University of Zagreb
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DEMINED - Developing Advanced Electromagnetic Induction Methods for Landmine Detection

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ACROSS Centre of Research Excellence for Advanced Cooperative Systems

CAPACITIES

Summary

- Croatian scientists in humanitarian demining – historical perspective
- ACROSS project
- Novel electromagnetic induction (EMI) methods in humanitarian demining
  - Metallic object characterisation
  - Model-based compensation of soil effects
- Next-generation EMI detectors – implementation challenges
- DEMINED – research activities
- Conclusion

Croatian R&D in humanitarian demining

1996. Working group within HAZU (Croatian Academy of Science and Arts) led by prof. V. Knapp

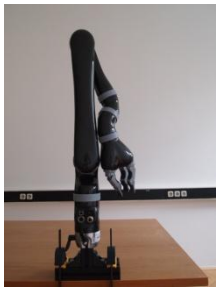
1998. CROMAC (Croatian Mine Action Center) w. Scientific Council

2004. HCR-CTRO (Center for Testing, Development and Training) w. Scientific Council

- Mechanical demining
- Airborne/satellite remote sensing
- Trace explosives detection (MEDDS, FIDO)
- Nuclear detection methods (PELAN device)
- Microbial mine detection
- Detection using dogs / bees
- Acoustic methods
- Metal detector testing (IPPTC)
- Ground penetrating radar (GPR)
- Classification of soils based on pedological properties

ACROSS project (UniZG, FER)

Center of Research Excellence for Advanced Cooperative Systems (ACROSS)



State-of-the-art in novel EMI methods and their transfer to humanitarian demining

- Strengths and weaknesses of existing metal detector technology are well-known in humanitarian demining community
- Novel induction-based methods have the potential to significantly improve metal detection performance and operation over non-cooperative soils

Novel EMI methods **feature**:

- Multiple coil arrays
- Complex excitation patterns
- Advanced signal processing
- Mathematical models
- Inversion algorithms

Information is obtained on object's:

- Size
- Principal shape
- Spatial orientation
- Position
- Material properties (el. conductivity, magn. permeability)

Applications:

- Geophysical measurements (on rocks and buried objects)
- Nondestructive testing (NDT)
- Treasure hunting
- Security systems (airport scanners..)

Metallic object characterisation

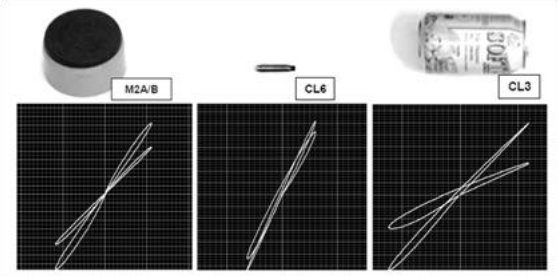
- Potential for significant reduction of false alarm rates (FAR)

Pattern recognition approach:

- Statistical processing of raw detector signals
- Method using basic features of the detector response
- Phase-plot method
- EMI spectroscopy
- EMI imaging

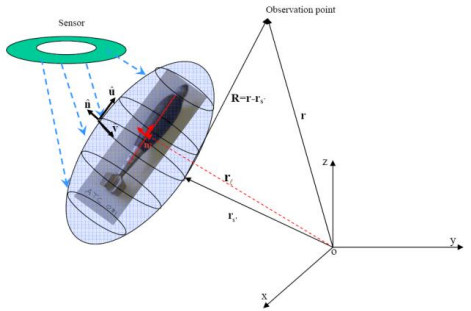
Model-based approach:

- Simple analytical models
- Induced dipole model (and its variations)
- Standardized excitation approach (SEA)
- Simple parametric models
- Empirical models



REF: H. Krueger *et al.*, "Advanced Signal Processing for Reduction of False Alarm Rate of Metal Detectors for Humanitarian Mine Clearance", IMTC 2006, pp. 1452-1456, Sorento, Italy, April 2006.

REF: F. Shubitidze *et al.*, "Application if NSMS model to multi-axis time domain EMI data", *Proc. of SPIE Vol. 6953* , 2008.

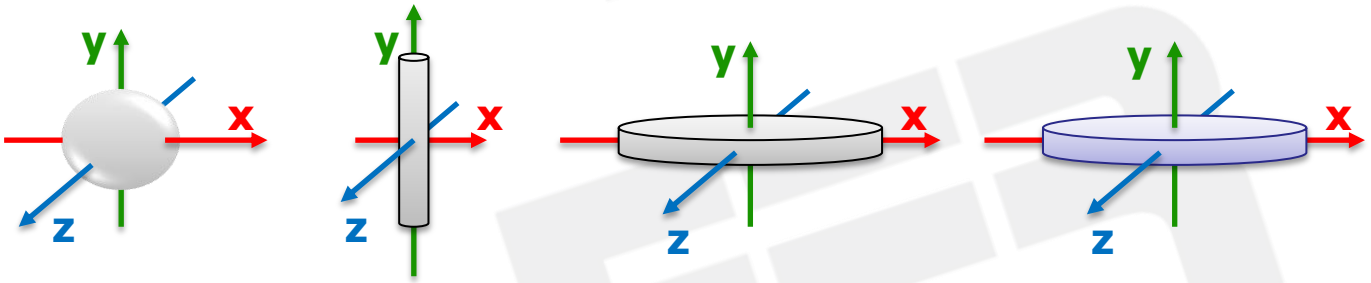


Induced dipole model

- Metallic object fully described by the magnetic polarizability tensor **M**
- Dipole approximation enables fast inversion algorithms (real-time detector operation).
- Field-proven in other applications (security, geophysics..)

- Further research needed on the method applicability to discriminating low metal content landmines from metallic clutter.
- Potential problem with large/composite metallic objects.

Sphere *Magnetic rod* *Magnetic disc* *Non-magnetic disc*



$$\bar{M} = \begin{bmatrix} m & 0 & 0 \\ 0 & m & 0 \\ 0 & 0 & m \end{bmatrix} \quad \bar{M} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & m & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad \bar{M} = \begin{bmatrix} m & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & m \end{bmatrix} \quad \bar{M} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & m & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Compensation of soil effects

Existing ground compensation approaches:

- High-pass filtering
- Phase correction
- Frequency differencing
- Excitation with pulses of different duration

- Reduction of detector sensitivity
- Loss of information on material properties

Model-based approach:

- Describes the spatial variation of EM properites:
  - Electrical conductivity
  - Frequency dependant magnetic permeability
- Half-space models (single or multiple layers)

- Compensation of non-cooperative soil effects without significantly affecting the metal detection and characterisation performance ?

Towards implementation of next-generation EMI detector

Critical design challenges:

- Sensing head position and orientation tracking system with sub-centimetre accuracy
- Accurate and field-proven model of soil
- Fast inversion algorithms
- Properly designed operator interface

GEM-3D+, Geophex, USA.

MPV-II sensor, G&G Sciences

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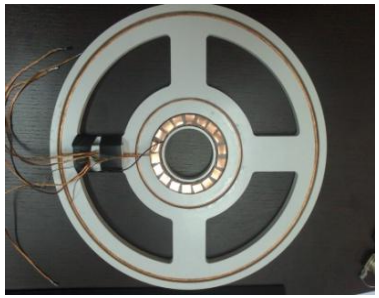
- Expected result:
  - Proof-of-principle and experimental demonstrator of the next-generation EMI detector
- Detector features:
  - metallic object characterization (based on dipole inversion)
  - model-based ground compensation (based on field-proven soil model)
- New laboratory set-up
- Experiments with ITOPs and metallic clutter items
- Tools and methods to be evaluated on HCR-CTRO test sites



Conclusions

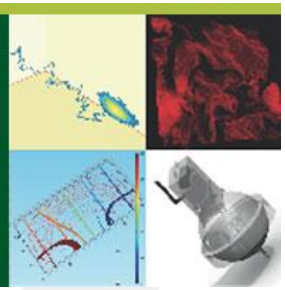
- Limitations of existing metal detector technology are well-known in humanitarian demining community
- In order to (significantly) reduce FAR and improve operation over non-cooperative soils, next-generation EMI detectors are needed, featuring:
  - novel methods for metallic object characterisation (possible candidate: induced dipole model)
  - novel methods of ground compensation relying on field-proven models of soil
- Numerous technical challenges still to be resolved…

Incoming events

IOP Institute of Physics

Sensors & their Applications XVII

16 – 18 September 2013, Rixos Libertas, Dubrovnik, Croatia



Deadlines:
15 May 2013

Link:
http://sensors.iopconfs.org

THANK YOU!