









## The 8<sup>th</sup> International Symposium "HUMANITARIAN DEMINING 2011"

26<sup>th</sup> to 28<sup>th</sup> April 2011 ŠIBENIK, CROATIA

# **Book of Papers**



MINISTARSTVO GOSPODARSTVA, RADA I PODUZETNIŠTVA





International Symposium "Humanitarian Demining 2011"



#### **CROATIAN MINE ACTION CENTRE**

- A. Kovacica 10, 44000 Sisak
- P.O. Box 8 CROATIA
- Phone: +385 44 554 100
- Fax: +385 44 554 142
- www.hcr.hr



#### HCR-CTRO d.o.o.

- Sortina 1d, 10020 Zagreb
- CROATIA
- Phone: +385 1 650 0020
- Fax: +385 1 652 0301
- www.ctro.hr

Editor-in-Chief **Zdravko Modrušan** 

Editorial Board Nikola Gambiroža, Damir Jelenić, Neven Karas, Davor Laura, Dražen Šimunović

> Editor Nikola Pavković

#### Published by

HCR-CTRO d.o.o. Sortina 1d, 10 020 Zagreb, Croatia Tel +385 1 650 0020; Fax +385 1 652 0301

**NOTE:** The material submitted by authors has not been revised. All terms, definitions and texts are the original constructions of the authors.

A CIP catalogue record for this book is available from the National and University Library in Zagreb under 786774

ISBN 978-953-99879-8-3

## CONTENTS

## EDUCATION OF PARTICIPANTS IN HUMANITARIAN DEMINING

	The Realities of Mine Action Training from a Commercial Company Perspective <i>Ashley Williams</i>
	Training of Personnel Participating in Humanitarian Demining Operations in the Republic of Croatia <i>Davor Laura</i>
	Knowledge Level and Name of Education Received in the Field of Mine Action <i>Nikola Gambiroža</i>
	Training for the usage of IT applications created by the CROMAC IT Department <i>Damir Jelenić</i>
	First Aid Education of Staff Participating in the Process of Humanitarian Demining Maša Bulajić, Ingrid Bošan-Kilibarda
V	ORKSITE SAFETY - MEDICAL PROTECTION AND DEMINING INCIDENTS
	Legal Aspects of Medical Care as a Prerequisite for Safe Operation in Humanitarian Demining Luka Pejčić, Nevena Tutavac, Maja Grba-Bujević
	Medical Education of Professionals Providing Health Care Services for the Participants in the Process of Humanitarian Demining <i>Maja Grba-Bujević, Ingrid Bošan-Kilibarda</i>
	Role Of Periodic Medical Examinations In prevention of Humanitarian Demining Accidents <i>K.Khalili, A.Bathaee</i>
	The Use of Mine Protected Vehicles as Safe Platform for Remote Controlled Flails: Eritrea Case Study <i>Ashley Williams</i>
	Safety in Humanitarian Demining <i>Tomislav Ban</i> 49
	Calculation of Safe Distance from the Bursting Effect during Detonation of Explosive Ordinances

### ESSENTIAL DIFFERENCES IN CLEARANCE AND QA/QC OF MINE SUSPECTED AND ERW SUSPECTED AREAS

The Specific Colombian Problem - the Antipersonnel Landmines and Improvised Explosive Devices in the Fields of the Illicit Crops <i>Yimmy Alexander Gomez Quevedo, Milan Bajić</i>
The Relationship Between Risk Management and Quality Management in the Clearance of Mines and Explosive Remnants of War <i>Darvin Lisica</i>
USE OF NEW METHODS AND TECHNOLOGIES - LATEST SOLUTIONS
Experimental Test and Evaluation of an Active Sensing Prodder Jun Ishikawa, Atsushi Iino75
Application of Advanced Intelligence Decision Support System in Croatia and Bosnia and Herzegovina gave new experience <i>Milan Bajić, Davor Laura</i>
Calibration of an Electro-Optical System for the Airborne Remote Sensing of the Mine Suspected Areas <i>Tomislav Ciceli, Milan Bajić</i>
Line Indicators of Mine Muspected Areas in E-SAR Images Antonela Marinov, Milan Bajic
Parametric Geocoding of the Aerial Hyperspectral Images of the Mine Suspected Area in Mountainous Terrain <i>Tamara Ivelja, Milan Bajić</i>
IARP HUDEM'2011 WORKSHOP
E-training in robot application Andrzej Kaczmarczyk, Marek Kacprzak, Andrzej Masłowski103
Semantic simulation for mobile robot operator training Janusz Bedkowski, Andrzej Maslowski107
OMNIDIRECTIONAL STEREO TRACKING SYSTEM FOR HUMANITARIAN DEMINING TRAINING Roemi Fernández, Carlota Salinas, Héctor Montes, Manuel Armada113
In-field tests of LOCOSTRA in Jordan Emanuela Elisa Cepolina, Matteo Zoppi, Gianni Polentes, Bassam Snobar, Frank Abel, Basem Kasesbeh 117
Careful Walking on Soft Terrains with Deformable Robots Jonathan Lepinette, Matthew Valente, and Thrishantha Nanayakkara

# EDUCATION OF PARTICIPANTS IN HUMANITARIAN DEMINING

# The Realities of Mine Action Training from a Commercial Company Perspective

Ashley Williams<sup>1</sup>

#### INTRODUCTION

Mine Action as we know it today is a relatively young profession with its origins in 1991. Prior to this Mine Action, known under such terms as landmine warfare and landmine countermeasures was mainly the domain of the military and in certain cases the police. The role of commercial companies such as Mechem was limited to research and development and the production of equipment and vehicles. The introduction of civilians into the field of Mine Action in 1991 essentially created a new industry.

Initially the personnel for Mine Action were mainly drawn from the existing pool of retired military officers and non-commissioned officers. The military training and background of these people was sufficient to get the Mine Action profession started. Even institutions such as UNMAS were initiated and manned by seconded serving military officers and NCO's, many of whom remained in the Mine Action field after retiring from the military. Most Mine Action personnel learnt their trade in the field whilst the training that was presented was very much task specific.

This paper will in no way serve as an exhaustive study on how Mine Action training should be done, but will rather concentrate on how we, as an industry, can get to a point where the training of Mine Action operatives is regulated. In essence we need to get to the position where qualifications in the Mine Action field can be evaluated objectively and enjoy international recognition.

#### SCOPE

The following realities that need to be understood and agreed upon will be discussed:

• The different professions within the field of Mine Action.

- The hierarchical structure within Mine Action.
- Recognition of prior learning.
- Standardization and international accreditation.

#### DIFFERENT PROFESSIONS WITHIN THE FIELD OF MINE ACTION

Mine Action in itself is not a profession, but is rather a field of work with various professions within the one field. It can be equated to the medical field where one finds doctors, dentists, veterinarians, nursing staff, paramedics, etc. Within the Mine Action field the following professions can be identified:

- Medical Orderlies. This profession is usually well regulated and most countries have a Board of Medical Practitioners (or similar) which accredit all qualified medical orderlies and paramedics. In Mine Action the problem often is in finding individuals with both trauma and primary health care training and experience. Experience has taught that Mine Action Medical Orderlies spend 90% plus of their time on primary health care, but trauma training and experience remains essentially their primary focus.\_
- Dog Handlers. This profession was fairly thoroughly discussed during last year's symposium and one of the main conclusions was that there are no internationally accepted training standards. In most countries dog handling as a profession is usually only found in the security and safety environment and no professional body exists for specialist mine detection dog handlers. Further to this dog handling has definite levels of expertise, ranging from a very lowly qualified kennel hand to highly qualified animal behaviourists. The level of explosives, mines and demining training and experience a Mine Action Dog Handler should possess, is also a question which is open for debate.

<sup>&</sup>lt;sup>1</sup> Ashley Williams, CEO of MECHEM (Pty) Ltd, South Africa; ashleywi@mechem.co.za



Photo 1: Medical orderly and Dog Handler training.

- Specialist Operators. Most companies manufacturing specialist Mine Action machines and equipment such as flails, deep search detectors and vehicle mounted detection systems offer their own courses to clients and issue the operators with competency certificates. Once again it is a question as to what level of explosives, mines and demining training and experience such a Mine Action Specialist Operator should possess.
- Explosive Ordnance Device (EOD) Operators. This profession is fairly well regulated within the military and police forces of most countries. However the IMAS distinction of EOD Levels 1 to 4 is often difficult to equate to the qualification an individual may have obtained in the military or police. More and more international institutions are starting to present EOD training based on the IMAS levels and it is becoming quite critical that there should be some sort of international accreditation of these institutions to ensure international recognition of qualifications. EOD Operators are such an essential part of Mine Action that it stands to reason that

they should also have demining training and experience. Furthermore the question arises whether EOD Operators should be regularly re-evaluated and what the time interval should be?

- Vehicle and Diesel Fitters. These are professions/trades for which most countries have specialist evaluating and accreditation standards and professional bodies. Most Mine Action contracts and projects require vehicles and machines of sorts, making vehicle and/or diesel fitters essential posts for the success of the contracts/projects. Each company will select individuals in accordance with their training and experience in the types of vehicles and machines being utilized. Seeing that these members may be required to recover vehicles or machines from hazardous areas, it is important for them to have basic demining knowledge and experience.
- <u>Support Staff</u>. Support staff such as human resources administrators and logisticians as a rule never enter hazardous areas and therefore need no Mine Action training or experience, although it will be good if they have a basic orientation regarding Mine Action.
- Demining Specialists. This is the only real specialist Mine Action profession and will form the crux of further discussions. Once again there is a huge distinction between a basic deminer and a highly qualified Country or Project Manager. However the baseline remains a Basic Deminer Course (or similar name) where the basics of manual demining as well as the differences between military landmine warfare and humanitarian demining are taught. Exactly what the content of such an introductory course should be differs vastly between companies and institutions. Most companies and institutions basically follow the IMAS, but it is very urgent that an international standard be determined and that companies' and institutions' curricula be internationally accredited. Whilst the standards for a basic manual deminer are broadly similar throughout the Mine Action community, the further training of members as supervisors and managers has no agreed upon standards. Most supervisory and management staff are appointed on their previous experience. Absolutely no standards exist on what qualifications, training or experience is needed to move up within the Mine Action hierarchy.



Photo 2: Large vehicle fleets and field camps require Diesel Fitters and Logistic Support Staff.

• Other Specialists. Specialists such as divers, information technology specialists and IMSMA specialists can all be included under this heading. These are all specialist professions that need only slight adaptations to be utilized in the Mine Action field.

From the above introduction to the various professions within the field of Mine Action it is abundantly clear that Mine Action is a very diverse field and no-one can really profess to be a so-called "expert" in the field. Having said this, it is still a fact that even though supervisory and managerial staff cannot be technical experts in all the professions they should possess sufficient knowledge of the assets under their control to utilize them effectively. It thus follows that supervisory and managerial training should rather concentrate on the correct operational deployment of specialist assets rather than the technical expertise.

#### HIERARCHICAL STRUCTURE WITHIN MINE ACTION

Presently there is no internationally accepted hierarchical structure within Mine Action. Positions such as Section Leader, Team Leader, Supervisor, Operations Coordinator, Operations Manager, Chief of Party, Project Manager, Country Manager, etc all have different meanings to different companies and institutions. Even within the United Na-



Photo 3: Demining Specialists form the backbone of Mine Action.

tions these positions and posts vary from contract to contract.

It may seem trivial, but I believe we need to standardize on the names of positions within the Mine Action hierarchy before we can start determining what level of training and experience should be attributed to each position. Once this has been agreed upon it will be possible to draw up comparable training curricula for each post. Such curricula should just spell out minimum requirements since most companies and institutions will add their unique equipment and systems to the training.

This lack of a standardized hierarchy often leads to confusion when curricula vitae need to be evaluated since the evaluation is usually done from "the eye of the beholder" meaning that the evaluator's background and experience determines the acceptability of the CV. The result of this is more often than not the wrong persons being appointed and a high staff turnover; or even worse, CVs being manipulated or "cooked" to obtain positions the candidates are not fit to hold.

#### **RECOGNITION OF PRIOR LEARNING**

Within a fairly new field like Mine Action and especially in the demining profession it is still very difficult to find individuals who have worked their way up from manual deminers to senior managerial positions. There are the odd exceptions that prove the rule. In Mechem there are a number of cases where individuals have worked their way up from manual deminers or drivers to Project Managers. In most of these cases however the individuals already had some managerial/leadership experience in other fields and made career changes when entering the field of Mine Action.

In order to suitably man Mine Action positions in the market, it is essential that the principle of recognition of prior learning is applied. This can assist in appointing the right persons for the specific position without going through unnecessary time consuming, duplicate and costly training. Whilst the principle is sound, one is again faced with the challenge of firstly knowing what the content of the specific position entails (hierarchically) and secondly how the individual's prior training and experience equates to the required norms.

Once again internationally required and accepted standards will assist in the process of recognition of prior learning. The existence of such standards will also assist in recognizing certain gaps in an individual's experience and training which can be addressed without going through the entire training cycle.

Irrespective of all the attempts by various companies and institutions to create a career path for individuals in the Mine Action field, it remains a fact that especially in the demining and EOD professions senior personnel will still mainly be drawn from the military and police. The principle of recognition of prior learning together with accepted international standards and accreditation will assist in ensuring that the best individuals with the best qualifications and experience enter the Mine Action profession. Mine Action should never become a "home for all" just because of previous security forces experience.

#### STANDARDIZATION AND INTERNATIONAL ACCREDITATION

Whilst the Mine Action community is a very small community it is an unfortunate fact that we tend to run one another down and very easily criticize. Every company and institution that presents training believes that their training is of the correct standard and that the other companies and institutions present sub-standard training. This not only creates unnecessary friction, it also does not enhance the image of our profession.

Unfortunately until an international body is established to lay down standards and accredit the different training companies and institutions this situation will remain. Unfortunately previous attempts at setting up regional standards and accreditation, such as the effort in SADEC some 10 years ago, have never really got off the ground mainly due to finances and the lack of a reputable body manned by qualified individuals to manage the initiative. Without such standards and accreditations our profession will remain quite a rogue profession with vastly varying standards. The United Nations and especially UNOPS through their Mine Action Office have set international standards to accredit Mine Action companies and institutions to perform certain Mine Action services. Most countries with functioning Mine Action Centres have a similar accreditation process. However this accreditation is only for UN/MACC projects and contracts whilst any fly by night can still perform so-called commercial work, mainly during the reconstruction phase in a country. This is mainly for construction, communications and mining companies. However on the whole this process of UN/MACC accreditations has led to the developmental agencies and companies approaching the UN and MACC's before appointing companies to perform Mine Action.

Similarly to the above I believe we need the UN and the local MACC's to take the lead in setting the training standards and accrediting the different courses as well as the companies/institutions doing the courses. Contrary to what certain companies/ institutions may believe, the fact that one presents certain training under a UN/ MACC contract does not mean that the course and/or company/institution has been accredited by the UN or MACC. Presently no training or institution is officially accredited by the UN.

#### CONCLUSION

In conclusion I believe all of us are very proud to be associated with the Mine Action profession; a profession which has made a positive difference in the lives of many people and communities across the globe. However our profession has now matured to such a degree that we need international training and qualification standards to ensure that we attract only the best personnel. The fact that there are already international, IMAS, and national, NTSG's, standards in place theoretically means that setting training and qualification standards should not be too difficult. Unfortunately there needs to be a credible organization appointed to undertake such a task. Such an organization also needs the necessary international recognition, acceptance and above all funding to execute its task. Therefore companies and institutions wanting to present internationally accredited training may have to pay a premium to ensure that standards are maintained. This paper is not intended to reach conclusive answers, but hopefully it has planted the seed for further discussions and action into the future.

## Training of Personnel Participating in Humanitarian Demining Operations in the Republic of Croatia

Davor Laura<sup>2</sup>

#### Introduction

As you know, the basic aim of deminer safety measurements is to avoid, eliminate or reduce identify and unacceptable hazards and risks that can occur during the conduct of humanitarian demining operations.

Only the well-qualified and educated staff represents the guarantee for ensuring basic - preventive measures of deminer safety.

Therefore, the basic task of training of humanitarian demining personnel is to ensure quality education for the purpose of acquiring contemporary expert knowledge and skills required for independent, competent, efficient and prior to all, safe conduct of humanitarian demining operations.

For all these reasons, a special importance is given to training of humanitarian demining personnel.

#### I. LEGAL FRAMEWORK

Training and education of employees participating in humanitarian demining operations in the Republic of Croatia is conducted according to:

- Law on humanitarian demining (National Gazette no. 153/05, 63/07 and 152/08)
- Book of Rules and Regulations on the Training and Professional Exam of Humanitarian Demining Personnel (2007)

The above-mentioned regulations define who conducts the training, stipulates the method of education and training, method of taking the professional exam, form of the certificate on the professional exam passed and program of training of humanitarian demining personnel.

#### **II. TRAINING**

Education and training of humanitarian demining personnel in the Republic of Croatia is conducted by the Police Academy of the Ministry of Interior in the Republic of Croatia according to the following programs:

- BASIC TRAINING FOR DEMINERS
- ADDITIONAL TRAINING FOR DEMINERS
- BASIC TRAINING FOR AUXILIARY WORKERS
- TRAINING FOR WORKSITE LEADERS
- TRAINING FOR QA OFFICERS
- TRAINING FOR QC MONITORS

It is clear from the above-listed types of training, that the training covers all most important segments of humanitarian demining.

Basic training for deminers and auxiliary workers represents the basic level of professional training while training for worksite leaders, QA officers and QC monitors represents higher levels of training for humanitarian demining personnel in the Republic of Croatia. The precondition for attending the higher level of training is to complete the basic training and pass the professional exam.

It is very important to mention that all the abovelisted Education and Training Programs are verified by the Ministry of Science and Education.

• BASIC TRAINING FOR DEMINERS is intended for education of personnel responsible for detection, marking, deactivation and destruction of landmines and UXO.

In order to start with the basic training for deminers, the candidates have to meet the following **criteria**:

- to be at least 18 years old,
- to have at least secondary school qualifications,
- the candidate must not be convicted for any

<sup>&</sup>lt;sup>2</sup> Davor Laura, Assistant Director for Operations, CROMAC, Croatia, E-mail: dlaura@hcr.hr, Tel: ++38544554108

criminal offence against the Republic of Croatia, against life and body, criminal offence against property, against values protected by the international law or criminal offence against public safety of people and properties if such criminal offences are persecuted ex officio or if no criminal proceedings are conducted against them for the above-listed criminal offences,

- the candidates have to be mentally, physically and medically able and prove that by the certificate issued by the institution accredited by the Minister of Health in the Republic of Croatia.

**Basic training for deminers** consists of theoretical and practical part and lasts for 273 teaching hours out of which 137 hours are dedicated to theoretical part and 136 for the practical part.

<u>Curriculum</u>		<u>No. of</u> <u>teaching</u> <u>hours</u>
I TI	HEORETICAL PART	
II S	Subject	137
1.	Explosive substances	10
2.	Means for ignition of explosive charges	5
3.	AP mines	5
4.	AT mines	5
5.	Special detonators	8
6.	Systems of placing minefields and groups of mines	3
7.	Systems of demining of minefields and groups of mines	4
8.	S&OH measures	4
9.	Ammunition	18
10.	Airborne projectiles	8
11.	Seaborne mines	4

Curriculum		No. of teaching hours
I TI	HEORETICAL PART	
II S	Subject	137
12.	Commando-terrorist devices	8
13.	Maintenance and storage of explosive ordinances	4
14.	Destruction of explosive ordinances	4
15.	Manual mine detection	8
16.	Use of demining machines	6
17.	Use of MDDs	3
18.	Method of conducting demining operations	5
19.	Worksite organization	6
20.	Law on Humanitarian Demining	3
21.	First Aid	8
22.	Stress prevention in humanitarian demining	8

Cu	Curriculum	
I PI	RACTICAL PART	136
II S	Subject	
1.	Individual ignition of explosive charge	8
2.	Preparation of ignition grids	8
3.	Demining of AP mines (mines used for training)	16
4.	Demining of AP mines (mines used for combat purposes)	8
5.	Demining of AT mines (mines used for training)	16
6.	Demining of AT mines (mines used for combat purposes)	8
7.	Removal of booby-traps and improvised mines	8
8.	Individual and group destruction of explosive ordinances and substances	8
9.	Organization of terrain search	30
10.	Airborne projectiles	8
11.	First aid	18
Tot	al:	273

#### ADDITIONAL TRAINING FOR DEMINERS

**Deminers** who do not conduct humanitarian demining operations uninterruptedly during the period of two years are obliged to attend the additional training. Additional training consists of theoretical and practical part. Additional training for deminers lasts for 78 teaching hours out of which 48 hours cover the theoretical and 30 hours the practical part.

Curriculum		No. of
		teaching
I TI	HEORETICAL PART	78
II S	Subject	
1.	Explosive substances	3
2.	Substances for ignition	3
3.	AP mines	4
4.	AT mines	4
5.	Special detonators	3
6.	Ammunition	6
7.	Airborne projectiles	3
8.	Maintenance and storage of explosive ordinances	2
9.	Demining methods and techniques	10
10.	Organization of demining worksite	4
11.	Law on Humanitarian Demining	2
12.	Method of Conducting Humanitarian Demining	4

Curriculum		No. of teaching hours
I P	RACTICAL PART	30
II	Subject	
1.	Ignition of explosive charge with slow- burning detonator and electrical means	8
2.	Demining of AP mines (work with mines used for training)	4
3.	Demining of AT mines (work with mines used for training)	4
4.	Individual and group destruction of explosive substances and means (work with mines used for training)	4
5.	Organization of terrain search	10
To	tal:	78

## • BASIC TRAINING FOR AUXILIARY WORKERS

BASIC TRAINING FOR AUXILIARY WORKERS is intended for employees conducting deminingrelated operations such as dog handler operations, demining machine operator's operations, vegetation cutting and removal etc.

In order to start with the basic training for auxiliary workers, the candidates have to meet the following **criteria**:

- to be at least 18 years old,
- to have at least secondary school qualifications,
- the candidate must not be convicted for any criminal offence against the Republic of Croatia, against life and body, criminal offence against property, against values protected by the international law or criminal offence against public safety of people and properties if such criminal offences are persecuted ex officio or if no criminal proceedings are conducted against them for the above-listed criminal offences,
- the candidates have to be mentally, physically and medically able and prove that by the certificate issued by the institution accredited by the Minister of Health in the Republic of Croatia.

**Basic course for auxiliary workers** consists of only the theoretical part and lasts for 40 teaching hours.

Cu	rriculum	No. of teaching hours
I T	HEORETICAL PART	<u>40</u>
II S	Subject	
1.	Explosive substances	2
2.	Substances for ignition	2
3.	AP mines	2

4.	AT mines	2
5.	Special detonators	2
6.	Ammunition	2
7.	Airborne projectiles	2
8.	Demining methods and techniques	10
9.	Organization of demining worksite	3
10.	Law on Humanitarian Demining	2
11.	Method of Conducting Humanitarian	3
	Demining	
12.	First aid	8

# • TRAINING FOR WORKSITE LEADERS

TRAINING FOR WORKSITE LEADERS is intended for personnel directly managing demining operations at the worksite.

In order to attend the basic training for the worksite leader, the candidates have to have previously finished training for deminers, professional exam for deminers passed and at least one year of work experience working as a deminer.

Basic training for worksite leaders consist of theoretical and practical part and lasts for 40 teaching hours out of which 26 hours cover the theoretical part and 14 hours cover the practical part.

Curriculum		No. of teaching hours
I TI	HEORETICAL PART	<u>26</u>
II S	Subject	
1.	Measures of deminer safety	2
2.	Law on Humanitarian Demining	2
3.	Mines and explosive ordinances	4
4.	Worksite organization	4
5.	Rules and Regulations on the Conduct of Humanitarian Demining and Record Keeping	5
6.	Basics of topography	6
7.	Equipment for humanitarian demining	3

Curriculum		No. Of teaching hours
I PRACTICAL PART		
	14	
II Subject		
1.	Practice – worksite organization	8
2.	Destruction and removal of mines and UXO (mines used for training)	6
Total:		40

#### • TRAINING FOR QUALITY ASSURANCE OFFICERS

TRAINING FOR QA OFFICERS is intended for persons conducting quality assurance and quality control operations during and upon the completion of demining operations.

In order to attend the basic training for QA Officer the candidates have to have previously finished training for deminers, professional exam for deminers passed, college degree and at least one year of work experience in humanitarian demining operations.

**Basic training for QA Officers** consists of theoretical and practical part and lasts for 40 teaching hours out of which 32 hours cover the theoretical part and 8 hours cover the practical part.

Curriculum		No. of
		hours
ΙŢ	FHEORETICAL PART	32
Π	Subject	
1.	Measures of deminer safety	2
2.	Law on Humanitarian Demining	3
3.	Worksite organization	4
4.	Rules and Regulations on the	4
	Conduct of Humanitarian	
	Demining and Record Keeping	
5.	Basics of management and	2
	guidance	
6.	Quality assurance	4
7.	Basics of topography and GIS	8
8.	Equipment for humanitarian	5
	demining	
Π	PRACTICAL PART	8
1.	Practice – worksite organization	8
То	tal:	40

#### • BASIC TRAINING FOR QC MONITOR

#### BASIC TRAINING FOR QC MONITORS is intended for persons that perform regular monitoring at the worksite.

In order to attend the basic training for theQC Monitor the candidates have to have previously finished training for deminers, professional exam for deminers passed, college degree and at least three years of work experience in humanitarian demining operations. **Basic course for QC Monitors** consists of theoretical and practical part and lasts for 40 teaching hours out of which 32 hours cover the theoretical part and 8 hours cover the practical part.

Curriculum		No. of teaching hours
ΙΤ	HEORETICAL PART	32
II S	Subject	
<u>1.</u>	Measures of deminer safety	3
<u>2.</u>	Mines and UXO	8
<u>3.</u>	Worksite organization	5
<u>4.</u>	Rules and Regulations on the Conduct of Humanitarian Demining and Record Keeping	5
<u>5.</u>	Basics of topography and GIS	6
<u>6.</u>	Quality control	2
<u>7.</u>	Equipment for humanitarian demining	3
II I	8	
1. Practice – worksite organization		8
Tot	40	

## III. PROFESSIONAL EXAM

The candidate can take the professional exam only after the completion of basic training. In exceptional cases, the Croatian veterans, employees of the Ministry of Interior and Ministry of Defence that passed at least six months working on demining operations i.e. auxiliary demining operations and persons that successfully completed the Course for anti-explosion protection is allowed to take the professional exam for deminers i.e. auxiliary workers without previously attending the basic training.

Test Committee for candidates – deminers consists of the chairman, Committee members and their deputies. The chairman and deputy chairman are appointed among Police Academy employees. The Committee members and their deputies are appointed among personnel conducting the training.

Decision on the appointment of the Test Committee members stipulates the teaching subjects that will be tested by the chairman and members of the Test Committee i.e. their deputies.

The success of the candidates taking the professional exam is rated as "passed" or "failed". The candidate "passed" the exam if he/she demonstrated satisfactory level of knowledge (results) at the theoretical part of the basic exam and realized all the specified tasks during which the candidate demonstrated a required level of self-confidence and stability during the independent work at the

practical part of the exam. The candidate who did not pass the practical part of the exam should take the entire basic exam all over again.

The candidate who passed the professional exam is issued a Certificate on passed professional exam for the deminer, auxiliary worker, worksite manager, QA Officer or QC Monitor. The certificate is a public document issued by the Ministry and the possession of the Certificate is registered into the employment booklet.

#### **IV. DECISION**

To conclude, only the well-trained, qualified and educated staff is a guarantee of safe and quality conduct of humanitarian demining operations, as for deminers so for the final beneficiaries.

## Knowledge Level and Name of Education Received in the Field of Mine Action

Nikola Gambiroža<sup>3</sup>

#### Summary

Humanitarian demining operations are often conducted is an extremely difficult and specific conditions that imply lots of risk and danger for the health of people and animals. Precisely those specific aspects require certain level of knowledge, responsibility, qualifications and special vocational training from personnel participating in humanitarian demining process. Knowledge level reached and several-years of experience in conducting operations at the level of particular national mine action bodies provide opportunity for quality training of personnel participating in humanitarian demining and mine action process.

With standardization of vocational training programme CROMAC wishes to develop the vocational training system that would define minimum criteria to be met by training programmes for deminers, auxiliary workers, machine operators, MDD team handlers, surveyors, worksite leaders, survey team leaders, leaders of mine and UXO destruction teams, QA monitors and QC officers, MRE instructors and project designers.

Proposed Croatian standard HRN 1132 aims at updating and expanding vocational training defined by valid laws and by-laws of the Republic of Croatia and to be as compliant as possible with the existing systems at regional level (compatible – compliant with other training programmes for personnel participating in humanitarian demining process.

#### **1** Introduction

Humanitarian demining operations at the authorized legal entity or tradesman can be conducted by persons that passed the professional exam i.e. have the relevant identity card that confirms their accreditation for the conduct of demining operations. The training for the conduct of humanitarian demining operations is conducted by accredited institution, academy, centre or college, according to the basic program adopted.

The education and training programme is verified by the responsible state body (institution). Based on the programme approved, accredited institution, academy, centre or college drafts the curriculums.

Accredited institution, academy, centre or college is allowed to conduct the training of attendees that meet the criteria stipulated by the Law on Humanitarian Demining regardless of the number of collected claims for attending the training.

After the completed education and training, the attendees take the professional exam in front of the test committee appointed by the responsible institution, academy, college or centre.

The attendee himself/herself is allowed to take the professional exam without previously attending the training, if he/she meets the criteria stipulated by the Law on Humanitarian Demining and if the attendee spent at least six months working in demining operations i.e. auxiliary demining operations or if they completed specialized courses of antiexplosion protection.

Having passed the professional exam, the accredited institution issues teh Certificate on passed professional exam.

#### 2. Qualifications

All qualifications in humanitarian demining may be classified into three groups:

- basic level of competency
- senior level of competency
- specialist level of competency

Each senior level of competency requires a completed training course and a professional exam passed for the previous level of competency from the same domain.

The professional exam consists of theoretical and practical part.

<sup>&</sup>lt;sup>3</sup> Nikola Gambiroža, Ph.D; Assistant Director, CROMAC,

Croatia, E-mail: nikola.gambiroza@hcr.hr

### 2.1 Basic Level of Competency

The basic level of competency implies attendance of a basic training course for the conduct of humanitarian demining operations and relevant upgrade (extension with theoretical and/or practical part). Having completed the basic training course and the professional exam passed, a trainee receives a certificate for:

- deminer
- auxiliary worker
- demining machine operator
- surveyor

The basic level of competency for the demining machine operator, dog-handler team leader and surveyor for surveying mine suspected areas requires attendance of basic training for the conduct of operations of a deminer or an auxiliary worker with the professional exam passed, having the identity card proving the person is accredited for the conduct of particular operations and completed course with corresponding upgrade as per prescribed program.

#### **Basic Training Course for Deminers -Curriculum**

Basic course of candidates for deminers lasts for 210 teaching hours at least out of which 100 hours cover the theoretical part, 100 cover the practical part and 10 hours for the professional exam.

**Table 1** – Basic training course for deminers – curriculum per subjects

Cu	No. of teaching hours	
Ι	General part	2
II	Subject	100
1.	Explosive ordnance	70
2.	Placing mines and mine clearance	6
3.	Method of conducting humanitarian demining operations	4
4.	Humanitarian demining: Mine search and clearance operations	4
5.	Storage, keeping and transport of explosive ordnance	4
6.	Mine and UXO destruction	4
7.	Medical support and first aid	2
8.	S&OH and protective equipment	4
9.	Stress prevention in humanitarian demining	2
III	Practical part	100
<b>IV Knowledge check and evaluation –</b> PROFESSIONAL EXAM		10
Tot	tal:	212

#### **Basic Training Course for Auxiliary** Workers – Curriculum

Basic training course for auxiliary workers lasts for 50 teaching hours at least out of which 30 hours cover the theoretical part, 10 hours for practical part (exercises + field practice) and 10 hours for the professional exam.

**Table 2** – Basic Training Course for Auxiliary Workers – Curriculum

Cu I (	No. of teaching hours 2	
II	Subject	30
1.	Explosive ordinance	20
2.	Method of conducting humanitarian demining operations	2
3.	Humanitarian demining: Mine search and demining methods and techniques	2
4.	Worksite organization	2
5.	Medical training: Medical support and first aid	2
6.	S&OH and protective equipment	2
III	10	
<b>IV Knowledge check and evaluation</b> – PROFESSIONAL EXAM		10
Total:		52

## **Basic Course for Demining Machine Operators – Curriculum**

Basic course for demining machine operator lasts for 35 teaching hours out of which 18 hours cover the theoretical part, 14 hours are dedicated to the practical part (test site + worksite inside the MSA) and 3 teaching hours for knowledge assessment and evaluation (professional exam).

The course is attended by candidates that completed the basic course for deminers or auxiliary workers, have the valid driing licence (B category) and have adequate experience in humanitarian demining.

**Table 3** – Basic Course for Demining Machine Operators – Curriculum

Curriculum		No. of teaching hours
I General part		2
II S	16	
1. Mechanical clearance – preparation of an area for humanitarian demining		4

### International Symposium "Humanitarian Demining 2011"

26	to	28	April	2011,	Sibeni	k,	Croatia
----	----	----	-------	-------	--------	----	---------

2.	Demining machines	4
3.	Machines for waste and vegetation removal	2
4.	Conformity assessment and verification of demining machine characteristics	2
5.	Work with demining machine and maintenance	4
III	14	
IV PRO	3	
Uk	35	

#### **Basic Course for Surveyors for MSA Survey - Curriculum**

Basic course for surveyors lasts for 44 teaching hours, out of which 35 hours are dedicated to the theoretical part, 6 hours for the practical part (exercises + field practice) and 3 hours for the knowledge assessment and evaluation. The course is attended by candidates that finished the basic course for deminers.

Curriculum		No. of teaching hours
I	General part	2
II	Subject	35
1.	General estimate of mine situation and mine action	2
2.	Basics of topography and Geoinformation System (GIS)	4
3.	Introduction to war events and impacts on mine situation	4
4.	Prikupljanje podataka o minski sumnjivim područjima	4
5.	Mine situation data analysis and processing	4
6.	Standard operating procedures of mine suspected area marking	4
7.	Standard operating procedures of general survey and mine suspected area reduction	4
8.	Standard operating procedures of technical survey	2
9. Record keeping and reporting		7
III Practical part		6
IV PR	3	
Tot	al:	46

Table 4 – Basic Course for Surveyors – Curriculum

#### 2.2. Senior Level of Competence

Besides basic competency for the conduct of humanitarian demining operations, senior level of competence requires organizational and management skills and autonomous decision making. Upon completion of senior level of training and professional exam passed, the candidate is issued a certificate for:

- worksite leader (group leader, team leader)
- dog-handler team leader
- survey team leader
- mine and UXO destruction team leader
- QC Monitor (worksite monitor)
- QA Officer

#### 2.2.1 The Course for Worksite Leaders – Curriculum

The course for worksite leaders lasts for 48 teaching hours out of which 30 hours for the practical part and 15 hours for the practical part (exercises + field practice) and 3 hours for the knowledge assessment and evaluation. The course is attended by candidates that finished the basic course for deminers.

Table 5 – The Course for Worksite Leaders – Curriculum

Cui	riculum	No. of teaching hours
ΙC	General part	2
II S	Subject	30
1.	Mines and UXO	8
2.	Basics of topography	6
3.	Measures of deminer safety	2
4.	Worksite organization	4
5.	Machines, devices and equipment in humanitarian demining	4
6.	Worksite organization and management	2
7.	Quality assurance	4
III	15	
<b>IV Knowledge check and evaluation</b> – PROFESSIONAL EXAM		3
Total:		50

#### 2.2.2 The Course for Dog-Handler Team Leader - Curriculum

The course for dog-handler team leader lasts for 336 teaching hours out of which 62 hours cover the theoretical part, 258 hours cover the theoretical part (exercises + field practice) and 16 hours for the knowledge assessment and evaluation. The course is attended by candidates that finished the basic course for deminers.

**Table 6** - The Course for Dog-Handler Team Leader- Curriculum

Cu	No. of teaching hours	
I	General part	18
II '	Theoretical part – thematic chapters	44
1.	Feeding, hygiene, maintenance of dwelling, transport and accomodation	6
2.	Dog illnesses and their identification, injuries and first aid	4
3.	Weekly and daily conditioning of dogs, obedience practice	8
4.	Types of training and work techniques, mine search methods	12
5.	Marking of above-ground and underground scent units, nadzemnih i podzemnih mirisnih jedinica, rewarding	4
6.	Safety measures, protective equipment, restrictions of dog-handlet team use, favourable factors and working conditions	8
7.	Record keeping and internal monthly evaluation	2
III	258	
IV PR	16	
Tot	al:	336

## 2.2.3 The Course for the Survey Team Leader – Curriculum

Course for the MSA Survey Team Leader lasts for 49 teachnig hours at least out of which 25 hours are dedicated to the theoretical part, 20 for the practical part (exercises + field practice) and 4 hours for the knowledge assessment and evaluation. The course is attended by candidates that finished the basic course for deminers, basic course for surveyors and with an adequate experience in humanitarian demining operations.

**Table 7** – The Course for the Survey Team Leader– Curriculum

Curriculum		No. of teaching hours
IC	General part	2
II Subject		25
1.	Basics of MSA definition	2
2.	Basics of topography and GIS	6
3.	Standard operating procedures for surveying (general survey, technical survey and MSA reduction)	4

4.	Introduction to Humanitarian Demining Mine Information System (MIS)	6
5.	Preparation and organization of survey	4
6.	Data collection and processing, record keeping and reporting. Entering data collected to MIS.	3
III	20	
IV PR	4	
Tota	51	

#### 2.2.4 The Course for the UXO Detection/ Removal Team Leader – Curriculum

The course for the UXO Detection/Removal Team Leader lasts for 50 teaching hours at least out of which 30 hours cover the theoretical part and 17 hours cover the practical part (exercises + practice) and 3 hours for the knowledge assessment and evaluation.

The course is attended by candidates that finished the basic course for deminers and have relevant experience in humanitarian demining operations.

**Table 8** – The Course for the UXO Detection/Removal Team Leader – Curriculum

Cu	rriculum	No. of teaching hours
IC	General part	2
п	Subject	30
1.	Description and intended use of all types of ammunition, avio bombs, air projectiles, maritime and fluvial explosive ordinances	12
2.	Construction basics and functional elements of each UXO type	4
3.	Basics of detection and removal of explosive ordinances	2
4.	Organization of UXO removal/ destruction	3
5.	Estimate of a situation with UXO	2
6.	Methods and procedures of UXO removal/destruction	3
7.	Equipment for destruction and calculation of safety distances during UXO destruction	2
8.	Measures of deminer safety	2
III	17	
IV PR	3	
Tot	al:	52

#### 2.2.5 The Course for QC Monitor – Curriculum

The course for QA Officer lasts for 49 teaching hours out of which 32 hours are dedicated to the theoretical part, 10 hours to the practical part (practice + field practice) and 5 hours to the knowledge assessment and evaluation. The course is attended by candidates who completed the basic course for deminers, have valid driving license (B category) and adequate experience in humanitarian demining operations stipulated by the Law on Humanitarian Demining.

 Table 9 – The Course for QC Monitor – Curriculum

Curriculum	No. of teaching hours
I General part	2
II Subjct	32
1. Basics of topography and geoinformation system - surveying	6
2. Mines and unexploded ordinances	6
3. Worksite organization	4
4. Use of demining machines, devices and equipment - efficiency	4
5. Book of Rules and Regulations on the Method of Conducting Humanitarian Demining and record keeping	3
6. Quality assurance- standard operating procedures	3
7. Mine and UXO Destruction and Removal	2
Record keeping and reporting	2
7. First aid and measures of deminer safety	2
III Practical part	10
<b>IV Knowledge check and evaluation</b> – PROFESSIONAL EXAM	5
Total:	49

## 2.2.6 The Course for QA Officer – Curriculum

The course for the QC Monitor lasts for 60 teachnig hours. 40 hours cover the theoretical part, 20 hours cover the practical part (exercises + field training) and 5 hours for the knowledge assessment and evaluation. The course is attended by candidates who completed the basic course for deminers, have valid driving license (B category) and adequate experience in humanitarian demining operations stipulated by the Law on Humanitarian Demining. Table 10 – The Course for QA Officer – Curriculum

Cu	rriculum	No. of teaching
I (	Concernation	
	Subject	40
1	Pasies of topography and	40
1.	geoinformation system - surveying	0
2.	Basics of planning, management and guidance	4
3.	Worksite organization	4
4.	Quality assurance and the quality control over demining operations - SOP	4
5.	Control methods and sampling for the inspection and control of demined area	2
5.	Book of Rules and Regulations on the Method of Conducting Humanitarian Demining and record keeping	4
6.	Mine and UXO destruction and removal	4
7.	Investigation of a mine accident and reporting	2
8.	Record keeping and reporting	2
9.	Use of machines, devices and equipment to be used in humanitarian demining operations	4
10	First aid and measures of deminer safety	4
III	Practical part	20
IV PR	Knowledge check and evaluation – OFESSIONAL EXAM	5
Uk	upno:	67

#### 2.3 Specialist training

Specialist training for the work on mine action and humanitarian demining operations requires specialist training and appropriate qualifications. Upon the completion of specialist training and professional exam passed, the candidate receives the certificate for:

- Mine risk education (MRE) instructor
- Project designer in humanitarian demining

#### 2.3.1 The Course for the Mine Risk Education Instructor in Mine Action – Curriculum

The course for the Mine Risk Education Instructor in Mine Action lasts for 35 teaching hours out of which 30 hours cover the theoretical part, 5 hours cover the practical part (practice) and 3 hours cover the knowledge assessment and evaluation. **Table 11 -** The Course for the Mine Risk EducationInstructor in Mine Action – Curriculum

Cu	rriculum	No. of teaching hours
Ι	General part	2
II	Subject	30
1.	Mine action basics	2
2.	Basics of mine danger and national strategy of informing about mine danger	2
3.	Andragogy	4
4.	Knowledge of mines and UXO (types and intended use, basic characteristics and most frequent placement methods)	18
5.	Training programmes – Informing about mine and UXO danger	2
6.	Procedures in case of mine and UXO detection	2
III – F	Knowledge assessment and evaluation PROFESSIONAL EXAM	5
To	tal:	37

## 2.3.2 The Course for Project Designer in Humanitarian Demining – Curriculum

The course for project designer in humanitarian demining lasts for 45 teaching hours out of which 30 hours are dedicated to the theoretical part, 15 hours for the practical part (exercises + field training) and 5 hours for the knowledge assessment and evaluation.

Table 12 - The Course for Project Designer in Hu-manitarian Demining – Curriculum

C	urriculum	No. of teaching hours
Ι	General part	2
II	Subject	30
1.	Basics of topography and	8
	geoinformation system - surveying	
	and moving inside mine suspected	
	areas	
2.	Basics of planning, management and guidance	2
3.	Mine Information System	4
4.	Interpretation oif Military Maps and Minefield Records	4
5.	Use of GIS in drafting pilot projects and execution demining projects	4
6.	Drafting of pilo projects and execution demining projects	8

III Practical part	10
IV Knowledge assessment and evaluation – PROFESSIONAL EXAM	5
Total:	47

### 2.4 Additional training

Deminers who have not been conducting demining operations for the past two years without interruptions should attend the additional training. It consists of theoretical and practical part.

Additional training for deminers lasts for 80 teachning hours at least out of which 50 hours cover the theoretical part, 30 hours cover the practical part (exercises+ field training).

 Table 12 – Additional training for deminers – Curriculum

Curri	iculum	No. of teaching hours
I Ge	eneral part	2
II Su	ıbject	50
1. E	Explosive ordinance	20
2. N c S	Methods of conducting humanitarian lemining – Rules and Regulations and Standard Operating Procedures	4
3. H	Humanitarian demining: demining nethods and techniques	2
4. V	Vorksite organization	4
5. Ç	Quality assurance and quality control	4
6. N	Maintenance and storage of explosive ordinances	4
7. E	Basics of mine and UXO destruction	4
8. N f	Medical training: Medical support and irst aid	4
9. S	6&OH and professional equipment	4
III P	ractical part	30
IV K – PR	nowledge assessment and evaluation OFESSIONAL EXAM	20
Total	:	102

#### 3 Professional and additional exam

The candidates take the professional exam after they finish the basic training. The professional exam for deminers consists of theoretical and practical part. The theoretical part of the professional exam for deminers consists of oral and written exam.

The practical part comprises the verification of skills relating to handling explosive ordinances and substances as well as competence to discover, detect, remove and destroy landmines and ammunition.

The professional exam for auxiliary workers consists of oral examination. The candidates take the professional exam after they pass the professional exam for deminers or auxiliary workers and completed course for demining machine operators.

The professional exam for the demining machine operator consists of oral examination and practical part of professional exam that covers the verification of competence to operate a demining machine. The candidates can take the professional exam for the handler of mine and UXO detection dogs after they finish the professional exam for deminers or auxiliary workers and completed course for MDD team leader.

The professional exam for MDD team leader consists of oral examination and practical part that comprises the verification of competence for MDD team leader.

The candidate can take the professional exam for surveyors of general and technical survey after they pass the professional exam for deminers or auxiliary workers and completed course for mine suspected area (MSA) surveyor.

#### **5** Conclusion

Considering the knowledge and experience gained in the field of humanitarian demining and results achieved during the ten years of work in humanitarian demining operations, it is necessary to upgrade the existing programs of vocational training that will follow the development of techniques and technologies implemented within the humanitarian demining process.

The paper defines the minimum requests the training for demining, auxiliary workers, demining machine operators, MDD handlers, GS surveyors, worksite managers, survey team leaders, mine and UXO destruction team leaders, QA officers, QC monitors, MRE instructors and project designers in humanitarian demining should meet.

## 6 Bibliography

- 1. Law on Humanitarian Demining, National Gazette (Narodne novine) no. 153, Zagreb, 2005
- 2. Book of Rules and Reguilations on the Method of Conducting Humanitarian Demining, National Gazette (Narodne novine) no.53, Zagreb, 2007
- 3. Book of Rules and Regulations on the Training and Professional Exam of Employees in Humanitarian Demining, National Gazette (Narodne novine) no. 42, Zagreb, 2007
- 4. The Standard for Landmine Removal in Bosnia and Herzegovina, BHMAC, Sarajevo, 2003

- 5. Book of Rules and Regulations on the Technical Requirements and Competence of MDD Team in Humanitarian Demining Operations, National Gazette (Narodne novine) no.53, Zagreb, 2005
- 6. Humanitarian Demining Demining Machine Requirements and Demining Machine Conformity Assessment, HRN 1142:2009

## Training for the usage of IT applications created by the CROMAC IT Department

Damir Jelenić<sup>4</sup>

**Summary:** From the establishment of CROMAC, Database Department at that time and later IT Department has been dealing with mine action data, from their collection to the usage of them in the system. Due to a fact that for the use of space related and mine situation data it was necessary to introduce GIS and spatial component, CROMAC MIS (Mine Information System) has been developed as a unique mine information system available to all actors in mine action activities in Croatia.

Development of procedures and operating methods in CROMAC, created the need for making of independent software applications (modules) as part of CROMAC MIS. After the needed applications were developed, it was necessary to train the end users as quickly as possible and in the best manner. In order to succeed it was necessary to assess the form and manner and choose the appropriate method of training to get good quality and expected results. Prior knowledge and motivation of applications users is of great importance for the future use and successful training. More information on training methods as well as on training experiences will be shown in this presentation.

Key words: IT applications, training, user guide, MIS, GIS

#### CROMAC-today national mine action coordination body



- Headquarter in Sisak
- Established by Croatian Government Decree in 1998
- Regional offices: Karlovac, Osijek, Zadar
- 156 employees
- SCAN- CENTER
- Modern managing system
- Qualitative equipment
- Cooperation with end users on all levels
- Regional and international cooperation
- Developed norms, standards and guidelines

#### Phases of mine action transition in Croatia and levels of progress

- 1st phase from 1996 to 1998 UNMAC active (low level – no time for traininh and education)
- 2nd phase from 1998 to 2003 UN assistance to CROMAC,WEUDAM assistance (start developing of MIS idividual training without printed matirials)
- 3rd phase from 2003 stand-alone mine action program with CROMAC as holder and coordinator (continuous progress of serious training)

<sup>&</sup>lt;sup>4</sup> Damir Jelenić, Croatian Mine Action Centre, Head of IT Department, Ante Kovačića 10, Sisak, 44 000 E-mail: damir.jelenic@hcr.hr





## **CROMAC IT Department**

Main Tasks of the IT Department:

#### **Basic:**

- Designing of Mine Information System
- Developing program aplications according to CROMAC needs
- Maintaining of Mine Informatiom System
- Designing and maintaining of Systems and Sub-systems for Data Exchange

#### Aditional:

- Maintaininig of CROMAC IT equipment
- Proposing and Suggesting new needs for IT equipment
- Education of users for applications developed by CROMAC

#### **CROMAC** Mine Information System



**Operations and Processes in CROMAC** 







## **GIS** in mine clearance





## G I S Mapping in demining





## Definition Process of MSA and demining priorities





## Business processes in CROMAC which use Spatial components

- In preparing and conducting general and technical survey, defining and marking of mine suspected area (MSA)
- In planning and setting demining priorities
- In preparing and development of demining projects and MSA search
- In execution of mine search and demining operations
- In preparing and performing quality assurance over the operations in progress
- In preparing and performing quality control over completed operations
- In analising and control the areas after QA
- In issuing the Certificate confirming the clearance of the area and/or building
- In answering on requests about MSA (area users out of CROMAC)

## Using of Aero imagery (Digital Ortho Photo)



## 3D area visualization in mine clearance process





Main IT Department's products (according to its purpose)

- APPLICATIONS FOR MINE ACTION PROCESS
- APPLICATIONS FOR MANAGEMENT

## APPLICATIONS FOR MINE ACTION PROCESS

## Survey Database



DDS:100011         State Days         Fears	
ZareC Dam         II 10.05.2001         [IV.           1112-122020-1         FARRAC I ONCUCA, tude I studnice         II stupmi           FORDER/D22A         FORDULE monthly bolis unanequi Cista         II mouni           FORDULE monthly bolis unanequi Cista         II mouni         Performant           FORDULE monthly bolis unanequi Cista         II mouni         II mouni           FORDULE monthly bolis unanequi Cista         II mouni         II mouni           FORDULE monthly bolis unanequi Cista         II mouni         II mouni           FORDULE monthly bolis unanequi Cista         II mouni         II mouni           FORDULE monthly bolis unanequi Cista         II mouni         II mouni	
11112-120201-1         PARFUC (1010/LAL, Isubi Islaufinio         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani           1012-120201-1         Pashulpi encisiti poja u naselju čista         II meani	리_ 티_ 티
Forger Tomoles         11.0.02.2000         [Odd         [Odd         [Odd         [Odd         [Odd         [Odd         [Odd         [II dup-any]         [II dup	
DDTFINIZZA         Postuly mestin poje u navelji Citat         I m.p.wi           IRFA trvdneki limit x         T 11 08 2000         Mala         Ipfa Statisticat           IRFA trvdneki limit x         T 12 11 2002         Mala         Ipfa Statisticat           IRFA trvdneki limit x         T 211 2002         Mala         Ipfa Statisticat           IRFA trvdneki limit x         T 211 2002         Postulje Real/orjeve Olence - FAZA         If incernit           IPFA trvdneki limit x         T 311 2002         Postulje Real/orjeve Olence - FAZA         If incernit	
NPA Involved vimit x         11.08.2002         Male         IP24           SXXXP1022CA         Promulije Ratorijeve Glance FAZA I         If Incomi           NPA Involved vimit x         12.11.2002         Promulije Ratorijeve Glance FAZA I         If Incomi           NPA Involved vimit x         13.11.2002         Promulije Ratorijeve Glance FAZA II         If Incomi	-
B038/F102/2A         Prodivulje Raljovjeve Olavice / FAZA1         [1 ingvari prifa zovlavlja mil 1]           DVR Zovlavlja mil 1]         T 2 11 2002         Prodivlje Raljovjeve Olavice / FAZA         [1 ingvari prifa           DVR Zovlavlja mil 1]         T 3 11 2002         Prodivlje Raljovjeve Olavice - FAZA         [1 ingvari	-
INPA (zvidnicki fimit ±)         12.11.2002         InPA           ID04P11-02/ZA         Podnučie Rezovljeve Olenice - FAZA         II stupanj           INPA (zvidnicki fimit ±)         13.11.2002         II	and the second se
004/PTI-02/ZA NPA Londrucki ImT ▲ 13.11.2002 I Podwide Risborijeve Olevice - FAZA II stupanj IPFA	A
NPA Izednotu tm1 13.11.2002	-
A ALLENDER DE LE CALENDER	A
005/PTI02/ZA Sire podłućje Radovljeve Glavice - II słupani	-
NPA tzvidnicki tm1 15.11.2002 FAZA III IVPA	A
M	
Kategorija površine Površina (n2)	
za isklučenje 3.000	

## QC / QA Database

	EVIDEN	ICIJA NADZOF	2A			
5H Altr	m Utimu L	Initoratu Zarik	eriodu s	edoori ae ponoviti	Gotovi projekti	
Oznaka projekta Datum zap	umarija Nativ projek	te Ziper	ije Površela projekta (	Tvrtia (n2) Pov	tine nettore (n2)	Novi Projekt
511-01-30-97-103-99	Trata vodovoda Brobce - Cranov Bak	V.S. Seal	to-Moderalka 115	+ MUP (2	119.675	Promieroa natuake
REBUARA 318-10-02	Spomen podlučje "BARUT	ANA" Byto	ranko-Bilogenka 87	· P#PER 608	70.956	projekta
BECA-001-01-02	Suna Vianjinina "Cegleda	erva njiva "Ejelio	ranko Ekogenka 34	- ALD H	NGOS	
BECA102-05-03-0250	Grad D-avv-ar K. 0. Veter-ac povrime	Lande Bein	ranito Eliogenita El	* MN010	NUFI	Projekt_
1600-106-05-03	Bole Estrears voorgik uit	biori li ole Bato	ranito-Bilogonika 7	+ Tenale 670	8.000	
1000-107-05-03/0178.18	1.182 i općine Bukwac	listo	akingdél-okine El	• FILLAU	4.87	Britanje projekta
1600-203-08-03/0179	Optina Bulovac 2. Dio	Eato	ranto Bilogocka 20	HERSO 857	0EN 20.660	Irvješče
1660-228-06-02	Suna Conersca	Faite	ransko-Bikogorska 50	• 547RA 3	105 E	too too
Bog projekata:	1321	UKUPNO	127.628.8	17	126.998.941	icondition.
Prosida poredati po Prosida prosida Prosidu prosida Prosida prosida Prosida prosida	Period of Tortia Zaparela Vista projekta		I	Operated	]	İstarək iz evidencija

## Minefield records Database

Minski zapisnici				
Minski Zapisnici				
😰 Unos - Pregled Minskih zapisnika	Export podataka za MapInfo           Image: Pretraživač zapisnika			
	Izvješća:			
	🗐 Analiza zapisnika			

## Mine incidents and victims Database



## **Client Application**



## **APPLICATIONS FOR MANAGEMENT**

## GeoSpatial Data in Planning & Analysis



#### Daily report of MSA status



Daily report of MSA status

large HSP a - Microsoft Internet Explorer provided by HCR		a Starje Mill a . i	Microsoft Internet Light	aren previded by HCH			
ER the fronte lak the		2 De DE 200 7	Anages 2mp 246				
tei * () · · · · · · · · · · · · · · · · · ·	1 2 3	0 0	· · · · · · · · ·	Sect. Stauma @	G- 🕹 🖾 - 🔂 😫		
All the costs of bringhades be perilities with her test	NO.	Line -	and and here allowed the for	incomprise (Marine Million Intellig			
: her	WSP	<u>&lt; /10</u>				1	District Experier
	Interno izvješi e			Stanj	e MSP-a na dan	10.12.2009.godir	ne
Dnevno izvj	ješće o stanju MSP-a u RH		Županija	MSP (m2)	Za razminiranje	Za pretraživanje	Na vl. odgevernost
			10	21026826	1791103	24248226	20447
			100	81097.28	3243201	42+5777	
×-	and the sec		*.8	79579844	20040131	84532946	92219.8
	Toronto		1.5	101064101	Terttare	100420134	279813h
	odicity		CHI	164082882	20991004	126405438	3688600
	Pipin		PS	ECHTHEI	101121227	41505771	1720348
			50	17122698	13394087	12030455	TERTA
			SAR	15/90/400	20139954	104442544	ID411128
				a labela	and a second	1000000	1,000,000
			10	58487877	Chatters.	20070842	1945179
			0	87121455	27809142	39646757	0.000
			Ukupne	807360821	273080912	601344730	22055270
		25-4 25-4	enarias Polasi en namijenjes asi at grenje tables per	ni samo ta interna apor da mto con GIS dopera negle	unatar HCE-a. Istanje tak i mepôfetanje tak, a je	oʻdrintijaja atarası stanjë 3659-a koje	er egicas na derenoj ban
	V The Computer	Circa Andrea					y Ri Crit

#### Final goal of CROMAC IT



## **CROMAC MIS**

Portal (introduce whole world with MSA problem in the Republic of Croatia)



Generally - on the map

detailed on the DOP

#### **Croatian Mine Action Centre**

IT Department, Head, Damir Jelenić, Sisak-44000, A. Kovacica 10, P.O.Box. 8 – CROATIA Phone: ++385 44 554 105, Fax. ++385 44 554 142, E-mail: hcr@hcr.hr, URL: http://www.hcr.hr

## First Aid Education of Staff Participating in the Process of Humanitarian Demining

Maša Bulajić<sup>5</sup>, Ingrid Bošan-Kilibarda<sup>6</sup>

#### Summary

Good planning reduces the likelihood of accidents to occur. However, the danger of the potential demining accidents remains real. It is therefore an obligation of a highest priority for the demining authorities to train their employees to be able to respond to the accidents.

A preparation for the accident should imply a training of all the employees at a demining workplace, as well as a definition of the equipment required to implement the demining accident response plan (a first aid kit). The demining staff should be trained to provide first aid, such as: how to place an unconscious victim who is breathing normally in the recovery position; cardiopulmonary resuscitation; control of external bleeding; splinting simple fractures; management of other injuries; methods of lift and carry and placement of victim on a litter (proper positioning of the victim during the extrication); psychosocial support; communication with the medical team. According to the aid contemporary doctrine, all the members of the demining staff should be trained to perform first aid at the incident site. Also, the first aid kit should be carried by all the members of the demining staff.

The article discusses the competences which the demining staff should acquire, as well as the content of the first aid kit.

**Key words:** competences, demining staff, first aid kit.

#### Introduction

Likelihood of demining accidents is reduced by good planning of the work, management of the demining site and supervision of the activities. In spite of all the efforts, there will probably always remain a danger of potential accidents occurring on the field. It is an obligation of a highest priority to train the demining employees to be able to respond to the accidents which may occur in their daily occupation. The demining operations must be safe not only for the demining staff, but also for local communities. An adequate first aid response includes both the knowledge and the equipment. Education as a part of the preparation for the accident should imply training of all the employees at the demining workplace. A special emphasize should be directed in particular to the demining workers. However, other employees and persons being present at the field have to be trained as well. Equipment and materials required to apply first aid must be included in the first aid kit for all members of the demining staff. Other medical equipment, supplies, drugs and transportation are within a scope of the professional medical team duties.

#### First aid

While providing the first aid, the demining workers should be fully aware of their responsibilities, but also the limitations. Just as in common life, the first person on the scene can and must initiate the first aid procedure.

Most common injuries caused by mines are trauma to lower limbs (lacerations, penetrating wounds, fractures), internal injuries - such as blast injuries, internal bleeding or penetrating injuries, burns and eye injuries. Post-traumatic stress disorder related to such events is not an injury, but is a common status in both the victims and the witnesses. The demining staff should be thoroughly trained in skills and procedures of the first aid, which include:

#### Life-saving measures:

- Assessing a safety of the demining scene and applying the body substance isolation precautions when dealing with human body fluids.
- Marking and securing the scene.

<sup>&</sup>lt;sup>5</sup> Maša Bulajić, M.D., M.Sc.Econ., Head of Medical Affairs, Croatian Insitute of Emergency Medicine, Croatia; <u>masa.</u> <u>bulajic@hzhm.hr</u>

<sup>&</sup>lt;sup>6</sup> Ingrid Bošan-Kilibarda, M.D., Ph.D., Deputy Director, Croatian Institute of Emergency Medicine, Croatia; ingrid.bosankilibarda@hzhm.hr

- Administering the emergency first aid (recovery position, cardiopulmonary resuscitation, control of external bleeding).

## Calling for help:

- Immediately informing the medical team about the incident (describing a type and a severity of the accident, a number of injured people, type of injuries).

#### First aid measures:

- Placing unconscious victim who is breathing normally in a recovery position.
- Starting cardiopulmonary resuscitating in an unconscious victim who is not breathing normally.
- External bleeding control.
- Management of soft tissue injuries, including burns by applying a sterile cover (a gauze, a compressive dressing, a bandage) and fixing it with a tape, a bandage or a triangular sling.
- Management of amputation injuries.
- Immobilization of fractures with a triangular sling or other available means.
- Management of other injuries (injuries to a spine, pelvis, head, chest, abdomen).
- Basic management of snake bites or scorpion stings.
- Psycho-social support (talking to a victim, calming down, comforting, encouraging and not abandoning, offering emotional support).

All the members of the demining staff should be trained in methods of lift, carry and placement of victim on a litter (proper positioning of the victim during the extrication). This is of extreme importance, as they have a responsibility to take the injured person(s) to a safe place from where a professional medical team takes over.

It is a common sense to protect a victim from cold/ heat, rain, snow and wind, as bad weather conditions affect the victim's condition much more than laymen might anticipate.

## Basic rules to follow when giving first aid:

- Do not create panic, act quickly and purposely.
- Adhere to the principles "above all, do not harm".
- Do not do more than expected.
- Take care of a safety of rescuers and victims.

#### **First Aid Equipment:**

All members of the demining staff must carry the equipment to be able to provide first aid already at the scene, as follows:

- sterile materials used for covering open injuries

- gauzes, compresses, bandages, "aluplast" (nonstick sterile materials),
- bandages used to fix the sterile material in place bandages and triangular sling (which is also used for immobilization),
- body substance isolation equipment for safety of the first aid providers - gloves, a foil for the application of artificial respiration,
- other tools and materials an adhesive tape and several safety pins (for attaching), a metalized polyester foil (to maintain the body temperature of the victim), a rounded tip scissors (to cut bandages and remove clothes from the wound), plastic bags (for preserving the amputated body parts, or for storing the blood contaminated materials).

#### Content of the first aid box HRN-1112:

- 1 piece 1st bandage 12cm x 5m with a single pad 12cm x 16cm
- 1 piece 1st bandage 8cm x 3m with a single pad 9cm x 11cm
- 2 pieces "Kaliko" bandages 8cm x 5m
- 2 pieces "Kaliko" bandages 4cm x 5m
- 2 pieces "Aluplast" for burns 80cm x 50cm
- 2 pieces sterile compresses 10 cm x 20 cm, 12 layers
- 5 pieces sticking plaster 10cm x 8cm
- 1 piece adhesive tape 2cm x 5m
- 2 pieces triangular sling 100cm x 100cm x 140cm
- 12 pieces safety pins
- 10 pieces sterile gauze compress 5cm x 5cm, 16 layers
- 1 piece scissors with rounded tip
- 2 pairs disposable gloves (PVC)
- 1 piece polyvinyl sleeve bag (at least 30cm x 60cm)
- 1 piece polyester metalized foil (at least 150cm x 200cm)
- 2 pieces protective film for artificial respiration
- 1 piece Specification of the content
- 1 piece First aid manual

#### **Conclusion:**

In the aim to increase the number of lives saved, to prevent permanent consequences and to minimize the length of treatment and rehabilitation, it is important that the mine cleaning employees adopt the first aid knowledge and skills, that they acquire life saving measures, and that they activate emergency medical teams on time.

#### **References:**

1. International Mine Action Standard. IMAS 10.40 First Edition. Dostupno na: www.mineactionstandards.org

- 2. Adler J. Standards for medical support to mine clearance operations. Report of the International Conference on Mine Clearance Technology; Elsinore, Denmark, 2-4 July 1996. Dostupno na: http://www.un.org/Depts/dha/mct/rpt00.htm
- 3. Hrvatski centar za razminiranje. Standard Operating Procedures : Medical Support, Medical Support and Evacuation, Humanitarian Demining. 2007. Dostupno na: http://www.hcr.hr/hr/ sop.asp
- 4. ERW/Demining. Training. Dostupno na: www. danakil.com
- 5. Pravilnik o izobrazbi i stručnom ispitu djelatnika u humanitarnom razminiranju. Narodne novine, 153/05.
- 6. Pravilnik o izobrazbi i stručnom ispitu djelatnika u humanitarnom razminiranju. Narodne novine 42/07.
- 7. Zakon o humanitarnom razminiranju. Narodne novine, 153/05, 63/07 i 152/08
- 8. United nations Developtemt Programme. Mine Action Capacity Building and Programme Development in Sudan. Dostupno na: http://www. sd.undp.org/projects/mine.htm
- Larmon B, Davis H. Basic Life Support Skills. Upper Saddle River, New Jersey: Pearson Education, Inc., 2005.
- Karren KJ, Hafen BQ. First Responder. Englewood, Colorado: Morton Publishing Company, 1990.
- 11. Campbell JE. Basic Trauma Life Support. 5th. ed. Upper Saddle River, New Jersey: Pearson Education, Inc., 2004.
- Javornik N. (ur.). Prva pomoć, priručnik. Prijevod 9. izdanja. Zagreb: Hrvatski Crveni križ, 2010.
# WORKSITE SAFETY -MEDICAL PROTECTION AND DEMINING INCIDENTS

# Legal Aspects of Medical Care as a Prerequisite for Safe Operation in Humanitarian Demining

Luka Pejčić<sup>7</sup>, Nevena Tutavac<sup>8</sup>, Maja Grba-Bujević<sup>9</sup>

Government of the Republic of Croatia and the Ministry of Interior have set the complete and systematic demining of the entire war-affected area as the priority task and key prerequisite for reconstruction and development as well as the safe return of the refugees to their homes. In order to complete this task Croatian Parliament passed laws and implementing regulation regarding demining in Republic of Croatia. Government of the Republic of Croatia established a public institution – The Croatian Mine Action Centre.

All of the above mentioned contributed to the recognition of the importance of the humanitarian demining and also gave an emphasis to the safety and medical care delivery to the persons performing the demining.

Regulating law for this area is Law on humanitarian demining (Official Gazette no. 153/05, 63/07, and 152/08) which prescribes the obligation to have medical staff present during the demining activities. Article 28 of the above mentioned law states as follows:

Authorized legal persons, tradesmen and Croatian Mine Action Centre during the activities of demining, search and technical survey are obliged to ensure presence of the nurse/medical technician, doctor and emergency medicine vehicle with a driver and all prescribed medical equipment in a manner that the necessary medical aid can be provided to the injured as soon as possible.

Authorized legal persons, artisans and Croatian Mine Action Centre must ensure and set up a constant and direct radio link system among the responsible persons in the mine field, the doctor and the emergency medicine vehicle. Several implementing regulations have been adopted. They regulate demining system in more detail, including the medical assistance provision:

- 1. Ordinance on education and state exam for humanitarian demining workers (Official Gazette no. 42/07) prescribes education methods, trainings, state exam procedure, template for the certificate for state exam and education programme for the humanitarian demining workers. Ordinance consists of: - Basic Education Programme for Pyrotechnicians which foresees 18 hours of first aid training; - Basic Education Programme for auxiliary workers which foresees 8 hours of first aid training. In the Additional Education Programme for Pyrotechnicians no first aid training is foreseen and this should be altered because like all other skills first aid should be revised and retrained in order to be correctly administered when needed.
- 2. Ordinance on competence assessment of the authorized legal persons and artisans for performing demining activities (Official Gazette no. 53/07) stipulates the competence assessment procedure of the authorized legal persons and artisans for performing demining activities, conditions with which the authorized legal persons and artisans for performing demining activities must comply and the manner of issuing the assessment certificate. In regard to the medical segment:
  - a. Authorized legal persons and artisans for performing survey and demining activities is compelled to fulfil the Template PO – MO (data regarding medical staff)
  - b. Allow the audit in the headquarters and regional offices (staff qualifications, training data, health certificates)
  - c. Allow on-the-spot checks at the site (safety on the site, site plan, markation of the dangerous areas, medical safety, on site procedures in accordance with the Standard Operating Procedure (SOP)

<sup>&</sup>lt;sup>7</sup> Luka Pejčić, LLB, Head of Administration and Legal Department, Croatian Institute of Emergency Medicine, E-mail: luka.pejcic@hznm.hr

<sup>&</sup>lt;sup>8</sup> Nevena Tutavac, MA;Croatian Institute of Emergency Medicine

<sup>&</sup>lt;sup>9</sup> Maja Grba-Bujević, M.D.,M.Sc., Director, Croatian Institute of Emergency Medicine, E-mail: maja.grba-bujevic@hznm.hr

3. Ordinance on the methods of performing the humanitarian demining activities (Official Gazette no. 53/07 and 111/07) prescribes the methods of performing the general and technical survey, search and/or demining, auxiliary demining activities, marking of the suspected mine area and expert supervision. According to the Ordinance, the destruction of the found devices is done in accordance with the destruction plan. Among other things destruction plan contains the measures of the medical disposal.

Besides the Ordinance, the Standard Operating Procedures (SOP) were also adopted.

Standard Operating Procedures of CROMAC (SOP) in line with the International Humanitarian Mine Action Standard (IMAS) represent a set of prescribed operating procedures which are implemented by CROMAC. Those are: survey of the suspected mine areas and/or buildings (general survey, marking of the suspected mine surface and technical survey), design of the project documentation, competence assessment of the authorized legal persons and artisans for performing humanitarian demining activities as well as the safety and quality control of the search and demining activities in the Republic of Croatia.

Standard Operating Procedure regarding medicine is Medical Support and Evacuation. This standard gives specifications and instructions necessary to ensure medical aid system at technical survey operations performed by the CROMAC. It regulates minimal requirements for preparedness of the emergency medical aid (medical support and evacuation – MEDEVAC) including the planning which is required before the beginning of the technical survey, necessary training of the pyrotechnicians and auxiliary workers as well as the training of the medical staff.

#### 1. Subject of the SOP:

Standard Operating Procedure (SOP) defines operative procedures and measures for medical support and evacuation (MEDEVAC) in accordance with the Law on Humanitarian Demining, Ordinance on the methods of performing the humanitarian demining activities, acquired standards as well as the tasks and internal organizational chart of the Croatian Mine Action Centre.

#### 2. Normative references:

SOP is based on international standards for humanitarian demining actions (IMAS 10.20, IMAS 10.30 and IMAS 10.40), laws and by-laws which regulate countermine actions in Republic of Croatia as well as the Law on occupational safety.

#### 3. Nomenclature

Terms and definitions of the SOP are in compliance with the international standards for defining the terms and procedures in medical support and evacuation of the casualties in demining accidents and total countermine actions according to the IMAS 04.10 and IMAS 10.40.

#### 4. General requirements

Implementation of the technical survey operations has elevated risks regarding safety and health of all those involved especially the pyrotechnicians. For that reason it is necessary foresee and create conditions for complete medical care and support during the planning phase of the demining operation. Medical support comprises of the following: Assessment of mental and physical capabilities of the pyrotechnicians and auxiliary workers to perform demining activities before hiring them; regular periodic medical examinations once a year; first aid training for pyrotechnicians; presence of the medical doctor, nurse/medical technician and emergency medical vehicle driver at the demining site; fast and effective medical intervention in case of accident; transport of the casualties to the proper medical facilities; treatment and rehabilitation of the casualties. Technical survey cannot begin unless medical support is not available and sufficient. It must ensure fast and effective medical intervention in the case of accident and transport of the casualties to the proper medical facilities. On safety and psychological grounds it is important to provide the pyrotechnician work team with the best possible safety and care in emergency situations.

#### 5. Evacuation of the injured:

It is necessary to make an evacuation plan for the injured in accidents occurred in the demining or technical survey operations.

# 6. Equipment of the medical staff and emergency medical vehicle:

Medical staff and emergency medical vehicle will be equipped with prescribed medical equipment in a manner that allows delivery of the necessary emergency medical care as soon as possible. Pursuant to article 70 of the Law on humanitarian demining (Official Gazette no. 153/05, 63/07 and 152/08) minister of health and social welfare, with the agreement of the Ministry of Interior adopts a regulation on equipment of the medical staff and emergency medical vehicle. Above mentioned regulation is being drafted but is still not conciliated with the Ministry of Interior.

From all above mentioned it is visible that medical care in the area of humanitarian demining is already defined through the series of legal regulations. However, all these regulations as well as the pyrotechnicans' skills need to be updated in order to remain lifelike and represent high-quality legal framework for delivery of quality medical care in the system of humanitarian demining.

# Medical Education of Professionals Providing Health Care Services for the Participants in the Process of Humanitarian Demining

Maja Grba-Bujević<sup>10</sup>, Ingrid Bošan-Kilibarda<sup>11</sup>

#### Summary

Planning and preparation of a demining process includes all the activities to establish and maintain appropriate medical support at the demining workplace, as well as to make appropriate arrangements with medical treatment facilities.

In addition to the good planning, developing a capacity to provide an appropriate medical response to a demining accident requires a well trained medical staff for a real situation / a particular field. In many countries affected by these remnants of war, the demining is often conducted in an environment where the medical facilities are limited, diseases may be widespread and natural disasters may occur in addition.

The casualty has to be extricated from the minefield by other demining staff operating in the area. A physician should be able to provide an advanced life support treatment before the patient is transported to the next level of care and during the transportation.

It is a necessity to specify the minimum requirements for medical emergency preparedness, including the planning and preparation required before the demining operations. The training of the medical support staff should include all the required competencies.

The article discusses the competencies the medical staff should acquire, as well as the standard medical equipment.

*Key words:* competencies, equipment, humanitarian demining, professional medical support.

#### Introduction

Planning and preparing in case of accidents during demining activities include training prescribed by the Law on Humanitarian Demining and the Ordinance on demining. They also include procedures and measures taken by the Croatian Mine Action Centreinorder to establish and maintain an adequate system of medical assistance on site and to ensure cooperation with local medical institutions, regional medical institutions and clinical hospital centers. Plan for the demining accidents care defines the responsibilities and obligations in terms of training requirements and qualifications for the demining staff and for the medical personnel responsible for the evacuation of the victims and for providing emergency medical and first aid. It also defines equipment and materials to implement the action plan in case of accidents during demining (including first aid, emergency medical care, medical equipment, supplies and drugs, vehicles to transport victims from the accident site to medical facilities, and communication system). Developing the capacity to provide appropriate responses to accidents in demining requires good planning, well-trained staff and availability of medical staff. Planning must take into account the real situation on the ground. Health service is responsible for the proper and safe care of the victims in the vicinity of the site, as well as on the way to a stationary medical institution. All organizations are obliged to clearly indicate the measures to evacuate the victims, both in their standard operating procedures (SOP) and in the implementation plans.

The most common injuries caused by mines are: - injuries of the lower extremities, including lacerations, soft tissue injury to the nervous and circulatory system, open fractures, skin lacerations and penetrating bone fragments;

- internal injuries, as penetration injuries, internal bleeding, "blast" injuries of the ears, lungs, intestines and other hollow organs;
- burns, especially the "flash" burns due to the proximity of the explosion;
- eye injuries, caused by the penetration of foreign bodies into the eye globe;
- post-traumatic stress disorder (PTSD), usually caused by witnessing traumatic events, but also present among the victims.

<sup>&</sup>lt;sup>10</sup> Maja Grba-Bujević, M.D.,M.Sc.; Director, Croatian Institute of Emergency Medicine; E-mail: maja.grba-bujevic@hznm.hr

<sup>&</sup>lt;sup>11</sup> Ingrid Bošan-Kilibarda, M.D., Ph.D.; Deputy Director, Croatian Institute of Emergency Medicine; E-mail: ingrid. bosan-kilibarda@hznm.hr

#### Medical team

The medical team by a worksite should consist of a doctor, nurse / medical technician and a driver, all with additional training in the care of injured and according to their levels of competence. Diversity of injuries that occur during accidents in humanitarian demining requires appropriate knowledge and skills necessary for the care. Competencies of the medical professionals include:

- assessment of the accident, with special emphasis on the safety of access to the site of the accident
- assessment of the overall state of the victim and the necessary procedures
- the process of triage in case of multiple injuries
- appropriate methods of maintaining airway patency, including suctioning device
- bag-valve-mask ventilation with an attached oxygen supplemental reservoir bag or tube (endotracheal intubation)
- application of advanced life support measures
- chest decompression
- external bleeding control
- circulating volume compensation
- use of various splints for immobilization
- bandaging and dressing
- application of analgesics.
- assessing the best ways of moving the victim (moving and lifting) and placing in proper position
- calling the additional medical help for treatment of injured before the transportation to medical facilities
- completion of medical records.
- selection and notification of the appropriate medical institutions.

#### Distribution of medical teams

Medical personnel should not be deployed in minefields before they are confirmed safe areas. The venue of both the medical team carrying equipment and the vehicle should be close to the demining teams, in a protected area, on the road facing the direction of the hospital and at a distance that can provide emergency medical care within 3 - 5 minutes from the time of the accident. Medical evacuation begins at the site of the injury and lasts until the injured is delivered to a health institution. The victim is evacuated by other members of the demining staff working in the field. These professionals know best how to avoid further hazards and are familiar with the tracks in a mine field. The first aid administered by the demining personnel is limited and mainly involves the external bleeding control and airway management. The victim is usually carried on the arms, preferably on a stretcher, to the emergency medical

services team. After completion of treatment at the checkpoint, the victim will be transported to the nearest hospital with adequate medical care during the transport.

#### **Medical Equipment**

Medical equipment kit should contain the necessary equipment and supplies to care for casualties on the scene and during transport to hospital, and includes:

#### 1. Doctor's medical bag / case:

- diagnostic equipment: stethoscope, pulse oximeter, glucometer, neurological hammer, diagnostic flashlight, blood pressure gauge, thermometer
- ampoules holder
- accessories for administrating the drugs in ampoules
- accessories for the standard protection against infection (gloves, masks, goggles)
- medical supplies
- triage tags.

#### 2. Nurses and medical technicians bag/case:

- medical supplies (bandages, gauzes, tapes, nets, burns dressings)
- a set of bandages for cooling of the burns
- tourniquet for the bleeding control in traumatic amputation of limbs and plastic bags of various sizes to preserve the amputated body parts
- accessories for the standard protection against infection (gloves, masks, goggles),
- other equipment (scissors, tweezers, a flashlight, a foil for protection from hypothermia and overheating)

#### 3. The resuscitation bag / case:

- bag-valve-mask ventilation with a reservoir and transparent masks in 3 sizes
- portable oxygen cylinder and the matching equipment: a manometer, an oxygen flow meter, a nasal catheter, a mask with reservoir
- oropharyngeal tubes, adult sizes
- nasopharyngeal tubes, adult sizes
- equipment and supplies for the endotracheal intubation
- laryngeal masks in sizes for adults
- Magill's forceps and paean
- soft suction-catheters
- hard wide-diameter suction-hose
- infusion solution,
- accessories for infusion
- supplies for establishing the venous path
- conicotomy set.

**4.** A defibrillator - a portable ECG monitor with 12 - channel ECG, noninvasive blood pressure (NIBP), SpO2, transcutaneous pacemaker.

- 5. Portable pump-suction unit.
- 6. An immobilization and extraction device.
- 7. A long spine board for immobilization and ex-
- traction with head immobilizers and belts.

8. A scoop stretcher with lateral fixation was the

head and straps for fastening.

- 9. A vacuum mattress with a hand pump.
- **10. Cervical spine collars** for the immobilization.
- 11. Limb splints for immobilization.
- 12. A cotton carrying sheet.
- 13. A set of bandages.

All equipment in the vehicle must be secured.

#### Conclusion

The demining professionals provide only the emergency first aid before moving the injured. A careful examination and stabilization of the victim will be possible only after the transfer of the injured to a safe area. A diversity of injury requires a thorough knowledge and skills in identifying and providing immediate and appropriate emergency medical care. To meet these requirements, each member of the medical team needs to complete a special training program in the care of injured persons, according to the level of competence.

# Role Of Periodic Medical Examinations In prevention of Humanitarian Demining Accidents

K.Khalili<sup>12</sup>, A.Bathaee<sup>13</sup>

#### Abstract

Occupational diseases are induced in contact with chemical, biological, physical, psychological and ergonomic hazards. Although it seems that the outbreak of such diseases are less compared to other diseases ,but there are evidences that show many workers especially in developing countries suffer from occupational diseases and their problem is more in such countries. Occupational diseases are such diseases that are mainly non-treatable but can be prevented and controlled.

With regard to the few demining workers in Iran, it is necessary to get a program in order to prevent disability and exit of the demining workers from mine action projects. One of these programs is occupational examinations including employment examination(EM) and periodic medical examinations(PMEs) that can lead to following aims:

- 1- The diagnosis of any physical or psychological conditions physical that can face the employee or his colleagues to dangers (like hearing loss in person who work with mine detectors and need to hear the equipment sound) .poor hearing may lead to unrecoverable damages.
- 2- Providing medical history to compare personal medical conditions in following examinations. (like psychological condition). Any unstable psychological condition can lead to accident. Or facing with explosives and ammunition may cause hepatotoxicity especially in a person with chronic hepatitis history.
- 3- Diagnosis of non-occupational diseases (like cardiovascular diseases or epilepsy) that may induce attacks and can increase risk of accidents.
- 4- Some diseases have a chronic progress and after years when they are in advanced stages can be

diagnosed. This condition has much cost for employers and may lead to partial or general disability of deminer.

#### Introduction

According to ILO (International Labor Office) report in 2002, two millions are being killed annually due to occupational accidents and illnesses, that is 3 times more than war.

"Occupational accidents are responsible for the main part of compensation costs", ILO stated, about 4% of ungross domestic production. (1)

Occupational diseases which seems to be much less prevalent than others are largely expanded in the work environment especially in developing countries. They are caused by variant hazards such as physical, chemical, biological and psychological factors. (2,3)

Chronic diseases and disabilities can be prevented extensively, if occupational diseases are diagnosed and treated at early stages. (4)

Prevention from occupational diseases may be so easy because : firstly, their cause is obvious and can be detected, measured and controlled ; and secondly exposed workers are available. Some scientific screening methods are used to detect these diseases at early stages , one of them is pre-employment examinations which is important in all occupations including demining.

There are some limitations to substitute these employees, so it is more necessary to prevent from occupational injuries in deminers.

This article is written to give an emphasis on health surveillance in demining and its importance. Demining Health Surveillance

#### **Pre-employment Medical Examinations**

Pre-employment screening tests may be established to determine which applicants are likely to possess sufficient physical and psychological work capacity to perform necessary tasks without injury to themselves or others and its most important aims are as follows:

<sup>&</sup>lt;sup>12</sup> Kamran Khalili, HSE Manager, Andishe Sazan Mandegar Co, Tehran, Iran, E-mail: Kkhalili2000@gmail.com

<sup>&</sup>lt;sup>13</sup> A.Bathaee, Assistant Professor of Shahid Beheshti Medical University, Iran

\_ To create a valid initial medical data bank. Demining is a life-threatening job, so deminers are extensively exposed to job stress. (5)

It is very important to detect any physical or psychological conditions which may cause injury to miners or others, for example, psychological disorders are prevalent among deminers and it is forbidden to hire applicants with history of these diseases. Also it is necessary to follow proper examinations to detect them before their placement. (6) Another situation is hearing loss, which may cause inability to hear detector alarms and subsequent occupational injuries.

There are some people who suffer from chronic hepatic disorders such as hepatitis B. Exposure to chemicals such as TNT with hepatotoxic effects can induce hepatic failure and these people must not hire as deminers. They can be easily screened during Pre-employment Medical Examinations by increased level of hepatic enzymes fortunately.

Some non-occupational, high morbidity and mortality diseases such as coronary heart disease will be detected on Pre-employment Medical Examinations which their detection at early stages has so much benefits for the employers, including reduction of disease costs and lost workdays.

Pre-employment Medical Examinations for deminers are as follows:

- a) Employee profile: past medical history, family history, occupational history and so on.
- b) Complete physical examinations with emphasis on target organs. Search for hepatomegaly in TNT-exposed employee and splenomegaly in benzene-exposed employee.
- c) Paraclinical examinations including:

Complete blood count

Fasting blood sugar

SGOT/SGPT

Nerve Conduction Velocity and neurobehavioral tests

G6PD

- Toxicologic tests Drug abuse tests Spirometry Audiometry Optometry
- d) Vaccination
- e) Psychological assessment

#### Periodic examinations

The main aims of periodic examinations are as follows:

- Collecting data about toxicant absorption, for example, evaluation of liver function in order to find if skin absorption or ingestion of chemicals has happened.

- Early detection of mood disorders which can distract the miner and cause occupational accidents because of loss of concentration.
- Early detection of parasitic diseases in food handlers of the camps, which can transfer easily to deminers.
- Collecting informations and analyzing them to reveal if physical or chemical exposure needs to be controlled.
- Any change in health level of deminers which reveal that some corrective interventions are needed.
- General health services such as vaccinations, coronary heart disease screening, hyperlipidemia and diabetes screening and so on.

# The Use of Mine Protected Vehicles as Safe Platform for Remote Controlled Flails: Eritrea Case Study

Ashley Williams14

MECHEM was awarded an UNOPS contract for an "Integrated Demining Capacity" in Eritrea from December 2004 to June 2008.

The contract entailed:-

- A manual capacity supplied by the Kenyan Army;
- > A Mine Detection Dog capacity; and
- > A mechanical capacity consisting of
  - 4 Bozena-4 Mini Flails.
  - 4 Tapir Mine Protected Vehicles (MPVs) fitted with steel wheels provided by MECHEM.
- In the past MECHEM had utilized Mini flails on various contracts, but mainly as single machines.
- This was the first contract on which the company was tasked to have 3 Mini Flails operational and one for training purposes.
- It was also the first time the company operated flails in a dry, semi-dessert region.
- The contract was executed in the Shilalo and Tserona areas of Eritrea, along the border with Ethiopia.

This presentation will demonstrate the advantages of using Mine Protected Vehicles as safe platform to operate Remote Controlled Flails.

- Initially the flails were operated from the ground in very arid areas and operators encountered difficulties to control the flails at distances further than 50m, due to the dust.
- This obviously created safety problems as operators moved closer to the machines to have better sight and control.
- Furthermore the machines could easily be damaged by falling into obstacles such as tank - and erosion ditches invisible to the operator on the ground.



Eritrea is a dry, arid country – photo shows the town of Shilalo in the background.



The mini flail at 10m

- The dry, semi-desert conditions decreased production substantially since the operators had to stop regularly to let the dust settle in order to obtain visibility of the machines, whilst simultaneously trying to adhere a safety distance.
- The machines also had to be pulled out to the maintenance area for their hourly check and cleaning service, reducing the productive time of the machines.
- Initially the machines were averaging approximately 2500m<sup>2</sup> per day; far below their production potential.

<sup>&</sup>lt;sup>14</sup> Ashley Williams, CEO of MECHEM (Pty) Ltd, South Africa; ashleywi@mechem.co.za



Machine undergoing hourly service; see the amount of dust in filters.



"Sekel" bush entangled on flail axle; had to be removed hourly or sooner.

- > The low production rate initially maintained The MPV driver acts as the assistant to the opwith the Mini Flails placed the MECHEM contract in jeopardy and a solution had to be found.
- > An obvious solution would have been the procuring of the Way Industry Operator Monitoring Cabin, but the UN did not have additional funding for the procurement.
- > The Tapir Mine Protected Vehicle's role on the contract was that of draw vehicles for the Bozena trailers and general purpose cargo vehicles.
- > This meant that these vehicles were standing most of the time and it was then decided, in conjunction with the UNMACC, to utilize the Tapirs as control vehicles for the Mini Flails.

## A Tapir Mine Protected Vehicle.

Utilizing the Tapir, or any other MPV for that matter, had the following advantages:

- > The operator had greater protection and could move 5 to 10m behind the machine.
- ➤ the height of the vehicle gave the operator excellent sight and control of the machine.

- > The team medical orderly could move with the operator.
- > The MPV driver acts as the assistant to the operator and assists with the hourly services.
- > All tools and equipment needed for the hourly service could be on the vehicle, thus saving the time needed to return to the maintenance site.
- > The MPV could also be used as a recovery vehicle in the case where the flail needed to be recovered.



Utilizing the Tapir, or any other MPV for that matter, had the following advantages:-

- > The operator had greater protection and could move 5 to 10m behind the machine.
- ➤ the height of the vehicle gave the operator excellent sight and control of the machine.
- > The team medical orderly could move with the operator.
- erator and assists with the hourly services.
- > All tools and equipment needed for the hourly service could be on the vehicle, thus saving the time needed to return to the maintenance site.
- > The MPV could also be used as a recovery vehicle in the case where the flail needed to be recovered
- > Once the MPVs had been introduced into the team, the productivity of the machines increased to an average of 7,000m<sup>2</sup> per day - an increase of approximately 250%.
- ➤ Utilizing MPVs as control vehicles for Remotely Operated Flails however, does have the following disadvantages:
  - MPVs are fairly expensive, but this can be overcome by using remanufactured vehicles which are a fraction of the price of new MRAP vehicles.
  - Additional running costs for the MPVs, although fairly low on maintenance, especially in this role, the vehicles are heavy on fuel.



Tapir MPV utilized as control vehicle for Bozena-4 mini flail

- Flails are arguably the most expensive asset any commercial demining company deploys on contract.
- It is thus logical that one needs to get the maximum production from the machines, however one has to balance production with the safety of the operator, as well as unnecessary damage to the machine.
- Utilizing MPVs as safe platform to control the machine, will increase the production rate of the machine and enhance the safety of, not only the operator, but the entire mechanical team.
- The greater productivity will also quite easily offset the additional costs involved with the MPV.

## Safety in Humanitarian Demining

Tomislav Ban<sup>15</sup>

#### 1. Introduction

Safety during the conduct of humanitarian demining operations is a set of measures and activities conducted with the basic purpose of health protection of people conducting humanitarian demining operations (deminers) and protection of property and health of citizens living in the vicinity of mine suspected area (MSA). Regardless of respecting all prescribed safety measures, at his working place, a deminer is exposed to increased risks – especially risk from uncontrolled detonation of explosive ordinance.

Table 1: Comparative overview of demined area and mien incidents per year<sup>16</sup>

	DEMINING KM <sup>2</sup>	MINE INCIDENTS				
YEAR		NO. OF INCIDENTS	NO. OF VICTIMS	FATALITIES	MAJOR BODILY INJURIES	MINOR BODILY INJURIES
2006	24,78	0	0	0	0	0
2007	27,12	3	3	1	1	1
2008	33,11	3	3	1	2	0
2009	37,87	2	3	1	1	1
2010	31,81	3	3	2	0	1

In the past five years, the number of mine incidents has been significantly reduced. It is our intention to make sure humanitarian demining operations are conducted in quality and safe manner, without any mine victims. When safety at a demining site is concerned, it is observed through the safety of direct performing party (deminer), safety of third persons and safety of property and other assets.

Quality legislative regulation of humanitarian demining is a precondition for implementation of safety measures and, at the same time, quality conduct of humanitarian demining operations.

<sup>15</sup> Tomislav Ban, Assistant Director, CROMAC, tomislav.ban@hcr.hr

<sup>16</sup> CROMAC, mine victim database, 31 March 2011

The work of deminers requires special working conditions due to increased risks from being injured (mine incidents). Therefore, it is important to clearly define the procedure during the possible mine incident at the worksite as well as the phases of administering medical treatment to the casualty.

#### 2. Normative system

Safety in humanitarian demining is a set of measures and procedures conducted with the main purpose of ensuring safe and quality demining. It is necessary for the implementation of safety measures to have a quality normative system whose preparation is the basic task of the national mine action authority. Safety and occupational health measures (S&OH) are defined by provisions which determine the humanitarian demining activity and general regulations which determine the field of occupational health. The basic regulations which define the safety measures at the international level are the international standards i.e. the set of IMAS<sup>3</sup> standards which provide guidelines for the preparation of the national mine action standards. When safety and occupational health measures are concerned, the above-mentioned primarily refers to the following: IMAS 10.1017, 10.2018, 10.3019, 10.4020 i 10.60<sup>21</sup>. Based on the international standards and its own experience, the Republic of Croatia made the national standards and is one of the few rare countries which established their own mine action model. The Law on Humanitarian Demining<sup>8</sup> gives full attention to the safety measures and represents the basis for preparation of Rules and Regulations and SOPs9. Through several chapters, the Book of Rules and Regulations on the Method of Conducting Humanitarian Demining Operations<sup>10</sup> speaks of the safety measures and represents the foundation for the preparation of SOPs of demining companies which develop work procedures and

<sup>17</sup> IMAS 10.10

<sup>&</sup>lt;sup>18</sup> IMAS 10.20

<sup>&</sup>lt;sup>19</sup> IMAS 10.30

<sup>&</sup>lt;sup>20</sup> IMAS 10.40

implement safety measures in line with the available resources and equipment.

Alongside with the regulations listed, general regulation which determines the field of safety and occupational health (Law on S&OH) has an important application in the implementation of safety and occupational health measures. Besides others, this Law also commits demining companies to training for the work in a safe way, training for administering the first aid and other measures and procedures important for the safety and quality of work.

#### 3. Safety measures

The primary task of the S&OH measures is to protect the worker and make sure he/she is able to work in a safe way. They are classified as:

- preventive
- restricting
- special

#### 3.1. Preventive safety measures

The task of preventive measures is to act preventively i.e. provide safety preconditions for the conduct of humanitarian demining operations what particularly refers to:

- quality of training,
- mental, physical and health capacity,
- respecting procedures and regulations,
- constant supervision and discipline.

Besides being trained for the conduct of primary operations, it is very important to be well-trained for administering the first aid in case of a mine incident. The curriculum prescribes 8 teaching hours of theoretical lessons and 18 hours of practical lessons from the subject "Administering first aid". Based on the Law on S&OH, the employer is committed to train one employee on each 20 employees for administering the first aid at the worksite.

At the same time, every deminer, prior to coming to the work place, is obliged to take the mental, physical and health capacity tests in the authorised health institution. Establishment of mental and health capacity is also conducted periodically every year i.e. during shorter periods with regard to the results of previous tests, in accordance with the Book of Rules and Regulations on the Establishment of Mental and Health Capacity.

#### 3.2. Restricting safety measures

Restricting safety measures refer to safety distances during the conduct of humanitarian demining and safe distances during destruction of explosive ordinances.<sup>8</sup>

Safety distances during the conduct of operations are defined by the Book of Rules and Regulations on the Method of Conducting Humanitarian Demining and they refer to minimum distances that need to be applied at the worksite.

#### 3.3. Special safety measures

Special safety measures refer to worksite marking, fire protection, sanitary support and protective equipment, devices and tools.

#### 3.3.1 Support of medical corps

The demining company is obliged to ensure the support of medical corps next to the worksite for the purpose of administering the first aid to the casualty in the shortest period possible. The support of medical corps assumes the presence of a physician, a medical technician and well-equipped ambulance with a driver.

Prior to the commencement of operations at the worksite, the company has to define in the Execution Project the procedure of evacuation of a casualty to the nearest health institution. The evacuation route should be marked on the map and it is also necessary to physically check the route before the beginning of operations i.e. the ambulance has to pass the basic and alternative roads to the nearest health institutions. The health institution has to be informed about the possibility of their arrival and capability to respond properly in case of a mine incident.

The worksite leader has to organize exercising the procedure of administering the first aid before the beginning of work. In case the project lasts for several months, the worksite leader is obliged to organize such exercises every month so that the workers could additionally train the procedures to be implemented in case of a potential mine incident at the worksite.

The evacuation procedures are:

- CASEVAC,
- MEDEVAC

CASEVAC means transport from the location of mine incident to the area safe for administering the first aid

MEDEVAC means the transport from the spot for administering the first aid to the specialized institution for medical treatment of the casualty

<sup>&</sup>lt;sup>9</sup> Law on Humanitarian Demining, NG 153/05, 63/07 and 158/08

 $<sup>^{\</sup>rm 10}$  SOP, Standard Operating Procedure

<sup>&</sup>lt;sup>11</sup> Book of Rules and Regulations on the Conduct of Humanitarian Demining, NG 53/07 and 111/07

<sup>&</sup>lt;sup>12</sup> Explosive ordinances

#### 4. The procedure during the mine incident

As already stated, the purpose of implementation of safety measures is to prevent mine incidents at the worksite. However, if the incident happens, each individual should know what to do in order to avoid panic and occurrence of new incidents and new victims. The worksite leader, in co-operation with the physician and the team leader, coordinates the process of administering first aid to the casualty.

When the mine incident occurs, it is necessary to immediately stop the operations at the worksite and establish at which part of the worksite the incident occurred i.e. detect the position of the casualty and order all deminers to return to the starting positions. It is necessary to identify the mine incident spot and perform terrain inspection to the casualty. The deminer performs the inspection under the supervision of the team leader while at the same time; the team leader sends another deminer to bring the stretcher to the control point.

The deminer closest to the casualty should try to establish contact with the person with the purpose of collecting information and warning the person not to move until he/she is administered the first aid. Deminers perform terrain inspection around the casualty and after that, the casualty is approached by th team leader and deminer with stretcher as well as deminer trained for administering the first aid, stopping the bleeding and imobilisation.

At the same time, the physician established contact with the nearest health institution and provides information on the possible need for emergency medical treatment while the worksite leader informs the police and demining company's management about the incident. After that, the casualty is put on the stretchers and carried out to the safe area where the professionals (doctor and tehnitian) take charge of administering first aid. After that, the casualty is transferred to the nearest health institution by ambulance.

This is where the procedure of administering the first aid at the worksite ends and starts the next phase – securing the incident spot for the needs of incident scene investigation. Additional ispection to and around the incident spot is performed as well as marking. During this phase, objects remaining after the incident must not be removed.

The worksite leader is obliged to make sure the vitnesses of mine incident are present at the worksite at the time of arrival of the investigating squad. Paralel with the investigation, CROMAC staff also collects information about the incident with the purpose of detecting possible ovesights during the conduct of operations and merging relevant data to be entered into the mine victim database.

#### 5. Conclusion

In order to conduct humanitarian demining in a safe way, besides the implementation of prescribed work procedures and adequate protection, it is also required to recognize the risks and prevent them or reduce to the minimum level possible. (Figure 1)



Figure 1: Elements that affect the safety

#### **Bibliography:**

- Law on Humanitarian Demining, NG 153/05, 63/07, 152/08
- Book of Rules and Regulations on the Method of Conducting Humanitarian Demining, NG 53/07, 111/07
- Book of Rules and Regulations on Standard Operating Procedures of Medical Support and Evacuation
- IMAS 10.10, 10.20, 10.30, 10.40 and 10.60

# Calculation of Safe Distance from the Bursting Effect during Detonation of Explosive Ordinances

Dražen Šimunović<sup>22</sup>

Summary: Apart from destructive effect, explosive ordnances (EO) at which explosive substance is in the metal or plastic case also have a bursting effect. As a consequence of the detonation, an explosive ordnance case breaks and bursts into the environment. The fragmentation products are called fragments (splints). After the detonation of an explosive substance, separated parts of the explosive ordnance case (in this case, mine and UXO in the minefield) are accelerating under the impact of a detonating wave and an impact wave. At a particular distance from the detonation centre, they reach their maximum speed. What is evident from the example given above is that the energy of gas products of the detonation of an explosive charge turns into the kinetic energy of the explosive ordnance case fragment.

Most correlations between factors that influence the bursting process of the explosive ordnance case such as type of material, thickness and shape of the case, type of explosive charge etc. are mostly of empiric character. Different measurements and recording by ultra-fast camera resulted in understanding of a pattern that rules in the process of fragmentation and distribution of splints within time and space.

The efficacy of bursting effect depends on two interconnected factors:

- factor of explosive ordnance construction,
- factor of use (position and EO detonation site)

The construction factor is influenced by: shape, mass, configuration, type of material and thermal processing of case material.

The use factor (exploitation) is influenced by: position and location of EO detonation (mine and UXO in the minefield). This paper elaborates the following:

bursting effect (fragmentation) of explosive ordinances (mine and UXO in the minefield); calculation of a number of case fragments; initial speed of splints during EO detonation; calculation of an efficient splint range, ballistic calculation of a splint flight; calculation of thickness of a lateral sheaf of splints during detonation; testing of EO fragmentation (bursting); bursting effect in the real conditions; consequences of bursting effect during EO detonation (mines and UXO) for people, material and technical means.

#### **INTRODUCTION**

- During the detonation, explosive ordinance with high blasting explosive in metal or plastic cartridge have a fragmentation effect on the target.
- Upon detonation of explosive, the body of a mine, projectile or bomb cracks and bursts into the environment.
- Fragments are the result of a detonation.
- They are of asymmetrical shape, of different volume, mass and speed.
- Density of a bundle of fragments is very important for the performance realization.
- Effects of a detonating wave and an impact wave result in an acceleration of fragments and, at specified distance, they reach their maximum speed.
- Transformation of energies of gaseous products of detonation into the kinetic energy of fragments of explosive ordnance body is evident.
- Correlation between factors that influence the fragmentation process (type of material, body shape, type of explosive charge...) of ERW body are mostly of empirical character.

Different measurements, experiments and videotaping with an ultra- fast camera resulted in be-

<sup>&</sup>lt;sup>22</sup> Dražen Šimunović, Head of Department for Organization and Analysis of General and Technical Survey, CROMAC, E-mail: drazen.simunovic@hcr.hr

coming aware of the pattern that governs the processes of fragmentation and distribution of pieces of shrapnel in space.

Since the mid-19th century until today, numerous scientists have been interested in this problematics such as Journée, Jousrow, Piobert, Morin, Poncelet, Newton, Harvey, Truet, Didion, Euler, Halie, Vallieur, Brezinski, Tasi, Adams and many others.

Efficacy of a fragmentation effect depends on two types of related factors:

- a) ERW construction factor
- b) ERW position factor

The following factors affect the ERW construction factor: shape, mass, configuration, type of material and thermal processing of a shell material. ERW position factor is influenced by the detonation centre of a mine, bomb or projectile as well as the environment the detonation takes place.

Fragmentation effect of ERW upon detonation can be perceived from the aspect of theoretical calculations and results obtained by the experiment. The findings refer to:

- 1. Number of ERW body fragments
- 2. Initial speed of ERW body fragment
- 3. Efficient reach of ERW body fragment
- 4. Density of lateral bundle of ERW body fragment
- 5. Testing of ERW fragmentation effect
- 6. Fragmentation of explosive ordinance in real conditions

#### 1 Number of shell fragments

• According to <u>Justrow</u>'s formula, expected number of fragments upon detonation of ERW with metal body is as follows:

$$N_0 = k_p \left(\frac{m_e}{d}\right) \cdot \left(\frac{\sigma_m}{\varepsilon \cdot \sigma_d}\right) \cdot \left(\frac{K^2 + 0.5}{K^2 - 1}\right)$$

- kp coefficient of the type of explosives and charge density of explosive ordinance, e.g. TNT=46
- me mass (weight) of the explosive charge (kg) d - outer diameter of a mine or other explosive ordinance (m)

бт - stress (tension) (MPa)

6d - ultimate stress (ultimate tension) (MPa)

 $\varepsilon$  - relative elongation of material in %

K=ds/du ratio between the outer (ds) an inner (du) diameter of the body



Figure 1 Cross-section or a mine with iragmentation effect on the target

Justrow's formula provides approximately accurate number of fragments during fragmentation of ERW body but does not provide data on the mass of each fragment (piece of shrapnel).

## 2 Initial fragment speed



Figure 2 Fragmentation of a projectile shot by the ultra-fast camera

- There are several formulas for determination of initial speed of EO body fragment but most of them are in collision.
- Testing carried out in the French laboratory LRSL by using an ultra-fast camera has been taken in this case in order to be given full consideration



Figure 3 The scheme of separation of body fragments during detonation

- D detonating speed of explosives (m/s)
- $V_0$  = initial separation speed of body fragments (m/s)
- $\beta$  angle of separation of a fragment in relation to the axis of symmetry of the mine

Analysis of experimental results established that an angle  $\beta$  depends on ratio between the body mass (mk) and mass of explosives (me)

Ratio mk/me > 0,5

$$\beta = \frac{\alpha}{2} = \frac{12^{\circ}30^{\circ}}{1 + \frac{0.5m_k}{m_e}}$$

 $V_0 = 2D \sin \beta$ 

Initial fragment speed during detonation is as follows:

$$V_0 = \frac{0,216D}{1 + \frac{0,5m_k}{m_e}}$$

- 1. Experiments (shooting with ultra-fast camera) proved that the fragmentation takes place grad-ually.
- 2. At first, gasses resulting from the detonation inflate the body and after that comes the fragmentation.
- 3. During the further movement of fragments, gasses still affect the fragments and they "fly" until the outer force does not change its course. At that moment, the fragments shall reach their maximum movement speed.
- 4. The fragments shall have the biggest initial speed V0 at the distance of the size of several EO diameters.

e.g. The diameter is 60 mm. The biggest fragment speed is at the distance of 300 to 400 mm. (0,3 to 0,4 m).



The scheme of bundles during fragmentation of a cylinder-shaped explosive ordinance



Diagram1. Initial fragment speed (m/s) is dependent of the ratio between the mass of the body and explosives.

In case of classical cylinder-shaped fragmentation mines, fragments fly in three zones:

- 1. **Upper bundle** of fragments emerges from the detonator and upper part of a mine. Those fragments are very small and in case of properly placed fragmentation mine (e.g. PROM 1 or PMR-2A), they have a very steep path what makes them inefficient.
- 2. Lateral bundle is vertical to the axis of symmetry of the fragmentation mine.
- 3. Lower bundle takes effect from the bottom of a mine towards its bearing.

#### 3 Efficient fragment range (ballistic calculation of a fragment flight)

Air resistance that affects the fragment in the air is given as follows

$$F_x = C_x \cdot S \cdot \rho \cdot \frac{v^2}{2}$$

Cx - coefficient of the aerodynamic air resistance S - reference (turbulent or lamilar) surface area of the fragment's cross-section

 $\rho$  – specfic air density

v – initial fragment speed

Differential equation of fragment movement is as follows

$$m \cdot v \cdot dv = F_x \cdot dx$$
$$m \cdot \frac{d^2 \cdot x}{d \cdot t^2} = -C_x \cdot S \cdot \rho \cdot \frac{v^2}{2}$$

International Symposium "Humanitarian Demining 2011" 26 to 28 April 2011, Šibenik, Croatia



Diagram 2 Distances of dispersion of each EO fragments upon detonation on the surface and in the ground.

Integration of a differential equation results in the fragment speed

$$v = v_0 \frac{C_x \cdot S \cdot \rho x}{2m}$$

To conclude, the route that the fragment flies over during the specified moment is as given:

$$X = \left(\frac{2m}{C_x \cdot S \cdot \rho}\right) \ln \frac{V_0}{V}$$

#### 4 Density of lateral fragment bundle

The criterion for the efficient fragmentation effect is not only a specific kinetic energy of the fragments but also their **density**  $\gamma$  (number of fragments per square meter) at a specified distance.

After detonation of the explosive ordinance, fragment paths are becoming wider as they cross the distance. Therefore, their density as per area unit is reduced.

There is a number of information in the expert books for:

 $\gamma$ =1 fragment /m2 or  $\gamma$ =0,1 fragment /m2 For live targets:  $\gamma$ =0,1 fragment /m2

According to that, the probability of hitting the target is as follows: ph= 0,1

#### For the surface area of the target

**P=1 m2** (section within the fence 2 m tall and 0,5 m wide), and continuous fragment bundle - probability of hitting the target ph=0,1 shall happen within the bundle density:

 $\gamma = 1 \text{ fragment} / 10 \text{ m}^2$  or  $\gamma = 0,1 \text{ fragment} / \text{m}^2$ 

What follows is: Re>R ymin

Re - efficient fragment range as per kinetic energy R γmin - efficient fragment range as per density



Figure 5 Dispersion and probability of hitting the lateral fragment bundle upon detonation

As can be seen from the figure 5, during the explosion, the fragments are positioned along the ringlike surface. It is the part of a ball of R diameter and can be determined from the following formula:  $Sb = 2\pi Rh$ 

50% fragments within the angle  $\delta/4$ 82% fragments within the angle  $\delta/2$ 96% fragments within the angle 3  $\delta/4$ - 100% fragments until the angle  $\delta$ 

Fragment density is calculated as follows:

$$\gamma = \frac{N_0}{Sb}$$

No – total number of efficient fragments as per kinetic energy at the distance observed

From the geometrical display and previous formulas we can calculate the efficient fragment range per density:

$$R_{\gamma} = \left\{ \frac{N_0}{2\pi\gamma \left[\cos\varepsilon - \cos(\varepsilon + \delta)\right]} \right\}^{\frac{1}{2}}$$

#### **5 Fragmentation effect testing**

# 5.1 Testing of an explosion of a fragmentation mine in the pit



Figure 6 The scheme of fragmentation mine testing in the pit

Fragmentation mine is placed in the wooden crate in the pit covered with sand.

The crate width is equal to the length of several diameters of a mine, in order to ensure the initial fragment speed.

Upon the explosion of the mine, fragments are collected (shrapnel, fragments)

Losses of a metal part of the shell should not exceed 5 %.

The pieces collected (fragments) are collected according to the weight groups, e.g. of 1g. 1,5 g, 2 g 2,5 g etc.

Average fragment mass is calculated for each group.

$$m_s = \frac{m_g}{N_i}$$

mg – mass of fragments classified into one group Ni – number of pieces in the group in question

#### 5.2. Fragmentation testing within the fence

Fences within which testing is performed consist of four sections. They are placed at different distances from the centre of an explosion.

Wooden boards are 2 m tall, 0,5 m wide, 25 mm or 41 mm thick. There are 100 boards. The area covered by the fragmentation of a mine is  $100 \text{ m}^2$ .

Each board represents a live target – a man. The boards are made of:

a) Fir tree (25 mm thick), for checking the boundaries of serious injuries  $Eks = 80 \text{ J/ cm}^2$ 

b) Poplar tree (41 mm thick), for checking the boundaries of fatal injuries  $Eks = 150 \text{ J} / \text{cm}^2$ 



Figure 7 Testing of the fragmentation effect within the fence

The probability of a breakthrough of a section  $0.5 \times 2 \text{ m}$  at the distance x is as follows:

$$p_x = \frac{f_x}{F_x}$$

fx – number of breakthroughs of sections at the distance x

Fx – number of sections  $0.5 \ge 2$  m at the sector, at the distance  $\ge$ 

Density of a breakthrough (average no. of breakthroughs) per sections at the sector, at the distance x is a ratio between the total no. of breakthroughs and number of sections at the affected sector

$$d_x = \frac{p_x}{f_x}$$

# 5 Explosion of explosive ordinances in real conditions

In 1880, French colonel **Journée** was the first to discover the intensity of the kinetic energy required for causing injuries and/or killing people and horses.

In case of humans, contusion and injuries happen during the crash of a shrapnel and a traget at specific kinetic energy of 20 J/cm<sup>2</sup>.

The border of the kinetic energy at which the bones are being injured comes to ca. 50 J. The bones are broken hen the intensity of the specific kinetic energy of a fragment exceeds 155 J/cm<sup>2</sup>.

The value of the kinetic energy for injuries and breaking of horse's bones is twice as bigger as the one for the humans.

#### The analysis of other researches established that the boundary for serious injuries to occur is ca. 80 J and for fatal wounds is over 100 J.

Example:

- a) Shrapnel of 5 g, at speed of 200 m/s can kill a man under the condition that it hits a part of the body that is classified as deadly zone of injuries.
- b) Shrapnel of 1 g, at speed of 500 m/s can kill a man under the condition that a man is hit in the deadly zone of injuries.



Figure 8 Zones and types of injuries at the human body

According to some authors, shrapnel is considered deadly if its kinetic energy is equal to  $150 \text{ J/cm}^2$ 

## CONCLUSION

This paper provides an insight into the scientific approach to studying the effect of an explosion of explosive ordinance during detonation of explosives within the ordinance. After the scientific and theoretical analysis of the fragmentation effect during detonation of explosive ordinance supplemented with results from the practical experience, it can be concluded that most formulas and forms could be used for preliminary calculation of safety zones.

It is very important for the calculation of safety distances in space, during the work with mines and UXO in humanitarian demining operations in order to avoid unwanted consequences and increase the safety level to the highest level.

#### **Bibliography:**

- 1. N. Kršić: Construction of projectiles and detonators, part II, TŠC KoV JNA Zagreb 1968
- 2. N. Kršić: Nuclear warheads and detonators of missile projectiles, TŠC KoV JNA Zagreb 1972
- 3. Dragi Dimitrijević: TŠC KoV JNA Zagreb 1982
- Ivan Šteker, Dražen Šimunović: Watch outmines – Središnji odbor Hrvatskog časničkog zbora 1997.
- 5. Lessons for students of Velika Gorica Community College (subject: EO 2 – Introduction to the construction)

Topic: Effect of explosive ordinance to the target

- Effect of an impact wave Fragmentation effect – Cumulative effect – Penetration of projectile
- -Misnay Sharidan's effect
- Author: Dražen Šimunović, B.Sc., January 2006

# ESSENTIAL DIFFERENCES IN CLEARANCE AND QA/QC OF MINE SUSPECTED AND ERW SUSPECTED AREAS

# The Specific Colombian Problem - the Antipersonnel Landmines and Improvised Explosive Devices in the Fields of the Illicit Crops

Yimmy Alexander Gomez Quevedo<sup>23</sup>, Milan Bajić<sup>24</sup>

Colombia is considered one of the countries with the highest numbers of emplaced antipersonnel mines, as well as the largest numbers of landmine victims in the world, [1]. It is estimated that antipersonnel mines are spread throughout 40 percent of Colombia's national territory, affecting 31 of the 32 departments, and present in one out of every two municipalities. The five departments with the highest number of victims were Antioquia (22%), Meta (10%), Caquetá (8%), Bolívar and Norte de Santander (7%) respectively. Statistics show that since 2008, average of 2 people per day is victims of antipersonnel mines and improvised explosive devices (IED), [1].

#### Coca fields and landmines

The specific of Colombian mine action is the wide appearance of antipersonnel landmines and IED in the fields of the illicit crops of coca, [2]. The Colombian Government has focused its efforts in combating drug trafficking in particular on one of the first links in the chain for the illicit crops cultivation. Integrated Project Monitoring System SIMCI, supported by the UN agency, has established itself as a source of valuable information on the location and quantification of illicit crops, based on satellite imagery analysis, [3]. The satellite scenes used in 2009 - 2010 were Landsat 7 ETM+ 64, Lansadt 5 TM 12, ALOS 10 and Aster 7. While SIMCI provides only an annual report, there is a need to have source of the updated information at any time of year as fundamental tool for decision-making for illicit crops eradication. One aspect of the problem can be conceived by comparison of the spatial distributions of the coca fields, Fig. 1, and the distribution of the landmines, IEDs, casualties, Fig. 2, in the year 2009.



Figure 1. Distribution of the coca fields in 2009 given by SIMCI.



Figure 2. Distribution of the landmines, IEDs, casualties in 2009.

<sup>&</sup>lt;sup>23</sup> Yimmy Alexander Gomez Quevedo, Detection group chief, illicit crops, in Colombian National Police, Bogota, Colombia, E-mail: yimmy.gomez@correo.policia.gov.co

<sup>&</sup>lt;sup>24</sup> Milan Bajić, Prof. PhD, Faculty of Geodesy University of Zagreb and Scientific Council of CROMAC-Centre for testing, development and training Ltd., Zagreb, Croatia, E-mail: milan.bajic@zg.t-com.hr

The development of aerial spray operations and manual eradication of the coca fields in the country has forced narco cultivators to implement strategies to avoid and lessen the impact of eradication operations, following the dispersion of the lots, reduced size of them and crop establishment in areas of difficult access. Due to the above it is necessary to search for new high-tech tools (the technique and the technology) that allow the localisation and quantification of the areas where illicit crops are present, taking into account that the information reported by SIMCI is temporary cut at December 31 each year. The limitations on the acquisition of information has been evident especially in the planning of the operations manual eradication, in which the security forces providing security for Groups Mobile Eradication activity carried out in coordination and support the High Council for Social Action of the Presidency of the Republic.

## Manual coca eradicators - numerous casualties from explosive devices, antipersonnel mines

One specific mine action problem in Colombia is very large percentage of manual coca eradicators in civilian casualties. In 2009 were identified 674 casualties from explosive devices, having been caused by antipersonnel mines, [2]. This represented a 16% decrease in annual casualties as compared with the 798 casualties recorded in 2008, a continuation of the trend of declining casualty rates since the peak of close to 1,200 casualties recorded annually in 2005 and 2006, [2]. Among the adult civilian casualties from explosive devices (landmines, improvised explosive devices) 28.4 % are manual coca eradicators. Since 2008, coca eradicator casualties have occurred in 12 municipalities and in seven of these, they made up between 75% and 100% of all recorded civilian casualties. In 2009, 57% of all casualties occurred in just four departments: Antioquia, Caquetá, Nariño and Meta, [2].

## Technologies for reconnaissance and surveillance of coca fields with landmines and IEDs

There is one very strong barrier for the remote sensing technologies considered for the reconnaissance and surveillance of coca fields with landmines and IEDs, this is the cloud coverage, Fig. 3. The aim of these technologies is to provide timely actual information needed especially for the planning of the operations of manual eradication and the security forces providing security for groups mobile eradication.



Figure 3. The cloud coverage of the Colombia, calculated from 22900 images collected from 1999 to 2008.

The satellite Landsat 7 ETM+ , Lansadt 5 TM, ALOS and Aster based surveillance of the coca fields in SIMCI is based on the multispectral images of on the enhancement of the scene contents and mainly on manual extraction of the coca fields vectors. The detailed interpretation key for coca and for opium poppy is developed, Fig. 4 and a "calibration" of the interpreters is considered. The application of vertical aerial photography is used for field verification of the data provided by SIMCI about the coca fields, Fig. 5. The application of PCs instead of large format paper maps for direct visual inspection flights is planned.

The aerial reconnaissance and surveillance of the coca fields should enable reliable detection and assessment of coca fields, which have tendency to become smaller, obscured by vegetation and camouflaged by combination of artificial and natural materials, Fig. 6, Fig. 7. Therefore the multispectral images are needed and the whole acquisition, processing and interpretation should be matched to mentioned conditions. While the task of detection, recognizing the coca fields is difficult due to the considered facts, the alone remote sensing technology can not provide satisfactory solution. The approach used in the advanced intelligence technology [ 6], [7] and [8] could help to develop

# International Symposium "Humanitarian Demining 2011"





Figure 4. The interpretation key of SIMCI.



Figure 5. Aerial verification of the satellite based data about coca fields.





Figure 6. Example of coca field, [3].

Figure 7. Example of coca field, [3].

and build up a modern aerial based reconnaissance and surveillance system for the detection and recognizing the coca fields contaminated by landmines. In this approach are fused data from the aerial and satellite images, data about terrain analysis, the contextual information and the experts' knowledge.

#### Conclusion

Landmines and IEDs are very serious problem in the illicit crops (coca, poppy, marijuana) eradication, thus Colombia is searching technology for this combined purpose.

The satellite based SIMCI project provides annual reports about the coca fields. There is a need to have source of the updated information at any time of year as fundamental tool for decision-making for illicit crops eradication.

The advanced intelligence decision support system technology developed in Croatia and succesfully applied in Croatia and Bosnia and Herzegovina for the needs of humanitarian demining, could support to solve this problem.

#### References

- Landmine monitor, (2010). Colombia, Mine Action, Contamination and Impact, Mines, Landmine and Cluster Munition Monitor.mht, Last Updated: 13 October 2010, http://www.themonitor.org/
- [2] Landmine and Cluster Munition Monitor, (2011). Colombia, Casualties and Victim Assistance, Last Updated 02 February 2011. http:// www.the-monitor.org/index.php/cp/display/region\_profiles/theme/509

- [3] Colombia Monitoreo de Cultivos de Coca, Junio 2008, Naciones Unidas Oficina contra la droga y el delito and Gobierno de Colombia. ISSN – 2011-0596.
- [4] UNODC, (2010). COLOMBIA Coca cultivation survey 2009, United Nations Office on Drugs and Crime, Government of Colombia, June 2010.
- [5] UNODC, (2008). Workshop on measurement of cultivation and production of coca leaves, Bogotá, Colombia, 25-27 November 2008.
- [6] Bajić, M., (2010). The advanced intelligence decision support system for the assessment of mine suspected areas, Journal of ERW and Mine Action, James Madison University, Issue 14.3, Fall 2010, Available: 1.03.2011, URL: http:// maic.jmu.edu/journal/14.3/r\_d/bajic/bajic.htm
- [7] M. Bajić,M., Turšič, T., (2010). Operations with Advanced Intelligence Decision Support System for Mine Suspected Area assessment in Croatia and Bosnia and Herzegovina, UN-MAS – GCIHD Workshop "Merging Mine Action Technology and Methodology", GICHD, Ženeva; 6-8.09.2010. Available 1.03.2011, URL: http://www.gichd.org/fileadmin/pdf/technology/Technology-Workshop-2010/C-6Sept2010-SMART-TechWS.pdf
- [8] Bajić M. (Editor), Matić Č., Krtalić A., Čanđar Z., Vuletić D., (2011). Research of the mine suspected area, Publisher CROMAC - CTDT Ltd., ISBN 978-953-99879-7-6. Zagreb, April 2011.

# The Relationship Between Risk Management and Quality Management in the Clearance of Mines and Explosive Remnants of War

Darvin Lisica<sup>25</sup>

I will begin my contribution on the relationship between risk management and quality management with a critic of mine actions stated at the Conference on Convention to Ban Landmines a few years ago, which roughly says: *You complicate the issue of mines too much, they just need to be removed*. It is a naive approach to the problem of mines and other remnants of war which criticized the complexity of managing mine actions. However, this idealistic conception of the implementation of the Convention to Ban Landmines has never been too sustainable, particularly today. Requirements of land users, vulnerable communities and the public in affected countries as well as donors are directed toward efficiency of work and effectiveness of the results of mine actions.

Today, the work efficiency and effectiveness of the results are fundamental problems of mine action management and all other humanitarian and development interventions as well. These problems are reflected in the debate on policies and strategies for mine action, in general assessment of the situation, operational planning, quality management and resources, in defining business processes, preparation of operational procedures and cost of interventions. It happens that implementation of certain solutions that were successful in one country are not so successful in another country because of diversity of conditions – whether because of the nature of armed conflict or in terms of level of development, certain cultural filters or the level of knowledge. Therefore mine action management is a complex area that can be viewed through different perspectives of management. This will give an overview of some important perspectives of mine action management that show what those who manage mine actions should address and understand. Within mine action management system, these perspectives can be viewed through its four sub-systems<sup>26</sup>. They are as follows: (1) Mine action policy and strategic planning; (2) Operational management; (3) Risk management; (4) Quality management.

<u>Mine action policy and strategic management</u> is a management sub-system with main components: mine action policy and legislation, general assessment of mine actions, advocacy, and mobilization of resources including communication with donors, strategic analysis and strategic planning as a whole.

**Operational management** is a management subsystem with components of mine actions which are directed towards reduction or complete recovery of the consequences of mines and other explosive remnants of war, out of which each has its own operational system which includes resources, operative planning, organization and interventions.

Introduction of land release concept has initiated faster development of sub-systems for risk management and quality management within mine action management system. Further consideration of efficiency and effectiveness of mine action here will focus only on the relationship between quality management and risk management.

Guide for the application of International Mine action Standards IMAS 01.10. has promoted integration of risk and quality management systems and their application on specific cases in mine action activities, while clearly distinguishing the requirements of one and the another sub-systems.<sup>27</sup>

"IMAS have been developed in line with the

Guide to risk management and IMAS, p. 12

<sup>&</sup>lt;sup>25</sup> Dr.sc. Darvin Lisica, Programme Manager, Norwegian People's Aid, E-mail: darvin@npa-bosnia.org

<sup>&</sup>lt;sup>26</sup> See figures 1: Model of mine action management system with main sub-systems, page 2.

<sup>&</sup>lt;sup>27</sup> Guide for the application of International Mine Action

Standards. IMAS 01.10. Second Edition 01 January 2003. 9. Quality and risk management, p. 5.:

recommendations and processes contained within the ISO Quality Management systems..."

<sup>&</sup>quot;Elements of these systems are contained within the majority of IMAS, thereby making the IMAS themselves an integrated risk and quality management system."

<sup>&</sup>quot;There is still a requirement, however, for NMAA and mine action organizations to develop their own specific individual risk and quality management systems."

<sup>&</sup>quot;It must be emphasized that quality is NOT a synonym for safety, and consequently the respective roles of quality management and risk management should not be confused." "The success of humanitarian demining is dependent on the integrated application of both quality management and risk management principles and procedures."



Figure 1: Model of mine action management system with main sub-systems

Integrated process-oriented models of governance are not a novelty but long-standing demands of the International Standards Organization, which is widely applied in various conditions of modern business.

Managing the risks of mines and other explosive remnants of war. The risk of mines and other explosive remnants of war have its two sides. The first one is the risk determined by the existence of minefields in a particular identified or unidentified area. The other side of risk is social, economic or environmental impact which this danger produces or can produce.

Assessment of these two sides of risk - the danger of mines and other explosive remnants of war and their social, economic and environmental impact are the essential content of risk management. This model is also the starting point for the assessment of the mine problem at the macro and micro level, for establishing priorities, short-term and longterm planning, and finally, for land release through different processes for clearing areas contaminated by mines and other explosive remnants of war Risk management is based on the needs of users

Risk management is based on the needs of users, efficiency in utilization of available resources and

the effectiveness of the results.

**Quality management of mine action.** Each community of people has developed system of values that all its members comply with. Moreover, each individual has his/her own value system which he/ she manifests publically or keeps it for herself/himself. Relation to any phenomena, process or their consequences is determined by the existing system of social and individual values. That is exactly the nature of the concept of quality. Quality is a relative term. What is for some "quality" may not be for another. Criteria of quality are changing with time. According to modern approach to its definition: "Quality is a measure or indicator that determines the volume, i.e. the amount of use value of a product or service to satisfy specific needs, at a certain place at a particular time - then when these products or services are through a social exchange process confirmed as a commodity". So the quality means satisfaction of buyers or exceeding his expectations and needs.<sup>28</sup> Quality management ensures confidence of end users.

<sup>&</sup>lt;sup>28</sup> Injac, Nenad (2002) Mala enciklopedija kvalitete (Small encyclopedia of quality). Introduce standard ISO 9000, Part 1. Zagreb: Oskar.

It has been confirmed in practice that monitoring of clearance is a central element of quality management subsystem in mine actions. Monitoring is: "A continuing function that uses systematic collection of data on specified indicators to provide management and the main stakeholders of an ongoing development intervention with indicators of the extent of progress and achievement of objectives and progress in the use of allocated funds."29 It is also one of the parallel processes involved in risk management in mine action. Basically, monitoring is composed of two elements: quality control and quality assurance. Generally, quality control represents monitoring of inputs and processes in mine actions, while quality assurance represents quality control of products, first of all released land and the effectiveness of results. Quality control mechanisms are designed to provide managers with information (Feedback) how the process which is monitored runs. Quality assurance is focused on products and final effects, but also on all those measures that provide a high degree of confidence in the process<sup>30</sup>. Both quality control and quality assurance are monitoring processes, intended to be carried out by managers and employees who are directly involved in the process being monitored. Both of these quality monitoring processes measure the degree of compliance with standards, finally, not taking into account whether set goals are to be achieved. It is important to fulfill standard minimal requests. Together with evaluation and continued quality improvement, monitoring constitutes an important element of quality management.

From the aspect of economic development, evaluation is a systematic and impartial assessment of ideas, implementation and results which determine appropriateness and fulfillment of set objectives enhance efficiency<sup>31</sup>, effectiveness,<sup>32</sup> impact<sup>33</sup> and sustainability of a current or completed projects, programs or policies. Evaluation provides information that is credible and useful, and allows us to include gained experiences in decision-making

- <sup>31</sup> Efficiency means the extent to which economic resources inputs are converted into results.
- <sup>32</sup> Effectiveness means the scope in which development goals are achieved, or are expected to be achieved, taking into account their relative importance.
- <sup>33</sup> The impact implies positive, negative, primary and secondary long-term effects produced by developing interventions (programs, projects, policies), directly or indirectly, intentionally or unintentionally.

process for recipients and donors.<sup>34</sup> It can be concluded from mentioned definitions of evaluation and monitoring that these are complementary processes. Monitoring provides information on where the policy, program or the project is at any moment with respect to compliance with goals and results. Evaluation provides evidence why the goals or results have not been or will not be achieved.<sup>35</sup> These two processes are mutually related. Evaluation uses data and results of monitoring, and its results are used for improvement of quality policy and procedures that lead to quality improvement and philosophy of success.

We should emphasize again that the integration of risk management and quality management within a unified management system is the request of International Standards for Mine Action. Analysis of their relation involves comparison of their normative frameworks that, with certain modifications on their peripheries, can be applied in almost all areas of mine actions.

Figure 2. Shows two standard models for risk management and quality management according to International Organization for Standardization. These models are also included in International Standards for Mine Actions. According to the standard ISO 31000 risk management is composed of: establishing the context  $\rightarrow$  risk identification  $\rightarrow$ risk analysis  $\rightarrow$  risk evaluation  $\rightarrow$  risk treatment. Risk identification  $\rightarrow$  risk analysis  $\rightarrow$  risk evaluation all together constitutes risk assessment.

Two parallel processes are added to them, one of which is communication and consultation, and the other supervision and review. According to standard ISO 9001 model of process-oriented quality management system sets the user at the center of attention. Requirements within the quality management systems begin and end with the user. Supervision and evaluation, the techniques of which allow measurement, analysis and improvement, are added to this standard model presented in ISO 9001 – Requests of quality management system.

Standards for risk and quality management are foundation of integrated normative framework

<sup>&</sup>lt;sup>29</sup> OECD (2002) Glossary of Key Terms in Evaluation and results Based Management. Paris: Development Assistance Committee, page 28.

<sup>&</sup>lt;sup>30</sup> Fitzpatrick, Jody L., Sanders, James R. and Worthen, Blaine R. (2004) Program evaluation. Alternative Approaches and Practical Guidelines. Third Edition. Boston: Pearson, page 503.

<sup>&</sup>lt;sup>34</sup> OECD definition of evaluation is as follows: "The systematic and objective assessment of an ongoing or completed project, programme or policy, its design, implementation and results. The aim is to determine the relevance and fulfilment of objectives, development efficiency, effectiveness, impact and sustainability. An evaluation should provide information that is credible and useful, enabling the incorporation of lessons learned into the decision-making process of both recipients and donors." OECD (2002) Glossary of Key Terms in Evaluation and results Based Management. Paris: Development Assistance Committee, page 21.

<sup>&</sup>lt;sup>35</sup> Kusek, Jody Z. and Rist, Ray C. (2004) Ten Steps to a Result Based Monitoring and Evaluation System. Washington: World Bank, page 13.



Figure 2: Comparative models for risk management and quality management according to International Organization for Standardization



Figure 3: Cross of the standards for integrated models of quality and risk management in mine actions

International Symposium "Humanitarian Demining 2011"





Figure 4: Logical model of managing the risk and the quality of clearing mines and explosive remnants of war

for mine action management. However, it also includes other general and special standards, guides, and documents of international and national legislation to complement it. In the center of the cross of standards, showed at Figure 3, are international standards for quality and risk management, but also the standards for environmental management, since mines and explosive remnants from war are, among others, environmental problems. A concrete standard from IMAS applied on certain areas of mine action should be added as well. Peripheries in the cross of standards present requirements from other standards related to the scope, conventions, policy and language by which certain process is shaped and its procedures described.

Previously considered problem of relation between risk management and quality management in mine actions and their integration in one process-oriented management system will be explained using the example of one of the most important components of mine action, <u>clearance of mines and explosive</u> <u>remnants of war.</u>

It is showed on Figure 4: Logical model of risk management and quality in clearing mines and explosive remnants of war. This, at first sight complex

process, can be divided into three parts: (1) Land release process; (2) Estimation process of social, economic and environmental impact of mines and explosive remnants of war; (3) Process of quality management in clearing mines and explosive remnants of war. All together, land release process, process of estimation of social, economic and environmental impact of mines and explosive remnants of war constitute a risk management process.

Land release process. Land release process is given on the left side of the sketch bellow<sup>36</sup> focusing on the economy in reducing the threat of mines and explosive remnants of war. The process involves identification and assessment of risk as well as criteria on which decision on proceeding with hazards of mines and explosive remnants of war is to be based upon. To put it simply, they are reduced to: exclusion of land from the suspicious area within the non-technical risk assessment, application of technical resources in estimation that can result in reduction of suspected/risky area or clearance of outstanding land for which there are no reliable data on mines.

<sup>&</sup>lt;sup>36</sup> Figure 4: Logical model of managing the risk and the quality of clearing mines and explosive remnants of war.

International Symposium "Humanitarian Demining 2011" 26 to 28 April 2011, Šibenik, Croatia



Figure 5: Final objectives of risk and quality management

Land release concept is already widely accepted in mine actions and its work techniques are significantly developed. Its first standardization in IMAS was finalized last year. Land release is, essentially, hazard management which provides enough elements for estimation of the risk level. However, the current concept of land release does not have enough elements to assess the social, economic and environmental impact, without which the determination of priorities is not possible.

The process of assessing the social, economic and environmental impact of landmines and explosive remnants of war. In the middle of presented model<sup>37</sup> is the second part of risk management which evaluates different impacts of mines and other explosive remnants of war. Generally, it includes assessment of vulnerability of groups and communities, assessment of environmental impact and the analysis of potential benefits. It should be emphasized that assessment of social economic and environmental impact is more dynamic activity than hazard assessment, and is subject to changes resulting from the social environment. It is also more than risk assessment focused on final users' needs.

**Quality management process of mines and explosive remnants of war clearance.** On the right side<sup>38</sup> are the most important elements of the quality management process of mines and explosive remnants of war clearance. They can be classified in four groups as follows:

 Monitoring of non-technical assessments (which do not include technical operational methods). It usually involves control of assessment procedures and quality assurance of data, reports and released land.

- 2. Preliminary evaluation of priorities setting which usually involves review of criteria, transparency and objectivity of priorities setting process.
- 3. Monitoring of technical survey and clearance tasks is a quality management element where the most progress was made in developing procedures for quality assurance and quality control.
- 4. Evaluation focused on results with its four crucial issues and estimation of final user's satisfaction. Until now it was left to the initiative of donors while adequate attention was not paid to internal evaluation.

From the above example of an integrated model for managing the risk and quality of mine and explosive remnants of war clearance, it can be concluded that risk management is more oriented on the needs of users and priorities. It had a more predictive power because it deals with predicting the social, economic and environmental impact of mines and explosive remnants of war as development interventions, and evaluation of operational conditions for work. These elements of risk management should be improved and brought to the level of hazard assessment. Finally, increased efficiency of land release is the result of progress made in hazard assessment. The development of techniques for assessing the social, economic and environmental impact will make a system for prioritization more objective and transparent. This will allow that land release becomes more effective and in accordance with the needs of users.

Quality management is more oriented to the confidence of users and assessment of actual results of interventions. Current experience suggests that it is necessary to improve and introduce as a regu-

<sup>&</sup>lt;sup>37</sup> Figure 4: Logical model of risk and quality management for mine and explosive remnants from war clearance.

<sup>&</sup>lt;sup>38</sup> Figure 4: Logical model of risk and quality management for mine and explosive remnants from war clearance.
lar practice the internal evaluation which is the responsibility of management for mine action organizations. Development of internal evaluation and its reliance on data that come through monitoring is a prerequisite for the success of mine action activities as a part of humanitarian-developing interventions. This is to ensure the confidence of land users and vulnerable communities in the appropriateness and results of interventions

Risk management and quality management of mine action are different concepts, but in their processing part they can be integrated into one management system. Their development and interconnection is a necessary precondition for the efficiency and effectiveness of mine action interventions and satisfaction of users of released land as the ultimate goal in the management of mine action activities.

#### Literature and other sources:

- 1. Fitzpatrick, Jody L., Sanders, James R. and Blaine R. Worthen (2004) Program evaluation. Alternative Approaches and Practical Guidelines. Third Edition. Boston: Pearson.
- 2. GICHD (2003) IMAS Guide for the application of International Mine Action Standards. IMAS 01.10. Second Edition: Geneva: GICHD.
- 3. Glendon, A. Ian, Clarke, Sharon G. and McKenna, Eugene F. (2006) Human Safety and Risk Management. Second edition. New York: Taylor & Francis.
- 4. Injac, Nenad (2004) Mala enciklopedija kvalitete. Upoznajmo normu ISO 9000, 1. Dio. Zagreb: Oskar. /Small encyclopedia of quality. Introduce standard ISO 9000, Part I. /
- 5. Kusek, Jody Z. and Rist, Ray C. (2004) Ten Steps to a Result Based Monitoring and Evaluation System. Washington: The World Bank.
- 6. Lisica, Darvin (2006) Risk management in mine action planning. Sarajevo: Ministry of Civil Affairs-Norwegian People's Aid.
- Mayne, John and Goñi.Eduardo Zapico ed. (1999) Monitoring performance in the Public Sector. New Jersey: Transaction Publishers.
- 8. OECD (2002) Glossary of Key Terms in Evaluation and results Based Management. Paris: Development Assistance Committee.
- 9. Sistemi okolinskog upravljanja Specifikacija sa smjernicama za upotrebu, BAS EN ISO 14001:2000. /Environmental management systems/ Guidelines for use/
- Sistemi upravljanja kvalitetom Smjernice za poboljšanje performansi, BAS EN ISO 9004:2002. /Environmental management systems/ Guidelines for performances improvement/

- 11. Sistemu upravljanja kvalitetom, Zahtjevi, BAS EN ISO 9001:2001. /Environmental management systems/Requests/
- 12. United Nations (2005) The United Nations Inter-Agency Policy. New York: Inter-Agency Coordination Group on Mine Action.
- World Bank Carleton University Ottawa (2005) International Program for Development Evaluation Training, Core Curriculum and Supplementary Resources. Ottawa: Carleton University.

## USE OF NEW METHODS AND TECHNOLOGIES - LATEST SOLUTIONS

#### **Experimental Test and Evaluation of an Active Sensing Prodder**

Jun Ishikawa<sup>39</sup>, Atsushi Iino<sup>40</sup>

#### Abstract

In this research, results of a preliminary test and evaluation of an active sensing prodder is reported. The active sensing prodder proposed here works to detect differences among natural frequencies, i.e., stiffness of materials during vibration. In measuring data, the active sensing prodder vibrates a target object by using a piezoelectric transducer (PZT) actuator and senses the vibration of the target by using an accelerometer. In this paper, the active sensing method is implemented to a real prodder used by deminers, and an analysis method to discriminate anti-personnel landmine-like targets from other object such metal fragments and stones is explained. A prototype of the active sensing prodder was evaluated by experimental test from a viewpoint of statistics based on analysis of variance (ANOVA). As the results, in an ideal condition (uniform soft soil and interior environment), success rate of landmine (simulant) discrimination was about 95%, and that of the other fragments such brasses and rocks was about 85% except for wood pieces and small brass pipes.

#### 1. Introduction

It has been more than decades since advanced mechanical demining have started, and demining machine technology has made remarkable progress. Furthermore, advanced sensing technologies such a ground penetrating radar (GPR) have recently become to be practically used in the minefields as well as metal detectors. In the closein detection phase, however, prodding still plays an important role. Actually, the use of prodders in manual demining and post clearance inspection after mechanical demining is still essential as a method of final confirmation whether it is a landmine or not. It is also well known that the prodding is one of the most difficult works in manual demining. Thus, it is desired that easy-to-use prodders will be developed to improve working efficiency and safety.

Many researches have been conducted on improving prodders. It is well known that many landmines have their own natural frequencies [1], which are related to the object stiffness and allow us to discriminate them from other objects such a stone. One way to utilize this feature is seismic/acoustic methods [2]. On the other hand, there are also researches on adding a kind of sensing function to prodders. In [3]-[7], prodders that use narrowband ultrasonic waves have been proposed and evaluated on a large scale. There is another kind of prodders that uses laser to sense plastic materials of landmines [8][9].

In this paper, an active sensing method for prodders is proposed [10]. In the proposed method, the prodder vibrates a buried target via a piezoelectric transducer (PZT) actuator and measures acceleration from the vibrated target. The measured signal is analyzed to discriminate landmine-like targets from other harder targets such stones and metals. In Section 2, concept of the proposed active sensing prodder is explained, and Section 3 states a design of experiment to evaluate basic performance of a prototyped prodder. Experimental results will be given in Section 4.

#### 2. Active sensing prodder

#### 2.1. Prototyping

Figure 1 shows a prototype of the proposed active sensing prodder. The basis of the prototype is a real prodder that was provided by Croatian Mine Action Center - Center for Testing, Development and Training (CROMAC-CTDT). The prodder has a PZT actuator and an accelerometer. The PZT actuator vibrates the prodding stick to transfer the vi-

<sup>&</sup>lt;sup>39</sup> Jun Ishikawa, Tokyo Denki University, Japan, E-mail: ishikawa@fr.dendai.ac.jp

<sup>&</sup>lt;sup>40</sup> Atsushi Iino, Tokyo Denki University, Japan, iino@robotics. fr.dendai.ac.jp



a) Overview



b) Close-up of activation part

Figure 1. Prototype of active sensing prodder.

bration to a buried target via the stick. Depending on the stiffness of the target, specific accelerations return through the stick and are measured by an accelerometer mounted on the prodder. Thus, the stiffness of the buried target being in touch with the pointed tip of the prodding stick can be estimated by analyzing the returned acceleration signals.

The weight of the prodder with the added part (the PZT actuator, the accelerometer, and the housing) is about 1kg, but, so far, other external components such a power supply, a PZT driver, and a charge amplifier for the sensor are needed. It should be lightened and simplified before field test.

#### 2.2. Experimental setup

Figure 2 shows an experimental setup in testing the prototype. The size of the container of soil is 50cm long, 35cm wide, and 30cm depth. In the experiment, a holder to set the prodding angle to be a constant is used. The target is set to be in touch with the pointed tip of the prodder in about 5cm depth and then is covered by the soil.

Although this interior setup is very ideal, all the data below to test the basic performance of the prototype were acquired by using this experimental system.



Figure 2. Experimental setup.

#### 2.3. Discrimination algorithm

Figures 3-a) to 3-d) show typical spectrum envelopes of the measured accelerations that return from four different targets, *i.e.*, respectively a landmine simulant (Type-72, King Associates Ltd.), a wood piece, a solid cylinder of brass of 218g, and a stone (see Figure 4 for the appearances). The input signal to make the PZT actuator vibrate was a square wave pulse of 40Hz, the duration time of which 0.128s, and the returned accelerations are measured at 128kHz sampling frequency. As shown in Figures 3-a) to 3-d), the features of the envelopes are different from each other. Thus, in this experiment, a performance index defined as

$$e_{r_i} = \sum_{k=K_1}^{K_2} \left| \hat{S}(k) - \overline{S}_{r_i}(k) \right|^2 \qquad (i = 1, 2, \Lambda, N_r)$$
(1)

is used to discriminate landmine-like targets from other fragments, where

- $\hat{S}(k)$ : spectrum envelope from measured data,
- $\overline{S}_{r_i}(k)$ : reference spectrum envelope stored in advance,
- $N_r$ : the number of reference spectrum envelope,
- $K_1$ : index for lower limit of frequency range, and
- $K_2$ : index for upper limit of frequency range.

In the experiments, two frequency rages corresponding to  $K_1$  and  $K_2$  were used. One is from 0.1 to 50kHz to cover all the measured signal dynamics, and the other is from 2.5 to 4kHz to extract a feature regarding stiffness of the targets.

26 to 28 April 2011, Šibenik, Croatia 100 50 [dB] Amplitude [dB] Amplitude -50 -100 4 5 6 Frequency [kHz] 10 Frequency [kHz] a) Type 72 (simulant) b) Wood piece 100 100 50 50 Amplitude [dB] Amplitude [dB] -50 -50 -100 -100 9 10 Frequency [kHz] Frequ ency [kHz] c) Brass 218g d) Stone

International Symposium "Humanitarian Demining 2011" 26 to 28 April 2011 Šibonik Croatia

Figure 3. Typical spectrum envelope of measured acceleration

#### 3. Design of experiment

In the experiment, using two kinds of soils (Figure 4, left), three kinds of landmine simulants, three kinds of brass pipe/cylinders, a wood piece and a stone (Figure 4, right) were tested to see if the proposed active sensing prodder can discriminate landmine-like targets from the others. As other conditions that could have influence on discrimination results, prodding angles (30, 40deg) and applied force in the axial direction of the prodding stick (10, 20N) are taken into consideration.

To acquire statistically-unbiased data from a limited number of experimental run, combination of all the conditions are determined based on Latin square design using  $L_{16}$  (2<sup>4</sup>) orthogonal array as listed in Table 1.

In the experiment, seven trials every experimental run were conducted, and the success rate (SR) for discrimination were calculated. These 112 (7 trials  $\times$  16 experimental run) tests were repeated four times.

In making decisions for discrimination, 16 reference spectrum envelopes that measured in advance were used. Twelve of those 16 references were measured in the same conditions as the experimental runs 1 to 6 and 11 to 16 in Table 1, the



Figure 4. Soils and targets used in experiment

Table1. Design of expe	eriment based Latin squa	are design using L	$(2^4)$	) orthogonal array.
		0 - 0	16 \ /	

Experimental run	Target	Soil	Prodding angle	Applied force
1	PMA-2	River sand	30 deg	10 N
2	PMA-2	Loamy soil	45 deg	20 N
3	Type 72	River sand	30 deg	10 N
4	Type 72	Loamy soil	45 deg	20 N
5	VS-50	River sand	30 deg	20 N
6	VS-50	Loamy soil	45 deg	10 N
7	Brass 3 g	River sand	30 deg	20 N
8	Brass 3 g	Loamy soil	45 deg	10 N
9	Brass 16 g	River sand	45 deg	10 N
10	Brass 16 g	Loamy soil	30 deg	20 N
11	Brass 218 g	River sand	45 deg	10 N
12	Brass 218 g	Loamy soil	30 deg	20 N
13	Wood piece	River sand	45 deg	20 N
14	Wood piece	Loamy soil	30 deg	10 N
15	Stone	River sand	45 deg	20 N
16	Stone	Loamy soil	30 deg	10 N

Table 2. Success rate (SR) for discrimination.

Experimental run (target)	1 <sup>st</sup> test	2 <sup>nd</sup> test	3 <sup>rd</sup> test	4 <sup>th</sup> test
1 (PMA-2)	1.000	1.000	1.000	1.000
2 (PMA-2)	1.000	1.000	1.000	1.000
3 (Type 72)	1.000	1.000	1.000	1.000
4 (Type 72)	1.000	1.000	1.000	1.000
5 (VS-50)	0.857	1.000	1.000	0.571
6 (VS-50)	1.000	1.000	1.000	1.000
7 (Brass 3g)	0.000	0.000	0.000	0.714
8 (Brass 3g)	1.000	0.000	0.286	0.000
9 (Brass 16g)	1.000	0.571	1.000	0.857
10 (Brass 16g)	1.000	0.857	1.000	0.286
11 (Brass 218g)	1.000	1.000	1.000	0.286
12 (Brass 218g)	1.000	1.000	1.000	1.000
13 (Wood piece)	0.286	0.000	0.286	0.000
14 (Wood piece)	0.143	0.000	0.000	0.000
15 (Stone)	1.000	1.000	1.000	0.714
16(Stone)	1.000	0.714	0.429	0.857

Table 3. Volumetric water content measured by using a time domain reflectometry (TDR) meter.

		Reference measuring	1 <sup>st</sup> test	2 <sup>nd</sup> test	3 <sup>rd</sup> test	4 <sup>th</sup> test
Divorcond	Before test	4.8%	4.2%	4.7%	4.6%	4.6%
River sand	After test	4.6%	4.8%	4.2%	4.3%	4.5%
Loamy soil	Before test	11.6%	12.2%	12.8%	10.8%	11.1%
	After test	11.0%	11.9%	11.6%	10.4%	11.6%

		r		1	
Source of Variation	Degree of	Sum of squares	Mean of	Computed F	Event
	freedom	_	squares	statistic	probability
A: Target type	7	7.03166	1.00452	20.92314**	0.0000 **
B: Soil	1	0.00289	0.00289	0.06018	0.8072
C: Prodding angle	1	0.05394	0.05394	1.12351	0.2940
D: Applied force	1	0.00286	0.00286	0.05962	0.8080
e <sub>1</sub>	5	0.18271	0.03654	(0.74266)	
$e_2$	48	2.36183	0.04920		
e	53	2.54454	0.04801		
Total	63	9.63590			

rest four references were measured in empty (no target) condition for two kinds of soil and two kinds of prodding angles. The performance index given by Equation (1) was calculated for every reference, and 16 calculation results were compared to determine which reference most resemble the measured one, *i.e.*, which minimized the performance index.

In this experiment, the success discrimination is defined as the case that the most resembling reference is the same category as the buried target, and all the other cases are treated as false. Then, SR was calculated as a ratio of the number of the success discriminations to 7 trials for every experimental run.

#### 4. Experimental results

Table 2 shows SR for four evaluation tests, and Table 3 shows volumetric water content measured in the experiment. For VS-50, a few false events occurred, and this is because the stiffness of VS-50 is similar to that of wood pieces. For the same reason, almost all the wood piece and brass pipes (3g hollow pipe) was classified as landmine-like targets.

Table4 shows results of analysis of variance (ANO-VA), and Figure 5 show average SR for each factor with 95% and 99% confidence intervals. The confidence interval of each main effect is experimentally derived by using  $V_e$ , i.e., the mean of squares due to error e. For example, the 95% confidence interval of the target type (factor A) is given by

$$a_T \pm t_{f_e,95\%} \cdot \sqrt{\frac{V_e \cdot (f_A + 1)}{n_d}}$$
 (2)

where  $f_A = 7$  and  $f_e = 53$  are degrees of freedom of factor A and error e respectively,  $a_T$  is average SR of factor A,  $n_d = 64$  is the total number of experiments (the number of experimental runs multiplied by repetitions), and  $t_{f_{e},95\%} = 7$  is the quantile of the t-distribution for probability 95% with  $f_e$  degrees of freedom.

A null hypothesis tested here was that means, *i.e.*, average SR of levels in a factor were the same as each other. In Table 4, factors, the null hypothesis of which has been rejected at the level of significance of 0.05/0.01, are indicated by \* (0.05) /\*\* (0.01). Only the factor of target type had significant differences in SR among the levels, and it can be said that it is meaningful to discuss how the factor influences SR. On the other hand, there is no difference in SR for other factors of the soil, prodding angle, and applied force. This means that the prodder has little influence from those factors.



Figure 5. Average of success rate (SR) for discrimination for each factor with 95% and 99% confidence intervals.

#### 5. Conclusion

This paper proposed an active sensing prodder that uses a PZT actuator to make a buried target vibrate and an accelerometer to measure the returned acceleration. Although it is in an ideal condition (uniform soft soil and interior environment), evaluation results of experiments using a prototype of the active sensing prodder shows that success rate (SR) of landmine-like target discrimination was about 95%, and that of the other fragments such brasses and rocks was about 85% except for a wood piece and a small brass pipe. Another sensor will be needed to solve the problem for discriminating landmine-like targets from other fragments that have similar stiffness like wood piece.

Future work will be to make the system more easyto-use and to conduct more realistic evaluation tests such a field trial.

#### Acknowledgement

The authors would like to thank Croatian Mine Action Center - Center for Testing, Development and Training (CROMAC-CTDT) for supporting this research.

#### References

- [1] S. Bishop, J. Vignola, J. Judge, P. Tsopelas, A. Kurdila, "Direct mechanical landmine excitation with scanning laser Doppler vibrometer surface measurements," *Proc. of SPIE Vol. 6553, Detection and Remediation Technologies for Mines and Minelike Targets*, pp. 655304-1-655304-12, 2007.
- [2] Dimitri Donskoy, Alexander Ekimov, Nikolay Sedunov, and Mikhail Tsionskiy, "Nonlinear seismo-acoustic land mine detection and discrimination," *Journal of the Acoustical Society of America*, pp. 2705-2714, 2002.

- [3] Patrick J. Gallagher, "Characteristic Discriminating Landmine Hand Prodder," United States Patent, US Patent 5,754,494, 1998.
- [4] Michael A. Borza, Fabio G. DeWitt, "Acoustic Landmine Prodding Instrument with Force Feedback," *United States Patent*, US Patent 6,109,112, 2000.
- [5] Michal A. Borza, "Prodder with Force Feedback," United States Patent, US Patent 6,386,036, 2002.
- [6] J. Schoolderman, S. G. M. van Dijk, D. Deurloo, K. Russell, "Instrumented Prodder: Preliminary Results of the Technology Demonstrator Evaluation," Proc. of the International Conference on Requirements and Technologies for the Detection, Removal and Neutralization of Landmines and UXO, Volume 2, pp. 673-679, 2003.
- [7] J. Schoolderman, S. G. M. van Dijk, D. Deurloo, "Instrumented Prodder: results from the tests under controlled conditions," TNO *Report*, pp. 1-90, 2004.
- [8] Wolfgang Schade, Christian Bohling, Konrad Hohmann, and Dirk Scheel, "Laser-induced plasma spectroscopy for mine detection and verification," *Leaser and Particle Beams*, vol. 24, pp. 241-247, 2006.
- [9] Christian Bohling, Dirk Scheel, Konrad Hohmann, Wolfgang Schade, Matthias Reuter, and Gerhard Holl, "Fiber-optic laser sensor for mine detection and verification," *Journal of the Optical Society of America*, Vol. 45, No. 16, pp. 3817-3825, 2006.

J. Ishikawa and A. Iino, "A Study on Prodding Detection of Antipersonnel Landmine Using Active Sensing Prodder," *Book of Papers of the 7th International Symposium on Humanitarian Demining* 2010, pp. 15-23, 2010.

### Application of Advanced Intelligence Decision Support System in Croatia and Bosnia and Herzegovina gave new experience

Milan Bajić<sup>41</sup>, Davor Laura<sup>42</sup>

The Advanced Intelligence Decision Support System (AI DSS), mainly based on the aerial multisensory acquisition of images, [1], is in intensive use since 2008, first in Croatia, [2], later in Bosnia and Herzegovina, [3]. Application of AI DSS in Croatia resulted by reduction of mine suspected area and by inclusion of new area in the category mine suspected area, [2]. The operational requirements and the benefits achieved by application of AI DSS in Croatia and in Bosnia and Herzegovina are presented and discussed in [4], [5]. The AI DSS technology in Bosnia and Herzegovina introduced methodological advancements in comparison to the technology used in Croatia, [6], [7], follow short description of several of them.

#### Matching the aerial imagery acquisition to the terrain, the conflict lines and the indicators of mine presence

The objects on the terrain, the indicators of mine presence shall be detected, recognized and localized with high probability and the confidence. Therefore the spatial resolution (the ground resolving distance), should be adequate for aimed purpose, e.g. defined by Johnson criteria, [8], while the spatial coverage should be maximum. These two requirements are opposite and the fine matching is mandatory. The example of one very demanding example is shown at Fig.1 and Fig 2. The objects that should be detected are remains from war, built many years ago, and they are ruined, covered by vegetation, soil. Therefore, despite the 100 %coverage of the region of interest with aerial geotagged images, Fig. 3, only images that contain indicators of mine presence are geocoded, Fig. 4.



Figure 1. Aerial acquisition missions are matched to features of the terrain, to provide ground-resolving distance needed to reliably detect the indicators of the mine presence.



Figure 2. Example of the aerial routes over terrain from Fig.1, [3].

### Complementary data detected in satellite images, contextual information

The complementary data can be detected in the near infra red and visible satellite images, important example are paths, pathways, Fig. 5, and the clearings in forested area. The quality of the information contained in the minefield records is

<sup>&</sup>lt;sup>41</sup> Milan Bajić, Prof. PhD, Faculty of Geodesy, University of Zagreb and Scientific Council of CROMAC Centre for Testing, Development and Training Ltd., Zagreb, Croatia; E-mail: milan.bajic@zg.t-com.hr

<sup>&</sup>lt;sup>42</sup> Davor Laura, Assistant Director, CROMAC, Sisak, Croatia, E-mail: davor.laura@hcr.hr



Figure 3. Positions of raw aerial images of the whole region near Bihać. Selected image can be shown by activating the icon on digital map



Figure 4. The geocoded aerial images that contain indicators of mine presence in the region near Bihać.



Figure 5. Forest paths of the region near Bihać, deteced on the satellite Ikonos2 color infra red images.



Figure 6. The additional contextual information increases the understanding of the mine suspected area and can partially compensate the lack of the information from mine field records.

generally low. For example, for region of Bihać, the positions of the landmines and the explosive obstacles are not known in 81 % cases, whereas the average accuracy of the positioning is only 40 %. The contextual information, which could exist or can be acquired in Regional MAC offices, can partially compensate lack of information from minefield records, Fig. 6.

# The aerial images of the indicators of mine presence, operational and static resolution

The aerial images acquired under optimum condition provide excellent data about the indicators of mine presence; see examples at Fig. 7 and Fig. 8. The vibration and the movement of the helicopter do blur the images.

The spatial resolution of the dynamic (moving) imaging system is coarser than the resolution of the sensor (camera) itself in static conditions on the ground. The consequence is a great loss of the



Figure 7. The system of old bunkers, trenches and new shelters in a rocky terrain of the mountain Velež, near Mostar, Bosnia and Herzegovina.



Figure 8. The trenches at the edges of the forest in the mine suspected area near Bihać, Bosnia and Herzegovina, detected on the aerial image acquired in 2010.

operational potential for detection of the small objects, the indicators of mine presence. The vibrations were thoroughly researched and passive dumping was developed and applied, Fig. 9, Fig. 10, [6]. The measurements start at A (helicopter on the ground, engines not active). In B are activated the engines, in C main blades started rotation, in D engines in full power, in E helicopter starts the hovering and in F starts the flight.



Figure 9. Measurement of the accelerations on axis X, Y, Z.



Figure 10. The passive dumping of the vibrations by the spiral wire rope isolators.

The significant improvement of the acquired aerial images was achieved by passive dumping of the vibrations. For color camera Nikon D90 the initial coarsening of the spatial resolution was 120 %, after the passive vibrations' dumping it decreases to 34 %. The multispectral camera MS-4100 shows much better behavior.



Image no dumping of vibration.



Image no dumping of vibration. Zoomed 9x.



Passive dumping of

vibration.

Passive dumping of vibration. Zoomed 9x.

Figure 11. Passive dumping of the vibration increases the quality of the aerial images.

#### **Operational calibration**

The calibration of the aerial acquisition system is standard task in the preparations for the acquisition flight. For this purpose were used designed and produced different test bars from 2008. to 2010. The limitations of such calibration forced us to introduce new calibration procedure, a slanted – edge modulation transfer function analysis, which also uses real objects whose images are acquired from the air, [9]. This calibration procedure enables to assess the obtained spatial resolution and to govern the flight altitude over the mine suspected area. It was used in Bosnia and Herzegovina in November 2011 and will be used in next AI DSS operations.

#### Conclusion

The AI DSS technology was advanced in many aspects, several of them were considered in this paper. Further advancements are expected, being driven by the future operations.

#### References

[1] Bajić M., Gold H., Fiedler T., Gajski D., 2008. Development of a concept from 1998 and realization of the system for the airborne multi-

sensor reconnaissance and surveillance in crisis situations and the protection of the environment in 2007 – 2008, Proceedings of the First International Conference on Remote Sensing Techniques in Disaster Management and Emergency Response in the Mediterranean Region, Zadar, Croatia 22-24, Sept. 2008, ed. M. Oulić, EARSeL, pp.401-410.

- [2] Bajić M., Krtalić A., Gold H., Matić Č., Čanđar Z., Pavković N., 2009. Deployment of the Decision Support System for Mine Suspected Area Reduction Final Report 2009, V2.0.0, ITF, CTRO, 12.09.2010, 61 P. Restricted to ITF, HCR CTDT, CROMAC.
- [3] ITF, 2009. Deployment of the Decision Support System for Mine Suspected Area Reduction in Bosnia and Herzegovina, Description of Project Version 0.0.1, April 2009., Submitted to US Department of State Bureau of Political-Military Affairs Office of Weapons Removal and Abatement, Project Category: "Fusing Data" – Impact-Survey, Impact Surveillance, Land Release, and National Planning, Submitted by: International Trust Fund for Demining and Mine Victims Assistance (ITF) Zabrv 12, 1292 Ig, Slovenija. Restricted to ITF, CTRO.
- [4] Bajić M., 2010. The advanced intelligence decision support system for the assessment of mine suspected areas, Journal of ERW and Mine Action, James Madison University, Issue 14.3, Fall 2010, Available: 1.03.2011, URL: http://maic. jmu.edu/journal/14.3/r d/bajic/bajic.htm
- [5] Bajić M., Turšič R., 2010. Operations with Advanced Intelligence Decision Support System for Mine Suspected Area assessment in Croatia and Bosnia and Herzegovina, UNMAS GCIHD Workshop "Merging Mine Action Technology and Methodology", GICHD, Ženeva; 6-8.09.2010. Available 1.03.2011, URL: http://www.gichd.org/fileadmin/pdf/technology/Technology-Workshop-2010/C-6Sept2010-SMART-TechWS.pdf
- [6] Bajić M., Kičinbači T., Ćosović Bajić S., 2009. Passive dumping of sensors pod vibration (Pasivno prigušenje vibracija senzorskog kontejnera). Deliverable for [3], Zagreb, 20.12.2009. Restricted to ITF, CTRO.
- [7] Bajić M. (Editor), Matić Č., Krtalić A., Čanđar Z., Vuletić D., 2011. Research of the mine suspected area, Publisher CROMAC - CTDT Ltd., ISBN 978-953-99879-7-6. Zagreb, April 2011.
- [8] Holst, G.C., 1996., CCD arrays, cameras and displays, JCD Publishing and SPIE Optical Engineering Press, pp.317-319.
- [9] Ciceli T., 2010. Kalibracija sustava. Deliverable for [3], Zagreb, 30.11.2010. Restricted to ITF, CTRO.

#### Calibration of an Electro-Optical System for the Airborne Remote Sensing of the Mine Suspected Areas

Tomislav Ciceli<sup>43</sup>, Milan Bajić<sup>44</sup>

The airborne multisensory images acquisition of the Advanced Intelligence Decision Support System (AIDSS) is in the intensive operational use. It is applied over the mine suspected areas (MSA) in Croatia, in Bosnia and Herzegovina, and a design of the similar system for Colombia is under way. The aim of the AIDSS is to detect the indicators of mine presence (IMP), the indicators of mine absence (IMA). Among the IMPs the most important are remnants of war which enable reconstruction of the former position of the warring units, the front lines and the separation zone between them. The object presenting IMPs shall be reliably detected, with high probability, but they are old, ruined and often obscured and overshadowed by the vegetation, and it is in general very difficult to perceive, detect and localize them. Therefore the electro optical airborne acquisition system shall have excellent operational parameters and the operational calibration of the most important features is mandatory. In the paper we present results of the calibration of the spatial and radiometric parameters for visible and near infrared images. Calibration of Nikon D90 and MS4100 was done. Modulation transfer function (MTF) was measured according to ISO 12233 standard using slant-edge function on special designed target, but also on the real objects on image. Line spread function and edge spread function for cameras were also derived. Calibration was made in static conditions, but also in dynamic conditions, on the flight. Radiometric properties of cameras were derived using Spectralon Multi-Step Target also in static and dynamic conditions.

#### Introduction

For the purposes of project<sup>45</sup> an airborne multisensory system, called the Advanced Intelligence Decision

Support System (AIDSS), was developed and realized. It is applied over the mine suspected areas (MSA) in Croatia, in Bosnia and Herzegovina, and a design of the similar system for Colombia is under way. The aim of the AIDSS is to detect the indicators of mine presence (IMP), and the indicators of mine absence (IMA). Its can also be used to provide the airborne civil service of the reconnaissance and the surveillance in the crises and the protection of environment.

This is a multipurpose airborne remote sensing system based on integration of several stand-alone sensors. Besides its primary role in application over the mine suspected areas and reconnaissance and the surveillance, it will also serve as the laboratory for the research in different scientific disciplines too.



Figure 1: The airborne multisensory images acquisition of the Advanced Intelligence Decision Support System (AIDSS)

Following sensors are applied in the system: the hyperspectral line scanner V9 that can work in the sampling or in the imaging mode; the multispectral camera MS-4100; 3) the long wave infrared (thermal) camera Photon; the digital video color camera Sony FCB-IX11AP; the digital photo colour camera Nikon D90.

On the Fig. 1 position of Nikon D90 and MS 4100 is pointed. The hyperspectral scanner V9 covers up to forty-five channels and the multispectral camera MS-4100 covers four channels in the visible and the near infrared wavelengths. Thermovision camera Photon works in the longwave infrared range from 7.5 to  $13.5 \,\mu$ m. Other two sensors cover red, green and blue channels in the visible wavelengths.

<sup>&</sup>lt;sup>43</sup> Mr.Sc. Tomislav Ciceli, State Geodetic Administration, Croatia, E-mail: tomislav.ciceli@dgu.hr,

<sup>&</sup>lt;sup>44</sup> Milan Bajić, Prof. PhD, Faculty of Geodesy, University of Zagreb, Croatia, E-mail: milan.bajic@zg.t-com.hr

<sup>&</sup>lt;sup>45</sup> "System for the multisensor airborne reconnaissance and surveillance in the crisis situations and the protection of environment", TP-06/0007-01, supported by the Ministry of science, education and sports, of the Republic of Croatia.



"controlled conditions"

**Data collection** 





Figure 2: Images collected in different conditions

For the purposes of calibration data was collected during the flight and on the ground (Fig.2). The flight data was captured in;

- So called controlled conditions. Data was collected on the airport, during the flight from different height : 100m, 200m up to 1000m.
- During the operational use of system, directly on the field.

#### Calibration

On the AIDSS two cameras where calibrated; Nikon D90 and multispectral camera MS-4100. For the purposes of calibration Modulation transfer function (MTF) was derived for both camera and radiometric properties where also defined during the process of calibration.

#### Modulation Transfer Function (MTF)

The perceived quality on imprinted or screen observed an image is dependable on two basic components: resolution and contrast (Williams, 1990). The measure of the image contrast modulation as a function of the input signal frequency, results in MTF of the lens, sensor or system.

The MTF describes the image structure as a function of its spatial frequencies, most commonly produced by Fourier transforming the image spatial resolution of spread function.

There are different procedures to determine MTF of system. All of them must ensure [URL1]:

- a test target containing frequency components beyond the system resolving power; this procedure supplies the ability to detect the response extinction or the false responses due to the presence of signal aliasing.
- the test target must be able to be positioned at different working distances provided the optical response is influenced by the object distance.
- the test must be dimensioned in size to be suitably positioned on the object field region corresponding with the image field area to be analysed.

For the purposes of deriving MTF for selected cameras of ADSS we used slanted edge methodology implemented in ISO 12233 standards.

### Slanted edge MTF according to ISO 12233 standard

Slanted-edge method consists in imaging an edge onto the detector, slightly tilted with regard to the rows. Fig 3. For that purposes target was made, with angle of 5°, according to ISO 12233 standard like it can be seen od Fig 2.



Figure 3. Projection of data alonge the edge

The profile of an edge in an image is called the Edge Spread Function (ESF). Differentiation of the ESF results in a one-dimensional version of the Point Spread Function (PSF). Finally, MTF iscalculated by taking the Fourier transform of the PSF (Fig. 4). MTF was also derived from natural objects, roof of houses, during the operational use of ADSS.



Figure 4. Deriving MTF from edge target



Figure 7. ESF, LSF and MTF of Nikon D90 during the flight of 500m above target

#### Nikon D90

For the purposes of deriving MTF data was collected during the flight, in dynamic conditions and in static conditions on the ground. During the flight system for vibration compensation was also turned on and off. On the left part of images ESF and PSF are shown, while on the right side MTF is shown, for all three RGB channels. MTF was derived from target shown on Fig. 2.

#### Static conditions

On Fig. 5 results in static conditions, taken from ground, can bee seen. Images where taken while ADSS was taken off the helicopter.

#### Dynamic conditions

For derivation of MTF in dynamic conditions, set of images was taken during the flight, from different height above the ground. Results for images taken in so called *controlled* conditions over the airport can be seen on the figures 6 and 7.

#### **Operational use**

During the operational use, images of the roof edges where taken for calculation of slant edge MTF. During that flight in one case system for vibration compesation was turned on, and in another was turned off. Results can be seen on images 7 and 8. It is clear that results on Fig. 7 shows us that ESF and LSF of camera are muc closer to ideal one, than results shown on Fig. 8. Conslusion is that for achiving maximum results system for compesation must be active.

#### MS 4100

For multispectral camera MS 4100 MTF was also derived in the following conditions; Static and Dynamic conditions.



Figure 8. ESF, LSF and MTF of Nikon D90 during the flight of 100m above target with active system for vibration compensation



Figure 8. ESF, LSF and MTF of Nikon D90 during the flight of 100m above target with pasive system for vibration compensation

#### Static conditions

Resoults can be seen on figures above.





Dynamic conditions



Figure 10. ESF, LSF and MTF of MS 4100 during the flight of 100m above target



Figure 11. ESF, LSF and MTF of MS 4100 during the flight of 200m above target

From images above, few general conlusions can be made. Nikon D90 produces images that are in all three chanells very similar. Main reason lies in the fact that camera is based on one CMOS Bayer filter. For camera MS 4100 we could not say the same. Prof for that statement lies in Fig. 5 (Nikon D90) and Fig. 9. (MS 4100). We must say that difernces in the chanells for both camera arise during the operational use (flight).

#### Radiometric properties of cameras

During the process of calibration, radiometric propreties of camera where also defined. Radiometric properties of an imaging system describe how the system responds to varios input radiance levels. For the purposes of radiometric calibration Labsphere Spectralon Target SRT-MS-180, with reflectance values 99%, 50%, 25% and 12%. Target is shown on Fig. 12.



Figura 12. Labsphere Spectralon Target SRT-MS-180

Calibration was done also in static, on the ground, and in dynamic conditions, during the flight over the airport.

#### Nikon D90

Results for Nikon D90 can be seen on figures 13 and 14, for red, green and blue channel separately.







Figure 14. Nikon D90 radiometric propreties in dynamic conditions

#### MS 4100

Results for MS 4100, for 750 nm, 650 and 550 nm separately.



Figure 15. MS4100 radiometric propreties in static conditions



Figure 16. MS4100 radiometric propreties in dynamic conditions

From results, we can see that Nikon D90 is behaving almost the same in no matter what conditions, but multispectral camera has some differences in radiometric response in static and dynamic conditions. Our assumption is that main reason for that lies in camera construction, which is based on three sensors, and prism beam splitter like it can be seen on Fig 17.



Figure 17. Main diference in color registration; left MS 4100, right Nikon D90

#### Conclusion

For the purposes of operational use of the ADSS calibration for two sensors, digital camera Nikon D90 and multispectral camera by Geospatial system (Duncantech) was made. Cameras where calibrated in dynamic and static conditions. For the purposes of deriving MTF during the operational use method according to the ISO 12233 standard give us new possibilities, and we can say that is ideal way of calibration on the filed without any man made targets.

Calibration also proved usage of vibration compensation system.

For the purposes of knowing the limits of our system, collecting data in every new mission is mandatory.

#### References

Williams, J.B. (1990) Image Clarity, High-Resolution Photography. Focal Press. Boston, London.

ISO 12233:2000: Photography -- Electronic still-picture cameras -- Resolution measurements

M.Estribeau, P.Magnan (2004): Fast MTF measurement of CMOS imagers using ISO 12233 slantededge methodology, "Proceedings of SPIE - Volume 5251 - Detectors and Associated Signal Processing",

[URL 1] M. Carles (2011): Image Quality of Photographic Cameras

http://cmitja.wordpress.com/2011/02/06/imagequality-of-photographic-cameras/

#### Line Indicators of Mine Muspected Areas in E-SAR<sup>46</sup> Images

Antonela Marinov<sup>47</sup>, Milan Bajic<sup>48</sup>

#### Summary

Line objects can be very good indicators of mine suspected areas, especially if they are placed near the separation zone between warring parties. In this paper, the subjective interpretation of polarimetric radar data belonging to mine indicators is described. In general, different polarization channels of the same radar frequency band give complementary information about the scene. For several line objects, confirmed as mine indicators by ground truth, the contribution of different L-band polarization channels here is explained.

#### 1. Introduction

Trying to find possible mine indicators in the radar image of the mine polluted terrain (here E-SAR amplitude data collected during E-SAR flight campaign above trully mined areas in the Republic of Croatia, project SMART<sup>49</sup>), in this work the beforehand knowledge (topographic and geocoded ortophoto maps, data from croatian mine infomation system, data from ground truth campaign and classified multichannel Daedalus<sup>50</sup> images) about the scene are exploited.

The most visible objects in radar images, that could indicate potentionally mine suspected area are line objects: trenches, man-made embankments, tracks no longer in use and partially used ones, irrigation channels, low stone walls etc. The visibility of line objects in the radar image depends on the flight direction, the radar frequency band and the type

<sup>48</sup> Milan Bajić, Prof. PhD, Faculty of Geodesy, University of Zagreb, Croatia, E-mail: milan.bajic@zg.t-com.hr of polarization channel (the transceivening antenna pair: HH, HV, VH, VV). Here, the contribution of all mentioned factors are demonstrated and explained.

### 2. Different polarization channels contribution

In the domain of the radar backscatter, line objects as trenches, man-made embankments and low stone walls have very similar characteristic. In the co-polarisation channels (primarily HH) they are the best seen if they are running parallel to the flight direction (double bounce scattering) and almost invisible (if vegetation content is not present) when they are running normal to the flight direction. In cross-polarisation channels they are well percieved if they are laying under angle of 45° to the flight direction (H-component is coming back like V-component and vice versa). Trenches are showed on the figure 1. Examples of low stone walls are showed on the figures 2a and 2b. Manmade embankments are well discernible at the open area, see figure 3.



Figure 1: Trenches in the geocoded colour-composite of different L-band polarisation channels (red: HH, green: HV, blue: VV) in the Ceretinci test site. Trenches are running almost paralell with the flight direction.

<sup>&</sup>lt;sup>46</sup> Experimental Syinthetic Aperture Radar - german fully polarimetric airborne SAR system for remote sensing in the P (0.45 GHz), L (1,3 GHz), C (5,3 GHz) and X (9,6 GHz) band

<sup>&</sup>lt;sup>47</sup> Antonela Marinov, mr.sc., Flying officer, Major, Croatian Navy, Croatian Coast Guard, Headquarter, E-mail: antonela. marinov@morh.hr

<sup>&</sup>lt;sup>49</sup> Space and airborne Mined Area Reduction Tools - EC project for improving general survey of the mine suspected area in South Eastern Europe, Contract No. IST-2000-25044

<sup>&</sup>lt;sup>50</sup> German airborne hyperspectral (12 channels) scanner for remote sensing





b)

Figure 2: Low stone walls in the geocoded colour-composite of different L-band polarisation channels (red: HH, green: HV, blue: VV) in the (a) Glinska poljana and (b) Pristeg test site. Walls are outlining in red colour (double bounce scattering is dominating). Pure hedges are outlining in green colour (volumetric scattering is dominating). On both images walls are running almost paralell with the flight direction.

In reality, trenches and low stone walls are covered with hedges and schrubs, that sometimes makes difficulties in their discrimination from the pure bush vegetation, which have the strong radar echo in all polarisation channels. Similarly, when a trench or wall has no steep slopes, the main part of the electromagnetic energy is scattered back to the sensor by the single bounce scattering from the surface of the wall/trench slope, showing similar characteristic like other more or less sloping smooth surfaces.

Tracks no longer in use or partially used ones are covered with vegetation in some parts, therefore they become less or not visible as dark lines in the radar image, see figure 4. In the Pristeg region tracks and paths no longer in use usually intersect roads of more significance and after that end in the bush or in the forest vegetation, see figure 3.



Figure 3: Man-made embankment (irregular white line) at the former Serbs deffence position (Pristeg test site) in the geocoded colour-composite of different L-band polarisation channels (red: HH, green: HV, blue: VV). The main path (dark line) parallel with the embankment was demined after the flight mission. Other paths of less importance are not demined and are disappearing in vegetation. Flight direction was approximately from the bottom left to the upper right corner of the image.

Irrigation channels intersects the whole agricultural part of the Ceretinci test site. Some of them are without significant vegetation content (channels in use) but most of them are covered with bushes (channels probably out of use, i.e. mine suspected), that is evident in cross-polarisation channels (like green parallel lines), see figure 5.

#### 3. Conclusion

By the visual inspection of radar images it is possible to fortify various categories of line objects that could indicate the mine suspected area, especially in cases where these line objects are surrounded with unused area (in polarimetric radar imagery also good discernible from areas in use, like agricultural plots, but not examined here). In general, the presence of some line indicators does not mean that the given area is really mine suspected. If this presence is registered in the separation zone between warring parties, on the land cultivated intensively before the war (now unused area or abandoned land), the assumption that this land is mine suspected or even mined is more justified.



b)

Figure 4: Tracks (paths) partially in/out of use in the geocoded colour-composite of different L-band polarisation channels (red: HH, green: HV, blue: VV): a) Glinska poljana test site - the track (black line) coming from the left is not visible after some time, e.i. ends in vegetation; flight direction was approximately from the bottom to the top side of the image; b) Ceretinci test site - path out of use is covered with vegetation along both sides (green echo); flight direction was approximately from the left to the right side of the image.

Figure 5: Irrigation channel (parallel green lines) covered with bush vegetation (Ceretinci test site) in the geocoded colour-composite of different L-band polarisation channels (red: HH, green: HV, blue: VV); flight direction was approximately from the left to the right side of the image.

#### 4. References

- [Hellmann2000] Hellmann, M., 2000., Classification of Fully Polarimetric SAR-Data for Cartographic Applications, PhD Thesis, Deutsches Zentrum für Luft- und Raumfahrt e.V., Institute of Radio Frequency Technology Oberpfaffenhofen, 2000.
- [SMART2002] Keller, M., Milisavljević, N., Suess, H., Acheroy, M., 2002., Reduction of mine suspected areas by multinsensor airborne measurements – first results, SPIE, 2002.
- [SMART2002] SMART, 2002, Tables of minefield indicators and locations, last updated at 13.02.2002., http://www. smart.rma.ac.be/Project Overview. htm
- [SMART2003] Marinov, A., 2003., Subjective interpretation of ESAR images in test sites Glinska Poljana, Pristeg and Ceretinci, Part of Expert Knowledge Information Report, Project SMART, March 2003.
- [Yvinec2003] Yvinec, Y., Borgis, D., Acheroy, M., Suess, H., Keller, M., Bajic, M., Wolf, E., Vanhuysse, S., Bloch, Yu, Y., Damanet, O., 2003., SMART: Space and airborne mined area reduction tools – Presentation, Proceedings EUDEM2-SCOT – 2003, International conference on requirements and technologies for the detection, removal, and neutralization of landmines and UXO, 15-18 September 2003, VUB Brussel, Brussels, Belgium, pp.595-602.

#### Parametric Geocoding of the Aerial Hyperspectral Images of the Mine Suspected Area in Mountainous Terrain

Tamara Ivelja<sup>51</sup>, Milan Bajić<sup>52</sup>

Since the year 2001. we have used the airborne hyperspectral *line scanner*, [1], which was advanced in 2008. into *imaging hyperspectral sensor system* (up to 95 channels, from 430 to 900 nm), [2], Fig. 1. From 2008. the imaging hyperspectral sensor system, together with several other digital electro optical sensors was applied in airborne remote sensing projects: a) the detection and mapping of the Adriatic sea pollution by ship sourced oil (2008.), [3], [4]; aerial acquisition of the multisensor imagery over the mine suspected areas b) in Croatia (2009.) and c) in Bosnia and Herzegovina (2010.), [5].

The processing, interpretation and delivery of the results of the hyperspectral data collected over the sea surface (flat) was developed, evaluated and operationally validated, [4]. The hyperspectral data collected in b) and c) should advance the assessment of the mine suspected area by provision of the imagesin a multitude of spectral channels. The problem arose at the mountainous and hilly terrain where the needed spatial accuracy and precision was not achieved by use of parametric geocoding based on the positioning system [2], and the software PARGE [6]. Utilization of this remote sensing potential was limited due to very large deviation of the helicopter route from the stright line and due to the random variations caused by the vibrations. The next source of difficulties is very variable relief of the terrain where aerial acquisition was done. The spatial accuracy and precision of the hyperspectral images can be increased by use of the ground control points (GCP) in the parametric geocoding process, [7]. This was tested at the flat test field, where the positions of the GCPs were known in cm range. Increase of the relative accuracy was around 10 times, the conditions were ideal. Such

<sup>51</sup> Tamara Ivelja, Bachelor in geodetic and geoinformatics engineering, Faculty of Geodesy, University of Zagreb, Croatia, E-mail: tamara.ivelja@gmail.com



Figure 1. The multisensor remote sensing system used on the helicopter Mi-8.



Figure 2. The pod below the fuselage contains the electro – optical sensors and the inertial measuring unit, [3].

ideal circumstances are not feasible in the mine suspected area. Therefore we are forced to seek other solution for the GCPs. An intensive analysis and investigation of the measures and the procedures is under way, it is aimed to collect experience about the achievable spatial accuracy and precision of the hyperspectral images at the mountainous and hilly terrain. The influence of different parameters on the spatial accuracy and precision of the hyperspectral images is analysed as well as the possibility

<sup>&</sup>lt;sup>52</sup> Milan Bajić, Prof. PhD, Faculty of Geodesy University of Zagreb and Scientific Council of CROMAC-Centre for Testing, Development and Training Ltd., Zagreb, Croatia, milan.bajic@zg.t-com.hr

of their control. In the paper is reported the main achievement for the used system [2], the increased spatial accuracy and precision based on the GCP's derived from the digital ortho photo map.

#### Geocoding of the hyper spectral cube to digital ortho photo map or a satellite image

Parametric geocoding is the procedure of the projecting the images data onto correct geographic positions, [6].

Several different parameters are used in this geometrical transformation. The geographical coordinates, flight angle parameters (roll, pitch and yaw) and altitude over the terrain are used in this transformation. The external orientiring elements are provided by the Inertial Navigational System (attitude) and location is provided by the GPS receiver, [2]. The crucial problem is how to synchronize considered data and the data provided by the hyperspectral line scanner.

#### The influencing parameters

The spatial accuracy and the precision of the aerial measurements or imaging depends on various parameters.

Dynamics of the aerial platform movement has the strongest influence on the quality of the acquired images. The aerial platforms often limit the productivity of the electro – optical sensors by spatial dispersion of the data or by decrease of the aeria coverage. The real causes are influence of the meteorogical conditions, wind, precison of the guidance, navigation and control.

#### The problem and a solution

The former analysis based on the aerial hyperspectral data and ground control points (GCP) measured 2008. at the calibration test site in Pula (Croatia) shows exellent results. The root mean square error 0.62 m was obtained for hyperspectral image, while the GCP were measured by centimeter accuracy. Starting by this fact, the problem was defined: is it possible to achieve similar accuracy if the GCPs are collected from the digital orthophoto map while the ground based measurements of the GCP is not possible (mine suspected area)? For analysis was used set of data collected 2009. on the mountainous terrain near Gospić (Croatia), Fig. 3, Fig. 4. The GCP coordinates were measured on the digital orthophoto map and not on the ground, the achieved spatial accuracy was around two pixels (1.82 m) while the root-mean-square error was 0.63 m. The corresponding hyperspectral cube parametrically geocoded and the cube additionally geocoded by use of GCPs are shown at Fig. 5 and Fig. 6.



Figure 3. Strips of the aerially acquired hyperspectral data shown on the digital elevation model of terrain (DEM).



Figure 4. The selected part of the aerial route.

The images Fig. 5 and Fig. 6 are visualised in the color infrared combination (red – presents near infrared, green – presents red, blue – presents green). The areas of the forest are shown in pink, while the forest clearings, rocky terrain and forest roads are shown in other colors. From the Fig. 5 is visible that forest covers most of the area and the number of geometrically well defined objects is small. Due to this fact, only five GCPs were identified on the hyperspectral cube. The another limitation was applied in the additional geocoding by GCPs. The digital elevation model is needed for the parametrical geocoding of the hyperspectral images. In the



Figure 5. The hyperspectral cube that was only parametrically geocoded. The dots in the strip are locations given by GPS.



Figure 6. The northern-western part of the hyperspectral cube from Fig. 3, after the additional geocoding by GCPs.

considered case was used very coarse approximation of the digital elevation model, the mean value of the terrain was used (flat plane approximation). After the definition of the GCPs follows the calibration - iterative decreasing of the root mean square (RMS) errors between the offset attitude and offset GPS position data . This process is performed iteratively with intention of decreasing RMS Errors (both for attitude and position). When these offsets are efficiently optimized, next step is final geocoding procedure. With this procedure succesfully finished, we can read the coordinates of the GCPs from the geocoded image. These coordinates were used for the calculation of the coordinate differences shown in Tab. 1 and the statistical moments shown in Tab. 2.

Table 1. Coordinate differences  $\Delta_y$ ,  $\Delta_x$  of GCP and hyperspectral cube before and after the calibration

	Coordinate differences					
	Before ca	alibration	After calibration			
GCP	$\Delta_y$ [m]	$\Delta_{x}$ [m]	$\Delta_y$ [m]	$\Delta_x$ [m]		
1	36,31	11,04	-3,99	-8,56		
2	34,89	25,19	-2,11	-7,01		
3	41,23	31,29	1,73	10,29		
4	43,47	22,07	5,07	-0,43		
5	33,69	33,31	-4,51	7,11		
$n_y, n_x$	37,92	24,58	-0,76	0,28		

Table 2. Standard deviations  $\Delta_x$ ,  $\Delta_y$  on coordinate axes y, x, RMS position errors  $m_x$ ,  $m_y$ , on coordinate axes y, x, and planar  $m_p$ 

	Before calibration	After calibration
$\sigma_{y}[m]$	4,23	8,82
$\sigma_{\rm x}[{\rm m}]$	4,08	8,35
m <sub>y</sub> [m]	84,79	1,70
m <sub>x</sub> [m]	54,96	0,63
$m_p[m]$	101,04	1,82



$n_{y}(n_{x}) = \frac{\sum_{i=1}^{n} \Delta y_{i}}{n}$ coord. differences mean	$\sigma_{y}(\sigma_{x}) = \sqrt{\frac{\sum_{i=1}^{n} (v_{y_{i}})^{2}}{n-1}}$ standart deviation of coord. axses
$m_{y}(m_{x}) = \pm \sqrt{\frac{\sum_{i=1}^{n} (v_{y_{i}})^{2}}{n}}$ <i>RMS error of coord. axses</i>	$m_p = \pm \sqrt{m_x^2 + m_y^2}$ RMS position error

#### Conclusion

The additional geocoding by GCPs provided a great improvement of spatial accuracy. Before the calibration the planar RMS error was 101.04, while after the additional geocoding with GCPs the error decreased to 1.82.

The performed analysis confirmed assumption that the additional geocoding by GCPs extracted at the digital orthophoto maps can improve spatial accuracy and precision of the hyperspectral cube. This fact enables intensive application of the hyperspectral images for humanitarian mine action.

#### References

- [1] M. Bajić, H. Gold, Z. Pračić, D. Vuletić, 2004, Airborne sampling of the reflectivity by the hyper spectral line scanner in a visible and near infrared bands, Proceedings of the 24th EARSeL Symposium, New Strategies for European Remote Sensing, Dubrovnik, Croatia, 25 – 27 May 2004, Millpress, Rotterdam, 2005, pp. 703-710.
- [2] S. Šemanjski, D. Gajski, 2008. Positioning and parametric geocoding subsystem, Deliver-

able for "System for the multisensor airborne reconnaissance and surveillance In the crises situations and the protection of environment", Faculty of Geodesy University of Zagreb, Technology project TP-006/0007-01, supported by the Ministry of science, education and sports, of the Republic of Croatia, Zagreb, 2007. - 2008. (in Croatian).

- M. Bajić, 2008. Technological project multisensor airborne surveillance systems, CleanSeaNet Info Day, Ministry of the Sea, Transport and infrastructure of the Republic of Croatia, EMSA European Maritime Safety Agency, Zagreb, September 8., 2008., (in Croatian), <u>www.mmpi.hr/UserDocsImages/080908-bajic.pdf</u>
- [4] Faculty of Geodesy, 2008., Results of the exercise on the integration of the satellite radar surveillance and the airborne multisensor measurements of the Adriatic sea pollution by oil, acquisition of the evidences, Operational – technical report, V1.0.0, 8.11.2008, Faculty of Geodesy University of Zagreb. Supported by Ministry Sea, Transportation and Infrastructure of the Republic of Croatia, Croatian Air Forces. (in Croatian).
- [5] M. Bajić, 2010. The advanced intelligence decision support system for the assessment of mine suspected areas, Journal of ERW and Mine Action, James Madison University, Issue 14.3, Fall 2010, Available: 1.03.2011, URL: <u>http://maic.jmu.edu/journal/14.3/r\_d/bajic/bajic.htm</u>
- [6] ReSe, RSL, PARGE User Manual, Version 2.3, Manual for the software PARGE.
- [7] D. Schlaepfer, M. E. Schaepman, K. I. Iten, PARGE: Parametric Geocoding Based on GCP-Calibrated Auxiliary Data, Imaging Spectrometry IV, San Diego, 1998, SPIE 3438:334-344.

## IARP HUDEM'2011 WORKSHOP

#### **E-training in robot application**

Andrzej Kaczmarczyk<sup>53</sup>, Marek Kacprzak<sup>54</sup>, Andrzej Masłowski<sup>55</sup>

**Abstract.** A concept of multi-level e-training of operators of mobile robots is presented in the article. This primeval concept is confronted with expectations of mobile robots users in Poland, and resulting solutions, introduced into practical testing, are described.

#### 1. Introduction

E-training, i.e. computer-network-based obtaining of operation skills, is an extension of e-learning that consists in obtaining of knowledge. Computer simulation with use of 3D graphics, computer games technology, as well as 3D Internet, are the means to develop an efficient e-training methodology and applications. In the same way as e-learning, e-training offers the possibility to serve large number of geographically dispersed learners via self-paced courses accessible 24 hours a day. Trainers-simulators having their applications in such areas as aviation, rail and road transport, heavy equipment operation, were an initial base for etraining development. But the means of e-training for use in robotics can't be any simple completion of this line of trainer-simulators. Earlier, trainers were dedicated to training of rather limited groups of highly professional staff. In contemporary robotics, robots more and more frequently are used by users of different levels of technical and intellectual skills, from advanced professionals to the everyday-world-users, including disabled persons and children. Because of intensive development of service robotics, the problem of robots' users training can reach the size comparable with problem of training of users of PCs after their wide spreading in 1980s. But robots are incomparably more diversified – both in respect of their functions and design - than PCs. So, one can expect a demand for diversified, individually-tailored trainer-simulators for robot users training.

#### 2. Training methodology

In the above mentioned project related to e-training of operators of robots, firstly general, speculative training methodology was worked out, then faced up to users expectations, and finally adapted to real needs.

#### 2.1. General methodology

For general methodology it has been assumed that the training should be multi-level, with introductory use of simplest and not so costly trainers, and at next levels more and more complex ones, closing to real robot operation. Moreover, trainers should enable to conduct an intelligent training, it means such training in which obtaining and perfection of operation abilities is adjusted to individual capabilities of trainees. A system of certification of operators' skills should be combined with the training system. General methodology has been described by characterization of aims of the training, applied technical means, concerning curriculum, and methods of evaluation of acquired skills together with issuing certificates.

Aims of the training:

- Acquainting with the robot with operator's interface, modes of work, functions.
- Training in observation tasks in operation of the robot's camera and other observational sensors, observation in conditions of disturbance, interpretation of results.
- Training in robot driving driving with immediate observation of the robot and with robot's camera view only, use of manual and autopilot control.
- Training in operation of robot's manipulator

   moving the manipulator while robot is motionless, with immediate observation and with robot's camera view only, operation of the manipulator while robot driving, programming of the manipulator.
- Training in performing of robot's missions typical for a given user, according to consecutive scenarios of progressive complexity, taking into

<sup>&</sup>lt;sup>53</sup> akamar@imm.org.pl; Institute of Mathematical Machines, Warsaw, Poland

<sup>&</sup>lt;sup>54</sup> makac@imm.org.pl, Institute of Mathematical Machines, Warsaw, Poland

<sup>&</sup>lt;sup>55</sup> a.maslowski@imm.org.pl, Institute of Mathematical Machines, Warsaw, Poland

consideration disturbances, robot failures, and time limits.

Technical means for training:

- Level 1 trainers built with use of typical PCs, performing simulation of the environment, of the robot, and of its control console. Trainer's utilization possible in electronic class, as well as for e-training in private or public net.
- Level 2 ditto, but with use of real control console of the robot; higher perfection of simulation.
- Level 3 training with application of AR technology real robot in the real environment with simulated elements added. A trainee uses special helmet.

Curriculum:

- Phase 1 -acquaintance with the robot by demonstration of the real robot and introductory class with instructor.
- Phase 2 -individual e-training on the Level-1-Trainer in observation, driving, operation of robot's manipulator, and performing of basic missions. After obtaining prescribed score going on to the next phase of training.
- Phase 3 -test in the electronic class with instructor.
- Phase 4 -individual e-training on the Level-2-Trainer within the same scope as in the case of the Level-1-Trainer, but with inclusion of much complex missions, dedicated to the concrete user needs, with inclusion of disturbances and robot failures. After obtaining prescribed score going on to the next phase of training.
- Phase 5 training on the Level-3-Trainer, consisting in performances of missions with use of real robot in the real environment with simulated elements added. A class with instructor, ending with final test.

Evaluation procedure:

Evaluation is carried out, by the instructor or automatically by computer trainer, on the basis of a point system. Points that may either be added to, or subtracted from the score, are to reflect the following attributes characterizing trainee's performance.

- Flexibility ability to cope with ambiguous, rapidly changing, and complex situations.
- Speed ability to make rapid decisions, even in the face of severe consequences.
- Resilience ability to operate in ambiguous, uncertain, stressful, and high-stakes situations without degradations in performance.
- Adaptability ability to recognize when and how to change or modify an action strategy.
- Risk management ability to quickly assess the risks in various courses of action, taking into account the consequences and payoffs.
- Accuracy ability to state accurately what is noticeable; quick and deep understanding and ef-

fective communication. Certification:

There are three categories of certificates.

- First grade an instructor entitled to train operator of robots.
- Second grade an operator entitled to operate many (specified) types of robots.
- Third grade an operator entitled to operate robots of one particular type.

For keeping validity of a certificate it is necessary to participate in periodical trainings and/or current operator's practice. Together with certification personal logs of training and practice should be introduced.

### 2.2. Lesson learned from the methodology evaluation

Evaluation of methodology was carried out in 2008. Not many users of mobile inspectionintervention robots were in Poland then, and the evaluation was based on the opinions of five respondents employing a hundred and a few dozen already trained operators of robots. It turned out that for training only real robots were used, any specific training devices weren't in use. Training, which took about 30 hours, was performed in 3-10 person groups.

The users estimated their future needs for training on average at 3 days monthly of use of training utilities: 2 days for training of new operators, and 1 day for improving training. They were skeptics about online training, however training on a simulator with real control console they considered useful and desirable. Positive attention was paid to the ability of simulation for training purpose of different types of surfaces and obstacles, different atmospheric conditions, disturbances and system failures. Ability to virtually perform of advanced, complex missions with use of rich toolset of accessories was valued highly also.

The conclusion is that volume of the then needs for training in Poland - not so much different at present - didn't economically justify any application of multi-level training with use of complex set of trainers-simulators. Key justification for use simulators in training lies in a need to train operators in missions performed in environments and conditions difficult and costly to create in real, and/or missions bringing dangers. Regarding skepticism about online training, one should take into account that the respondents didn't apply it in their practice, and had no experience with it. It's necessary to take also into consideration that online training is successfully in use in such significant fields as learning to fly and pilot training, learning to drive cars, training of heavy equipment operators.



Fig.1. Training appliance with real robot's control console

### 3. Trainers and training according to the methodology

With respect to the results of methodology evaluation, two types of trainers-simulators have been designed by means of the computer platform built in the Institute of Mathematical Machines: first of them with virtual and second with real control console of the "Inspector" robot.

These types of trainers enable:

- Generation of robot's model composed of five inter-dependent sub-models: physical model representing physical properties, geometric model representing method of visualization, sound model, models of sensors, and models of actuators. The repertoire of virtual entities that can be created includes wheel and caterpillar robotic platforms, manipulators, cameras and other standard sensors, grippers and typical tools.
- In the case of the first type trainer, generation of virtual control console composed of physical, geometric, sound, and actuators sub-models. A virtual console can include joysticks, push-buttons,



Fig.2. Training screen from lifting explosive device and putting it in a container

switches, and displays.

- Generation of environment's model composed of three sub-models -physical, geometric, and sound ones - for indoor- and outdoor-type environments. Virtual environments can have different relief and can include both rigid and soft objects – complex objects as well – with different types of surfaces (rough, slippery); intensity of lighting can be changed, and the effects of smoke and fog can be introduced.
- Integration of the above models.
- Compilation of training tasks having a form of games played by a trainee in a virtual world composed of the virtual robot with real or virtual control console, and of virtual environment. An evaluation point system is assigned to the game, and after the end of game a report including description of events that happened during the game, with their timing and a score, is created.
- Creation of training programs and/or certification tests composed of tasks-games connected flexibly: the choice of a next task (or a decision to finish the training/test) depends on the evaluation of



Fig.3. Training screen from getting out explosive device form a car



Fig.4. Training screen from destroying explosive device by shot it down

the level of skills achieved by the trainee. A program/test can be depicted in the form of a graph, which vertices represent tasks, and edges – paths between tasks.

The trainers have been implemented on PCs under MS Windows XP. Computers are connected by fast LAN with CORBA (TAO version) technology. The software is based on MS Visual Studio 2005/2008 integrated programming environment, graphical libraries Open GL i GLUT, NVIDIA CUDA libraries, tools for the XML standard, tools for the UML language. For graphical effects OGRE graphical engine was applied, and OpenAL for sound effects. Blender, 3DMAX, SolidWorks and Vortex were used as CAD software.

A training appliance presently in use in the Police Academy, showed in the Fig.1, is equipped both with real robot's control console, and with the possibility of working with virtual console – so is a combination of both types of trainers. First taskgames tested on it, in both modes of operator's work, are the followings:

- Lifting, with use of the robot's gripper, of an explosive device, and putting it in a container. The operation is carried out in the indoor environment of a subway station (Fig.2).
- Getting out an explosive device from a car. The operation is carried out in an outdoor environment of a hilly type terrain (Fig.3).

• Destroying of an explosive device situated under a truck by shot it down with robot's gun. The operation is carried out in an outdoor environment of a hilly type terrain (Fig.4).

#### References

Kacprzak M., Kaczmarczyk A., Masłowski A.: Software creation for trainers of mobile robots operators (in Polish). (Techniki Komputerowe) 1/2008.

Kaczmarczyk A., Kacprzak M., Masłowski A.: Mutilevel simulation training of devices operators. An application to mobile robots operators (in Polish). Electronics – Construction, Technologies, Applications (Elektronika) 11/2009.

Kaczmarczyk A., Kacprzak M., Masłowski A.: Extension of e-learning: e-trening of operators of vehicles and devices (in Polish). Electronics – Construction, Technologies, Applications (Elektronika) 12/2009.

Kacprzak M., Kaczmarczyk A., Masłowski A.: Designing of computer simulators for mobile devices operators (in Polish). Electronics – Construction, Technologies, Applications (Elektronika) 12/2009.

Kaczmarczyk A., Kacprzak M., Masłowski A., Będkowski J., Kowalski P., Musialik P., Pichlak T., Piszczek J.: E-Training in RISE (Robotics for Risky Interventions and Environmental Surveillance). Bulletin of the Institute of Mathematical Machines, Computer Technologies (Techniki Komputerowe) 1/2009.
#### Semantic simulation for mobile robot operator training

Janusz Bedkowski, Andrzej Maslowski<sup>56</sup>

#### Abstract

The paper concerns the research related to the semantic mapping application for automatic virtual scene generation. Data is acquired by a mobile robot equipped with 3D measurement system. The virtual scene composed by several entities and relations between them is the core of the proposed semantic simulation engine. Semantic mapping is still an open problem because of its complexity. There are several robotic applications that use semantic information to build complex environment maps with labeled entities, therefore advanced robot behavior based on ontological information can be processed in high conceptual level. We are presenting a new approach that uses semantic mapping to generate physical model of an environment that is later integrated with mobile robot simulator. Semantic map is generated based on raw data acquired by a mobile robot in INDOOR environment. This raw data is transformed into a semantic map and then consequently NVIDIA PhysX model is constructed. The PhysX model is used to perform an inspection intervention mobile robot simulation in which collision detection and rigid body simulation is available.

#### Introduction

Semantic simulation engine [24] is a project that main idea is to improve State of The Art in the area of semantic robotics [4] [30] [18] with the focus on practical applications such as robot supervision and control [23], semantic map building, robot reasoning and robot operator training in hazardous environment using augmented reality techniques [25]. Semantic information [4] extracted from 3D laser data [33] is recent research topic of modern mobile robotics. In [30] a semantic map for a mobile robot was described as a map that contains, in addition to spatial information about the environment, assignments of mapped features to entities of known classes. In [18] a model of an indoor scene is implemented as a semantic net. This approach is used in [32] where robot extracts semantic information from 3D models built from a laser scanner. In [9] the location of features is extracted by using a probabilistic technique (RANSAC) [16]. Also the region growing approach [15] extended from [41] by efficiently integrating k-nearest neighbor (KNN) search is

able to process unorganized point clouds. The improvement of plane extraction from 3D Data by fusing laser data and vision is shown in [3]. The automatic model refinement of 3D scene is introduced in [31] where the idea of feature extraction (planes) is done also with RANSAC. The semantic map building is related to SLAM problem [34] [39] [14]. Most of recent SLAM techniques use camera [10] [43] [1], laser measurement system [35] [40] or even registered 3D laser data [26]. Concerning the registration of 3D scans described in [28] [2] we can find several techniques solving this important issue. The authors of [6] briefly describe ICP algorithm and in [20] the probabilistic matching technique is proposed. In [29] the comparison of ICP and NDT algorithm is shown. In [37] the mapping system that acquires 3D object models of man-made indoor environments such as kitchens is shown. The system segments and geometrically reconstructs cabinets with doors, tables, drawers, and shelves, objects that are important for robots retrieving and manipulating objects in these environments.

A detailed description of computer based simulators for unmanned vehicles is shown in [13]. Also in [7] the comparison of real-time physics simulation systems is given, where a qualitative evaluation of a number of free publicly available physics engines for simulation systems and game development is presented. Several frameworks are mentioned such as USARSim which is very popular in research society [42] [5] [19], Stage, Gazebo [36], Webots [21] and MRDS [8] [38]. Some researchers found that there are many available simulators that offer attractive functionality, therefore they proposed a new simulator classification system specific to mobile robots and autonomous vehicles [12]. A classification system for robot simulators

<sup>&</sup>lt;sup>56</sup> Institute of Mathematical Machines, April 8, 2011

will allow researchers to identify existing simulators which may be useful in conducting a wide variety of robotics research from testing low level or autonomous control to human robot interaction. Another simulation engine -the Search and Rescue Game Environment (SARGE), which is a distributed multi-player robot operator training game, is described in [11].

The paper is organize as follows: in section 2 general description of semantic simulation engine is described.

#### 2 Semantic simulation engine

Semantic simulation engine combines semantic map with rigid body simulation to perform supervision of its entities such as robots moving in IN-DOOR or OUTDOOR environments composed by floor, ceiling, walls, door, tree, etc. Semantic simulation engine is composed of data registration modules, semantic entities identification (data segmentation) modules and semantic simulation module. It provides tools to implement mobile robot simulation based on real data delivered by robot and processed on-line using parallel computation. Semantic entities identification modules can classify several objects in INDOOR and OUTDOOR environments. Data can be delivered by robot observation based on modern sensors such as laser measurement system 3D and RGB-D cameras. Real objects are associated with virtual entities of simulated environment.

#### 2.1 Data registration module

Alignment and merging of two 3D scans, which are obtained from different sensor coordinates, with respect to a reference coordinate system is called 3D registration [22] [17] [27]. Range images are defined as a model set M and data set D, where  $N_m$  and  $N_d$  denotes the number of the elements in the respective set. The alignment of these two data sets is solved by minimization of the following cost function:

$$E = (\mathbf{R}, \mathbf{t}) = \sum_{i=1}^{N_m} \sum_{j=1}^{N_d} w_{ij} \|\mathbf{m}_i - (\mathbf{R}\mathbf{d}_j + \mathbf{t})\|^2$$
(1)

 $w_{ij}$  is assigned 1 if the i-th point of M correspond to the j-th point in D as in the same bucket (or neighbor bucket). Otherwise  $w_{ij}$ =0. **R** is a rotation matrix, **t** is a translation matrix. **m**<sub>i</sub> and **d**<sub>i</sub> corresponds to the *i*-th point from model set *M* and *D* respectively. Solving equation 1 is related to Nearest Neighborhood search. The distance between two points in Euclidean distance metric for point  $p_1 = \{x_{1i}, y_{1i}, z_1\}$ and  $p_2 = \{x_{2i}, y_{2i}, z_2\}$  is defined as:

distance
$$(p_1, p_2) = \left[ (x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2 \right]^{\frac{1}{2}}$$
 (2)

To find pairs of closest points between model set M and data set D and compute 3D data sets alignment the GPGPU (General-Purpose computation on Graphics Processing Units) ICP is implemented. Performed experiments shown that the ICP can be performed on-line.

## 2.2 Semantic entities identification modules

The proposed approach is dedicated to structured INDOOR environment where floor is flat and walls are straight and orthogonal to floor and ceiling, stairs are parallel and ergonomic. It is obvious that if we try to use this approach in unstructured environment, algorithm will generate numerous not-labeled objects. To find semantic objects such as Wall, Ceiling, Floor, Doors (with joint), Stairs we are using a new idea that is based on prerequisites generation from projected single 3D scan (onto OXY plane for Wall, Door, Stairs and onto OXZ for Ceiling and Floor). Prerequisites are generated using image processing techniques such as Hough transform for line extraction. The prerequisites are checked in next step, if the constraint is satisfied, the semantic object is assigned. For instance if we assume 3D scan projected onto OXY plane, a single line is related to a wall prerequisite, 3 parallel lines are prerequisite of stairs, 2 connected lines are prerequisite of opened doors and the connection can be a joint. Single long line in 3D scan projected onto OXZ plane is a prerequisite of Ceiling and Floor.

The interpretation of the scene comprises generic architectural knowledge like in [18], [31] and [9]. Nodes of a semantic net represent entities of the world, the relationships between them are defined. Possible labels of the nodes are  $L = \{Wall, Wall above door, Floor, Ceiling, Door, Free space for door\}.$  The relationships between the entities



Figure 1: Graphical model of Metro station.

are  $R = \{$ parallel, orthogonal, above, under, equal height, available inside, connected via joint $\}$ . The semantic net can easily be extended to more entities and relationships which determine a more sophisticated feature detection algorithms.

#### 2.3 Semantic simulation module

Due to semantic simulation module is the main topic of the paper, in this subsection the detailed description of rigid body simulation that integrates semantic map is given. The concept of semantic simulation is a new idea, and its strength lies on the semantic map integration with mobile robot simulator. The engine basic elements for INDOOR environment are: semantic map nodes(entities)  $L_{sm} = \{$ Wall, Wall above door, Floor, Ceiling, Door, Free space for door, Stairs...}, it is important to noticed that the  $L_{sm}$  set can be extended by another objects, what is dependent on robust and accurate 3D scene analysis, robot simulator nodes(entities)  $L_{rs} = \{$ robot, rigid body object, soft body object... $\},$ semantic map relationships between the entities  $R_{sm} = \{$ parallel, orthogonal, above, under, equal height, available inside, connected via joint...}, robot simulator relationships between the entities  $R_{rs} = \{\text{connected via joint, position...}\}, \text{ seman-}$ tic map events  $E_{sm}$  = robot simulator events  $E_{rs}$  = {movement, collision between two entities started, collision between two entities stopped, collision between two entities continued, broken joint...}. Robot simulator is implemented using NVIDIA PhysX library. The entities from semantic map correspond to actors in PhysX. L<sub>sm</sub> is transformed into  $L_{rs}$  based on spatial model generated based on registered 3D scans.  $R_{sm}$  is transformed into  $R_{rs}$ . All entities/relations R<sub>m</sub> has the same initial location in  $R_{\rm eff}$  obviously the location of each actor/entity may change during simulation, therefore accurate object tracking system is needed. The transformation from  $E_{sm}$  to  $E_{rs}$  effects that events related to entities from semantic map correspond to the events related to actors representing proper entities. Following events can be noticed during simulation: robot can touch each entity, open/close the door, climb the stairs, enter empty space of the door, damage itself (broken joint between actors in robot arm), brake joint that connects door to the wall.

As an example of the INDOOR environment Metro station is created manually and shown on figure 1. The main goal of semantic simulation module is to monitor robot operator behavior during neutralization of hazardous object. Following events can be monitored by semantic simulation: robot fall down into area A or B (see figure 1 and 2), robot touch obstacle C, robot arm is damaged (see figure 3). Obviously set of events can be extended by supervision of robot roll and pitch etc.



Figure 2: Semantic simulation module visualization.



Figure 3: Event -robot arm damaged.

#### Conclusion

In the paper new concept of semantic simulation engine composed of data registration modules, semantic entities identification modules and semantic simulation module is proposed. Semantic simulation engine provides tools to implement mobile robot simulation based on real data delivered by robot and processed on-line using parallel computation. Semantic entities identification modules can classify door, walls, floor, ceiling, stairs in indoor environment. Data can be delivered by robot observation based on modern sensors such as laser measurement system 3D and RGB-D cameras. Semantic simulation uses NVIDIA PhysX for rigid body simulation. By the association between real objects and simulation entities it is possible to supervise them by prediction of possible collisions and dangerous motion (pitch, roll). Future work will be related to AI techniques applied for semantic entities identification (furnitures, victims, cars, etc...), localization and tracking methods.

#### References

[1] Henrik Andreasson. *Local Visual Feature based Localisation and Mapping by Mobile Robots*. Doctoral thesis, Orebro University, School of Science and Technology, September 2008.

[2] Henrik Andreasson and Achim J. Lilienthal. Vision aided 3d laser based registration. In *Proceedings of the European Conference on Mobile Robots* (*ECMR*), pages 192–197, 2007.

[3] Henrik Andreasson, Rudolph Triebel, and Wolfram Burgard. Improving plane extraction from 3d data by fusing laser data and vision. In *Proceedings* of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pages 2656–2661, 2005.

[4] Minoru Asada and Yoshiaki Shirai. Building a world model for a mobile robot using dynamic semantic constraints. In *Proc. 11 th International Joint Conference on Artificial Intelligence*, pages 1629–1634, 1989.

[5] B. Balaguer, S. Balakirsky, S. Carpin, M. Lewis, and C. Scrapper. Usarsim: a validated simulator for research in robotics and automation. In *Workshop on Robot simulators: available software, scientific applications and future trends at IEEE/RSJ IROS*, 2008.

[6] P. J. Besl and H. D. Mckay. A method for registration of 3-d shapes. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 14(2):239–256, August 1992.

[7] Adrian Boeing and Thomas Bräunl. Evaluation of real-time physics simulation systems. In *GRAPHITE '07: Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia*, pages 281–288, New York, NY, USA, 2007. ACM.

[8] Caitlin Buckhaults. Increasing computer science participation in the first robotics competition with robot simulation. In ACM-SE 47: *Proceedings of the 47th Annual Southeast Regional Conference*, pages 1–4, New York, NY, USA, 2009. ACM.

[9] H. Cantzler, Robert B. Fisher, and Michel Devy. Quality enhancement of reconstructed 3d models using coplanarity and constraints. In *Proceedings of the 24th DAGM Symposium on Pattern Recognition*, pages 34–41, London, UK, 2002. Springer-Verlag.

[10] R. O. Castle, G. Klein, and D. W. Murray. Combining monoslam with object recognition for scene augmentation using a wearable camera. 28(11):1548 – 1556, 2010. [11] Jeff Craighead, Rodrigo Gutierrez, Jennifer Burke, and Robin Murphy. Validating the search and rescue game environment as a robot simulator by performing a simulated anomaly detection task. In *Proceedings of the 2008 International Conference on Intelligent Robots and Systems (IROS 2008),* September 2008.

[12] Jeff Craighead, Robin Murphy, Jenny Burke, and Brian Goldiez. A robot simulator classification system for hri. In *Proceedings of the 2007 International Symposium on Collaborative Technologies and Systems* (CTS 2007), pages 93–98, May 2007.

[13] Jeff Craighead, Robin Murphy, Jenny Burke, and Brian Goldiez. A survey of commercial and open source unmanned vehicle simulators. In *Proceedings of ICRA*, 2007.

[14] A.J. Davison, Y. Gonz´alez Cid, and N. Kita. Real-time 3D SLAM with wide-angle vision. In *Proc. IFAC Symposium on Intelligent Autonomous Vehicles, Lisbon*, July 2004.

[15] Markus Eich, Malgorzata Dabrowska, and Frank Kirchner. Semantic labeling: Classification of 3d entities based on spatial feature descriptors. In *IEEE International Conference on Robotics and Automation (ICRA2010) in Anchorage, Alaska, May 3*, 2010.

[16] M. A. Fischler and R. Bolles. Random sample consensus. a paradigm for model fitting with apphcahons to image analysm and automated cartography. In *Proc. 1980 Image Understandtng Workshop (College Park, Md., Apr i980) L. S. Baurnann, Ed, Scmnce Apphcatlons, McLean, Va.*, pages 71–88, 1980.

[17] Andrew W. Fitzgibbon. Robust registration of 2d and 3d point sets. In *In British Machine Vision Conference*, pages 411–420, 2001.

[18] O. Grau. A scene analysis system for the generation of 3-d models. In *NRC '97: Proceedings of the International Conference on Recent Advances in 3-D Digital Imaging and Modeling*, page 221, Washington, DC, USA, 1997. IEEE Computer Society.

[19] Nicola Greggio, Gianluca Silvestri, Emanuele Menegatti, and Enrico Pagello. A realistic simulation of a humanoid robot in usarsim. In *Proceeding of the 4th International Symposium on Mechatronics and its Applications (ISMA07), Sharjah, U.A.E.,* March 26-29 2007.

[20] Dirk Hähnel and Wolfram Burgard. Probabilistic matching for 3D scan registration. In *In.: Proc. of* 

the VDI -Conference Robotik 2002 (Robotik), 2002.

[21] L. Hohl, R. Tellez, O. Michel, and A. J. Ijspeert. Aibo and Webots: Simulation, Wireless Remote Control and Controller Transfer. *Robotics and Autonomous Systems*, 54(6):472–485, 2006.

[22] Daniel Huber and Martial Hebert. Fully automatic registration of multiple 3d data sets. *Image and Vision Computing*, 21(1):637–650, July 2003.

[23] A. Maslowski J. Bedkowski. Methodology of control and supervision of web connected mobile robots with cuda technology application. *Journal of Automation, Mobile Robotics and Intelligent Systems*, 5(2):3–11, 2011.

[24] A. Maslowski J. Bedkowski. Semantic simulation engine for mobile robotic applications. *Pomiary, Automatyka, Robotyka 2/2011, Automation 2011 6-8 April, Warsaw,* pages 333–343, 2011.

[25] G. Kowalski, J. Bedkowski, P. Kowalski, and A. Maslowski. Computer training with ground teleoperated robots for de-mining. *Using robots in hazardous environments, Landmine detection, de-mining and other applications,* pages 397–418, 2011.

[26] Martin Magnusson, Henrik Andreasson, Andreas Nüchter, and Achim J. Lilienthal. Automatic appearance-based loop detection from 3D laser data using the normal distributions transform. *Journal of Field Robotics*, 26(11–12):892–914, November 2009.

[27] Martin Magnusson and Tom Duckett. A comparison of 3d registration algorithms for autonomous underground mining vehicles. In *In Proc. ECMR*, pages 86–91, 2005.

[28] Martin Magnusson, Tom Duckett, and Achim J. Lilienthal. 3d scan registration for autonomous mining vehicles. *Journal of Field Robotics*, 24(10):803–827, Oct 24 2007.

[29] Martin Magnusson, Andreas Nüchter, Christopher Lörken, Achim J. Lilienthal, and Joachim Hertzberg. Evaluation of 3d registration reliability and speed — a comparison of icp and ndt. In *Proc. IEEE Int. Conf. on Robotics and Automation*, pages 3907–3912, 2009.

[30] Andreas Nüchter and Joachim Hertzberg. Towards semantic maps for mobile robots. *Robot. Auton. Syst.*, 56(11):915–926, 2008.

[31] Andreas Nüchter, Hartmut Surmann, and

Joachim Hertzberg. Automatic model refinement for 3D reconstruction with mobile robots. In *Fourth International Conference on 3-D Digital Imaging and Modeling 3DIM 03*, page 394, 2003.

[32] Andreas Nüchter, Hartmut Surmann, Kai Lingemann, and Joachim Hertzberg. Semantic scene analysis of scanned 3d indoor environments. In *in: Proceedings of the Eighth International Fall Workshop on Vision, Modeling, and Visualization* (VMV 03), 2003.

[33] Andreas Nüchter, Oliver Wulf, Kai Lingemann, Joachim Hertzberg, Bernado Wagner, and Hartmut Surmann. 3d mapping with semantic knowledge. In *IN ROBOCUP INTERNATIONAL SYMPOSIUM*, pages 335–346, 2005.

[34] Jan Oberlander, Klaus Uhl, Johann Marius Zollner, and Rudiger Dillmann. A region-based slam algorithm capturing metric, topological, and semantic properties. In *ICRA'08*, pages 1886–1891, 2008.

[35] L. Pedraza, G. Dissanayake, J. Valls Miro, D. Rodriguez-Losada, and F. Matia. Bs-slam: Shaping the world. In *Proceedings of Robotics: Science and Systems*, Atlanta, GA, USA, June 2007.

[36] Radu Bogdan Rusu, Alexis Maldonado, Michael Beetz, Intelligent Autonomous Systems, and Technische Universität München. Extending player/stage/gazebo towards cognitive robots acting in ubiquitous sensor-equipped environments. In *in Accepted for the IEEE International Conference on Robotics and Automation (ICRA) Workshop for Network Robot System, 2007, April 14, 2007.* 

[37] Radu Bogdan Rusu, Zoltan Csaba Marton, Nico Blodow, Mihai Dolha, and Michael Beetz. Towards 3d point cloud based object maps for household environments. *Robot. Auton. Syst.*, 56(11):927– 941, 2008.

[38] D. Sallé, M. Traonmilin, J. Canou, and V. Dupourqué. Using microsoft robotics studio for the design of generic robotics controllers: the robubox software. In *ICRA 2007 Workshop Software Development and Integration in Robotics -"Understanding Robot Software Architectures"*, April 2007.

[39] Stephen Se and David Lowe Jim Little. Mobile robot localization and mapping with uncertainty using scale-invariant visual landmarks. *The International Journal of Robotics Research*, 21(8):735–758, August 2002. [40] Sebastian Thrun, Wolfram Burgard, and Dieter Fo. A real-time algorithm for mobile robot mapping with applications to multi-robot and 3d mapping. In ICRA, pages 321–328, 2000.

[41] N. Vaskevicius, A. Birk, K. Pathak, and J. Poppinga. Fast detection of polygons in 3d point clouds from noise-prone range sensors. In *IEEE International Workshop on Safety, Security and Rescue Robotics, SSRR,* pages 1–6, Rome, 12 November 2007. IEEE.

[42] J. Wang, M. Lewis, and J. Gennari. Usar: A game-based simulation for teleoperation. In *Proceedings of the 47th Annual Meeting of the Human Factors and Ergonomics Society, Denver, CO, Oct.* 13-17, 2003.

[43] B. Williams and I. Reid. On combining visual slam and visual odometry. In *Proc. International Conference on Robotics and Automation*, 2010.

#### OMNIDIRECTIONAL STEREO TRACKING SYSTEM FOR HUMANITARIAN DEMINING TRAINING

Roemi Fernández, Carlota Salinas, Héctor Montes, Manuel Armada<sup>57</sup>

#### Abstract

The paper proposes a training tool intended to improve deminer sweeping technique during close-in detection tasks. The tool consists of an omnivision stereo system that tracks the movement of a handheld detector head (landmarks) and computes its 3-D world position. With this information a coverage map could be built up and training feedback on trainee performance could be provided to the deminer, showing him missed areas during scanning, and areas where the detector is outside of its optimal operating range. The system combines two parallel-placed central catadioptric cameras separated by a distance D, and with their focal points displaced a distance d along z-axis. This configuration allows an easily image rectification, by means of an estimation of parallel epipolar lines for real-time stereo processing.

#### Introduction

The consequences of the use of antipersonnel mines go far beyond the military field, since the activity of these weapons does not stop with the end of the hostilities. The landmines, cluster munitions and explosive remnants of war (ERW) can remain active for decades, they are not aware of negotiations or peace treaties, and do not distinguish between soldiers and civilians. As of 2010, 66 internationally recognized states and seven other areas were confirmed or suspected to be mine-affected, and in 2009 alone, landmines and ERW were responsible for over 3956 casualties [1]. The presence of landmines also produces negative economic effects, as it denies access to the affected areas and their resources, causing deprivation and social problems among the affected populations. In addition, harmful effects on the environment are evident. They alter the characteristics of the soil, disrupting the ecological balance, and the soil degradation increases with the explosions. They also pose some threat to the local fauna. For example, in the North of Africa, it has been confirmed that gazelles disappeared from the areas that were mined during the Second World War. Therefore, the medical, social, economic and environmental consequences are immense, which is why the elimination of antipersonnel mines is a vital requirement for many regions to recover their impact. In military demining the objective is to clear a minefield as fast as possible using brute force, and usually a clearance rate of 80% to 90% is accepted [2]. On the other hand, humanitarian demining is more difficult and dangerous, as it requires the complete removal of all mines and ERW and the return of the cleared minefield to normal use [3]. Today, most humanitarian demining is done using handheld metal detectors or sniffer dogs, attempting to carefully locate each explosive item and then either blow it up or burn it in situ, or render it safe and remove it for dismantling or disposal elsewhere. Metal detectors are active, low frequency inductive systems, usually composed of a search head, containing one or more coils carrying a time-varying electric current. This current generates a corresponding timevarying magnetic field which propagates towards the metallic target in order to induce eddy currents in it, which in turn generate a detectable magnetic field [4]. Old landmines contain metal parts (e.g. the firing pin), but modern ones contain very small amounts or no metal at all. In order to alleviate this problem, a number of new handheld mine detectors are emerging as alternatives to the traditional ones. An example is the Handheld Standoff Mine Detection System [5], a handheld mine detector capable of detecting all metallic and non-metallic anti-tank and antipersonnel mines by combining an electromagnetic induction sensor, ground penetrating radar and sophisticated algorithms.

Unfortunately, the proficiency of land mine detection equipment operators is highly variable. Expert operators of the most commonly-used handheld

<sup>&</sup>lt;sup>57</sup> Centre for Automation and Robotics CSIC-UPM. Ctra. Campo Real Km 0,200 La Poveda, Arganda del Rey, 28500 Madrid, Spain. e-mail: roemi.fernandez@car.upm-csic.es

detectors exhibit mine detection probabilities of 0.9 [6], but a simple mistake can jeopardize their lives. Thus, training is a very important aspect in order to improve the safety and effectiveness of the mine detection activities performed by the human operators.

This paper proposes a training tool intended to improve the deminers sweeping technique during close-in detection tasks with handheld detectors. The projected methodology and the description of the designed tracking system are presented in the following sections.

#### Projected methodology for the training tool

Analysis of the expert's handheld detection activities shows that their techniques and strategies differed from conventionally taught operating procedures. Whereas other operators perform detection on the basis of auditory outputs pointing out the existence of conductive materials, experts use the onset and offset of outputs that occurred during sweeping motions of the handheld detector to create spatial patterns that they compare to learned models [7]. They also modify their detection techniques to adapt to environmental variations (deserts, hilly rocky terrain, lands with a wide variety of vegetation). For this reason, the projected methodology proposes as a first step, the utilization of an omnidirectional stereo tracking system to study the experts' skills. With the compiled information, some critical performance variables will be extracted, assessed, and quantified, so that they can be used after as reference values for the training task. The chosen critical variables are the safety distance to advance the detector search-head on each sweep, the sweep velocity, the scan height, and the inclination of the handheld detector head with respect to the ground. Using these variables and the omnidirectional stereo tracking system, the training tool will evaluate the efficiency of the deminers during the scanning tasks and will feedback them

important information for improving their competencies.

Since Fuzzy Set Theory has proved to be a worthwhile means for handling and representing experience-based heuristic knowledge, it will be used to representing the training goals. Given a universe of discourse *U*, a fuzzy value *A* is defined by means of a possibility distribution  $\pi^A$  defined over *U* [8]. Given a precise value  $x \in U$ ,  $\pi^A(x) \in [0,1]$  represent possibility of A being precisely *x*.

The possibility distribution  $\pi^A$  could be represented by means of a trapezoidal function specified by four parameters. In this way,  $A = (\alpha, \beta, \gamma, \delta)$ ,  $\alpha \leq \beta \leq \gamma \leq \delta$  where  $[\beta, \gamma]$  represent the core, core  $(A) = \{x \mid \pi^A(x) = 1\}$  and represent  $[\alpha, \delta]$  the support, support (*A*)={ $x \mid \pi^{A}(x) > 1$ }. The minimum and maximum values acceptable for the chosen critical variables are the beginning and the ending of the distribution support, respectively. In this way, if the deminer advances the handheld detector with a lower velocity than the value corresponding with the beginning of the support, the scanning task is too time-consuming. If the deminer advances the handheld detector with a higher velocity than the one corresponding with the ending of the support, the sweep is being carried out too fast for efficient and safe landmine detection. The beginning and ending of the core are the limits of the interval within the ideal values lie.

If  $v_i$  is the sweep velocity output in cm/s, the degree to which the training objectives are being achieved is  $\pi^A(v_i)$ . If  $\pi^A(v_i)=0$  then the acquired velocity is outside the range of ideal values. Conversely, if  $\pi^A(v_i)=1$ , the acquired velocity is within the range of ideal values. The closer  $\pi^A(v_i)$  is to 1, the closer the sweep velocity output is to the ideal values.

#### Sensory tracking system

The sensory system approach is based on catadioptric panoramic cameras and high intensity LEDs as landmarks (see Fig. 1) for tracking the



Fig. 1. Sensory tracking system: catadioptric system and simulated metal detector with high intensity LEDs.



Fig. 2. (a) Result of LEDs detection, (b) Tracking of a LEDs line along a vertical movement.

handheld detector position. Omnidirectional catadioptric systems combine a high resolution colour camera and a hyperbolic mirror aligned with the focal axis of the camera. The LEDs are placed along the handheld test structure (simulated handheld metal detector) in order to detect and track its position and orientation during the sweeping motions. A stereo rectified configuration system can be accomplished with two decoupled high resolution catadioptric systems vertically aligned. The rectification process provides epipolar radial lines onto the image plane and when they are projected onto the panoramic perspective they become parallel lines to the vertical axis. Consequently, the depth is isotropic in all directions.

#### **Preliminary results**

The approach is presented in an early stage. For preliminary results, a line of LEDs has been moved by a controlled drive with an error position of +/-1.3 mm and tracked by the sensory system. The purpose of the experiment was not only to show the capability of the system for tracking known positions of a specific shape but also to compute the target trajectory and the system accuracy. The

landmarks were moved in different directions with steps of 20 mm. In Fig. 2 the result of tracking a vertical movement is illustrated.

A second experiment shows the tracking of the handheld test detector during a semi-circular scanning motion.

#### Discussion and future research

In this work a training tool for improving the deminers' skills during close-in detection tasks with handheld detectors was introduced. The approach is based on an omnidirectional stereo sensory system and high intensity LEDs utilized as landmarks for tracking the handheld detector movements. With this sensory system, the experts' skills could be studied by quantifying some critical performance variables, so that they can be used later as reference values for the training task. The experience-based acquired knowledge is represented by means of Fuzzy Set Theory. Using the critical variables, the omnidirectional stereo tracking system, and a friendly human interface, the training tool will be able to evaluate the efficiency of the deminers during the scanning tasks and to feedback them important information for improving their competencies.





Fig. 3. Handheld detector tracking.

#### References

[1] Landmine Monitor Report 2010, Landmine and Cluster Munition Monitor. http://www.the-monitor.org/index.php/publications/display?url=lm/2010/

[2] Rosengard, U., Dolan, T., Miklush, D. and Samiei, M. Humanitarian Demining – Nuclear Techniques may help the search for Landmines. IAEA Bulletin, February 2001.

[3] Hussein, E. M. A., Waller, E. J. Landmine detection: the problem and the challenge. Applied Radiation and Isotopes 53, pp. 557-563, 2000.

[4] Guelle, D., Smith, A., Lewis, A. and Bloodworth, T. Metal Detector Handbook for Humanitarian Demining. Luxembourg: Office for Official Publications of the European Communities, ISBN: 92-894-6236-1, 2003.

[5] Doheny, R. C., Burke, S. Cresci, R., Ngan, P and Walls, R. Handheld Standoff Mine Detection System (HSTAMIDS) Field Evaluation in Thailand. SPIE, Detection and Remediation Technologies for Mines and Minelikes Targets, X, Orlando, Florida, USA, 2005.

[6] Staszewski, J. J. Information processing analysis of human land mine detection skill. In Detection and Remediation Technologies for Mines and Minelike Targets IV, Proceedings of the Society for Photo-Optical Instrumentation Engineers 13th Annual Meeting, 3710, 766-777, 1999.

[7] Staszewski, J. Models of expertise as blueprints cognitive engineering: applications to landmine detection. Proceedings of the 48th Annual Meeting of the Human Factors and Ergonomics Society, 48, pp. 458-462, 2004.

[8] Zadeh, L. The concept of a linguistic variable and its application to approximate reasoning. Inform. Sci., *8*, 199–249, 1975.

#### In-field tests of LOCOSTRA in Jordan

Emanuela Elisa Cepolina<sup>58</sup>, Matteo Zoppi<sup>59</sup>, Gianni Polentes<sup>60</sup>, Bassam Snobar<sup>61</sup>, Frank Abel<sup>62</sup>, Basem Kasesbeh<sup>63</sup>

#### Abstract

The paper summarizes results obtained during the in-field test of LOCOSTRA machine that took place in Jordan during February-March 2011 with the very important support of Norwegian Peoples Aid Jordan, the National Committee for Demining and Rehabilitation, the Geneva International Centre for Humanitarian Demining and the University of Jordan. LOCOSTRA is the output of an 18 months project co-funded by the Italian Ministry of Economic Development and the Italian Institute for Foreign Trade and coordinated by the University of Genova. The test was very successful and proved the concept of LOCOSTRA tractor as a reliable, easy to use, versatile verification asset to be used in technical survey. LOCOSTRA could speed up technical survey operations consistently thanks to its low cost (50.000 €), its local worldwide sustainability and its simplicity. Being a modified tractor, LOCOSTRA can be used in agricultural activities when demining is over.

LOCOSTRA is produced and sold by Pierre Trattori with the support of Snail Aid Technology for Development.

#### 1. Introduction

LOCOSTRA as verification asset can be equipped with many different tools:

- a mulcher that allows vegetation to be cut and a visual inspection to be done either by a person on a small tower, by a camera on a balloon, or a video camera on board, or

- <sup>59</sup> DIMEC, University of Genova, Via AllOpera Pia 15/A, 16145 Genova, Italy; <u>zoppi@dimec.unige.it</u>
- <sup>60</sup> Pierre Trattori s.n.c, Via Novi 19, 15060 Silvano dOrba (AL), Italy; <u>info@pierretra.com</u>
- <sup>61</sup> Faculty of Agriculture, University of Jordan, Amman 11942, Jordan; <u>snobar@ju.edu.jo</u>
- <sup>62</sup> Geneva International Centre for Humanitarian Demining (GICHD), 7bis, avenue de la Paix, P.O. Box 1300, CH-1211 Geneva 1; <u>f.abel@gichd.org</u>
- <sup>63</sup> National Committee for Demining and Rehabilitation (NCDR), <u>basem@ncdr.org.jo</u>

- with a agricultural derived tool for removing/destroying landmines, or
- with an array of metal detector or a large loop detector to check for the presence of metallic parts of buried mines.

According to the tool with which the tractor is equipped LOCOSTRA machine can be classified as ground preparing machine, ground processing machine or mine protected vehicle (used as a platform for a detection system in a SHA). LOCOSTRA is an intrusive, remotely operated machine. Being the overall weight of the tractor and the blast resistant wheels approximately 3000 kg, the machine can be classified as light.

LOCOSTRA is better described in [1] and in the project website, but its main characteristics are reported here for reference. LOCOSTRA is based on a 77hp, 4WD small tractor, 3.5m long, 1.45m wide and 2.3m high. The only components added to the original tractor are:

- Innovative blast resistant wheels, designed to resist several explosions (at least 5) while protecting the tractor from damages caused by the explosions. Wheels are essentially built around a COTS solid rubber wheel embedded in an outer steel structure providing ventilation and protection.
- Remote control system, designed to allow driving the tractor from the safe distance of 100m. Its of industrial type and with a very simple human machine interface. Only essential commands are actuated remotely by electro-hydraulic valves mounted in parallel to hydraulic valves that were on board in the original tractor. Therefore LO-COSTRA can be driven both on board with traditional commands and remotely by the transmitter.
- Armouring; simple metal sheets 3mm thick are mounted to protect delicate parts. LOCOSTRA reached Jordan equipped with agricultural pneumatic wheels, pulling an agricultural trailer containing tools needed for the test. This configuration was used to drive LOCOSTRA to the test sites and for short distance movements. Among the tools contained in the trailer were the blast resistant wheels, a small crane plus hoist to be mounted at the back of the tractor for loading and

<sup>&</sup>lt;sup>58</sup> Snail Aid Technology for Development, Via Cabella 10/12, 16122 Genova, Italy; <u>patfordemining@gmail.com</u>



Fig.1. LOCOSTRA and trailer, LOCOSTRA and ground processing tool (potato digger), LOCOSTRA and mulcher.

unloading the trailer, an UPEX large loop detector kindly provided by Ebinger, but unfortunately not used for tests, and a mulcher kindly provided by FAE – Advanced Shredding Technologies, UML/ST 150 type. The University of Jordan kindly provided the ground processing tool that was used during the test: a potato digger produced by Nardi / Elli Spedo, model type CP-BD-150.

#### 2. Test conditions

The test took place in two different locations: in the safe area in front of the minefield Sabha12 along the boarder with Syria, near to Jabir village (later on referred to as Jabir test site) and in the suspected hazardous area (SHA) near to the border with Israel near to Karama village in the Jordan Valley (later on referred to as Karama test site). Jabir test site had no vegetation and class I soil (according to the CWA 15044:2009); Karama test site had vegetation and class I soil.

The test protocol followed as much as possible the CWA15044:2009 and took place in three subsequent phases: Performance test, Survivability Test and Acceptance test. Depending on the vegetation and on the landmines used, LOCOSTRA was equipped with the ground processing tool (GPT), i.e. the potato digger, or the vegetation cutting tool, i.e. the mulcher, or with no tools. More information on the test protocol and on test results can be found in the reports [1],[2].

#### 3. Performance test

The performance test of LOCOSTRA equipped with the GPT took place in Jabir test site, while the performance test of LOCOSTRA equipped with the vegetation cutting tool took place in Karama test site. Due to the fact that the test area in Karama was a suspected hazardous area, the performance test here coincided with the acceptance test of LO-COSTRA equipped with the mulcher.

LOCOSTRA equipped with the GPT was tested along one lane, as only one type of soil was available, where three different types of landmine wooden targets were previously buried at different depths. The lane was divided in three sectors and three fibreboards 3mm thick were buried into the lane at the beginning of sector A, between sector A and sector B and at the end of sector B. A total of 42 targets were used. According to the CWA 15044:2009, mine targets depth was measured from the top of the mine to the soil surface. Results are summarized in table 1.

depth	target mines deployed	target mines removed
0mm	11	11/11
5cm	11	9/11
10cm	11	0/11
10cm*	3	2/3
15cm*	6	5/6

Tab.1. LOCOSTRA and ground processing tool, performance test.

Results signed with the asterisks are relative to the third sector, sector C. Before approaching sector C, modifications to the length of the third point linkage connecting the GPT to the tractor were made to achieve a deeper soil processing.

#### 4. Survivability test

The survivability test was done on the GPT mounted on LOCOSTRA. In order to be sure that the mine would be exploded by the tool it was decided to bury the live mines flash with surface underneath the GPT and activate them by the GPT weight, by lowering the three point linkage system (trough which the GPT is connected to the tractor) by remote control.

First a live M14 mine, containing 28g of Tetryl, was placed under the first blade of the GPT near to the left hand side (looking at the GPT attached to the tractor from the tractor). The mine was buried flush with surface. The engine was started and the three point linkage system lowered on the mine, remotely. Secondly, a live M35 mine, containing 100g of TNT, was placed under the second blade of the GPT near to the right hand side. The mine was buried flush with surface. The engine was started and the three point linkage system lowered on the mine, remotely. Results are summarized in table 2.



Fig.2. Performance test of LOCOSTRA equipped with ground processing tool (potato digger).

live mine type	damag	repairs	
M14		The blade under which the M14 mine was placed bent 60mm upwards at the very tip. The blade near to it bent in the middle 15mm.	The blade that bent 60mm was removed and hammered back to its original shape in half an hour
M35		The blade under which the mine was placed detached and was found 1.3m away from its original position, underneath the tractor. The lower right linkage was slightly deformed probably because hit by the blade.	The blade was placed back into its original position using new screws.

Tab.2. LOCOSTRA and ground processing tool, survivability test.

#### 5. Acceptance test

The acceptance test was divided in two major phases that took place in two different test sites. The first major phase was done in Jabir test site, where LOCOSTRA was tested in three lanes where live mines were buried at different depths: a lane where 4 M14 (28g of Tetryl) live mines were buried, a lane with 3 M35 (100g of TNT) live mines buried, and in a lane where 2 PMN (240g of TNT) live mines were buried. The three parts of the first phase were called phase 1.A, 1.B, 1.C. In the first two LOCOSTRA was tested equipped with the GPT, in the last one, phase 1.C, LOCOSTRA was tested alone, without attachments.

During the first phase, live mines were buried only at two different shallow depths (0cm and 5cm) in order to increase the possibility for the tractor wheels to actuate the mines and for the GPT to process mines. Moreover, this was considered to be the worst case scenario both for damages possibly caused to the wheels and the tractor and to the GPT. Test lanes were prepared in class I soil, the only type of soil available in the Jabir test site, by running the tractor first on the test site to leave footprints on the soil and make it easier to dig the holes for mines in the right places. Holes were dug trying to disturb the soil as little as possible. The second major phase was done in Karama test site, with LOCOSTRA equipped with the mulcher. The machine was used to clear vegetation and process the top soil in a suspected hazardous area (SHA) covered by low, medium and high vegetation. The schemes of the test lanes of phase 1.A, phase 1.B and phase 1.C are reported in table 3, table 4 and table 5, together with results.

scheme	mine name	depth	mine location	result
4,2m	A	5cm	under rear right wheel	exploded by the wheel, without causing any damage
14m	В	5cm	under front left wheel	not exploded
16m B. 5cm deep	С	5cm	in between track footprints	exploded by the right wheel of the GPT, causing little damage to the wheel
A. 5cm deep				
potato digger	D	0cm	in between track footprints	removed by the GPT and left 65cm away from its original position. The mine was not damaged by the GPT

Tab.3. LOCOSTRA and ground processing tool, phase1.A of acceptance test.



Tab.4. LOCOSTRA and ground processing tool, phase1.B of acceptance test.



Tab.5. LOCOSTRA and ground processing tool, phase1.C of acceptance test.

LOCOSTRA equipped with the mulcher kindly provided by FAE Advanced Shredding Technologies was tested along two days of work. Because of the availability of three different types of vegetation the machine was tested in all of them. Details of the test results can be found in table 6.

Vegetation type	n° of lanes processed	total area processed	time
low	3 lanes	75m2	149s
medium	3 lanes	100m2	240s
high	2 lanes	40m2	253s

During the test no explosion occurred. Personal protective equipment and protective boots were worn by the test team, a metal detector was used to check for the presence of mines while investigating the area processed, but no mine was found.

#### 6. Conclusions

The overall result is very satisfying and proves that the innovative concept of LOCOSTRA is good: LO-COSTRA tractor equipped with agricultural tools readily available on the market can successfully be employed in humanitarian demining activities. LOCOSTRA resisted well, without needing any repair four explosions, as described in figure 3. The

121

worst explosion was the one with 269g of explosive. Also this last one didnt cause any damage.

The tests with the GPT opened up space for further study and a proposal on the possible application of agricultural tools in demining has already been written and submitted. Even if the GPT would benefit from further studying, it proved to be a very efficient tool for ground processing and mine removal. In fact, the GPT successfully removed mines down to a depth of 5cm without exploding them. When tested with target wooden mines, after adjusting the length of the third point linkage, it reached the working depth of 15cm. Damages recorded after the survivability test were very localized and easy to repair. The cost of the new bolts was 2.5 €, the time to hammer back in original shape the deformed blade was less than 30min. The combination of LOCOSTRA with the mulcher proved to be ready to be exploited in mine action activities. LOCOSTRA with the mulcher successfully cut low, medium and high vegetation up to small trees 15cm in diameter. Especially during the pre-test in Italy, where LOCOSTRA equipped with the mulcher was tested in forest-like area, the high agility and great efficiency of the machine could be appreciated. Thanks to the double steering system, the tractor could turn around the bigger trees (that generally do not have to be cut) and cut all the others. Moreover, the mulcher capacity to slightly process the soil was also appreciated, as it can be seen from figure 3.



Fig.3. Explosions occurred under LOCOSTRA, an M14 mine removed and processed by the GPT without explosion, the worst damage caused to blast resistant wheels (very light) after a PMN explosion, medium vegetation before and after clearance.

#### 7. References

[1] WP3\_Task3.6\_Deliverable\_v5, LOCOSTRA in field test protocol. Will be available soon on project website, www.snailaid.org

[2] WP3\_Task3.9\_Deliverable\_v1, LOCOSTRA in field test protocol. Will be available soon on project website, www.snailaid.org

#### Careful Walking on Soft Terrains with Deformable Robots

Jonathan Lepinette<sup>64</sup>, Matthew Valente<sup>65</sup>, and Thrishantha Nanayakkara<sup>64</sup>, Member, IEEE

Abstract — This paper discusses the interplay among the visco-elastic parameters at the groundleg contact point of a legged walker and the emerging properties of interaction dynamics of walking on soft terrains. Two prototype robots with segmented bodies and passive elements at the legs and the buffer have been discussed to highlight the importance of giving due consideration to the above interplay in the design of field robots to be deployed in an area reduction or quality assurance phase of a humanitarian demining process.

#### I. INTRODUCTION

Throughout the world many countries have been affected by Antipersonnel Mines (APM) and their effects. The complexity and difficulty of detecting and clearing APM represents a global challenge for the humanitarian demining (HD) community. Currently, demining processes need to be completed in shorter time frames, with better safety at an affordable cost, and with the use of easily transferable and efficient technologies. Previous work has identified opportunities for robotic solutions (Carruthers, A. et al., 1999; UWA, 1998; GICHD, 2002b), guidelines for the development (UNMAS, 2003b), and procurement (UNMAS, 2003a) of technology applicable to the mine action domain. Applying robotized solutions to HD is a challenging and realistic objective from both scientific and technical points of views. There is an open need for a reliable and accurate technique that accelerates the HD processes with acceptable safety and quality measures.

Among many different phases of the demining process – area reduction, actual demining, and quality assurance - the robots are best suited for risk assessment in the area reduction and quality assurance phases because the primary objective is risk assessment, and consequently probabilistic (Pedro F. Santana; José Barata & Luís Correia, 2007). Therefore, even though a mine detector mounted on a robot may not provide 100% area coverage, it can be used as a back up source of information for the decision making process with minimum damage to the environment. However, area reduction involves moving into an abandoned land with overgrowth and years of soft deposits.

A robot should survive the variability of the interaction dynamics with such visco-elastic soft terrains. The quality assurance stage poses less mobility issues to a robot since it is often carried out on cleared lands after vegetation cutting. However, the challenge of locomotion on soft terrains will be shared even in this phase (Habib, 2008).

Although demining machines have been developed in several forms, they often find it hard to move through clutter and overgrowth. Most of these APM contaminated areas are densely vegetated and populated so there isn't enough space to bring in large and unwieldy machines. Furthermore, these large scale machines remove or disturb the uppermost soil layer which is fertile and extremely valuable for agricultural purposes. However, on the other hand, mobility of lightweight robots that cause less damage to the environment is severely constrained in unstructured environments typically found in the area reduction phase. Despite broad R&D efforts in multisensory fusion and robotic technologies, the detection and clearance processes remain unsatisfactorily robust (Cornelis, J. & Sahli, H., 2003). Due to these technological limitations, manual operators with metal detectors continue to be the current practices, since they are believed and perceived to be more reliable. This is the case especially in the phase of close-in detection and actual neutralization.

Therefore, a robotic system capable of maneuvering through thick vegetation, inclined surfaces, and soft terrain will significantly improve the efficiency of the area reduction phase based on statistical information of APM distributions. The design

<sup>&</sup>lt;sup>64</sup> Jonathan Lepinette and Thrishantha Nanayakkara are with the Division of Engineering, King's College, University of London, Room 1.23, Strand Building, Strand, London, WC2R 2LS, UK (phone: +44-(0)20-7848-2256; fax: +44-(0)20-7848-2932; e-mail: jonathan.lepinette@kcl.ac.uk, thrish.antha@kcl.ac.uk ).

<sup>&</sup>lt;sup>65</sup> Matthew Valente is with the School of Engineering and Applied Sciences, Harvard University, USA (e-mail: siliconcenturion@gmail.com).

approaches to such field robots can benefit from a theoretical knowledge in the dominant features of emerging interaction dynamics between a robot and visco-elastic terrain.

This paper discusses a theoretical model of the interaction dynamics between a walker and the visco-elastic terrain. The theoretical claims were tested using two prototype robots designed to combine the advantages of legged locomotion, passive deformation of a split body mechanism, and a rimless wheel mechanism.

## II. Current challenges in robotic locomotion

There are three main recognized categories of robotic systems: Tele-operated Machines, Multifunctional tele-operated robots, and demining service robots (Habib, 2002a).

*Tele-operated machines*: miniature versions of the flail type machines have been developed such as the Light-Flail. This type of machines are large and unwieldy as well as being only effective in sparsely vegetated environments. They also exhibit difficulty in flailing in soft soil, and can inadvertently scatter mines into previously cleared areas (Habib, 2008). Similarly, other machines such as remotely operated vehicles from Kentree Limited or Pookie from Trevos Davis Engineering also show difficulties in moving through soft terrains or environments with overgrowth. This is mainly due to their large sizes and wheels inefficiency, they also can damage soils.

Multi Functional Tele-operated Robots: they are remotely operated vehicles with on board robotic manipulation mechanisms and sets of task oriented tools (Havlík, 2005). Commercial products such as the ROV, an articulated modular robotic mine scanner (Engineering Service Incorporation (ESI)) has a locomotion strategy based on wheels and tracks. Although this type of robot is designed to perform in dense environments with sand or soft soils, the ROV is an expensive and heavy robot; therefore it doesn't comply with the requirements of a safe, easily transferable and affordable technology that this study aims to validate. Furthermore, the Multi Functional tele-operated robot category also encompasses systems like vehicles with added vegetation cutters or costly multi-sensing technologies, there again there is an issue with size, cost of the machine and its damage to environment. The six legged Robots COMET I, II and III from Chiba University in Japan, they are some of the only fully autonomous robots being researched. COMET I weighs 1000kg, 4m long, and is powered by a

gasoline engine driving a generator and hydraulic pumps (Habib, 2008). Due to the high weight of the platform, its legs may easily sink in soft terrains (Habib, 2002b).

Demining Services Robots: Although, some of the previous technologies have demonstrated lack of adaptability to soft terrains and vegetated environments as well as unbalanced cost-effectiveness, this category is close to the focus of this study. They include systems such as the Shrimp Robot (EPFL/ Switzerland), a purpose-built demining robot prototype platform that utilizes passive compliance. This robot is extremely small, weighing only 5.4kg and capable of carrying a 3kg payload (BlueBotics, 2005). The unique design allows the structure to passively adapt to any obstacle in its path. Shrimp III has not yet been testing in a demining environment, but it illustrates the path which humanitarian demining robots have begun to take. Similarly, AMRU and Tridem (I and II) are legged systems that are fitted with wheels at the tip of each leg, compliance is offered from the legs but the wheels will reduce the grip to soft terrains. This approach provides improvements in terms of penetration through dense vegetation but the wheels will ultimately reduce adherence to ground in those environments with soft soils.

Other robotic platforms like the RHex, a simple hexapod robot, utilizes compliant legs that rotate in a circle, similar to the hybrid approach taken in this project. Six of these compliant legs are attached to a rigid body, each leg powered by an individual actuator. Using this mechanism, the robot illustrates a highly successful implementation of compliant legs and how they greatly aid locomotion. RHex is able to traverse unstructured terrain with a payload (Saranli et al., 2001). The RHex project has been created as the culmination of 5 years and nearly 8 million dollars in government grants. Aspects such as the cost and maintenance requirements make the robot unsuitable for HD projects. In general, the main open technical challenges are to improve mobility on soft terrains while reducing the weight of field robots available to assist in various phases of humanitarian demining (Nanayakkara, 2010).

## III. Emerging interaction dynamics of legged locomotion on soft terrain

Animals are able to use legs (and other mechanisms) to a high level of effectiveness in soft and rough terrains. Legs, joints, and bodies are flexible, allowing quick adaptability to whatever terrain the creature encounters. This results in high

levels of stability, excellent traction, and a very robust system of locomotion. In this context the robot platform would have to be able to move through springy and readily deformable soil conditions, and thus make the best use of passive dynamics of locomotion. As it maneuvers through uncertain terrain structures, an important criteria for the prototype's design is static and dynamic stability, thus increasing passive compliance would be the best solution for the robot to be able to adapt to the changes of environment as it moves.

#### A. Locomotion



Figure 1: The hybrid wheel-leg mechanism

From the previously discussed range of available robots, locomotion components include legs, tracks and wheels. The first design approach relies on the implementation of a hybrid wheelleg system that is implemented as a center wheel hub with leg-like spokes protruding. This approach was chosen due to its advantages over a traditional wheel. In soft terrain, wheels are very inefficient due to the characteristics of soil deformation. As the wheel rolls through soft terrain, a portion of the torque always compresses the soil, creating a crevice that the wheel sits in. The other part of the torque of the wheel is used constantly climbing out of this crevice as shown in figure 2. The leg allows the system to have more adherence over deformable grounds as it uses little energy to compress the soil and no energy to lift out of the soft terrain as shown in figure 3. In addition, this particular design also increases the robot's ability to climb over obstacles as shown in figure 4 due to the fact that legs benefit from greater frictional force at the edge of the obstacle.



Figure 2: Wheels and Soil deformation



Figure 4: Wheel and legs scaling obstacles.

The aspect ratio of an obstacle which can be scaled this manner is only limited by the radius of the leg, which must be able to make contact with the top of the obstacle.

# **B.** The relationship between the velocity profile and the visco-elastic properties of the contact point

We model the interaction between the leg and the soft ground as shown in figure 5, where *M* is the mass of the robot's body, *L* is the length of a leg,  $\alpha$  is the angle between two legs of the rimless wheel,  $\gamma$  is the angle of the slope, *x* is the visco-elastic displacement of the ground contact point along the surface, *y* is that perpendicular to the surface, *K* is the elasticity, and *C* is the viscosity at the contact point. The viscosity can also come from Coulomb friction. Then the dynamics can be written as given in equations (1) and (2).



Figure 5: The schematic diagram of the ground contact model for a rimless wheel.

$$\begin{bmatrix} \ddot{x} \\ \dot{x} \\ \ddot{y} \\ \dot{y} \end{bmatrix} = \begin{bmatrix} -\frac{C}{M} & -\frac{K}{M} & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & -\frac{C}{M} & -\frac{K}{M} \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{x} \\ \dot{y} \\ y \end{bmatrix} -----(1)$$
$$+ \begin{bmatrix} g\cos(\theta + \gamma) + L\ddot{\theta}\sin\theta - L\dot{\theta}^{2}\cos\theta \\ 0 \\ g\sin(\theta + \gamma) - L\ddot{\theta}\cos\theta - L\dot{\theta}^{2}\sin\theta \\ 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ \dot{\theta} \end{bmatrix} ----(2)$$
$$+ \begin{bmatrix} \frac{g\cos(\theta + \gamma) + \ddot{x}\sin\theta - \ddot{y}\cos\theta}{L} \\ 0 \end{bmatrix}$$

Figures 6 and 7 show the movement at the contact point in x and y directions, the angle and angular velocity of the rimless wheel for two different viscoelastic conditions. It can be seen from figures 6 and 7 that the evolution of the velocity profile is not deterministic, but show stochastic properties governed by a combination of the viscous and elastic coefficients K and C. Therefore, an intelligent walker can benefit from using an estimate of the distribution of viscous and elastic coefficients at successive contact points to predict the future evolution of its velocity profile. On the other hand, a walker's ignorance of such emerging stochastic dynamics may lead to inefficient counter measures when in fact the passive dynamics could be used to minimize energy spent on controlling the velocity. Then we plotted the history of velocities just before collision with the ground for different K and C, in order to understand the periodic properties of the velocity profile across different visco-elastic conditions at the contact point.



Figure 6: The evolution of ground deformation, angle, and the angular velocity of the rimless wheel for K=1000[N/m] and C=100[Ns/m]



Figure 7: The evolution of ground deformation, angle, and the angular velocity of the rimless wheel for K=1000[N/m] and C=10[Ns/m]

K<4000[*N*/*m*] and C>60[*N*s/*m*] for this particular rimless wheel. Most conventional controllers that set a desired speed of locomotion run into inefficient control measures when the walker's passive dynamics exhibit period bifurcation. An intelligent walker may take radically different approaches such as changing the internal stiffness and damping to move to another locus of more predictable profile of velocities.



Figure 8: The history of angular velocities of the rimless wheel just prior to collision with the ground for K = 10 - i1000[N/m], i = 1,2,3,..., 6 andC = j [Ns/m], j = 1,2,3,..., 100

#### C. Prototype development and testing

The first design was aimed at decoupling the asymmetrical stochastic dynamics developing on either sides of a walker on soft terrain conditions. This was achieved by a segmented body mechanism as shown in figure 9. It was expected that the decoupling would allow the robot to move on an uneven soft terrain without compounding any disturbances experienced due to uneven terrain profile.



Figure 9: Body segmentation

In order to test the hypothesis that a segmented body will be efficient and stable in unstructured soft terrains, we conducted experiments on thick brush as shown in figure 10. The robot not only accomplished a move across a 6m patch of brush with limited on-board power, but also left no trace behind. A wheeled robot in contrast, would waste energy in crushing the vegetation and leave an unwanted trace.



Figure 10: Outdoor experiments in thick brush.

Further improvements on the wheel system were undertaken on an additional prototype, the objective was to introduce compliance within the leg spokes. Our modeling studies in figures 6-8 show that lower viscosity helps a walker to move away from period bifurcation of the velocity profile. Considering that the soils with which the wheels are interacting have spring-like and deformation properties, we predict that a passive element in the wheel would help the robot to keep a predictable and efficient velocity profile where the robot stores energy at collisions and releases it in the subsequent movement. In addition, the leg extremities are also equipped with a deformable/ shock absorbent rubber pin (Figure 11). The proposed design improvement also decreases the chances of the wheel-leg system to sink into muddy or humid soils.



Figure 11: Prototype spring system leg design

Figure 12 shows the fabricated outcome of the investigated design in a vegetated environment.



Figure 12: Fabricated wheel system prototype

#### D. Stability and passive degrees of body

In addition to the improvement in the interaction dynamics with the soft terrain, mechanical compliance allows the shape of the robot to adapt to the terrain, offering a large increase in the stability of movement over uneven terrain. Compliance is implemented in two different aspects of the robot in order to maximize the utility of this technique. By making the legs out of compliant material, obstacles and terrain disturbances local to that leg can be decoupled from the rest of the robot. E. Improvements based on field trials We conducted field trials in Sri Lanka in 2009 in collaboration with the demining units of the Sri Lanka army. Follow up suggestions were used to improve some design features of the system. The first was the implementation of paws on the wheel's legs extremities in order to increase the contact area. The design solution to this suggestion is discussed and presented in the locomotion section of this paper. Figure 13 below shows the initial idea behind the further developments.



Figure 13: The improved paws mechanism to minimize energy loss at collisions and sinkage in muddy terrains.

Another suggestion was to introduce a deformable buffer to improve the locomotion efficiency by wedging through bushes or dense vegetation as well as being able to move around the larger obstacles. There again, the concept of the damper spring system was utilized to produce a deformable wedge that is able to absorb shock and guide the machine towards an alternative route. In addition, the front buffer has the purpose of working as a force sensor to estimate the stiffness of vegetation. From a practical point of view, the added buffer component will act as a bumper. Thus, it will act as a protective semi circle at the front, preventing mounting accessory such as the detector to collide with external obstacles like trees. Experts suggested that the buffer should be made out of a non-metallic material.

In order to obtain performance indicators on those two design suggestions, a simplified prototype comprising only those two features was fabricated in the frame of further research. The aim of this prototype is to evaluate and model the effects of the modified design features. The simplified robot was constructed out of simple materials therefore it complies with technology cost and requirements. The wheel's hubs are made out of wood, whereas the legs are composed of brass cylindrical tubes. The paws at the end of each leg are natural rubber. The main body frame is also wood material and the front plastic was conceptualized with deformable resistant plastic. Figures 14 show the completed simplified prototype from different angles.

Further experiments will be conducted on passive walking down a ramp as illustrated in figure 14. Passive walking is best poised to understand the properties of interaction dynamics that can not be seen when the robot is actively controlled. Further tests will be conducted on different types of ramps or natural curves to fully evaluate the performance in different terrain conditions. In addition, obstacles will be placed to assess the efficiency of the front buffer to absorb collision forces to passively guide the robot towards safer directions.



Figures 14: The second prototype with visco-elastic passive elements at legs, and a deformable buffer maneuvering down a steep curve in Hyde Park, London.

#### Acknowledgements

This work was partly supported by a grant from the Engineering and Physical Sciences research Council, UK, Radcliffe Institute for Advanced Studies, Harvard University, and Harvard Committee on Human Rights.

#### References

BlueBotics 2005, Shrimp III Specification, <u>http://</u> www.bluebotics.com/solutions/Shrimp/specification.php

GICHD (2002b). *Mine Action Equipment: Study of Global Operational Needs*, The Geneva International Centre for Humanitarian Demining (GICHD), Geneva, Switzerland

Habib, M. K. (2002a). Mine Clearance Techniques and Technologies for Effective Humanitarian Demining. *International Journal of Mine Action*, Vol. 6, No. 1

Habib, M. K. (2002b). Mechanical Mine Clearance Technologies and Humanitarian Demining: Applicability and Effectiveness. Proceedings of the 5th International Symposium on Technology and Mine Problem, California, USA, April 2002

Habib, Maki K. (2008) Humanitarian Demining: Innovative Solutions and the Challenges of Technology, Book edited, pp. 392, I-Tech Education and Publishing, Vienna, Austria

Havlík, Š. (2005). A modular concept of robotic vehicle for demining operations. *Autonomous Robots*, Vol. 18, 2005, pp. 253-262.

Nanayakkara , T; Sahin, F; Jamshidi, M, (2010) Intel-

*ligen Control Systems with an Introduction to System of Systems Engineering*, CRC press, Taylor and Francis group.

Sahli, H., Bottoms, A.M., Cornelis, J. (Eds.), 2003. EUDEM2-SCOT-2003, International Conference on Requirements and Technologies for the Detection, Removal and Neutralization of Landmines and UXO, 15–18 September 2003. Vrije Universiteit Brussel, Brussels, Belgium, 2003

Santana, P; Mestre, A.; Barata, J. & Flores, L. (2005a) Roadmap for Mine Action Robotic Technology Development. *Journal of Mine Action*, Vol. 9, No. 1, pp. 89-91

Saranli et al., (2001) Haldun Komsuoglu, Dave Mc-Mordie, Uluc Saranli, Ned Moore, Martin Buehler, Daniel E. Koditschek: Proprioception Based Behavioral Advances in a Hexapod Robot. ICRA 2001: 3650-3655

UNMAS (2003a). IMAS 03.10 - *Guide to the procurement of mine action equipment*, United Nations Mine Action Service (UNMAS), New York, USA

UWA (1998). Deminer's Needs, Available from: <u>http://www.mech.uwa.edu.au/jpt/demining/</u> <u>needs/de miner-needs.html</u>, Accessed: 2006-11-10, University of Western Australia

# The Tastiest Croatian souvenir!



Gaurilović

Ininia

Ora salama, paysonapina pi tap masturi, sagayonta p 50 dan pad budaan paype





delight



tradition

### **DOK-ING Mine Clearance Systems**

# **Your Safe Side of Demining**



### DON'T SEND A MAN TO DO A MACHINE'S JOB!

More than 100 DOK-ING Mine Clearance Systems are in operation around the world. The highly efficient systems have been safely clearing mine contaminated areas for over 10 years with no reported injuries to operators.

#### MV-4 – Mine Clearance System

- · Remote operating distance: up to 2000 m (6600 ft)
- Mine clearing capacity: 944 2,184 m<sup>2</sup>/h (10,160 23,500 ft<sup>2</sup>/h)
- Digging depth up to: 30 cm (1 ft)
- Resistance: on AP mines and UXO
- Easy transport: on trailer, in container, by helicopter or airplane
- · Additional tool attachments: flail, tiller, roller, blade and gripper



#### MV-10 – Double Tool Mine Clearance System

- Remote operating distance: up to 2000 m (6600 ft)
- Mine clearing capacity: 1,500 4,500 m<sup>2</sup>/h (16,145 48,437 ft<sup>2</sup>/h)
- Digging depth up to: 60 cm (2 ft)
- Resistance: on UXO, AP and AT mines
- Easy transport: on flat-bed trailer, in container or by airplane
- Additional tool attachments: flail/tiller, blade/gripper and roller

DOK-ING, Žitnjak bb, 10000 Zagreb, Croatia, Europe Phone: + 385 1 2481 300, Fax: + 385 1 2481 303 e-mail: dok-ing@dok-ing.hr, www.dok-ing.hr

Pictures may not represent actual model of MV-4 and MV-10.





www.ddsv.hr



We bring you the world's best demining machines produced by Istrazivac:

**VF - 100 and VF - 001** 



**VF** - 100

- Human control
- Balistic protection
- Heavy construction

VF - 001



- Field proven
- Remote control
- Heavy construction



• www.istrazivac.hr •

Istrazivac d.o.o. Bana Jelacica 29a 32221 Nustar Croatia, Europe

Tel. + 385 32 338 356

# VALLON MINE & UXO DETECTION

Metal Detector VMH3CS with pinpointing feature

60-cm-Search Head for deep lying metal cased mines / UXOs

UXO Detector VMXC1-3 with special firmware to detect country-specific submunition



Dual-Sensor-Detector VMR3 GPR and metal detector to detect metal and metal-free objects

Vallon GmbH has been a manufacturer of mine detectors for more than 40 years. The own R&D division develops hand-held mine detectors, hand-held bomb locators, vehicle mounted multi sensor detection systems, navigation tools for the field work, and powerful software for automatic evaluation of the detector data and following identification of UXOs.

Vallon GmbH's engineers and technicians work closely with the users in order to integrate their requirements into the equipment.

Additional tools for EOD and demining are offered by Vallon's subsidiary company Force Ware GmbH. For more information please visit www.forceware.de.



Customized Vehicle-Mounted Detection Systems, for example VMV8

Vallon GmbH • Im Grund 3 • D-72800 Eningen • Phone: +49.7121.9855-0 • Fax: +49.7121.83643 E-Mail: info@vallon.de • Internet: www.vallon.de



### **RELIABLE • EFFICIENT • VERSATILE**







Bozena 4







### THE BEST CHOICE FOR SAFE WAY FORWARD

NCAGE 1001M





ina sustan

Priemyselná 937/4 963 01 Krupina, SLOVAK REPUBLIC Tel.: +421 2 393 902 39 Fax: +421 2 399 000 08 E-mail: info@bozena.eu

www.bozena.eu



## ON THE SPOT SECURITY

#### Safe

Contact free disposal of UXOs and mines No interference with electromagnetic products

#### Versatile

Low and high order missions Electrical or pyrotechnical ignition

#### Qualified

UN and NATO qualified Used in more than 50 countries



Saab Bofors Dynamics Switzerland Ltd Allmendstrasse 86 CH-3602 Thun/Switzerland Phone: +41 33 228 27 24 | Fax: +41 33 228 27 91 Web: www.saabgroup.com/sm-eod E-mail: sbds@saabgroup.com



## **Complete Mine Action Solutions**







#### HCR-CTRO d.o.o.

- Sortina 1d, 10020 Zagreb,
- CROATIA
- Phone: +385 1 650 0020
- Fax: + 385 1 652 0301
- e-mail: nikola.pavkovic@ctro.hr
- www.ctro.hr

With its testing capacity (test sites and equipment) and highly professional staff, the Centre offers the following services:

- testing and certification of:
  - demining machines
  - mine detection dogs
  - metal detectors, PPE and prodders
- field testing and operational validation of technologies used for mine contaminated area detection and mine suspected area reduction
- training and issuing certificates for the use of metal detectors
- training of EOD officers, worksite managers, demining teams and monitoring personnel
- organizing workshops, conferences and other gatherings on the subject of mine action
- preparation for introducing quality management in demining companies as per ISO 9001:2000
- lease of test sites
- implementation of research and development projects in the field of mine action