A GEOGRAPHICAL INFORMATION SYSTEM FOR HUMANITARIAN DEMINING

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ABSTRACT

A review of some Geographical Information Systems dedicated to humanitarian demining is presented together with PARADIS, a Prototype for Assisting Rational Activities in Demining using Images from Satellites, designed for the Mine Clearance Service of the Belgian Army.

1 INTRODUCTION

Millions of mines are infesting over seventy countries on all continents. The whole industrial, economical and social life of a country can be disrupted by a mine infection. Indeed, mines still maim or kill decades after they were laid, injuring the young generation, reducing the farming capabilities, disorganising the transportation system, preventing the use of some drinkable water points thus causing the appearance or re-appearance of diseases, etc.

Mine Action programs often refer to "Headquarter", "Mine Action Centre" and "Field Work". The Headquarter is the place where general information is collected and humanitarian campaign decided and organised; it takes care of international co-ordination between programs and thus works at a "world scale" level. The Action Centres are located in the infested countries; their job is to collect mine information, disseminate this information to task force units, and instruct mine awareness classes. They deal only with the information related to the country thus making the "country level scale". Finally, the Field Work makes use of information concerning a given minefield, or a small region, thus working at a "local scale" or "field scale".

One key issue in humanitarian demining is the choice of the areas to clear, thus, the planning of demining campaigns. The gain of a demining campaign does not depend on the number of mines removed but rather on the socio-economic benefits of the clearing. In order to determine these benefits, a Level 1 Survey (General Survey) is performed at the country level; it aims at roughly identifying suspected or mined areas and collecting information such as socio-economic, victim and behavioural data over these zones. Once the area of work has been chosen according to the priorities, the Level 2 Survey (area reduction) may take place. When the areas are clearly defined, a precise clearing work can be started; cleared areas are recorded in the Level 3 Survey. This Three Levels Survey is part of the standards for demining activities set up by the United Nations[1] (UN).

In the following, we review some GIS dedicated to humanitarian demining. We then present PARADIS, a Prototype for Assisting Rational Activities in Demining using Images from Satellites, and finally expose a case study.

2 OVERVIEW OF GIS FOR HUMANITARIAN DEMINING

The socio-economic impact of a demining campaign requires the analysis of a large amount of georeferenced information of various kind: accident location, population location, resettlement areas, historical information (who has mined/cleared the area, at what time, what types of mines have been used), location of the socio-economic poles, etc. A GIS can thus be very helpful not only for computing such an impact, but also to manage the spatial information of the Level 2 and Level Three Survey, as several project already demonstrated.

In this section, we give an overview of some Geographical Information Systems developed in the scope of humanitarian demining. The following projects are considered: the project undertaken at James Madison University (JMU), the Information Management System for Mine Action (IMSMA) developed by the Geneva International Centre 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). These GIS are described in (JRC, 1998).

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[1] http://www.un.org/Depts/Landmine/Standard/s-index.htm

Information Management System of JMU: In August 1996, the Humanitarian Demining Center was established at JMU. During the last few years the center has completed a serie of projects related to humanitarian demining among which a Geographic Information System for Humanitarian Demining Management ((Gustafson et al., 1998), (Gentile et al., 1997)) and a "Clearing House" project[2]. In the first one, they evaluate the data needs and requirements for an information managing system devoted to humanitarian demining in the Third World, more precisely in Cambodia and in Bosnia. The result of this project is a list of recommendations about maps, aerial and satellite images, where and how to get them, about the ideal software features (i.e vector and raster capabilities), and the realisation of a well designed system based on a high technology support facility. This support facility does not need to be located in the infested country; its aim is to acquire and integrate standard data types such as images, maps and vector layers. Appropriate data fusion and data reduction may then take place. After quality control, the data set for a portion of the project area abroad is written to CD ROM and sent to the site. This CD is immediately useable with any Pentium PC. Because all materials are standardised and georeferenced, the various data layers can be viewed and printed by field personnel very easily in virtually any combination. Thus, thanks to this system, JMU can prepare some data package very useful for the Action Centers or for Field Work, data ranging from the "country scale" to the "local scale".

IMSMA: IMSMA[3] has several components. The first one is the "Field Module", a collection tool that could be used by field programs or entities performing activities in the field for Mine Action. It provides a standard format for information collection and may serve as a Starter Kit for new programs. The second module is the "Information Processing Module", an analytic tool for the United Nations Mine Action Services (UNMAS) and the various agencies involved in Mine Action at UN Headquarters to help them managing and co-ordinating their activities at world-wide level. The last module is the "Information Dissemination Module", a communication tool for the UNMAS as focal point for Mine Action in the UN, designed to improve the interaction between the Mine Action community and the international community.

The Field module is basically a database set configured for Mine Action applications. It unables day to day local management tasks. The "nude" Field module, based on MS office, includes a GIS and a "Starter Kit"; the later contains already established databases, standarised data, forms, reports, technical information resources, and Mine Action information resources. This information comes from the UN standards, the UN Standard Operating Procedures, and from the Mine Action Center Databases from one side, and from demining experience, Non Governmental Organisations (NGO) databases and Test Fields from the other side.

MINEDEMON: Prior to issuing a tender to the European industry to build an operational GIS for both Field and Headquarters use, the European Commission (EC) contracted ITC to develop the Mine Database Demonstrator (MINEDEMON) for the demonstration of what an operational GIS could provide and to prepare the technical tender specifications for such a GIS.

MINEDEMON contains the functionality for the field and the headquarters levels, including spatial analysis capabilities, data entry, storage, updating, processing, reporting, etc. A region of 100x100 km around Huambo, Angola was selected as the test area for the demonstration. Intensive data collection was carried out: topographic maps of 1:100000 scale, SPOT and Landsat satellite images, minefield data from the central demining database in Angola, NGO reports and miscellaneous data from the EC DGVIII. Besides the real data some simulated data had to be included into MINEDEMON too to demonstrate all the possibilities of geoinformation technology. The following main GIS functions have been implemented: map, remote sensing image and table input, output, querying in the database, data model transformation (vector to raster and raster to vector transformations), overlaying raster and vector maps, and spatial analysis.

The Digital Mine Documentation System Prototype: IABG is developing a Digital Mine Documentation System Prototype that has the following components: GIS, mine database, UXO database, mine/UXO/accident/mine area location database, database of object specific clearance procedures, signature database, resource database, project/management databases. As vectorised topographic maps or vectorised satelite images are expensive, they proposed the use of intelligent algorithms to vectorise satelite images thanks to segmentation and classification algorithms.

FOCUS HD: Landair International Ltd. is developing "FOCUS HD", a mapping information system designed for humanitarian de-mining operations. This company is actually working in several connected fields such as intelligence support tools, GIS and remote sensing, historical analysis, electronic documents, technical and defence consultancy, operations research and analysis, business and combat models, decision and support tools, operational support tools. The system is based on MapInfo GIS and Access database, and is conceived for a base station or a portable to use on the field. The system follows the scheme of UN assessment missions: Level 1, 2 and 3 surveys and it incorporates the latest UN international standards and minefield data requirements.

The system contains possibilities to prioritise some tasks using GIS and dynamical modelling. GIS can correlate mine data with population densities, draw routes to fields, between centres, etc. The system may perform a cost benefit analysis,

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[2]http://www.hdic.jmu.edu/gis/index.html
[3]http://www.gichd.ch/docs/imsma/index.htm

a terrain/climate analysis to identify threat areas and best time to clear and a socio-economic impact analysis, thanks to adaptable dynamic socio-economic models.

DERA integrative approach: DERA views a good demining field system as a simple system that could be part of larger system used to control regional and national operations; the means of communications being floppy or CD; while the main system should be networked to other regional/national systems for controlled interchange of information.

They suggest the use of satellite mapping as a substitute for poor small scale or non-existent paper mapping and detection of changes in landcover as a tool for indicating mined areas. The input data are DEM produced by SPOT, Landsat thematic mapper imagery for land use at different seasons, soil and rock digitised maps, monthly temperature and rainfall averaged over 30 years, military vehicle characteristics, scanned photographs of selected points. The roads network is digitised from the imagery and classified by estimated width and construction; rivers are also digitised from imagery; specific information can be superposed (checkpoints, bridges, tunnels, minefields). They propose two outputs useful for humanitarian demining: maps or overlays at 1:50.000 to show where the mine free areas are (village, fields, roads, etc.), and maps (or overlays) at about 1:1.250 of suspected areas to plot mine locations and plan clearance operations.

The system is also able to calculate the least cost on-road (and off-road) route between two points taking into account the vehicle characteristics, the status of checkpoints/bridge/tunnel, the minefields, the road class, the slope (if of off-road) and landcover, and the user set weightings.

3   PARADIS

3.1   Objective

The aim of the PARADIS project is to build a prototype for helping the Mine Clearance Service of the Belgium Army (SEDEE-DOVO) in planning humanitarian demining campaigns. The prototype is not the only issue; a methodology for gathering the information, a summary of the problems involved in managing and "fusing" them, and a list of relevant pointers will also be provided to the end users. In order to be complementary to other systems, most of the efforts will be concentrated on exploiting images, and IMSMA will be considered as the "collecting tool" component.

A humanitarian demining campaign for the SEDEE-DOVO implies the following steps: general data collection at mission announcement, Level 1 Survey (field survey), planning campaigns, Level 2 Survey, clearing minefields and finally evaluating the quality of the work. The "world scale" level is thus not addressed by PARADIS; indeed, it is assumed that the International Community assigns to the SEDEE-DOVO the country to clear. The coarsest scale at which PARADIS will work is thus the "country scale", while the finest scale will be the "field scale", as we should consider the spatial information collected on the minefield.

3.2   Overview

We have analysed the needs in spatial information at each step of the campaign, and set up the requirements of a system that could manage all this information. A system working at three scales embedded in a GIS and allowing two levels of complexity, seems best suited to the problem. The small scale (1:250 000) or "country scale" is more relevant to the headquarter; it mostly contains maps as background for geographical information. The intermediate scale (1:100 000 to 1:25 000) that we will call "region scale", is fed with maps and georeferenced satellite images, useful for the headquarter and for the Action Center as well. Finally, the large scale (1:10 000 to 1:2 500) or "field scale" , more devoted to the field work and its management at the Action Center, displays aerial photos, very high resolution satellite images and sketches. Information should circulate between these different scales, thus generalisation problems have to be addressed. At the country and region scale, the "expert" level is designed for a GIS and photo-interpretor specialist, while the "naive level" is for the users from SEDEE-DOVO. At the field scale, the "expert" is a user from SEDEE-DOVO, while the "naive" user is a local worker.

We are considering, as a case study, the Tete province of Mozambique for which we have already much information thanks to a previous project (van Genderen and Maathuis, 1998).

Actually, though the ideal working scale for collecting the general country information is 1:250 000, a 1:1 000 000 scale seems more realistic. At this smallest scale, the SEDEE-DOVO is expected to enter the information in the GIS manually. In order to help the user to capture vector information from digitised maps, some semi-automatic tools for raster to vector transformation are under development. All geographical information should be entered in a similar projection (UTM WGS-84). Projection transformation will be available to the user, but, in order to avoid cumulative errors, the system will only allow transformation from the original projection. Note that satellite images will in general not be considered at the smallest scale, except the ones giving meteorological information. The Clearing House project of the JMU, a database of

Web resources concerning humanitarian demining and the TELSAT project (Wolff et al., n.d.) will be a start for building a list of Web sites providing this information. One user at the headquarter will be responsible to keep this list up-to-date.

At the intermediate scale, an Image Processing tool box will help the user for image interpretation: extracting road and hydrological networks, landcover classification, etc. The system can also provide rough population estimation from polygons associated to villages extracted either manually or with the help of Image Processing tools.

3.3 Information Needs according to Mission Schedule

In the following, we detail the information needs according to the mission schedule, we propose some sources for this information and we suggest the scale level at which it should be entered in the GIS.

Mission Announcement

Information	Source	system scale
Global topographic data: Relief, hydrographic network, inhabited areas and local names, administrative limits, roads	DCW, road maps, Web	country
Local topographic data: Practical roads and bridges, hydrographic network, landcover, flooding areas, important buildings, military buildings	Topographic maps, local people, aerial photos, high resolution satellite images	region
Climate: Precipitations, dry and wet seasons	Meteorological data Webb, satellite images	country
Conflict: Which parties? Where were the fights? What explosives? Which patterns? Analysis of changes	News, local people images (aerial & satellite)	country region
Injured/deaths: Description and localisation of accidents	International Red Cross Database, hospitals	country
Refugees: Where do they come from? Where do they have to go? Where are they? How many? Free cultivable areas	UNHCR, NGO, Local people Satellite and aerial Images	country & region
Economy: Which activities are still running? Where are they? Which activities should be settle up? Where?	Local people, topographic maps, atlas	country
Government: Which attitude towards demining? Which regions are economical important for reconstruction?	Local People, government, funding agencies	country
Mine Clearance: Which organisations? What do they do? How (material, practice)? Which personal? Where? Cleared areas?	Web, embassy, organisations, UNDP	country
Level 1: Which responsible organisation? Method?	Web, Organisations	country

When the mission is announced, the SEDEE-DOVO has between one week up to six months, in the best case, to collect, from its headquarter in Belgium, the above information. Relief is needed to know which material is appropriate to the region. Accurate location of inhabited areas is crucial as they are among the priorities for being cleared. Information about the climate is necessary to know at which season the demining team can work. More precise information about climate history is also required. Indeed, in the case of floods, for example, the mines may move, and thus, all the Level 2 minefields have to be analysed again. Learning about where the conflicts took place enables to predict the minefield location, while getting information about the type of mines and patterns they used facilitates the clearing. Historical background about the conflicts is also necessary not only to know what were the targets but also to learn population mentality and susceptibility. The number of accidents is in general proportional to the buried mines, so that precise information about accidents is useful. Up-to-date information about refugees is required, as allowing them to return home is also among the priorities; locating free cultivable areas or abandoned fields in their home villages is a requirement for their resettlement. A good knowledge of the country is needed in order to know what kind of economy should be settle up first. Government attitute towards demining is fundamental for managing the campaign and the local teams. Contacts with other demining organisations are required to know what has already be done, and what complementarities can be expected to enhance efficiency. Finally, establishing the network of practicable roads and bridges is important to estimate travel needs and schedule.

Satellite images are useful at the intermediate or region scale. An up-to-date list of satellites can be found at the TELSAT guide at http://telsat.belspo.be/. In order to choose the appropriate sensor, the user will look at the sensor resolution, spectral characteristics, and data availability over the region of interest. The sensor resolution is expressed as the 1D size on earth of one image pixel. In order to relate this number to the scale, i.e. the ratio of a given 1D segment on earth to its representation on the map, one should know the printing or the screen resolution. Assume a precision of p dpi ($5p/127$ pixels per mm), and a sensor resolution of r metres, then the printed picture will be at scale $1/w$ with $w = pr/0.0254$. For example, a SPOT panchromatic image has a 10 meters resolution ($r = 10$), printed with precision $p = 127$ dpi, it will produce an image at $1/50\ 000$. Human eye is able to detect, at viewing distance, from 6 to 10 lines per mm (150 to 250 dpi); a print with a higher, lower or such a precision will respectively be considered as high, low or medium quality.

Field Survey

All information not already obtained from the headquarter should be collected in the country; no special demining material is required for this task..

Information	Source	system scale
Practicable Road network	Population, images (Aerial and Satellite)	region
Level 1: General minefield location, collateral information suspected zones, marked zones	Maps (reliability?), database, government, local people, hospitals, mark on the field	region & field
Minefields Level 2 already done, minefield location and extent. Who put it? How? mine types, installation potentially mined, cleared areas,	Government, NGO, UNDP, sketches	region & field

Planning Campaigns

Information	Source	System scale
Priorities: Which ones (economical, agricultural, population, social)? Who is determining them? What are the constraints (seasons, soil, roads, etc.)? What type of material (dogs, robots, etc.)?	Government, local authorities, funding agencies, demining organisation	region
Tasks schedule: map production, areas to clear first, constraints (seasons)	GIS	region

A GIS is adequate to formulate these priorities. Indeed, it is possible to give a weight to all elements involved and to let the system compute which areas are the most important according to that list of priorities.

Level 2 and Clearing Minefields

Information	Source	System scale
Level 2: Detailed maps, precise minefield location and extend, nature of area to clear, type of mines, presence of traps, demining techniques, staff, demining speed/soil, productivity, security Cleared areas: location and precision	National Geographic Institute, maps, automatic drawing demining organisation, work on the field GIS satistics	field
Planning Update New maps, new schedule	GIS computation	region

It is unrealistic to plan a long term field work with computer laptop on the field. However, the system installed at the Action Center could be used to print aerial photos or very high resolution satellite images, or enlarged maps, with a precise grid on top of them, so that the demining team could add references points, and transfer them day after day. The system will be able to automatically draw the demined areas, compute the demining speed and predict the time for the whole field.

Quality Evaluation

Information	Source	System scale
Level 3 Quality control method, demining quality, number of accidents in cleared areas	Work on the Field	field
End of Mission Land use of cleared areas	Satellite images	region

Some statistics relevant to the quality can automatically be computed in the system, provided that accidents are continuously added into the GIS. Finally, the analysis of satellite images taken over the cleared areas provided a powerful tool to control the use of the cleared land, so that feed back can be given to donors and NGOs.

3.4 Case study

Here is a brief summary of conflicts in Mozambique (see Figure 1). FRELIMO (Frente de Libertacao de Mocambique) led a war against Portuguese to end colonialism from 1964 until 1975, the year of Mozambique's independence. But, the war of liberation never covered more than 30% of the country and less than 10% of the population lived in FRELIMO's liberated areas. In 1976, Mozambique supported the Zimbabwean nationalist struggle against the white minority of the Rhodesian regime, which created RENAMO as a Mozambican opposition force in 1977. Finally, Rhodesia became Zimbabwe in 1980, and the control and management of RENAMO was passed to South Africa. From 1980 to 1982, South Africa used RENAMO as a tool to destabilise Mozambique. In 1980, the Mozambican government laid defensive minefields along the South African border (as anticipation for invasion) and also mined the Malawian border. In 1982, Zimbabwe sent troops to protect the Beira transport corridor because Zimbabwe and Malawi depend on the Mozambique route for much of their foreign trade. Tanzania troops were also sent to patrol the Nacal transport route in the north, accessing their country. In 1985, Tanzanian and Zimbabwean decided to support FRELIMO. RENAMO advanced in Zambesia and Tete province. In 1987, the conflict was at its largest extent: RENAMO made gains in Tete, Nampula and Niassa provinces, and in the South of the country. Starting from 1989, peace negotiations appeared intermittently. Finally, in 1992, a cease fire was signed in Rome between the Mozambican president Chissamo and RENAMO.

To summarise, the country is polluted by mines led over about thirty years; mines positions sometimes follow rules and patterns in the case military people led them, like the defensive lines around bridges , military camps and around some factories, but most of the time they are randomly disseminated around water points, schools, hospitals, playgrounds, in farmer's fields, and in walking pads.

Figure 1: (a) Mozambique map; (b) Image Interpretation: during the war (1986); (c) after the war (1995)

We have collected maps from various sources: the Digital Chart of the World (DCW), tourist map from IGN France at 1:2 000 000, maps from Defence Mapping Agency Topographic Center at 1:250 000, topographic maps at 1:250 000 from the "Direction Nationale de la geographie et du cadastre", and a landcover map at 1:250 000 from IGNFI and CENACARTA.

We have purchased various types of satellite images over Tete province (Songo and Mameme areas): SPOT, Landsat MSS, Landsat TM and RADARSAT images. The landsat images are useful to analyse the situation during and after the conflicts. Figure 1 shows the interpretation of two images during and after the war. A mission is planned in April 2000 in order to simulate a Field survey, to evaluate the image interpretation, and to analyse their potential as spatial information at this step of the campaign.

4 CONCLUSIONS

GIS offer a powerful tool in the framework of humanitarian demining, especially when combined to satellite and aerial images. Indeed, the GIS enable the user to set priorities in order to plan campaigns and the images replace the out-of-date maps while being very accurate, as needed for the in-field work.

ACKNOWLEDGEMENTS

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