Simulation analysis of IoT_based police force effectiveness on hostage rescue

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Abstract. Even the fast spread Internet of Thing (IoT) technology has penetrated many fields, there are huge parts of society that is still far behind the people's expectation in using new technology for public safety and risk reduction, such as the issue of resolving the crime scene by police or fire fighting. This paper aims at proposing an alternative for using IoT in support of police operation in rescue the kidnapped civilian by criminal. Models were developed for a specific scenario. A simulation was used to run for gathering the simulated data in order to prove the effectiveness of the IoT aided police operations. The result has shown the proposed alternative does improve the effectiveness in executing the rescue mission.

Keywords: Detection, IoT, PF, Screen, Sensor, Simulation, Criminal, UAV

1 Introduction

Nowadays, the police operation on the given mission still follows the traditional way, which is manpowered with the skills accumulated by training and experiences [1], such as Hong Kong police relied on past experience to deal with third unexploded Second World War bomb[1]. With that factor, the safety to both of the public and police would be our greatest concern. However, the fast pace in the progress of information technology has been bringing us with the never ever appeared superiority in the sensing, positioning, and communication field that can benefit us with a great leap in saving manpower, cost and the unnecessary risk of life. The crime is a worldwide

[1] South China Morning Post, "Hong Kong police rely on past experience to deal with third unexploded second world war bomb to be found at Wan Chai construction site", 11 May, 2018.

issue that always jeopardize the public safety. The worst of which is the criminal pursuing their purposes from kidnapping that would give the police a hard time in the resolving the crisis while keeping the hostage as intact as possible. How to aid the current police with the modern technology for achieving the planned rescue mission with lesser risk and cost is the concern in this paper.

The sensors connected internet makes ad hoc connections, shares data and allows unexpected applications forming as human's nervous system [2] that forms IoT. With a sharp weapon such as IoT, the human being can rely on in building new applications in so many areas, such as business, industry, government, and healthcare, etc. [3].A key of the hostage rescue task is the situation awareness that can be buildup by sensor network linking to the internet. Some of the sensors are carried by unmanned aerial vehicle (UAV) or small vehicle being mainly for the search and detection assignment. This paper proposes a way of examining the effectiveness of using IoT on a specific scenario, in which the police force (PF) needs to cross the unknown setup screens for criminal's early warning and defense. . Modeling the proposed scenario is the major part in this study, which includes mathematical models and Monte Carlo simulation. The PF effectiveness will be evaluated with and without the aid of IoT.

2 Related Work

According to Roser et al. [4], until 2016, there were 511,047 criminal's incidents occurred on the world and caused 1,150,580 deaths since 1970. The reports [5] claimed, in 2016, the criminal attacks took place in 104 countries. 55% percent of all attacks took place in five countries (Iraq, Afghanistan, India, Pakistan, and the Philippines), and 75% of all deaths due to criminal attacks took place in five countries (Iraq, Afghanistan, Syria, Nigeria, and Pakistan). The Islamic State of Iraq and Syria (ISIS) was responsible for more attacks and deaths than any other perpetrator group in 2016. The counter criminal (CT) special response force originated from Israel in 1957 for carrying out the cross-border tactics against Palestinian guerrilla bases. The Special Weapons and Tactics (SWAT) units had emerged for managing hostage-taking incidents in the post-1972 [6].

Situation awareness is the key for having the war zone under control. The top priority of situation awareness is to be able to provide the identified location, deployment, and activity of the enemy, as well as friend force information. Situation awareness (SA) is one of the most critical factors in operation that can determine the mission accomplishment. There are many definitions for the term of "situation awareness", some of them, easily understood, are illustrated in the following. Endsley [14] suggested that SA provides "the primary basis for subsequent decision making and performance in the operation of complex, dynamic systems..." At its lowest level the operator needs to perceive relevant information (in the environment, system, self, etc.), next integrate the data in conjunction with task goals, and, at its highest level, predict future events and system states based on this understanding. Green and Yates [15] thought SA requires an operator to "quickly detect, integrate and interpret data gathered from the environment. In many real-world conditions, situational awareness is hampered by two factors. First, the data may be spread throughout the visual field... Second, the data are frequently noisy." Wickens' [16] definition is much simpler, "Situation Awareness refers to the ability to rapidly bring to consciousness those characteristics that evolve during a flight." However, the most frequently cited definition is by Endsley [17], "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future." Endsley also indicated that SA involves for levels of activities [18]: 1) Perceiving the status, attributes and dynamics of relevant elements in the environment. 2) Understanding the significance of those elements in light of the goals of the decision-maker. 3) Projecting the future actions of the relevant elements and the consequences of these actions in that environment. 4) Sharing situational awareness, its components, and the decision-making process.

In order to achieve the goal of SA, it requires to rely on sensors to collect relevant data from the targeted field and to process gaining the useful information for the local end-user. The SA involves for levels of activities, Hence, from the design views in SA engineering, Kantorovitch et al. [19] suggested that the SA system must support the end-user the providing integrated view, supporting work process, decision support, and to be usable, simple as well as attractive.

Using the concept of internet of things (IoT), such as the variety of sensors or sensor network, platforms, positioning device, in the support of SA has been largely applied lately. The definition of IoT for smart environments by [24] is "Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework. Other than sensors and actuators, the augmented reality (AR) can be a multiplier in the supporting end-users for providing important command control (C2) information of the environment that [25] indicated " Accessing information via an Augmented Reality system can elevate combatants' situational awareness to effectively improve the efficiency of decision-making and reduce the injuries." AR is defined as systems that have the following characteristics: 1) combines real and virtual; 2) interactive in real time; and 3) registered in 3-D. AR can replace the oral communication not only on head-mounted devices (HMDs) but integrating the real and virtual objects in real time interactively into an individual's physical environment for whom can perceive the information existing in the surroundings [26] [27] [28]. AR provides the user with superimposed information that can be seen in the real world, that is, it complements the real world with virtual information [29].

The Unmanned Vehicles, including UAV and UGS, have an important role in carrying sensors and weapons to perform the assigned missions. In light of technological advances, the UAV is the effective measure for the defensive side to monitor the potential threat. In [30], Sun et al. proposed an all-in-one camera-based target detection and positioning system for integrating into a fully autonomous fixed-wing UAV being capable of on-board, real-time target identification, post-target identification. However, lower altitude mini-UAV is easy to carry and deploy in the scenario of this study. Carrying the precision sensors, the UAV can loiter in the air for the purposes of detection to the ground target. Väärs [11] pointed out the use of UAV has become an essential feature of land operations. This widespread technology is now systematically used by the militaries of almost all countries and with an exponential increase in military investments in UAV. The specifications of the thermal camera include sensor pointed out in [31] with the resolution as 640 x 512, Lens/FOV with 19 mm/32^{o}x 26^o, operating temperature range from -21C^o to + 50^{o}C, a frame rate of 30 Hz, and operational altitude up to 3,048 m.

3 Modeling

To model the hostage rescue mission for analytical purpose, we concern three steps including scenario, operational concept, and algorithm.

There are many different hostage rescuing scenarios having occurred. However, for satisfying the analytical purpose of distinguishing the difference between the conventional and IoT-based way of rescue mission, we intend to design a simple scenario for a simulation in order to find out the fundamental difference and to check if it is significant. The scenario is with two sides' interaction, i.e. the criminal's defense and PF.

This specific scenario is designed to have the hostage on the mountain top which is defended by the setup of two screens' alert that the criminals intend to have an early warning which may gain time for shifting the hostage to other place if there is any penetration occurred. The concept of the criminal's deployment is in figure 1. The outer screen (screen 1) is setup with manned-posts somewhere around the mountain. The last screen (screen 2) is by the security guards that they are deployed around the building where is the criminal's headquarter for keeping the hostage.

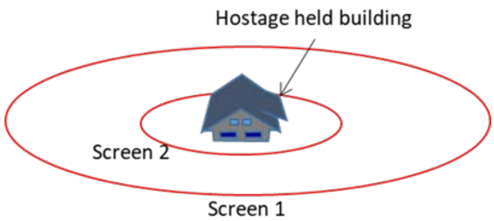

Figure 1. Screens scenario

In this scenario, there are two types of police forces (PF) with different equipment: the IoT-equipped and not-IoT-equipped (conventional method).

Based on the given scenario, the concept of PF operation is to aim at rescuing the held hostage in the remote mountain area. The successful rescue mission is defined as that if the PF penetrates all two screens then it is counted as success. The logic is starting with the initial setup such as the density of landmine, the characteristics of UAV and criminal's security guard. The followings is to check the chance of penetrating each screen. The screen 1, a landmine model would do the check the rescue squad can penetrate with success, if not then the missions is count as a fail. Screen 1 is setup by several posts in specific points around the hill that will be a manned-post model for calculating the probability of the detection to the trespasser.

Screen 3 would be the last resort for having the mobile security guard detection model to detect the penetrating rescue force. The logic flow is as Figure 2.

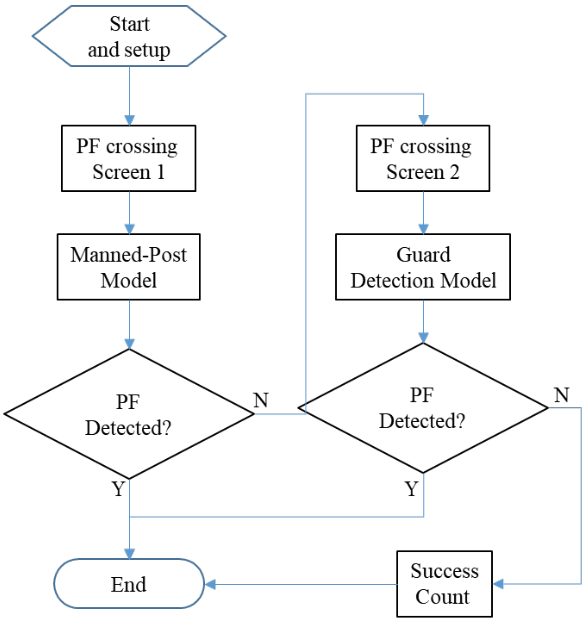

Figure 2 PF's penetrating operational logic

The scenario can be regarded as a simple two screens which would create probability of successful penetration for the PF, i.e. P_i, i=1,2,3.

Screen 1 is setup by a number of posts (NP) which are manned with thermal device for watch the specific area which is depicted in Figure 3. The lateral range is defined by "cookie-cutter" approach in cell probabilities [32]. The concept of using lateral range (LR) to form the sweep width of the watcher to determine the probability of detection is as Figure 4. The range in between posts is denoted by 2R. The probability of detection (P_{d_post}) as the PF moving across the circle of the post in simulation can be derived as (1)

$$P_{d\_post} = 1 - 2(R - LR)/R \tag{1}$$

Then, the count of detection by the post is as (2)

$$\begin{cases} = 1, \ if \ P_{d\_post} > RAND(\,) \\ = 0, \ otherwise \end{cases} \tag{2}$$

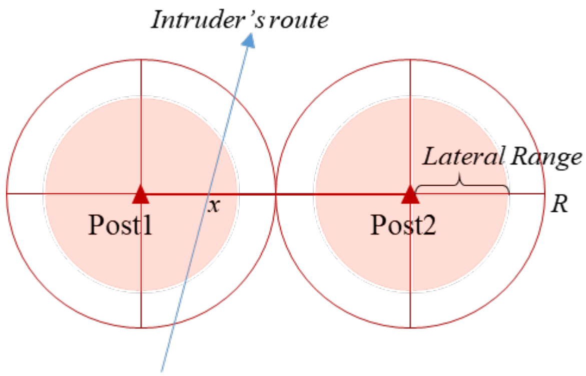

Figure3 The concept of deployment of posts in Screen 1

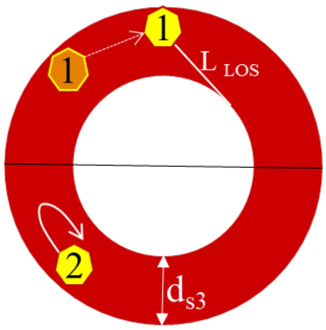

Figure 4 The lateral range and detection probability

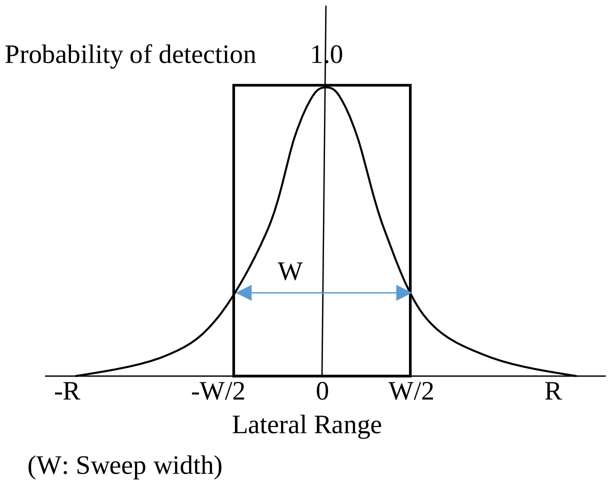

Figure 5 The security check concept of Screen 2

Screen 2 is the location where is next to hostage held building. The deployed secruity guards are patrolling around the area. The guards are grouped and randomly spread out at the assigned sector for security check around the building. The conept is in Figure 5. Assume two groups to be responsible for the building's security. The parameters concerned here would include the width of field to the building(d_{s3}), moving speed of the guard (V_{Guard}) and PF (V_{Squad}). Since, during the ngiht, the thermal equipment is used, the guard has line of sight (LOS) with a specific range based on the condition of building periphery. The time for guard to compelete the length of half circle (L) check is $T_{complete\_L} = \frac{L}{V_{guard}}$. When under the LOS condition, the quard patrol on line of the premeter of the circle for having LOS to the building that can save time in patrol. Assume, the range of LOS is L_{LOS}, which is 1/n L, then patrol range is L(1-2/n). Then, the time to complete the patrol is in (3)

$$T_{complete\_L} = \frac{L(1-\frac{2}{n})}{V_{guard}} \tag{3}$$

The PF has to pass the field without being detected. In simulation, the time starts to move across the field at time 0, the time for crossing over the field is T_{cross_d} . If the distance between these two groups is greater than e L_{LOS}, then the detection would not happen. Hence, randomized two points for both of PF and guard as ($Rnd\_location_{PF}$, $Rnd\_location_{guard}$) to represent both location in the moment when PF starts crossing action, where $Rnd\_location_{guard}$ is no less than L_{LOS}. The detection can be expressed as (4)

$$\begin{cases} = 1, & if\ L_{LOS} \geq \mathrm{Rnd}_{\mathrm{location}_{\mathrm{guard}}} - \mathrm{Rnd}_{\mathrm{location}_{PF}} \\ = 0, & otherwise \end{cases} \tag{4}$$

For IoT-based PF, due to the sensor network and unmanned systems are applied that much more data about the local situation including detection of the hidden screens can be acquired. After processes, those data become useful information including the criminal deployment such as the detailed location of the landmine and posts. The decision support system (DSS) can then make the predicted penetration points and time in terms of avoid the detection from those deployed criminals.

The UAV carried GPR has been used in the detection of landmine. Since there is no publications specify the range of detection probability (Pd) in terms of UAV carried GPR in against landmine, we assume an error exists due to the possible missed detection. The error rate will be generated randomly within a given range. The mini drones are used to fly over the planned route for searching the potential criminals by the sensors on board, such as camera and thermal sensor, which can provide a certain probability of detection on the object on land day and night. With mini drones in reconnaissance, the chance of crossing PF being spotted by the manned post is reduced due to the penetration route in between two posts is in a narrow range around the estimated least chance of the detected point, which we express the route of penetration by Normal random variable, i.e. $N{\sim}(\mu_{screen1}, \sigma_{screen1})$. The generated random number, which is a range x, if (x+LR ≧ R) then PF is detected. The range of x is changed when sensor's error is taken into account. The last screen is with the guard patrolling around the hostage held building. The sensor on mini drones, the type of bug or little bird, can send the data of the criminal's guards, such as the location, patrol behavior, and the number, back to the PF. With fast process, PF can figure out the best time to cross over the field with minimum risk. The unpredictable uncertainty, i.e. the mistake made by PF, sensor error or the sudden turnaround of guard, is concerned in this crossing that it is described as Uniform random variable such as $U \sim (0, UB)$, where UB is the upper bound of detection probability of guard. The UB is varied by the integrated concern of the unpredictable uncertainty.

4 Analysis

The main objective of analyses is to find out if there is a significant difference between the PF of conventional and IoT_based. In order to achieve that, we start with the assumptions which are required for matching the scenario. Then the cases representing the proper condition of sensor are proposed. After running through the simulation model, the output data will be presented for further analysis.

Following the given scenario and two major alternatives, i.e. conventional and IoT-based PF, some assumptions are required to make. In action, with extraordinary caution but without remote sensors, the conventional PF would rely on their experience and instinct trying to climb the hill for completing the mission. Taking advantage of IoT technology, before action, IoT-based PF is trained to wait until the collected data from remote sensors are processed by DSS for having the high possible defensive setup by criminal and the accurate route suggested. In light of the unknown performance of sensors used by PF which may cause error and for the purpose of finding if there is a significant difference among the various sensors, the parametric study is used in the study. The required assumptions are as the following:

- The average lateral range of the manned post (m): 135
- Range between the post (m): 300
- Responsible range of guard in screen 3: 50
- Length of line of sight of criminal guard (m): 20
- The possible error rate of IoT sensors: 0.15, 0.3, 0.45, 0.6, 0.75
- Landmine detection probability by PF's UGS: 0.8
- IR sensor carried by UAV: Lens/FOV with 19 mm/32^{o}x 26^{o}, operating temperature range from -21C^{o} to + 50^{o}C, a frame rate of 30 Hz, and operational altitude up to 3,048 m.
- The definition of successful task for PF is under the condition that they are undetected when crossing all two screens

Combination of case would concern the sensor's performance with certain sensing error. The cases we concern are the conventional PF and IoT_based which is with UAV and UGS carried sensors such as camera and thermal sensor. The conventional PF is case 1. IoT-based PF is classify into five cases based on the performance of sensors, e.g. when sensor's possible error is 0.15, 0.3, 0.45, 0.6, and 0.75. From the simulation of all cases, the result allows us to examine if the IoT_based PF can make a significant difference from the conventional.

Simulation result of all cases that are with each screen's detection or kill for failing the PF in the conventional version and IoT_based.

Table 1 The failure probability of PF in crossing the screens setup by criminal

	Conventional	IoT_based				
	Case1	15%	30%	45%	60%	75%
		Case 2	Case3	Case4	Case5	Case6
Screen1	0.629	0.111	0.215	0.335	0.436	0.514
Screen2	0.961	0.058	0.369	0.404	0.641	0.660

The successful probability of PF for finally penetrating all two screens is in figure 6.

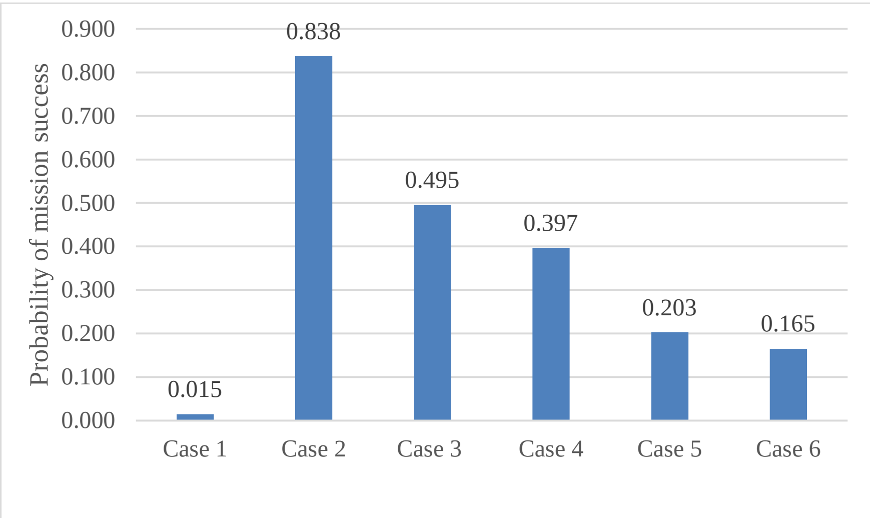

Figure 6 The successful probability of PF in crossing all screens

5 Conclusions

IoT is more and more popular in many areas but it is insufficient used by police in their works. For convincing the IoT is useful, this study proposed a methodology in simulating the interaction between police PF and criminal for showing the value of IoT in support of hostage rescue task. There were six cases were simulated and with the output data that proved the effectiveness of IoT in support of hostage rescue mission by police force. However, the accuracy of sensors of IoT also plays an important role that the study revealed difference between the two is getting small when sensor's error of accuracy is getting bigger. This study has shown the IoT can make a great contribution to the police operation, not only the probability of successful mission but also the risk and cost reduction.

Acknowledgement

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