Development of Framework for Wireless Intelligent Landmines Tracking System Based on Fuzzy Logic

Salem S. M. Khalifa, Kamarudin Saadan, Norita Md Norwawi

Abstract**:** ***The losses of developing countries from landmines accidents are very large. Thus, the need for new techniques to improve the efficiency of Landmines tracking systems is evident. In the recent years, many of research efforts have been directed to develop new and improved landmine detection methods. However, the increased costs of improving these methods led to drive up their prices. Thus they will not be available to the general public. The aim of this paper is to find a cheap and an effective method to help people for protecting and warning them from landmines risk during practiced their daily lives. In this context, this paper presents the design and development of framework for a Wireless Intelligent Landmines Tracking System (IWLTS) using mobile phone based on GPS and fuzzy logic. Proposed framework is really very helpful for the users who living near mine affected areas to track their children and themselves through Smart phones from landmines risk.***

Keywords**:** ***Landmines, Fuzzy logic, Fuzzy set, MATLAB.***

I INTRODUCTION

So far, many countries throughout the world are still being affected by landmines. According to statistics, an estimated 100 million landmines in more than 64 countries cause about 26,000 casualties each year. 4,000 victims were recorded in 2010 of unexploded residues of war and land mines, which means at least one person is dead every two hours. One-third of the victims of these weapons are children [1], [2], [3], [4]. One of difficult tasks that are faced researchers is to find a cheap method to detect of buried landmines, where the hand prodding and metal detection are still the widely used approaches for locating mines [5]. Although many techniques have been designed for landmine detection, they designed especially for Military service and demining operations. Thus, the most of these are expensive equipment and need experts to deal with it.
Furthermore, they will not be available to the general public. In this paper, we have tried to present a cheap method (Framework) for tracking landmines and accessible to everyone using smart phone and GPS.

The rest of the paper is organized as follows: The previous section of this paper gave a detailed explanation of the problem. Section II gives a brief review of technology tracking systems. Section III presents the system architecture for the IWLTS and the user interfaces. Finally, Section IV presents the concluding remarks.

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II TECHNOLOGY OVERVIEW

A. *Landmine Detection and Tracking Techniques*

There are many methods are used for locating mines. However all of them still lack technological expertise. Some methods used animals such as dogs and rats [5]. Table 1 presents the most techniques that used for locating mines.

Table 1: Landmine Detection Techniques

Technique	*Sensor*	*Arthur*
Manual Mine Clearance	Manual prodders	[5]
Sensing Technologies	Lasers	[6],[7]
	Smart phone	[8],[9]
	Ground Penetrating Radar	[10], [11]
Biological detection	Dogs	[12],[13],[14] ,[15]
	Rats	[13], [16], [17],[18], [19]
	Honey bees, Plants and Bacteria	[13], [14], [20], [21]
Mechanical Demining	Machine	[21]
Robotization of Humanitarian Demining	Robot	[22],[23],[24] , [25]
Unmanned Aerial vehicles (UAV)	Helicopter plane	[26], [27], [5]

Due to its reliability and effective, Manual Mine Clearance is still the most widely utilized approach to detect landmines. However, this approach induces a loss of concentration, and increases cost, because each alert needs to be carefully checked [5], [28], [29].
Sensing Technologies are new technologies that are used to improve the reliability and speedup the detection operation such as Commercial sniffers. Sensing Technologies includes X-ray Tomography, Nuclear Quadrupole Resonance (NQR), Infrared Imaging, Ground-Penetrating Radar (GPR), Neutron Back-scattering etc [30].
Biological detection methods have reduced the false alarm rate of metal detectors dramatically, because they depend on detection of explosive compounds Instead of detection of metal where mammals, insects, microorganisms are used for this purpose [13].
Machines demining originally were developed to meet the military requirement for fast breaching of minefields in combat situations and to clear out or detonate mines and create a safe path. Machines demining are remote controlled, which minimizes the risk to personnel [21], [31].

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All methods that we mentioned before are still slow, costly and dangerous and it is not guaranteed that it can destroy all the buried mines. Given that the Robot able to carry out pre-programmed, there are serious attempts to produce a robot which able to detect landmines [32].

B. Fuzzy Systems

A Fuzzy logic is a form or system of logic based on set theory of fuzzy sets which described by Lotfi A. Zadeh in 1965. Lotfi later developed many of the methods of fuzzy logic based on this simple theory, thus establishing the foundation of a comprehensive and mathematically sound logic of imprecisely or ambiguously defined sets [33], [34], [35], [36].

Fuzzy systems are employed in many areas of science and engineering which use fuzzy logic in modeling a given inputs–outputs set. In spite of that the main disadvantages of the fuzzy system is lacking the learning capabilities, it has a major advantage which is the ability of representing the knowledge characterizing the relations between the input and the output in a natural way using the IF-Then rules. Hence It is very suitable for uncertain or approximate reasoning, furthermore it appropriateness for systems whose mathematical model is hard to derive such as control, prediction and computer vision [37],[38]. The Components of fuzzy system are Fuzzy set, Membership Functions, Logical Operations, Fuzzy Rules and Parameter variables. Parameter variables are fuzzy concepts which may be represented as fuzzy sets such as low, below average, average, above average, high. This process is called fuzzy quantization [39].

A fuzzy set is a set with fuzzy boundaries that it allows its elements to have a degree of membership [40]. It contains an endless variety of truth values that can be anywhere in the range of 0-1, normally it is called the degree of membership. The degree of membership of fuzzy set is considered the main difference between an ordinary crisp set and fuzzy set. The traditional way of representing elements U of a set A is through the characteristic function:

$$f_A(u): U \rightarrow 1, 0, \qquad (1)$$

Where

$$f_A(u) = \begin{cases} 1, \text{if } u \ni A \\ 0, \text{if } u \nexists A \end{cases}$$

While in the fuzzy theory, fuzzy set A of universe U is defined by function $\mu A(u)$ called the membership function of set A

$$\mu_A(u)\ U \rightarrow [0,1] \qquad (2)$$

$\mu A(u)$ = 1, if x is an element of the set A, and
$\mu A(u)$ = 0, if x is not an element of the set A.

Where U is called the universe, and A is a fuzzy subset of U.

III FRAMEWORK ARCHITECTURE

To get a cheap and effective solution for people whose living beside Mine-Affected areas to help them avoiding the risk of landmines in real time , we proposed a Framework for the IWLTS Using Fuzzy Logic , GPS and Smart Phone. The Framework comprises of four parts includes: Model Base Management System MBMS, Data Base Management System DBMS, Knowledge Base Management System KBMS and User Interfaces. Fig 1 shows the framework architecture.

A. Data Base Management System DBMS

DBMSs are specially designed software applications that enable user to store, modify, and extract information from a database. There are many different types of DBMSs, ranging from small systems that run on personal computers to huge systems that run on mainframes. Well-known DBMSs include MySQL, MariaDB, PostgreSQL, SQLite, Microsoft SQL Server, Oracle, SAP HANA, dBASE, FoxPro, IBM DB2, LibreOffice Base and FileMaker Pro.

MySQL database is used for database hosting on server site. The database contents of two main tables were developed to manage the system: the first one is a user's Table which stores all the users' details with their login information and location such as username, password and phone number. The second table is Locations Table; it contains information about the mined areas. The information includes area name, area number and coordinates of land (Longitude, Latitude, and Elevation compared to sea level).

B. A Knowledge Base Management System (KBMS)

KBMS is a computer application which is used to manage the Knowledge base. Similar to databases, knowledge base is represented as a set of facts, a number of fuzzy

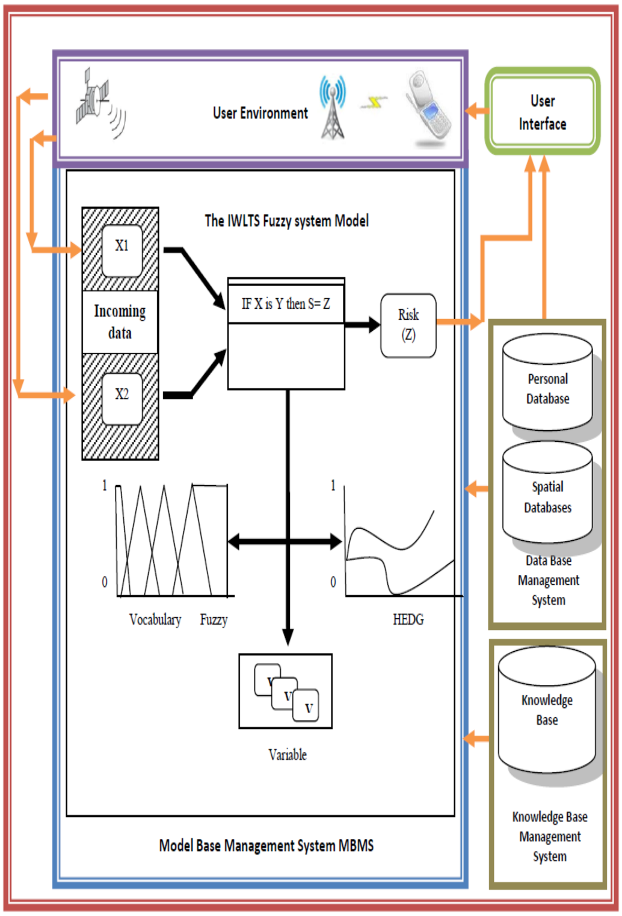

Figure 1: The Conceptual Framework of IWLTS

inference rules (fuzzy rules) and a number of fuzzy Parameter variables (fuzzy sets). Fuzzy sets are defined by their membership functions based on input variables metrics, while fuzzy rules are used to capture human knowledge that are defined as a list about risk detection of landmines. Parameter variables are represented in fuzzy sets which are used to describe a term or concept with vague or fuzzy.

C. The User Interface

The user interface enables interaction and communication between the user and system in a user-friendly manner which enables the user to track him-self and receive advice to how avoid the risk of landmines. It provides Graphical User Interface like Google maps in the android environment.

D. *Model Base Management System MBMS*

This part is considered as the most important part of our framework where in this stage the IELTS Fuzzy system Modeling will be built.

IV PROPOSED IWLTS FUZZY SYSTEM MODEL

Fuzzy models are used to describe complex nonlinear systems where it is offers a convenient way for user to deal with uncertainty and vagueness. Very early, many researchers began to develop fuzzy models where a few inference systems were available, such as: Mamdani Fuzzy models, Sugeno Fuzzy models and Tsukamoto Fuzzy models. Mamdani Fuzzy model was first proposed by Lotfi A. Zadeh in 1975 [41].

Identification of fuzzy models has four stages that comprise the identification of (a) the input and output variables, (b) the rule base, (c) the membership functions and (d) the mapping parameters. In this work, a fuzzy model identification method based on Mamdani Fuzzy model is proposed.

This model consists of three main blocks namely: The Fuzzification block, the Reasoning block and the Aggregation and Defuzzification block as shown in Fig. 2.

- **THE FUZZIFICATION BLOCK**

Inside this block where the crisp input values are transformed into fuzzy sets, so that each ordinary (crisp) input has its own group of membership functions or sets to which they are transformed. This transformation is called Fuzzification that is using the membership functions to calculate the degree of membership in different fuzzy sets. Once the crisp input values are transformed, it can assessed by block inference engine.

At the beginning, the fuzzy linguistic variables should be determined and their membership degree to be determined.

Definition 1: Basic fuzzy linguistic variable

A fuzzy linguistic variable is a 4-tuple (X, T, M, A), (3)

Where:

X is the name of fuzzy linguistic variable.

In the fuzzy theory, fuzzy set A of universe X is defined by function $\mu A(x)$ called the membership function of set A.

$$\mu A(x) : X \rightarrow [0 \quad 1] \tag{4}$$

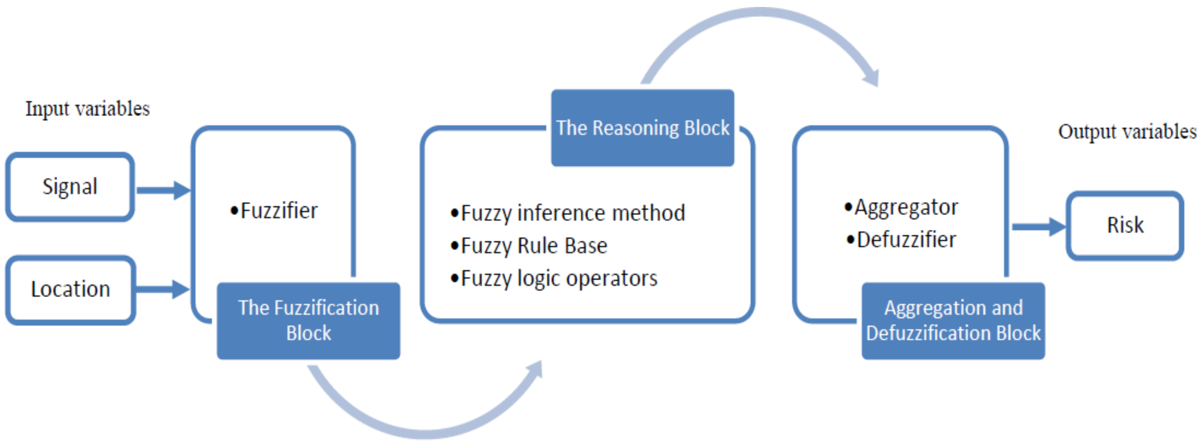

Figure 2: Structure of Fuzzy Inference System (FIS)

$$\mu A(x) = \begin{cases} 1, \text{if } x \text{ is totaly in } A \\ 0, \text{if } x \text{ is not in } A \\ \in (0,1), \text{if } x \text{ is partialy in } A \end{cases} \tag{5}$$

T term set of linguistic values (fuzzy variables).

M is the mapping rules which map every term of T to fuzzy set at A.

A is the universe of discourse.

Definition 2: Extend fuzzy linguistic variable

Extend fuzzy linguistic is 5-tuple $O_F = (ca, CF, R, F, A)$, (6).

Where: *ca* is a concept on the abstract level (*Signal-Quality*, *Position*, *Risk*). The corresponding element of *ca* is X in definition 1.

CF is the set of fuzzy concepts which describes all values of *ca*. The corresponding element of *CF* is T in definition 1 (Poor, Average, Excellent).

R is the fuzzy relation between concepts in CF.

F is the set of membership functions at A.

A has same interpretations as defined in definition 1.

Signal Strength: Checking a state of GSM signal is very important for the IWLTS system. Landing for GSM Signal level would be caused in stopping the system and posing a real threat for user's life. Therefore, IWES system monitors regularly the dynamics of the strength level change of GSM Signal to avoid these risks.

Usually the Signal strength ranges from -113 dBm (poor) to -50 dBm (Excellent).

The variable of Signal-strength can be defined as:

O_{F1} (Signal-Strength) = (ca = Signal-Strength, CF = {Poor, Average, Excellent}, R = {Poor $\leq$ Average $\leq$ Excellent}, F = {F_{Poor} (x), $F_{Average}$ (x), $F_{Excellent}$ (x)}, A = [-50, -113]).

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(7)

Location: This variable is obtained by using the Global Positioning System (GPS) and positioning technologies that utilized in cellular networks using a GSM cellular network. The location will be used to calculate the distance between the user and the areas-landmines affected

The variable of Location can be defined as:

O_{F2} (Location) = (ca = Location, CF = {Inside, Beside, Far-away}, R = {Inside $\leq$ near-side $\leq$ Far-away}, F = {F_{Inside} (x), F_{Beside} (x), $F_{Far\text{-}away}$ (x)}, A = [0, 200]). (8)

MATLAB is a high-level language and interactive environment with a collection of functions called Matlab toolbox that enable user to analyze data, develop algorithms, and create models and applications [42] [43]. In our study, all rules and fuzzy set have been developed using Matlab with the Fuzzy Logic toolbox.

The triangular membership function is used to fuzz the input data and their membership degree. Each input variable have been partitioned in to three Fuzzy Sets defined using three membership functions (two trapezoidal and one triangular in shape).

The fuzzy sets of the Signal-Strength variable are given in Table 2 and the membership functions are shown in fig. 3.

Table 2 Fuzzy set of input variable for Signal-Strength.

Linguistic Variable	Interval (dBm)
Poor	{-113, -113, -99, -92}
Average	{-106, -85, -64}
Excellent	{-78, -64, -50, -50}

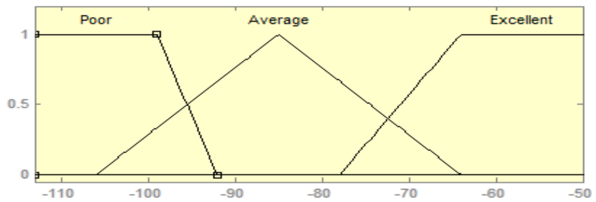

Figure 3 Membership functions for Input Variable Signal- Strength

The fuzzy sets of the Location variable are given in Table 3 and the membership functions are shown in fig. 4.

Table 3 Fuzzy set of input variable for Location.

Linguistic Variable	Interval (Meter)
Inside	{0, 0, 25, 45}
Beside	{30, 50, 70}
Far-away	{55, 75, 100, 100}

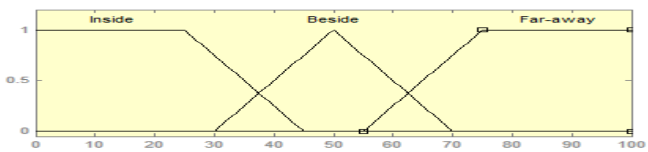

Figure 4 Membership functions for Input Variable Location

Risk: Risk is considered as the output of the fuzzy model. The ranges of the risk of landmines can be determined by expert judgments (Deminers).In other words, we can ask the expert to give numbers between 0 and 1 per cent that represent the safe distance between the user and the areas-landmines affected.

The variable of Risk can be defined as:

O_{F3} (Risk) = (ca = Risk, CF = {Low, Medium, High}, R = {Low $\leq$ Medium $\leq$ High}, F = {F_{Low} (x), F_{Medium} (x), F_{High} (x)}, A = [0, 1]). (9)

The fuzzy sets of the Risk variable are given in Table 4 and the membership functions are shown in fig 5.

Table 4 Fuzzy set of out variable for Risk.

Linguistic Variable	Interval
Very-Low	{0, 0, 0.15 ,0.25}
Low	{0.102, 0.252, 0.402}
Moderate	{0.25, 0.5, 0.75}
High	{0.6, 0.75, 0.9}
Very-High	{0.75, 0.85, 1, 1}

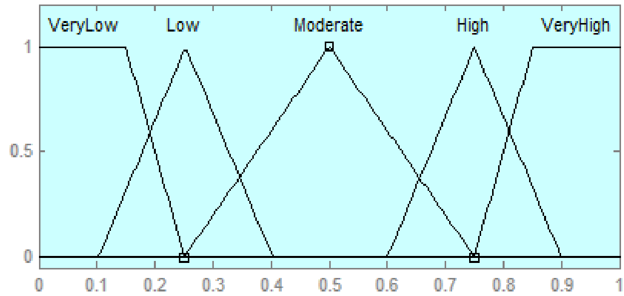

Figure 5 Membership functions for Input Variable Risk

- **THE REASONING BLOCK**

This block is the most important component and is considered the brain of the model. The next step is to apply if-then rules that are used to connect multiple input variables to output variable. The fuzzy rules for the IWLTS System have been built based on Mamdani models. The Rules of a Mamdani fuzzy system are divided into two operators:

IF, called before (a premise or condition); and THEN, it is called effect (conclusions or actions).

If x is A and y is B then z = C (10)

Where x, y are the inputs and A, B, C are fuzzy sets. The

The following Table 5 presents fuzzy rules that constitute the basis of the IWLTS System.

- **AGGREGATION AND DEFUZZIFICATION BLOCK**

There are two processes are performed within this block. The first one called Aggregation which is the process of unification of the outputs of all rules, while the second process called Defuzzification , where the input for it is the aggregate output fuzzy set and the output is a single number.

Table 5: Fuzzy Rule of the IWLTS Fuzzy system Model

Rules
1. If (O_{F2} is Far-away) then (O_{F3} is VeryLow)
2. If (O_{F2} is Beside) then (O_{F3} is Moderate)
3. If (O_{F2} is Inside) then (O_{F3} is VeryHigh)
4. If (O_{F1} is Excellent) and (O_{F2} is Far-away) then (O_{F3} is VeryLow)
5. If (O_{F1} is Average) and (O_{F2} is Far-away) then (O_{F3} is Low)
6. If (O_{F1} is Poor) then (O_{F3} is VeryHigh)
7. If (O_{F1} is Excellent) and (O_{F2} is Beside) then (O_{F3} is Moderate)
8. If (O_{F1} is Average) and (O_{F2} is Beside) then (O_{F3} is High)
9. If (O_{F1} is Poor) and (O_{F2} is Beside) then (O_{F3} is VeryHigh)
10. If (O_{F1} is Poor) and (O_{F2} is Inside) then (O_{F3} is VeryHigh)
11. If (O_{F1} is Average) and (O_{F2} is Inside) then (O_{F3} is VeryHigh)
12. If (O_{F1} is Excellent) and (O_{F2} is Inside) then (O_{F3} is VeryHigh)

V MODEL VALIDATION

It is recommended that the model is validated once the model structure, Parameter variables, fuzzy rules and fuzzy sets parameters have been identified.

The first step is to take the crisp inputs, x1 and y1 (Signal strength and Location), and determine the degree to which these inputs belong to each of the appropriate fuzzy sets.

We, supposed that we have two inputs, the first input (Signal strength =- 95 dBm) and the second input (Location = 50 M).

In this case, we rated the Signal strength has an -95, which, given graphical definition of poor, corresponds to $A1$ = 0.4, $A2$ = 0.5 for the Average membership function as in fig 6

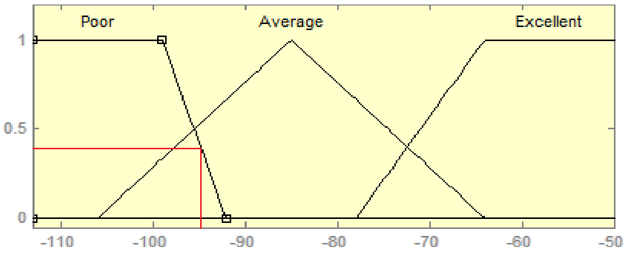

Figure 6 Fuzzifying of input variable "Signal strength"

In the same way, we rated the Location has 50, which, given graphical definition of Beside, corresponds to $B2$ = 1 for the beside membership function as in fig 7.

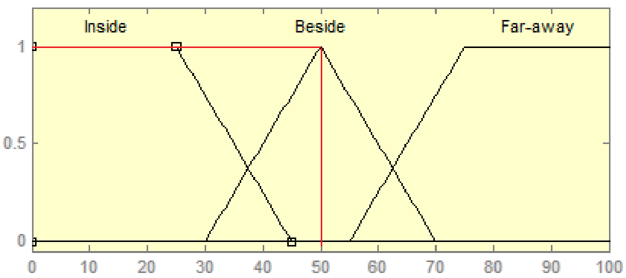

Figure 7 Fuzzifying of input variable "Location"

The next step called rule evaluation (see fig 8) where the fuzzified inputs are taken and apply them to the antecedents of the fuzzy rules.

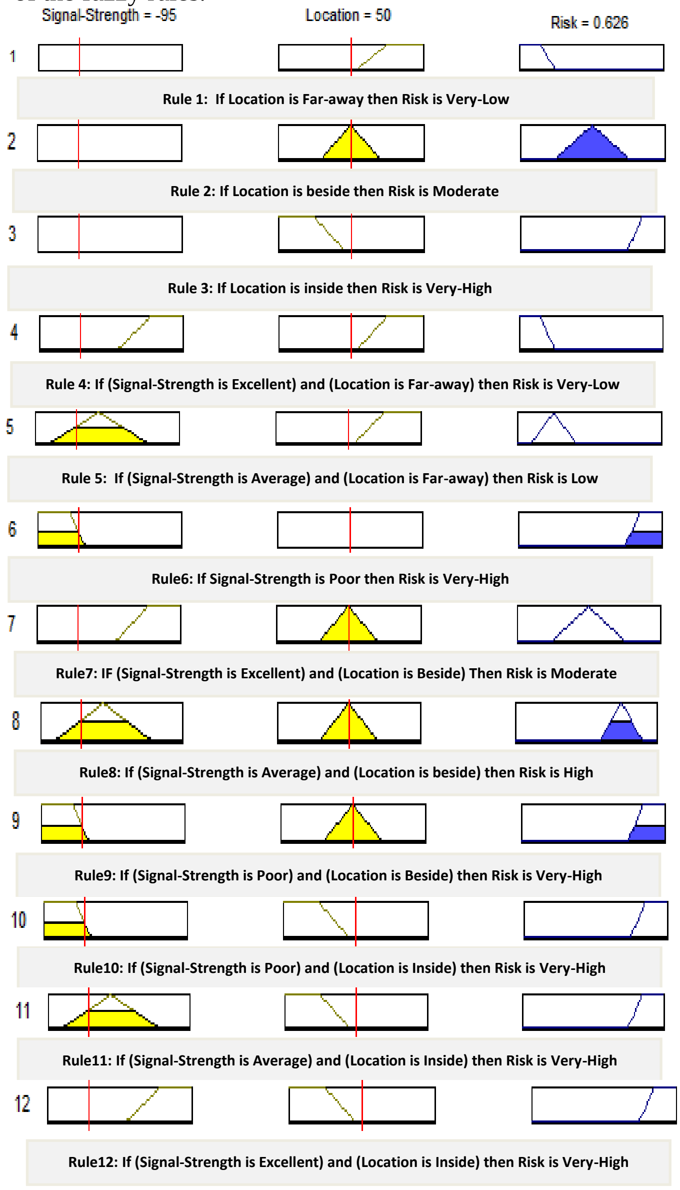

Figure 8: Rule evaluation following Mandani fuzzy model.

The next stage called Aggregation process where the outputs of all rules are united (see fig 9). In other words, the membership functions of all rule are clipped or scaled and combine them into a single fuzzy set.

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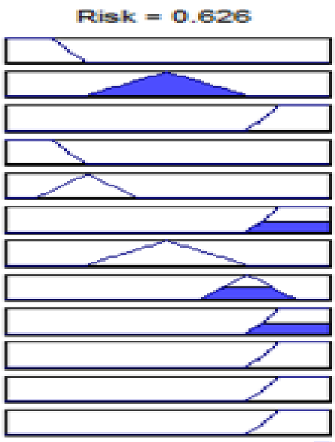

Figure 9: Results aggregation.

Finally, the last step called Defuzzification that is used to resolve a crisp value from the results of the inference process. The input for the Defuzzification process is the aggregate output fuzzy set and the output is a single number. Thus, the result of Defuzzification, crisp output z1, is 0.626. It means, for instance, that the risk involved in our 'fuzzy' project is 62.6 per cent (see fig 10).

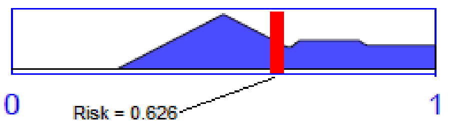

Figure 10: Defuzzifying the solution variable's fuzzy set.

We have used MATLAB software to validate the model based on Takagi-Sugeno-Kang method and Mamdani method. The Model has been tested 13 times. Table 6 shows the result of test.

Table 6: RESULTS OF TESTING WITH 12 RULES

Seq	Input (X1)	Input (X2)	Output (Z)	
	Signal Strength (dBm)	Position (Meter)	Risk ratios %	
			Mamdani Method	Sugeno Method
1	-109.8	50	0.68 %	0.667 %
2	-104.6	35.91	0.748 %	0.752 %
3	-75.72	65	0.362 %	0.199 %
4	-63.58	65	0.3 %	0.134 %
5	-91.33	64.09	0.391 %	0.241 %
6	-57.8	25	0.9 %	0.8 %
7	-53.76	50.45	0.5 %	0.4 %
8	-93.64	82.27	0.275 %	0.167 %
9	-101.2	91.36	0.486 %	0.379 %
10	-71.1	68.64	0.227 %	0.0734 %
11	-91.9	93.18	0.157 %	0.0803 %
12	-76.88	69.55	0.19 %	0.803 %
13	-113	0	0.9 %	0.8 %

VI CONCLUSION

The aim of this work is to develop an inexpensive intelligent strategy for the tracking and navigation of users who living near mine affected areas to protect their children and themselves from landmines risk through mobile phones. This paper has presented an overview of research work on development of Framework for the IWLTS Using Fuzzy Logic. We have discussed the Mamdani approach which often adopted for building Fuzzy system. The suggested framework approach provides to a user a cheap and inexpensive method to protect him from the risk of landmines using his Smartphone. The framework has been successfully tested for landmines case-study using MATLAB software. The results obtained are promising and demonstrate that the proposed Framework for the IWLTS can provide an effective support for real-time to avoid the risk of landmines.

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