An Agent Based Approach for Improvised Explosive Device Detection, Public Alertness and Safety

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***Abstract*—One of the security challenges faced by our contemporary world is terror threats and attacks, and this is no doubt posing potential threats to lives, properties and businesses all around us; affecting the way we live and also travel. Terror attacks have been perpetrated in diverse ways whether from organized terror networks through coordinated attacks or by some lone individuals such that it is now a major concern to people and government. Indeed, there are numerous forms of terror attacks. In this proposal, we look at how the explosive substance kind of threats can be perceived and taken care of prior to potential attacks using intelligent agent systems requirement analysis. Thus, the paper demonstrates using an agent-oriented system analysis and design methodology to decompose the problem. Through defined percepts, goals and plans, agents possess capabilities to observe and perform actions. This proposal demonstrates: how agents can be situated in our cities, goal refinement for agents in the detection and rescue of potential terror attacks, and inter-agent communication for the prevention of chemical terror attack.**

***Keywords*—*multi-agents, explosives, terror attacks, Prometheus design tool, smart security and cities, first-order logic*

I. Introduction

One of the security challenges faced by our contemporary world is terror threats and attacks. The seemingly increasing trend has no doubt affected the way and manner in which people live and travel. Different form of terror attack exists from the use of improvised explosive devices (IED) to vehicular run into a crowd and gun-running on innocent people. In response, government and security agencies have employed different strategies to stop these attacks. In this research we propose to address one of this problems, namely, the IED problem through the use is of agent based systems in the detection and prevention of attacks from IED. The purpose of the research is to design and implement an intelligent agent based system on mobile devices and physical infrastructure within our cities as a pro-active measure. By IED, we mean explosive or hazardous materials that can be constructed from dangerous gases, liquid or solid substances. The remaining part of this is section explains terrorism and its types and earlier preventive approaches. Section II describes the motivation for the research, research aim and objectives. Section III presents the concept of agent and agent methodology. In Section IV is the decomposition of the steps to addressing the problem and the agent reasoning approach using first order logic. Section V is conclusions.

A. *What is Terrorism*

Terrorism is the illegitimate or extra-normal use of violence against non-combatants to achieve political ends [1, 2]. In furtherance, [1] state that terrorism is a form of social influence, employing acts of extra-normal violence (instead of leaflets or loudspeakers, for example) to influence a target population's emotions, motives, objective reasoning, perceptions, and ultimately, their behaviour.

B. *Types of Terrorism*

In [3], two types of terrorism are identified, namely, state terrorism and individual terrorism. *State* terrorism, according to [2], is the sponsored support given by a nation outside its borders to unleash harm and violence against another nation or its people. *Individual* terrorism amounts to the violence unleashed by a person who is mindless of the consequences of the action to him/herself in the act of causing harm to others. A third form are those organised by some *religious sect* based on their belief ideology.

C. *Counter-Terrorism & Computational Techniques*

Different counter terrorism approaches have been proposed to tackle the act of terrorism. For example, the web mining technique to arrest terror by discovering patterns in a terrorist's web usage based on the web content and links that they may have visited [4]. Carley [5] studied the strategies to destabilise covert network (i.e. terror organisation) to predict their next line of action. [5] states that covert networks are difficult to manage and to reason about. This is because they are adaptive and dynamic in their operations. To destabilise a covert network, you will need to identify their leader. That destabilising them only last for a short period of time as their leaders are always emerging. The study of [6] applied social network theories to covert group and organisations. The theory collects, analyse and explain data about who talks to who, who works with who, and who is connected to who in the social network paradigm. In [7], this type of theory may lead to misleading information. Archer [8] states that despite the much recent study directed into the understanding of cyber terrorism, there continued to be problems of identifying the actors and their collective targets.

For the purpose of ensuring internet security, [9] states that staff's commercial training packs on cyber security are likely to increasingly show similarity with those of an offensive cyber group. This way cyber capabilities could be difficult to monitor. Cyber offences are much easier to commit than defend, and this has led to so many cybercrimes being committed and hidden without trace. In addition, that so many terrorist groups have successfully hidden their online pro-crime activities (p.95). Conversely, the work of [10] and [11] focused on the identification and detection of chemical, biological and explosive (CBE) substances using the Raman detector -- an unmanned ground vehicle. The Raman detector is a sensor that can identify the presence of CBE, and can reveal the molecular composition of organic or inorganic materials. It is capable of remote sensing and compliant with the Joint Architecture for Unmanned Systems (JAUS). In [10] the following:

RDX - Cyclotrimethylene-trinitramine,

HMX - Cyclotetramethylene-tetranitramine,

PETN - Pentaerythritol-tetranitrate

were identified as chemical and explosive substances. Similarly, in [12], from the in-depth analysis of explosives and IED, methods of detection and tools were presented. In the study, [12] asserted that hydrogen, nitrogen, carbon and oxygen are the main chemical composition of explosives. Furthermore, they categorised explosives into low, medium and high explosives based on their vapour concentration in air at 25^0C (Table I).

TABLE I CATEGORIES OF IED SUBSTANCES

Categories by vapour concentration	**IED**	**Concentration in air at 25^0C**
Low	HMX	1ppq
Low-Medium	RDX, PETN	1ppt
High-Medium	NH_4NO_3, TNT	1ppb
High	DNT, NG DMNB EGDN, TATP	1ppm

As shown in Table I, the low vapour pressure explosives are HMX (also known as octogen), RDX (otherwise known as hexogen or cyclonite) and the PETN with concentration in air in the range of one part per quadrillion to one part per trillion. In the middle category are NH_4NO_3 (ammonium nitrate) and TNT (2,4,6- trinitrotoluene) with vapour concentration near one part per billion. The high vapour concentration materials are the EGDN (ethylene glycol dinitrate), NG (nitroglycerin), and DNT (2,4-dinitrotoluene) that have air vapour concentration of about one part per million.

Since the prevention of terror acts cannot be 100% guaranteed by the monitoring of their online activities on the web, there is the need to shift focus to the identification and prevention of terror acts in the physical space: to detect IED. When materials such as these (i.e. CBE) form the content of an IED, how can they be intelligently detected?

This paper takes a leap, forward beyond the identification or classification of CBE reagents. In our view, the sensing and identification of hazardous reagents should assist in the prevention of terror attacks. In our agent based approach, the identified properties of these and other substances must be integrated with agent architectures that can provide useful information on safety to members of the public. What is required in our cities are smart and intelligent devices that can exhibit intelligent behaviours. Such that can perceive events (IED substances), learn and process events, raise alert about events, communicate the information about events, and issue safety information to the public. When portable/mobile devices e.g. mobile phones become smart to perceive IED and alert users, we would not only isolate and identify the IED, but also may be able to track the terror individuals behind the acts: may from the point when IEDs are being transported into private or public domains. This way, we can keep our city safe from this harm.

II. MOTIVATION FOR RESEARCH

A. *Scenario and Smart Security*

The problem of IED terror attacks have been known to be common in densely populated areas e.g. in public gathering and commercial centres. Now, in modern cities where digital technologies have become smarter, the position of this paper is that, it is not impossible to prevent these attacks. In the concept of smart cities [13, 14, 15], government can guarantee smart security to protect citizens by the installation of public facilities (e.g. streetlights and traffic cameras) that can intelligently communicate with devices such as mobile phones so as provide personalised advice services to individuals at the point of (near) potential hazards. This way every citizen passively take charge of their security matters with respect to IED.

Mobile phones and several other devices have become part of human's daily lives and routines. For instance, aside their use for communication, mobile devices are smart in such a way that they now help people to, for example, plan and monitor their health indexes, and give notification to users about events e.g. email alert or credited bank account. Now, can this aspect of "*event notification or alert*" be extended into IED detection and notification to the general public? Since humans cannot naturally perceive or sense the chemical constituents of IED objects, extending the use of intelligent machines or agents to assisting people can go a long way in seeking some solutions to these deadly practice of terror.

The following is the statement of problem: *an IED object is in a spatial environment of crowds. People in this crowd are unaware of this object. But there is a mobile device embedded with intelligent sensor and it is turned on. This device recognises the data in the object as IED data, and then provide safety advice to the user of the device.*

B. Research Aim

The aim of this research is to use intelligent agent techniques in system development for situation awareness so as to avert potential public attack from IED substances.

C. Research Objectives

The objective of this research are:

1. *To investigate the process of embedding intelligent agent technique in portable/mobile devices and public facilities to support collaborative data capture:* between devices and inter-agent communication for the detection and prevention of potential IED attack. This part shall focus on how to integrate intelligent agent programs in personal mobile devices e.g. mobile phones and in public facilities e.g. street cameras so as to make these devices smarter for the collection of IED data into a single cloud data storage system. For instance, like the mobile phone, a street camera or traffic light would be built-in with a sensor-camera that integrates with a server to observe IED percept and communicate percepts to other connected agent based system -- internet of things (IoT) -- for informed decision making.
2. *To investigate the process of sensing and capturing potential explosives data and their storage in cloud knowledge base (KB) systems.* This involves the identification of software and hardware systems that can support this work. From this, we shall evolve an optimal data representation format and structure of the data, and how agents can communicate data during rescue and safety needs. This shall include the application of a suitable agent oriented platform.
3. *To use cognitive intelligence i.e. perception, situation awareness and reasoning in the analysis and classification of the acquired data.* In this objective, the agent system shall be trained to recognise the chemical composition of IED and to respond to events in context.
4. *To use classified data to inform public safety and guidance prior to potential attack.* Given that agents are aware of their geographical location via the GPS (global positioning system), agents shall provide safety advice as in: where there are potential hazards, what the hazards are, and safety route for users in the areas of IED materials. While the first three objectives have focused on the internal architecture of the multi-agent agent system (Fig. 5), the emphasis here is on the external aspect i.e. human users. This includes the type of images and information that can be provided on the user's mobile device, for instance, IED image, google map with direction, etc.

III. Agents and multi-agent Systems

Agent [16, 17] is an autonomous computer system that is situated in some environment and capable of exhibiting properties of autonomy, sociability, reactivity and deliberation in order to meet their design objectives. When a group of independent agents interacts to solve a given problem, they make up a multi-agent system (MAS) e.g. Fig. 1. In this work, agent shall monitor the physical environment using laser range or microwave sensors as well as global positioning system [e.g. 18] to locate perceived areas of IED materials and direct mobile device users to safety. As stated in [19] this is because laser sensors can obtain and use accurate depth information.

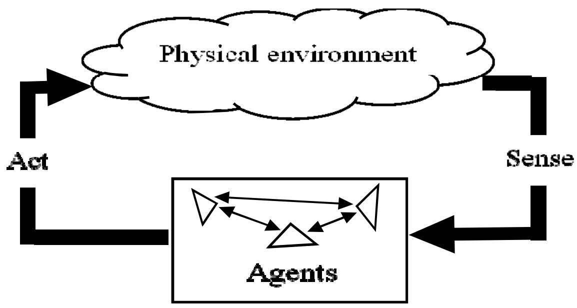

Fig. 1. Environment and inter-agent interaction

[20] states that the design and development of a large MAS is a complex and difficult activity. Because of the reactive capability of distributed system or MAS in capturing dynamic changes in real time situations, MAS are feasible approaches to complex and difficult problem solutions such as the identification, detection and notification of IEDs materials. Different programming language and platforms are used for developing MAS applications. Continually, agents monitor their environment through sensors or customised artifact and react to percepts. The reaction of agents to percept are based on the BDI (Belief, Desire and Intention) model of programming MAS [21, 22]. In developing a MAS, the system can be viewed as an organisational design [23] where goals, roles and functionalities and the number of agents in the system organisation are first identified, and then functionalities transcend into agent actions in the system.

A. Agent Methodology

A number of methodologies exists for analsing a MAS before implementation. Amongst them are Gaia [23], Tropos [24], MaSE (2004) [25] and Prometheus [26]. In this proposal, we demonstrate Prometheus: a methodology for developing intelligent agents, and describe the design phases of the methodology in the development of the agent system that can detect IEDs in order to prevent the actualisation of violence on the innocent public. Prometheus supports the design of BDI agents using the Prometheus Design Tool (PDT). We chose the PDT tool for this analysis because of its explicit software design activity and detailed refinement process. The

Prometheus methodology has three phases of design, which are *System specification* phase, *Architectural design* phase and *Detailed design* phase.

The Fig. 2 presents a real life problem scenario to visualise the problem. It shows the abstraction of interconnected entities in the detection of IED, safety alert and rescue. There are street_camera and mobile_phone entities that can be embedded with intelligent agents. These are the computational entities meant to detect IED materials whether in a vehicle (motion or motion-less) or in a particular location. On perceiving the explosive material through its sensors, the *street camera* and *mobile phone* agents would process the perceived object and issue "*safety*" alerts as well as communicating with security outfit for rescue operations.

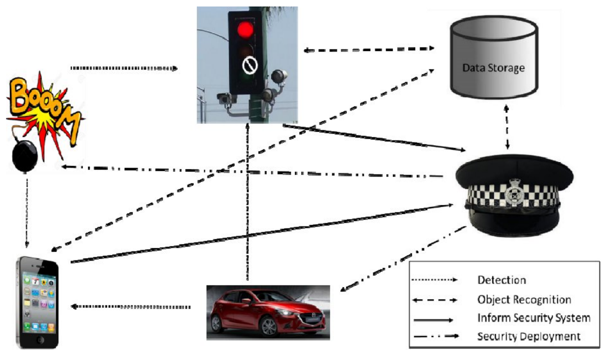

Fig. 2. Real life problem scenario

B. System Specification

This phase comprises the initial specification where the problem is broken down into scenarios, system goals, and the inter-connection between goals.

1) Scenario: This is part of the system specification process. Fig. 3 shows the breakdown of the problem into achievable scenarios from the problem description and purpose of the agent based system.

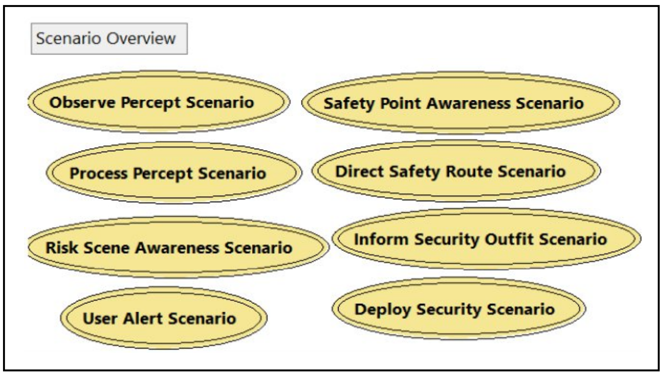

Fig. 3. Prometheus Design Tool scenario formulation

2) System Goals: This is the stage where scenarios split up into achievable system goals, and the interaction between goals are made visible (Fig. 4).

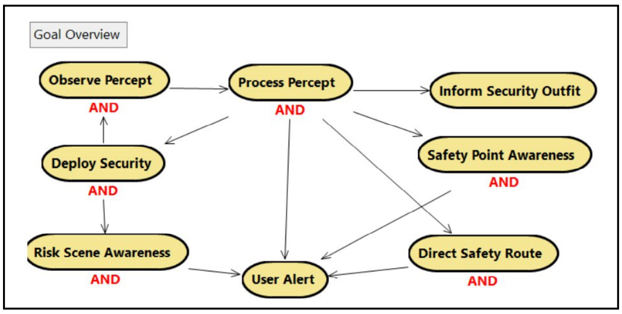

Fig.4. Goal refinement from Scenario development

C. Architectural Design Phase

In this phase, agents of the system are decided and are given their roles. At this stage, agents, their perception, and data coupling are specified in the design including agent communication using directed arrows (Fig.5). The *action* symbol represents what *action* an agent would take at a given point in time. Interaction with the databases implies either an agent is updating the database (DB) (see DB symbol containing the hazards e.g. hazards(RDX)) or other agent is reviewing/matching the DB for some appropriate action. The agent use of the Geo-location DB is for locating the exact position and locality of an observed event. The action decided by the agent is based on the *context* or *pre-condition* of its plans. Plans are courses of action meant for agent execution during implementation.

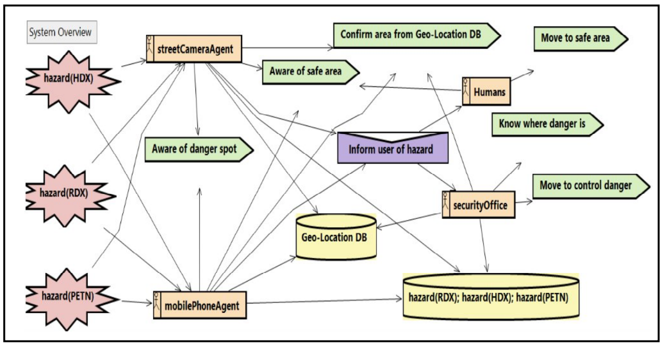

Fig. 5. System overview diagram in the architectural design phase. RDX, HDX and PETN have been used to model hazardous materials in this system diagram based on [13] classification of some CBE substances (see section I).

D. Detailed Design Phase

In this phase, individual agent details in the system are specified. This include the nature of percept , achievement goals and how agents would achieve their goals. Agents achieve their goals through agent plans which contain their intentions and through inter-agent communication using performative messages. The type of messages (declared by performatives e.g. "***tell**, Danger_Alert*") between agents for the actualisation of goals (see Fig. 6). The Fig. 6 presents the dynamic phase of interaction protocol between agents and public users. Performatives are action words or verbs used by agents in exchanging messages. *For details on **performatives** please see [21].*

As shown in Fig. 5 and 6, the agent based system has the "people" entity and programmable agents:

1) people entity: These are people in physical space. As such, they are the people that own the mobile devices and use the street camera facilities on the roads in our cities. With mobile devices, users are the beneficiary of the proposed IED detection and alert notification system.

2) mobilePhoneAgent: This is a programmable computer software in a mobile device that has the capability to: recognise IED materials, perceive IED data, provide alert to human users, communicate with other agents, store perceived data in a data store as well as accessing the data for intelligent decision making.

3) streetCameraAgent: This agent is similar in terms of functionality to the *mobilePhoneAgent*. Unlike a mobile device that is portable due to its user's mobility, street cameras that are mounted on metal posts on our streets are stationary. From their stationed position, the agents embedded in street cameras would monitor the physical environment for IED materials.

4) securityOfficeAgent: At any given time, every disaster always demands the attention of security agencies such as the police to salvage the situation. Thus the *securityOfficeAgent* is the agent in security outfits or agencies' systems. While this agent would have access to the stored database as well, its main function is to receive IED percept from the *mobilePhoneAgent* and *streetCameraAgent* for the purpose of deploying security agencies to IED locations.

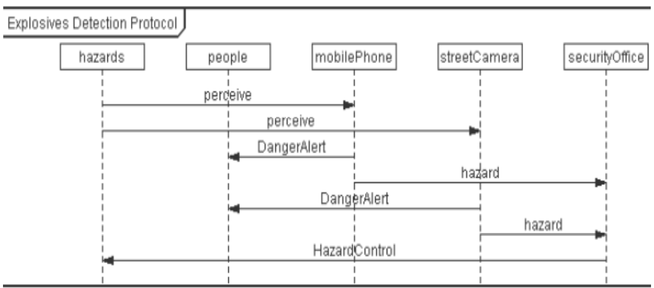

Fig. 6. Agents interaction in explosive detection protocol

E. A Prototype Model of Intelligent Approach in First-Order Logic (FOL) and AOP Equivalent

In this section, we generate a prototype code on how this problem would be addressed. We start by narrating the presence of an IED material in a location. Firstly, this is given in natural language and then transformed into its equivalent form in first-order logic (FOL) (Table II).

TABLE II NATURAL LANGUAGE AND FIRST ORDER LOGIC EQUIVALENT

Natural language scenario	First-order logic (FOL)
There is a hazard:	$\exists\alpha\ hazard(\alpha)$.
There is a hazard in a location:	$\exists\alpha\ hazard(\alpha) \wedge location(x, y)$.
If there is a hazard then it is definitely in a location:	$\forall(x, y)\exists\alpha\ hazard(\alpha) \Rightarrow location(x, y)$.
Every hazard is in a location at a given time:	$\forall t\ \forall(x,y)\exists\alpha\ hazard(\alpha) \Rightarrow location(x, y, t)$.

Given a ***REACTIVE AGENT*** plan structure in Jason:

+trigerring_event : context <-- action.

then in our system, the ***mobilePhoneAgent*** behaviour is modelled as:

+hazard(α) : hazard(α) & location(x, y) & date(YY, MM, DD) & time(HH, MM, SS)
<-- .println("CAUTION: stop moving.");
.println(α, "dangerous and explosive material around you.");
.println("Take alternative route that is", ~location(x, y));
-+hazard(α); // update KB or database
-+location(x, y, t); //update KB
-+location(x, y).

Then for other agents e.g. the ***securityOfficeAgent*** that subscribes to the KB, we have

+hazard(α) : hazard(α) & location(x, y)
<-- .send(AgX, tell, securityOfficer("on their way for rescue.").

The action part of the plan posts the message *securityOfficer("on their way for rescue.")* to the KB. Thereafter, every agent e.g. the ***mobilePhoneAgent*** with the relevant plan will respond to the message from the ***securityOfficeAgent*** with:

+securitOfficer(x) : true
<-- .println(x). // i.e. informing people in crisis area about the rescue team

The *println(x)* outputs to every user's mobile phone the content of the *x* variable. Of course, one other property of these CBE materials or substance might be the *intensity* of the material. Should material *intensity* be measured at a certain threshold value given their concentration in *ppm, pttb, ppt* or *ppq* (Table I)? This is to, probably, check false alerts from agents during substance recognition . In that case, the context (i.e. *pre-condition*) part of agent reasoning over its belief would be:

hazard(α) & location(x, y) & intensity(α >= Threshold_value)

Thus, given that P is a set of *percept*, L different geographical *location*, D the *date* function of event (i.e. percept), T the *time* function of event, and K the *knowledge* *base* (KB), the Fig. 7 presents the algorithm of the detect, safety and rescue procedure.

```
WHILE parameters = [P, L, D, T, K]
    IF P is a new percept
        K ⊭ P    // P is false in K i.e. KB
        K = K ∪ [P, L, D, T]
        IF K ⊨ P    // P is true in KB
            alert user about the percept P
            direct user to safe location L
            alert security officers of location L of the Percept P
        END IF
    END IF
END WHILE
```

Fig. 7. Algorithm for IED detection and safety procedure.

IV. Conclusions

This research proposal has presented the problem of improvised explosive devices (IED) in our cities and a methodological description on how this problem can be tackled using intelligent agent technique. Given the scenario, the problem has been analysed using an agent UML tool. In addition, First-order logic (FOL) was employed to highlight the scenario which was stated in natural language and code equivalent generated in Jason.

V. Further Work

The next stage of this work is to test the proposed solution through a system simulation of a busy shopping centre using virtual reality and/or game engines. This would involve the construction of a 3D model of the scenario environment using terrain models photographic images and bitmaps, and integration with agent architecture and data silos.

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