CHAPTER I

INTRODUCTION

1.1 Background

The most significant challenges to growth and development that most developing countries encounter worldwide are the remains of wars and landmines. A landmine is an explosive device or weapon that is used to kill or hurt people or to damage buildings. It is a type of bomb placed under the earth or in the sea that explodes when vehicles, ships or people go over it (Handicap International, 2011).

Landmines have many types, but can be classified into two main groups, namely, anti-tank (AT) and anti-personnel (AP) mines. AT mines are designed to be triggered by heavy vehicles, such as tanks, whereas AP mines are designed to wound people. Every year, approximately 15,000 to 20,000 people die by landmines (UNICEF, 2012a). Handicap International (2011) reported that over 4,000 victims of unexploded remains of war and landmines were recorded in 2010, which means 1 person for every 2 hours. One third of the victims are children.

At present, over 50 countries worldwide suffer from the consequences of AP mines and unexploded ordnance (UXO). Landmines are still a major problem among developing countries and a major threat to citizens who live near mine-contaminated areas (UNMAS, 2012; JMACT, 2011). Libya is a developing country that had been under

European colonisation during the past century. Italy infiltrated Libya in 1911. The Italian occupation of Libya lasted for approximately three decades. Libya was a major theatre of operations during World War II. Thus, Libya has approximately 100,000 mines, most of which are from the World War II era, that is, the Italian occupation. Furthermore, 11,845 landmine victims, including 6,749 deaths, have been recorded in Libya. These numbers provide insight into the real extent of the effect of landmines in Libya (ICBL, 2011).

Table 1.1: Landmine casualties in Libya

Period	Deaths	Wounded	Total
1940–1952	3,780	3,290	7,070
1952–1975	1,890	1,645	3,535
1975–1995	1,079	161	1,240

Source: ICBL (2011)

Explosives still pose a major threat to the lives of millions of people in many places on Earth. Explosives, which remain a global problem, kill millions of innocent people whilst leaving many others disabled. As a result of landmines buried underground, numerous children are killed or permanently injured whilst playing with these mines without realising their danger. Approximately 200 million landmines had been planted in over 80 countries worldwide. Moreover, approximately 300,000 people had been wounded, paralysed or permanently disabled as a result of mines left during wars or by terrorist organisations worldwide. Explosives have many kinds, which can be classified into enhanced radiation weapon, landmines and cluster munition (ICBL, 2011; IHH, 2012).

1.2 Problem Statement

Environmental risk assessment (ERA) is one of the most complicated tasks because of the uncertainties and non-availability of data. In a risky environment where human life is at stake, safety and reliability must be given primary importance, particularly for tracking and ERA systems. Improving the probability of these systems is a challenging task for many scientists and poses a serious challenge to identifying risks and supporting decision-making.

Artificial intelligence (AI) techniques are increasingly extending and enriching decision-making, decision support and ERA. In conventional methodologies, explicit logic and numerical calculations are typically used to solve a problem. By contrast, several intelligent systems use training and learning, which mimic several biological systems for this purpose.

Different frameworks and models have been proposed in the literature for tracking and ERA systems. Among them, the widely used approaches are fuzzy logic (FL) and artificial neural networks (ANNs). Other frameworks and models, which do not use any intelligence technique, have also been designed. Although intelligence techniques have become relatively well-known and have achieved considerable success in tracking and assessing environmental risk in various fields, these techniques still exhibit several limitations. For example, systems that use FL can represent imprecise knowledge in a simple and understandable manner for users and specialists and provide support for decision-making. However, systems that use FL typically require considerable expert knowledge and the defined parameters may not be necessarily applicable to all cases.

Moreover, systems that use FL face a serious problem when defining membership function (MF) parameters because no systematic procedure for defining such parameters exists, and thus, these systems lack the capability to adjust themselves to a new environment.

By contrast, systems that adopt ANNs can learn from and adapt to input–output pairs in an interactive manner to deal with complex nonlinear relationships and rapid data processing and to handle a large number of variables. However, systems that adopt ANNs are incapable of explaining the steps that lead to decision-making and are ambiguous to the user.

Given these limitations, the need for a coherent architecture that integrates AI techniques into a single coherent environment is apparent. To overcome the limitations of individual intelligent techniques and to improve the performance and operational effectiveness of tracking and ERA systems, integrating these techniques to form one coherent environment and analysing the advantages and benefits of such integration are recommended.

The current research combined three intelligent techniques, namely, ANNs, FL and genetic algorithm (GA), to improve the accuracy of tracking and ERA systems. As a result of this integration, a new architecture, called the Environmental risk assessment architecture, has been implemented in the form of two models, i.e. the neuro-fuzzy risk assessment model (NFRAM) and the safe path selection model. NFRAM requires three steps: (1) defining the linguistic variables and fuzzy sets, (2) determining the fuzzy rules and processing the fuzzy inference and (3) using back-propagation (BP) learning algorithms (e.g. ANNs) to train the model. The safe selection model also requires three steps: (1) the encoding step, which involves defining the size, the structure of the search space and the representation of the chromosomes (solutions); (2) determining the fitness function and (3) defining the safe path representation method.

1.3 Research Questions

The following research questions will be answered by this study:

- **a.** What are the components of intelligent tracking and environmental risk assessment systems?
- **b.** How can ANNs, FL and GA be integrated into tracking and environmental risk assessment systems?
- **c.** What are the operational effectiveness and efficiency of the proposed architecture?

1.4 Research Objectives

This thesis aims to propose a hybrid architecture based on the problems presented in the previous section. Specifically, its objectives are as follows:

- **a.** To design and develop an optimised environmental risk assessment architecture for landmine tracking and decision-making using ANNs, FL and GA.
- **b.** To implement the proposed architecture in a mobile environment.
- **c.** To evaluate the performance of the proposed architecture and prototype.

1.5 Research Scope

The scopes of this study are as follows. This thesis aims to optimise tracking and ERA systems that use individual intelligence techniques.

a. The original scope of the research is to design and develop a hybrid architecture composed of an assessment model that can perform objective risk analysis and realistic prediction and tracking.

b. The research environment is the Libyan Mine Action Centre, which focuses on Libyan citizens who live beside mine-affected areas.

c. The research is concerned with the improvement of tracking and assessment systems through the integration of AI technologies.

d. The architecture is validated by developing a proof of concept for a neuro-fuzzy architecture for landmine tracking and risk assessment.

e. The prototypes developed in this study are intended to help populations affected by landmines in Libya to access to their basic needs, such as health facilities, water and use of fertile agricultural land.

1.6 Significance of the Research

The significance of this research is to improve the quality of ERA systems and to enhance the performance of these systems by integrating FL, ANNs and GA into one coherent environment. This study also provides a warning tool, which can reduce the hazards of landmines and help affected populations.

1.7 Thesis Organisation

This thesis comprised seven chapters. Chapter I presents the "Introduction," which includes the background and statistics of landmines and their victims, followed by the problem statement, research questions, research objectives, scope of the study and significance of the study.

Chapter II presents several tracking strategies and their characteristics, which are used to determine the position and location of users, such as vehicle, personal and animal tracking systems. This chapter also introduces AI tools and their characteristics, presents different perspectives on risk assessment and risk analysis and describes several studies that were conducted in the past to address risk analysis. This chapter also provides an overview of intelligent decision support systems (IDSS).

Chapter III describes the research methodology used in this study, which is adopted from the design science research methodology (DSRM). This chapter also discusses several methods and techniques that have been applied to achieve the research objectives.

Chapter IV describes the main characteristics of ERAA. The characteristics of ERAA have been proposed based on the literature review presented in Chapter II.

Chapter V discusses the construction of the conceptual architecture and the design of its function. This chapter also presents NFRAM built using FL and ANNs and developed through several phases. In addition, this chapter describes the safe path selection model based on GA, the Global Positioning System (GPS) and Google Maps, which can be used to help people avoid mine-affected areas using a smartphone.

Chapter VI presents the implementation stages of an ERAA prototype. This chapter also discusses the system analysis, which used the unified modelling language to describe important diagrams, such as case and sequence diagrams.

Chapter VII presents the verification and discussion of NFRAM and the safe selection model. This chapter also describes the assessment of the prototype based on expert review and user evaluation. Two methods are used to validate the proposed architecture. The analytical method validates NFRAM and the safe path selection model, whereas the experimental method is used to evaluate the prototype.

Chapter VIII summarises the results and contributions of this dissertation. It also provides suggestions for future research that should be conducted in this specific area.