CHAPTER III

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research approach applied in this study. To accomplish the research objectives, the design science research (DSR) approach is adapted from the well-known design research approach in information systems. Each phase is described in detail in each section.

3.2 Research Approach

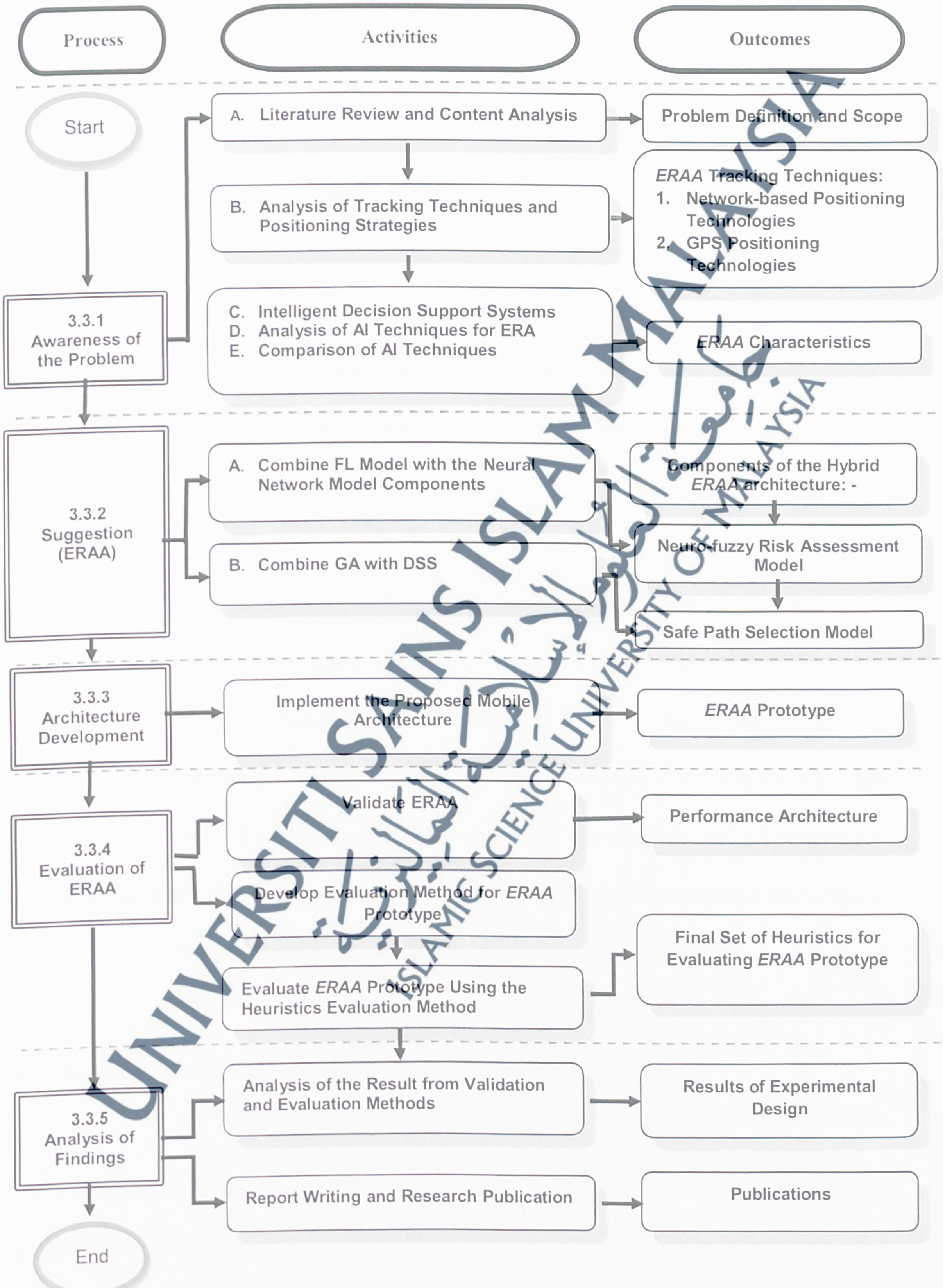
The most important part of any research is to find the most efficient and appropriate approach. The selection of a correct approach helps to obtain answers to the research questions, whereas working within the framework of the methods helps to verify and test authenticity (Arora H., 2011). A variety of approaches and techniques have been adopted in different disciplines and fields, particularly computer science and engineering, including grounded theory, interpretive research, theory building and testing and action research (Vaishnavi & Kuechler, 2008).

Over the past five decades, DSR has become a highly popular and well-accepted approach for research as a fundamentally problem-solving approach. 'DSR is of importance in a discipline oriented to the making of successful artefacts' (Peffers et al., 2008). DSR is a dominant and common approach in multiple disciplines, including information technology disciplines (i.e. IS, SE and CS), instructional design and technology, educational research and human–computer interaction (Vaishnavi & Kuechler, 2011). Thus, the DSR approach is adopted (Vaishnavi & Kuechler, 2007) to accomplish the research objectives of this study.

3.3 The Design Science Research Methodology

The Design Science Research Methodology (DSRM) is adopted to accomplish the research objectives because this method is a widely applied research approach when dealing with new technologies/techniques and it focuses on the interaction between a user and an artefact (Vaishnavi & Kuechler, 2007). In this section, the objectives are divided into various work steps. This research methodology is mainly based on the procedural approach to perform each objective step by step. DSRM aims to create an innovative artefact, which includes models, methods and instantiations. This methodology is divided into five phases: (1) awareness of the problem, (2) suggestion (proposing the hybrid ERAA components), (3) architecture development, (4) evaluation of the ERAA prototype and (5) analysis of the findings (Vaishnavi & Kuechler, 2007), as illustrated in Figure 3.1.

Figure 3.1: Research methodology



3.3.1 Awareness of the Problem

A. Literature Review and Content Analysis

The first stage of this methodology is literature review and content analysis, which are used to understand the requirements of the prototype, the objectives and scope of the study and the problems that should be solved. During the alternating cycles of discussion and individual cogitation that characterise many design research efforts, several software engineering concepts were combined with a final key insight to yield an ultimately successful direction for development.

Preece et al. (2002) defined content analysis as 'a process of obtaining sufficient knowledge about the intended study, in which the contents can be acquired from many sources of information, including text, video, audio and other forms of elements'. The sources used in this research are books, archives, magazines and Internet sites. Through the literature review and content analysis, the researcher observed the lack of integration among AI technologies and focused only on using individual intelligence techniques, such as FL or ANNs, in developing landmine tracking and ERA systems.

B. Analysis Tracking Techniques and Positioning Strategies

The strategies and technologies used for basic positioning are presented in Section 2.2 and are classified into four categories: basic positioning methods, outdoor positioning systems, network-based positioning technologies and indoor positioning systems. Basic positioning methods can be classified into dead reckoning, proximity sensing, trilateration and multilateration.

Most previous related systems and LBS applications are similar in design and form. They are composed of four units, namely, transmission, controlling, processing and data collection units, which consist of location-detecting components, such as GPS. The characteristics of LBS application are summarised in Table 2.1 according to the previous discussion of applications.

C. Comparison of Artificial Intelligence Techniques

The main objective of this activity is to present the advantages and disadvantages of individual intelligence techniques, where an overview of AI tools, including ES, FL, GA and ANNs, is introduced. Table 2.2 in Chapter II summarises the comparison among AI technologies in terms of their advantages and disadvantages.

D. Intelligent Decision Support Systems

IDSS has been defined as the incorporation of AI techniques and computer-based systems that use data, expert knowledge and models to support decision makers in organisations in solving complex and imprecise problems, such as traffic congestion, demining, emergency management (disasters and healthcare institutions) and human navigation. Existing IDSS and their limitations are presented in Table 2.3.

E. Analysis of Artificial Intelligence Techniques for Environmental Risk Assessment

Previous works were reviewed to address risk analysis, with the focus on the most important tools, which are FL and ANNs, to learn more about different risk analysis techniques and to understand the shortcomings and limitations of each study. A summary of the established techniques, areas of application and limitations is provided in Chapter II. A list of previous works on ERA using intelligence techniques with their advantages and disadvantages is presented in Table 2.4.

3.3.2 Suggestion Environmental Risk Assessment Architecture

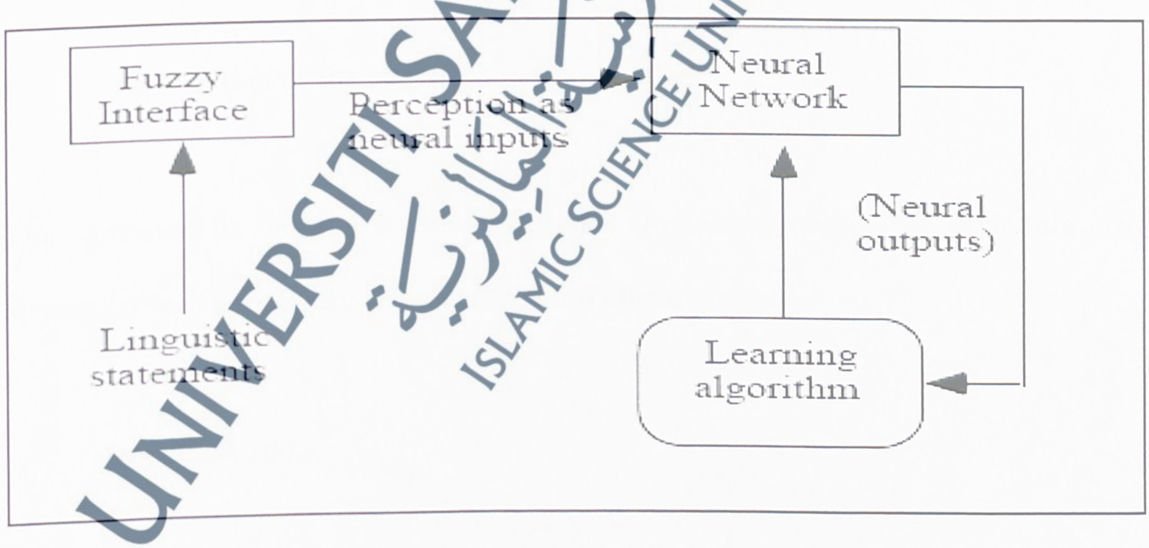
This stage, which is closely linked to the awareness phase, aims to explore and evaluate potential solutions. Further insights into the problem domain are acquired during the initial analysis and design. Furthermore, the specifications of the required solutions are defined. In this phase of the research, the outcomes of the literature review and content analysis are used to document the components of the proposed architecture. This stage involves the suggestion of a hybrid architecture. A hybrid intelligent architecture combines two or more computational intelligence techniques to solve complex and challenging problems. The proposed architecture intends to address the drawbacks of individual intelligence techniques used in tracking and assessing applications for environmental risk by integrating FL, ANNs and GA. Detailed descriptions of the proposed architecture are provided in Chapter V.

The architecture developed in this study is composed of two models, which are based on the combination of three well-known techniques in reliability engineering, namely, ANNs, FL and GAs. The first model is called Neuro-Fuzzy Risk Assessment Model, which uses FL and ANNs, whereas the second model is called the safe selection model, which uses GAs and DSS.

A. Systematic Methodology to Obtain Neuro-Fuzzy Risk Assessment Model

The main objective of this process is to identify the methodology of the proposed NFRAM. Three stages are followed to develop the risk assessment model, as shown in Figure 3.2.

Figure 3.2: Systematic methodology to obtain NFRAM



i. First Stage: Develop Fuzzy inference system

Data that define the behaviour of the system were collected through interviews with experts (Deminers), where data collection resulted in a total of three linguistic variables, namely, signal strength, position and landmine intensity and risk. Linguistic variables and fuzzy sets are also defined. Afterward, Fuzzy inference system (FIS) processes are defined as follows.

a. Determine the fuzzy rules

Fuzzy rules are proposed according to the investigation and analysis of the features of landmines and consultation with experts, which constitute the basis of the FIS according to the Sugeno models.

b. Aggregation of the outputs

The truncated fuzzy MFs that represent the implication outputs of each rule are aggregated using the fuzzy union (maximum) operation.

c. Defuzzification

Defuzzification is the process of converting the fuzzy result into a matching numerical value that can be adequately represented using FIS.

ii. Second Stage: Applying the Neural Network

In this stage, ANNs are applied and used to tune the MFs using the FIS controller whilst keeping the semantics of FIS intact.

iii. Third stage: Training Neuro-Fuzzy Risk Assessment Model

Neural networks are a group of algorithms inspired by human netral systems. In this model, BP learning algorithms are used to train the FIS, which aims to minimise error in network weights whilst considering the training samples. The training process is terminated when the maximum iteration is at its peak, the gradient performance falls below the threshold or the error is minimised to the required value.

B. Methodology for Developing the Safe Path Selection Model Using Genetic Algorithm

DSS is adopted to assist the user in making appropriate and quick decisions in case of an emergency (e.g. exposure to the risk of landmines in this study). GA has been used in finding the optimal shortest paths to search through a large space within a limited time frame. This path aims to direct the user in escaping from mine-affected areas without any incident by using Google Maps.

In this context, GA is used to encode a path in a graph into a chromosome. In this process, the methodology that is used to develop the safe path selection model is identified through the following steps, which are illustrated in Figure 3.3.

(1) The number of nodes (latitude and longitude) that will be used to produce an optimal itinerary is defined.

(2) A fitness function that will measure the performance is defined.

(3) The parent population is initialised.

(4) The fitness of each individual chromosome is calculated.

(5) A pair of chromosomes for mating is selected from the current population.

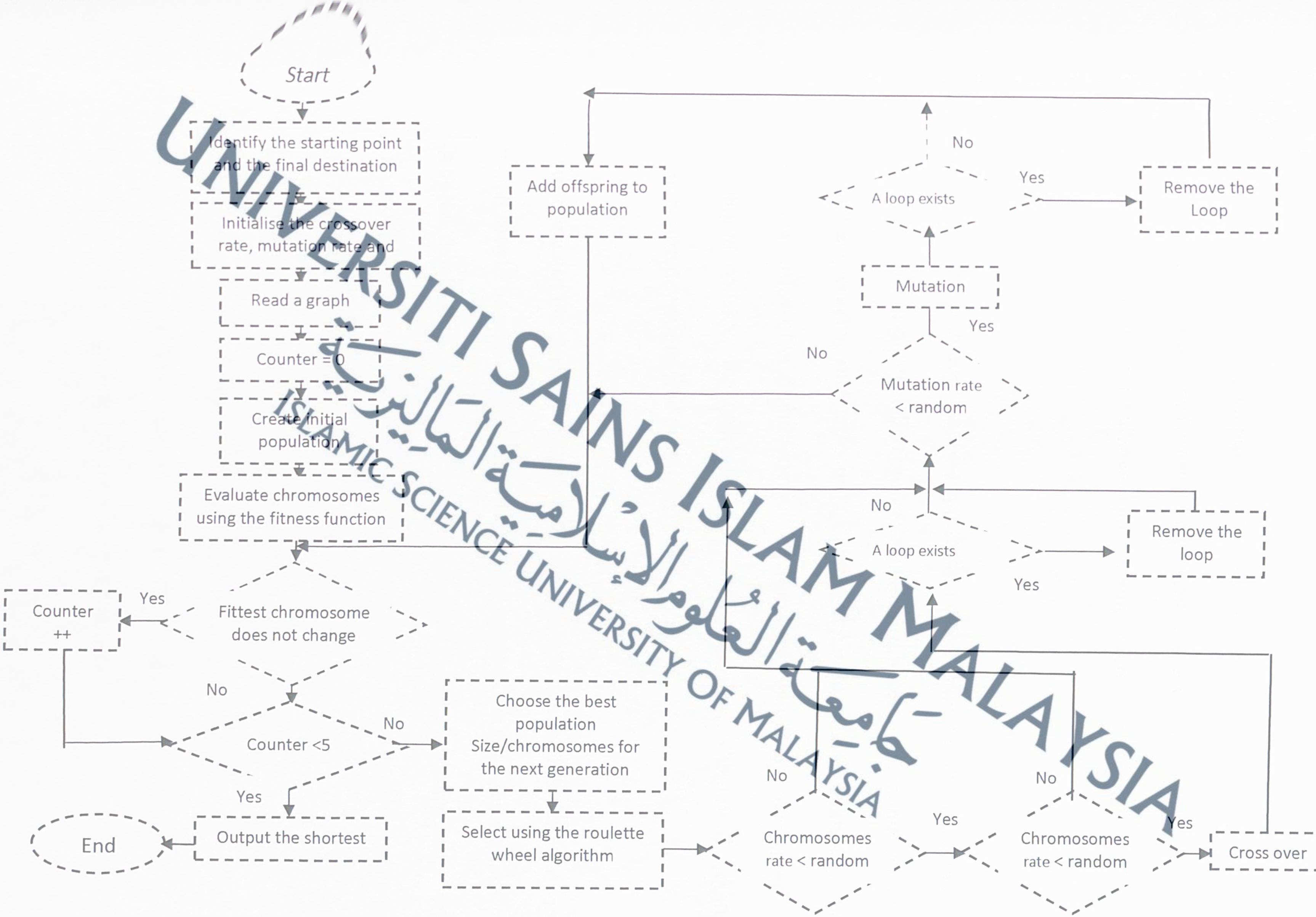
(6) A pair of offspring chromosomes is created by applying the genetic operators, i.e. crossover and mutation.

(7) The created offspring chromosomes are placed in the new population.

(8) Step 5 is repeated until the size of the new chromosome population becomes equal to the size of the initial population N.

(9) The initial (parent) chromosome population is replaced with the new (offspring) population.

(10) Return to Step 4. The process is repeated until the termination criterion is satisfied.



Start
Identify the starting point and the final destination
Initialise the crossover rate, mutation rate and
Read a graph
Counter = 0
Create initial population
Evaluate chromosomes using the fitness function
Fittest chromosome does not change
Yes
Counter ++
No
Counter <5
No
Yes
Output the shortest
End
Choose the best population Size/chromosomes for the next generation
Select using the roulette wheel algorithm
Chromosomes rate < random
No
Yes
Chromosomes rate < random
No
Yes
Cross over
A loop exists
No
Yes
Remove the loop
Mutation rate < random
No
Yes
Mutation
A loop exists
No
Yes
Remove the Loop
Add offspring to population

3.3.3 Implement the Proposed Mobile Architecture

The third phase involves the development of the ERAA prototype. The tentative design is implemented in this phase. The first section presents the development toolkit used to develop the ERAA prototype, whereas the second section describes the ERAA architecture.

The major challenge that hinders mobile application development is the heterogeneity of mobile devices and the pre-installed browsers on these devices. Each mobile platform has different characteristics, such as security features, capabilities and weaknesses. The limits and capabilities of a mobile device environment should be recognised. A developer should consider the capabilities of mobile devices, which will run the application, before developing the prototype.

Several capabilities of the mobile device environment were structured into the following points, which should be considered during the development of the ERAA prototype.

a. **Application size:** The prototype should be small to ensure compatibility with the mobile platform. ERAA has been developed using the Android software development kit (SDK) because the .exe file is relatively small.

b. **Interruptible:** ERAA should be interrupted when receiving a call or a text message whilst the application still works in the background.

c. **Mobile platforms:** The target devices of ERAA should be considered from among all devices supported by the Android platform.

d. **Sound for warning messages:** The system should produce an alarm in case the user approaches a minefield. Thus, the MP3 format will be used for the sound of ERAA.

e. **Input and navigation controls:** All devices that will use this prototype should support the capabilities of a selection key (touch screen).

f. **Screen size:** The display size of the ERAA prototype should be adjustable to the screen size of a mobile phone because it is developed using Java language.

A. Prototyping Development Toolkit

The following sections describe the development toolkit (hardware and software tools and resources) that will be used to develop the ERAA prototype.

i. Hardware tools

The hardware tools include a PC and a mobile phone. The PC is used to interact with all the required software (Eclipse software), whereas the mobile phone is used to view the system and processes. During this stage, the Samsung GT-18552 phone is used to operate the ERAA prototype.

ii. Software tools

Table 3.1 lists the tools and techniques that will be used to develop the proposed prototype and describes the purpose of the software.

Table 3.1 : List of software used to develop the proposed prototype

Software	Utilisation
Rational Rose Enterprise Edition 2000	Rational Rose incorporates the modelling and development environments, which can be used to provide a solid foundation for the user to start coding and allows the user to see how different components and parts of the system interact.
Extensible Markup Language (XML)	XML is a markup language that defines a set of rules for encoding documents in a format that is human-readable and machine-readable. XML will be used to design pages that can be displayed on the mobile browser.
Google Maps	Google Maps is a desktop and mobile web mapping service application and technology provided by Google. Google Maps will be used to display the locations of areas affected by mines/UXO and the location of the user.
Eclipse software (Android SDK)	Eclipse software is an integrated development environment that contains a base workspace and an extensible plug-in system for customising the environment. This software will be used to create the prototype of the ERAA mobile client for the Android platform.
Wireless application protocol (WAP)	WAP is a technical standard that allows users to instantly access information and Internet resources via handheld wireless devices.
GPS service	GPS technology is a free service that is available everywhere, except in a concrete bunker or underwater.
PHP language	PHP is a server-side scripting language designed for web development. It will be used to write the web servers as the code behind the language. The website will be the interface that an operator interacts with.
WampServer64	WampServer64 (64 bit) is a Windows web development environment that will be used to create web applications with Apache and the MySQL database.

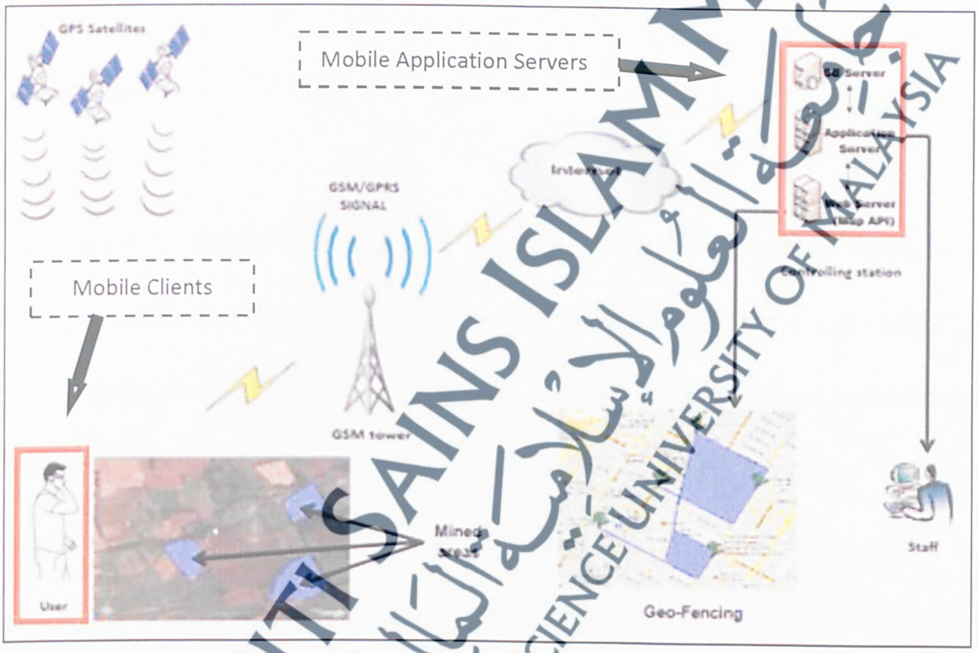
B. System Architecture of Environmental Risk Assessment Architecture

The system architecture can be divided into the following parts, as shown in Figure 3.4:

i. A mobile client running on the mobile phone device of the user

ii. A mobile application server running on a gateway server

Figure 3.4: System architecture of ERAA



i. Mobile Application Servers

A mobile application server is a server that hosts, installs and operates mobile applications and other services that provide a broad range of functions in a typical mobile application server, such as content adaptation, notification and security. A mobile application server is divided into three parts, as follows.

a. Web servers

The PHP language is used to write the web servers as a code behind the language. The website can be used as an interface that an operator interacts with. The side of the web is managed by government departments or mine clearance organisations. An operator can set up a virtual perimeter, i.e. a 'fence' around mined areas, and save it in the database by using the interface.

b. Database

MySQL is used for database hosting on the server site. The database contents of two main tables are developed to manage the system. The first table is a 'user table', which stores all of the details of the users with their log-in information and location, such as username, password and phone number. The second table is a 'location table', which contains information about mined areas. The information includes the name, number and coordinates of an area (i.e. longitude, latitude and elevation compared with the sea level).

c. Map service

Many companies own an application programming interface (API) for integrating web-based maps into web sites, e.g. Google, Microsoft, Multimap and ViaMichelin. Google Maps is the best choice for web mapping because it has many advantages. Accordingly, Google Maps is used in this system to track and view the status of a user. When using

Google Maps, a Google Maps API Key should be obtained by registering at http://www.google.com/apis/maps.

ii. Mobile clients

a. Functionality

The most important function in this system is the position function, which is used to calculate the distance between the current location of users and the Geo-fence boundaries that have been set up previously. The following formula can be used to measure the distance between locations A (LongA, LatA) and B (LongB, LatB) that have been previously determined:

$$F = acos[cos(latA) \times cos(latB) \times cos(lonB - lonA) + sin(latA) \times sin(latB)] \times R, \quad (3.1)$$

where F is the distance in metres, R is the radius of the Earth in kilometres (6,371 km), $latA$ is the latitude of point A, $longA$ is the longitude of point A, $latB$ is the latitude of point B and $longB$ is the longitude of point B.

b. Algorithm

The algorithm shown in Figure 3.5 provides an overview of the mechanism of the system. Once the system is installed into a mobile phone, it starts to capture position information from the satellite as soon as the user successfully logs in. The information contains the longitude, latitude and elevation compared with sea level. This system turns a cell phone into a GPS tracking device. Once the user moves and changes his location, the system automatically opens the database stored in the server and retrieves the longitude, latitude and elevation that have been previously saved in the database (the borders of the land where the mines are buried).

Calculations must be performed in the mobile application to determine the current location of the user. The system can measure the distance between the two locations that has been determined previously by using the formula for the spherical law of cosines. The system then checks the result. If the distance is less than or equal to 20 m, then the system can generate alerts when the user passes through special zones (e.g. the borders of land where mines are buried), show his/her location in real time on Google Maps and display the borders of the land that hide mines. On the basis of the alerts, the user must take caution, must be aware of the mines and must pay attention to his/her next steps.

Figure 3.5: Algorithm mechanism system

1: Initialisation
2: Open database
3: Fetch Geofences boundaries (latA, lonA).
4: Get the location of a a user (latB, lonB).
5: Calculation:
For each point, calculate
$F = \mathrm{acos}[\cos(latA) \times \cos(latB) \times \cos(lonB - lonA) + \sin(latA) \times \sin(latB)] \times R.$
6: **If** $F \leq 20$ m, **then**
Generate alerts for the user.
Proceed to 7.
Else
Proceed to 3.
End if
7: **End**

3.3.4 Evaluation

This stage aims to prove that the implemented system satisfies the initial requirements and to evaluate the partly or fully successful architecture. To evaluate and validate the research outcome, Vaishnavi and Kuechler (2007) proposed different types of approach, namely, mathematical proofs, logical reasoning, benchmarking, simulation, metrics, experimentation and demonstration, which vary in terms of their appropriateness and strength. Furthermore, a list of methods that can be used to evaluate the research outcome are provided and described in Table 3.2.

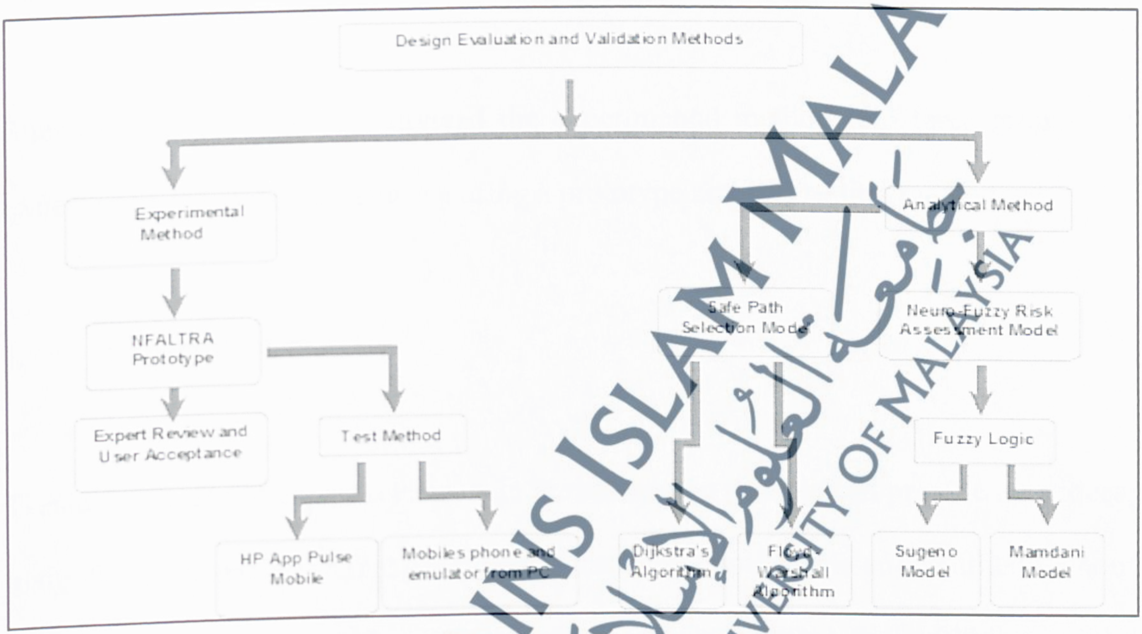
Table 3.2: Design evaluation methods and techniques

Evaluation Method	Description
Observational	Case Study: Study artefacts in depth in a business environment
	Field Study: Monitor the use of artefacts in multiple projects
Analytical	Static Analysis: Examine the structure of artefacts for static qualities (e.g. complexity)
	Architecture Analysis: Study the fit of artefacts into technical IS architecture
	Optimization: Demonstrate the inherent optimal properties of artefacts or provide optimality bounds on artefact behaviour
	Dynamic Analysis: Study artefacts that are used for their dynamic qualities (e.g. performance)
Experimental	Controlled Experiment: Study artefacts in a controlled environment to determine their qualities (e.g. usability)
	Simulation: Execute artefacts with artificial data
Testing	Functional (Black Box) Testing: Execute artefacts interfaces to discover failures and identify defects
	Structural (White Box) Testing: Perform coverage testing of certain metrics (e.g. execution paths) in artefact implementation
Descriptive	Informed Argument: Use information from the knowledge base (e.g. relevant research) to build a convincing argument for artefact utility
	Scenarios: Construct detailed scenarios around artefacts to demonstrate their utility

Source: Hevner et al. (2004)

Two evaluation methods, namely, analytical and experimental, are used in this study. The former is used to validate ERAA, whereas the latter is used to evaluate the ERAA prototype, as shown in Figure 3.6.

Figure 3.6: Evaluation methods



A. Analytical Method

Two verification methods were used to examine the efficacy and performance of ERAA for landmine tracking and risk assessment based on FL. The same dataset, which is considered the same input for the three models (i.e. the Mamdani model, the Sugeno model and NFRAM), along with three parameters (i.e. signal strength, position and landmine intensity), was used in this research. The positive results confirm the potential and effectiveness of the proposed architecture.

The safe selection model is tested using two algorithms, namely, Dijkstra's algorithm and the Floyd–Warshall algorithm. Detailed descriptions of the verification of ERAA are provided in Chapter VII.

B. Experimental Method

Sherwood and Rout (1998) divided the experimental method into three groups: (i) expert review, (ii) user acceptance using a prototype and (iii) testing method.

i. Expert Review

The involvement of expert reviewers in the evaluation process can provide new ideas, insights and valuable external perspectives that might not have been identified without the help of experts. Therefore, expert reviewers can increase the credibility of the evaluation process and findings. For the present research, the expert review process was conducted with two deminers (experts) who have experiences in mine clearing. The interviews were performed in Libya and the expert review process was conducted with two deminers who work at the Libyan Mine Action Centre. Chapter VI provides the descriptions and results of the expert review process.

ii. User Acceptance

This stage intends to obtain end-user acceptance evaluation and measure the reliability and usability of the prototype. The prototype was evaluated by Libyan citizens who live in the areas that surround the capital. This sample was selected because it represents the people who live in unsafe environments and areas that are affected by landmines.

The next section presents the questionnaire design, which aims to obtain end-user acceptance evaluation (refer to Appendix 1 for the questionnaire). With regard to the formulation and construction of the questionnaire, the researcher relied on four key factors taken from Lewis (1993), Lin et al. (1997), Lund (2001), Mallat et al. (2006) and Flora V. et al. (2014).

The questionnaire is divided into two sections. The first section includes questions about the background of the respondents, such as name and age. The second section comprises 38 questions based on 4 heuristic evaluation strategies that will be used to examine the prototype, namely, ease of use, usefulness, user satisfaction and reliability. The questions are scaled in 5 levels, as follows: 1 = Strongly Disagree, 2 = Disagree, 3 = Not Sure, 4 = Agree and 5 = Strongly Agree.

iii. Testing Method

Testing is a critical tool that is used to ensure the quality of mobile applications and software systems to meet requirements and user expectations. In this regard, two tools will be used to test our application: (1) emulators and mobile devices and (2) the HP App Pulse Mobile.

3.3.5 Analysis and Findings

This section summarises the work conducted in this research, the contributions and limitations of the architecture and recommendations for future research. This section also examines the research objectives and research questions and determines whether they have been successfully met.

3.4 Summary

This chapter discusses the approach used in this study, which is adopted from DSRM. DSRM can be grouped into five phases based on the draft, namely, (1) awareness of the problem, (2) suggestion (i.e. proposal of ERAA), (3) architecture development, (4) evaluation of the ERAA prototype and validation of ERAA and (5) conclusion. The characteristics of ERAA are discussed in the subsequent chapter.

In the awareness stage, the requirements of the prototype, the objectives and scope of the study and the research problems are identified and solved through a literature review and content analysis.

In the suggestion stage, the proposed architecture, which intends to address the drawbacks of individual intelligent techniques used in tracking and ERA applications by integrating FL, ANNs and GA, is presented. Detailed descriptions of the proposed architecture are provided in Chapter V.

The development stage involves the development of the ERAA prototype. Detailed descriptions of this process are provided in Chapter VI.

In the evaluation stage, two evaluation methods, i.e. analytical and experimental methods, were adopted. The former is used to validate ERAA, whereas the latter is used to evaluate the ERAA prototype. Detailed descriptions of the evaluation process are provided in Chapter VII.

The conclusion stage provides a summary of the contributions and limitations of the proposed architecture and recommendations for future research. Detailed descriptions of the summary are provided in Chapter VIII.