October 2010

The Advanced Intelligence Decision Support System for the Assessment of Mine-suspected Areas

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that the behavior of four of the six dogs was biased toward indicating, and this bias strength decreased as reinforcement for hits increased for all six dogs. The behavior of two dogs was biased toward ignoring, and this bias was unaffected by reinforcement-rate manipulations. Thus, the present procedure appeared to not produce consistent effects on response bias, nor did it produce bias in one direction over another. Instead, each dog tended to maintain a fairly reliable preference for either indicating or ignoring, and biases toward indicating were counter-intuitively reduced by increasing reinforcement availability for correct indications.

REST programs should include ongoing monitoring of response bias, so they can reduce any imbalances. Manipulation of reinforcement rates can eliminate response bias more easily in procedures where responses to positive and negative filters are directly reinforced. In procedures where responses to only one type of filter are reinforced, such as in the present REST system, response bias may be eliminated by careful manipulation of the ratio between positive and negative filters. REST programs should seek to determine the optimum ratio for their procedure and animals, and maintain this ratio while continuing to monitor ongoing response bias.

Other factors which affect the overall accuracy of animals’ responses concern the quality of the samples. Sampling can be optimized in terms of filter material, climatic condition, avoidance of contamination, and so on. Once collected, fibers should be handled to minimize cross-contamination. By maintaining as clear a signal on the filter as possible, the animal is given the best chance to obtain high hit rates.  

Author note: The authors conducted this research while employed by the Geneva International Centre for Humanitarian Demining, conducting research on landmine-clearance systems, studying the environmental influences on demining and developing the Remote Explosive Score (REST) system. McLean has taught environmental policy and wildlife management at the Universities of Otago and Waikato in New Zealand, and is currently raising his two children and consulting on environmental issues.

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After completing a Ph.D. in psychology, Rebecca J. Sargisson was a Research Consultant at the Geneva International Centre for Humanitarian Demining from 2003 to 2006 working on many aspects of the use of dogs in demining. Sargisson is currently employed by the University of Waikato, New Zealand. She remains interested in dog research but is also researching issues related to children’s play and playground design.

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The Advanced Intelligence Decision Support System for the Assessment of Mine-suspected Areas

Several research and development projects have been created to utilize airborne and spaceborne remote sensing for mine action, but the Advanced Intelligence Decision Support System is the first mine-action technology to successfully combine remote sensing with advanced intelligence methodology. The result is a rigorously operationally validated system that improves hazardous risk assessment for greater efficiency in land clearance and release. This article discusses the components of the AI DSS system and its achievements in mine action.

by Milan Bajic | University of Zagreb |

Application of AI DSS in the community. Figure 11 (left): The state of the mine-suspected area (56 square kilometers) before the project. Legend: crossed pink for undergoing clearance, striped pink for undergoing survey, yellow if used on owner’s responsibility, blue if excluded from MSA. Figure 1.2 (right): The state of the MSA after the application of AI DSS, as carried out by CRFAMAC. Note the MSA reduction in the southern part of the MSA caused at the edge of Lebl Mountain. Legend: crossed pink for undergoing clearance, striped pink for undergoing survey, yellow if used on owner’s responsibility, blue if excluded from MSA.

The Croatian Mine Action Centre tries to reduce mine-suspected areas by using conventional technologies such as General Surveys, however, the repeated use of these mechanisms eventually becomes ineffective and ground-based costly means (skimming, Technical Survey) called Non-technical Survey) and reduction of mine-suspected areas while International Mine Action Standards define wider and more general aspects of general mine-action assessment and land releases.

Development of AI DSS

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must then be used. CROMAC has tried to re-
duce these costs by supporting the develop-
mement of more efficient technologies.10,11

Hopes of such a cost-effective solution arose through the development of the SMART system, an advanced intelligence system that
arose through the development of the SMART development projects, SMART and Airborne
imagery and multisensor airborne imagery
served as the data’s main sources. CROMAC’s
use of AI DSS has resulted in increased land
cancellation/release and improved hazardous-
areas management. AI DSS was deployed in Croatia, and its application is underway in Bosnia and Herzegovina.10 Other countries/associations from
as use as well through regional cooperation and
capacity-building efforts.10

Advanced Intelligence Methodology and Technology

The AI DSS is a system and technology that
combines the following main subsystems:
• Analytic assessments and derivation of
statements of operational needs about the
data availability and quality, and informa-
tion in the Mine Information System and
Geographic Information System of the MAC. The experts within CROMAC made these assessments and derivations.10
• The airborne multisensor acquisition system
and satellite imagery usage, which provide
new data about an MSA’s state, such as the
indicators of mine presence and indicators
of mine absence, with high accuracy and
confidence.12 The scientists from the Faculty of Geodesy at the University of Zagreb, in cooperation with other
researchers and pilots, applied this sub-
system. This partnership proved very suc-
cessful in Croatia and in BiH.11
• The subsystem for multi-level fusion and
multi-criteria, multi-objective processing, and
interpretation and production of output-
puts, operated by remote-sensing scien-
tists and researchers from the Faculty of
Geodesy at the University of Zagreb.10
SMART’s genetic methodology and its
theoretical background are presented in sev-
eral references.10,11 Therefore only AI DSS
advancements that go beyond the SMART
system are described in the following sections.

Generating the statement of needs. The
intelligence applied in AI DSS serves to re-
construct the spatial, temporal and situational
state at the scene during and after the mine-
bearing process. It starts with a data overview—
information existing in the MAC’s Mine
Information System. If military maps and/or
other military documents are available (e.g.,
orders, commands and reports), they are used
to define the situation at the MSA. Also, oper-
ational data sources in the MAC serve the
statement of operational needs as the set of
requirements related to the missing or low-
quality data, and methods and technol-
gies that can be used for their collection or
for improving their quality. Not every MAC
uses this process; it was developed and defined
only for the needs of the earlier research and
development projects, SMART and Airborne

Minefield Area Reduction (ARC) project,10,11
and was successfully ap-
plicated in the first operational project.12

The statement of operational needs will con-
train:
• The MAC’s analytical description and
assessment
• Map reconstruction of the minefield polygons based on the avail-
able minefield records and other data in the Mine Information System of the MAC.

Derivation of general and particular requirements. Once the state-
ment of operational needs is derived, the next step is developing two
requirement types: the general and the particular requirements for col-
lecting new data to replace missing or unreliable data or for improv-
ing information quality. The general requirements include analyzing
data on mine barriers, exploring mine incidents, analyzing military and
U.N. demining records and maps, and examining land conditions where
military operations occurred. The particular requirements are a set of
hypotheses based on available data sources in the MAC, and they pre-
sent desired results of the AI DSS application. In Croatia, due to envi-
ronmental changes at the scene that happened after the minefields were
lost, along with a lack of available data, only a percentage of the particu-
lar requirements and hypotheses derived in CROMAC were achievable.

Nevertheless, the airborne and spaceborne imagery processing and in-
terpretation can still provide valuable evidence about the indicators of
mine presence and indicators of mine absence at the minefield scene.

When the system is implemented and results are collected and deliv-
ered to the MAC, the next phase starts: application of the project results
in the MAC. The project results in this phase need to pass the SOPs for
results verification for General Survey within the MAC.12 Project results
in Croatia show that this verification process increases benefits pro-
duced by the project.12

Assessing the terrain’s impact. Observing terrain characteristics as
a means for identifying indicators of mine absence has proved valuable.
In the SMART project report from 2003,13 only several kinds of indi-
cators of mine absence were considered, so the addition of terrain fea-
tures as indicators of mine absence marked one AI DSS advancement.10

In the community of Gospić, one of the three communities in Croatia
where the project was implemented, the Velebit Mountain ridge was in
the MSA (see Figure 1.1 and 1.2 on page 69 with space evidence of the
minefields and military positions. The terrain’s slopes are the main fea-
tures for the accessibility evaluation and were analyzed for Velebit (see
Figure 3) in Gospić and are shown in Figure 4. The AI DSS application
results provided evidence that enabled CROMAC to exclude an MSA at
the Velebit Mountain ridge, except on several small areas (see Figure 3).

Evaluating quality of data/information. The quantitative evaluation
of the data quality, information and knowledge (from here on referred
to as data) is one of AI DSS’s important functions. It should cover:
• Data provided by the Mine Information System of the MAC
• Data collected and derived in AI DSS by airborne multispectral acquisi-
tion, by use of satellite multispectral imagery, derived contextual
information and experts’ knowledge

Evaluation of AI DSS sourced data will be considered later. The evalua-
tion of the Mine Information System sourced data should assess the prob-
ability of the data’s accuracy, confidence and completeness as the main
features of data quality; these are considered in the following sections.

Minefield records. Minefield records, if available, are usually the
most valuable sources of minefield data. In Croatia and in BiH, the
minefield records have similar structures and usually have 39 vari-
ables (e.g., cartographical data, minefield characteristics, number of

Figure 3. Changes of MSA at the ridge of the Velebit Mountain after the minefield polygons are excluded from underlying clearance, thus I excluded from MSA.

Figure 4. This diagram displays the correlation between the degree of slope and the area of MSA at the ridge of Velebit Mountain. The total area of MSA on Velebit’s ridge is 246,4 sq. km, with 4–36 sq. km of that land having a slope of greater than or equal to 35 degrees.
Military maps. Military maps, if they exist and are available, can provide information about the war history on the considered terrain and improve understanding about the spatial and temporal distribution of the units and the minefields. The most usable—although rarely available—are the maps of the engineers’ activities; they contain details of the spatial and temporal placement of minefields. The maps of higher ranked military personnel contain less data about the minefields but can provide contextual information about the scene. Separation lines, distribution of units and engineers’ preparation support the scene reconstruction and can provide the spatial frame for the detected indicators of mine presence or mine absence.

In the operational project in Croatia, military maps became available at the middle of the project, and their contribution was not used for the whole area or at every point during the project. In the operational project in BrahM, military maps were not available at all, but deminers who participated in the war reconstructed the battle-situation maps. Besides the military maps, auxiliary map sources can include mem-
ors of former military commanders. Although edited for publishing, these maps can add missing spatial, temporal and situational contextual information. In the operational project in Croatia, the memoirs were used in the analytic assessment of the MSA status and helped to better understand the MSA site’s behavior.

Aerial digital orthophoto maps as sources of indicators of mine presence. Aerial digital orthophoto maps, if they exist, are very important for AI DSS application. They serve as the cartographic reference that optimizes spatial accuracy of AI DSS products. In the preparation phase for AI DSS application they can be an auxiliary data source for strong indicators of mine presence, e.g., trenches, bunkers, shelters, unused paths, bridges, etc. However the digital orthophoto maps alone are not sufficient indicators of mine presence.

In the considered projects14,15 two types of digital orthophoto maps were available: panoramic at a scale of 1:5000 and color at the scale of 1:2000. If the digital orthophoto maps do not cover the areas outside the official MSA, Note that in Gospić, 6 sq km was added to the previously determined MSA. The digital orthophoto map did not cover this area. The radiometric compression decreased the digital orthophoto map utility for remnants-of-war detection. The quality of the aerial digital orthophoto map that has a ground resolving distance of 0.20 m is weaker for the detection of the remnants of war than the satellite image that has a ground resolving distance of 1 m.

The MSA borders delineated the digital orthophoto area at the fine scale (1:2000). Due to this mistake the digital orthophoto maps did not cover areas outside the official MSA. Note that in Gospić, 6 sq km was added to the previously determined MSA. The digital orthophoto map did not cover this area.

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Multisensor aerial imagery acquisition. The multisensor aerial system used in mine action’s first operational remote-sensing project16 and in current use17 was developed and realized in the project funded by the Ministry of Science, Education and Sports of the Republic of Croatia18 (Figures 7.1 and 7.2). The installation on the aerial platform (helicopters Mi-8 and Bell 206, airplane Cessna 172R) takes less than two hours. The system enables imagery acquisition in the strip mode and in a sequence of the frames of bandwidth of 2400 to 900 nm and from 4 to 14 µm, with several sensors. The hyperspectral scanner in imaging mode provides a strip mode image in 95 channels, in wavelengths 430 to 900 nm, using a multispectral camera in visible and near infrared bands. The inertial navigation unit is integrated into the pod’s sensor system and enables parametric geocoding of the hyperspectral data’s scan.

Extraction of data and formalization of experts’ knowledge. The preprocessing phase finishes after terrain analysis, after the multisensor aerial imagery acquisition and after obtaining the satellite multispectral imagery. The next phase is data extraction from these sources and information-quality assessment. This phase also includes a formalization of the experts’ knowledge, which provides contextual information correlated with the particular terrain. The objects that should be detected are defined as the indicators of mine presence and the indicators of mine absence; this is a valuable contribution from the previous R&D project19 (as shown in Table 1).

An example of the detection project’s indicators of mine absence includes the observations of the MSA recorded in 2009 in the MSA community of Gospić.20

Table 1. A list of the indicators of mine presence, indicators of mine absence and importance rank given by an expert in the MSA in the community of Gospić.

Indicators of Mine Presence (IMP) Importance
Minefield records 1
Mine accidents 2
Table marking of the minefield 3
Forts 4
Trenches 5
Bunkers 6
Natural objects modified to serve for fire action 7
Dry wall in a battle area 8
Shelters for artillery, vehicles, infantry 9
Brickers, masses of water ways 10
Dominant hill 11
Edges of forest 12
Forth 13
Helicopter landing area 14
Roads not in use (in a battle area) 15
Abandoned overgrown areas 16
Demobilized housing in a front line 17
Observation posts (usually for hunting) 18

Indicators of Mine Absence (IMA) Importance
Houses in use 1
Areas in use 2
Roads in use 3
Step terrains, slope greater than 30 degrees 4

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The data extraction is used by different remote-sensing interpretation methods and by subjective interpretation supported by different techniques (imagery enhancement, feature mapping, principal component analysis, etc). Experience from the operational projects17 shows
that the subjective computer-assisted indicators of mine presence extraction was the most efficient solution for the extraction of the remnants of war and similar objects (see Figures 7 on page 72). There are more efficient classification methods for indicators of mine absence extraction that usually cover larger areas. The goal of the considered activity is the cancellation and indication of mine presence and indicators of mine absence with high probability and at the same time provide very high confidence. For this purpose, we use images from one, two or more images that are from different sources until the accuracy of the detection and/or classification confidence. For this purpose, we use images from one, two or more images that are from different sources until the accuracy of the detection and/or classification confidence.

Quantitative spatial analyses of the terrain. Detection and extraction of the indicators of mine absence (IMA) and presence (IMP). Formalization of expert knowledge: membership function, relative importance of IMP.

Detectivity of the AI DSS, relative danger map, confidence level for re-categorization, for IMA and for IMA in MSA, maps of conflicts between MSA and AI DSS results.

Functionalities of the AI DSS and CROMAC. Between the processes of the General Survey in CROMAC(12) and the Advanced Intelligence Decision Support System(13) commonalities exist in their functions and data. However AI DSS also introduces new functionalities, as seen in Table 2.

Implementation Results in Croatia

The three Croatian communities where AI DSS was implemented had 104.97 sq km of MSA and nearly 46 sq km outside of the MSA prior to the project. The proposals for reducing MSAs with the highest level of accuracy and reliability resulted in a suggested MSA reduction of 57.97 sq km to 23.34 sq km, and certain areas were proposed for MSA inclusion. The project results were delivered in September 2009 to CROMAC so it could make decisions about MSA additions and reductions in accordance with its standard operating procedures. In July 2010 the AI DSS process results as applied to the community of Gospić, Croatia, were available. See Figures 1, 2, 3, 8, 11, 12, 8 and 4 for the map of Gospić. The results of its successful application in Gospić were:

• Exclusion of 28 sq km from 56 sq km of MSA (i.e., MSA reduction).
• Inclusion of 8 sq km in MSA, new areas that were not registered before in the Mine Information System as hazardous risk areas.

CROMAC was the most pertinent information was the map of proposals for the MSA exclusion and inclusion.(14) See Figures 8.1 and 8.2 for the map of the indicators of mine presence and indicators of mine absence.

Figure 8.1 and 8.2: Indicators of mine presence and mine absence (except for Velebit Mountain in the southern part) shown over the MSA in Gospić. For Velebit Mountain, please see Figure 9 on page 75. This map that visualizes conflicts of statements between MSA of MACs and the results of AI DSS project are also very suitable for further application of AI DSS results in MACs. A similar experience was obtained by the map that shows detected indicators of mine presence and indicators of mine absence on the MSA as shown in the figures above.

Monument Centre

AI DSS Decision Support System

**New content is shown in red.**