

University of Cincinnati

Date: 3/28/2018

I, Abdou Lahat Fall, hereby submit this original work as part of the requirements for the degree of Master of Science in Information Technology.

It is entitled:

Assistive Drone Technology: Using Drones to Enhance Building Access for the Physically Disabled

Student's name: **Abdou Lahat Fall**

This work and its defense approved by:

Committee chair: Jess Kropczynski, Ph.D.

Committee member: James Scott



30406

Assistive Drone Technology: Using Drones to Enhance Building Access for the Physically Disabled

A thesis submitted to the
Graduate School
of the University of Cincinnati
in partial fulfillment of the
requirements for the degree of

Master of Science

in the School of Information Technology
of the College of Education, Criminal Justice, and Human Services

by

Abdou Fall

Bachelor of Science in Information Technology
University of Cincinnati

Committee Chair: Jessica Kropczynski, Ph.D.

Abstract

This thesis explores improvements to assistive capability so that those living with a physical disability can also maneuver their environment, especially buildings, with ease. To do so, this study outlines a step-by-step process to understand better how buildings can be mapped using drone technologies as a method for members of society with physical challenges, especially mobility, to determine ease of accessibility before entering a building. By way of interview, observation, and survey, this thesis embarks upon requirement analysis for the use of drones as assistive technology. The study employs mixed methods to gather as well as analyze data to articulate requirements for use by universities and institutions. By doing so, the contribution of this work is to inform universities and institutions about technical and policy related requirements for using drone videos in a way that will be of most use to those in need of the building layout information.

Today, technology improves at a rapid rate, and often there are limitations to the building access by the physically disabled. In some cases, it is due to a lack of proper infrastructure that can accommodate movement by the physically challenged or exposure to the technology tools necessary to improve their mobility. However, in most cases, physical incapability can be mitigated by enhancing the accessibility. This thesis addresses the issue of exclusion of the disabled, which is a human rights issue as well as a safety issue within buildings. There is, therefore, need to understand the technology advances or lack of it that enables or inhibits the physically disabled to utilize the opportunities in the physical environment at a given time. The physically challenged need to know in advance and in the shortest time possible if their mobility in a building is possible. For this, a specific innovation is suggested—sending a drone specially

designed to maneuver inside of a building. This is because the remote control is better regarding navigation than *telepresence* robots, which have been used in previous work and ultimately have the same mobility problems as the physically disabled. This study concludes that the drone technology will fit the premise of assistive technology in buildings for the people living with a physical disability. It only requires flexibility and improvement regarding regulations, innovation, design, and functionality of the drone use and technology. This research has therefore defined the niche for using the drone as assistive technology. The presented modifications and recommendations that will work and have worked elsewhere, and hope to bring out the ease of accessibility that will give the physically disabled students who find navigating a big building especially in their first attempt hard, dangerous or time-consuming. It enables independence among the target group.

Key Words

Assistive Technology; Drones; Physically Challenged; Requirements Analysis; Uninhabited Aerial Vehicle (UAV); telepresence robots; Federal Aviation Authority (FAA); Regulations; Using drones as assistive technology to navigate university buildings (applies within the scope of this thesis only).

Copyright Notice

© Copyright by Abdou Fall 2018

All Rights Reserved

Acknowledgment

First and foremost, I would like to sincerely thank the almighty God for the gift of life, wisdom, and strength to handle all the challenges through the life of this thesis. Without him and his undoubted guidance, I would not have reached this milestone today.

Secondly, my sincere gratitude also goes to my family and friends for their moral support in my journey towards this degree and especially during the time of this thesis research.

Thirdly, I wish to pass my heartfelt appreciation to my advisor Dr. Jessica Kropczynski for sparing her valuable time whenever I was in need of support and ensuring that I stay the course of this thesis. Her insightful guidance, patience, substantial knowledge, and motivation were pivotal to my research and information gathering for this task. I couldn't ask for a better advisor for my studies and by extension, this thesis.

I would never forget the rest of my thesis committee: A special thanks to Professor James Scott for his continuous support to my Postgraduate study, his powerful ways to always boost my confidence, his intuitive feedbacks, his words of encouragement, as well as his practical tips that could last me a lifetime.

This acknowledgment will be incomplete if I don't shout out a big thank you to Rebekah Michael who was the School of IT Graduate program coordinator when I started this journey. She was there for me every step of the way when I had a torn decision to make between two graduate programs. The pieces of advice she gave me and the actions she took contributed tremendously to this current achievement.

Last one but not least, an appreciation to The School of IT: I want to express my sincere gratitude to Dr. Chengcheng Li and Dr. Hazem Said for the great opportunity with the full scholarship award. Also, I was honored to receive both The Nabila Hassan Honorary and The Education Alumnaal scholarship awards, which all played a huge impact financially throughout this journey. Thanks to all the donors.

Thank you all.

Table of Contents

Assistive Drone Technology: Using Drones to Enhance Building Access for the Physically Disabled	1
Abstract	2
Key Words	3
Acknowledgment	5
Table of Contents	7
List of Tables	8
Table of Figures	8
Introduction and Methodology	10
Introduction	10
Literature Review	11
Review and Background Information	11
Scope of the project	19
Purpose and Importance of the study	19
Statement of Research Problem	21
Research Questions	21
Methods	22
Phases of the Research	23
<i>Phase One</i>	23
<i>Phase Two</i>	23
<i>Phase Three</i>	23
Tools, Decision, and Action Process	24
Results	24
Results of Phase One: Interaction with the Environment and People	24
Results of Phase Two: Methods, Tools, and Activities	29
Results of Phase Three: Methods, Tools, and Activities	30
Stakeholder Analysis	35
Results and Analysis	36
Discussion	39
Recommendations	43

Conclusion and Future Work.....	48
Conclusion	48
Future Work.....	50
References	52

List of Tables

Table One: Observable Indications for the need for Drone use as Assistive technology	28
Table Two: Results of Interview and personal observations	29
Table Three: Summary of Results from the Literature and Questionnaires	31
Table Four: Categories of regulations for UAV (Meola, 2017)	31
Table Five: Recommendations that this Thesis Focuses on to Apply Drones as an Assistive Device	46

Table of Figures

Figure One: A Typical Drone (Passifume, 2017).....	11
Figure Two: The growth of Investment in drone hardware by different economic players (Joshi, 2017).	12
Figure Three: Drone in use to inspect a building and environment (Industrial Skyworks, 2017)	17
Figure Four: Map showing the distribution of all registered drone users in America (Atherton, 2016).....	26
Figure Five: Unmanned Aerial System over a Cincinnati horizon (Enterprise Risk Management, UC, 2018)..	34
Figure Six: Recommendations for the Use of Drone as Assistive Technology.....	39
Figure Seven: A drone fitted with Stereo Fisheye lens navigates inside of a building during tests, Courtesy of the University of Tokyo and Blue Innovation (Gilhooly, 2018)	46

Introduction and Methodology

Introduction

Drone technology is an emerging area of interest in the field of IT. According to Russon (2017), the concept of officer drones where drones hover around crime scenes to gather evidence is already in use in the US to improve the speed of remote investigations and to solve crime through rapid response. In other fields, such as architecture, the drone is used to assess the overall design of a building during construction and final touches on buildings. However, modification of drones as assistive technology for the physically disabled has not been implemented in many areas. The use of drones for those who cannot move around quickly to determine in advance of entering a building, if it is accessible is a novel concept. But technical and policy related requirements need to be determined before it can be recognized and adopted institutions meet inclusivity needs.

Drone systems need to be modified to understand their environment and to perform this specific navigation. The drone, therefore, must be able to deliver information to a person that will help them tell the difference between an open door, a steep stairwell, or one that can enhance navigation for individuals moving around by wheelchairs or to perform these tasks autonomously. Today, using infra-red sensors, laser, and optical sensors, the drone can scan its environment from varied angles to mimic how the human eye creates perceptions of vision (Passifume, 2017). In this case, an Uninhabited Aerial Vehicle (UAV) can navigate on its own to complete any task that they are set to perform. It is with modifications that the use of drones will suit the needs of physically disabled individuals to navigate and determine accessibility. For the ease of modification of the drone technology regarding functionality and regulations that control the use of drones in public places, this paper recommends drone technology as an assistive tool for the physically challenged. Since modern technology, especially intelligent systems, are characteristic

of increasing autonomy, this research presents a distributed and modified navigation system for unmanned aerial vehicles which might include quadrotors in GPS-denied environments such as inside of school buildings. The figure below is a typical image of a drone.



Figure One: A Typical Drone (Passifume, 2017)

Literature Review

Review and Background Information

According to Newcome (2004), unmanned aviation originated almost in the same era that manned aviation was featured. Drone technology has existed for over a decade but roots itself to its testing in the events of the World War I with most scholars recording some success in the World War II (Atkins, Ollero, & Tsourdos, 2017). The primary uses of drones have been aerial photojournalism. Shipping deliveries, building safety inspection, precision monitoring of crops, cargo transport, thermal sensor drones applicable for search as well as rescue operations, gathering

information for disaster management, law enforcement and border surveillance, storm tracking, and hurricane and tornado forecasting (Joshi, 2017). The estimated investment in drone hardware in government, consumer, and enterprise players has been on the rise from 2015 according to the figure below.

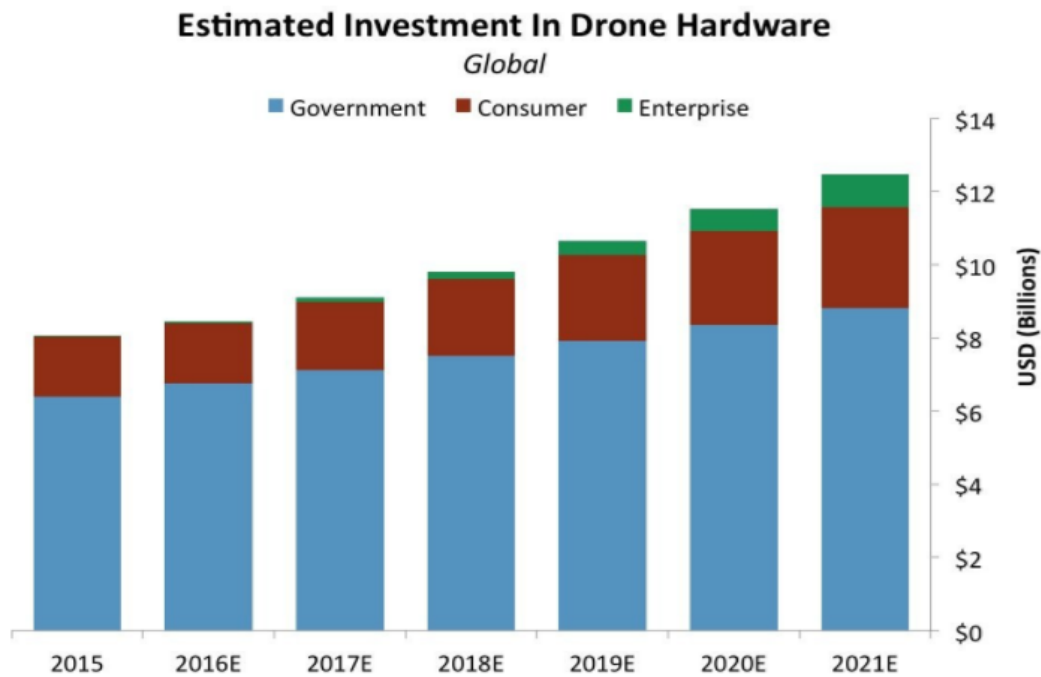


Figure Two: The growth of Investment in drone hardware by different economic players (Joshi, 2017).

Though Google has a technology to map the inside of buildings, they have limited mapping as this does not exist in all buildings yet as it only exists for essential buildings such as airports (Amal, 2015). Lack of daily updates on construction limits the effectiveness of Google mapping on structures. Drone technology advancement as in the proposition of this research will address the issue of inside building mapping. It will enable people with physical disabilities to save the time that would otherwise be wasted if they send someone to look around on their behalf or send a *telepresence* robot, which also has the same problem of mobility.

The technology scope is evolving rapidly, and systems are now automated, this maintains that mobility of the physically disabled requires sophistication and improvement to the existing tools to aid movement or in this case to ease navigation and accessibility. Automation of systems in buildings means that everyone in the future needs to at least be in a position to easily move around to save time. Video conferencing does a lot to stop the movement time being wasted, but by improving the drone technology to help the physically disabled survey the inside of buildings for accessibility, not only saves time but is set to be a milestone in designing assistive technology for the incapable.

Escalators and lifts are existing technologies that work to reduce mobility time wastage for the general population. However, assistive drone tools can ensure those living with a physical disability also save time by knowing in advance if their mobility will be limited. Ease of maneuverability and time saving is the basis of assistive drone technology. Cook & Hessey (2008) in their book “*Cook & Hussey's Assistive Technologies*” presents that in case an individual inability is visual, it is clear that the assistive technology should accommodate needs in this area such as auditory or tactile sense. It goes without saying that the physically disabled requires an assistive technology in buildings that address their mobility problems. Many sectors of the economy already experience the practical use of drones. According to MIT Technology Review (2015) a drone which has a directional sense that incorporates small drones that can navigate buildings on their maps of an interior space already in use to inspect oil rigs or crops in the field. The limitation in these small drones is that they still need highly skilled human pilots. Moreover, even the drones that are semi-autonomous still require an already built-in maps or access to data over a wireless link (Byrne, 2015). There is already work in progress to make drones more independent primarily by researchers in some institutions of higher learning such as those in the Zurich’s Federal Institute

of Technology (Byrne, 2015). The suitability to this in the cases of building navigation to suit the needs of a physically disabled is that they can help draw its three-dimensional map of an unfamiliar space with minute help from an expert.

Research shows that the drone technology available now features a Quadrotor model that weighs about 1.6 kilograms. In particular, the AscTec Firefly model is equipped with a stereo camera as well as sensors (Byrne, 2015). The research also reveals that drone technology still requires human help to start operations in the new space. In all these indoor and field applications and use, the depth pictures as taken by the drones apply to three-dimensional maps with areas that the drone cannot fly to left out. After completion of the navigation, the map is made to represent a direct route that is complete and accessible. Even though the idea of mapping and sensors presentation features are identified in the past research, cases of autonomous drones are lacking. In particular, professionals believe that the milestone with the drone technology used brings it closer to real-world use and customization that will suit anyone for both indoor and outdoor use. Surveillance and navigation for accessibility or mapping will be the goal of this technology. With many presentations on papers of the new drone system to the International Conference on Intelligent Robots and Systems according to MIT Technology Review (2015), the use of this technology and its necessary modification is close to reality.

Currently, beginner drones do not have GPS, and they rely on visual tracking to determine position as well as orientation. However, by allowing the use of GPS technology that was initially reserved for the military to be accessed by civilians, adding few more functionalities to the underlying drone technology, will help reach this hopeful milestone. This functionality allows the drone to maintain a fixed position regarding latitude and location. Return to home function also allows the drone to recall the point at which it took off from and by pressing the return button, the

drone would automatically get back to the spot. The autonomous flight that is a fundamental improvement on the drone technology is a way to predetermine the flight path of a drone through a set of GPS points on which the machine flies referred to as its trajectory. Subject to its application the drone uses autopilot to follow the trajectory, the GPS waypoints (DroneOmega, 2017).

Currently, the drone technology applies to the building inspections, surveying of building construction, and road maintenance. In all these aspects, the drone waypoints functionality allows the drone technology to follow the predetermined GPS points within and without a building. Also, in closed areas and for inspection roles of the drone, the controller system of the drone gives more capacity to the camera that will apply to send signals such as pictures or maps for route definition. Literature records also show that the drone technology and navigation dramatically increase regarding use, application, utility, and range of use. It supports the fact that use of drones as assistive technology for the physically challenged is a feasible concept.

Past work reveals that the target of drone technology experts is to reduce the noise produced as they move. However, cases of drone technology utilization as assistive technology to the blind exists as a researcher at the University of Nevada applies the notice that the drone produces to give a direction on a path of visually impaired athletes (Couch, 2015). Couch (2015) observes that there are several new modifications and technology improvement on drone technology to suit fitness purposes for the disabled and as such, a drone that guides the blind in navigating a track is an example. The idea is the need for the incapacitated people to live and partake of their duties independently hence, the role of the drone technology as an assistive tool.

Efforts to customize the drone technology into homes and buildings readily available to everyone take a new perspective in the current technological space as experts' device personal aerial drones to take pictures. The concept of the Flone of the Next Things Award in 2013, which

turns a mobile device into a drone that flies approximately sixty-five feet above ground, is a groundbreaking innovation that could apply to the physically disabled in navigating a building for access (BBC, 2014). Within this concept is the modification of drone technology to help construct a bridge made of ropes. It is a technology that can apply to create a pathway and output it in maps of a building to suit the purpose of shortening the time to assess the nature of a building regarding accessibility for those with a physical disability. In fact, the drone technology already exists that helps to determine the condition of buildings, and with small modifications, it can suit the purpose of the physically challenged to navigate both the inside and outside environment for accessibility. In this perspective of building inspection, engineers faced with corners, wall obstacles or impossible roofing enclosures send drones for up-close observations. These situations and structures include church steeples, steep slope roofs or clock towers (Industrial Skyworks, 2017).



Figure Three: Drone in use to inspect a building and environment (Industrial Skyworks, 2017).

Literature records that among the ten technological advancements that will change the course of the world and people's lives forever is the drone technology. It affirms that drones have already begun capturing pictures of our immediate environment and the world at large. There are strict questions of privacy preservations as falling cost of drone technology enables even an average consumer to be a drone operator (European Parliament, 2017). Two terms of drone technology used are featured in various books; Remotely Piloted Air Systems (RPAS) and Uninhabited Aerial Vehicles (UAVs). The RPSA control occurs outside of the aircraft while UAVs' occurs automatically. Key applications of the drone by the military, civilians authorities would rely on discharging safety duties, policing or security that will count for conducting surveillance as well as gathering of intelligence. The future of drone is to assist in risky operations by both the members of the public as well as the military such as navigating rooftops, fighting of forest fires and spying. Drone technology forms a critical strategy for delivery companies to improve efficiency and speed of logistics. Practical applications and resulting impacts are documented and implemented by law enforcement agencies. Issues of security, the privacy of the people around. The fundamental issues that limit the use of drones in buildings are the potential impact of drones and aerial cameras in buildings and public places are the fear of the society of being watched. However, trying to quantify is subject to anecdotal results from the public that even the media outlets report from time to time (European Parliament, 2017).

Research is already complete on the drone technology that the physically disabled can control with their mind. The drones can assist the people with a motor impairment to interact with the environment and give them an ability to have a close-up view of objects and places within their

immediate environment that is out of the reach (Wrenn, 2012). The onboard cameras for the drones would give real-time data back down on any Windows PC enabled an environment for users to access. The description of the system by the Chinese researchers, in this case, utilizes an off the shelf electroencephalography (EEG) headset developed by Amotive Inc. The headphone can interpret brain activity (Wrenn, 2012). The drone technology for the physically disabled such as the one developed by The Digital Agency Kindai and LADAPD, HandiDrone, is already in use for navigation of the environment by the incapacitated (Fouache, 2016). Though it aims to allow the people that live with a disability, especially those with reduced mobility to rediscover half-forgotten sensations through an FPV as well as take a discovery at a new vacation, drone pilot, the technology is a step towards assistive technology for the physically disabled.

Drone use in public places that conforms to the guidelines of the FAA rules is critical. However, it is essential that private and other commercial users of drone apply common sense as they navigate public and private spaces with drones. It regards the individual rights and the rights of the people around as far as the Federal Aviation Administration regulations are concerned. Determining how correctly one uses the drone is critical even before considerations to the rules by FAA. For those who need to make money by their UAV in the US, there is an FAA test that they must pass to get certification. Flying drones for fun requires few restrictions, and for those flying as assistive technology within public spaces, the institutions must bear the licensing of the drones. However, there are regulations for registration for every drone within the US jurisdiction. The fundamental law as regulated by the FAA requires that drones fly below or at four hundred feet. It is vital to keep the drone within sight, not to fly near other aircraft and airports. It is important not to fly drones over groups of people, stadiums or sports events, not flying drones near efforts of

emergency responders, not flying under the influence, and conform to the airspace regulations by FAA.

Scope of the project

The study is based on using drone technology as an assistive device and technology for the physically disabled. The target group is the people with living with a disability in the institution of learning and others that might want to access a building beforehand to determine whether the infrastructure is accommodative regarding ease of movement. The study stipulates modifications that developers and engineers can effect on the drone technology regarding features or characteristics to make them relevant for navigation. The Project seeks to offer an alternative to the use of robots which like the physically disabled, have mobility problems in buildings. Ultimately the Paper outlines the use of drone technology to enhance the accessibility of the environment by the physically disabled in a way that seeks to define regulations to the use of unmanned none GPS drones for building navigation. It entails optical modifications, software adjustments as well as the need for institutions to install drones ready for the physically challenged population to use.

Purpose and Importance of the study

This study is critical to exploring the use of drones for this use case since it gives an adequate determination of the way an individual physically challenged person can improve their access to buildings and if limited to know in time to avoid time wasted. It can be an insight to drone technology experts and a developer's guide including the needs regarding assistive devices for students living with physical disability. It places engineers and technology designers in a pool of like-minded professionals and focuses on openly sharing ideas such as application source code for improving the technology and features used in the drone to suggest improvement. In matters

of transforming access to buildings within the institution, administrators can factor this technology into their budget and set up a department that manages accessibility aid for the physically incapable. A building that does not have enough supportive means of access can set aside a computer room or a room on the first floor where unmanned drones can be remotely controlled by interested parties to know in advance the specific locations of the building that they can access. They can get a map drawn to aid their movement. All this will be printed on the computer screens or copied to their Android device or smartphones. It will not only limit chances of accidents within a building but limit time wastage, losing of tracks and getting stuck in an area for more extended hours waiting for help from the able members of the institution. It will also ensure that the physically disabled can navigate a building within the institution independently as they determine beforehand those areas they can easily access and the areas they must seek assistance.

Another reason this study is critical is that it is also a milestone that the area of Artificial Intelligence will reap benefits from as a result of the new drone technology. Though the drone technology already exists, improving and modifications to act as assistive technology is critical and should be publicly available to all buildings. With such modifications, accessibility to the building will have a roadmap to look into future technology that guides even the visually impaired into buildings. It is, therefore, necessary because it will inform the onset of drone technology modifications for all forms of disabilities that can affect building access.




The importance of this study is that it is an effort to solve building accessibility problems for the disabled. In developing countries, for instance, there is recognition of the need for enabled access to primary areas of a building and architects should work on such aspects as a way to conform to regulations inclusive architectural design as most buildings in developing countries have no supportive structures for people with disability. Access problems occur indoors and within

hallways, electrical switches, sockets, bathrooms, and air conditioners (Daily Nation, 2016). The input of the drone technology and software modification is to aid in mapping these areas within a building and report their location and proximity along with a report on whether or not they are accessible to a particular form of disability. It saves the time that would otherwise apply in personally navigating these areas or use of a *telepresence* robot which has the same mobility problems.

Statement of Research Problem

The research seeks to determine whether it is possible to define in advance the accessibility of a building to save the time and avoid surprises. Further, it gives solutions that determine whether drone technology modifications is a solution and answers as to what parameters regarding technology used in drones needs modification to suit this purpose and the regulations according to by Federal Aviation Requirements.

Research Questions

-  What are the requirements for drones to be used as assistive technology for the physically disabled when it comes to navigating and assessing indoor environments?
-  Do people living with a disability perceive the use of drones as a potential way to increase accessibility?
-  What are the necessary modifications to drone technology regarding regulations, features, design, and functionality to use them for navigation of a building for accessibility?

Methods

This study applies mixed methods to better understand technical and policy requirements for the use of drones as assistive technology. One of the primary methods employed includes a review of the literature to determine the specific and general modification regarding features regulations or software to recommend on drone technology to apply as an assistive tool. Literature analysis is instrumental in this study to answer the first research question (RQ1), *What are the requirements for drones to be used as assistive technology for the physically disabled when it comes to navigating and assessing indoor environments?*

Field interviews and questionnaires administration are other vital methodologies that form the basis of this study. In this context, interviews develop the concept of a guided conversation between randomly selected respondents living with physical disability to aid in answering the next research questions, (RQ2) *Do people living with a disability perceive the use of drones as a potential way to increase accessibility?* (RQ3) *What are necessary modifications to drone technology regarding regulations, features, design, and functionality to use them for navigation of a building for accessibility?* This study applies ethnographic observation too as a means to determine the trends in the institution of learning to identify cases of drone technology use among the physically disabled. In this case, observation forms a critical part of quantitative and qualitative intuition that is key to gather data for the instances of drone technology cases or lack of it among the disabled. Observation and recording are critical in this study since the research intends to find out what the population of the disabled do in the case where a building is not accessible and the suitability of drones in such cases.

Phases of the Research

Phase One

Connecting with the University of Cincinnati infrastructure to gather information and identify policies through face-to-face interviews, observation, and recording. An actual visit to meet the people living with a disability to assess the tools available to them to ease their access and navigation of the building. The research relies on a non-random sample of 25 respondents interviewed, the majority of whom are people living with physical disabilities. School stakeholders and other randomly selected people within the University of Cincinnati compound also constitute the sample population.

Phase Two

Determination of the technology specifications for indoor use of drones. Issues such as consideration for camera range, quality, and indoor safety concerns. Review of the existing literature and research on the regulations to the use of indoor drone technology stipulated by the Federal Aviation Requirements and Guidelines. It is based on an actual survey through questionnaires.

A sampled population of the disabled within the school and its environs participates in this activity. The questionnaires as a tool were used to assess the use of drone technology, the popularity of drone technology among the disabled population, their thought concerning a possibility to use the technology as assistive technology to explore their environment and by extension the buildings around for ease of access.

Phase Three

The last phase of this thesis paper entails further actual survey by way of interviews, observation and recording, and questionnaire administration to the interest group, people living

with a disability within the university and elsewhere, law enforcement agency experts, and professionals within the FAA. This exercise focus is to understand the information needs of the people living with a disability so that the need for drone technology adjustments is understandable from the perspective of the disabled.

Tools, Decision, and Action Process

Includes tools that aid the research process to solve the problem of each step of decision making. The tools applicable includes survey questionnaires that help in the gathering of the quantitative and qualitative data concerning the drone technology, knowledge of its existence among the population living with a disability and suggested technology advancements.

The actions such as observation and recording, library literature search, online resource, and technical analysis are used to determine the state of drone technology among the physically disabled. Includes taking interviews and administering questionnaires to gather information about the use of drones, recommendations suitable for the physically disabled and the possible observable assistive technology already applicable to the individual physically disabled population.

The evidence collected through observation, interview sessions and questionnaires are assessed to determine patterns and recommend a course of action. Entails analysis of data presented in each section in tables to determine patterns.

Results

Results of Phase One: Interaction with the Environment and People

In this section the study asses through questionnaire an interaction with the University of Cincinnati to gather information about possible adoption of drone technology within the establishment to enhance accessibility. An account of questions used in semi-structured

interviews administered by pamphlets to a non-randomly selected population living with a physical disability within the University of Cincinnati along with representative respondents' quotes are featured below:

1. Have you heard of the existence of drone technology?

Almost all the people responded that they have at least heard of the drone technology and have a good picture of its use. While some people still believe drone technology is a reserve of the military and law enforcement agencies, others have used a drone to take pictures or seen one fly over their head.

One person laments *"Yes, I have used a drone, a remote-controlled quadcopter, to take aerial pictures of the Redwoods in Humboldt County with permission from the concerned authorities of course and the video was amazing."* Another respondent said, *"Yes, but that machine has a lot of regulations, and I think it's a reserve of the military, I have never thought much about its use by private citizens."*

2. Have you purchased a drone?

The map of the drone ownership in the US speaks volumes as to the number of the people who have purchased and licensed drones for personal use. According to this sampled population, only one person living with a disability has been authorized to fly the unmanned aerial vehicle. The rest of the people have either not personally handled one or have only seen it operated by a friend. Otherwise, drone ownership according to the sampled population is low because of the price or lack of awareness that it's not just a reserve of the military.



Figure Four: Map showing the distribution of all registered drone users in America (Atherton, 2016).

3. Do you think the drone is safe to use in schools and institutions of higher learning especially for people with mobility problems to maneuver buildings?

Irrespective of the law and regulations of the FAA, the use of drone according to the sampled population appears to suggest safe use. At least fourteen out of the twenty-one people living with a disability believe drone use as an assistive tool would be safe. One of them responds that *“It’s safe as long as it can be legalized and made to suit inside of buildings. The only concern is to ensure that an operator has a license, so it won’t be prone to crashing on other objects or people.”* Only one person believes the technology is not safe however would not point a reason why it’s not safe. Some people pointed reservation to comment on its safety concern out of lack of exhaustive information about the drone technology and use.

4. Please allocate 0% or 100% on why you would want a drone Used:

- a. To attend a class and record notes on your behalf?

About eighteen students fancy the need to improve drone technology to use it for class attending and taking notes. In the idea of assessing the environment for accessibility, almost a half of the people believed it suitable, and it’s needed for such function. One of the interviewees said, *“Attending class in the fourth floor of our campus would be both safe for me and time saving since reaching an elevator in the first floor is a struggle as many students flock the entrance during rush*

times. I would also spare my assistant trouble as I set a drone to attend and record class proceedings for me.”

- b. To assess the accessibility of a building and its environs

The majority believes that it's necessary for buildings to be equipped with drones to help the disabled access the routes for quick maneuverability. One of the students in their fourth year of studies concludes; *“If I can find in advance that there is an easier way to reach the elevator or locate the restrooms, I would save on time and I would be more independent in moving around. The Idea that drone can be modified to do this is relieving enough; I wish it were possible during my first year”.*

- c. To spy on other students and take pictures

Only one of the respondents believe in using drone technology to spy on people. In fact, there is a majority of the respondents that believe the drone modifications can aid in either assessing the condition of the building for ease of access and spy, attend class sessions and for assessment purpose or spying and assessing the building and its environs. Even a more significant majority believes in using the drone technology for all the three essential functions for the physically disabled.

5. How satisfied are you with the physical infrastructure of your college regarding movement?

At least ninety-five percent of the sampled respondents are not satisfied with the physical layout of their institution and wish something was done to ensure their mobility or at least assist their movement. One of the respondents said; *“I wish the college engineers and architectures would have given much more thought to the physically disabled especially when students are rushing to lectures. In my first year, I would not move with ease because I did not know where to*

go. With the possibility of using the drone to know whether I can access some areas or not, would save on time and I would not have to reach a dead end in the middle of a lesson to know it was not possible to use a particular route. It would be easy to other people who at times end up putting a halt at their duties to assist you to move around. I would sit back at my desk or a room reserved to monitor drones to know where to go. It would be like using CCTV cameras only that this can give you specific feedback, draw for you a map or take pictures of whatever you are interested in as they move around.”

6. Would you recommend installing drones to assist the physically disabled to have an extra eye for the areas that are potentially not accessible to them?

Some students response was, “Yes, a drone room should be set aside in schools, either for fun of having an eye where we cannot go or for knowing the map of the school, buildings, and environment as we fly it ourselves.”

“Yes, I would wish to move, but that won't happen as easily so if I can fly a drone to see all the beauty in this school, bot aerial and ground from time to time, why not? “

“We have recommended for the school to set aside a computer room, purchase a couple of drones and license their use. With a few lessons and customization, we can have our eyes everywhere as easily as those with no mobility problems.”

Table One: Observable Indications for the need for Drone use as Assistive technology.

Method		Results
Observable Use	Drone	There is no particular drone use with any person living with a disability within the School buildings.
Observing Challenge	Mobility	There are a lot of cases when students living with a disability encounters problems moving from one place to the next only to realize at a later

	<p>time they are unable to complete their journey. They Would either ask for assistance or give up. In few instances, no one would help at all. In one occasion; I observed first hand here at the University of Cincinnati, a student with a wheelchair who tried going from Teachers/Dyer college to <i>Tangeman</i> university center and could not find a directly accessible ramp to that location. The only possible way was to enter University <i>Pavillon</i>, take the elevators down to the second floor to finally see a direct ramp to his destination, which can be challenging if you don't have proper guidance.</p>
--	--

Results of Phase Two: Methods, Tools, and Activities

A sampled population of the disabled within the school and its environs participates in this activity. The questionnaires as a tool were used to assess the use of drone technology, the popularity of drone technology among the disabled population, their thought concerning a possibility to use the technology as assistive technology to explore their environment and by extension the buildings around for ease of access.

Table Two: Results of Interview and personal observations

Method	Results
Face-to-Face Interviews	<p>Interview with the administration on their plans for the people with less mobility capacity and the possibility of improving drone technology reveals willingness, but the interview comes as a shocker since there are yet to feature any form of drone modification for purposes of assistive technology.</p>

Observation	Observation around the school reveals that there is reluctance on the use of drone technology to aid the physically disabled.

Results of Phase Three: Methods, Tools, and Activities

The primary tool applied to analyze the drone technology regarding regulations is the existing list of regulations on the use of drone technology in the online library. According to evidence at Business Insider (2017), mass adoption of drone comes with several restrictions that limit its use to the general public and institutions. In particular, the recreational, as well as commercial use of drones, falls under regulations such as drone pilot license to determine whether or not one qualifies to fly a drone as a remote pilot (Meola, 2017). There are laws concerning drone registration for whether the drone use applies to a hobby or by a state agency. Table Four below summarizes the FAA laws and regulations for drone use. Also, the new drone rules by the FAA that become effective have several processes in place to help users take advantage of the drone operation rules. For instance, waivers ensure that in case the proposed operations by a company does not comply with the regulations within the descriptions of Part 107 of the regulations, the institution or individuals can apply for a waiver to some restrictions (Federal Aviation Administration, 2016). The only task is to prove that proposed flights will be efficient safely under such waivers. Aside from a waiver, one can fly their drone, class G (uncontrolled) airspace regardless of airspace traffic control authorization. However, operations that take place over any other airspace must include air traffic approval (Federal Aviation Administration, 2016).

Table Three: Summary of Results from the Literature and Questionnaires

Method	Results
Questionnaires	<ul style="list-style-type: none"> Most of the Students living with Physical Incapacity recorded the need for drone use for leisure or as an assistive device.
Literature Analysis	<ul style="list-style-type: none"> There is a need in the most institution to implement the idea of drone use to assist in navigation in large buildings. Already significant buildings such as airports use Google inside mapping technology for a similar purpose. Innovation, the literature indicates promise for the use of improved drone technology as a ready to implement technology (Amal, 2015).

Table Four: Categories of regulations for UAV (Meola, 2017)

Category	Recreational use	Commercial Use
Pilot requirements	<ul style="list-style-type: none"> No requirements 	<ul style="list-style-type: none"> Must obtain remote pilot airman certificate Must be at least 16 years old Must pass TSA vetting process
Aircraft Requirements	<ul style="list-style-type: none"> If it weighs more than 0.55lbs, it must be registered except when it is exclusively operated 	<p>Must be less than 55lbs</p> <p>Registration mandatory if it weighs over 0.55lbs</p>

	in compliance with Section 336 regulations of the Public law 112-95(A special rule for Model Aircraft)	Must take a pre-flight check for safe operating conditions
Location requirements	<ul style="list-style-type: none"> • Locations for drone operations must be five miles away from the airports without providing advanced notification to airports and air traffic control 	Glass G airspace
Operating Rules	<ul style="list-style-type: none"> • Mandatory to yield right of way to manned aircraft at all times • Need to keep aircraft in line of sight at all times • UAV weighs less than 55 lbs. • Must comply with community-based safety guidelines • Need to provide advanced notification to airports and air traffic control to fly drones within five miles of an airport 	<ul style="list-style-type: none"> • Need to keep aircraft in line of sight at all times • Mandatory to remain under 400 feet • Only fly during daytime • Must fly at or below 100 mph • Must always yield right of way to manned aircraft • Must not fly over humans • Must not fly from a moving vehicle

The University of Cincinnati specific drone definition and regulations, however, require adjustments as per the study to enable drone use as assistive technology. According to the University of Cincinnati (UC), the definition of Unmanned Aerial System (UAS) is an aircraft operated with no direct human intervention from within or on the aircraft (Enterprise Risk Management, UC 2018). No human pilot on board. The regulation of operating the UAS according to the UC vests with the FAA as well as applicable state laws. The central tenets of the University Compliance with these regulations are to reduce risks to the safety, privacy, or security of the University Community in regards to UAS flights. However, recreation or personal use is not allowed at any time. The rules specific to the use of drones at UC include:

- 🚁 Remote pilot certification and approval from the University for drone operators.
- 🚁 Operate only one drone at a time
- 🚁 Flight only takes place during the daylight hours
- 🚁 No flights over people

Other regulations specific to the drone such as weight, speed, and a maximum height of flight and environmental or health concerns are concerning the FAA regulations.



Figure Five: Unmanned Aerial System over a Cincinnati horizon (Enterprise Risk Management, UC, 2018).

This study, therefore, relies on the possibility of modification to the entire spectrum of drone technology; regulations for its use, its design, and technology. Most drone used within the institution is for purposes of studies or research. Adjusting the regulations due to a specific appeal and acquiring appropriate design and technology would enhance the use of drones within a building to determine its accessibility, ease of movement and solve mobility problem and risks for the physically disabled students within the School.

Observation and recording is also a fundamental tool to use for assessing the drone technology within a population of study. Online resources are a necessary tool to analyze the drone application elsewhere. Within most schools and public buildings, drone technology in use is equipped with cameras to take pictures of the environment rather than apply as assistive tools or aids to ease environmental accessibility for the disabled. Online articles reveal that modifications are possible, and some modifications are already in place to utilize the drone technology entirely. In fact, the drone technology that applies to the members of the public is of far more powerful functionality compared to the tradition military drone. The GPS and optical capacity of these drones have improved to specific uses within and outside buildings.

Personal face to face interviews were conducted with someone from the FAA about the regulations that might influence the use of drones within school premises and by extension in public buildings. Policy makers at the FAA and other law enforcement agencies point to the possibility of exploring the drone technology within institutions and for the private citizens without restrictions. Certain modifications and lifting of restrictions such as the concept of waiver to restrictions when an institution applies drone technology as assistive tool for members living with

a disability (mobility problems). For the better part of the interview sessions, what stands out among the officers, law enforcers and experts at the FAA is applying common sense even as people use drones in public places. If an institution adopts a drone technology as an assistive device to aid building access, it is paramount that users do not infringe on another person's privacy. It is important to observe common sense alongside regulations for the use of UAV.

It is important to observe the technology that exists among the people living with a physical disability that helps them with natural movement around. The drone technology adopted by the people living with a physical disability now is the drone camera that can take pictures of the environment. It is yet to include inside of buildings. At least one out of twenty people living with a disability and of college age has a drone for leisure and recreational purposes. Another technology among the people living with a disability that makes their locomotive issues easy is the use of an electric wheelchair. However, unlike drones, the wheelchair cannot navigate areas that are inaccessible such as a steep stairwell.

Stakeholder Analysis

I've contacted Mr. Greg Hollon, the program director of the College of Education, Criminal Justice, and Human Services of the University of Cincinnati regarding my research. Aside from referring me to the Enterprise Risk Management Department of the University, he responded with optimism for this study. His response to one aspect of the inquiry was particularly instrumental for the research:

What are the regulations that will limit or support the use of drone as assistive technology within the School and inside of the buildings?

"I believe the regulations for and against the drone use in public are all about common sense. You can fly your drone over our space much as you like as long as you are not destructive,

we already have some drones around. If regulations allow, you can hover around corridors with your drone as long as it doesn't cause disturbance to others. As far as the regulations are concerned, use of drones inside of a building as assistive technology is a unique concept, with specially designed drones I believe this concept is possible and drafting or modifying regulations upon a special request is likely. The FAA regulations, which our drone regulations borrow a lot from, allows for certain special exemptions."

Results and Analysis

This study confirms the core hypothesis of this study that in fact, there is a possibility of using a drone to access a building by those living with physical disability. With modification and flexibility in the regulations of an institution and those given by the FAA, drones can serve as an assistive device in massive buildings. In support of this study are the Google in-house mapping technology and the Use of UAV in the building industry to inspect an inaccessible section of a structure. More recently Engineers at a University in Japan tested a drone specially designed to navigate and operate inside a building to monitor a warehouse or a plant building (Gilhooly, 2018).

The results show that at least ninety-five percent of the people living with a disability requires the drone technology to help as a tool for easing their time spent with assistants looking for points of access within the compound and in buildings. With the most percentage recommending its use as an accessibility determination technology, it is paramount that building and construction engineers, policymakers and the institutional laws and regulations work to ensure drone technology availed to people living with a disability to help with the environmental maneuver.

The FAA regulations recommend drones flying within a height of four hundred feet which is within the height for many buildings within institutions of learning where the modifications for the technology to suit the disabled needs most to apply. It means flying of UAV would be within the regulations. It is, therefore, necessary to conclude that students living with a disability, according to the results of the study need to have drone technology modified as assistive technology. It would help to overcome most of their inhibitors to movement within the premises such as steep stairwells, congested pathways to elevators when students rush for classroom attendance, and other functions such as recreation especially to use drones to observe parts of the environment where their movement would otherwise be limited.

Evidence shows that even with strict laws on drone regulations and ownership, individuals can still take advantage of the provisions such as waivers to make drones that can fit within specific requirements and functionality. People within the regulatory authority and law enforcement agencies believe modifications to the drone technology is possible as a result of the interview sessions. It indicates that modifications recommended as assistive technology to the physically disabled require investing in innovative ideas and models for the drone technology. Simply put, regulations for the use of UAV is not a restriction to adopt a drone technology as assistive technology to ease building access.

According to evidence, all of the twenty-one people interviewed have heard about the existence of the drone technology. Only five percent of the disabled population who are of college age have drone ownership, and even so, they only use it for fun and to take pictures during vacation.

Most people living with a disability would recommend to their schools the improvement necessary for drones to apply as assistive technology. It would require that the sole purpose of the

technology applied to assessing buildings, especially the multi-story buildings within the institutions for ease of accessibility. It would also be important according to them for that technology to be used to maneuver the outside environment for fun. Some people, however, believe the technology needs to aid in attending classes and even a smaller proportion, about 5%, believe it should be applicable for spying. Interestingly, there is about four percent of the population sample that believes the technology should apply for spying, attending classes as well as assessing buildings for accessibility. The pie chart below (Figure Six) is a summary of the recommendations for the use of drones within the school buildings and environment.

About 95% of the people interviewed feel dissatisfied by the physical design of the building regarding accessibility and would not mind having as assistive technology to help with their mobility. Only fourteen percent of the sampled population of those in the college premises that day believes there are safety issues on the use of drone technology as an assistive tool. About 90% of them, however, point to safety concerns because they do not know much about drone technology and the extent of its use within the country other than that it is a reserve of the law enforcement agencies.

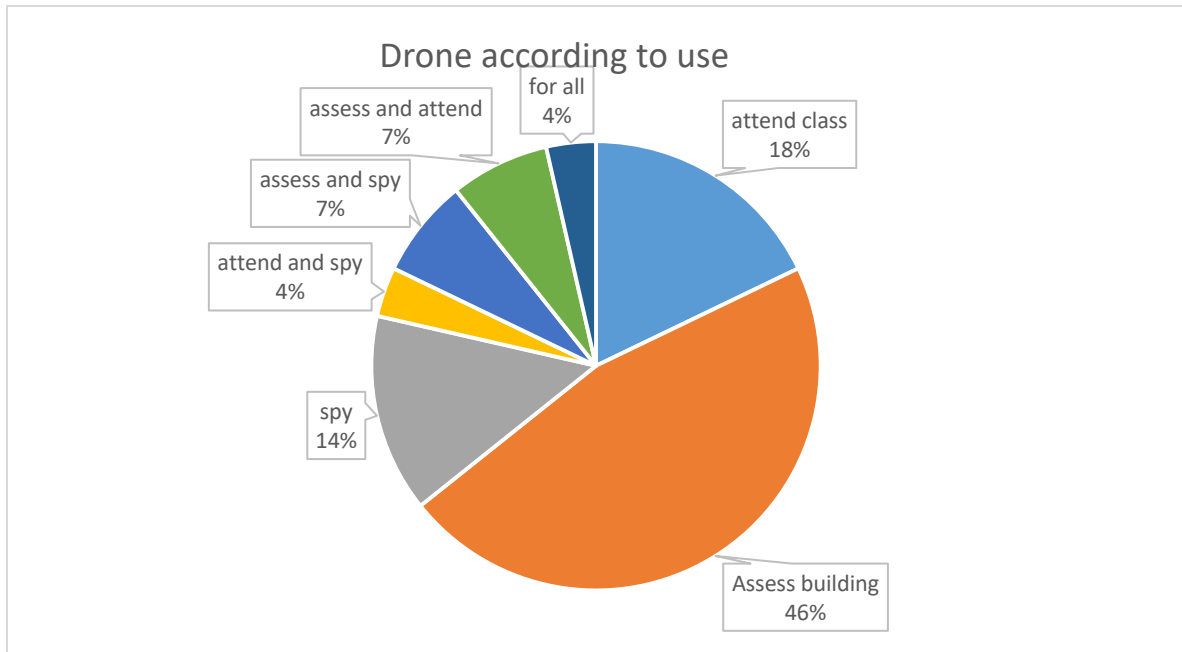


Figure Six: Recommendations for the Use of Drone as Assistive Technology

Discussion

This study attempts to solve one of the problems that students living with a disability have and by extension the people living with physical incapacity experience in daily life, ease of mobility. Drone in many quarters applies to military, business, and as a leisure supporting device. For instance, drones have been applied in service of the military and government to distribute relief food, medicine or surveillance to areas that otherwise are inaccessible to other forms of transport. People use a drone to take photographs of physical features as well as the environment or access building points that are not readily within their reach. Modifications to the drone regarding size, functionality or technologically could apply as an assistive tool for the physically disabled for school building access and navigation just as it applies to the military and relief food distribution. To answer the **RQ3**, the following recommendations are part of the findings of this research.

- Colleges and institutions of higher learning should adopt a policy to maintain a drone room. In the technology room, students with disability registers to use drones both for leisure and to determine precisely where they would move. It would mean a student maps a path on which they would take from one point to another, to know in advance whether or not their destination is reachable or if they would require assistance. The drones need equipping with a map drawing capability that would ensure time-saving within a learning institution and ensure a sense of independence among the students living with physical disability.
- For every student that signs up for the use of the drone, certificate of operations as required by the Aviation Authority must be attained to certify the use of drones within the college premises. The drones themselves requires GPS restrictions regarding radius and heights beyond which they cannot fly. It refers to safety measures recommendation and restrictions to ensure that the drones within a particular institution do not violate another person's privacy. The optical capacity of such drones is also recommended to include powerful optical sensors to ensure they can maneuver corners and take explicit photographs so that a student can then readily interpret.
- Instead of the students themselves flying the drone within a building, an institution can readily adopt an infrastructure in which a database with all the possible mappings of a building is made available for access by all the new physically disabled students. It recommends a computer room with drone mappings of the buildings be located on the premises. Because drone use within the US requires some certification by the Federal Aviation Authority, this recommendation would save the time and trouble as every possible corner of the building would be available within the database created by drone and updated

every time there are new tracks and alterations to the original mapped tracks. A student only goes to the database to print a map.

However, managing drones that are already installed to serve specific units of an area within an establishment would suitably solve the cost that will come with the maintaining a database for the drone mappings. It would mean a student logs into a drone depending on the area within the campus they would want to visit. The institution is responsible for the drones, but this will require the students to have some knowledge and certification in flying of AUV. The overall idea of the drone navigation and mapping of a building focusses on a new student, a visitor or a student visiting an area of campus for the first time. It saves them time as it assists in knowing whether or not they might require an assistant or the destination is inaccessible to them. Ultimately, it solves the chances of accidents among the disabled students. According to the Association of Disabled Americans, a few stairs or a high curb can be a disastrous cause of injury to someone living with physical disability. It further maintains that a lawyer in a wheelchair can be as competent as their counterpart with normal ability as long as they can equally access the courts and library. Having a system in place to identify in advance, parts and sections of an establishment that are dangerous for access by a physically disabled is an objective of the ADA Standards for Accessible Design. They require that physical access to include accessibility to routes, parking, curb ramps, elevators, passenger loading zones, signage, and entrances (COMMUNITY TOOLBOX, 2018). Modifications to drone as an assistive device for navigating the environment is a contribution towards the overall safety and accessibility goal of the ADA.

The question of the mode through which drones are applicable by physically disables features in the course of the study. Most of the students interviewed expresses willingness to have had a chance and a way of knowing in advance the areas within the school that they visit from time to

time when they were still newly admitted. It would be time savings and safer option. Also, some students thought the drone technology could preferably assist in navigating the external environment as well as their physically able counterparts who move around and enjoy the aesthetic beauty of the compound. Among the recommended option to apply drone as an assistive device for use by the physically disabled is schools operating a database with drone mappings. The school can also set aside a room with computers that are utilized by new students and visitors to navigate the school compound and building for assessable areas, points of danger to save time and ensure they move around independently. The objective is to understand the physical layout of the establishment and environment in which they move about hence by answering this question within the technology, functionality, and legal modification to the drones; the study gives further enabling infrastructure for an institution to conform to lobby groups' equitable accessibility and safe infrastructure for all.

To address the **RQ2**, the question as to whether there is drone usage by the population of disabled people in schools or elsewhere critically indicate that improvement recommended in this study for the drone technology is possible. In fact, drone technology use is already available among registered users with a disability. However, these users utilize the technology for leisure in other spheres other than buildings. It is because of privacy issues and Federal Aviation regulations that limit drone use in public places. With modification and recommendations to change legislation for some establishments like schools, the technology can find its way as assistive technology for the physically disabled for navigation and access hence a realization to the question of drone technology as a milestone in assistive technology.

The results of this study determine the regulations that control the use of drones as defined within the FAA documentation. Ultimately, common sense in the use of UAV plays a significant

part in dealing with drones in the current functional areas of drone use among the private citizens. Dominated by leisure and business, the same regulations would apply when institutions take up technology to assist the physically disabled with environmental and building access. Moreover, the manning of drones and regulating their use within the institution will be the mandate of the institution. Restrictive software to moderate and govern the use within the defined areas would make it to the list of regulatory modifications to the drone technology used as an assistive device. Other modifications such as size and color would be a matter of convenience and semantics. To successfully use drones in the buildings, an optical capacity of drones adjustments, improved sensors, and specific color definitions needs to apply for it to be both safe for other people within the premises and to navigate corners with ease and take high-resolution photos even in slightly dark areas. This successfully addresses a roadmap to the premise of **RQ2**.

Recommendations

Schools and institutions of higher learning need to embrace the drone technology and welcome the modifications recommended to its utilization as an assistive device. Currently, as the regulations for commercial as well as personal use of drones within the United States comes into place, it is estimated by the FAA that the private drone industry has the potential for a ninety billion dollar return within the industry at least in the next decade (ESRI, 2015). Even as the drone breaks away from being the province of the military, users and institution that needs to embrace and modify the technology to aid the disabled must observe compliance with the FAA regulations. This thesis presents modifications essential for the drone technology that applies to the disabled as a result of the observation of real life evidence among the people living with physical disability. It entails drawing recommendations according to the regulations that govern the use of drones within buildings as evident on the data, and literature analysis results.

There is a proposed framework for national regulations on the use of drones as stipulated by the Federal Aviation Administration (FAA) for unmanned aerial vehicles that make it simpler for businesses, institutions as well as individuals to own and use drones. Institutions, therefore, need to take advantage of this window of possibility to come up with the technology to assist the physically disabled to maneuver their immediate college environment. There is also some value in bringing drones to the classroom as studies already show this milestone within the drone industry. At a Kentucky educational cooperative, there are new ways to offer training relevant to operating the drone technology. These are the necessary steps that the institution can exploit to ensure the technology among the population of physically incapable students knows how to man these aircraft within the buildings. After months of training and developing drones, students test their drones in the classroom to leave others wondering at the site of yellow, four-legged drone passing passed one another in a gym at Kentucky's Hazard Community and Technical College (Nix, 2017). It is evidence to recommend the use of drones as an assistive tool to perform more customized duties, reduction in size to fly in buildings and equip powerful cameras and GPS system to help with map and location reporting for the physically disabled to aid building and environment maneuver among other related roles.

Introduction of drone technology calls for vigilance within the institutional management team that will handle implementation of the technology within the public space and buildings. Strict conformity with the FAA regulations will need to be observed by the people manning the drones for various functions. It is essential that users embrace common sense and that they do not fly the drones very close to people. The drone is thus required to feature a variety of functional, as well as design modifications. They can be made to move in hallways, against the walls, move

along the ceilings or fitted with x-ray technology to improve the visibility in areas it would be risky to fly them over.

Life on the campus as a disabled might be challenging. As a result of the findings in this study, understanding the need to improve the general environment of the physically disabled has been the result of previous waves to develop robots. Robots work to help with some aspects of mobility and assistance to the movement of a disabled person. The modifications recommended to the drone technology would mean an improvement to the limitations of the robots that still have the same mobility issues as the physically disabled people or an electric chair. The drone technology innovations, modifications, and availability of the technology beyond the law enforcement agencies and the military ensures that its use becomes more relaxed, customizable and applicable to all. Applying the technology to fit the premise of assistive technology in buildings for the people living with a physical disability is possible within these regulatory, innovatory, design and functionality revolutions to the drone technology. Figure 7 below, is a test technology for in-house drone use.



Figure Seven: A drone fitted with Stereo Fisheye lens navigates inside of a building during tests, Courtesy of the University of Tokyo and Blue Innovation (Gilhooly, 2018)

Table Five: Recommendations that this Thesis Focuses on to Apply Drones as an Assistive Device

Technological	Regulation Based
<ul style="list-style-type: none"> • Design Drones that can be made to navigate hallways, against the walls, and move along the ceilings • Drones should be fitted with x-ray technology to improve the visibility in 	<ul style="list-style-type: none"> • Strict conformity with the FAA regulations will need to be observed by the people manning the drones for various functions. It is essential that users embrace common sense and that

<p>areas it would be risky to fly them over, crowded or with obstacles.</p> <ul style="list-style-type: none"> • Enhanced optical angle for the cameras used(Wide angle Capacity) • Improved Optical power. • Drones to be fitted with motion sensors. The powerful sensors will ensure they do not knock on walls, obstacles, or ceiling. • The noise produced must be near zero as much as possible to avoid disturbance of other people in the building. • The color schemes of the drone must camouflage as much as possible to the surrounding. The more invisible the drones, the better for minimizing destruction. 	<p>they do not fly the drones very close to people.</p> <ul style="list-style-type: none"> • The University stakeholders need to change the whole concept of the UAV regulations that only focus on flying drones for photography, surveillance or for leisure to realize the goals of using the technology as an assistive design, assume exceptions as recommended by FAA for special drone use. • Regulations of the school will be modified and improved to accommodate in-house maneuver. The School owns 400 feet of their space hence will have to draft its rules to use drones inside of the building. It is a provision of the FAA regulations. • The university administration will manage and man the drones on behalf of the population living with a disability.
---	---

Conclusion and Future Work

Conclusion

The average person living with a disability suffers exclusion in uncountable ways within the society. Given the fact that in any population, the people living with physical disability in the US college education system between the years 1951 to 2012 stood at 38.3% (Gelber, Madaus, & Dukes, 2015) and required as much assistive devices and technology as possible to compete and study favorably with others. It is within the spirit of inclusiveness and empowering those living with a physical disability that this article determines and defines drone technology as an assistive device for ease of accessibility within colleges. The objective as with the findings of the research is to save time and avoid surprises that would otherwise occur if the students had no knowledge and picture in advance of the infrastructure through which they navigate. The research proposes that drone technology, its registration and user manual be available within the premises at the disposal of the physically disabled. In this regard, the research focuses on new students who would waste time looking for assistance to help them navigate to their respective destinations, such as libraries, classes, elevator directions. The research achieves for the physically disabled a fulfilling independence as they can take photos of the corridors and draw a path within the building using the drones managed from a centrally located room within the premises.

The research is an attempt to solve the parameters of the drone technology, and regulatory documentation that requires modification achieves an enabling technology that can universally accommodate not only the physically disabled within the institution but first-time visitors. It is an opportunity even for those with a hearing problem with the capacity to read and interpret graphs within institutions to move around without having to construct conversations that most of the general populace of the institutions would be adamant to entertain. Within the confines of FAA

UAV regulations, the study determines a way to incorporate the drone technology as essential part of school building architecture that assists the physically disabled population navigation and knowledge of easily accessible points of the school or a building. With minimum modifications, the drone technology will suite use within large buildings as they have suitably applied in the external navigation of buildings by architectures over the years to determine faulty structures within remote and visually obstructed corners on walls or roofs of skyscrapers. In fact, the majority of students questioned agree they wish a drone would assess buildings for accessibility. It is because they often meet obstacles after long struggle around in infrastructure which in turn wastes time or results into injury when it proves more convenience and mandatory reaching the destination despite dangerous obstacle. In a school environment, time is of the essence. Knowing in advance when one can quickly reach an identified destination is a grand strategy to save time, and the study identifies drone technology modification to help with advance navigation among the physically disabled students in an institution.

A sample of students was assessed in this study based on the satisfaction they derive from the physical infrastructure of their environment. Most students with physical disability express concern and dissatisfaction with the nature of stairs, corridors leading to elevators or escalators. The study determines a general trend in feeling that a mechanism to establish in advance the physical design of the institutional buildings would be a step in the right direction especially for new students with physical incapacity. The comparison made between the drone technology and the use of robots within to improve accessibility also reveals that drone modification is the most effective option for assistive technology in this context. The robots, just as the physically disabled experiences the mobility problems. Installing of drone technology enables students and other users within an establishment another set of eyes on areas that are not readily accessible. Available

evidence in this study and literature supporting the use of assistive drone technology supports observation and a conclusion that modifications to the drone technology are critical. Modifications need to encompass regulations, software upgrade, technical modifications and hardware designs will solve navigation, accessibility and cases of accidents caused subject to lack of knowledge of the surrounding infrastructure by physically a disabled population in an establishment. Moreover, drones that can navigate inside of a building are already under test elsewhere in Japan (Gilhooly 2018). People primarily in the business sectors who own large premises are already looking for drones that can function within their buildings.

Future Work

This thesis is instrumental for future work. The findings of this study offer a break away from the traditional view of drone technology and innovation. Now, it is potentially beneficial for covering crime scenes, disaster management, carrying missiles, surveillance, or in the supply chain. However, it will thence represent an all-inclusive technology that will help those living with physical disability to have a relatively more comfortable and less obstructed life as they move around, it will shape future studies to advance the perspective and scope of Assistive technology. This study is pivotal to open investigatory analysis of innovations and technologies that support mobility in the educational environment for the people living with physical disability. Open and distance learning might in future take the form of virtual presence where drones and *telepresence* robots report real-time classroom proceedings on the smart devices of those living with a physical disability or any party willing to sign up for "*smart learning*" options. Even court processes will assume the technology to avoid time wasted for mentioning or crowding of courtrooms.

References

- Amal, W. (2015). *Learning Android Google Maps*. Birmingham: Packt Publishing Ltd.
- Atherton, K. (2016). *Aviation: Here's The Map Of All of America's Registered Drone Users*. Retrieved from Popular Science: <https://www.popsci.com/map-registered-drone-users-resembles-population-map-united-states>
- Atkins, E., Ollero, A., & Tsourdos, A. (2017). *Unmanned Aircraft Systems*. New York, NY: John Wiley & Sons.
- BBC. (2014, July 24). *How to build and fly your own home-made drone*. Retrieved from BBC: <http://www.bbc.com/news/av/technology-28090632/how-to-build-and-fly-your-own-home-made-drone>
- Byrne, C. (2015, October 28). *Intelligent Machines: A Drone with a Sense of Direction*. Retrieved from MIT Technology Review: <https://www.technologyreview.com/s/542816/a-drone-with-a-sense-of-direction/>
- COMMUNITY TOOLBOX. (2018). *Section 4. Ensuring Access for People with Disabilities*. Retrieved from A community tool box website: <https://ctb.ku.edu/en/table-of-contents/implement/physical-social-environment/housing-accessibility-disabilities/main>
- Cook, A., & Polgar, J. (2008). *Cook & Hussey's Assistive Technologies*. Elsevier Health Sciences: Amsterdam.
- Couch, C. (2015, October 16). *Connectivity: Fitness Technology That Helps the Blind Get Moving*. Retrieved from MIT Technology Review: <https://www.technologyreview.com/s/542426/fitness-technology-that-helps-the-blind-get-moving/>

- Daily Nation. (2016, June 23). *Making buildings accessible to people with disabilities*. Retrieved from Daily Nation: <http://www.nation.co.ke/lifestyle/dn2/Making-buildings-accessible-to-people-with-disabilities/957860-3262896-xdj8bx/index.html>
- DroneOmega. (2017). *How GPS Drone Navigation Works*. Retrieved from DRONEOMEGA: <http://www.droneomega.com/gps-drone-navigation-works/>
- Enterprise Risk Management, UC. (2018). *Drones*. Retrieved from A University of Cincinnati Website: <https://www.uc.edu/gencounsel/rmi/Training/drones.html>
- Esri, N. (2015, March 3). *Want to Fly a Drone? Here's Where You Can Do It (Legally, at Least)*. Retrieved from Smithsonian.com: <https://www.smithsonianmag.com/innovation/where-drones-fly-legally-united-states-180954454/>
- European Parliament. (2017). *Ten Technologies which could change our lives: Potential Impacts and policy implications*. London: Directorate for impact assessment and European Added Value.
- Federal Aviation Administration. (2016). *The FAA's New Drone Rules Are Effective Today*. Retrieved from Federal Aviation Administration: <https://www.faa.gov/news/updates/?newsId=86305>
- Fouache, A. (2016, June 20). *HandiDrone Brings FPV Flying to People with Disabilities*. Retrieved from Make: <https://makezine.com/2016/06/20/handidrone-brings-fpv-flying-to-people-with-disabilities/>
- Gelber, W., Madaus, W. L., & Dukes, L. (2015). COLLEGE STUDENTS WITH PHYSICAL DISABILITIES: COMMON ON CAMPUS, UNCOMMON IN THE LITERATURE. *Physical Disabilities: Education and Related Services*, 14-31.

- Gilhooly, R. (2018, January 20). Entering the drone age: Japan seeks to tap into the potential of unmanned flying vehicles. *Japan Times*. Retrieved from Japan Times: <https://www.japantimes.co.jp/life/2018/01/20/digital/entering-drone-age-japan-seeks-tap-potential-unmanned-flying-vehicles/#.WqG5nOhubIU>
- Industrial Skyworks. (2017, February 23). *Drones For Building Inspection*. Retrieved from Industrial Skyworks: <http://info.industrialskyworks.com/blog/drones-for-building-inspection>
- Joshi, D. (2017). *Exploring the latest drone technology for commercial, industrial and military drone uses*. Retrieved from Business Insider: <http://www.businessinsider.com/drone-technology-uses-2017-7?IR=T>
- Meola. (2017, July 25). *The FAA rules and regulations you need to know to keep your drone use legal*. Retrieved from Business Insider: <http://www.businessinsider.com/drones-law-faa-regulations-2017-7?IR=T>
- Newcome, L. (2004). *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles*. Reston, VA: AIAA.
- Nix, N. (2017, August 18). *The Value of Bringing Drones to the Classroom*. Retrieved from The Atlantic: <https://www.theatlantic.com/education/archive/2017/08/the-value-of-bringing-drones-to-the-classroom/537150/>
- Passifume, B. (2017). *'Vision-based navigation is just like in humans': Calgary professor developing new drone technology*. Retrieved from Calgary Herald: <http://calgaryherald.com/technology/science/vision-based-navigation-is-just-like-in-humans-calgary-professor-developing-new-drone-technology>

Russon, A. (2017, July 20). *US police are now using drones to gather evidence on crime investigations*. Retrieved from The International Business Times Website:

<https://www.ibtimes.co.uk/us-police-are-now-using-drones-gather-evidence-crime-investigations-1631256>

Wrenn, E. (2012, August 31). *The thought controlled flying drone that could act as 'virtual eyes' for the disabled*. Retrieved from Mail Online:

<http://www.dailymail.co.uk/sciencetech/article-2196407/The-flying-quadcopter-disabled-people-control-mind--use-virtual-eyes.html>