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**AN EFFICIENT DRONES PATH PLANNING APPROACH
USING ENHANCED GENETIC ALGORITHM FOR
COMBATING TERRORISM AND CRIMINAL ACTIVITY**

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Master's Thesis

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**AN EFFICIENT DRONES PATH PLANNING APPROACH USING
ENHANCED GENETIC ALGORITHM FOR COMBATING TERRORISM
AND CRIMINAL ACTIVITY**

by

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Mohammed Muayad Abdulhussein Haneefa

DEDICATION

First, I would like to thank Allah Almighty for the power of the mind, health, strength, guidance, knowledge, and skills to complete this study.

This thesis is wholeheartedly dedicated to my parents. There are no words to describe what you mean to me; there is nothing that I can repay for what you have done to me. I will continue to do my best to achieve your expectations.

Lastly, I dedicated this to the family, relatives, and friends who have been encouraging me during this study.

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ABSTRACT

AN EFFICIENT DRONES PATH PLANNING APPROACH USING ENHANCED GENETIC ALGORITHM FOR COMBATING TERRORISM AND CRIMINAL ACTIVITY

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Drones are a very popular type of aircraft that has seemingly taken over the world. Other widely used names for drones are Unmanned Aerial Vehicles (UAVs) and Remotely Piloted Aerial Systems (RPAS). Drones are being extensively consumed in today's world, not just by government authorities and law enforcement but also by commercial and private entities. However, the effectiveness of using drones as a long-term strategy for counter-terrorism, counter-insurgency, controlling criminal activities remain unclear. This research aims to examine the perceived effectiveness of using drones in combating terrorism and criminal activities. Moreover, presenting new path planning techniques based on tree seed algorithm and genetic algorithm (TSAGA). The presented approach applied to find the best path for the drone when used to visit more than one location or goal. The proposed TSAGA assist the drones to find the minimum path which lead to Energy saving and solving the energy problem in the drones which is one of the main problems in drone technology. Then, the obtained results by the TSAGA compared with classical GA and show that the proposed approach is best and better in both energy saving and execution time.

Keywords: TSAGA, genetic algorithm, tree-seed algorithm, drone.

ÖZET

TERÖR VE SUÇ FAALİYETLERİYLE MÜCADELE İÇİN GELİŞTİRİLMİŞ GENETİK ALGORİTMA KULLANARAK VERİMLİ BİR İHA YOLU PLANLAMA YAKLAŞIMI

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Dronlar, görünüşte dünyayı ele geçiren çok popüler bir uçak türüdür. Drone'lar için yaygın olarak kullanılan diğer isimler İnsansız Hava Araçları (İHA'lar) ve Uzaktan Kumandalı Hava Sistemleri'dir (RPAS). Drone'lar günümüz dünyasında yalnızca hükümet yetkilileri ve kanun yaptırımları tarafından değil, aynı zamanda ticari ve özel kuruluşlar tarafından da yoğun bir şekilde tüketilmektedir. Bununla birlikte, dronları terörle mücadele, isyanla mücadele, suç faaliyetlerini kontrol etmek için uzun vadeli bir strateji olarak kullanmanın etkinliği belirsizliğini koruyor. Bu araştırma, drone kullanımının terörizm ve suç faaliyetleriyle mücadelede algılanan etkinliğini incelemeyi amaçlamaktadır. Ayrıca, ağaç tohumu algoritmasına ve genetik algoritmaya (TSAGA) dayalı yeni yol planlama tekniklerinin sunulması. Birden fazla yeri veya hedefi ziyaret etmek için kullanıldığında drone için en iyi yolu bulmak için sunulan yöntem uygulandı. Önerilen TSAGA, drone teknolojisindeki temel sorunlardan biri olan drone'larda Enerji tasarrufu ve enerji sorununu çözen asgari yolu bulmalarında drone'lara yardımcı oluyor. Daha sonra, TSAGA tarafından klasik GA ile karşılaştırıldığında elde edilen sonuçlar ve önerilen yöntemin hem enerji tasarrufu hem de uygulama süresi açısından en iyi ve daha iyi olduğunu göstermektedir.

Anahtar Kelimeler: TSAGA, genetik algoritma, ağaç tohumu algoritması, drone.

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LIST OF ABBREVIATIONS

GA : Genetic Algorithm

TSA : Tree-Seed Algorithm

OA : Optimization Algorithms

UAVs : Unmanned Aerial Vehicles



1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The use of drones has become widely popular in today's world. Drones are also known as Unmanned Aerial Vehicles as these aircrafts can be operated from the base quarters by experienced pilots. This characteristic is what gives this technology an edge over other strategies for combating terrorism and criminal activity. This prevents a lot of bloodshed and saves time in locating the possible targets [1].

Drones are considered very efficacious when compared with other manned vehicles. UAVs have a clear advantage of reducing risk for military men since they are not physically present in the targeted area. Also, the drones can be comprehensively loaded with specific and appropriate weapons accordingly and can aim at distinct individuals or a part of the building [2]. UAVs can stay in the air for several hours which gives enough time to the pilots to strategize and then strike targeting only at the identified combatant and minimizing risks of killing civilians [3]. This technology is affordable and involves comparatively lower risks than other counterterrorism and counterinsurgency strategies [2]. The world has seen a huge increase in the usage of drones and the demand for their multi-purpose implementations is increasing continuously and globally. The omnipresent feature of these drones is due to their capacity to respond to the needs of people. They offer users a keen lookout at the targeted individual/place that can be used virtually at any time from any place. The Law Enforcement Department can also use drones to detect suspects and to thoroughly investigate a crime scene Police force use drones to chase the suspects as the drones give a better view from the sky above, it helps in accurately identifying the running law-breaker. Drones are also used to closely inspect the crime scene by printing 3-D images and collecting evidence against the suspect. Law Enforcement Agency also make use of the drones to identify unregistered drones owned illegally by inexperienced private individuals [4].

Considering the main purpose of using drones in the first place, that is to target and eliminate terrorist group leaders and prevent further recruitment of new members, it is plausible that sometimes groups are strong and irrepressible enough to survive without their leader [2]. Often, the group comes up with more dangerous methods of avenging the death of their leader. This, in a way, potentially means that the drone strikes are capable of increasing terrorism instead of curbing it. Similarly, the use of drones by Law Enforcement Department to reduce criminal

activities can sometimes backfire when this technology falls into the hands of the criminals themselves. Criminals are capable of using UAVs to carry out their master criminal schemes and to acquire sensitive information on the potential targets [5]. Moreover, the usage of drones always has an attached risk of killing non-combatants along the way and the introduction of the 'Signature Strikes' by US has further escalated the issue. These strikes are not directed at a specific suspect; rather follow upon the questionable behavioral patterns. This undoubtedly involves higher risk of putting civilians in great danger as it becomes difficult to separate combatant from non-combatants [1]. In the bargain of the affordable nature of the UAVs, it is now availed by private body along with the military use. This can constitute to serious consequential damages if in they fall into the wrong hands [6]. While drones in the wrong hand can be dangerous, they serve as a powerful tool for the law enforcement department. They may use this technology to track incidents, conduct surveillance, and investigate natural disaster sites and much more. However, the drone usage in military operations has been growing steadily to combat criminal activities, to counterinsurgency and to counterterrorism.

There is a growing debate on the effectiveness of the usage of drones in terms of counterterrorism and prevention of criminal activities.

Drones, another name for Remotely Piloted Aerial Systems (RPAS), are used to precisely target the already identified individuals. These are unmanned but are piloted by the trained professionals situated at the base quarters. The operating team analyses and targets the identified suspects through the monitoring cameras. It is indeed noticeable that usage of drones is spreading throughout the globe and the serious consumption of drones pose a serious question on its effectiveness and appropriate use. Many commentators believe that drones should only be used where there is no other alternative present. The drone attack should be analyzed against other strategies to carefully determine whether the use of drones will help in achieving the desirable outcomes. In addition to that, there should be an active transparency for the use of drones to ensure accountability. This will not only make the user-force careful in their decisions regarding drone strikes, it will also help in keeping tracks of casualties. Lack of transparency gives them an advantage of getting away with irreversible damages. Currently, where there are numerous technological advancements made by the second, there comes potential threats along with them. Therefore, legalization and efficient policy making is highly necessary to maintain a smoother system. With the increased use of this technology, it needs to be made sure that the

policies are also in alliance with the appropriate usage of the drones [7]. Moreover, the affordable nature of drones is also what is making it so accessible to general population. By acquiring the statistics through this study as to how many people are using it for personal use, they could potentially further continue the study and gather qualitative data regarding the reason of such purchases. This is essential as there is always a potential risk of it landing in wrong hands. This technology should not go beyond official users, or otherwise can give rise to serious threats and dangers. To conclude, the contestability on the effectiveness of drone attacks remains abstruse.

1.2 SIGNIFICANCE OF THE RESEARCH

By conducting the study on the usage of drones as a strategy to battle against the prevalent terrorism and the criminal activities, the effectiveness of this strategy can be determined and rightly put into perspective. It is important to investigate the efficiency of drone to counterterrorism and counterinsurgency so that further improvements could be made. With the lower risk and lower cost factors, the usage of UAVs has been widened globally. This growing consumption of drones need to be analyzed based on its practicality. Through this research, it can be evaluated whether the usage of drones is a helpful short-term or a long-term strategy or is it beneficial at all in reducing or controlling terrorist and criminal actions. As of now, there are no facts or numbers as to how many terrorists in actual are eliminated and how many innocent civilians had to give their lives. Therefore, this study, could potentially highlight those facts, and give the concerned authorities a chance to improve their operations and get a better idea on the rationale of terrorists' whereabouts. Studying the usage of drones in detail would also help in deducing the success and the failure factors attached to this technology. The drone strikes often result in various un-called for casualties for civilians, the study would help in communicating the impact of such loss on the surrounding people. After studying the number of civilian casualties, they would be certain about the places that should not be targeted, so that no civilian must suffer further. Lastly, as this technology is becoming accessible day by day, the research can perhaps assist in postulating the appropriate usage of drones for combating terrorism and criminal activities. This in turn will be useful for the military and law enforcement force in making informed and conscious decision regarding drone UAV usage. Then, drone UAV technology required new and efficient algorithms to save energy with minimum computation time and this done by developing new path planning protocol based genetic algorithm and tree seed algorithm.

The presented protocol tested in several scenarios and the results show that the presented protocol obtained remarkable outcomes.

1.3 RESEARCH AIM

The aim of this study is to assess the level of effectiveness of using drones, also commonly known as Remotely Piloted Aerial Systems (RPAS) and Unmanned Aerial Vehicles (UAVs), as a means to control or minimize the terrorist and criminal activities and to determine the ratio between the civilian casualties and the number of terrorists being eliminated. Moreover, developed new path planning model to find the minimum path within low computational time. This issue is very important because save the energy of drone which assist drones to remain in the sky more time with low energy.

1.4 RESEARCH OBJECTIVES

This research aims to investigate:

- Participants' awareness on the technology of drones
- Participants' awareness about the reasons for the usage of drones
- Perceived effectiveness of the usage of drones for counterterrorism
- Perceived effectiveness regarding the usage of UAVs for controlling criminal activities
- Extent to which terrorists are eliminated successfully
- Participants' awareness about the civilian casualties
- Participants' support level for drone strikes
- Participants' comfort level regarding drone patrol in crowded places/events such as concerts, galas, matches/stadiums, clubs etc.
- Possible impact of witnessing a drone attack
- Participants' attitudes toward civilian fatality
- Participants' support for the commercial use of drones
- Developed new method based genetic algorithm (GA) and tree seed algorithm algorithms for path planning

- The presented path planning model are new which optimized using optimization algorithm. The tree seed algorithm applied to enhance the performance of the genetic algorithm to find the best path that cover all locations in minimum energy.

1.5 RESEARCH QUESTIONS

- How effective is the usage of UAVs in controlling criminal activities?
- How effectively can the drone strikes reduce or slow down terrorism?
- What is the possible influence of UAV attacks on the surrounding individuals?
- Can drones successfully target and eliminate terrorists?
- What is the ratio between the targeted terrorists and civilian casualties?
- Does public support drone strikes?
- Is the killing of non-combatants justified?
- How comfortable people are in the presence of drones?
- Do drones make an effective tool for commercial purposes?
- How developed new path planning model that can find optimum path?
- How applied optimization algorithms to optimize the proposed optimization algorithm?

1.6 RESEARCH LIMITATIONS

It is inevitable that the research has some sorts of limitations fettered to it. Similarly, in this research, there are certain limitations that can be later incorporated in the future research. First and foremost, since the sample size used for the study was comparatively smaller as it is often difficult to recruit many participants virtually. Due to this small-scale research, there could be potential drawback of concluding the findings for a wider population. Every individual is entitled to different opinions and generalizing responses of a limited sample can be a little conflicting. Along with the generalization issue, the nature of the research could also be one of the limitations. Lack of face to face encounter of the participants with the researcher or the authoritative figure can sometimes be a problem as participants might not feel accountable enough and may in turn fake their responses as a result of social desirability or may answer without properly acknowledging the research items. The accurateness of the answers may not be

necessarily true, and this would cause issues in the practical applications of the findings. Since this was a quantitative research, the responses were narrow and limited. The in-depth responses could not be recorded and analyzed accordingly. Lastly, the research did not include the concept of a likely idea of banning of the drone strikes. That being the case, future researchers can incorporate a larger sample size, combination of quantitative and qualitative research, and participants' attitude towards banning of the UAVs.

1.7 STRUCTURE OF THE THESIS

This research has been categorized into five parts. The first part comprises of the introduction. This part briefly explains the impact and the perceived usage of drones against terrorism and criminal activity. Introduction consists of the concise background of the study, significance of the research, research aim, research objectives, research questions and research limitations. The second part of the research is on literature review. This part provides an in-depth summary of previous works as well as includes analysis and evaluation of a detailed literature on the various usage of drones and its effectiveness. The third part is in regards with the methodology used in this particular research. This part of the research talks about the methods used to collect data and the main sources of data collection. Then comes the fourth part, which lays out the major results of the research. This part of the study carefully analyses and discusses the data collected item by item. The collected data is also compared with the findings of the previous researches mentioned in the literature review, second part of the study. The fifth part of the study is about conclusions, in which careful deductions are made in accordance with the data collected. In this part, there is also the mention of recommendations about the appropriate use of drones that the study postulates keeping in mind the findings and conclusions of the study.

2. LITERATURE REVIEW

2.1 USAGE OF DRONES

Drones, often known as Remotely Piloted Aerial Systems (RPAS) and Unmanned Aerial Vehicles (UAVs), are one of the famous inventions of the modern times. UAV is an autonomous vehicle that does not require pilots to be on board. Drones have always been a target of an ongoing debate regarding its usefulness when it comes to counterterrorism and prevention of criminal activity. Seeing this advanced technology flourish, people have different opinions on its usage. There is an outright conflict on legality and prohibition of drone strikes by International Humanitarian Law (IHL). Drones have numerous advantages e.g. being an unmanned system there is lower risk for casualties, drones can target the specific individual adjudged as threatening, and they can be armed meticulously with appropriate weapons [2]. Drone attacks reduces militants' vulnerability by limiting their interactions with alleged informants, Intelligence Officials note that these drone strikes disrupt the militants' networks and have killed Pakistan's key leaders and hampered operations [1]. According to (Shima, 2015), one of the major benefits of using drones is cost efficiency. Since it is autonomous, does not need any pilot or passengers, the cost could be minimized. Secondly, during urgent situations they would still have the ability to strike even in uncertain conditions like bad weather, which would not be possible if there were a pilot [8].

Doubtlessly, there are also some drawbacks of using UAVs. Milton Hoenig, an adviser on mass destruction weapons, has right out expressed his opinion regarding the manufacturing and usage of Unmanned Aerial Vehicles. He says that it is high time that we all should carefully evaluate the usage and drastic consequences of drone strikes. He even goes on to prompt the option of considering the ban on the usage and production of Unmanned Aerial Vehicles for defence and military reasons. He mentions the fact that commercial use of drones is most likely to be authorized in the near future and the Federal Aeronautics Administration is also considering laying out rules for its usage in the space. He emphasizes that analysing the advantages of using drones in a society should be the only priority [9].

Usage of Unmanned Aerial Vehicles is mostly associated with the military usage (Lidyana). However, drones are also being frequently used for a range of purposes. Many industries are now

taking a serious interest in this technology. Apart from its obvious military usage, drones are now also used for commercial reasons. Thompson (2013) has also expressed the similar thought pattern of public of UAVs association with targeting and killing suspected individuals on a mission abroad. However, drones are being used for much more [10]. According to Kyrkou et al. (2019), the three major interesting applications of this technology include monitoring of road transportation network, civil defines protection and powerline inspection.[11]. As the drone usage is expanding to all sorts of markets, it is very much likely to have an influence on industries ranging from entertainment to agriculture. Many Hollywood film makers have already started incorporating drones as one of their highly valued equipment. Factors such as easy availability and affordability of drones are promising enough to contribute to the multi-purpose use Of UAVs in law enforcement department, news production and for construction sites. It all makes sense since the resourcefulness of drones is commendable as it can carry multitudinous transmitters, sensors and imaging equipment without needing men on board [12].

Schneider et al., (2016) conducted a survey and an experiment to study and understand the conditions in which people of America preferred manned strikes, unmanned strikes, platforms air strikes or complete avoidance of air strikes. This experimental design enabled the participants to evaluate these choices between various channels and offered the opportunity for individuals to justify their rationale (p.3). According to the results, the United States public were essentially unaware about the difference between unmanned and manned aircrafts. Moreover, it was observed that people are typically more inclined towards favouring unmanned uses of force rather than manned, however, this choice would be at a lower grade in circumstances in the presence of citizens, and in the likelihood of minimal danger to aircrews (p.4). Indeed, when it comes to air strike priorities, the American public is much more platform-agonistic than is commonly known. Regardless of whether the platform was unmanned or manned, the participants, in each of these cases, shared a preference for or against these strikes. This shows that the people of United States do not view UAVs as radically separate instruments of armed aggression in many situations, and casts doubts on claims that unmanned drone attacks are growing U.S. public approval for overseas war (p.15) [13].

It is crucial that the concerned authorities weigh down the costs and benefits of using the drones. The user-force should also be clear about the desired outcomes and analyse whether the usage of

UAVs will successfully cater to the aimed needs [14]. Furthermore, there are major concerns related to the issue of lack of transparency regarding the usage of drones. Lack of transparency automatically suggests that there is also lack of accountability and an unclear measure of possible consequences and damages. When there is sufficient transparency concerned to when, where and why the strikes are being carried out, the potential benefits can be recognized in a better manner. [15]. Apart from the general realizations, transparency is a required field under the international humanitarian law. Altson calls for greater transparency and Roth Kenneth also in her open letter to Barack Obama has asked the administration to publicly declare its legal reasoning for carrying out drone strikes and also to restrict such killings through legally means. In addition to that, the government should also act responsibly towards recognizing the potential threats to the society caused by drone strikes [16]. These indicate that there is a dire need for the transparency is an important element of the drone attacks and should be provided at all costs. This not only improves the legal system but also help the public to understand the possible benefits associated regarding public interest.

Engberts&Gillissen (2016) mention a great deal of usage of drones in their article, Policing from Above: Drone Use by the Police. According to its authors, the most used form of drones by police is for surveillance and monitoring of crowd during large-scale events such as concerts, award shows, gala, and football matches etc. The use of drones helps in keeping a keen eye on any suspicious activity that might occur and thus can be stopped before it occurs. Police department can also keep records of the number of visitors and the possible group movements to ensure that the events take place smoothly. Helicopters are most times compared with drones; however, drones have an edge of being more affordable and quieter. Regardless, sometimes the edge is taken back by the fact that drones are incapable of prolonging their stay in the air for longer periods. Therefore, UAVs have the potential to only be used for events that are short and for longer-time events, a series of drones can be used to have a continuous view of the crowd beneath [17]. Drone usage differs for the Law Enforcement Force, here the UAVs are used specifically to target identified individuals. This targeted use of drones is often utilized when the suspect is unaware of drone watching over. Additionally, the heat detection technique and infrared camera can also serve fruitful in spotting illegal growing of drugs. The drone can be fitted with such devices and this would in turn help in reducing drug-related criminal activities.

In January' 2012, under Freedom of Information Act, EFF sued FAA, also known as Federal Aviation Administration, to ascertain which public and private agencies had sought to fly drones for authorization. As the number of entities approved to fly drones is increasing in the following years, the FAA estimates that by the year 2020 approximately 30,000 UAVs would fly in the United States [18]. Drones are highly capable of technical surveillance. Many military models can remain in sky for hours or days, and their high technology sensors can scan entire towns, and also focus in and read a 60,000 foot milk carton [18]. Aerial drones have come over to military activities in the post 9/11 period. Surveillance, intelligence, and unmanned reconnaissance almost always follow the troop movements [19]. In a 2010 report by Alston to the United Nations, drone strikes are referred to as breaching human rights and international law, as these two demand accountability with regard to the protocols and protections in place to make sure that killings are just and abiding by the laws. The avoidance of transparency allows United States an illegal authority to proceed with the killings [19].

The prominent reason for the widespread of the drone usage at an interestingly fast pace can be dedicated to its implicit capabilities and incorporation of advanced technology. Some commentators have even made forthright statements about its extensive use. It is believed that soon, drones will be utilized for travelling purposes and even for delivery of groceries. The large-scale manufacturing of drones along with a great deal of investments in this aircraft is a living proof of its global use. The use is only expected to increase. Despite UAVs being an essential tool for military department, it appears to be consumed more frequently for daily basis commercial purposes. Given the current circumstances, the market for drones is expected to increase at a yearly growth rate of 19% and only 5% of this growth will be in the direction of military side [11].

2.2 COMBATING TERRORISM

The drone usage in military operations has been growing steadily and is frequently accessed and consumed for this purpose in approximately seventy countries including United States, China, Iran, and United Kingdom [20]. The first use of an armed drone to attack fighters happened in 2002 in Yemen. Byman (2013) that drones are an essential military's choice of weapon for combating terrorism. This sentence highlights the significance of usage of drones in today's world when it comes to slowing down or reducing the terrorist attacks (p. 32) [1]. He also says

that the utilization of drones in carrying out strikes against specific individuals is much better than using allies to locate and arrest the terrorists (p. 35) [1]. There is an evident increased reliance on UAVs by United States in order to target groups of insurgents and terrorists in countries such as Yemen, Libya, Syria, Pakistan and other places [2]. According to a report in the New York Times, United States considers all military men in the target zone as militants but this is inapplicable if there is a strong evidence of the opposite follows the attack [21]. In addition to that, Teal Group has implied that by 2023 annual sales of UAVs is expected to reach \$11.6 billion [22]. This suggests that the drones are being frequently used not just by the military entity but are also owned by private users.

Despite of the various advantages of using drone such as they can wait several hours before striking, giving the monitoring force enough time to decide the appropriate target, it can be still very difficult to separately recognize suspects from non-combatants. According to Library of Congress (2013), it is not evident whether the UAV attacks have successfully killed the suspects or killed enough innocent non-combatants to generate a significant global outcry to oppose the system of United States [25]. Nevertheless, critics remain critical; claiming that such strikes kill a significant number of innocent civilians, enrage the people outside of America, target Americans unlawfully, alienate allies and set a threatening example for such governments that misuse the drone strikes [1]. The government of the United States has categorized nearly all possible specifics of the drone's programs but hasn't ever provided clear accounts of the statistics of attacks or the civilian fatality resulting from such attacks. It is interesting that neither the critics of these strikes nor the supporters of drone usage are aware of the number of deaths drones have caused in the remote lands/strike zones. [21]. Boyle (2013) also talks about these signature strikes where the target is not on specific individuals, but groups are speculated to be potentially threatening by observation of the behavioural patterns. This vague basis of target only through subjective element of behaviour is looked down by many authors because it involves a very evident risk of putting civilians into danger resulting from the force's own misinterpretation (p. 8-9) [21]. Another article talks about signature drone strikes, where the target is inferred to potentially be dangerous by witnessing behavioural trends, not on individuals, but groups. Many researchers only through a subjective element of behaviour look down this ambiguous foundation of the target, because it involves an obvious risk of putting civilians in danger due to the miscalculation of the force itself [21]. If the State's very existence were at stake and

autonomous armed robots could be used to save the day, it is safe to presume they would be used. The use of automated killing machines in such situations might even be considered a legal practice [19]. In the United States counterterrorism activities, the drone usage has exponentially grown in recent years and changed the face of war [26]. The United States government is right now involved in two separate drone programs, one operated by the armed military forces in Afghanistan and Iran to fight against the insurgents, and one is operated by CIA to fight against terrorism to combat Al-Qaeda and associated powers [26]. The aim of drone strike campaigns is deterring and punish terrorists and insurgents. They teach such organizations a lesson by murdering them and raising ambiguity within the group which further leads to fear. According to a research, drones have reduced the amount of terrorist's attacks in Federally Administered Tribal Areas of Pakistan, also known as FATA [2]. According to Groves (2013), the United States drone strikes criticism typically argues that cross-border acts of terrorism should be controlled as a matter of law enforcement and the suspected terrorists to be prosecuted and charged as ordinary law offenders [27]. In recent months, the United States officials have been constantly implying the reduction in the killings of civilians in the drone strike program carried out in Pakistan, although, the overall number of strikes have been rapidly rising. Nevertheless, some accounts are insisted in voicing out their opinions in International newspapers that there have been civilian casualties to a very large extent in Pakistan. Also, few non-governmental organizations have manifested doubts about the statements of US officials, noting that there is a shortfall of credible corroborating evidence [28].

In the World of Drones Database, drones are being used by over thirty-six countries but did not necessarily develop their UCAVs at home. Drones, made by Chinese, have been widely used outside of China to counter terrorism, but the Chinese military itself has resisted lethal strikes [30]. Groves (2013) expresses his steadfast opinion regarding the drone usage in wars [27]. According to him, United States should make absolute use of this powerful aircraft to make sure that the homeland is protected at all costs. He believes that Unmanned Aerial Systems are very effective and efficient functionally and United States has the complete right to continue using this strategy to combat terrorism until the threat completely evaporates [27].

Another recent research Ruth Blakely, (2018), also mentions that the common thinking among American policy makers is that UAVs allow for accurately targeted strikes and thus restrict

resulting loss. Critics, on the other hand, are of the opinion that there have been numerous casualties faced by the civilians and quote that the reasons for this pertains to the inadequate judgment and inaccuracy of the drone attacks [31]. Kreps et al., (2016) investigated the use of drone strikes for counterterrorism and noted critics from groups including NGOs and International Organizations (IOs) believe that these attacks produce more terrorist than destroy and violate legal commitments. They conducted a survey to study to investigate if, after knowing about the international legal criticism on drone strikes, there was an impact on public's support for drone attacks or whether they were more persuaded towards it. The results showed that the support dropped by 6% to 80%, however, 40% of the public was still supporting the drone attacks.[32].Drones are considered as precision tools for targeting threatening individuals when compared with other aerial weapons used in the warfare. The use of UAVs also abides by the International Humanitarian Law [23].

This technology has also led the terrorist leaders to hide in confined places so that it becomes difficult for the drones to identify them. Instead of making the tracking system feasible, it sometimes makes it harder. Despite of the improved technology of roaming in the air for extensive period to accurately locate the target, sometimes drones often end up missing the targeted individual. This makes us question whether this is indeed a reliable strategy to follow upon or not [33].

In the end, it all comes down to evaluation of the drone attack and how successfully it can kill the intended target and will the strike eventually result in reducing the criminal activities and terrorism. The article by Lee Ludvigsen also mentions that as a result of the civilian's casualty, it would encourage the terrorists to act aggressively in return. This makes us think about the possibilities such as; can this statement determine the effectiveness of drones? Can the very use of drones hit right back with a more adverse set of consequences? Are drone strikes beneficial in the long run? All these general questions arise when one tries to examine the productiveness of using Unmanned Aerial Vehicles.

2.3 COMBATING CRIMINAL ACTIVITIES

The study by Sakiyama et al. (2017) surveys the attitudes of people about the UAVs usage for recognizing unlawful activities in public places, search/rescue operations, traffic monitoring and crowd management (p. 2). The results indicated that 94% participants were in favor of using drones in rescue and search operations. A large majority still endorse drone use for border control (76%) and traffic monitoring (74%). In comparison, acceptance of UAVs uses for the identification of illegal activity in open public areas (57%) and crowd control (47%) is slightly lower. The average score of the total composite index of drone's support (3.49) converts into an average approval of 70% for drones use in all the above mentioned activities (p. 9) [15]. However, it should be noted that often when people think about such operations, they usually have remote places in mind. Whereas, in reality, most of the targeted places that attract terrorists are in fact crowded (p. 13) [15]. If majority of the participants support the 'idea' of drones in combating criminal activity and terrorism but are not in favor of having them around for the sake of their own security, this ambiguity brings us back to assessing the effectiveness of drones in such circumstances.

Unmanned Aircraft Systems (UASs) also serve as an important instrument for the police force. Since drones have the ability to closely monitor and capture the scenes during the patrol, the law enforcement agency can use this to improve the investigations of the criminal activities and to better the security system [34]. Drones can be used to collect evidence in forms of pictures and maps. Police Department can also use drones to chase down the law offenders. Sometimes, the suspects hide over the roofs of the buildings making it difficult for the policemen in cars to locate them. But, with the UAV technology, they can even monitor from the sky. In addition to that, police often use drones to detect illegal drones owned by many inexperienced private entities [35]. The ownership of drones by private entities can be very dangerous and life threatening. It can cause drastic and unrealizable consequences. New York Times reported that a series of blasts started to occur in a peaceful community in Washington. Police broke the case when an inhabitant's monitoring camera captured the incident. The perpetrator was identified as a drone [36]. Given that drones also have an evidently clear edge when compared with a manned vehicle, because of which it has become an interesting choice of equipment to be used by domestic law enforcements along with the much obvious military use [6].

Drones are being consumed domestically by several law enforcement departments. These are currently being used as an important criminal detector by the Department of Homeland Security to prevent crossing of border through illegal means; the suspects could include any unauthorized trespasser, known terrorist or big criminals. It was also reported that police department in North Dakota made an arrest with the help of UAVs [10]. The successful arrest suggests that UAVs are in fact a beneficial tool that is now being treasured by police force in their mission of controlling criminal activities. Per the article of Krykou (2019), drones are regarded as one of the most effective tools in the civil defense department [11]. The recent features of UAVs can assist in improving the protection system and enhancing the rescue operations such as wood fires, floods, and earthquakes. If the police force decides to use this short-term strategy of drones to decrease or control criminal activity, they should be efficient and effective in doing so. They should evaluate the possible effects of making use of this strategy and make sure that the usage of drones does better than harm. It should be beneficial enough to add a real added value to the project [17].

The studies have also shed light upon the precision of the drone strikes and other success factors but pressed on the matter that drone strikes are more likely to meet their goals when used for counter terrorism and a weaker substitute for counter insurgency campaigns. Few of the articles also highlighted that the affordable nature of the drones is giving access to military and private users both. However, if in wrong hands, it can create a havoc with serious casualties. The United States Air Force conducted a survey, which showed 46% of Predator and Reaper pilot's and 48% of Global Hawk sensor operators suffered from high operational stress [23].

2.4 INFORMATION TECHNOLOGY OF DRONES

The continuous advancement in the technology of drones is one of the major contributors for its preponderate use. In the present age, Unmanned Aerial Vehicles (UAVs) are operated by humans and computers both. However, with the given pace of improvised technology, it is predicted that in the future, the drones will solely be controlled by computers [42]. With regards to the technology of drones it has been identified that there is a range of uses that could be taken from drones by individuals, governments, commercial entities and more. Some of these uses have been identified to be aerial filming and photography, express shipping, supplying essential for disaster management, developing safety inspections, thermal sensor drones for rescue

operations, geographic mapping of inaccessible locations, unmanned cargo transportation, border control surveillance, storm tracking and forecasting hurricanes [42]. While all of these uses have been taking place by various organizations today, hundreds of more uses are being developed through constant research and development. Considering the benefits associated with it, military has depicted a high inclination towards the usage of drones in the future. Many militaries all over the world have been investing in drone technologies to take use of it in the future and use it as a primary method to conduct the operations. The technology of drones is constantly evolving and future drone tech could be considered as a potential area of growth and usage. Drones have been there in the market for several years and different generations of drones have been launched and used:

- The generation 1 of drones was basic remote control aircraft of all forms.
- Generation 2 has static design, video recording and photos, fixed camera mount and manual piloting control.
- Generation 3 had static design, HD video, two-axis gimbals, safety models and assisted piloting
- Generation 4 had transformative designs, HD video, improved safety models, three-axis gimbals and autopilot modes
- Generation 5 has had transformative designs, 4K video, intelligent piloting modes and 360 degree gimbals
- Generation 6 had commercial suitability, safety standards based designs, payload and platform adaptability, full autonomy and intelligent pilot modes, airspace awareness and automated safety modes.
- Generation 7 has complete commercial suitability, fully regulatory and complaint safety standards based design, payload interchangeability, enhanced intelligent piloting models, automated safety modes, complete airspace awareness and auto-action.

As the drone technology leads to develop further and grow they will become more usable and safer. Once these changes are inculcated in the design, more companies and individuals will lead

to use the technology and become more dependable. Mass adoption of the usage of drones is expected as a continuous improvement approach in drone technologies is mitigating the adversities and making it more effective by all means. With regards to the adoption of drones and its usage, it must further be taken into consideration that certain legislations that are against the usage of drones for certain purposes might limit the people from utilizing the technology [29]. For drone usage taking place at a mass level it is necessary that all legislations accept the usage of drones and makes it more feasible for organizations to inculcate the technology for varied activities and tasks. Smart drones are being taken into consideration as the limitations of present in previous drone technologies are being resolved and a better approach for the implementation is being established considering the aspects of safety, security, costs and more. People are now watching drones being used as not limited to warzones but also for commercial, entertainment and surveillance purposes. Drones have now become widely popular form of technology that is being used at a more extensive level. If we talk about this aircraft in terms of its technologies involved, the most known technology in relation to the UAVs appears to be infrared cameras. Drones use infrared imaging to detect the spectrum of light that cannot be seen with a naked eye. Infrared cameras are used in drones to play a significant role in thermal imaging. Second most known technology has been identified to be Remote Ground Control System. As the name suggests, Unmanned Aerial Vehicle (UAV), it was anticipated that this system would be on the top 3 technologies that the people are most aware with. Since the main advantage of using drones is that no pilot needs to be on board and that the drones can be operated by an experienced team from the base quarters. GPS navigation is what helps the UAVs to fly independently to the pre-decided landing place. This guides the drones regarding the height to maintain while flying, where to fly to, and at what speed to keep going or alter as according to the configuration into its remote-control navigation software. The least known technologies seem to be laser guidance and imaging system development.

2.5 RELATED WORKS TO OPTIMIZATION ALGORITHMS

Ernst et al. [70]; addressed the problem of scheduling aircraft landings on one or more runways in a busy airport. This problem has been compared to the machine work planning problem in terms of earliness and delay penalties related to sequencing. Thus, for one or more runways, it is aimed to keep the aircraft at a certain separation distance and land in an optimum way. In his

work, a special Simplex Algorithm is presented that very quickly evaluates the optimum landing times of all aircraft based on some partial order information. This method was then used in a problematic field study in the intuitive as well as branch and boundary method for single and multi-track problems. The effectiveness of algorithms has been tested using some standard test problems in the literature.

Beasley et al. [71]; presented the formulations of the static airplane landing problem for both single and multiple runway situations of the problem of planning airplane landings at an airport. The problem has been solved using Linear Programming Based Tree Search. Formulations in the landing problem have been strengthened with additional restrictions. Computational results for an intuitive and optimal algorithm are presented for a series of test problems involving up to 50 planes and 4 tracks. The formulations in this study showed how they can be used to model a range of issues commonly encountered in practice.

Gotteland and Durand [72]; by using Genetic Algorithms, they aimed to minimize the taxi and departure times of the aircraft by considering the runway capacity at the airport. The study was applied to Roissy Charles De Gaulle airport. Simulations were made on a one-day traffic sample and the ground delay was associated with the traffic density at the airport and the efficiency of different methods was compared.

Wen [73]; developed and implemented a Branch Algorithm for the aircraft landing problem. The aircraft landing problem was determined by the side constraints of a limited number of existing runways and rearranged the problem. Tested using general data from the OR-Library, which includes up to 50 aircraft and 4 runways.

Wen et al. [74]; they tried to develop a precise parsing algorithm based on producing columns for the aircraft landing problem. The problem was reformulated as a partitioning problem determined by side constraints using the Dantzig-Wolfe decomposition after it was formulated as a mixed integer program. Then, a mixed integer formulation is created so that the sub problem produces columns with negatively reduced cost. The Branch and Boundary Algorithm has been developed to obtain the exact solution of the problem with the specified partitioning formulation. Computational results are presented for public test problems involving 50 aircraft and 4 runways.

García et al. [75]; presented a new method that automatically generates the best routes and schedules of airport ground operations in a decision support system for tower controllers. He explored the potential advantages of hybridizing two types of complementary algorithmic approaches with the Genetic Algorithm and a Time Domain Dynamic Flow Management Algorithm to find solutions with minimum lag. A fit program was analyzed to combine the strengths of the two algorithms and take advantage of their complementary properties. While optimizing a highly simplified problem with flow management algorithm in a deterministic way, Genetic Algorithm searched for a more realistic representation of the real problem.

Atkin et al. [76]; Using the Taboo Research Algorithm to solve the airport departure problem. They aimed to eliminate the obstructions that occurred during take-off at the airport by working on the solution.

Pinol and Beasley [77]; Using Scatter Search and Bionomic Algorithm, the multi-runway situation is discussed for the aircraft landing problem. Thus, effective use of the track is aimed. The results have shown that good quality feasible solutions can be produced quickly for public test problems involving up to 500 aircraft and 5 runways. It has dealt with effectively compared to results in previous algorithms presented in the literature regarding runway dependent problems.

Clausen [78]; dynamically solved the aircraft landing problem. He made changes in the algorithms of the static airplane landing problem to solve the dynamic problem.

Moser and Hendtlass [79]; chose Extremal Optimization for dynamic single runway landing problem. Extremal Optimization is a deterministic algorithm that optimizes the timelines of permutations found by the solver. To evaluate the results, their solutions are compared with known problems.

Yu et al. [80]; the linear objective function has handled the aircraft landing sequencing problem for a single runway. The aircraft landing sequencing problem consists of a deterministic algorithm that can effectively solve the Cellular Automaton and Genetic Algorithm in a very short time. A pre-program has been created by the Cellular Automat, where each aircraft updates its own rules with some rules as they approach their destination. The results were then obtained

using the Genetic Algorithm and a Relaxation Operator according to the landing sequence created by the Cellular Automaton.

Kupfer [81]; developed a programming and sequencing model that defines the boundaries of sequencing for very closely spaced parallel approaches. In his studies, it was aimed to minimize the arrival time of the last aircraft by placing the earliest and last arrival times of an aircraft in a sequence. Thus, he compared first come first served (FCFS) methods and advanced timing methods with Mixed Integer Linear Programming and Genetic Algorithms. Results obtained from 45 scenarios; production times, average delays and required calculation times are presented.

Balakrishnan and Chandran [82]; It provided a class of scalable dynamic programming algorithms for runway programming, taking into account the restricted displacement of aircraft and other system constraints. It has shown that the problems of increasing efficiency, reducing latency and ensuring fair times can be effectively modeled. In the study, the results of a prototype implementation fast enough to be used in real time are also given.

Bennell et al. [83]; It covered the techniques and tools of operational research and management science used to plan aircraft landings and take-offs. Dynamic programming, branching and limitation, heuristic and metaheuristic methods are studied as the main solution techniques.

3. METHODOLOGY

This chapter talks about the detailed procedure adopted to conduct this research. The Research Methodology is categorized into two major types: Survey procedures and Practical Methodology. These two are further divided into its subparts; Survey procedures comprises of Conceptual Research Framework, Data Collection Methods, Theoretical Approach to Data Analysis, Survey and Traditional Criteria to Evaluate Research while The Basic Tree-Seed Algorithm (TSA) and Proposed Path Planning Method come under the Practical Methodology.

3.1 SURVEY PROCEDURES

3.1.1 Conceptual Research Framework

The conceptual framework for this research can be summarized as in the list below:

- **Literature Review:** the study began with a thorough literature review. Various works (articles, books, websites and researches) were deeply studied in regards with the usage of drones. This helped in assembling important information related to the multiple uses of Unmanned Aerial Vehicles. The drones are used to combat terrorism, criminal activity, and insurgency and are even used for commercial purposes. In addition to that, the effectiveness of using UAVs in each area of its usage was also explored along with its potential impacts and consequences.
- **Understanding the process:** It is important to understand the processes involved with attaining observed and factual data. The research method used in this part of the study is survey i.e. Questionnaire consisting of more closed-ended items (combination of multiple choice questions, liker scaled questions and dichotomous scaled questions).
- **Recommendations:** The data obtained from the survey will assist the researches to further evaluate the details provided by the literature review along with the current data. This thorough and careful analysis will in turn help in proposing recommendations on appropriate usage of drones.

3.1.2 Data Collection Methods

To entirely and accurately learn about the potential impacts and the effectiveness of the use of drones, the research uses primary data collection method. This kind of data is directly obtained from the participants themselves. Primary research is conducted through the quantitative data collection means of a survey. Survey included the use of a questionnaire to evaluate the responses of the participants. Under mentioned figure briefly outlines the data collection method adopted for this part of study. Due to the global pandemic, it was difficult to conduct survey at a physical place. Instead,

The choice of online surveys was made. The suitable option for sampling technique for only survey was non-probability sampling as it would have been complicated to recruit participants by other means of probability sampling methods. This research used convenience sampling as a non-probability sampling method. For the construction of survey, a careful combination of closed-ended items was formulated.

3.1.3 Theoretical Approach to Data Analysis

Descriptive Statistics and Inferential Statistics are the most frequently used methods of analyzing data of a quantitative research.

- Descriptive Statistics are an important tool used by the researchers to describe the common aspects of the data [65]. It assists the researchers in summarizing the obtained data and determining recurrent patterns [66]. Such statistics also facilitate in categorizing large amounts of data systematically [65].
- Inferential Statistics: Inferential statistics are used by the researchers to draw out the findings of the study that go beyond the direct availability of the current data. In simpler words, such statistics are used for the purpose of making useful deductions from the data collected and making them relevant for a wider set of situations [65]. Such statistics also help in understanding the relationship between multiple variables to infer future predictions [66].

- a. Correlation
- b. Regression
- c. Analysis of Variance

For this study, descriptive statistics have been used to analyze the data collected through the online survey. The above-mentioned categories of descriptive analysis have been helpful in explicitly summarizing the responses of the participants. This, sequentially, was helpful in deducing important findings and relevant applications.

It is now established that the quantitative data can be presented using any of the two types of statistics: descriptive or inferential. However, specifically to surveys, the data can be analyzed in the following ‘forms’:

- a. Charting tools
- b. Trend Analysis
- c. Cross-tabulation
- d. Conjoint Analysis
- e. MaxDiff Analysis
- f. Turf Analysis
- g. Text Analysis

The study uses charting tools i.e. pie charts to represent the responses of the research and to subsequently draw generalized findings and conclusions from those responses.

3.1.4 Survey

3.1.4.1 Types of Surveys

Survey is a broadly used research method and is usually categorized into two wide categories: Questionnaires and Interviews. A survey can vary from a simple paper pencil task (questionnaire) to a rigorous, in person interview session [65].

Questionnaire vs. Interviews: Questionnaire caters to a larger sample of participants since it's less time-consuming and involves lower costs, whereas, interviews usually involve a

smaller sample size because of the extensive sessions conducted individually takes up a lot of time. Questionnaires are mostly used to obtain quantitative form of data while interviews provide qualitative data. Questionnaires are objective in nature and interviews include subjective responses. Questionnaires produce restricted set of responses, while interviews are famous for collection of in-depth data. However, both of them are considered equally important and effective tools of data collection.

The study uses questionnaire to record responses of the participants.

3.1.4.2 Types of Questionnaires

1. Exploratory Questionnaire: These types of questionnaires often come under the qualitative category of the questionnaires. Another name for exploratory questionnaire is unstructured questionnaire [67].
2. Formal Standardized Questionnaire: Formal Standardized Questionnaires fall under the quantitative category of the questionnaires. Since the data can be quantified, it can be further beneficial in the statistical analysis of the research. This type of questionnaire is often times referred to as structured questionnaires [67].

Structured questionnaire was chosen to be adopted as a part of the research method.

3.1.4.3 Types of Questions in a Questionnaire

1. Closed-ended questions: These types of questions offer a limited set of response choices, which is why, the responses, are easier to analyze and less complex.
 - a. Dichotomous questions- As the name suggests, such questions provide the participants with only two response choices. For example, True or False, Yes or No, Likely or Unlikely, Agree or Disagree etc.
 - b. Multiple choice questions- These questions offer multiple but limited set of answers. For example, the question asks the participant to choose one of the five schools he thinks is the most prestigious out of the five.
 - c. Scaled questions- Such questions are used to evaluate the degree of a feeling [67].
 - Likert scale- This scale includes minimum of five and a maximum of seven points on a scale. It is most commonly used to record degree of agreeableness. For

example, 1 represents strongly agree and 5 represents strongly disagree, in between the numbers 2, 3, 4 represent agree, neutral, and disagree respectively.

- Rating scale- This is a very straight forward kind which offers a range of 1-5 or 1-10. For instance, the question asks the participants to rate the effectiveness of a particular object, 1 being the lowest and 10 being the highest.
- Semantic differential scale- This is a seven-pointer scale for deducing the implied meanings of the topic in case.
- Open-ended questions: These questions present the participants with the freedom to answer as they like. The participants can write as long or as little as they want. These questions are commonly used when there is a need to understand a phenomenon in detail or where participants' responses need to be analyzed from a broader perspective.
- Pictorial questions: In pictorial questions, participants are provided with pictures as the answer choices instead of the traditional use of text [67].

The questionnaire used in the study was a combination of closed-ended questions: dichotomous scale, liker scale, rating scale and multiple choice questions. There was no utilization of pictorial questions.

3.1.4.4 Conduction of Survey

A questionnaire focusing on the effectiveness, impact and influence of the usage of drones was formulated specifically for this part of study. The questionnaire also consisted of an Informed Consent form and a Demographic form respectively. Informed consent ensured the participants that there would be no invasion of privacy by the third party, the responses recorded will be confidential, participants had a complete right to withdrawal and that there would be no physical and mental harm. Next, in the demographic form, information regarding name (this was considered to be optional), age group, gender, first language, education and email address was inquired.

The questionnaire was posted online, to get maximum responses and the links were sent to the potential participants. The questionnaire consisted of 11 questions; 2 rating scaled

questions, 3 multiple choice questions, 3 dichotomous scaled questions and 3 likert scaled questions. Our sample consisted of 100 participants (60% males and 40% females). The sampling technique used to conduct the survey is termed as convenience sampling, which is a type of non-probability sampling.

Since the questionnaire posted was online, multiple responses of the questionnaire couldn't be restricted to a single individual. However, a prominent advantage of conducting surveys through convenience sampling was that the participants filled out the questionnaires per their choice. The lack of 'obligation' eliminates participants' biases and possible faking of responses. Since the information was collected through digital means, the data was automatically processed in a representative form. This also proved to be cost-effective because there was no postage of survey conductors, neither the participants required to be accommodated for the transportation purposes. This method was less time consuming as there was no paper pencil task involved that required additional time of collecting questionnaire in paper forms, assembling and manual recording of the participants' responses.

3.1.5 Traditional Criteria to Evaluate Research

The criteria based on reliability, validity and generalizability is frequently used by quantitative researchers. This criterion is often referred to as the traditional criteria to evaluate research [68].

1. Reliability –Reliability of the study refers to how consistently the research measures its factors. There are two types of reliability: Internal reliability and External reliability. Internal reliability refers to the standardization of the method, whereas, external reliability is concerned with the consistency of the responses when the test is repeated.
2. Validity- Validity of the research has to do with appropriateness of the tools, whether the questionnaire is measuring what it is supposed to measure. There are five different kinds of validity: Face/Content validity, Concurrent validity, Construct validity, Predictive validity and Ecological validity. Face validity assesses whether the content of the questionnaire looks like it is measuring the right objectives. Concurrent validity is established when the questionnaire is compared with an already established

questionnaire on a similar topic. Construct validity refers to whether the findings of the research can be confirmed by its applications. Predictive validity is established when the findings of the research can successfully predict future performance. Lastly, ecological validity refers to whether the questionnaire represents the naturally occurring behavior or not.

3. Generalizability- This term refers to the extent to which the findings of the research from a selected sample can be applied to a wider population. Generalizability of the research depends upon the appropriate sampling technique and diversification of the sample size.

The survey has a content validity as the questionnaire based on four variables does look like it is measuring what it is supposed to measure. Also, large sample sizes of 100 participants also meet the criteria of generalizability to a great extent.

3.2 THE BASIC TREE-SEED ALGORITHM (TSA)

The TSA was proposed by Kiran in 2015 based on the basic idea of the relationship between trees and seeds to solve continuous optimization problems. At TSA, trees and seeds represent possible solutions to optimization problems. Initially, the trees are randomly generated in the search area. The number of trees in the TSA is called "planting size", it is investigated in and it is recommended between 10% (minimum number of seeds) and 25% (maximum number of seeds). The seeds are generated by equations. (3.3) or (3.4) for each tree in each iteration.

$$S(k) = T(i) + \alpha (B - T(r)) \quad (3.3)$$

$$S(k) = T(i) + \alpha (T(i) - T(r)) \quad (3.4)$$

Where $T(i)$ is i th tree, $S(k)$ is k th seed of $T(i)$, α is a consistently dispersed chance amount in the assortment of $[-1, 1]$, B is the finest tree gotten so far, $T(r)$ is a chance tree which is dissimilar from the $T(i)$. The most important kind is what equation is defined to create a new starting location. This selection (either equation (1) or equation (2)) is controlled by a method control parameter called search trend (ST) in the range $[0, 1]$. Higher ST values provide reliable local searches and faster convergence. A lower ST value results in slow convergence but strong global search. In other words, the TSA detection and usage functions are controlled by the ST parameter. In short, TSA detection and usage functions are controlled by the ST parameter. At

the beginning of the search with TSA, the initial tree positions are created using the equation that represents possible solutions to the optimization problem. (3.5).

$$T_{i,j} = L_{j,min} + r_{i,j}(H_{j,max} - L_{j,min}) \quad (3.5)$$

where $L_{j,min}$ is the lower bound of the search space, $H_{j,max}$ is the higher bound of the search space and $r_{i,j}$ is a random number produced for each dimension and location, in range of [0, 1]. For minimization, the best solution is selected from the population using Eq. (3.6).

$$B = \min\{f(\vec{T}_i)\} \quad i = 1, 2, \dots, N \quad (3.6)$$

Where N is the number of trees in the population. When creating new seed locations for a tree, the number of seeds can be greater than one, and this number depends on the size of the population. When analysing the effect of the control parameters on the efficiency of CST, 10% of the population size is the minimum number of seeds produced for the tree and 25% of the population size is the maximum number of seeds produced. Made of wood. The number of semen production in TSA is completely random.

3.3 PROPOSED PATH PLANING APPROACH BASED TREE SEED OPTIMIZATION AND GENETIC ALGORITHMS

The proposed approach is called Hybrid Tree Seed Optimization and Genetic Algorithm (TSAGA). The TSAGA is based on three mechanisms. The first mechanism is applying the TSA optimization to balance between the exploration and the exploitation process in the proposed algorithm. The second mechanism is the dimensionality reduction process and the population partitioning process by dividing the population into sub-populations and applying the arithmetical crossover operator in each sub-population in order to increase the diversity of the search in the algorithm. The last mechanism is applied in order to avoid the premature convergence and avoid trapping in local minima by using the genetic mutation operator in the whole population. Then, the algorithm become ready to applied to solve the problem which is represented in optimization problem format as shown in Equation (3.7)

$$\min \sum_{i=1}^n \sum_{j=1}^n C_{ij} x_{ij} \quad (3.7)$$

Then, the TSAGA applied to minimize the equation 3.7, our problem can presented more than one true solution but the amount and cost of these solutions differ and we need to obtain the least cost.

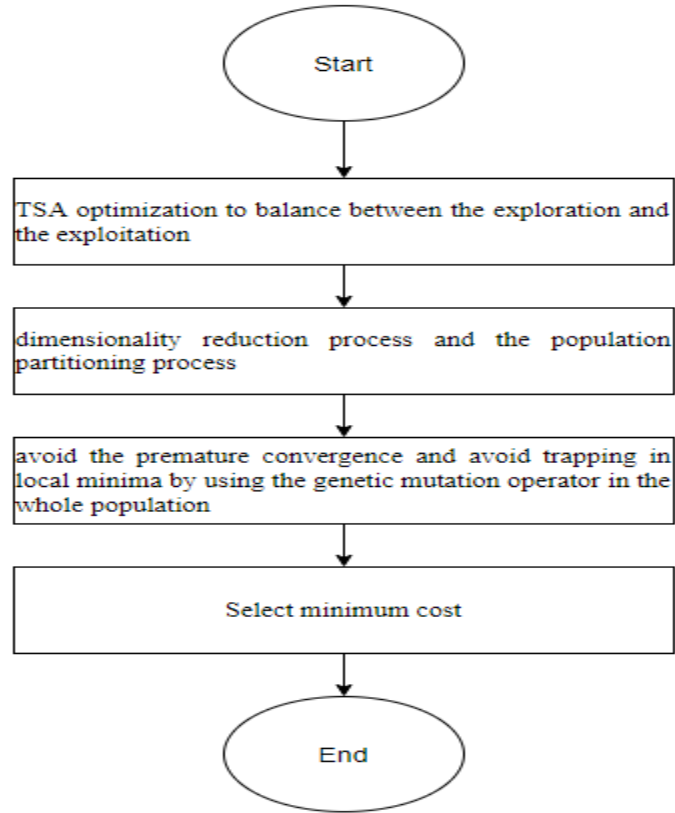


Figure 3.1: Proposed path planing protocol

4. EXPERIMENTS AND DISSCUSION

In this part of the study, the data collected from the respondents through the online survey has been assembled under the four variables: Awareness of drones and the technology, Perceived Effectiveness, Support for the drone usage and Impact of drone strikes. This categorization of data has been done to individual layover important aspects of the use of drones in combating terrorism and criminal activity. It goes further to identify support level of the people and also recognizes potential impacts of a UAV strike. The responses have been represented with the use of one of the most common charting tools i.e. pie charts.

4.1 AWARENESS OF DRONES AND THE TECHNOLOGY

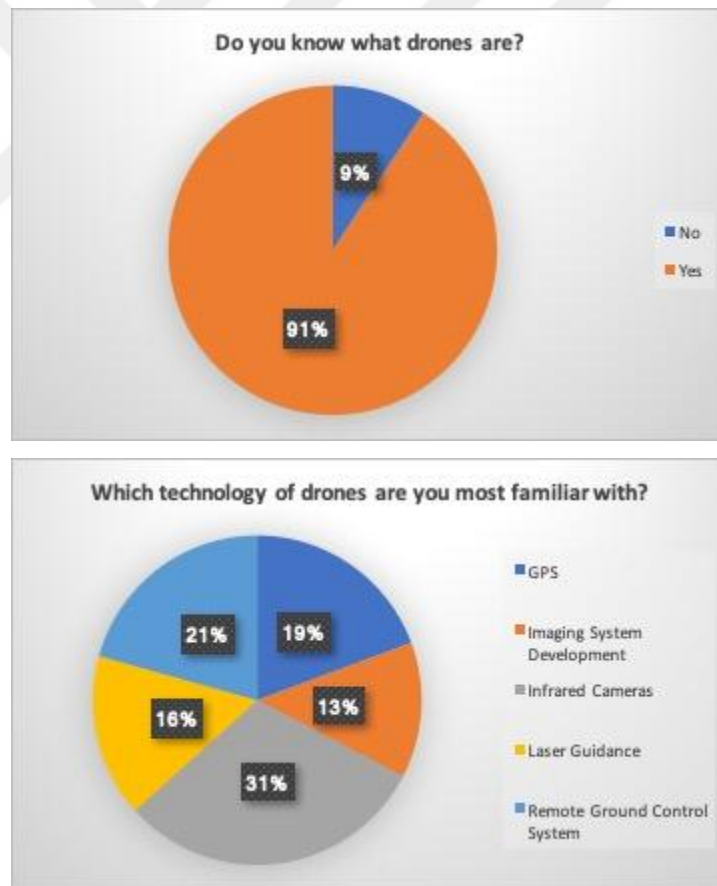


Figure 4.1: Technology of drones

Gathering information regarding the technology of drones it has been identified that the respondents had ample knowledge regarding GPS, Imaging system development, infrared cameras, laser guidance and remote ground control system. Drones have been used for various purposes and the technologies of it have been utilized by various institutes to carry out different objectives. Considering terrorism and criminal activities these technologies and its uses could be taken into usage and meet the operational activities.

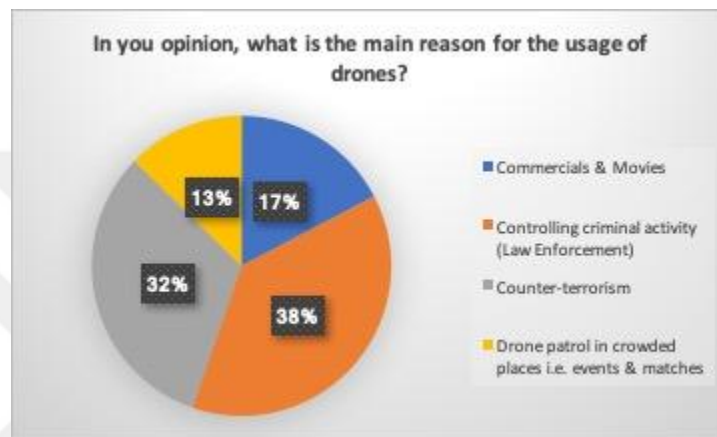


Figure 4.2: Reason for the usage of drones

With regards to the reason of using drones it has been identified that majority of the individuals consider controlling criminal activities as the main purpose. It has been depicted by most of the respondents that with the use of drones it becomes easier to control the criminal activities and so the purpose of law enforcement is adequately rendered with its use. Further, 32% of the individuals stated that drones could be well used in terms of counter-terrorism. In situations where terrorism activities take place, drones could be used to fight terrorist activities in terms of locating terrorists, taking pictures, providing guidance, showing paths and much more. The other reason for usage of drone has been identified to be commercials and movies. Other than combating terrorism and criminal activities drones could be used for involving in activities related to commercial and movies. Lastly, patrol in crowded places has been identified to be another use of drones which takes place at events and crowded places for several purposes.

4.2 PERCEIVED EFFECTIVENESS

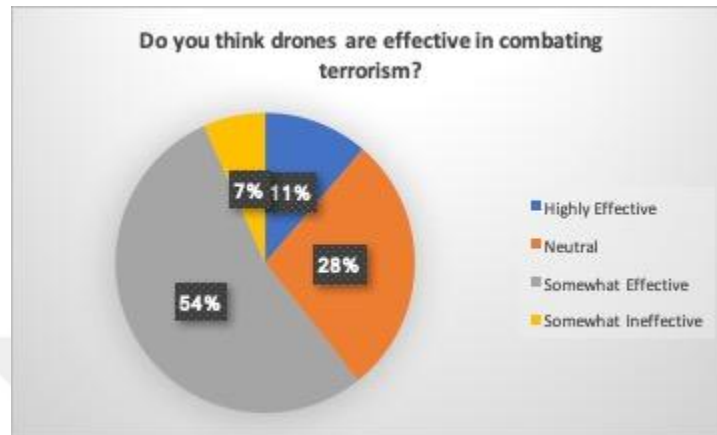


Figure 4.3: Efficacy of Drones

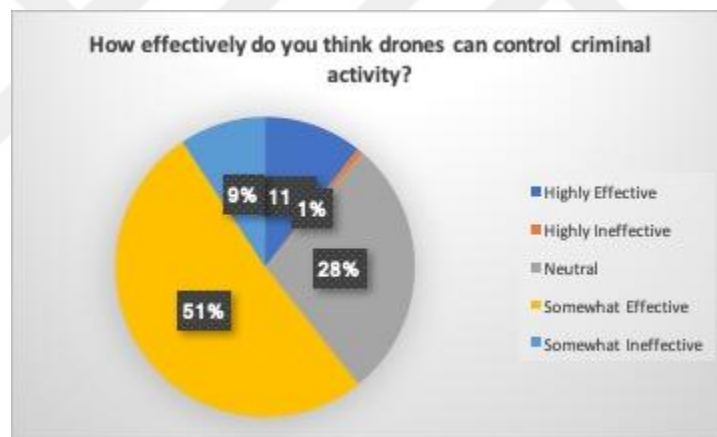


Figure 4.4: Ability of drones to control criminal activities

Considering how effective drones have been in controlling terrorism and criminal activities it has been understood that most of the respondents have agreed to the fact that drones are effective in combating terrorism. Further, with regards to the effectiveness of drones in controlling criminal activities the majority responses have been between 'somehow effective' and 'neutral'. The inclination of individuals regarding this have depicted that drones are considered to be an effective way of controlling criminal activities as well. In other words, it could be deduced that as usage of drones is considered to be an effective means of combating terrorism it may equally be effective in controlling criminal activities as well.

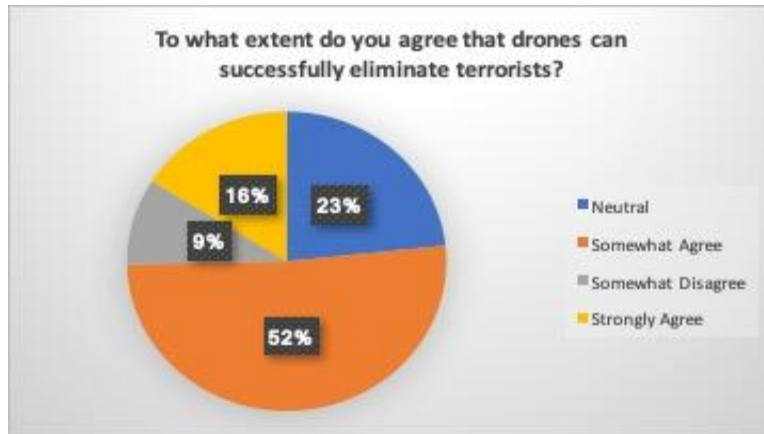


Figure 4.5: Drones eliminate terrorists

The fact that most of the respondents have agreed the usage of drones to be effective in terms of combating terrorism it has been identified that its utilization may also assist in eliminating terrorism. Through the use of drones the terrorist activities could be combated and this eventually could lead to lowering and finishing off terrorism in a society.

4.3 SUPPORT FOR THE DRONE USAGE

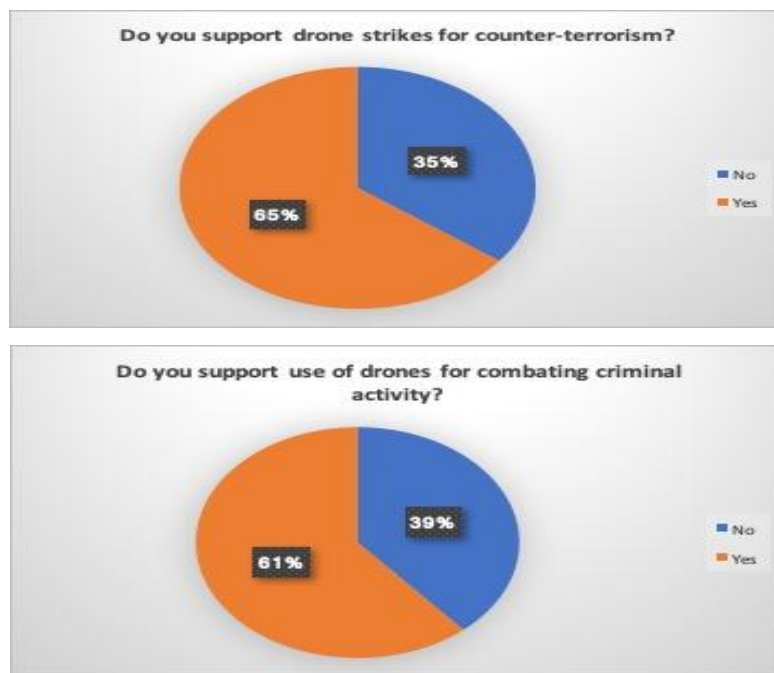


Figure 4.6: Opinion to support Drones for counter terrorism

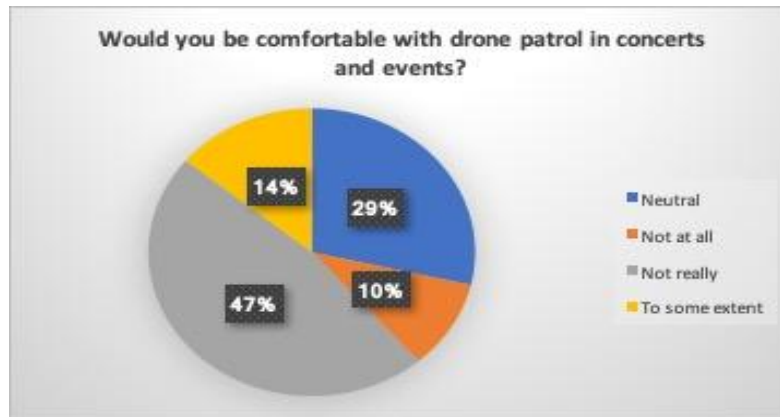


Figure 4.7: Use of Drone patrol in concerts and events

Investigating about the usage of drone for combating criminal activities it has been identified that most of the individuals have agreed to the usage of drones for using drone strikes for counter-terrorism. In order to combat criminal activities, the participants have further stated that they support the usage of drones for combating criminal activities. Furthermore, while inquiring about the usage of drones it has been explored that people have not depicted to be comfortable with drone patrol in events and concerts. One of the reasons related to this has been the issue of safety and disturbance to a certain extent. Having said this, individuals do not feel prefer drones being used for the purpose of filming or surveillance in such occasions.

4.4 IMPACT OF DRONE STRIKES

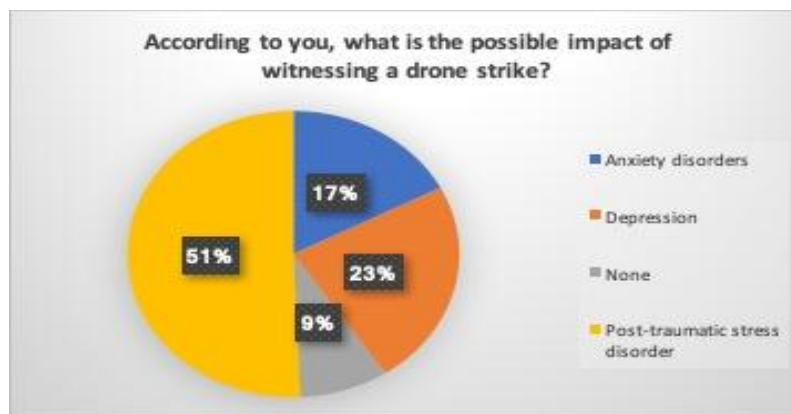


Figure 4.8: Impact of drone strike

4.5 PATH PLANING APPROACH BASED TREE SEED OPTIMIZATION AND GENETIC ALGORITHMS

In this section three scenario applied to validate and test the presented approach and compare the results with several technique. In the first experiment, the drone used to visit thirty location and the presented our method TSAGA used as path planning and we obtained 46.5641 kilometer which is lower from other techniques. The results visualized in Figure 4.9.

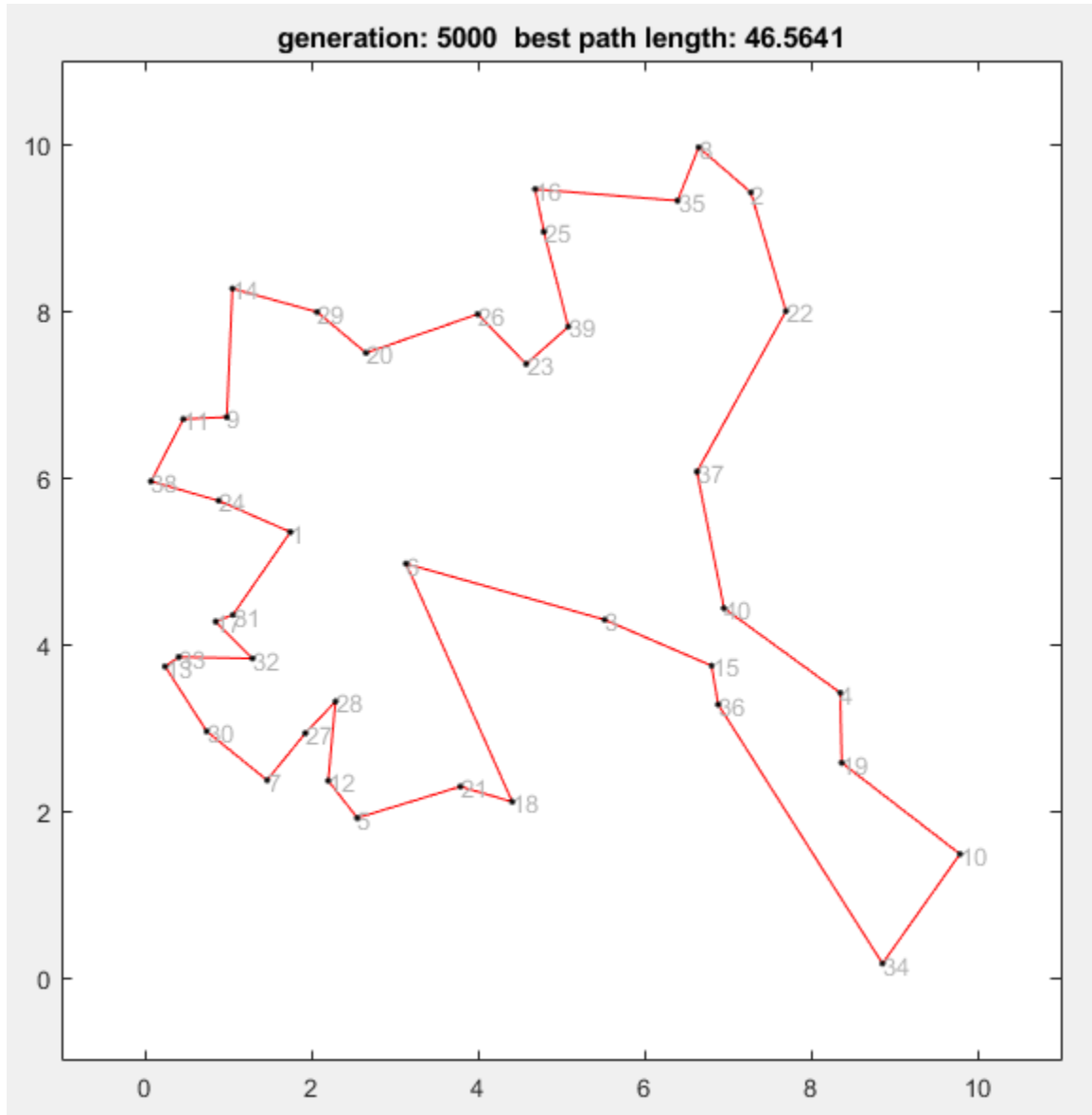


Figure 4.9: Simulation of 30 location visiting

Furthermore, the proposed path planning approach validated using 40 location which 52.4143 kilometer obtained as minimum path.

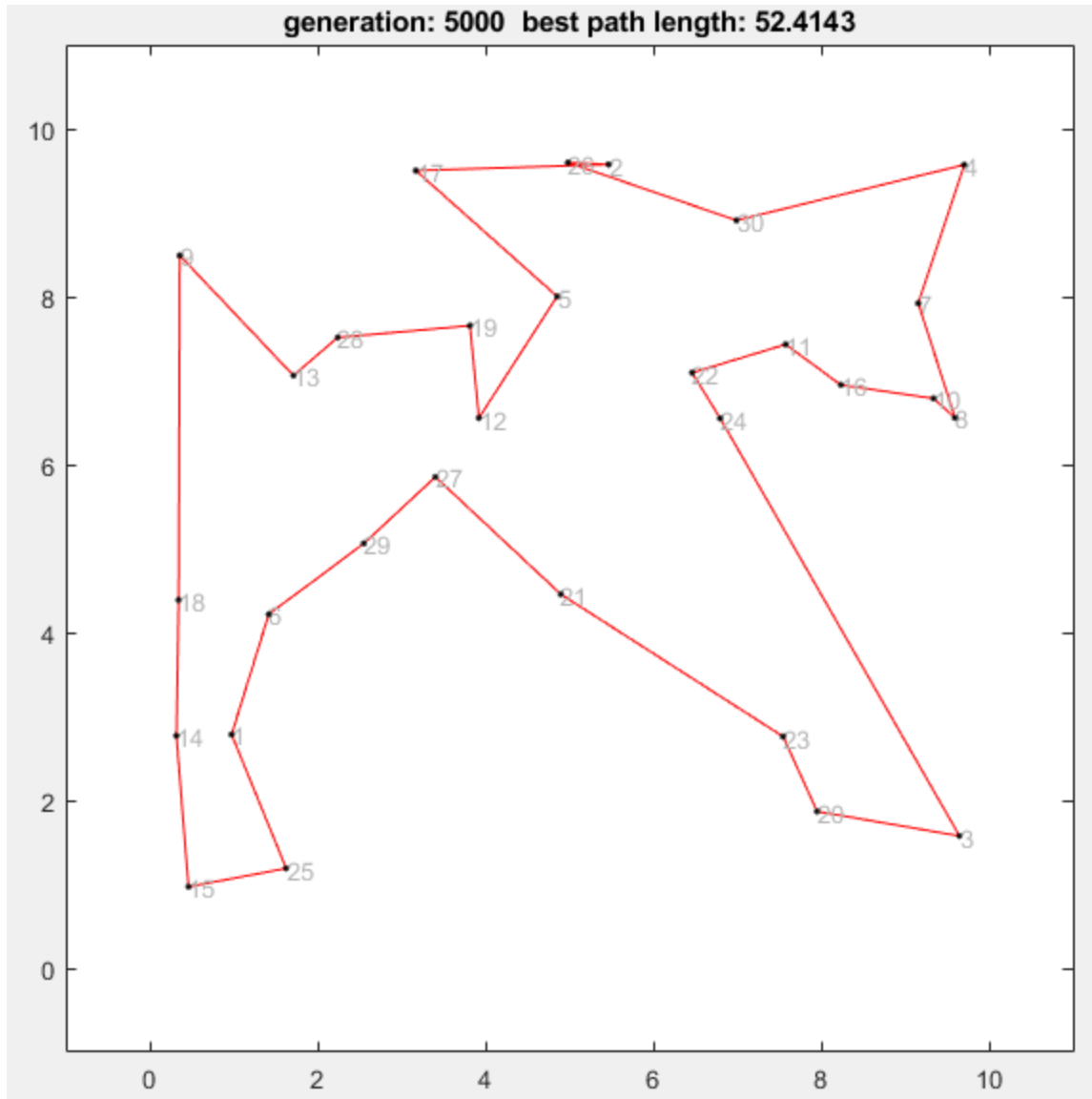


Figure 4.10: Simulation of 40 location visiting

Moreover, the proposed approach presented 66.1555 kilometer which is optimal cost when compared with GA we can see that the presented approach presented best results see Figure 4.11.

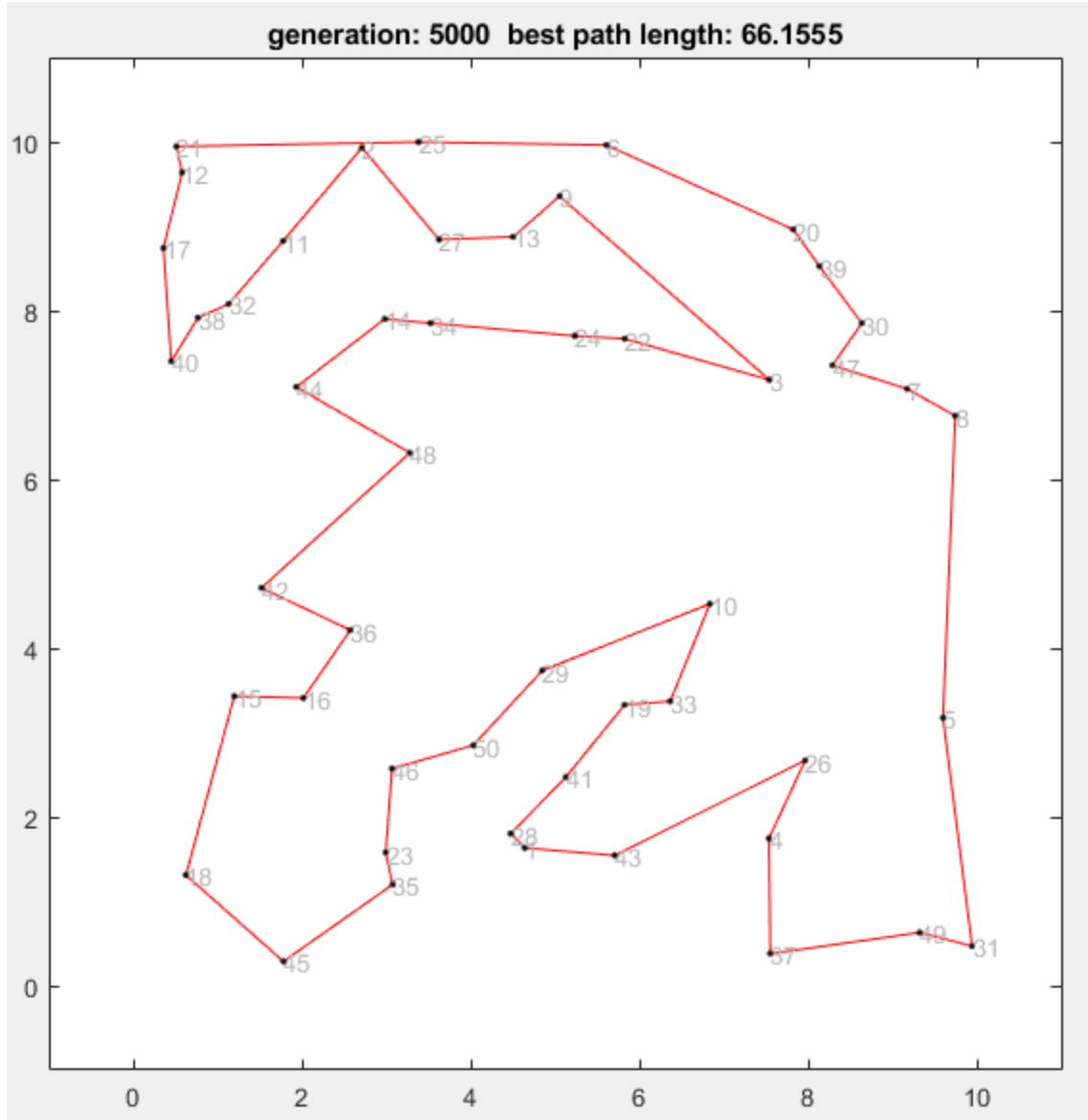


Figure 4.11: Simulation of 50 location visiting

The presented approach compared with GA and show that our approach obtained best results in both the cost and execution time. On the other hand, the execution time of both techniques are compared and presented in the Figure 4.12.

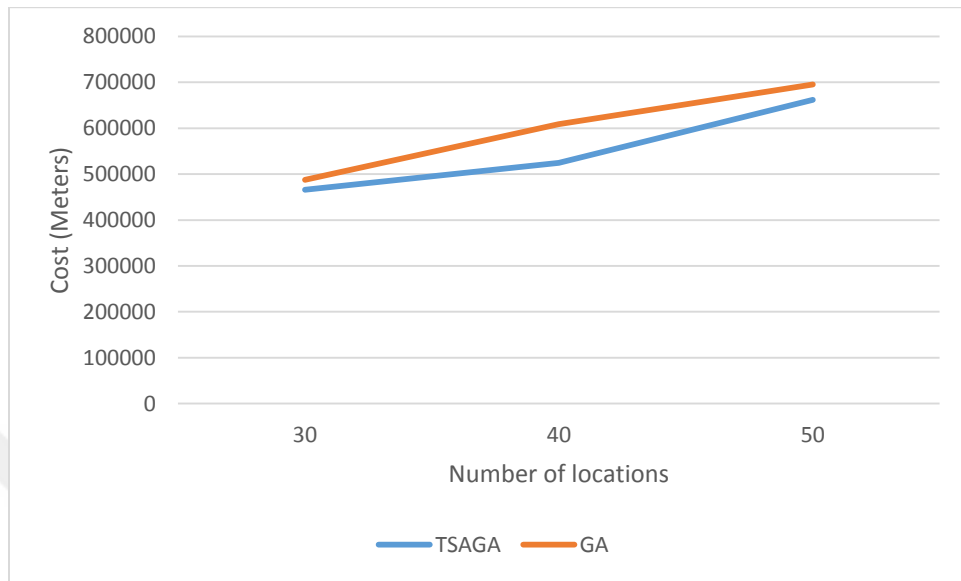


Figure 4.12: Cost Comparisons

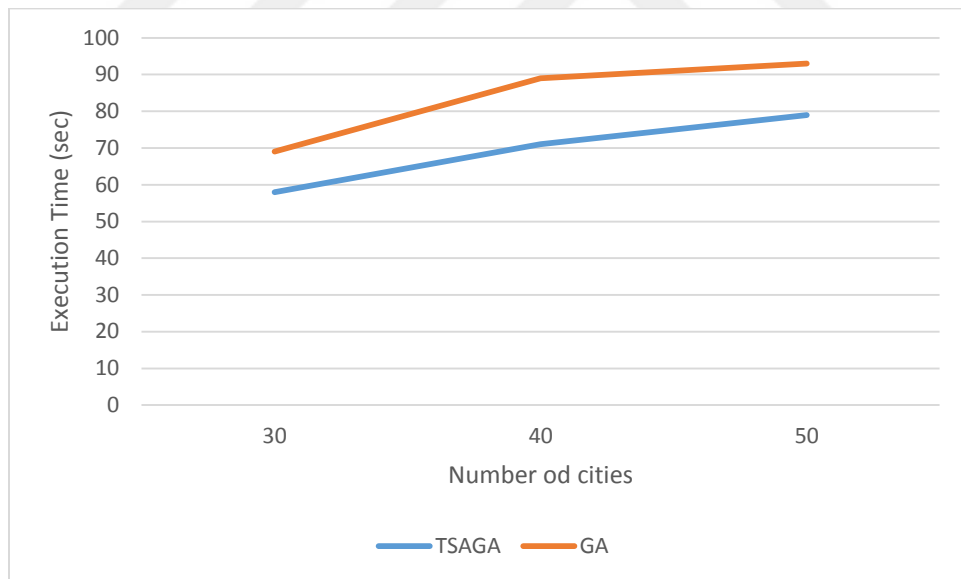


Figure 4.13: Execution time Comparisons

5. CONCLUSION

Information technology of drones is one of the important aspects that the study aims to cover. Imaging system development, infrared cameras, GPS, laser guidance and remote ground control system are the major technological components of UAVs. The wide-spread use of technology has made it essential that the effectiveness of drones be measured and whether the extension of drones to private users is in fact beneficial or not. Drones are mostly known to be used in warzones, however, with each passing day the improvised technology is paving the way for a more global use. The TSAGA validated in several scenarios and presented remarkable results when compared with classical GA in both execution time and cost of the path. Genetic Algorithm programs contain a several of parameters counting the likelihoods of crossover and mutation, the population size and the number of generations. A factorial experiment has been performed to identify appropriate values for these factors that produce the best results within a given execution time. So, the genetic algorithm parameters play important issues in the problems that GA applied to solve them.

In future work, we advise to enhance the GA performance by combining with several new proposed optimization algorithms. Moreover, the drone path can be solved by using several optimization algorithm techniques.

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APPENDIX

SURVEY

Below are some general questions regarding the usage of drones. Consider each question carefully before answering. Remember that there is no wrong or right answer.

Do you know what drones are? *

- ☐ Yes
- ☐ No

Do you think drones are effective in combating terrorism? *

Highly Effective

- 1
- 2
- 3
- 4
- 5

Highly Ineffective

How effectively do you think drones can control criminal activity? *

Highly Effective

- 1
- 2
- 3
- 4
- 5

Highly Ineffective

Which technology of drones are you most familiar with? *

- ☐ Imaging System Development
- ☐ Laser Guidance
- ☐ Infrared Cameras
- ☐ GPS
- ☐ Remote Ground Control System

In your opinion, what is the main reason for the usage of drones? *

- ☐ Counter-terrorism
- ☐ Controlling criminal activity (Law Enforcement)
- ☐ Drone patrol in crowded places i.e. events & matches
- ☐ Commercials & Movies

To what extent do you agree that drones can successfully eliminate terrorists? *

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly agree

Do you support drone strikes for counter-terrorism? *

- ☐ Yes
- ☐ No

Do you support use of drones for combating criminal activity? *

- ☐ Yes
- ☐ No

Would you be comfortable with drone patrol in concerts and events? *

- ☐ To great extent
- ☐ To some extent
- ☐ Neutral
- ☐ Not really
- ☐ Not at all

According to you, what is the possible impact of witnessing a drone strike? *

- ☐ Anxiety disorders
- ☐ Depression
- ☐ Post-traumatic stress disorder
- ☐ None

To what extent is civilian fatality as a result of drone strikes justified? *

- ☐ To great extent
- ☐ To some extent
- ☐ Neutral
- ☐ Not really
- ☐ Not at all