PARADIS: a GIS Tool for the Management of Humanitarian Demining Campaigns

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1. Introduction

PARADIS stands for a Prototype for Assisting Rational Activities in Demining using Images from Satellites. The aim of this project is to improve the planning of humanitarian demining campaigns using Remote Sensing data and GIS techniques. In this context, a user interface has been developed in ArcView GIS to integrate the tools needed for the management of the campaigns. The interface is built upon four scales (global, regional, local and advancement) and really follows the evolution of the campaign from global to local scale by providing the user with scale-dedicated tools. The system uses high and very high resolution satellite images and their interpretation, onto which one can overlay vector data taken from the IMSMA (Information Management System for Mine Action) database, which is used as data repository. The tool is also compatible with the Belgian EOD Champassak database, aimed at gathering information related to the collection of UXO's on the field.

PARADIS has been funded from 1999 to 2001 by the TELSAT program of the Scientific, Technical and Cultural Affairs of the Prime Minister's Service (Belgium State) as a PILOT project and is now funded by the Belgian Defense. Collaborators to the project are the SEDEE-DOVO (Belgian Armed Forces Bomb Disposal Unit) as the team of deminers, and the ULB-IGEAT (Institut pour la Gestion de l'Environnement et l'Aménagement du Territoire) as scientific partner.

2. Previous work

2.1. A GIS for humanitarian demining

At the beginning of the project, other GIS have been analysed [1]. The following systems have been considered: the project undertaken at the James Madison University (JMU), IMSMA developed by the Geneva International Center for Humanitarian Demining, Minedemon developed at ITC, the Digital Mine Documentation System Prototype developed by IABG, "FOCUS HD", a Mapping Information System designed by Landair International Ltd., and the integrative approach proposed by the Defense Evaluation and Research Agency (DERA).

After analysing these systems, we concluded that none of these GIS tools are oriented by the tasks assigned to deminers during a mission. However, IMSMA was attractive because it was (and is still) available free of charge, and it was already widespread. In fact, we decided to build a system which would be complementary to IMSMA, as the latter does not provide means to manage UXO (UnExploded Ordnance) data, nor does it integrate satellite imagery. The fact that IMSMA has since become a UN standard confirms our choice to use it in our system.

2.2. Using satellite images for humanitarian demining

The first phase of the project [2] had demonstrated the benefits of using Remote Sensing data in humanitarian demining. It had also showed that high resolution images contain relevant information and can be used as a substitute for topographic maps provided their interpretation has been done by an expert, and that very high resolution images are useful for the field work and do not require any interpretation. An operational method had been set up. The method had been designed based on a test case in Mozambique and evaluated during a mission in Laos.

A first functional version of the interface has been produced. The tool is still being developed in order to enhance its functionality and to enable the exchange of information with other mine action information systems. The main scope of this paper is to present the PARADIS interface as it is now and the possibilities of future developments.

3. Structure of the system

3.1. Actors and Data Flow

The data flow represented on figure 1 involves three actors: a demining team, an image interpretation team, and a signal processing center. During the test campaign led in Laos, these roles were held by the SEDEE-DOVO as the team of deminers, the SGR-IM as image interpreters, and the SIC as image processing center. At mission announcement, the deminers team identifies the zone where they will work and collects climate information for the zone. The image interpreters consult their archives to gather existing data for the zone and program the satellite to obtain new images of the zone if necessary. Maps and satellite images are then generated, processed by the signal processing center and geometrically corrected. Features are then extracted from the images and classified using supervised methods. Specialists then interpret the images based on the extracted features. Deminers working on the field will then validate the interpretation of the image and its geometric validation, and give feedback to the image interpreters.

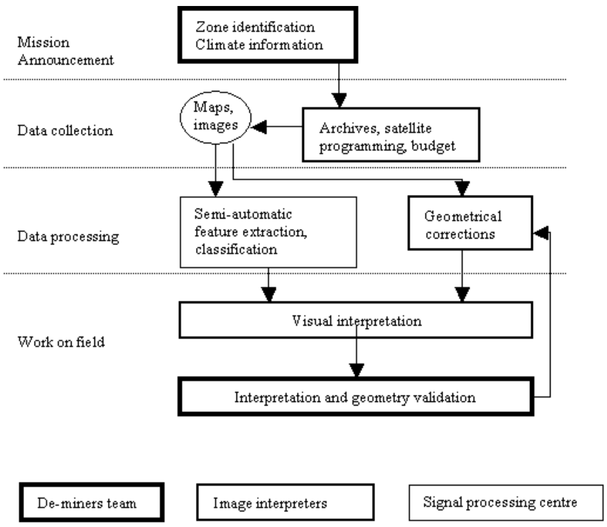


Figure 1: data flow of a campaign

3.2. Structure

PARADIS uses the IMSMA database as a repository for vector data. A geodatabase is needed to convert the data read in IMSMA into an ArcGIS compliant format to allow, in the interface, the displaying of these data. The export of data from the geodatabase to IMSMA is one of the future prospects of the project (see point 6). The rather simple structure of the PARADIS system is given in figure 2.

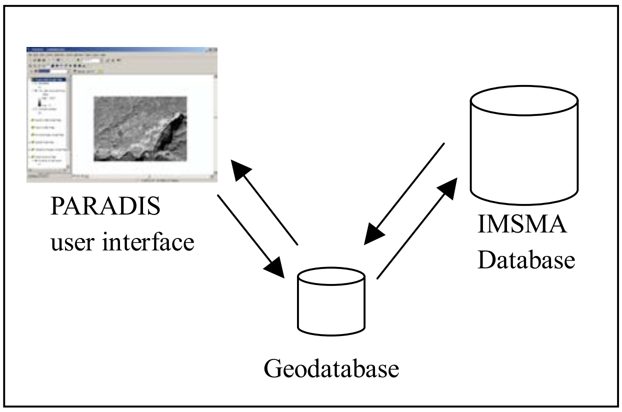


Figure 2: future structure of the PARADIS system

4. Following the campaign

Before starting to work with the interface, it is important to ensure that each prospective user has appropriate rights on the data. In order to allow safe manipulation of the interface and the data it contains, three user levels - Administrator, Basic and Expert Users - have been defined. The role of the Administrator is to manage all the users. Expert Users have all rights on the data, while Basic Users have read-only access to the data.

4.1. Global scale

At Global Scale (1 : 1 000 000), managers introduce background information as data from the DCW (Digital Charts of the World), topographic maps, etc. During mission announcement, they can overlay administrative entities, infrastructure data, and other types of data such as climate zones, soil types, etc. Later on, they can globally evaluate the status of the mined areas in a certain zone by displaying the proportion of cleared, ongoing, suspended and unknown zones in the form of pie charts for each administrative subdivision. The computing of the proportions is based on the mined areas data in IMSMA.

Also, the extent of each layer can be displayed in order to better estimate the zones where data is actually available (figure 3).

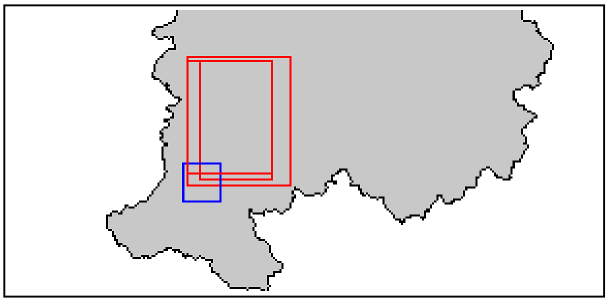


Figure 3: some layers extents in the south of Laos

4.2. Region Scale

The Region Scale (1 : 250 000 to 1 : 50 000) aims to provide reference maps by rectifying high resolution satellite images and their interpretation; these maps will be used to map minefields and UXO's. We have seen that satellite images are geometrically corrected before their use on the field (point 3.1). In fact, this correction is not accurate enough: GPS points taken on the field and introduced in the interface do not match with the corresponding spots in the image. To accurately georeference the image, the user is able to link these GPS points to the corresponding locations in the image. In order to keep the correspondence between the image and its overlay, the interface enables the simultaneous rectification of the image and of all its interpretation layers (figure 4).

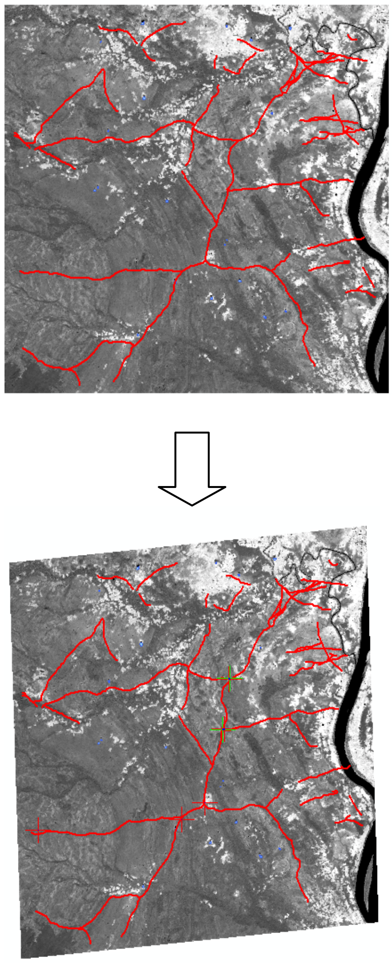
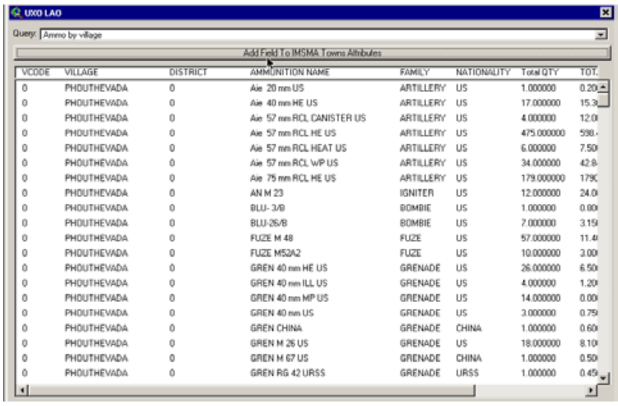


Figure 4: rectification of an image and its interpretation

At regional scale, one may query IMSMA in order to obtain logistic information about a selected town or village. From the UXO LAO database one can retrieve the weight and quantity of ammunition found near a chosen city (figure 5). The symbol of the layer representing the towns may then be modified in order to visualize the geographical repartition of the values of the chosen attribute (weight/quantity of ammunition of a certain type).



VCODE	VILLAGE	DISTRICT	AMMUNITION NAME	FAMILY	NATIONALITY	Total QTY	TOT.
0	PHOUTHEVADA	0	Aie 20 mm US	ARTILLERY	US	1.000000	0.20
0	PHOUTHEVADA	0	Aie 40 mm HE US	ARTILLERY	US	17.000000	15.3
0	PHOUTHEVADA	0	Aie 57 mm RCL CANISTER US	ARTILLERY	US	4.000000	12.0
0	PHOUTHEVADA	0	Aie 57 mm RCL HE US	ARTILLERY	US	475.000000	598.
0	PHOUTHEVADA	0	Aie 57 mm RCL HEAT US	ARTILLERY	US	6.000000	7.50
0	PHOUTHEVADA	0	Aie 57 mm RCL WP US	ARTILLERY	US	34.000000	42.8
0	PHOUTHEVADA	0	Aie 75 mm RCL HE US	ARTILLERY	US	179.000000	179
0	PHOUTHEVADA	0	AN M 23	IGNITER	US	12.000000	24.0
0	PHOUTHEVADA	0	BLU- 3/B	BOMBIE	US	1.000000	0.80
0	PHOUTHEVADA	0	BLU-26/B	BOMBIE	US	7.000000	3.15
0	PHOUTHEVADA	0	FUZE M 48	FUZE	US	57.000000	11.4
0	PHOUTHEVADA	0	FUZE M52A2	FUZE	US	10.000000	3.00
0	PHOUTHEVADA	0	GREN 40 mm HE US	GRENADE	US	26.000000	6.50
0	PHOUTHEVADA	0	GREN 40 mm ILL US	GRENADE	US	4.000000	1.20
0	PHOUTHEVADA	0	GREN 40 mm MP US	GRENADE	US	14.000000	0.00
0	PHOUTHEVADA	0	GREN 40 mm US	GRENADE	US	3.000000	0.75
0	PHOUTHEVADA	0	GREN CHINA	GRENADE	CHINA	1.000000	0.60
0	PHOUTHEVADA	0	GREN M 26 US	GRENADE	US	18.000000	8.10
0	PHOUTHEVADA	0	GREN M 67 US	GRENADE	CHINA	1.000000	0.50
0	PHOUTHEVADA	0	GREN RG 42 URSS	GRENADE	URSS	1.000000	0.45

Figure 5: list of ammunition found near a city

The demining staff can also create a list of the personnel; a detailed description of each member of the personnel is made, enabling other users to get quick information about the member.

The personnel is then divided into teams which are disseminated on the map (figure 6). This operation is performed by drag-and-dropping the persons from the list of existing personnel to the list of members of the chosen team. A check is performed so that a person can belong to one team at a time.

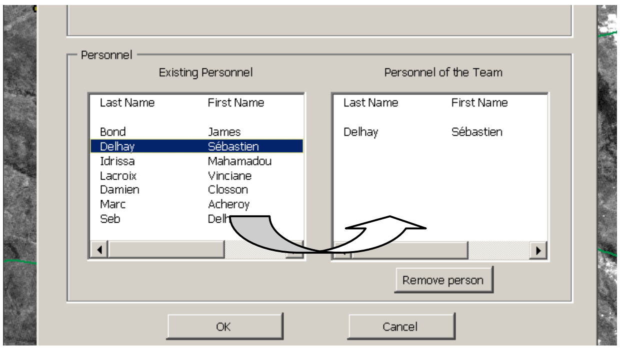


Figure 6: filling the list of personnel of the team

4.3. Field Scale

The Field Scale (1 : 10 000 to 1 : 1 500) may contain aerial photos, very high-resolution satellite images (IKONOS) and sketches. One may import the minefields locations from IMSMA as overlay in order to obtain an overall picture of the minefields on the zone. The Advancement Scale (1 : 500) enables to "zoom in" to a specific minefield the team wants to work on. The SEDEE-DOVO demining staff typically "splits" the minefield into 20 x 20 m sub-minefields which are, in turn, divided into rows (typical width of 1 m). One deminer is placed on each sub-minefield, and he moves along each row by approximately 0.5 meter at a time, clearing small elements of surface (1 x 0.5 m) one after the other. In the interface, these elements of surface define the cells of a grid which can be superimposed with the sub-minefield. The grid is generated in the interface after the user has selected one of the sub-minefield borders, and an extremity of the border. The latter gives the position of the 'first' cell, that is the cell labeled as (0,0). T o facilitate the positioning of a cell in the grid, each cell is labeled and axes are drawn along the border of the subminefield starting from the first cell (figure 7).

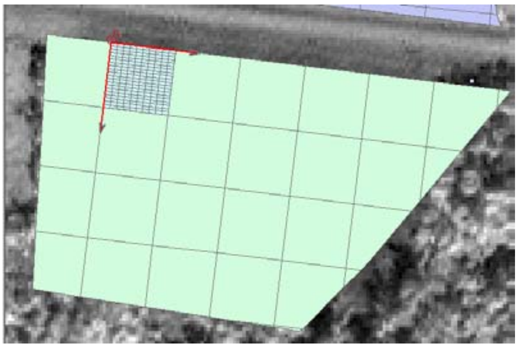


Figure 7: a grid has been superimposed on one of the sub-minefields over the Ikonos image

A status is associated with each cell to reflect the evolution of the work on the sub-minefield. Three situations are possible: the cell has been cleared, work is in progress in the cell, or nothing has been done yet within the cell. In the first two situations, one may have found ammunition in the cell or not, which leads to the five possible statuses for a cell: Cleared with/without mine, Ongoing with/without mine, and Unknown. One may also introduce which type and quantity of ammunition has been found within each cell. This, as the changes of cell status, is done at the end of each working session.

This process enables to compute an estimation of the time left to work on the minefield. After the user has introduced the estimated future number of working detectors per day, the system is able to estimate the number of days left to work before the minefield being completely cleared, and conversely. This calculation must take into account the calendar of non-working days. This tool also offers the possibility to automatically update the status of the mined areas in IMSMA (see point 6.). Another possibility would be the automatic production of sketches. The user could choose the zone and the layers of data to be drawn in the sketch.

5. Development constraints

The demand for an easy-to-use tool is clearly justified by the need of the deminers to use the interface without thorough computer skills or deep knowledge of geographic concepts.

The stability of the system is also important to enable a reliable use on the field, far from a specialist who could solve an eventual technical problem.

Another important aspect of the interface is its user-friendliness. For example, in the context of data exchange between the interface and other systems, the user would not have to switch from one application to another to encode his data. Instead, the interface should exchange data with other information systems in a way transparent to the user.

6. Future of PARADIS

The enhanced interface will be tested by the SEDEE-DOVO during campaigns similar to the Laos campaign described in [1]. It should also be evaluated in contexts involving other methods of work than manual demining (teams working with rats or dogs, for example).

A user manual has been written to guide the user through the use of the different tools. It has to be validated by a group of deminers who will individually use it for the following of a campaign with the interface.

As an output of the interface, we can imagine the automatic production of standardized, printable reports at the different scales. For example, a satellite image and its interpretation layers could be printed out as a regional map. Another example would be the impression of a grid to offer an accurate sketch of the evolution of the work on the sub-minefield.

We could imagine to split the interface into several specialized entities in order to better fit the specific needs of end-users. For example, a customized interface could be produced to satisfy the needs of supervising teams that work at global and regional scale only.

The user-friendliness of the interface, its development flexibility and its adaptation to the last version of the supporting platform are important aspects of the development; in that scope, PARADIS is currently being ported to the new ArcGIS 8.3 system.

Another important point is related to the little interoperability among mine action information systems, which makes it difficult for them to share their respective data. The emerging standard ma-XML (Mine Action eXtended Markup Language, [3]) could provide a means to facilitate the sharing of information among the mine action domain, and also with other domains that have relevant information. To enable a harmonized use of PARADIS with other systems, the interface will be made compliant with the ma-XML specification. This will lead to automatic export of data from PARADIS to IMSMA (or other candidates), enhancing the easiness and transparency of data encoding. Examples of exportable data are: coordinates and surface of a mined area, path to an automatically generated sketch representing a minefield, updated status of a minefield, etc.

7. References

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2. V. Lacroix, E. Wolff and M. Acheroy, PARADIS: A Protoype for Assisting Rational Activities in humanitarian Demining using Images from Satellites, http://maic.jmu.edu/journal/6.1/notes/lacroix/lacroix.htm
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