests. Only when both sides come to an agreement on what is going-effective information exchange will we overcome this final hurdle.

- Can technology deliver? No. But technology can be delivered. CCMAT's program is one example of how it can work.

Technological and Uganda: A Prototype for Assisting Rational Activities in Humanitarian Demining Using Images from Satellites


http://www.ccmat.org/paradis/paradis.htm

http://www.ics.ran.pl/projects/minefield/download/minefield_rectangle.htm

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From the Director's Desk continued from page 112

With different motivations and different alternative models and models that are in a unit in which all are not identical, but all are in synchronization. Not only does the manager have to integrate the information and mind set of the various department leaders and support, and he also has to plan and carry out a system of rewards, promotions and bonuses of a well done. I am reminded of a saying, which the critic often use (and which unfortunately is too often true), that there is a typical project will. "push the button and it is golden, and push the non-project. " Would it be wonderful if we could actually turn it off and see it on to that the doing is justified. I am not saying that the equipment, how well trained the dog, how smooth the logistics, how precise the GPS, how generous the donor, how firm the stan-