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Utilization of Drone Technology to Improve Tower Worker Safety and Productivity

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Abstract

The purpose of this research is to identify techniques by using drones to improve the safety and productivity of tower workers. Tower work requires that workers frequently climb structures for inspections at heights between 200 and 400 feet with some towers that exceed 1000 feet above ground level. The fatality rates of tower workers frequently exceed all other professions in the United States and is regarded as one of the most dangerous industries to work in. This is because tower workers have to make a several hundred foot climb for a simple visual inspection, thus exposing them to hazards that a drone could reduce. Workers also spend significant time climbing up and down a tower to perform theses inspections. With drones the goal was to decrease the amount of climbs and to decrease the amount of time on the job site. Through the use of drone technology it was concluded that drones can significantly improve the safety of tower workers and improve productivity.

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Introduction

In the technology driven world today almost everyone has a cell phone in their pocket, a television in their house, and a radio in their car. It is often forgotten the process of receiving the information through these different medias. Throughout the United States there are different towers scattered standing high above us. These towers are what give people the ability to look up information, call, and send texts on their cellphones. They also provide us with the local news and with the radio stations that people listen to in their cars and at work. What is often forgotten is that these do need maintenance, and this dangerous job falls on the men and women in the tower climbing industry.

Because of civilizations reliance on technology, tower workers are busy. Towers, like any most objects, need periodic maintenance and examinations. That means that every day tower workers are up taking care of these inspections and maintenance. These workers are often climbing at heights over 400 feet sometimes up to heights over 1000 feet. The greatest hazard of this industry is working at these heights. Hazards from working at heights include a number of different dangers. The most common tends to be the danger falling. In the tower work industry this can result from faulty equipment, ignoring safety equipment, free climbing, and slips or losing balance. Other hazards of working at heights can be weather and possible injury to workers on the ground if equipment is dropped from the height. Because of the danger of this industry a large concern has been how to keep boots on the ground and eliminate the hazard of working at heights.

With recent advances in technology in the past years, Unmanned Aerial Vehicles (UAV) have become a crucial piece of equipment in many commercial fields. They have had success in both the agriculture and construction fields with mapping, photography, and videography. With

their prior success and use in other fields that can easily be utilized in the tower work industry. These drones are also the answer to keeping workers on the ground and not putting them at risk. These drones can be used to get clear pictures and videos of different parts of a tower, and it will significantly reduce the hazards that workers are exposed to. By have a drone perform a simple visual inspection a tower worker can assess if a climb on a tower is necessary or not.

Purpose

The purpose of this study is to determine if a UAV drone can perform simple inspections on different types of radio and cell towers, with the main goal to improve the safety within the tower climbing industry. Tower workers face the hazards ranging from electrical hazards, structural failure, weather conditions, dropped objects, and falls. This leads to a very high workplace injury and fatality rate. With the implementation of UAVs within the industry to goal is to reduce these rates and ensure everyone makes it home alive at the end of the day.

Rationale

Within the tower working industry the average death rate per 100,000 workers is 123.6, a huge number compared to the construction industry with a rate of 10.7 (Knutson & Day, 2012). It is a clear that people working within the tower climbing industry have a very dangerous job. Every time that a worker climbs a tower they face a varying amount of risk. This risks can range from the hazards of working at heights, structural failure, weather, and electrical hazards. Within the industry some workers ignore basic safety protocols such as wearing safety equipment or not using safety equipment properly, in turn increasing their exposure to this risks. With the use of different systems such as UAVs for simple inspections companies can eliminate the number of climbs a worker has. This results in less exposure to the hazards which would help with the overall safety of the industry. Tower workers frequently climb over 400 feet for simple inspections. The process of climbing up and down for an inspection can take hours. However, the UAV system could do the same job in less time. The use of UAVs to prevent climbs, workers are exposed less to the hazards of work at heights.

Research Questions

Considering the dangers of work at heights and the possibility of using UAVs to prevent this, some important, fundamental research questions can be asked. Can a drone successfully perform a visual inspection of a tower? The biggest reason a drone is being considered for use in the tower climbing industry is for its ability to get up close with a tower for inspection without sending a worker up, thus avoiding the risk of falling. However, if the drone cannot successfully perform the duties that a worker can there is little need use for it. Weather, particularly the wind, are potential hazards to flying the drone around a tower. If it is too windy it can make the drone hard to control, resulting in unclear pictures and videos. The drone also operates on radio waves, something that all the towers broadcast out. This means there is a chance for an interference between the drone and the tower.

Will the drone's ability to examine a tower eliminate some need for a worker to climb the tower for simple inspections? Tower workers often make climbs for visual inspections. Through the use of pictures, videos, and Above Ground Level (AGL) measurements will be used to determine the feasibility of drones. The dangers of climbing a tower will be reduced because more boots will be on the ground instead of up on a tower.

Can the use of a drone in examinations make workers more efficient? Sometimes workers make climbs to inspect a tower that has not problems, making it a wasted climb. While the inspection was necessary it could be done quicker and cheaper. In business driven world time is money, and companies do not want to waste time paying workers for activities that can be

replaced by more efficient machines or techniques. The time and quality of work will be compared in a worker climbing a tower and the time it takes for a drone to examine a tower.

Hypothesis

Within this research there are three main hypotheses investigates:

- If a drone can successfully fly around a tower without interference, it can be used for visual inspections.
- If a drone is used for simple visual inspections of towers, the number of injuries and fatalities in the tower work industry will be reduced.
- If a drone is used for simple visual inspections of a towers, the amount of time and money spent on each tower can be reduced

Literature Review

To fully understand why there is a need for a UAV to replace a tower climber one must realize the dangers of the tower climbing industry. Between the years of 2003 and 2016 there were 130 deaths in the United States within the tower working industry (Wirless Estimator, 2017). These deaths ranged from improper personal protective equipment (PPE), structural failure, electrical hazards, inclement weather, and falls from great heights. This was mainly due to the increase in the amount of towers being built and needing to be upgraded. In the 1990s there were around 5,000 different cell towers scattered throughout the United States (Knutson & Day, 2012). However with the emergence of the cell phones more and more towers started to pop up all over the United States. By the year of 2012 there were over 280,000 locations nationwide (Knutson & Day, 2012). While the number of 130 is very small in number compared to other industries, the number of tower workers hovers around 10,000. Between the years of 2003 to 2010 Occupational Safety and Health Administration (OSHA) calculated that the deaths per 100,000 workers would be 123.6. Compared to the construction industry with a number of 10.7 (Knutson & Day, 2012). That number being over ten times more should send a red flag to the tower climbing industry. Even though these numbers were so high the tower working industry did not improve.

On February 10th 2014 OSHA sent a letter to all communication tower industry employers addressing the continued dangers of the industry. In this letter OSHA talked about prior incidents in the industry and "Every single one of these tragedies was preventable" and "it is your responsibility to prevent workers from being injured or killed while working on communication towers" (Michaels, 2014). The letter then went on to address how OSHA "…strongly urge you to do everything you can to prevent these needless injuries and deaths

before anyone else is hurt, and before OSHA issues additional financial penalties" (Michaels, 2014). With the constant dangers within the industry different employers have been looking for ways to improve safety within the industry. This is when the recent emergence of drone has become a major factor for safety improvement.

On September 8th 2014 the mobile giant T-Mobile partnered up with drone manufacturer Aerialtronics to test the abilities of drones to perform visual inspections of different T-Mobile towers (Aerialtronics, 2014). This marked the first collaboration between a drone manufacturer and a telecommunication company. With this agreement T-Mobile was to use Aerialtronics drones to inspect all of their different towers in the Netherlands while keeping human inspectors on the ground (Best Best & Krieger LLP, 2015). This was possible in the Netherlands because of different regulations compared to the United States. Within the United States the FAA (Federal Aviation Administration) has very strict regulations on drones flying. The main reason behind this is to keep the commercial, business, and general aviation community safe. Another test overseas without the regulations of the FAA was done in Dubai in 2015. Nokia Networks was wanting to test their networks at Dubai International Stadium, so they flew drones with smartphones attached to them to test reception throughout the stadium. They then used these same drones to inspect the tower and collect the data from the different towers around the stadium. This data was then stored and delivered to engineers who were able improve the reception at the stadium (Smith, 2015).

The use of any sort of drone to replace a worker for certain jobs was originally an idea from the electrical utility companies here in the United States. The different utility companies were using these drones to inspect their transmission lines, towers, and some wind generators. However, strict regulations from the FAA stopped any real progress until April of 2015 (Esch,

2015). In 2015 the FAA allowed seven utility companies to test the benefits of drones, one of which was Consumer Energy of Michigan. The company was allowed to use drones for these routine inspections. The main process that the company compared was the process of workers examining wind turbine blades. When workers would climb the turbine they were "…hanging off the blades by a rope a couple hundred feet in the air to do inspections visually, at a cost upwards of $10,000 per site.." compared to a drone that kept boots on the ground for only $300 per site (Esch, 2015). The company said that even though there was a larger cost at first to purchase drones and the drone equipment the "cost savings are far greater than the investment" (Esch, 2015).

Within the telecommunication industry the first company to get permission from the FAA to perform these different flights was Solusia Air, an affiliate of Solusia Services. Solusia services is a Dallas based tower builds and modifications and manages services for wireless carriers (Smith, FAA Okays Drones for Tower Inspections, 2015). Solusia Air was founded with the main goal to be able to perform asset audits and safety inspections on different telecommunication infrastructure (Smith, 2015). Solusia Air was able to attach still and infrared cameras to a drone that was then flown around a cell tower. Solusia Air said the inspection was able to produce "high-definition photo and video inspection, asset audits, RF microwave path validation, intermodulation/interference identification and safety assessments" (Smith, 2015). The CEO of Solusia Air, Chris Moccia, said that "It is such a dynamic process at a cell site. Towers are an asset that are always being redone and reworked" and that "As new technologies are deployed, towers need to be audited to document and verify existing configurations and equipment inventories" (Smith, FAA Okays Drones for Tower Inspections, 2015). Solusia Air also started their drone flying by inspecting their own towers. Moccia said "We used it internally

to check the quality of our work and we decided there are a lot of potential uses for the carriers and tower owners" and that "It gives you a lot of data that you might not necessarily get through traditional physical climbs. It is also a lot safer than doing physical climbs" (Smith, 2015). However, even though there was repeated success within multiple industries in the United States and around the world the FAA still had tight regulations stopping any company from using UAVs.

When Solusia Air first started their business they had to apply for a Section 333 Exemption, which they started on back in 2014 (Smith, 2015). This was a burdensome application process with a long waiting time. However this exemption allowed for the company to operate their drones under certain circumstances. This program did not make it easy for any company to get involved with drones in any industry. Especially the telecommunication industry because the FAA did not approve of drones working around towers until April of 2015 (Smith, 2015). However on August 29th of 2016 the FAA introduced FAA Part 107 (McSweeney, 2016). FAA Part 107 is the basic guidelines that are required for a business to legally use drones in most commercial applications. This rule phased out the Section 333 Exemption and removed the long wait list to get acquire the exemption. Within these guidelines it includes requirements for pilot and drone, this includes a new rule that allows a drone to fly 400' horizontally and vertically of a structure (Smith, FAA Opens Door for Drones with New Rules). With this rule it allowed for drone use on any public safety or broadcast drone as well as antennas attached to the top of any building (Smith). With the introduction of this FAA regulation the telecommunication industry was finally allowed to have unrestricted use of drones to perform inspections of different towers.

After the release of FAA Part 107 companies were finally able to easily get UAVs working within their company. Shortly before the release AT&T, one of the largest

telecommunication companies, started to deploy drones in a test program for tower inspections. AT&T has been on the forefront of improving safety conditions in the tower industry in recent years because of their record in the past. Between 2003 and 2010 AT&T had fifteen workers killed in climbing accidents, a number twice that of all other national carriers combined (Knutson & Day, 2012). However, AT&T is out to change that now. To improve the safety of their work AT&T partnered with the drone manufacturer DJI to use their Inspire I drone for inspections of towers. To inspect a tower AT&T would send out a pilot to a job site. They would then fly the drone with a live feed going straight to a technician (AT&T, 2016). The technician could then specify which areas need more inspection and which did not. With this technology AT&T was able to determine what would need to be worked on a tower and what equipment would be needed for a crew when they arrived at the tower site. The use of the drone also allowed for different angles to be seen that a normal worker could not see, such as an overhead view of different parts of the tower. Art Preger, AT&T drone program director, said that "Every time we use a drone it's just one less tower climb…every tower climb that we can save provides a safer situation, or less opportunity for potential injury" (DJI). AT&T plans it will save a significant amount of money because it has over 65,000 towers scattered throughout the United States that are in constant needs of repairs and upgrades (Hamblen, 2016). AT&T had a complete roll out of their drone program in September of 2016.

Methodology

The process of examining different towers with a drone is a procedure that requires planning and pilot skill. When using a drone to examine a tower a certain list of criteria for a tower must be met. First, the biggest and most important factor in examining a tower is to ensure the examination is legal. According to FAA Part 107, a pilot have a line of sight with the drone. Aircraft must not be flown in Class A airspace however it can fly in Class B, C, D and E airspace required Air Traffic Control (ATC) permission. Most often drones will be flying in Class G airspace which does not require any permission. Another rule is that aircraft cannot fly over 400' AGL. However in cases where an aircraft is flying around a structure the 400' rule is exempt, but an aircraft must stay within 400' of the structure.

Second, a tower must be clear of obstacles. If a tower is not clear of obstacles it presents a danger to the aircraft and possibly to nearby bystanders or buildings and equipment. This is also important for the fact that winds differ at heights compared to what they are on the ground. One other factor in towers is the presents of guy-wires. While these support pieces do not eliminate the possibly of examining the tower with a drone it requires greater planning and pilot skill. A tower being clear of obstacles is also important for the slight chance of a radio interference between the aircraft itself and the remote control for the drone. When there is interference a drone will automatically ascend or descend to a predetermined altitude and land from the location where it took off.

The next step in examining the tower is to ensure that the drone is ready to fly. This pre-flight inspection includes ensuring batteries are updated and charged, ensuring blades are properly attached without any damage, ensuring that the camera and mount are in working condition, and lastly ensuring the remote controls the drone. Even though the aircraft will be

flying in an autonomous flight mode is it important to test the controller for if the pilot has to disengage this mode and fly manually. It is also crucial to make sure that the drone is in Global Positioning System (GPS) flight mode for the beginning of the flight. This is done by selecting the "P" mode on the controller for the drone. Besides needing the drone and the remote controller for the drone the operator will need some sort of cell phone or tablet to display the feed from the camera on the drone. This device will have to have the DJI application downloaded. Having some sort of device is critical that way the operator can see the drone's view of the tower.

Once all pre-flight checks have been made the aircraft is finally ready to examine the tower. The drone needs to be placed in an open area for take-off and landing, this is crucial for times when the drone returns to its "home" location. Its home location is an area where the GPS automatically makes a drone return to when it has a low battery or loses signal with the remote. Once in the open area the drone and remote needs to be turn on. The drone can then be started by the remote by holding both sticks downward. Once the drone blades are spinning the drone is ready for take-off. To ensure proper connection between the remote and drone and to ensure no mechanical problems with the drone it is crucial that the pilot test all flight controls. Once the test is completed the drone is ready to examine the tower.

Now that the drone is ready to examine the tower the first step is getting the drone to whatever altitude is needed for the examination. This all comes down to the tower, how the tower is built, and whatever the drone is specifically looking at on the tower. When the drone is at the desired altitude the drone needs to be switched over to the autonomous flight mode, or F mode, on the controller. Once this is completed a screen will pop-up on the DJI app. There will be three different flight modes available, one of which is point of interest (POI). Once this is

selected a center point is selected and then the operator selects how far the radius of the flight will be. From there the drone will start flying around the tower with the camera always facing the tower. When this starts the operator has the choice to either take pictures at certain intervals or record video of the point. As the operator is letting the drone fly they can adjust the radius around the point or increase/decrease the speed of drone. The aircraft will stay in the POI flight mode until the operator manually turns it off.

After gathering pictures and videos from the first POI flight the pilot can adjust altitude and see different parts of the tower. Once the initial examination is completed the operator on the ground can review the photos taken by the drone. This is when an operator can decide if they want to further examine any part of the tower. If an operator does want to examine more closely they can once again do this with the drone. In this flight every pre-flight routine is the same. However, when it comes to flying the operator does not need to use the POI flight mode. Instead the operator will manually fly the drone to examine the area they desire. This is when precision flying is required by the pilot that way no harm is done to the tower or to the drone. Once the operator is completed with this flight they can examine the photos and decide if an actual climb up the tower is needed or if it is not.

Results

With the use of a UAV for inspecting towers both clear pictures and video were able to be captured. These pictures and videos were captured at various heights and angles of the tower thus allowing for clear inspections of all parts of the tower. These different pictures and videos were able to be taken at different lengths from the tower. This means that broader pictures of the tower can be taken but if certain areas need a closer look the drone was able to zoom in closer. The pictures and videos that were taken were then able to be inspected for damage or wear on the tower.

The process of setting up the drone and flying was also measured. In this part of the experiment the time from setup to takeoff was less than ten minutes. This included all pre-flight inspections on the drone and the controller. The drone could also effectively examine a tower from different angles in less than one hour. If the drone just needed to check it certain spot on the tower it could take less than ten minutes of flight time. The longest part of the inspection was typically setting up the POI flight mode. This is because the center point must be marked and this can only be done by flying above the center point. In the case of the towers the drone would have to either flight extremely close to the tower or fly above it. Both of these maneuvers can be very difficult and to ensure no damage is done to tower or drone is must be done with caution.

When it came to flying the drone for inspection purposes there were a few factors that affected the ability of drone. The biggest factor is flying the drone is weather. While the drone was able to lock-in at certain points because of GPS that wind still strongly effects the drone. It was always much easier to fly the drone in GPS mode instead of manual flight mode. Other factors with the weather were humid and temperature. While only slight difference the drone tended to perform better when temperatures were cooler and less humid. Another factor that was

not noticed in this experiment is possible radio wave interfere between the controller and the drone. This could result in losing control of the drone, however there was no inference in flights.

Conclusions

To conclude the research the use of an UAV drone can greatly increase both the safety and efficiency of the tower work industry. There were three main research questions that were to be evaluated. This three questions would help in determining if the use of a UAV was in fact the better alterative in the tower working industry. These three questions were can a drone successfully perform a visual inspection of a tower, will the drone's ability to examine a tower eliminate the need for a worker to climb the tower for simple inspections, and can the use of a drone in examinations make workers more efficient?

Can a drone successfully perform a visual inspection of a tower? Through this research it was proved that a drone can successfully perform a visual inspection of a tower under proper conditions. Under certain conditions it is recommended to not use a drone to inspect a tower. This can be instances where a certain tower is un-flyable because of factors such as guywires, proximity to other building or objects. The biggest factor that can make ground an UAV and stop a flight is the weather. Because of the close proximity that a drone will be in towards a tower it is recommended that the winds not be above certain speeds. With proper weather conditions, a proper location and type of tower, and a competent drone pilot an UAV can successfully perform a visual inspection of a tower.

Will the drone's ability to examine a tower eliminate the need for a worker to climb the tower for simple inspections? As answered in the previous questions a drone can successfully

perform a visual inspection of a tower. Because of a UAVs ability to capture both clear photographs and videos a tower worker can inspect a tower from the ground. It is undeniable however that a tower worker could perform a more thorough visual inspection than what these drones can. However by allowing the use of drones to perform this inspections a company can keep its tower workers from having to climb a tower therefore eliminating the main hazard of working at heights. If a tower worker is supplied the appropriate drone and drone equipment they can replace a tower climb with a drone flight for simple visual inspections.

Can the use of a drone in examinations make workers more efficient? Most often when a tower worker climbs any type of tower it takes a significant amount of time to both climb up and then climb down the tower. When these climbs are for a simple inspection and there is nothing wrong with the tower is can be a waste of time for the worker and waste of money for the company. A drone can successfully inspect a tower in under thirty minutes compared to the possible hours it would take a worker to climb. Therefore by using a drone to perform these simple inspections it can eliminate the need for these unnecessary climbs. By allowing workers to use a drone to perform simple visual inspections a worker can become more efficient. If a tower worker is supplied with the proper equipment they can effectively reduce their time on a job site.

Recommendations

Moving forward with this technology it is recommended that workers within the field start to implement this technology. The conditions that were tested through this research were under very controlled conditions are days when the weather was calm and on towers that were not in need of current repairs. To truly test if a tower worker needs some sort of drone within their tool bag they need to test it out and figure out if it is something they want and need.

However, regardless of if workers believe it less efficient than a normal climb it is still recommended to implement just because of the safety within the use of a drone.

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