Implementation of Unmanned Ground Vehicle for Landmine and Bomb Detection

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Abstract

This paper is about the prototype implementation of an Unmanned Ground vehicle for landmine detection, which includes several design aspects and module implementation, requirements and metrics for hardware, experimental results and analysis, Conclusions and some future experiments.

Unmanned ground vehicle is a modern military based warfare machine which of its primary duty is to detect the landmines using sensors and GPR based techniques and diffuse the landmines as possible.

Most of the landmines are non-diffusible for example the proximity mine. This is very commonly used weapon against military tanks.in such scenario a human inspection would be bad idea. It can cause severe injury to the EOD officers or even death

Landmines are biggest treat to any military force in the world. It could even take millions of lives of innocent citizen who lives nearby the warzone

Several death has been reported around the world. So this is a social relevant problem that as an engineer we should solve to protect our people from this worst catastrophes

Keywords: *Unmanned Ground Vehicle, Swarm intelligence, Landmine detection, Robotic arm, Software Defined Radar.*

I. Introduction

In our previous paper we mentioned about the proposed system with methodology we used to implement this robotic system (see reference [1]). So this paper is a continuation towards the same. While prototyping a robotic system we have to consider many design aspects and need to calculate many complexity related to the system. The system consist of many terminology which need to be understood first to get clear idea about this paper.

Starting from the basics. We have a Base U.G.V which is in charge of diffusion or

making decision we call this as *"**Mother Module".*** Each mother module have its own child. Known as ***"child modules"*** or node UGV. Which is in charge of detection of Landmines using the GPR / landmine detection sensors attached into it. There will be many child node which is constantly communicating with mother node**.** As the child detect the landmine. It immediately contact the mother node for detailed inspection to examine the explosive contaminant

Mother uses computer vision techniques to analyze the visual composite and make a prediction if its prediction was positive it will send a notification to Command Module.

Robot make moves by its own. But in case of emergency / machine failure command module debug the issues, also this is a panel of experts in the field. So the panel will inspect the visual composite send by the mother module as a result the command module can pass an acknowledgement to mother as green light for its decision. Decision can be either destroy the mine/ diffuse using its artificial intelligence knowledge / with help of remote officers.

So consider a tree topology of child and mothers who are in a network and constantly monitoring and talking to each other for making a optimize solution. This we call as swarm intelligence. This project is an application of swarm intelligence robot.

II. Design Aspects and Module Implementation

The system is divided into many hardware modules. Each modules have its own functionality and objectives.

The types of modules and its design aspects is given below.

1. Command Module

Command module is the manual control unit for controlling the U.G.V remotely. The U.G.V normally operates automatically but in case if the U.G.V controls goes wrong or if any scenario need a human inspection, then command module role comes into play.

Command module is a collection of units which includes many electronic setups to communicate with the U.G.V , for example, the transmission antenna , receiving antenna, Modem , Serial connections etc.

One of the major part of Command module is the Software used to encrypt the signal transmitted to U.G.V and decode the signal from U.G.V.

This software helps to communicate with the Mother U.G.V and child U.G.V. "Astra" is name of the project. The term "astra" comes from Sanskrit which means weapon. Since this system is used for Defense system the project was named after it.

a) Astra Modem

Astra Modem is a hardware used to communicate with mother module and command module center.

This is like a transceiver to transmit and receive the encrypted signal to and from mother module

Each astra modem is unique and specially designed only for one mother machines. Each modem contains the unique access key pair and hex codes to encrypt the signal along with authentication key to identify the modem.

Access key pair is like an encryption key which is used to encrypt each signal. Hex code is a hexadecimal equivalent code related to a signal this may vary according to the modem model. Access key and hex code is decided with help of ***"Red book"***

Red book is a hardware specific manual which contains the data about the hex code and access key related to a specific modem

b) Astra U.G.V Console GUI

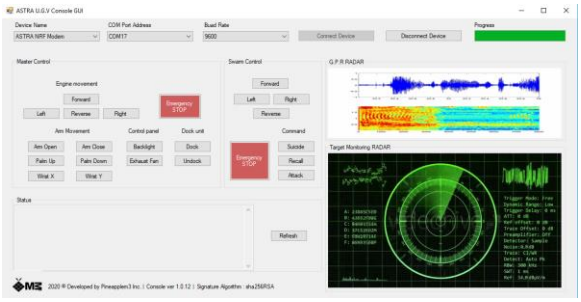

Fig 2.1.b: *Astra U.G.V Console GUI*

Astra U.G.V Console GUI software is designed to remotely control and operate the UGV actions and decisions whenever it requires a manual assistance

In order to use the software at first we need to connect the astra modem to any com port of computer using **Serial UART cable**

Check the device manager to check the modem com port address and after that open the software as we just opened, all the console controls is locked until we establish a secure connection with modem

Secure connection can be established in following ways.

- **Step 1:** select the device name or type of modem. We have many variance of modems available. Since for this prototype we are using the nRF transceivers, we need to select the Astra nRF modem
- **Step2:** select the comport address in which the modem is attached. Use device manager to check the com port address we already checked it once. so we are selecting the available comport address
- **Step3:** select the baud rate of modem. This depends upon the type of microcontrollers we use.in this project we are using at mega microcontroller with baud rate 9600.
- **Step4:** click connect device.

So that we can established a fastest secure connection .this software comes up with password updates in its beta version.

Since we established a secure connection with modem. Our console controls are unlocked.so the fact is, the whole buttons in the console act as a real hardware switches to operate the UGV remotely from command centers

Now let's checkout each switching panels we have inside the software

On the top left we have the master control panels, in which each switches act a direct control over mother module. Here master is related to "mother module". So next to master controls we have swarm control panels .Swarm related to "child module" this single swarm control panel is a control over entire child node connected to the mother module. So this entire signal goes via mother module. As a fact mother controls Childs. We have some updates available soon to choose the swarm in beta versions.

On the top right we have GPR radar panel. Here we constantly monitor the GPR signals to detect the landmine. This GPR reading is receiving from mother module as an output from the program currently running on mother module setup.

And moving on to the bottom right we can see test Radar sample reading generated from the mother module program. This radar is used to locate the child locations and make decisions according to A.I algorithms

So moving on to the bottom left we can see the status panel. This is like a Command line interface to monitor the inside working and current activities flowing through the channel. So this status will be saved as a log files for future purposes and trainings.

So this is the entire core structure inside astra GUI console. As a fact software seems pretty simple and user friendly.

While clicking on the buttons console code is transmitted into mother module and child module as encrypted cipher code via astra modem. Also the data is constantly transmitted by mother module to command module. Cipher code is broadcasted into child module via mother module. So, that's the overview of this software. We can disconnect the modem after use.

2. Mother Module

Mother module is the master of all U.G.V. which means the master U.G.V controls all child U.G.V. Let's consider the army. In any army there will be a head to guide and give orders to attack or repositions. Similarly mother is the head of all U.G.V.

In this project let's consider one Mother U.G.V and one Child U.G.V. Mother Module is also known as ***"Base U.G.V"***.

a) Base U.G.V

Also Known as ***"Base Node"*** is in charge of diffusion or making decisions and also controls all child node associated with mother module. As a fact in our project we have one Mother U.G.V and two or more child U.G.V.

The function of Base U.G.V is to give instructions to all child node. The instruction can be broadcast, multicast or unicast depending upon the situations.

Functionality of Base U.G.V is as follows

- Broadcast, Multicast or Unicast message to child nodes
- Use RADAR technology to keep track all its child U.G.V
- Use Robotic arm to pick and Diffuse the landmine
- Use Computer vision to identify the landmines by analyzing using visual composite and training set.
- Recall all its child U.G.V
- Reposition its child U.G.V
- Decide the strategies in decoy missions.
- In-charge of Child U.G.V safety
- Inspect the suspicious items
- Make way for child U.G.V in congested sites

b) Robotic Arm

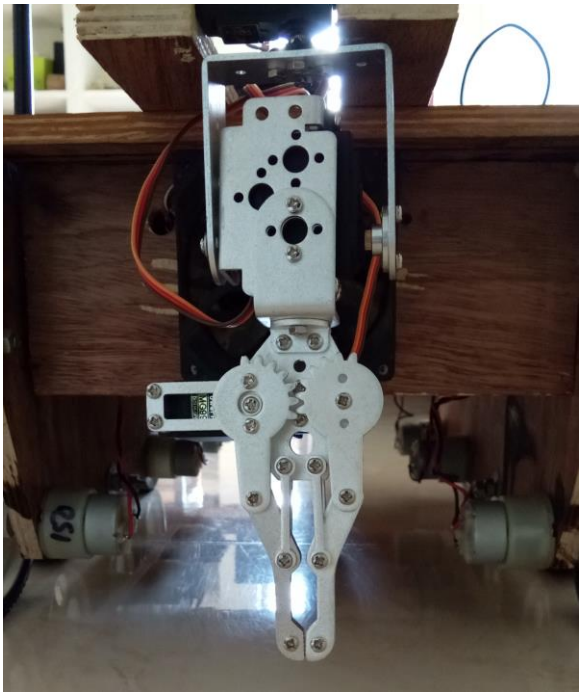

Fig 2.2.b: *Robotic arm in mother module prototype*

Robotic arm is attached into the Base U.G.V for picking up the suspicious object and identify the landmine with help of Computer vision powered cameras attached to the arm.

In our project we have attached 3 DoF Robotic Arm. Robotic arm comes into play whenever child U.G.V reports about suspicious object. Base U.G.V will operate the Robotic arm. In some cases Robotic arm can also operate manually with help of Command Module via Astra U.G.V Console GUI software.

c) RADAR Technology

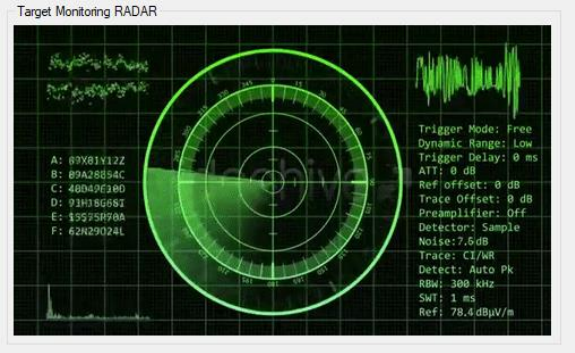

Fig 2.2.c: *RADAR in Astra U.G.V Console GUI*

Base Node uses RADAR technology to identify the positions of its child Node. This technology helps Base Node to plan its Decoy operations.

3. Child Module

Also known as ***"Child Node"*** is in charge of detection of Landmines using the GPR / landmine detection sensors attached into it. Child node is operated and controlled by Base U.G.V moreover can be operated manually using Command module via Astra U.G.V Console GUI software. Main part of child Node is its detection coil

a) Detection Coil

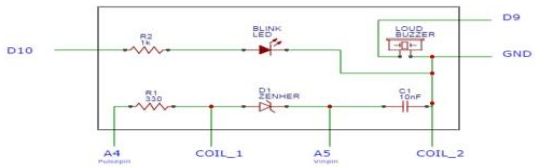

Fig 2.3.a.1: *Circuit diagram of Detection coil*

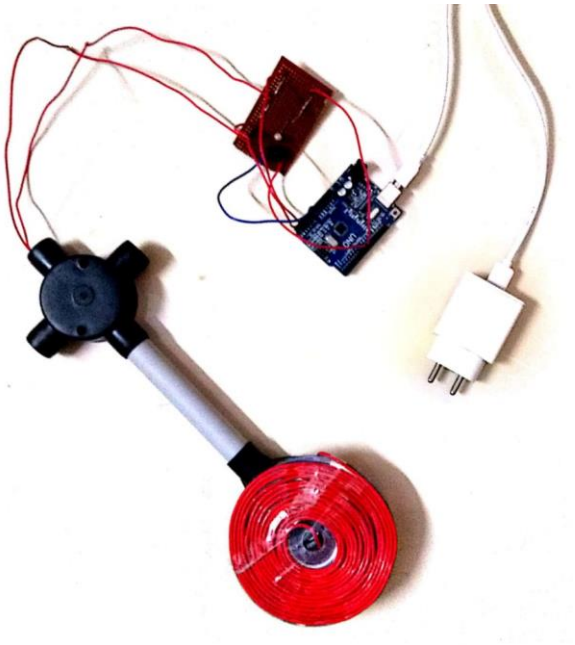

Fig 2.3.a.2: *Prototype of Detection coil*

Detection coil is made out of 30 AWG 90% copper conductive wire of diameter 0.255mm with a resistance of 338.6 Ohm winded together with 42 turns with 12 cm diameter.

Detection coil will produce magnetic induction when get nearer to suspicious explosive contaminant and produce a particular waveform.

These analog waveform is fetched and filtered using microcontroller. Each material will produce different waveform. Using this technique Landmine or explosive contaminants are identified.

Once the waveform matches to pre-Recorded landmine frequency child node will send an alert message to Base U.G.V. Base U.G.V will respond to signal and get into the child node and begin its detailed inspection with help of robotic arm.

III. Requirement and Metrics

In order to build the prototype of proposed system we need the following requirements.

1. Hardware Requirements

Microcontrollers and Microprocessors play an important role in this project. For the prototype we are using AT Mega Microcontroller and actuators, servos, DC Motors etc... Are also used to perform basic motions. Sensors are used to identify the obstacles, location mapping and to protect the U.G.V from false movements.

Prototype Chassis of the U.G.V is made out of metal finishing and acrylic glass. Also some of the part was made with non-metallic material like wood and plastics to avoid distortion in detection coil waveforms. Some of the parts are 3D printed with aluminum finishing especially robotic arm.

nRF24L01+ Transceivers are used to establish a tree topological network connection between a one base node and many child nodes

Serial UART Network cables are used for modem at command module to send and receive signal to and from PC.

2. Software Requirements

In order to build a complex system good planning is required. Software made this simple and cost efficient to understand the errors and some mechanical requirements.

Software helps us to stimulate the working of system by applying real world conditions. This helps to understand how system reacts in the real world environment

Some of the important software we used is mentioned below

a) Arduino IDE

Arduino IDE is a cross platform application used to compile and flash program into Arduino compactible microcontroller boards

Servos, Sensors, Actuators, Detection coil, DC Motors are able to program using this IDE.

b) Microsoft Visual Studio

Visual Studio is IDE to develop web apps, PC consoles etc. Astra U.G.V Console GUI Software is written in **c#** using Visual studio.

c) Proteus 7 Professional

Proteus is a Design suite primarily used for electronic device designs and automation. Most of the electronic board of this project is designed with help of Proteus which includes mother module circuit, Detection coil circuit, Child module Circuit, Astra Modem circuit etc…

d) AutoCAD

AutoCAD is software used to design product 3D models. This software helps to design the chassis of U.G.V and also major parts of Robotic arm

IV. Experimental Results and Analysis

Before deploying the U.G.V into the real world environment we need to analyze some results to get expected outcome. We conduct some experiment to test the type of motor we need to use for prototype. We also conduct experiment to check the readings of detection coil. Ensuring security for the system is essential so we also conducted some ping tests for secure communication. Selecting the power unit is a major task in robotic system so we conducted experiment to select best battery to power up the system.

Experiment conducted and its results are mentioned below.

1. Selection of Motor & Motor Shield

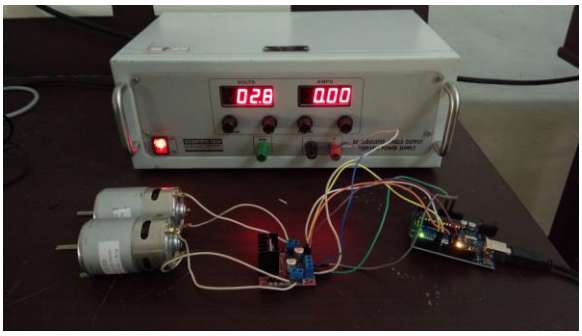

Fig 4.1: *Experiment setup for selection of Motor and motor shield*

Selecting a suitable motor and motor shield for the motion of robot depends on many factor includes weight of the entire system, total torque needed for the system to run in any terrain, Maximum speed needed, Power required to run the system, Stall current, Heating etc…The experiment is done by testing two different type of motor. The experiment report is given below.

- **Motor Shield Specs:**

Double H Bridge Drive Chip: **L298N**
Logical Voltage: **5V**
Drive Voltage: **5V-35V**
Logical Current: **0-36mA**
Drive current: **2A (MAX single bridge)**
Max Power: **25W**
Dimensions: **43 x 43 x 26mm**

Weight: **26g**

- **Experiment 1**

Model	775
Shaft Diameter	5mm
Shaft length	17mm
Body length	66.7mm
Front steps diameter	17.4 mm
Former high level	4.7 mm
Body diameter	42 mm
Motor Overall Length	98 mm
Diagonal installation pitch	28.8 mm
Mounting hole size	M4
Mounting hole	2
Torque	2kg.cm or 0.2N.M

Voltage(V)	Current(A)	Speed(RPM)
12	0.14	3500
18	0.15	4500
24	0.16	7000
30	0.17	8100
36	0.20	9000

Test Result:

Voltage (V)	Current (A)	Stall applied	# motor	Current (A0)	Heating (Y/N)
5.9	5	N	1	0.32	N
5.9	5	Y	1	0.60	Y

- **Experiment 2**

Motor Type	DC with Gear Box, Metal Gears
Base Motor	DC 3000 RPM
Shaft Type	Circular 6mm Diameter with Internal Hole for coupling, 23 mm shaft Length
Maximum Torque	~1.5 Kg-cm at 12V
RPM	150 RPM at 12V
Weight	130 g
Max Load Current:	~330mA at 12V

Voltage (V)	Current (A)	Stall applied	# motors	Current (A0)	Heating (Y/N)
12.5	5	N	1	0.01	N
5.9	1	Y	1	0.40	N

Experiment Conclusion:
As per our motor specification we need to get 3 motor shield for each motor under controlled voltage of 12v 2amps. The experiment is concluded as test 2 is successful therefore we need to use 150 RPM motor instead of RS775 for our system.

2. Detection coil Frequency Testing

Detection coil is attached in Child node and is used to find landmine buried under the ground. The detection is done with help of analyzing the frequency created due to

magnetic induction between coil and explosive contaminants.

- **Coil Specification:**

Wire Gauge: **30 Gauge AWG**
Wire diameter: **0.32mm**
Number of turns: **42 turn**
Total length of wire: **2m**
Diameter of Coil: **12cm**

Experiment 1: *Calculate the analog reading difference of each material at different voltage (v) at a constant distance from the ground.*

Distance of coil from ground: **10 cm**

Test No	Material	Voltage (V)	Current (A)	Analog readings
1	Aluminum	8	2	15
2	Wood	6	2	9
3	Iron	11	3	16

Experiment 2: *Calculate the minimum or average distance for each material at constant voltage and at varying distances of each material*

Test No	Material	Const. Voltage (V)	Dist.	Analog Reading
1	Wood	5	9	8
2	Aluminum	5	12	14

Experiment Conclusion:

Status of Experiment 1: analog readings were found as a bit higher for metallic objects

Status of Experiment 2: even though distance increases for metallic objects, to certain extent still deflection remains the same or slightly varying only.

3. Selection of Battery

Selecting a right battery to power up the entire robotic system depends on many factors includes the current drawn by each modules, Working Voltage of Each electronic component, Stall current expected, Lifetime of battery, Runtime expected etc…

The battery is selected by considering following data.

Mother module

Max Current Drawn:(Stall)	~2A
Min Current Required:	~0.5A
Max Working Voltage:	~12V
Min Working Voltage:	~3.3V
Min Run Time Required:	~1 Hrs.
Power Supply Type:	Battery

Battery Needed: ~12V 2AH Lead Acid Battery

Child module

Max Current Drawn:	~1.5A
Min Current Required:	~0.5A
Max Working Voltage:	~5V
Min Working Voltage:	~3.3V
Min Run Time Required:	~1 Hrs.

Coil Working Voltage:	~5V
Coil Drawn Current:	~0.3A
Power Supply Type:	Battery

Battery Needed: ~12V 2A Lead Acid Battery

Command module

Max Current Drawn:	~0.5A
Min Current Required:	~0.3A
Max Working Voltage:	~5V
Min Working Voltage:	~4.5V
Power Supply Type:	Power cable

Supply Needed: Power Supply ~5V 2A

V. Safety and Security Measures and Implementation

For any robotic or electronic system safety and security should be ensured. Safety is required to prevent the circuit from burning due to stall current, overheating, short Circuit. Security need to be ensured to prevent the middle man attacks and other vulnerable form of attack to crash the system. In our project we ensured enough safety measures by implementing Fuse and Switches also we have ensured security by encrypting the signal send to and from command module to mother module, mother module to child module, child module to command module and vice versa.

1. Implementation of Fuse for safety measures

Fuse is a safety device to provide protection to the electrical and electronic circuits from short circuit and overheating. Fuse is used in this project mainly in mother module and child module to protect the component from short circuit or overheating. Since the components inside the mother and child modules are expensive fuse prevents the cost of damages.

2. Implementation of Encryption based Security in End-to –End Communication

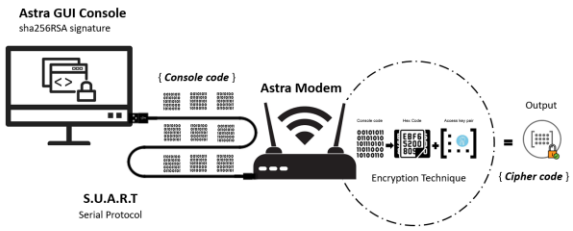

Fig 5.2: *Sketch of encryption technique*

For any military machines, security is a very important thing to enforce. Also it is the most challenging part to any technology we build. U.G.V enforce security protocols on its communication system with help of encryption algorithms and techniques. U.G.V only send and receive encrypted signals to and from specified transceiver.

So, the encryption is done in the following ways. The signal from the GUI console is transmitted to modem through the serial cable using **SUART protocol** this transmitted signal is called as ***"console code".*** Modem will convert the console code into the **Hex code**. Hex code is encrypted with help of access key pair. This method will hide the actual structure of hex code. This code is known as ***"cipher code".*** Cipher code is transmitted wirelessly to a remotely operating mother module. Mother module's receiving antenna will pick up the

signal and decode the signal. Decoding is done using decryption algorithm.

This security measures can prevent the middle man attacks. Mother module will only respond to the signal send by specified modem. This is ensured with help of device authentication rules and protocols. We cannot enforce 100% security to any device .but we can increase the security levels And decrease the breaching possibilities to some extent.

VI. Conclusion

The project was implemented according to the design plan proposed in our previous paper reference [1]. Some changes has been made after analyzing and stimulating through different environment.

The main purpose of this project is to detect the landmine and diffuse the landmine using robotic arm, computer vision, Sensor fusion, GPR or detection coils. And our project have been tested in the real world environment. The Project was able to successfully detect and identify the landmine in its first phase attempts itself.

As of now the entire testing was done semi-automatically with manual assistance. In our upcoming tests we make the system run by itself driven by swarm intelligence technology.

VII. Future Work

This project was able to solve the real time problem but still there are some limitation. Since now the machine work Semi-Automatically. We are currently working to make this robot work completely automatic by itself by enhancing the capabilities of Deep Learning, Computer vision and Swarm intelligence.

VIII. References

1. Nirmal Ram, Mohammed Fasin AF, Sonu Sebastian, Namitha Gopinath, & Dr Rajeshwari. M. (2020). *Design of Unmanned Ground Vehicle for Landmine and Bomb Detection using Software Defined Radar*. Research and Reviews: Advancement in Robotics, 3(1), 1–12.

2. P. Gader, M. Mystkowski, and Y. Zhao. *Landmine detection with ground penetrating radar using hidden Markov models.* IEEE Trans. Geosci. Remote Sens. 2001.39(6):1231–1244p.

3. K. C. Ho, L. M. Collins, L. G. Huettel, and P. Gader. *Discrimination mode processing for EMI and GPR sensors for hand-held land mine detection.* IEEE Trans. Geosci. Remote Sens. 2004.42(1):249–263p.

4. Q. Zhu and L. M. Collins. *Application of feature extraction methods for landmine detection using the Wichmann/Niitek groundpenetrating radar*. IEEE Trans. Geosci. Remote Sens.2005.43(1):81– 85p.

5. H. Frigui, O. Missaoui, P. Gader. Landmine detection using discrete hidden Markov models with Gabor features, Proc. SPIE.2007.6553:65532p.

6. N. Dalal and B. Triggs. *Histograms of oriented gradients for human detection* Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit., Jun. 2005.1(1):886–893p.

7. D. Reichman, J. M. Malof, and L. M. Collins. *Algorithm development for deeply buried threat detection in GPR data.* Proc. SPIE.2016.9831:98231Ap. 12. D. Reichman, K. D. Morton, L. M. Collins, P. A. Torrione. *Target localization and signature extraction in GPR data using expectation maximization*

and principal component analysis, Proc. SPIE, May2014. 9072. 90720Qp.

8. O. Missaoui, H. Frigui, and P. Gader. *Land-mine detection with ground penetrating radar using multistream discrete hidden Markov models.* IEEE Trans. Geosci. RemoteSens.2011.6:2080–2099p.

9. O. Missaoui, H. Frigui, P. Gader,(2009), *Multi-stream continuous hidden Markov models with application to landmine detection*, EURASIP J. Adv. Signal Process.Dec.2013.240p

10. H. Frigui, P. Gader,(2009), *Detection and discrimination of landmines in ground-penetrating radar based on edge histogram descriptors*, Proc. SPIE.2006.6217:621733p.