CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This study has an interdisciplinary nature, and thus, the literature associated with the strategies of tracking techniques is reviewed and discussed, with a focus on the advantages and limitations of each technique. This chapter presents existing decision support systems and AI that are used in a wide range of environmental decision support and risk assessment systems. Some of the most important AI approaches, including expert systems (ES), FL, GA and ANNs, are described.

2.2 Tracking Techniques and Positioning Strategies

Since humans had started travelling to discover different places on Earth, they had been looking for new methods to help them find their location and direction. In the past, determining the position of stars is the only method used by humans to locate their direction. At present, many approaches are used by systems to determine and track the position of objects. Classification techniques can be mainly categorised into four groups, namely, basic positioning methods, outdoor positioning systems, network-based positioning technologies and indoor positioning systems.

2.2.1 Basic Positioning Methods

This section provides an overview of the technologies used for basic positioning, including dead reckoning, proximity sensing, Trilateration and Multilateration.

A. Dead Reckoning

Dead reckoning is the process of calculating the current position of an individual or an object by using a previously determined position based on previously determined positions, travel direction and time elapsed since the last known position, speed and acceleration. Advances in navigational aids that provide accurate information about position have made simple dead reckoning performed by humans obsolete for most purposes. However, inertial navigation systems still provide ultra-fine information guidelines, which are widely applied. Dead reckoning is subject to significant errors although it may provide the best available information on position because of many factors, such as speed and direction, which must be accurately known at all instances to determine positions accurately (Munoz et al., 2009).

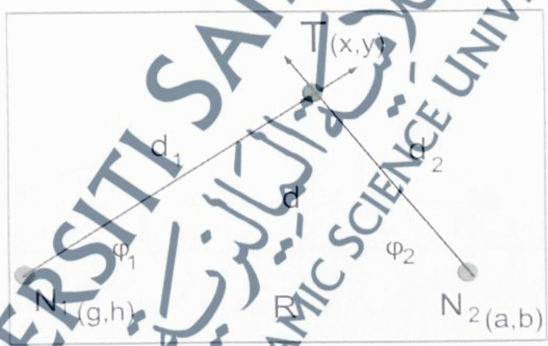
B. Proximity Sensing: Signal Signature Tracking

A mobile position, which is frequently referred to as the target of the proximity sensor, is derived from base station coordinates. Such coordinates have their own signal pattern, which often emits a beam of electromagnetic radiation (e.g. infrared [IR]) and looks for changes in the field or return signal. Signal signature-based technologies are typically composed of mobile location analysis, neighbour list updating and signal signature estimation (Munoz et al., 2009, Andersen A.C., 2013).

C. Trilateration

Trilateration is the one of the geometric techniques used to determine the absolute or relative locations of points by measuring distances using the intersection of a circle and a series of triangles adjacent to one another that can be obtained from a set of reference positions. The trilateration technique uses the intersections of three points, that is, two reference points (N_1 and N_2) and a target point (T), as shown in Figure 2.1. Angles $\varphi 1$ and $\varphi 2$ are obtained from the intersection of the lines from N_1 to T and from N_2 to T.

Figure 2. 1 : Positioning based on the trilateration technique

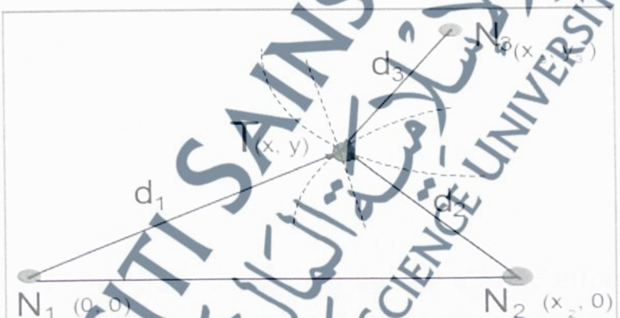


In Figure 2.1, d is the perpendicular line between target point T and line R; d_1 is the line between target point T and reference point N_1; d_2 is the line between target point T and reference point N_2; R is the line between reference points N_1 and N_2; $\varphi 1$ is the angle between lines d_1 and R; $\varphi 2$ is the angle between lines d_2 and R; (X, Y) are the coordinates of target point T; (g, h) are the coordinates of reference point N_1 and (a, b) are the coordinates of reference point N_2 (Munoz et al., 2009).

D. Multilateration

Multilateration, also known as hyperbolic alteration, is a navigation technique that is based on the positioning process by estimating the time difference of arrival (TDOA) of a signal in 2D or 3D Euclidian space. This technique is similar to time of arrival (TOA) estimation but does not need clock synchronisation (Andersen A.C., 2013). The multilateration technique uses three reference points to find the assumed location of objects, as shown in Figure 2.2. If the three points (N_1, N_2 and N_3) and the distances from the reference points (d_1, d_2 and d_3) to object T are known, then the location of object T is the intersection of the three circles (Munoz et al., 2009).

Figure 2.2: Multilateration principle



The distances (d_1 and d_2) can be estimated by calculating the time of flight (TOF) of the signal based on the radii of the first (d_1) and second (d_2) circles.

2.2.2 Network-based Positioning Technologies

The network cell ID method (Cell ID), also called cell global identity (CGI) or cell of origin (COO), is a network-based proximity-positioning method that is frequently used in Global System for Mobile Communications (GSM) (Brimicombe & Li, 2009). Locating a mobile phone based on Cell ID is considered the simplest and most common method. However, this method does not provide useful location information to all applications because of the high variability in cell sizes (from less than 1 km to 20 km). The standardisation location systems have been categorised by the European Telecommunications Standards Institute (ETSI) and the T1P1 committee as follows (Liu et al., 2007; Gu et al., 2009):

i. TOA (network)

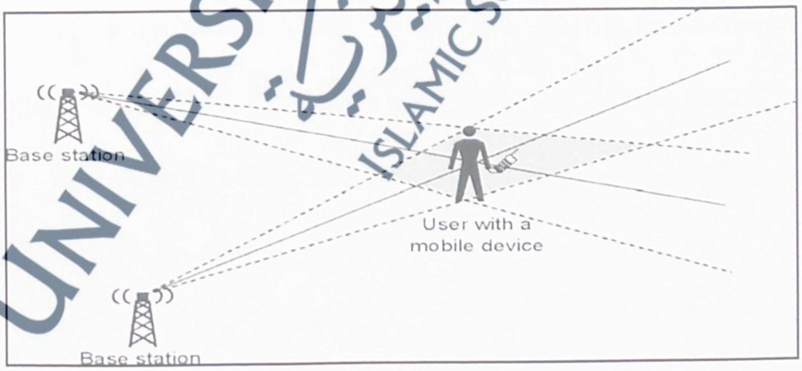
ii. Assisted GPS (handset)

iii. Enhanced observed time difference (handset)

The TDOA and TOA methods depend on the travel time information (equivalent to a range) between a base station and a mobile terminal. The former measures the time of the signal arrival of the user using the network of base stations that observe the apparent arrival time differences between pairs of sites, whereas the latter directly uses the transit time between the transmitter and the receiver to determine the distance between them (Ciurana et al., 2006). TOA uses the points of intersection of circles or spheres whose centres are located at fixed stations to determine the location of a target (Munoz et al., 2009; Bensky A., 2016), whereas TDOA uses the intersections of hyperbolas or hyperboloids that are generated with foci at each fixed station of a pair. The TDOA method provides accuracy between 50 m and 200 m, with the commonly reported accuracy being approximately 125 m (ITU, 2011b; ITU, 2011c; ITU, 2012).

The angle of arrival (AOA), also called the direction of arrival, is a network-based position-locating method that measures the AOA of a signal (i.e. the time taken by radio signals to arrive at several points) from a base station to a mobile phone, or vice versa. The AOA method has been widely used in vehicle navigation systems, surveying and radar tracking. As shown in Figure 2.3, the location of the desired target in two dimensions can be found through the intersection point of two line-of-sight paths. Each path is formed by the circular radius from a base station or a beacon station to a mobile target using antennas with direction characteristics that contain a multiple element array in which the exact location of each AOA element is precisely known. These elements are small and are capable of receiving a separate signal (Munoz et al., 2009; Bensky A., 2016).

Figure 2.3: Basic principle of the AOA positioning method



2.2.3 Indoor Positioning System

During the past decade, research on indoor localisation has become a hot topic and increasingly important to many companies and universities. Numerous applications, such as emergency, medical, military and logistics, can be found for indoor localisation (Liu et al., 2007). An indoor positioning system is considered an alternative solution to low-cost location systems, such as GPS in indoor environments, because no line-of-sight path exists between indoor receivers and satellites; furthermore, signal strength is too low to penetrate most buildings (Maneerat & Prommak, 2011).

Most technologies that rely on high-accuracy systems tend to use short wavelengths, such as electromagnetic and mechanical (sound) waves. In contrast to outdoor positioning technologies, indoor positioning technologies are independent of any 'external' network. However, 'external' networks typically use a set of technologies to transmit wireless data in closed environments, such as Wi-Fi (Baniukevic et al., 2011; Sen et al., 2013), Bluetooth (Altini et al., 2010; Baniukevic et al., 2013), ultrasound (Mautz, 2012; Koyuncu & Yang, 2010; You, 2013), radio-frequency identification (RFID) (Ting et al., 2011), Cramer's rule (Maneerat & Prommak, 2011), wireless local area network (WLAN) (You, 2013), radio (Yoony et al., 2013) and ultra-wideband (Ubisense, 2010; Curran et al., 2011).

Context categories and inferred context information, which have been identified previously, can be implemented in many fields, such as commerce, education, security, military, civil engineering, emergency response, warehouses, exhibitions, libraries and museums. Given their limited coverage range, context-aware systems are restricted to indoor applications. The requirements for deploying positioning systems in an indoor environment are wireless networks that generate the referencing signal used to define object location, such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11 WLAN and the IEEE 802.15.4 wireless sensor networks (Maneerat & Prommak, 2011; Kuflik et al., 2011).

Emergency services have been customised for individuals who are unaware of their exact location in case of an emergency (injury or criminal attack) to use their mobile devices. These services can also determine the location of the user in case of life-threatening injuries by automatically using the positioning capability of a mobile device.

Compared with outdoor positioning technologies, indoor positioning technologies have a set of constraints with a limited coverage range, such as a stadium, an exhibition or other confined spatial area. Their dependency on pre-installed infrastructure makes them unsustainable for a dynamic environment. Indoor positioning technologies are more complex than outdoor positioning technologies because of a variety of obstacles, such as walls and furniture, which cause multipath effects on the wireless signal. Furthermore, the quality of the received signal can be poor because of human mobility and interference from other wireless networks in the building (Rehman et al., 2009; Au, 2010).

2.2.4 Outdoor Positioning Systems

The race to conquer outer space started during the Cold War between the USSR and the USA, during which the first navigation satellite system, i.e. the GPS, was developed by the US Department of Defence (DOD), whereas the Global Navigation Satellite System (GLONASS), the equivalent system of the Soviet Union, immediately followed the European Galileo. Other systems are either already available or under development in various parts of the world, such as in Japan, India and China. This section describes the current status and the foreseen improvements of major global navigation satellite systems (GNSS).

The GPS is the most well-known satellite navigation system that is widely used in outdoor position determination to find the location and position of objects. This technology is currently utilized in many mobile devices. The GPS was originally developed by the US DOD in the early 1970s for the use of the US military (Yeh et al., 2009; Deak et al., 2012). The GPS became available for civilian use in the 1980s (Mama, 2008; Figueiras & Frattasi, 2010; Akinode, 2011).

A. Location-based Service

Localisation and the possibility of providing location-based information are key features that make mobility vivid and practical. The union among wireless communication, the Internet, geographic information systems (GIS), location-finding techniques and mobile devices has hastened the emergence of a new and dynamic field called location-based systems, which have a major effect on navigation and businesses. Location-based Service (LBS) has rapidly evolved and its application is currently a hot topic, thereby making it one of the fastest growing sectors in the cell phone industry (Labrador, 2011). LBS can be divided into different components, as shown in Figure (2. 4).

Figure 2.4: LBS architecture

Source: Labrador (2011)

i. Mobile Devices

Mobile devices, such as personal data assistants (PDAs), mobile phones and laptops, can be defined as tools used by an individual to request the required information and to retrieve results. Mobile devices are the most important part of the entire system, which is composed of the subscriber identity module (SIM) and mobile equipment, because it is used by the subscriber to communicate (Kwok & Lau, 2007).

The majority of cell phones consist of a basic set of comparable features and capabilities, such as a liquid crystal display (LCD), a camera, a random access memory, a digital signal processor, a read-only memory, a variety of hardware keys and interfaces, a microprocessor, a radio module, a microphone, Bluetooth connection, a speaker and GPS (Schmidt, 2011; ITU, 2012).

Each device has different technical and physical characteristics, such as processor speed, memory capacity, size and Universal Serial Bus (USB) connection. Moreover, most mobile phone manufacturers provide their cell phones with different types of expansion capabilities for increased functionality (e.g. camera, PDA and GPS).

The increase in the number of operating systems for mobile phones has been considered one of the principal reasons for the development of applications for mobile devices. At present, manufacturers of devices can select from an overwhelming number of mobile operating systems (approximately 30 to 40) to use in their product lines (Schmidt, 2011; Google, 2012; Microsoft Corporation, 2013).

ii. Communication Network

The cellular network is currently the most important wireless technology and has become one of the most successful technological innovations in history, providing mobile phone and data services to handheld devices. This technology includes second-generation (2G) mobile systems, also known as GSM, and their evolutions, frequently called 2.5G systems, IS-136 and general packet radio service (GPRS) (Glisic & Lorenzo, 2009; Raychaudhuri & Gerla, 2011).

Cellular networks are ubiquitous in all parts of the world and cover most populated areas. Furthermore, they are used by nearly 4 billion cell phones worldwide. Cellular networks have evolved through several stages—starting from first-generation analogue systems, such as the Advanced Mobile Phone System, to 2G digital systems, such as GSM and code-division multiple access (CDMA), to third-generation (3G) systems, such as CDMA2000 and Universal Mobile Telecommunications System/wideband CDMA (Glisic & Lorenzo, 2009; Raychaudhuri & Gerla, 2011).

Given the failure of the first generation to meet all requirements and to address capacity shortfall, the development of GSM began in 1982 and it was standardised by ETSI (Kwok & Lau, 2007; Mishra, 2010). GSM, also known as 2G, is a widely used mobile communication standard that has become more popular than first-generation analogue systems (Kumar et al., 2008). The GSM network is divided into the following domains: the network management system, the mobile station, the base station subsystem and the network subsystem (Kumar et al., 2008; Mishra, 2010; Agrawal & Zeng, 2011).

GSM experienced tremendous economies of scale for everything because it offered a rich selection of capabilities and features that provided incremental revenues for operators, such as intelligent functions for the support of personal mobility, particularly with regard to user identification and authentication, and for the localisation and administration of mobile users (Eberspächer et al., 2009; Sauter, 2011). Several billion text messages are being sent via short message service (SMS) among mobile users each month; SMS has become extremely popular among GSM users despite the fact that GSM was used nearly exclusively for speech communication in the beginning (Eberspächer et al., 2009; Mishra, 2010).

GPRS is a non-voice value-added service provided to the GSM of 2G and 3G cellular communication systems by overlaying a packet-based air interface on an existing circuit-switched GSM network. GPRS has been implemented as 2.5G, that is, a technology between 2G and 3G mobile telephony. GPRS was originally standardised into the GSM specifications in Release 97, and its usability was further approved in Releases 98 and 99 by ETSI (ETSI, 2013; Zheng et al., 2010; Eberspächer et al., 2009).

GPRS provides moderate-speed data transfer and offers faster data rates than plain GSM by using unused time-division multiple access channels in ETSI (2013). Theoretical maximum speeds of up to 171.2 kbps can be achieved with GPRS by simultaneously using all eight time slots (ETSI, 2013). Such speeds are not offered by most operators because GPRS is based on the combination of slots; moreover, not all mobile operators can aggregate all combinations of slots (ETSI, 2013). The GSM network architecture has been combined with two new components, namely, gateway GPRS support node and serving GPRS support node, which resulted in GPRS (Zheng et al., 2010).

iii. Positioning Component

Positioning component (context) can be defined as 'any information that can be used to characterise the situation of entities (i.e. whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves'.

iv. Data and Content Provider

Content providers (e.g. mapping agencies, yellow pages and traffic companies) are responsible for storing and collecting geographic base data, location information and other related data. By contrast, service providers typically do not store and maintain all of the information requested by users.

v. Service and Application Provider

Application is frequently software developed by an application provider that is used as an interface by the user to access LBS after being downloaded and installed on the mobile device of the user.

LBS can be used in many areas, such as military and government institutions, the commercial sector and emergency services. The subsequent section describes current types of LBS applications, which can be categorised according to several approaches that have been adopted by analysts and researchers.

B. Tracking Services

At present, many services require real-time or continuous tracking of assets, such as vehicle tracking, logistic systems, fleet management, workforce management and finding people. The accuracy and coverage of GPS is well suited for most outdoor navigation tasks. Therefore, GPS is used by nearly all of the aforementioned systems for location estimation. The subsequent section describes some of these applications and their characteristics.

i. Emergency Support Services

The most immediate application of location-based services is to aid in assisting individuals who may be lost, hurt or in danger, i.e. their safety and security are under threat. Many events cannot be reported to an emergency centre when they occur in real time (e.g. when an individual is involved in a serious traffic accident, when an individual is being subjected to a criminal or terrorist attack or when the car of an individual suddenly breaks down). At present, users are able to send their location by using their mobile devices. Thus, emergencies can be addressed more efficiently; consequently, more lives can be saved.

Nandhini et al. (2016) presented a system that aims to save the lives of fishermen at sea and provide a user-friendly and well-understandable environment to avoid accidents and to alert fishermen about border areas. This system has been designed using GSM, GPS and a microcontroller unit, which protect fishermen by notifying the country border patrol (GPS). The system uses a GPS receiver to find the current location of a fishing boat or vessel. The mechanism of the system is simple. The GPS receiver is used to find the current location of a fishing boat or vessel. Then, the information will be sent to the controller unit to find the current location by comparing the present latitude and longitude values with the predefined values. In case the fishermen move further and reach the warning zone, the LCD displays the warning zone. The GSM signal is used by the system to connect to the Internet to access the database. Thus, covering all border areas within the sea using the GSM network is difficult and is considered a disadvantage of this system.

A new system developed by Sivagnanam et al. (2015) aims to warn and prevent fishermen from crossing a sea border by allowing them to calculate its exact location using an integrated GPS receiver and to transmit the information to the nearest coastguard station via GSM communication. The system is composed of three units: GSM, GPS and a microcontroller unit. This system was implemented with the help of GPS by integrating the code it provided and the code generated in the arm microcontroller through a timer. The system was designed by integrating a GPS unit and GSM communication into the microcontroller. The system can be integrated into mobile phones to ensure that it exhibits high efficiency.

Most fishermen are unaware of borders at sea, where long-time disputes between countries still exist. A system called the Fisherman Auto-boat presented by Vinothkumar and Arunkumaran (2014) aims to determine the location and position of a boat in the ocean. The system can transmit voice messages in case fishermen cross border limits. Even if fishermen attempt to drive the ship/boat forward, the motor will be stopped automatically; thus, the ship/boat will halt. Consequently, the system can save the lives of fishermen or reduce the harm that will be inflicted to them by coastguards. The GPS receiver is used by the system to receive signals from a satellite and to provide the current position of a boat. The system can also be used to detect icebergs in the sea via an ultrasonic sensor and to predict tsunamis through microelectromechanical systems. Smartphones can be used as better alert and warning systems than complex hardwires; they can reduce complexity and enhance ease of operation, thereby improving this system.

Kumar et al. (2015) presented a research that aims to prevent Indian fishermen from navigating beyond the borders of other countries. To achieve this objective, they created a device that will prevent Indian fishermen from moving beyond the India–Sri Lanka maritime border, as shown in Figure 2.5. This device generates an alarm in case fishermen cross the border. This system is composed of four units, namely, transmission, control, processing and data collection units, which consist of location-detecting components, such as GPS, and other components attached to the boat.

Figure 2.5: Overall flow diagram of the proposed system

Source: Kumar et al. (2015)

The majority of Tamil Nadu fishermen face problems of being harassed, assaulted, shot at and chased by the Sri Lankan navy. To address this problem, a new system of cloud computing to protect the lives and properties of fishermen from the Sri Lankan navy was proposed by Samuel et al. (2014). The system uses a new methodology, called cloud computing, as a service to save the lives of fishermen, which is the main purpose of the system. The new methodology aims to reduce hardware cost and to avoid hardware errors and problems in tracking vessels. Moreover, businesses will no longer need to spend on advanced and expensive hardware. The system framework consists of three main phases, namely, tracking the boat, alerting the GNSS device and alerting the PC using the cloud.

An intelligent boundary alert system developed by Thangapushpam et al. (2012) aims to help fishermen in maritime navigation. This system provides the current position of a boat based on latitude and longitude data using a GPS receiver, which continuously receives signals from a satellite.

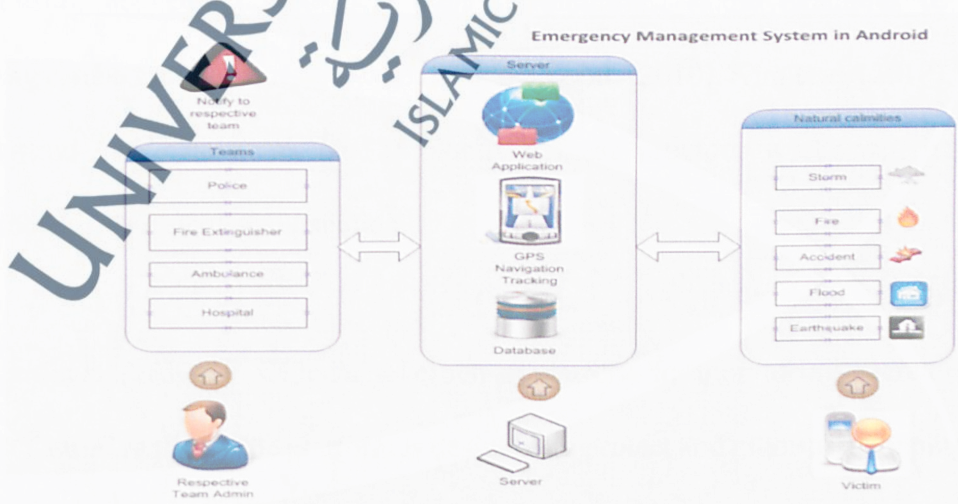
In the field of sports, a large number of rowing athletes of different ages practice alone, without their coaches or additional equipment apart from their boat, thereby placing themselves at risk. To solve this problem, a new system, called the ZigBee/GPS tracking system, was developed by Simões et al. (2015), with the main objective of real-time monitoring of boats in rowing races as a safety device. The system architecture consists of mobile units (MUs) located in boats, a ZigBee wireless module, an LCD interface and a fixed unit (FU). A point-to-multipoint ZigBee wireless network was implemented to facilitate communication between an FU and MUs located in boats.

Most of the previously presented systems are similar in design and form. Moreover, these systems are composed of four units, namely, transmission, control, processing and data collection units, which consist of location-detecting components, such as GPS. The main objective of the previously presented systems is to reduce the cost of advanced and expensive hardware to prevent fishermen from moving beyond a maritime border. However, these systems are still more complicated than their portable counterparts.

The main characteristics shared by previous regimes are still more complicated than their portable counterparts because of the complex technology and electric parts necessary for their operation. Thus, these systems can be integrated into mobile phones to make them portable and easy to carry by modifying design specifications.

During times of disaster, communication between the rescue teams and victims is highly important to reduce economic and human losses. In this context, Jadhav et al. (2014) proposed the emergency management system (EMS), which enables smartphone-based ad hoc communications over Wi-Fi to function in case of emergencies. EMS can be used by people in an emergency situation or any individual at an emergency site where the system works based on the principle of the client–server system. EMS consists of a web server and a smartphone-based application, as shown in Figure 2.6.

Figure 2.6: Architecture of EMS



Source: Jadhav et al. (2014)

The server is implemented as a web-based Java application, whereas the client and rescue applications are implemented as an Android application. Although the system can help people during emergency, it cannot provide a street map, it cannot submit a photo or video, it cannot share events by email or post links to Facebook and Twitter and it cannot provide feedback regarding the credibility of a post to prevent fraudulent posts.

ii. Environmental Surveillance

Many applications that use LBS are considered useful in hazardous areas, where human lives are endangered. Even animals can benefit from LBS technology during migration season by monitoring their movement and helping them as necessary. Public concern for wildlife has motivated many resource agencies to change their management approach to address issues such as conservation of biodiversity and effects on wildlife and their habitats. Since 1991, a variety of animal tracking systems have been designed for use by researchers to analyse the activities of animals and to understand the complex relationship between animals and their surroundings. Many examples of animal tracking can be found in the studies of Broadbent et al. (2010), Kim et al. (2010), Dopico (2011) and Chakchai et al. (2012). Some of these previous works will be briefly mentioned in the subsequent section.

Anthony et al. (2012) presented a novel sensor platform for monitoring migratory birds, called 'CraneTracker'. The platform is designed to protect and monitor whooping crane, which is one of the most endangered bird species native to North America. The aim of CraneTracker is to obtain information on the movements and behaviour of these birds during their migration, which extends from Texas to Canada. This system has been proven effective through component evaluations, controlled system experiments and ongoing field experiments.

The common characteristics shared by the previously presented systems are the use of GPS and a system tracker designed in the form of a collar, which is easy to install around the neck of an animal.

Malet et al. (2011) developed a methodology that uses permanent GPS stations for near real-time characterisation of displacements. In the past few years, several GPS receivers have been installed on active landslide areas in France to monitor landslides. As a complement to conventional geodetic methods, GPS has been mainly used for repeated measurements. The aim of GPS receivers is to collect the same type of kinematic, hydrologic and seismic observations on landslides. These data are disseminated by the collaborative structure of the French Research Council (CNRS) to the scientific community through relevant graphs and emails. The proposed system offers certain advantages in monitoring landslides in France, but suffers from its inability to support decision-making.

iii. Tracking Management System

GPS navigation auto tracker systems have become prevalent since the development of satellite positioning technology and GPS. In recent years, controlling vehicles through long-distance supervision has become possible with the development of wireless communication technology.

Dinkar et al. (2011) developed a vehicle monitoring system (VMS) that uses GPS, GIS application technology and GPRS wireless communication to obtain an example of VMS based on MapX. This system consists of a data terminal fixed on every vehicle, which takes the signal transmitted by a GPS satellite, a GPRS communication network and a centre monitoring system at the command centre. Visual C++ software platform is adopted to establish the system software, whereas MapX 5.0 is utilised to display and control the map. SQL Server 2000 is used as the background database to save information received from the data terminal.

Popa (2011) presented a system for tracking a fleet of vehicles by combining digital maps, mobile communications and embedded systems. A device for tracking a vehicle consists of three parts: (1) communication and CPU modules, (2) positioning module and (3) localisation and positioning modules. This system is characterised by a small footprint, high storage capacity due to the use of microSD memory cards and high possibility for expansion.

Jog et al. (2011) proposed that the limitations imposed by GSM technology can be overcome by adding differential GPS and mobile WiMAX. This integration achieves a high bandwidth (data rates from 3 Mbps to 50 Mbps), improves system accuracy and enables the transmission of live videos from inside and outside the vehicle.

Verma and Bhatia (2013) described a new vehicle tracking application that enables users to track a target in any weather condition based on GPS and GSM technologies. The system consists of two parts, namely, the hardware part, which comprises GPS, GSM, Atmega microcontroller MAX232 and 16 × 2 LCD, and the software part, which aims to transfer all the required modules. The system can be easily installed and provides a platform for further enhancement. Although the applications are user friendly and provide the exact location of a target, this project can be further enhanced by using a camera and developing a mobile-based application.

The tracking system proposed in this study aims to track vehicles using the Google Earth application; it aims to assist corporations with a large number of automobiles and has several other usage purposes. Hybrid techniques have been used to implement the system, including embedded applications, geographical positioning and wireless communication. The system can graphically provide users with the location on Google Earth and users can view other relevant information of each automobile in the fleet. This system can be used for other purposes, such as monitoring various parameters related to safety, emergency services and engine stall (Al-Khedher, 2012).

Most available vehicle tracking systems, which use GSM technologies, have several limitations because of their dependence on the GSM service provider to transmit information using GSM/GPRS. However, failure to receive GSM/GPRS signal causes a system to stop. Another limitation of these systems is related to the accuracy of GPS for positioning information. At present, the accuracy of GPS is approximately 10 m. Occasionally, it can reach up to 100 m when the GPS is operated by the US DOD (Garmin, 2007).

iv. Tracking People

Tracking patients with Alzheimer's disease is a difficult task and a considerable challenge faced by their relatives every day. Alzheimer's disease is a form of dementia that affects 20% of people aged over 80 years and 5% of people aged over 65 years, which prevents them from remembering where they live. In recent years, this problem has generated a growing interest on how sensor-based technology can be used to assist patients with Alzheimer's disease (AZ, 2009; Alzheimer's Association, 2012).

Keeping constant watch over a dementia patient is difficult; accordingly, an American company has designed shoes with a built-in G-sensor (tracking device) to track patients with Alzheimer's disease and to provide worried relatives with peace of mind. The heels of the shoes are equipped with GPS function, which cannot be seen or felt. This device contains a battery, an antenna, a USB connection and a SIM card slot, which indicates that the shoes will be able to work in different countries. The USB connection is used to charge the shoes, which takes approximately 2 h, approximately every 2 days (Hodgekiss, 2012).

Another example similar to the aforementioned case is that reported by Dahl and Holbo (2012a, 2012b), who developed a system called 'On-Sat Safecracker' that aims to assist patients with Alzheimer's disease. The components of this system are similar to many other GPS tracking systems, including a car and supported services, with regard to hardware and user interfaces. On-Sat Safecracker is characterised by a small GPS tracking unit that allows patients with Alzheimer's disease to place it in their pocket. The tracking unit has a red button that is used by patients to notify a predefined client about their position, which can be visualised on a map in the web interface of tracking systems.

Keeping an eye on children every day is a difficult task for parents. Millions of children are reported missing annually across the US and in African countries. In South Africa, these cases have inadequate statistics; however, the South African Police Service Missing Person Bureau has issued a report in 2007 that 1 child goes missing every 6 h (NCIDP, 2011).

A tracking system devised by Jawad et al. (2009) is capable of detecting threats that surround children by using a specific sensor. The system consists of two modules: the parent and child modules. The proposed child module for this design is sufficiently small to be attached to a child and to be implemented on a single chip microcontroller.

A new system is proposed to assist security agencies in Nigeria to identify the location of kidnapped persons based on the position-locating capability of GPS. The system is composed of four major components, as follows. Firstly, a memory is used to store preloaded data that comprise GPS locations. Secondly, the GPS module is used to obtain location data. Thirdly, the microcontroller accesses memory location data from the GPS module and compares them with the data stored in the memory. Finally, the GSM modem enables the transmission of location data through the GSM network. The system keeps a record of the trajectory of a tracked person or device, and on demand, sends an SMS message that contains the last five locations of the tracked object or person to the monitor. The data will be used to enable rapid response in the location of the tracked person or object. A panic button is provided by the system, which will result in the transmission of the location data to the monitor when activated by the tracked person (Idachaba F.E., 2011).

Anand et al. (2012) proposed an employee tracking system that allows managers to monitor the office cell phone of their employees with an Android platform. Managers can access the history of their employees and determine their location. They can set up alerts if their employees go beyond the approved geographical zones. The proposed system has additional features that use cloud technology to store and retrieve information using the Simple Object Access Protocol; however, data loss during message transfer due to the use of SMS is possible.

Murat et al. (2009) proposed a web-based mobility analysis system, called the TRACK ME! Framework, which converts low-level location data into high-level mobility information and then adds a temporal dimension. The TRACK ME! Framework consists of the following components: (1) a data collection system, which contains a software that runs on the cell phone platform; (2) a data mining subsystem, which contains different processes that convert low-level location data units into high-level mobility profiles; (3) a query engine, which provides a query definition interface to the high-level application for executing complex queries over mobility profiles and (4) a location prediction subsystem. Although this framework converts low-level location data into high-level mobility information, it still needs to extend its data collection system from GPS-enabled cell phones.

The previously presented systems are characterised by strong dependence on GPS services, ease of use and flexible mobile platforms, but lack intelligent technology to support decision-making. Moreover, most of these systems use GSM modems to send and receive data. GSM modems have a limitation of accessing 6 to 10 SMS per minute. Thus, a GPRS modem is required for these systems to increase such capacity.

v. Infotainment Services

Infotainment services are used to meet user requests, such as requests on how to reach a given destination, how to localise the current position (on a map) of a lost user, how to find another mobile user and where to find a particular service (e.g. automated teller machine, restaurant, parking lot or gas station).

Chandra et al. (2011) proposed an awareness system that can be used to share locations with friends and family and view them on Google Maps, determine the current location of users and send the location using SMS. The application consists of five parts: a web server, a mobile client, a GPS system, a database and a map service. The mobile client is implemented using J2ME, whereas the web server-side programming is executed using PHP and the database is maintained by MySQL.

Deidda et al. (2010) developed a client–server framework that is compliant with Free and/or Open Source software and compliant with the OpenLS standard for LBS, which provides tourist information on Cagliari City in Sardinia. The architecture of the system includes the client application, which obtains its position from its integrated GPS receiver and sends it to the LBS server, and the server that is used to answer with information on interest points near the client. The Python 4 programming language was used to develop the server, whereas the open source GIS gvSIG was used to develop the client side.

Another framework similar to the personalised location-based traveller recommender system developed by Husain and Dih (2012) is used to provide personalised tourism information to its users. The framework is composed of five components, namely, LBS, a user profile database, a tour information database, user positioning information and usage log, which tracks the interaction of a user with the system.

The personalised location-based restaurant recommendation system (PLRRS) (Wen-ying and Guo-ming, 2013) is another example of an LBS framework, which can solve the cold start problem, keep new user effort to a minimum and provide accurate and timely recommendation to users. The PLRRS framework uses cold data to reduce the complexity of the operation of a mobile user. The framework includes context information, such as weather conditions, time season and location, which can be used to provide users with the most effective recommendation based on their short-term and long-term preferences. The database of the framework is divided into four files, as follows: (1) user profile and mobile device information; (2) contextual information, including the current context information, season, weather, time and location of users; (3) restaurant information, including category, features and basic information of restaurants and (4) user usage log records.

A new application, called G-Sense, which was developed by Perez et al. (2010), aims to improve the quality of life of individuals and to address large-scale societal problems. The system integrates static wireless sensor networks in support of LBS, mobile, participatory sensing (PS) and human-centric sensing (HCS) applications into one coherent environment. G-Sense is a hybrid architecture that is composed of a two-tier client–server and peer-to-peer architecture among servers to scale the system to worldwide deployments. G-Sense supports the development of local and global LBS, PS and HCS applications. The characteristics of LBS applications are summarised in Table 2.1 based on the preceding discussion of applications.

Table 2. 1 : Characterisation of LBS applications

Service category	Author(s)	Characteristics
Infotainment services	Finder applications: Chandra et al. (2011) Tourist information application: Deidda et al. (2010) Restaurant recommendation application: Husain and Dih (2012) HCS applications: Perez et al. (2010)	• Location information is either transmitted by request or assessed by service. • Pull-based model • Mobile user-initiated, query-based and request-driven
Tracking services	Environmental surveillance: Broadbent et al. (2010); Kim et al. (2010); Malet et al. (2011); Dopico (2011); Anthony et al. (2012); Chakchai et al. (2012) Tracking management system: Dinkar et al. (2011); Jog et al. (2011); Popa (2011); Al-Khedher (2012); Verma and Bhatia (2013) Tracking people: Murat et al. (2009); Hodgekiss (2012); Dahl and Holbo (2012a, 2012b); Anand et al. (2012)	• Pull-based and push-based • Tracking requests are frequently initiated by a remote monitoring entity and not by the mobile entity as per the state-based nature of the application.

Table 2. 1 Continued

Service category	Author(s)	Characteristics
Emergency support services	Fishing boat: Vinothkumar and Arunkumaran (2014); Samuel et al. (2014); Nandhini et al. (2016); Kumar et al. (2015); Simões et al. (2015); Sivagnanam et al. (2015) Natural disasters: Jadhav et al. (2014)	• Mobile user-initiated • Pull-based • Rely entirely on the available position-locating technology

2.3 Artificial Intelligence

Although intelligence is one of the most important operations or activities of the human mind, this concept is difficult to define precisely. John McCarthy coined the term 'artificial intelligence' or 'AI' when he held the first academic conference at the campus of Dartmouth College in the summer of 1956. This term means 'the science and engineering of making intelligent machines, especially intelligent computer programs' (McCarthy, 2007).

2.3.1 Artificial Intelligence Techniques

Over the past 50 years, robots and computers have progressively assisted humans, initially only in relatively simple computational and manipulation tasks, but recently, in higher cognitive tasks that used to be the exclusive domain of the human brain, including language, mathematics, probabilistic reasoning and decision-making. Kalogirou (2007) reported that AI comprises several branches that can be classified into the following categories: expert systems (ES), robotics and sensory systems, computer vision and scene recognition, intelligent computer-aided instruction, machine learning, handwriting recognition, natural language processing and voice technology, neural computing, FL, intelligent agents, problem solving and planning, non-monotonic reasoning, logic programming, ANNs and various hybrid intelligent systems.

ES is considered one of the scientific applications of AI; it aims to transfer human intelligence to computer systems through design software and computing devices that mimic the behaviour and thinking of humans. Feigenbaum (1982) defined ES as 'an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough and require significant human expertise for their solution'.

Computers can make decisions by interpreting data and selecting from a list of alternatives supplied by ES. Despite its sophistication, ES still does not approach the complexity of human intelligence because it deals with knowledge processing and complex decision-making problems (Kalogirou, 2007). Many fields of human activity, such as business and finance, manufacturing, education and training, engineering, medicine, science, agriculture and design, successfully use ES.

One of the advantages of ES is providing knowledge of expert staff. Furthermore, ES can be used as a training aid to increase the expertise of staff, to make rational decisions without any emotional overhead and to obtain answers efficiently given that it does not involve an additional help staff (Chiang et al., 2001). ES provides the advantage of making rational decisions and increasing the expertise of staff. However, this approach suffers from its inability to cover a wide range of knowledge. ES is difficult to develop and requires considerable time and effort from many experts. Most ES cannot deal efficiently with ambiguous problems, cannot learn from mistakes and cannot experience or adapt to new environments.

FL is one of the most talked-about technologies in the embedded control field in recent years. This section provides insight into the structure of fuzzy systems for modelling and control. Some basic vocabularies related to fuzzy systems, which are required for the development of fuzzy systems in this study, are presented.

The first attempt to introduce the logic of fuzzy sets was reported in the mid-1960s by Dr. Lotfi Zadeh (1968); this concept has been widely adopted as a methodology for representing uncertain knowledge in many engineering applications in recent years. The logic of fuzzy sets is used to deal with linguistic variables associated with natural languages by providing a mechanism for approximation using graded statements instead of those that are strictly Boolean.

Humans have a natural tendency towards uncertainty; thus, FL enables a person to interface more easily with an automated system than in the conventional case. The fuzzy approach can represent imprecise knowledge in a simple and understandable manner for users and specialists (Lee C.C., 1990; Garg & Bansal, 2015; Khalifa & Frigui, 2016). Furthermore, this approach is suitable for uncertain or approximate reasoning, particularly for a system whose mathematical model is difficult to derive (Munakata T., 1998). However, FL faces a problem in defining the MF parameters when no systematic procedure is available to define such parameters; thus, FL must be predetermined by expert knowledge about the modelled system (Sandhu & Rattan, 1997; Othman et al., 2014; Khalifa & Frigui, 2016). Fuzzy systems lack the capability to learn and cannot adjust themselves to a new environment, but they can explain how they arrive at a particular solution (Munakata T., 1998).

GAs can be defined as a class of stochastic search algorithms based on the basic principles of biological evolution and natural selection; these algorithms were introduced by John Holland in the early 1970s (Negnevitsky, 2005; Scrucca, 2012).

The mechanism of GA is based on survival of the fittest in nature, in which the succeeding generation should be better than the previous one because its members were bred from healthy parents. GAs are tools for search and optimisation that have been widely used in many fields, such as science, commerce and engineering, over the years. GA uses a vocabulary borrowed from natural genetics, called chromosomes, which are made of units (also features, characters or decoders) arranged in linear succession.

GA is generally accepted as the best option for solving a variety of complex problems. The GA technique can be used for traditional nonlinear problems that cannot always achieve an optimal solution. GA is also used as a problem-solving mechanism, which can generate multiple results that are the most appropriate (Maali & Al-Jumaily, 2012; Garg & Bansal, 2015). Furthermore, GA can optimise a wide variety of problems, such as the travelling salesman problem, which can be eventually link to circuit design, scheduling and delivery problems (Kasabov & Nikola, 1996).

Although GA has many advantages, it also has limitations. One disadvantage of GA is that it occasionally requires a decent-sized population and numerous generations;

therefore, GA can be a slow process when it is solving a complex problem that has a large number of parameters, and it may take a long time before it obtains good results (Riko & Andreja, 2006; Ganatra et al., 2014). GA can also present incomprehensible solutions because it communicates with the system through the fitness function. Therefore, GA provides different results each time, which is inefficient or incomprehensible from an engineering point of view (Munakata T., 1998).

ANNs are computational techniques that have been designed to simulate the low-level operations of the human brain. They are composed of a collection of neurons that are interconnected to form a network.

ANNs are non-parametric models, whereas most statistical methods are parametric models that require a higher statistical background. ANNs with the BP learning algorithm is widely used to solve various classifications and forecasting problems (Uraikul et al., 2007; Shang & Hossen, 2013). ANNs have interesting properties that made this family of machine learning algorithms appealing when dealing with difficult discovery tasks. ANNs have a number of advantages, such as the capability to implicitly detect complex nonlinear relationships between dependent and independent variables (Dumitru & Maria, 2013; Garg & Bansal, 2015). ANNs also have the capability to learn from input–output pairs and adapt to them in an interactive manner. However, ANNs are a black box learning approach, which cannot interpret the relationship between input and output and cannot deal with uncertainties (Tu J.V., 1996; Sandhu & Rattan, 1997; Cordón O., 2011; Srivastava, 2014). Moreover, ANNs cannot extrapolate results and are incapable of extracting knowledge (weights in ANNs). Table 2.2 summarises the advantages and disadvantages of AI technology.

Table 2.2: List of Major Advantages and *Disadvantages Associated with AI*

Advantages				**Disadvantages**			
GA	**FL**	**ANNs**	**ES**	**GA**	**FL**	**ANNs**	**ES**
Used for traditional nonlinear problems	Represents imprecise knowledge	Capability to learn	Provides knowledge	Too slow and complex	Requires high expert knowledge	Black box approach	Inability to learn
Solves complex problems	Suitable for uncertain reasoning	Handles a large amount of data sets	Increases expertise	Incomprehensible solutions	Inability to define MF parameters	Difficulty in extrapolating results	Difficulty in developing
Generates multiple results	Supports decision-making	Detects interactions between variables	Supports decision-making	Dependent on the speed of computers	Inability to learn	Difficulty in extracting knowledge (weights in ANN)	Unsuitable for ambiguous problems

2.3.2 Decision Support System

Decision Support System (DSS) can be defined as a computer technology solution that can be used by a decision maker to provide support for complex decision-making and problem solving (Turban et al., 2005; Sauter, 2010; Burstein et al., 2011).

The area of DSS and executive information systems is located between management information systems and ES. Both types of systems aim to help decision makers determine and obtain information, which may be useful in addressing poorly structured search spaces, and to select what they want in substance and format by providing tools that help obtain possible solutions and understand the problems in and the flexible mechanisms for analysing and retrieving data (Sauter, 2010).

A. Decision Support System Components

Decision Support System (DSS) consists of the following components (Stanciu, 2009; Jao, 2010; Sauter, 2010).

i. Database Management System

Database Management System (DBMS) is a computer software application that interacts with the user, other applications and the database itself to capture and analyse data. It provides access to data, which include the database that contains relevant data for the problem, such as facts about market research or intelligence, internal processes, generally available information and all software necessary to obtain those data in a form that is suitable for analysis under consideration without exerting considerable effort on user programming. A general-purpose DBMS is designed to allow the definition, creation, querying, updating and administration of databases.

Well-known DBMSs include MySQL, PostgreSQL, Microsoft SQL Server, Oracle, Sybase, SAP HANA and IBM DB2. A database is generally non-transferable across different DBMS, but different DBMS can interoperate by using standards such as SQL and ODBC or JDBC to allow a single application to work with more than one DBMS.

DBMS is frequently classified according to the database model that it supports. The most well-known database systems since the 1980s have all supported the relational model as represented by the SQL language.

ii. Model Base Management System

Model Base Management System (MBMS) is a set of computer programs integrated into DSS that performs a similar task for the models in DSS and allows users to create, update, edit and/or delete a model (Stanciu, 2009).

iii. User Interface

User interface is a set of commands or menus used to input information into the system and output it from the system. User interface includes control sequences (such as keystrokes with the computer keyboard, movements of the computer mouse and selections with the touch screen) and software 'logical' components (such as graphical, textual and auditory information presented by the program to the user).

B. Intelligent Decision Support System

The inclusion of AI techniques, such as knowledge bases, ANNs, GAs, natural language, multi-agent systems and FL, has recently added improvements to the DSS field (Phillips-Wren, 2007), which is regarded as an effort to develop computer-based systems that mimic human qualities, such as approximation, reasoning, intuition and common sense. Consequently, a new common denomination, called 'intelligent DSS' or 'IDSS', has emerged (Ribeiro, 2006).

IDSS has been defined as incorporating AI techniques and computer-based systems that use data, expert knowledge and models to support decision makers in organisations in solving complex, imprecise and ill-structured problems (Turban et al., 2005; Ribeiro, 2006; Zhou et al., 2008). AI techniques and human knowledge are two components that should be integrated to develop IDSS that can help decision makers during different phases of decision-making.

ES is a form of AI that can mimic the decision capability of humans by utilising human expert knowledge. Thus, ES can be used to assist human experts in their routine tasks. ES has a limited capacity to mimic the decision capability of humans; hence, FL can be used in conjunction with ES for this purpose to improve the quality of decisions and to increase ES reasoning capability (Kildišas, 2000).

A neural network is a set of interconnected neurons created by computer programs, which have the capability to perform brain-like functions, such as forecasting, classification and pattern matching. GAs can be defined as a class of stochastic search algorithms based on the basic principles of biological evolution and natural selection (Scrucca, 2012), which can be used in a wide range of applications, such as job scheduling and control, water networks, robotics, image processing and medicine.

C. Applications of Intelligent Environmental Decision Support

AI has been widely adopted in many environmental DSS in recent years (Sibai et al., 2011; Wu & Liu, 2011; Kuo et al., 2011; Dinkar & Sambyal, 2012; Melin et al., 2012; Zeng & Wang, 2012; Uzun & Bicakci, 2012; Choi et al., 2012; Connolly et al., 2013; Banerjee & Datta, 2013; Lin & Lin, 2013; Müller et al., 2013; Youssef & Asari, 2013; Zaidan et al., 2014). The subsequent section presents a review of existing DSS and AI that are used in ERA.

i. Demining

Organising mine clearing operations in a controlled and effective manner is extremely important for countries affected by landmines. The reduction of suspected hazardous areas (SHA) is an expensive process that takes a long time and that requires collecting additional information from the depths of SHA. Therefore, the need for a new tool designed to assist experts and managers in their decisions is evident. Although airborne and space-borne remote sensing have been used in several research and development projects for mine action, advanced IDSS is the first mine action technology regarded as a successful system by combining remote sensing with an advanced intelligence methodology. This system aims to improve hazardous risk assessment to achieve high efficiency in land cancellation and release. This section describes the components of the AI DSS system, where AI and DSS have been used in the mine clearing domain.

Several organisations, such as Development and Training Ltd., Centre for Testing and Faculty of Geodesy of the University of Zagreb, have developed and implemented AI DSS. The result is a system called space and airborne mined area reduction tool (SMART) that improves hazardous risk assessment to achieve high efficiency in land cancellation and release. The first operational service for reducing a suspected mine area and performing risk assessment was applied via airborne remote sensing, spatial imagery and AI DSS, where the aforementioned partnership was proven successful in Croatia (BiH Bajic, 2010; ITF & CTDT, 2010, 2011).

SMART provides additional information that can be used to reinforce the suspicion of several places and reduce the suspected area in other places. The SMART project aims to provide a GIS-based system by integrating dedicated tools, designed methods and radar data to assist human analysts in interpreting a mined scene. The approach of SMART is based on (1) the extracted indicators of mine presence and mine absence, (2) the interpreted and fused multi-sensor imagery, (3) the combined contextual data, (4) the spatial data, (5) the data contained in other information systems and (6) the formalised expert knowledge.

The SMART project has used the system to acquire aerial hyperspectral data on a blimp, which was designed and constructed for such purpose. SMART allows an operator to transform maps that are gathered into 'danger maps' to show how dangerous each area is according to the location of known indicators.

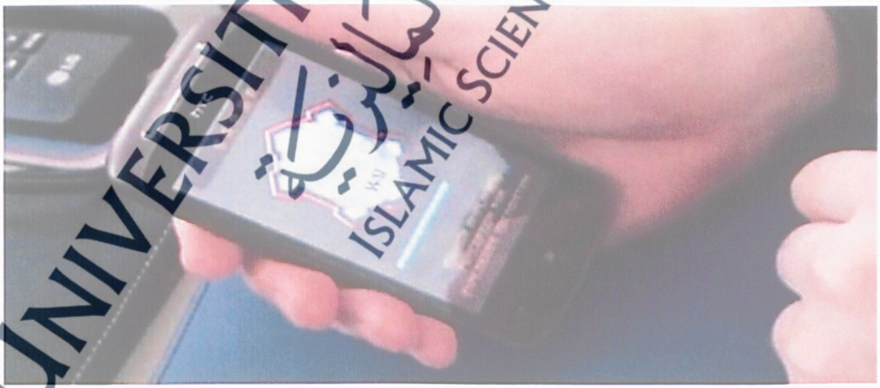
A fusion method was developed based on fuzzy inference to detect buried objects using ground-penetrating radar data (Karem & Frigui, 2011; Khalifa & Frigui, 2014a; Khalifa & Frigui, 2014b). The proposed method is capable of learning meaningful and simple fuzzy rules for different regions of input space and obtaining additional background information. Several steps are followed in the learning process. Firstly, local contexts were identified through the partitioning of input space. Secondly, input MFs are learned. Thirdly, output MFs are generated. Finally, input and output MFs are combined into a Mamdani-type fuzzy inference system (FIS). A fuzzy rule base adapted to different contexts is the output of the learning process.

Schiebel Technology designed and manufactured small and low-cost versions of an unmanned remote controlled/autonomous vertical take-off and landing aerial platform called 'CAMCOPTER', which is composed of an aerial vehicle, a ground station and support equipment. During test and evaluation flights, CAMCOPTER has been particularly successful in detecting, identifying, mapping and marking landmines. The main components of CAMCOPTER are an electro-optical/IR sensor. The features of this technology still have limitations and weaknesses; for example, several unmanned aerial vehicles do not have the capability to resist high wind speed whilst undergoing demining operations, thereby yielding erroneous results. Moreover, this technology requires further training and experts to deal with its limitations and weaknesses (Schiebel, 2015).

Tran et al. (2010) developed a new approach called 'an automated decision system for landmine detection and discrimination'. The authors used several techniques, such as the generic majority voting scheme, fuzzy ARTMAP, wavelet transforms and a gradient-based peak isolation method, to develop this system. Despite the good results achieved by this technique, focus has been on a single technology (i.e. FL).

A new Windows phone application is the 'sensor amplified perception for explosives recognition' (SAPER). 'SAPER' came from the Polish term for 'minesweeper'. This application can be a good approach for people living near landmines to avoid the risks of landmines and UXO, as shown in Figure 2.7.

Figure 2.7: SAPER Mobile Application



Source: Belezina J. (2012)

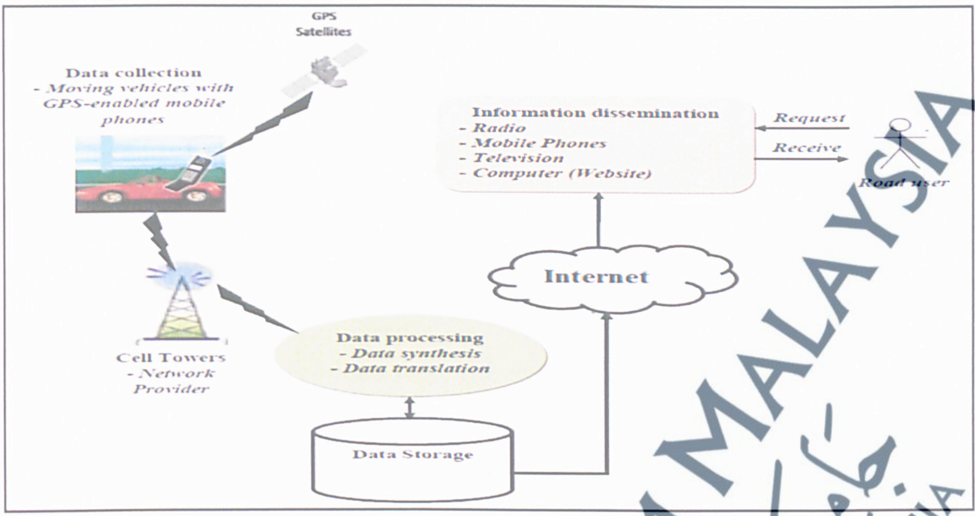
The application uses magnetometer technology within all smartphones to detect minute disturbances in the magnetic field around an explosive material by reading the background magnetic field of an area (CBRNE-Terrorism Newsletter, 2012).

ii. Traffic Management

Many examples for real-time traffic situation, prognosis and simulation have been reported (Abdalla et al., 2011; Bieker, 2012; Pillac, 2012; Qureshi, 2013; Ramya et al., 2014). The subsequent section presents existing DSS and AI that are used to solve traffic congestion and control problems.

Runyoro (2013) proposed a real-time road information system to solve the traffic congestion problem in three cities that are highly affected by traffic congestion, namely, Arusha, Mwanza and Dares Salaam, by helping road users make decisions based on ground information. This system is based on the analysis of road traffic data provided by organisations that are responsible for road traffic management and road users. FL is used by the system for real-time traffic level detection and decision-making. The system consists of three components: (1) data collection, (2) data processing and storage and (3) information dissemination, as shown in Figure 2.8.

Figure 2.8: Architecture of a proposed real-time road information system



Source: Runyoro (2013)

The data collection unit was used to collect road traffic data using mobile phones by developing software that was installed in all the phones that participated as traffic probes. FL was used to formulate the mapping from a given input to an output using fuzzy inference processing to handle traffic data processing. Then, 2 available inputs (i.e. speed range and density range), 1 output (i.e. congestion level range) and 25 fuzzy rules were used in fuzzy inference processing. Although the use of mobile phones for real-time road status data collection can control traffic congestion, failure to receive GSM signal causes the system to stop and yield incorrect results.

Pillac et al. (2012) proposed a framework called JMSA to address the dynamic vehicle routing problem with stochastic demands that can anticipate unknown changes in problem information. JMSA has been designed to be easily embeddable into DSS that copes with a wide range of contexts and side constraints. The framework is composed of two layers, namely, a problem layer, which has problem-specific components, and a kernel layer, which is common to all dynamic combinatorial optimisation problems. The kernel layer is composed of the measurement system analysis procedure, which contains the logic of the algorithm and instantiates all other components. The problem layer provides ready-to-use functionalities for common dynamic combinatorial optimisation problems. Although the system has attempted to address the dynamic vehicle routing problem, the system and the cost/benefits of using these techniques should be examined further. Moreover, the system requires improvement in real-time LBS using new algorithms based on AI.

Interest in the use of DSS to analyse systems at the operational level is increasing because of the data requirements and the complexity of urban planning and transportation problems. Santos et al. (2011) presented a user-friendly web-based spatial decision support system (wSDSS) to generate optimised vehicle routes for multiple vehicle routing problems. wSDSS includes a database and Google Maps (cartography and network data). A heuristic and an ant colony metaheuristic were used to generate routes and detailed individual vehicle route maps. The system only requires the use of an Internet browser that allows remote access to cartography, network data and algorithms via the web. Thus, failure to receive GSM signal causes the system to stop.

The need to introduce advanced technology and equipment to solve the problem of traffic congestion is urgent because of the increasing number of vehicles and the limited resources available with the current infrastructure. To solve this problem, Mittal and Singh (2013) designed an intelligent system for solving the problem of road traffic congestion in high congestion hotspots in developing regions. The system uses CCTV camera feeds to obtain video, which will be used by an image processing algorithm (image mosaicking techniques) to estimate traffic density at a hotspot. Most conventional control systems face major problems. For example, if the position of a vehicle does not align with the IR rays, then the response given by the IR sensor will be inaccurate. To solve this problem, the proposed system can use multiple cameras instead of a sensor, multiple sensors or a single camera, where the data from various cameras are collected and integrated to match two images using the image mosaicking technique. Although the system can be used to improve the accuracy of traffic, it faces the previously mentioned problem because of their high installation and maintenance costs.

A short-term traffic state prediction approach is implemented in many countries to better utilise the existing road network. This approach connects online traffic measurements with a real-time traffic model. In this context, Wismans et al. (2014) presented a framework for a real-time traffic model that can be used to deliver predictions and is applied to a real-life case in Assen City, the Netherlands. Although the current approach exhibits promising results by using a smoothing procedure for traffic counts near traffic lights, it does not use AI to analyse available information on current traffic.

Lazarowska (2012) conducted a study that aimed to design and achieve computer DSS in collision situations among ships, which was implemented onboard the research and training ship HORYZONT II. The system uses radar to collect input data for determining the safe trajectory of a ship through a dynamic programming algorithm. The system aids the deck officer in selecting an anti-collision manoeuvre. It is composed of two subsystems, namely, a system that determines safe trajectory and a navigational situation display system. The former is used to collect input data from the automatic radar plotting aid system and to display the current navigational situation, whereas the latter is used to evaluate the performance of anti-collision calculations. Although the system provides different methods for determining safe ship trajectory in a collision situation, it needs further research to make it independent of the MATLAB environment, e.g. it can be implemented in C programming language to constitute a stand-alone application.

iii. Emergency Management

Information technology is used in many hospitals and other medical facilities to support nursing care. However, most hospitals and other medical facilities use manually recorded vital sign data for patient care and control. Trappey et al. (2009) developed a mobile intelligent medical system (MIMS) that supports mobile nursing applications and clinical decision, which can be the solution for managing real-time remote collection of medical data to support the provision of dispersed nursing care. MIMS adopts a web platform to manage patient information, nursing processes and care information. It uses the JESS system, an RFID system and a wireless network environment to support real-time communication between patients and medical staff. Mobile devices use RFID readers to obtain data and integrated software to manage vital nursing operations. The mobile nursing care system uses RFID technology to track the vital signs of patients. However, RFID technology is definitely more expensive than other systems. It also requires more parts, hardware and software. Furthermore, architectural management increases the cost of the system.

Rural healthcare in Nigeria faces numerous challenges. For example, healthcare institutions are lacking, staff members are few or have no educational background, roads are poorly constructed and social development is minimal or even nonexistent. To overcome these difficulties, Aworinde et al. (2014) developed an IDSS that aims to aid medical practitioners in rural communities in making more accurate decisions rapidly and with less stress. This system can help decision-making by automating the manual method, thereby making the process faster and more reliable.

The efficiency of road and rail transportation systems face many challenges during major accidents and disasters, which should be addressed by rescue forces to ensure the provision of emergency aid and the transportation of goods and people. In this context, Detzer et al. (2015) presented a study that aimed to extend multimodal transportation systems and the capability of rescue forces by upgrading such systems with two additional means of transportation (i.e. public transportation and freight transportation), thereby enabling multimodal consideration. The VABENE++ system and the simulation software SUMO were used to achieve the desired expansion. Recently, new functions were added to the VABENE++ system to enable decision support information regarding traffic and logistic fleet management at major accidents and disasters. Nevertheless, the system still requires further technical details, more realistic scenarios and the development of interfaces and operational applicability in terms of technical link to existing information systems for emergency forces.

iv. Human Navigation Systems

Several examples that can help the elderly and the visually impaired to navigate unfamiliar indoor environments have been reported (Dharani et al., 2012; Ganz et al., 2012; Liao C.F., 2012; Jain, 2014; Dong, 2014; Apostolopoulos et al., 2014; Liao C.F., 2014; Rodriguez-Sanchez, 2014; Chaccour et al., 2015).

TAO (2015) developed an indoor navigation system that aimed to help visually impaired and blind people obtain navigation instructions generated automatically by a navigation generation algorithm using an Android smartphone. The system was deployed and tested at the campus of the University of Massachusetts in Amherst. However, the system faces a problem because of its high installation and maintenance costs.

Older adults frequently encounter problems and difficulties in wayfinding outdoors and in large indoor environments and are typically less likely to use digital services compared with younger adults because they have less experience with interactive technologies. On the basis of this finding, Fuchsberger et al. (2012) presented a study that aimed to support older adults in wayfinding outdoors and indoors by developing a home platform that can be used for trip planning and navigation and as a mobile navigation aid. To achieve this project, the authors conducted surveys to identify the requirements of users regarding travelling and navigation (e.g. end user interviews, workshops and a survey). The results indicated that the development of a navigation aid should use navigation and orientation strategies that are already applied to support recognition rather than recall.

The most common problem faced by visually impaired individuals is navigation in indoor environments, particularly in spaces they are visiting for the first time. Although several solutions have been proposed to deal with this challenge, they involve an important deployment effort or use artefacts that are unnatural for blind users. To solve this problem, Guerrero et al. (2012) designed an indoor navigation system that regards usability and suitability for deployment in several built areas as quality requirements, as shown in Figure 2.9.

Figure 2.9: Components of the designed navigation system

Source: Guerrero et al. (2012)

The system allows anyone to calculate the velocity and direction of the movement of a person. It can be used by visually impaired individuals to determine trajectory, locate possible obstacles in a route and obtain navigation information. The system is composed of two IR cameras, a white cane, a smartphone that delivers navigation information to the user through voice messages and a computer that runs a software application that coordinates the entire system. The main disadvantage of this system is that it will fail when a piece of furniture (e.g. a sofa) is moved because the system depends on the map for locating possible obstacles in a route. Therefore, when an object in the environment is moved, the map should be refreshed. Table 2.3 presents a summary of existing DSS and AI used in traffic management and human navigation.

Author(s)	***Field***	***Intelligence techniques***	***Problem***
Wang et al. (2008)	Traffic management	FIS	• This approach depends heavily on expert knowledge; thus, lack of knowledge may arise as a problem. • Uses individual intelligence techniques
Tran et al. (2010); Karem & Frigui (2011); Khalifa & Frigui (2014, 2014b)	Landmine	FL	• Uses a single intelligent technology (FL)
Dai et al. (2011)	Traffic management	ANNs	• Most of the time, the design and training of ANNs are complex and experience is required. • Uses individual intelligence techniques
Pillac et al. (2012)	Traffic management	Null	• This approach requires improvement in real-time LBS using new algorithms based on AI.
Guerrero et al. (2012)	Human navigation	Image processing algorithms	• Unable to avoid obstacles that have been moved, such as a sofa or chair • The system is compatible only with indoor navigation. • Uses individual intelligence techniques
Mittal & Singh (2013); Singh & Rewari (2014)	Traffic management	Image mosaicking techniques	• The simulation model uses one-way roads. • Unable to allow vehicles to turn left or right • This approach uses RFID technology, which is more expensive and requires more parts, hardware and software. • Uses individual intelligence techniques
Wismans et al. (2014)	Traffic management	Null	• This approach does not use AI to analyse available information on current traffic.
Chaccour et al. (2015)	Human navigation	Image processing algorithms	• The mobile application is compatible only with an Android device. • The system is compatible only with indoor navigation. • Uses individual intelligence techniques

2.3.3 Risk Management

In normal everyday life, each person can face a wide range of events where most activities have a certain degree of threat that can positively or negatively affect his/her life. Risk management has been defined as 'a formal orderly process for systematically identifying, analysing and responding to risk events throughout the life of a project to obtain the optimum or acceptable degree of risk elimination or control' (Al-Bahar & Crandall, 1990). Schwarz and Sánchez (2015) defined risk management as 'a structured approach to administrate (analyse, evaluate and control) risks'.

Risk management is the application of a process that aims to identify risk events as early as possible and to quantify their effects, which include identifying activities, assessing risks and monitoring and reducing their effects on business. Bohm theory states that risk management is a process that consists of two main phases, namely, risk management (risk monitoring and corrective action plan and planning of risk management) and risk estimation (identification, analysis and prioritisation) (Hojjati & Noudehi, 2015).

A. Risk Definition

A wide range of perspectives and approaches have defined the term 'risk'. Risk has many meanings and interpretations, which differ from one context to another (Moskowitz & Bunn, 1987). CIOCA (2010) defined risk as 'the probable level of deaths, injuries, damages produced by a certain natural phenomenon or group of phenomena, in a certain place and time'. Al-Bahar and Crandall (1990) defined risk as 'the exposure to the chance of occurrences of events adversely or favourably affecting project objectives as a consequence of uncertainty'. Liu (1998) referred to risk as 'the volatility of the outcome', which can be measured by 'the deviation from expected values'. Risk can also be defined as the intentional interaction with uncertainty. Uncertainty is a potential, unpredictable and uncontrollable outcome; risk is a consequence of action taken in spite of uncertainty (Antunes & Gonzalez, 2015). To date, however, no consensus about an exclusive definition of uncertainty and risk exists.

B. Risk versus Uncertainty

Risk management is important in the development of any project, which involves the use of basic concepts, such as 'risk' and 'uncertainty', where these concepts are frequently confused with each other. The first attempt to distinguish between risk and uncertainty was made by Knight (2012). These concepts can be differentiated based on their quantifiability, where risks can be defined as identifiable and quantifiable possible events or factors, whereas uncertainty refers to unknown and unforeseeable events or factors (Schwarz & Sánchez, 2015). Therefore, the two concepts should be differentiated. Uncertainties are always unexpected and/or unquantifiable, whereas risks are possible to identify and control. Many sources of uncertainty and risk, such as project management skills and experience, environment, technology, complexity, contract and weather, have been cited in the literature and are frequently considered critical risk factors for any project life cycle.

C. Environmental Risk Assessment

ERA generally focuses on environmental changes that result from human activities, including impacts on biophysical environments, biodiversity and other resources. The applications of technology, such as nuclear bombs and landmines, frequently result in unavoidable and unexpected environmental impacts. The environmental impact of war and its costs to human life and society are significant. Scorched earth methods during or after wars have been used for a considerable part of recorded history. With modern technology, however, war can cause greater devastation on the environment. UXOs can render land unusable or make access across it dangerous or fatal.

D. Artificial Intelligence Techniques for Environmental Risk Assessment

During the 1970s, risk analysis has become one of the most significant subjects and a major stimulus of research (Moskowitz & Bunn, 1987). Cooper and Chapman (1987) noted that many approaches have been used to deal with the problems created by uncertainty, including the identification, evaluation, control and management of risk. Several techniques used to perform risk analysis were classified by Kangari and Riggs (1989) under two categories: subjective models (i.e. fuzzy set methods) and classical models (i.e. probabilistic methods).

The subsequent sections outline major AI techniques that use risk assessment and then provide specific examples. This study focuses on the first category (i.e. subjective models), in which the most common techniques are FL and ANNs techniques.

i. Artificial Neural Networks

ANNs are considered one of the new AI methods used in risk analysis. ANNs consists of a set of one or more neurons, which are the basic processing elements. Different sections of layers, typically the middle layers, are called hidden layers. A neuron consists of multiple inputs and a single output. Each input is modified by a weight, which is multiplied with the input value. A neural network has significant features, which can be utilised to develop predictive models in environmental risk applications.

ANNs are characterised by several advantages that make it an excellent technique. ANNs learns by experience by defining inputs and outputs subjectively, thereby making it the best candidate technique in the area of risk analysis. Furthermore, the entire process (training and testing) mimics human brain reasoning. Nevertheless, one of the major criticisms of ANNs are their being black boxes. Moreover, ANNs are limited by overfitting and constrained when small sets of data are used for training during the learning process.

ii. Fuzzy Logic

The first attempt to introduce the logic of fuzzy sets was made in 1965 by Dr. Lotfi Zadeh (1968). Since then, the logic of fuzzy sets has been used in many applications. This technique is characterised by providing a mechanism for approximation using graded statements instead of strictly Boolean ones. FL can be used to solve complex problems, in which no simple mathematical solution exists to accommodate the problem.

Probability models play a key role in risk quantification and assessment; consequently, they have become the main base for informed decision-making related to risk in many areas. Risk assessment is a complex process that requires considering diverse parameters, which are frequently difficult to quantify.

FL has been successfully adopted in many applications to address complex risk assessment processes. The subsequent section presents several studies that were conducted to support risk assessment in emergency operations.

E. Use of Artificial Intelligence in Environmental Risk Assessment

Risk assessment and AI approaches for environmental issues are increasingly being used at all policy and regulation levels. These techniques have a wide range of applications, including detecting landmines, oil products, landslides, tsunamis, air pollution, water pollution and even drowsy drivers.

Deepa et al. (2012) developed a robot based on swarm intelligence (SI) for defusing bombs in army fields. The robot, called DETECTOR, uses a technique that involves acoustic detection and a metal detector and is deactivated through its intelligence. The SI approach is a relatively new paradigm that aims to improve control of large numbers of interacting entities and the management of satellite constellations and computer and sensor network communications, which can be classified into positive feedback, negative feedback and random. Although the proposed robot is effective in increasing safety in demining, its high cost and sophisticated technology require highly trained experts to operate it.

Achkar and Owayjan (2012) developed an autonomous robot system for landmine localisation using ANNs and digital image processing; this robot can identify and classify an object, e.g. a landmine, particularly an AT mine, a cluster bomb or an UXO. A landmine-detecting robot uses different sensing techniques, such as image processing, recognition and classification techniques, in which a camera is used to capture real-time images of the scanned area and signal processing determines whether a mine exists. Then, the processed images are inputted into a neural network for classification. One of the main advantages of a neural network is its capability to learn from experience. Consequently, the system is trained to recognise and classify specific objects (i.e. landmines). The system suffers from several complications. For example, the output at the neuron is always calculated to be 1 because of the large number of inputs. In addition, changes in brightness cause considerable changes in the RGB representation of a certain colour, thereby causing the machine (robot) to inaccurately classify an object.

Hasanzadeh and Li (2013) discussed intelligent transport systems that aim to learn and predict the behaviour of drivers. These systems can be useful for predicting the actions and reactions of drivers during driving. The proposed approach for this purpose consists of three major phases: learning, modelling and predicting. An ANNs are used for the learning stage. Then, the output of the learning phase (i.e. the learned parameters) is utilised to generate a fuzzy model for the behaviour of the driver. The output of the modelling phase can be used as the basis for the predicting phase.

Rafiean and Aliei (2013) developed a fuzzy model, called adaptive neuro-FIS (ANFIS), and a multilayer perceptron (MLP) to predict variations in sea levels for the next month in a case study. Statistical analysis was conducted by the researcher to select the most appropriate predictors as prediction model inputs and to explore the relationship between predictors and sea level rise. Although both models have performed efficiently in predicting sea level and its changing patterns, the ANFIS model requires more parameters for estimation and is more complicated than the MLP model. Therefore, using MLP to predict sea level for the next month is better.

Singh and Banga (2013) proposed a vehicle driver drowsiness warning system based on facial image analysis to warn drivers of drowsiness or inattention, and thus, prevent traffic accidents. The system uses a neural network-based algorithm to determine fatigue level by measuring eye opening and closing and then warns the driver accordingly. The researchers followed three stages to develop this system. The first stage is pre-processing, which includes face and eye detection and normalisation. The second stage performs pupil position detection and characterisation, combined with an adaptive lighting filtering. The third stage computes PERCLOS from eye closure information. The system was evaluated according to an outdoor database, and several experiments were conducted during more than 25 h of driving. Although the results indicated that the proposed ES is effective in increasing safety during driving, the system cannot detect the shape of the iris when the driver is drunk.

Vedadi et al. (2013) presented an ANNs model for ranking the risks of a project in the National Iranian Oil Products Distribution Company. A total of 3 layers were used to obtain a network that is capable of demonstrating connections among the inputs, which are 16 neurons in 1 hidden layer, 42 neurons in the input layer and 5 neurons in the output layer. Although the model provides a complete list of the risks that may affect the project, it does not support decision-making under uncertainty.

Umoh and Nyoho (2015) presented a new FL model to address the vagueness, incompleteness and uncertainty of information used in predicting pregnancy risks. The model was developed based on expert knowledge, medical diagnoses and clinical observations. The studies and observed results were computed from 25 pregnant patients who participated in the survey. The model can be used as a pregnancy risk factor by researchers, physicians and other healthcare practitioners in obstetrics to provide a decision support platform. Furthermore, women should be educated about pregnancy risk factors and encouraged to start antenatal clinic early in pregnancy. The FL model uses 3 input variables: existing health condition, condition of pregnancy and lifestyle factors. By contrast, 3 output parameter values (i.e. low, moderate and high pregnancy risks) are determined using 27 rules according to the 3 input values. The FIS aims to eliminate uncertainty, ambiguity and vagueness that are inherent in healthcare diagnosis and monitoring. Although the results have exhibited good performance, the system can be defined with more than 3 inputs to achieve more efficient human diagnoses and monitoring results. The performance of the proposed system can also be improved in the future by integrating FL with particle swarm optimisation tools.

Nawrocki and Kowalski (2014) presented the concept and practical application of the operational risk assessment fuzzy model using fuzzy methodology with financial indicators. The authors used a resource approach and considered human, material and financial resources when establishing the basic assumptions of the model. The model depends on operational risks in the surroundings and considers relational and organisational resources. The model for operational risk assessment is characterised by certain advantages, such as combining analytic and synthetic operational risk assessments, using assessment process data and providing reliability and flexibility simultaneously given the use of quantitative and qualitative data.

Bibi et al. (2016) presented a paper that discussed the effectiveness of the FL approach for landslide susceptibility mapping in Mansehra District, Pakistan. The fuzzy MFs were assessed for each class. The factor maps were modified for landslide susceptibility. The results indicated that 17% of the study area is classified under high susceptibility, 32% under moderate susceptibility and 51% under low susceptibility. Thus, the fuzzy model can be effectively integrated with various spatial data for landslide hazard mapping.

Bertuccio and Moraleda (2012) presented a new methodology for evaluating uncertainty in risk assessment based on FL to assess the risk of corrosion in natural gas pipelines. The proposed methodology considered the chemical, mechanical and design variables of pipelines and allowed the identification and rapid evaluation of the effects that change the values of these variables in the final result.

Das and Dutta (2013) and Dutta (2013) investigated several fuzzy models to represent epistemic-type uncertainty and to attempt fusing with triangular fuzzy numbers. They also conducted risk assessment under a fuzzy environment. These studies have been applied to health risk assessment. The risk assessment model aims to assess the lifetime daily dose of exposure as provided by the Environmental Protection Agency via the consumption of contaminated drinking water. The FL model uses the following parameters as input variables: IR is the intake of water (L/day), EF is the exposure frequency (days/year), ED is the exposure duration (years), BW is the body weight (kg), AT is the average time (days) and CDI is the concentration of 1,1,2-trichloroethene in water (mg/L). The model was tested according to two scenarios. In Scenario 1, the uncertainty involved in the output risk was 0.0045. In Scenario 2, the output risk was obtained in the form of a fuzzy number of approximately 1.102e-02, ranging from 0.597e-02 to 1.762e-02. Consequently, the uncertainty involved in the output risk is 0.0054.

Narasimhan and Malathi (2014) proposed a new model for risk classification of coronary artery heart disease (CAHD) among females with diabetes mellitus or have a high occurrence of CAHD using FL. The input parameters for this model are age, body mass index, diastolic blood pressure and plasma glucose concentration, whereas the outputs are predicted as low, intermediate and high. A total of 25 fuzzy rules were used in risk prediction. The model was designed based on Mamdani-type FIS. Then, it was implemented through MATLAB 2012a. The results showed that the model is accurate for classifying CAHD risks.

Wang and Chen (2010) developed a fuzzy aggregation modelling approach for the cumulative risk assessment of air pollution based on multiple air pollution factors and evaluation criteria in a GIS-based air quality management system. The ordered–weighted product (OWP) approach was used to identify the relative importance of each pollution factor. Meanwhile, fuzzy MFs were used to quantify these uncertainties and complexities. The researchers described the steps necessary to implement the model, including the definition of input and output variables, the construction of fuzzy rules and fuzzy sets, the construction of fuzzy MFs, the calculation of the relative importance of each air pollution factor, the construction of fuzzy aggregation–OWP modelling and the assessment of the air pollution cumulative risk. This model was tested in case studies conducted in California. Reasonable results, which are useful for the decision-making process of the California air quality management, were generated.

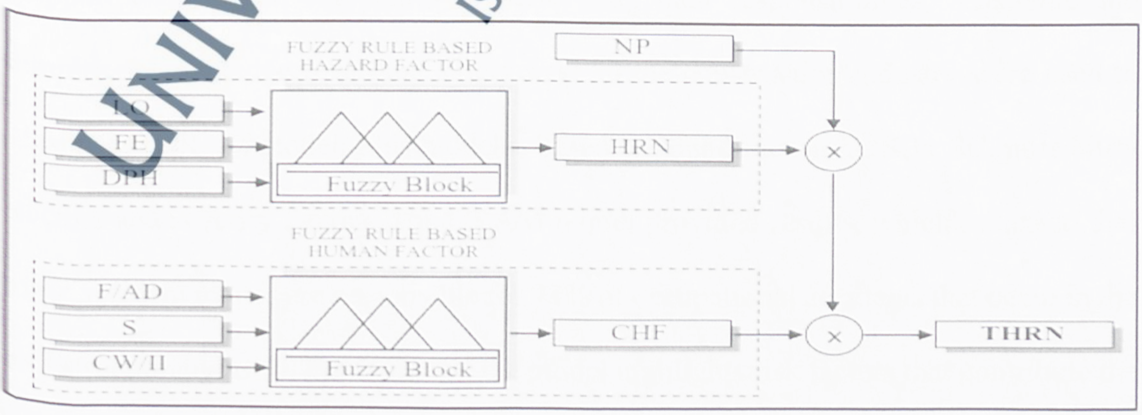
Yan et al. (2010) presented a new model, called neuro-FIS, which is used to classify the water quality status of rivers by applying several physical and inorganic chemical indicators, such as ammonia nitrogen, chemical oxygen demand and dissolved oxygen. The performance of the model was then compared with those of eight models constructed with different MFs and trained using ANFIS methods, where 845 sample points of various rivers were verified. The performance of the new model is better than that of the ANNs model and it can generate the output value in continuous form, thereby making water quality assessment more comprehensible.

Tayal and Prema (2014a, 2014b) developed a fuzzy system to determine the occurrence of tsunamis based on certain factors. The system was designed using the MATLAB Fuzzy Logic Toolbox in terms of linguistic parameters, namely, volcanic eruption index, earthquake magnitude, rare tsunami and tsunami advisory by considering the characteristics of tsunamis. A total of 83 rules are used to describe the system. The data used were collected from well-known organisations, such as the UNESCO International Tsunami Information Centre, the NOAA Pacific Tsunami Warning Centre and the Japan Meteorological Agency. The system generates three types of alerts: rare tsunami alert, in which a tsunami will not occur; advisory tsunami alert, in which a tsunami may occur and major tsunami warning, in which a tsunami will definitely occur.

To avoid road accidents, Lin et al. (2012) proposed a generalised EEG-based fuzzy system to predict the drowsiness of drivers. They discussed the reasons that lead to drowsiness, the sensors used and their advantages and limitations. Two drowsiness prediction models were investigated in this study to analyse system performance. During the development process, the system faced difficulties, such as the interference of complicated noise in a realistic and dynamic driving environment and the lack of a significant index for detecting the drowsy state of drivers in real time. Four models for drowsiness prediction, namely, SVR, MLPNN, RBFNN and SONFIN, were adopted in this study. The structure of the models was described for each predictor.

Aras et al. (2014) proposed a new model called the novel risk assessment model, which considered the human factor. In this model, the FL approach was used as a suitable method for risk assessment. The LabVIEW program was adopted to develop the risk assessment interface, which was designed with different combinations and options to provide an opportunity for users to assess risks under a wide range of consequences. The model is composed of two main assessment units, namely, hazard and human factors. Each unit includes three inputs, as shown in Figure 2.10.

Figure 2.10: Structure of FL Risk Assessment



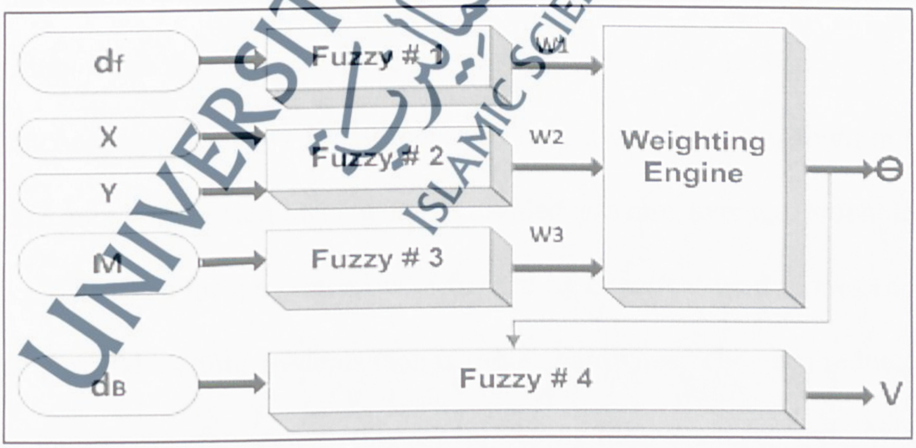
Source: Aras et al. (2014)

Khazaeni et al. (2012) presented a study that aimed to develop a fuzzy adaptive decision-making model for selecting balanced risk allocation based on the concept of competence–tendency trade-off using FL. This model transforms linguistic principles and experiential expert knowledge into a more usable and systematic quantitative-based analysis by integrating the adaptive capabilities of the FL qualitative approach and the analytic hierarchy process to evaluate the allocation of project risks and identify the best party to bear each risk. To develop this model, the authors followed several steps: (1) identification and classification of criteria, (2) conversion of linguistic terms into MFs (this operation is called fuzzification), (3) evaluation of allocation criteria, (4) calculation of the priority weights of criteria and (5) calculation of the total allocation fuzzy value.

Occupational safety is important for moral, legal and financial reasons. This situation has motivated researchers to study this field. This process is complex and requires the consideration of diverse parameters that are frequently difficult to quantify. Pinto is one of authors who has contributed to this area. Pinto (2014) presented the fuzzy quantum random access memory (QRAM) model based on FL to assess the effectiveness of the safety climate (SC) and safety barriers (SBs) to reduce occupational safety risks and support construction companies in performing their responsibilities. Academic and empirical knowledge regarding safety risks in the construction industry were used to design the QRAM model. This model is based on four dimensions: SBs, SC, possibility factors and severity factors. The QRAM model provided results, which indicated that nine accident modes are responsible for 98% of occupational accidents that occur in the construction industry. Furthermore, the model highlights risk factors that contribute the most to the risk level.

Alshbatat (2013) designed and developed an intelligent controller, which can be used to control and enable a robot in detecting landmines. This intelligent controller uses sensors, including an IR distance sensor, a metal detector, an ultrasonic range finder and an accelerometer sensor, to guide soldiers when passing landmines. The system is capable of planning the path of soldiers across known landmines and to plan the local path for real-time obstacle avoidance. The system is composed of two parts: hardware and software. The most important part is software, where the proposed fuzzy controller based on mine detection and sensor data is implemented. The intelligent controller was designed based on creating fuzzy rules that reflect the behaviour of soldiers in controlling a robot in an area with known landmines. Figure 2.11 presents the structure of the proposed fuzzy system, which consists of four subsystems. Each subsystem is responsible for an independent decision and is attached to a single sensor, which is used to generate a weighting factor (w_i) that represents the degree of robot orientation.

Figure 2.11: Structure of the proposed fuzzy controller

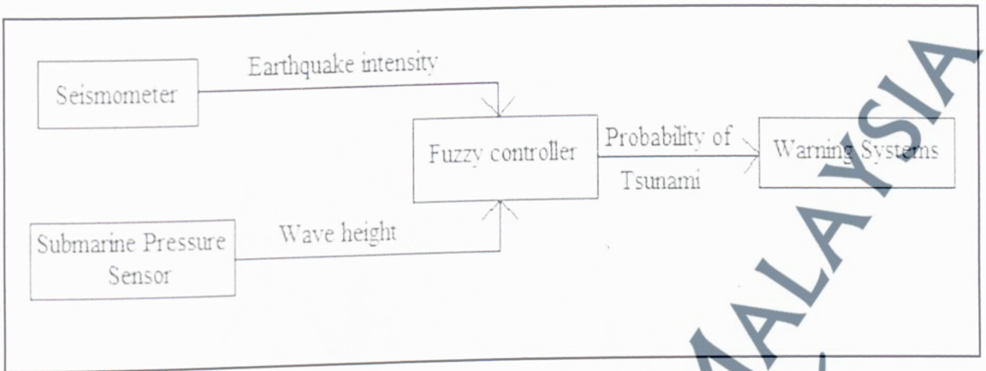


Source: Alshbatat (2013)

Li et al. (2010) developed a new fuzzy human error risk assessment methodology that aimed to determine human error risk importance. The modelling technique was designed according to the concept of FL in the form of IF–THEN rules, which provide a convenient method for representing the relationships between the inputs and outputs of a risk assessment system. The model was tested using the MATLAB toolbox based on Mamdani techniques, and the results showed that the method is more realistic than traditional methods. The fuzzy risk assessment model of human error has three stages: (1) the preliminary phase, (2) the measurement phase of risk indices of human error and (3) the fuzzy inference phase. Although the fuzzy risk assessment model of human error has been successfully tested, it still has limitations. For example, the interval of input and output variables leads to a set of discrete rules. Moreover, experts who are familiar with the underlying problems can validate the design of MFs.

Cherian et al. (2010) proposed an intelligent system that uses the fuzzy type of reasoning to predict tsunamis on a real-time basis. The LabVIEW programming interface was used to implement the system. The fuzzy controller is composed of the fuzzifier, where real word inputs are converted to values between 0 and 1, and the fuzzy interface engine, which consists of the MFs for all input and output variables, as shown in Figure 2.12. The FIS output is the alert level, which is divided into rare, average, probable and certain ranges. The rules for the system were framed by experts. Smartphones can be used as better alert and warning systems than complex hardwires. They can reduce complexity and enhance ease of operation, thereby improving the system.

Figure 2.12: Block diagram of the proposed system



Source: Cherian et al. (2010)

Sharma and Banga (2010a, 2010b) discussed various artificial detection methods for detecting driver's drowsiness based on facial image analysis to warn drivers of drowsiness or inattention, and thus, prevent traffic accidents. FL is used to determine fatigue level via an image processing technique. The warning given to the driver is based on the measurement of blinking duration and blinking frequency. The system uses piezo-film movement sensors integrated into the car seat, seat belt and steering wheel. The system faces problems, e.g. the difficulty in detecting the eyes of drivers who are wearing spectacles and the lack of proper light after sunset, which can cause problems in reading the images.

Fares and Zayed (2009) designed a model for evaluating the risk of water main failure using a hierarchal fuzzy ES. A total of 16 deterioration factors that represent the probability of failure and the negative consequences of failure are categorised into 4 main risk-of-failure factors. The hierarchal fuzzy ES was used to build the model, which considered the uncertainty of water main attributes. . In the future, GIS can be incorporated to ensure a more efficient use of resources allocated for the rehabilitation of the water main network. Table 2.4 provides a list of previous works on ERA using individual intelligence techniques with their advantages and disadvantages.

Author(s)	Environment	Sensor used	Tracking techniques	Intelligence techniques	Advantages	Limitations
Tayal & Prema (2014a, 2014b)	Tsunami	• Databases provided by organisations	Null	FL	• 5 parameters • 83 rules	• Requires high expert knowledge • Inability to learn
Cherian et al. (2010)	Tsunami	• Richter scale • Submarine pressure sensors	Satellite	FL	• Operating autonomously • 3 parameters	• Uncertain information
Alshbatat (2013)	Landmine	• Ultrasonic sensor • Infrared technology	Special algorithm	FL	• Operating autonomously • Supports decision-making	• Too complex • Unfriendly interface • Slow • High cost • Inability to learn
Deepa et al. (2012)	Landmine	Acoustic detection and metal detector	Laser	SI	• Emerging technology used for demining	• High-cost and sophisticated technology used in robots that requires highly trained experts to operate

Author(s)	Environment	Sensor used	Tracking techniques	Intelligence techniques	Advantages	Limitations
Achkar & Owayjan (2012)	Landmine	• Camera • IR technology • Ultrasonic sensor • Ground penetrating	Image processing technique	ANNs	• Operating autonomously • Capability to learn	• High cost • Too complex • Ambiguous • Lacks decision-making
Lakshmi et al. (2015)	Detecting drowsy drivers	• CCD video camera	Image processing technique	ANNs	• Classification accuracy = 95% to 97%	• Lack of light • Ambiguous
Singh & Banga (2013)	Detecting drowsy drivers	• Video camera	Image processing technique	ANNs	• Positive detection rate = 92%	• Cannot detect the changing size and shape of the iris
Nandhini et al. (2016); Sivagnanam et al. (2015)	Saving fishermen	• Microcontroller	GSM, GPS	Null	• Automatically controlled	• Failure to receive GPS or GSM signal causes the system to stop

2.4 Summary

Several challenges hinder the efficiency of tracking and ERA systems; these systems are necessary to ensure safety during accidents and disasters. From the analysis of the previous literature review, the majority of tracking and ERA systems use individual intelligence techniques, and the most common technique used is FL.

From the results of the comparison study conducted among individual AI techniques, as listed in Table (2.2), and the previous literature review, systems that used the fuzzy approach are capable of representing imprecise knowledge in a simple and understandable manner for users and specialists. However, these systems face problems when defining MF parameters, given that no systematic procedure can be used to define such parameters. Thus, these systems cannot adjust to a new environment; consequently, MF parameters must be predetermined from expert knowledge regarding the modelled system. Fuzzy systems also lack the capability to learn. Systems that use ANNs cannot explain the steps that lead to decision-making. Moreover, ANNs are ambiguous to the user because the user cannot explain how learning from input data was performed.

Although previous systems use different individual intelligence techniques, they still exhibit limitations. To address these limitations, intelligence techniques should be combined to improve the performance and operational effectiveness of tracking and ERA systems. The development of a comprehensive tracking and risk assessment model is recommended. This model should be sufficiently explicit by providing the capability to predict and support decision-making. In many real-world applications, knowledge from various sources should be acquired and different intelligence technologies that are capable of reasoning and learning in an uncertain and imprecise environment should be combined.

A more powerful and effective ES can be established and the performance and operational effectiveness of tracking and ERA systems can be improved by combining the advantages of intelligence techniques, which support the previously mentioned problem statement.