Conclusion

In the course of study I have examined the possibility of a novel metal discrimination system as it is the need of the day when demining is considered. Commercially available metal detectors which are used in demining have very high sensitivity but unfortunately none have good discrimination between landmines and other ferromagnetic materials. Results from this research show using a simple technique, different ferromagnetic objects could be classified into different classes.

Initial look was given to Humanitarian Demining and related R&D; most of the data were collected from the field visit and servery. The field visit was a very useful one in this regard where I was able to get the first hand information on landmines and its impact.

In the technical point of view, I have examined the types if metal detectors giving emphasis to Very Low Frequency metal detectors. VLF is considered to be the ideal technology to discriminate the ferromagnetic objects when compared with others and further development in the metal detector construction with this work implemented would definitely help to speed up the demining.

When the experimental point of view is considered, the results are in the acceptable level and can come to the following conclusions from the experimental results:-

Aliasing, considered to be the most descriptive phenomenon in signal processing, is used in this study for constructive purpose. The advantage of using aliasing is that the number of samples taken in the computing process is very less and thus the processing time is increased very much. When the Discrete Wavelet Analysis is used in the process as described in the earlier chapter an integrated chip could be used as the Wavelet Analyser thus gives more accurate results at a higher speed. This is very essential in real world demining. Usage of intelligent classification system instead of a conventional classification system like lookup table is that this can adapt to the environmental changes, thus the classification is more accurate.

Two major issues, the speed of processing and discrimination could be achieved by the developed study and with the statistical analysis of results we could say with 95% confidence that different metal alloys could be classified into different groups. This is a very high percentage and the results with all the templates show that the discrimination level is very high, with 90% confidence we could say, different sized same alloy could be classified in to different groups. Alloys of same material with different composition may not be classified separately into different groups. This is not a major drawback as they can be classified into classes depending on our need. Classifying these into different classes depends on the number and signature type of the bands.

As a whole the results give very high confidence to the study and this could be applied with modifications depending on the metal detector used.

REFERENCE

[1] J. MacDonald, J. R. Lockwood, J. McFee, T. Altshuler, T. Broach, L. Carin, R. Harmon, C. Rappaport, W. Scott, and R. Weaver, "Alternatives for Landmine Detection", RAND publications, pp. 1 – 13, 2003.

[2] J. Cornelis, H. Sabli, M. Acheroy and Y. Baudoin Antipersonnel Mines, A world wide problem: From political conscience towards humanitarian, research and industrial action. "Detection of abandoned landmines", 7-9th October 1996. Conference publication No 431, IEE

[3] Landmine Problem In Sri Lanka – as reported in the Global Landmine Monitor Report 2002

[4] International Campaign to Ban Landmines, *Landmine Monitor Report 2001: Toward a Mine-Free World*, (New York: Human Rights Watch, August 2001, 1,175 pages).

[5] K. Eblagh (1996): Practical Problems in Demining and their Solutions. "Detection of abandoned landmines", 7-9th October 1996. Conference publication No 431, IEE

[6] Kathy Kowalenko (2004): Saving Lives, One Landmine at a Time, The Institute, March 2004 Vol 28, No1 IEEE.

[7] R.M.J. Ratnayake, A.G. Silva, S.A.P. Siriwardana, K.A.M. Priyanga, T. Nanayakkara, J.R. Lucas (2004): A Low Cost Metal Detector for Landmine Detection. *www.elect.mrt.ac.lk/projects_apr04/abstract05_apr04.pdf*

[8] Canicious Abeynayake & Ian Chant: The Detection of Landmines Using Kalman Filtering and Fusion applied to metal detector data.

[9] J. Groenenboon , A.G. Yarovoy: Data Processing For a Landmine Detection Dedicated GPR

[10] Ning Xiang and James M. Sabatier: Applications of Acoustic-to-Seismic Coupling for Landmine Detection

[11] S.I Ivashov V.N. Sablin (2000): New Technologies in Humanitarian Demining Operations. 0-7803-5803-1/00, IEEE

[12] Claudio Bruschini, Metal Detectors for Humanitarian Demining: from Basic Principles to Modern Tools and Advanced Developments, Web: *http://diwww.epfl.ch/lami/detec/*

[13] Claudio Bruschini (2002), A Multidisciplinary Analysis of Frequency Domain Metal Detectors for Humanitarian Demining, Thesis submitted to the Faculty of Applied Sciences of the Vrije Universiteit Brussel to obtain the degree of Doctor in Applied Sciences

[14] About Pulse Induction Metal Detectors web: http://www.protovale.co.uk/technical-papers/TechnicalNotes/Pulse_Induction_Metal_Detectors.htm#pulse

[15] GICHD, Metal Detectors Catalogue 2003, the Geneva International Centre for Humanitarian Demining.

[16] Lloyd S. Riggs, Electromagnetic Induction, Auburn University

[17] Greg Humphreys (2003), Sampling and Reconstruction, University of Virginia

[18] Allan W. Jayne, Jr. (2000), *http://members.aol.com/ajaynejr/nyquist.htm*

[19] Bracewell, R. (1999), The Fourier Transform and Its Applications, 3rd ed. New York: McGraw-Hill.

[20] Corey Cheng (1996), Wavelet Signal Processing of Digital Audio with Applications in Electro-Acoustic Music, Thesis submitted to DARTMOUTH COLLEGE Hanover, New Hampshire

[21] Don Percival (2000), An Introduction to the Wavelet Analysis of Time Series, Presented at the 2000 IEEE Int'l Frequency Control Symposium Tutorials

[22] Wavelet Tutorials - Mathlab, www.mathworld.com

[23] Amara Graps (1995), Introduction to Wavelets. IEEE Computational Science and Engineering Seminar 1995, Vol 2, Num 2, published by IEEE Computer Society.

[24] Gail A. Carpenter and Stephen Grossberg (1987): ART 2: Self-organization of stable category recognition codes for analog input patterns, December 1987/Vol.26,No23/APPLIED OPTICS

[25] Gail A. Carpenter and Stephen Grossberg (1986), A Massively Parallel Architecture for a Self-Organizing Neural Pattern Recognition Machine, Computer Vision, Graphics and Image processing 37, 54-115 (1987)

[26] Gail A. Carpenter and Stephen Grossberg (1998), Adaptive Resonance Theory, The Handbook of Brain Theory and Neural Networks, Second Edition Michael A. Arbib, Editor Cambridge, Massachusetts: MIT Press

[27] Gerard E. Dallal (2000): The Little Handbook of Statistical Practice; Significance Tests / Hypothesis Testing

[28] Eduardo do Valle Simões, Luís Felipe Uebel & Dante Augusto Couto Barone, Hardware Implementation of RAM Neural Networks, technical Paper Informatics Institute - Federal University of the Rio Grande do Sul, Brazil

Appendix A

Mathematical Model of ART

Mathematical modal for a basic ART network could be found as follows

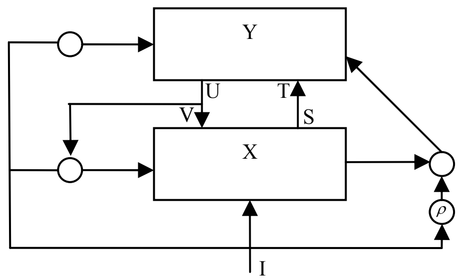

Figure A.1: *ART Network*

Let's define;

$I = (I_1, I_2, I_3 ......I_M)$

$X = (X_1, X_2, X_3 ......X_M)$

$Y = (Y_{M+1}, Y_{M+2}, Y_{M+3.} .....Y_{M+N})$

$S = (h(X_1), h(X_{2)}, h(X_3)......h(X_M))$

$T = (T_1, T_2, T_3 ......T_N)$

$U = (f(X_{M+1}), f(X_{M+2}), f(X_{M+3})......f(X_{M+N}))$

$V = (V_{1,} V_2, V_3 ......V_M)$

$v_i, i = 1.....M - Nodes\ in\ F_1$

$v_j, j = M+1.....M+N - Nodes\ in\ F_2$

$z_{ij}, Bottom\ up\ weight$

$zji, Top\ down\ weight$

STM activity x at any node obey membrane equation

$$\varepsilon \frac{d}{dt} x_k = -x_k + (1 - Ax_k) J_k^+ - (B + Cx_k) J_k^- \qquad (A.1)$$

where total excitatory input is denoted by J_k^+ and Total inhibitory input is denoted by J_k^-.

For the F_1 node

$$\varepsilon \frac{d}{dt} x_i = -x_i + (1 - Ax_i)J_i^+ - (B + Cx_i)J_i^- \qquad (A.2)$$

Here excitatory input (J_i^+) is the sum of bottom up input (I) and top down input (v_i)

$\Rightarrow$

$$J_i^+ = I_i + v_i \qquad (A.3)$$

Top down template v_i is,

$$v_i = D_1 \sum_j f(X_j) \times Z_{ji} \qquad (A.4)$$

Inhibitory input J_i^- governs the attentional gain control signal.

$$J_i^- = \sum_j f(X_j) \qquad (A.5)$$

Thus

$J_i^- = 0$ iff F_2 is inactive and

$J_i^- > 0$ iff F_2 is active

and hence has a non specific inhibitory effect on all STM activity.

For the F_2 node

$$\varepsilon \frac{d}{dt} x_j = -x_j + (1 - Ax_j)J_j^+ - (B + Cx_j)J_j^- \qquad (A.6)$$

Excitatory input to J_j^+ is sum of bottom up template (T_j) and feedback from itself ($g(X_j)$).

$\Rightarrow$

$$J_j^+ = g(X_j) + T_j \qquad (A.7)$$

Bottom up template T_j is

$$T_j = D_2 \sum_i h(x_i) \times Z_{ij} \qquad (A.8)$$

Total inhibitory input is the negative feedback from all other nodes

$$J_j^- = \sum_{k \neq j} g(x_k) \qquad (A.9)$$

In F_2 Layer Y will be enhanced in response to T and F_2 will choose the node v_j which has large T_i

$\Rightarrow$

$$f(x_j) = \begin{cases} 1 & if\ T_j = \max\{T_k\} \\ 0 & otherwise \end{cases} \qquad (A.10)$$

From $(A.4)$ and $(A.10)$

$$v_j = \begin{cases} D_i Z_{ji}\ if\ node\ v_j\ in\ F_2\ active \\ 0\ otherwise \end{cases} \qquad (A.11)$$

$$\Rightarrow v_j \infty Z_{ji} \qquad (A.12)$$

LONG TERM MEMORY TRACES

Bottom up LTM traces (from v_i to v_j) obey the learning equation,

$$\frac{d}{dt} Z_{ij} = K_1 f(x_j)\left[-E_{ij} Z_{ij} + h(x_j)\right] \qquad (A.13)$$

We define

$$E_{ij} = h(x_i) + L^{-1} \sum_{k \neq i} h(x_k) \qquad (A.14)$$

and

$$K_1 = KL$$

$\Rightarrow$

$$\frac{d}{dt} Z_{ij} = Kf(x_j)\left[(1 - Z_{ij}) Lh(x_i) - Z_{ij} \sum_{k \neq i} h(x_k)\right] \qquad (A.15)$$

Case 1: If node v_i in F_1 is inactive and v_j in F_2 is active,

If node v_i in F_1 is inactive

$$h(x_i) = 0 \qquad (A.16)$$

and v_j in F_2 is active,

$$f(x_j) = 1 \qquad (A.17)$$

then,

$$\frac{d}{dt} Z_{ij} = -KZ_{ij} \sum_{k \neq i} h(x_k) \qquad (A.18)$$

During learning,

$$\sum_{k \neq i} h(x_k) = |X| \qquad (A.19)$$

from (*A.18*) and (*A.19*)

$$\frac{d}{dt} Z_{ij} = -KZ_{ij} |X| \qquad (A.20)$$

Case 2: If both node v_i in F_1 and v_j in F_2 are activate

Note: to make v_i active

Binary input pattern *I* will activate node v_j

$$\sum_{k=1}^{M} h(x_k) = |I| \qquad (A.21)$$

and

$$\sum_{k \neq i} h(x_k) = |I| - 1 \qquad (A.22)$$

Thus

$$\frac{d}{dt} Z_{ij} = K\left[(1 - Z_{ij})L - Z_{ij}(|I| - 1)\right] \qquad (A.23)$$

Case 3: If v_j is inactive

$$f(x_j) = 0 \qquad (A.24)$$

Thus

$$\frac{d}{dt} Z_{ij} = 0 \qquad (A.25)$$

In generalised from,

$$\frac{d}{dt} Z_{ij} = \begin{cases} K[(1 - Z_{ij})L - Z_{ij}(|I| - 1)] & \text{if both } v_i \text{ and } v_j \text{ are active} \\ -KZ_{ij}|X| & \text{if } v_i \text{ is inactive and } v_j \text{ is active} \\ 0 & \text{if } v_j \text{ is inactive} \end{cases} \qquad (A.26)$$

At equilibrium,

$$\frac{d}{dt} Z_{ij} = 0 \qquad (A.27)$$

thus,

$$Z_{ij} = \frac{\alpha}{\beta + |I|} \qquad (A.28)$$

where $\alpha = L \text{ and } \beta = L - 1$

DIRECT ACCESS TO SUBSET AND SUPERSET

The problem faced in this algorithm,

If $I^{(1)}$ is a subset of $I^{(2)}$ and if $I^{(1)}$ and $I^{(2)}$ are sufficiently different, then hoe to differentiate the subset from the superset and viz versa.

Solution:

Subset $I^{(1)}$ must activate its relevant node $v^{(1)}$ and not the node $v^{(2)}$ which is relevant to $I^{(2)}$. On the other hand superset must activate $I^{(2)}$

Weber Law Rule and Associative Decay Rule can be used to get the correct matching.

WEBBER LAW RULE

As the learning takes place at equilibrium, When $I^{(1)}$ is presented

$$Z_{ij} = \frac{\alpha}{\beta + |I|} \qquad (A.29)$$

$\Rightarrow$

$$T_{11} = \frac{\alpha}{\beta + |I^{(1)}|}|I^{(1)}| \qquad (A.30)$$

$$T12 = \frac{\alpha}{\beta + |I^{(2)}|}|I^{(1)}| \qquad (A.31)$$

Since $|I^{(1)}| < |I^{(2)}|$

$$T_{11} > T_{12} \qquad (A.32)$$

Thus $I^{(1)}$ activates $v^{(1)}$

ASSOCIATIVE DECAY RULE

Since $I^{(2)}$ is a superset of $I^{(1)}$ only those F_1 nodes in $I^{(2)}$ that are activated by $I^{(1)}$ project to LTM trace $v^{(1)}$ (As explained in Chapter 5),

$$T_{21} = \frac{\alpha}{\beta + |I^{(1)}|}|I^{(1)}| \qquad (A.33)$$

$$T22 = \frac{\alpha}{\beta + |I^{(2)}|}|I^{(2)}| \qquad (A.33)$$

Since $I^{(1)} < I^{(2)}$

$$T_{21} < T_{22} \qquad (A.34)$$

Thus $I^{(2)}$ activates $v^{(2)}$

TEMPLATE LEARNING RULE

For the top-down LTM trace from v_j to v_i

$$\frac{d}{dt}Z_{ji} = K_2 f(x_j)[-E_{ji}Z_{ji} + h(x_i)] \qquad (A.35)$$

For simplicity we take $K_2 = E_{ji} = 1$

$\Rightarrow$

$$\frac{d}{dt}Z_{ji} = f(x_j)[-Z_{ij} + h(x_i)] \qquad (A.36)$$

If node v_i in F_1 inactive and node v_j in F_2 active,

$$\frac{d}{dt}Z_{ji} = -Z_{ji} \qquad (A.37)$$

If both active,

$$\frac{d}{dt}Z_{ji} = -Z_{ji} + 1 \qquad (A.38)$$

Learning Rule governing the LTM trace Z_{ji} in top down template,

$$\frac{d}{dt}Z_{ji} = \begin{cases} -Z_{ji} + 1 & if\ both\ v_i\ and\ v_j\ active \\ -Z_{ji} & if\ v_i\ in\ active\ and\ v_j\ active \\ 0 & v_j\ inactive \end{cases} \qquad (A.39)$$

VIGILANCE LEVEL

Depending on the vigilance level the network will automatically rescale its sensitivity.

Let's define

Vigilance Parameter - ρ

$|I|$ - No of input pathways receive positive signal

P - Excitatory Signal Level

Thus total excitatory input to A,

$$A_e = P|I| \qquad (A.40)$$

$|x|$ - No of F_1 pathways receive positive signal

Q - Inhibitory Signal Level

Thus total Inhibitory input level to A,

$$A_i = Q|x| \qquad (A.41)$$

To reset the Y

$$P|I| > Q|x| \qquad (A.42)$$

$\Rightarrow$

$$\frac{P}{Q} = \rho \qquad (A.43)$$

Hence STM reset is prevented if,

$$\frac{|X|}{|I|} \geq \rho \qquad (A.44)$$

Appendix B

The Demining Process

This gives a brief idea of detection and clearance process as represented in the humanitarian demining modal.

1. Visual Checking for Mines and UXOs

Before the deminer carries out any other procedures in a lane, He will use his eyes to assess any potential threats and to check for any mines, UXOs or tripwires which may be located in the area directly in front of him.

2. Checking for tripwires

When a deminer is moving down a lane, and a tripwire threat is suspected, he will normally carry out a check before commencing vegetation clearance or using detector. This consists of the deminer using a thin stick, or heavy gauge wire device, to move through the area in front him to feel for any tripwires that may be there. Should a tripwire be located, a time consuming procedure takes place to locate a device any destroy it.

3. Vegetation Clearance

Before a deminer can use his detector over an area of ground, that area has to be cleared of vegetation in order for him to effectively use the detector. Vegetation clearance is the process of removing vegetation in order to allow the detector to be close enough to the ground to function correctly

4. Marking Hazardous Areas

The International Mine Action Standards (IMAS 08.40) clearly outlines the procedures to be used when marking areas undergoing clearance. Some of this is undertaken prior to clearance and some is undertaken during the clearance.

5. Investigate False Alarms / Investigate Mines

A metal detector will indicate when the presence of metal is found in the ground blow the head of the detector. Using standard operational procedures, a deminer will investigate that reading until he either locates a mine, or locates something that is not a mine, yet gives a positive reading on the detector. If the investigation of this reading leads to the location of an item which is not a mine or UXO, the action is classified as the investigation of a false alarm. If the reading turns out to be a mine, the process is classified as investigation of a mine.

6. Expose / Excavate Mines

Once the investigation of a mine has taken place, and the reading has been identified as a mine, excavation has to be undertaken before destruction or removal. For destruction, *in situ*, the side of the mine has to be exposed and prepared for placing of an explosive charge. For removal, the whole of the surrounding soil has to be carefully removed and the location checked for booby-traps before the mine can be removed.

7. Render Mines / UXOs safe

Once mines have been exposed or moved to another location, they must be destroyed. This is normally carried out by placing an explosive charge in contact with the mine and initiating the charge, thus causing destruction of the mine.