Prospectus

Commanding Unmanned Assets for Search and Rescue
(Technical Topic)

Actor-Network Theory and the Boeing 737 MAX 8 Accidents
(STS Topic)

By

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Introduction

Hiking is becoming increasingly popular in the United States. The number of hikers in the United States increased by 34% from 2015 - 2020 (Carney, n.d.). Search and Rescue (SAR) teams throughout the country are beginning to implement drone technologies into their operations. Drones are able to search more quickly than ground teams, increasing mission speed while reducing risk to searchers.

SAR teams are currently focusing drone integration efforts on camera-equipped drones. Although these drones have been shown to be effective, their usefulness can be mitigated by environmental factors, such as trees (Wallace, 2013). SAR teams may also lack the infrastructure necessary to process the video and/or still photographs in real time (Snohomish County Volunteer Search and Rescue [SCVAR], 2018). A drone constellation that uses cell phone sensors may be more efficient. Although cell service can be sparse around hiking trails, hikers frequently carry their cell phones. However, for this system to be effective, drones and humans must be able to work together as a team. To aid human-machine teaming, a visual representation displaying information on the drone constellation and the phone signals detected will be created. This visual representation will then be used by a human operator to direct SAR personnel on the ground.

However, a purely technical approach fails to take social factors into consideration. As more systems are integrated together, the opportunities for failure grow. The Boeing 737 MAX 8 accidents in 2018 and 2019 illustrate how decisions can propagate and cause system failures. Avoiding analysis of social factors leads to an incomplete understanding of the problem. Including social factors and using Actor-Network Theory can provide a more complete analysis and enhance efforts to prevent future accidents.

As the role of autonomy increases, the importance of finding solutions that address both technical and social aspects also increases. Clear communication between team members is vital to the success of human-machine systems. The technical components of creating a visual representation for human operators will be described while highlighting the dangers of unclear communication throughout a system.

Technical Problem

In 2007, approximately 3,600 search and rescue (SAR) incidents were reported to the National Park Service (Heggie & Amundson, 2009). This number increased to over 4,000 SAR incidents in 2017 (National Park Service [NPS], n.d.). This increase in incidents strains the current SAR infrastructure, leading to increased time and costs. In 2017, 84,000 man hours were spent on SAR incidents, resulting in a total cost of over 3 million dollars (Vollman, 2019). Reducing the time spent searching also increases the likelihood that the lost individual will be found alive. Time is one of the best predictors of survival (Adams et al., 2007).

To speed up search missions, SAR teams are currently in the process of integrating drone technologies into their efforts. In 2016, Albemarle County in Virginia was gifted a DJI Phantom 3 for search and rescue purposes (Baars, 2016). Snohomish County Volunteer Search and Rescue (SCVSAR) in Washington state began implementing drone technologies in late 2017 (SCVAR, 2018). In 2019, King County Search and Rescue in Washington state was able to use a drone to determine that a man who had fallen into a river was no longer in the water. This reduced the risk to the search team and sped up the mission overall (Flatt, 2020).

Currently, SAR teams are using drones equipped with cameras. However, the effectiveness of these cameras can be significantly reduced by trees and vegetation (Wallace, 2013). Search and rescue teams also may not have the infrastructure necessary to effectively use the technology. SCVSAR is currently determining what tools are necessary to process the information in real time from the drone so the information can be effectively used (SCVSAR, 2018). Additional considerations are also necessary when using drone technology. Tradeoffs must be made between live video, which may limit range, or higher quality photographs/video, which takes more time to process (Wallace, 2013).

As drone technologies are implemented in SAR operations, human-machine teaming becomes increasingly important. A lack of effective teaming can cause a breakdown in coordination between the human and the machine, increasing total mission time and reducing effectiveness. Interdependence between humans and robots is extremely important. Acting as a team allows both the human and the machine to operate at their strengths and increases adaptability (Lematta et al., 2019). Ensuring reliable and trustworthy communication in drone-human teams will only increase in importance as the role of autonomous vehicles in SAR operations increases.

As the number of SAR incidents rises, it is paramount to ensure that resources are used effectively and efficiently. According to Modern Conservationist, hikers “often rely on their cell phones as their first line of defense” (Vollman, 2019). Although many hiking trails and rural areas lack cell service, hikers often carry their cell phones. A drone constellation composed of drones with cell phone sensors could speed up rescue efforts.

To facilitate human-machine teaming, a visual representation that displays information about the drone constellation and the phone signals detected will be created. This visual representation will be used by a human operator to direct search and rescue personnel on the ground.

Mock-up tools, such as Figma, will be used to create the interface. Frequent client meetings will occur to evaluate usability and ensure that appropriate use cases are considered. Continuous iterations on the visual representation will occur to ensure that the final design facilitates effective communication between the drone constellation and the operator, leading to effective communication between the operator and the ground team.

STS Problem

On October 29, 2018, Lion Air flight 610 crashed into the Java Sea in Indonesia. Less than a year later, on March 10, 2019, Ethiopian Airlines flight 302 crashed in Ejre, Ethiopia (National Transportation Safety Board [NTSB], 2019). There were no survivors of either accident. Three days later, on March 13, 2019, the Federal Aviation Administration (FAA) grounded all Boeing 737-8 and Boeing 737-9 aircraft. The aircraft for both flights was a Boeing 737 MAX 8 (United States Department of Transportation Federal Aviation Administration [FAA], 2019a).

Media coverage has frequently highlighted the Maneuvering Characteristics Augmentation System (MCAS) as the cause of these accidents. Designed to improve pitch stability, MCAS prevents the aircraft from pitching-up. It uses data from hardware outside the aircraft to determine the angle of attack. At elevated angles of attack, MCAS is activated. (Boeing, n.d.). Before both accidents, MCAS was deployed multiple times, repeatedly pitching the nose of the aircraft down (NSTB, 2019). Both the angle of attack and airspeed determine the duration of MCAS deployment (FAA, 2020a).

However, as the margin for error for commercial aircraft flying in FAA airspace is miniscule, the development of MCAS had to follow a thorough and detailed aircraft certification process. To comply with certain Federal Aviation Regulations requirements, catastrophic failure conditions must occur with a probability of 1 x 10^{-9} or less. Catastrophic failure conditions are classified as “failure conditions that would prevent the continued safe flight and landing of the airplane” (FAA, 1988).

Before the grounding of the 737 MAX 8 on March 13, 2019, the 737 MAX 8 had approximately 8,600 successful flights a week (Lu et al., 2019). As the 737 MAX 8 is considered a derivation of the Boeing 737 Next Generation (NG) aircraft, it was certified by the FAA with an Amended Type Certificate (FAA, 2020b). However, the 737 MAX 8 has “larger and more powerful engines” than the 737 NG. The engines on a 737 MAX are “installed higher and farther forward” than those on a 737 NG. Installation of MCAS was necessary to meet FAA certification standards and provide 737 MAX pilots with a similar experience to flying a 737 NG aircraft (FAA, 2020a). The certification process took approximately five years. The FAA does not allow companies to certify their aircraft themselves (FAA, 2020b).

The aircraft used for Lion Air flight 610 provided faulty data for both the speed and altitude on its previous flight (Gröndahl et al., 2018). Data from the digital flight data recorder (DFDR) reveals a discrepancy of approximately 20 degrees between the left and right angle of attack sensors that was present until the end of the recording (NTSB, 2019).

Pilot response to the MCAS alerts differed from what was expected. Boeing and the FAA assumed that “the pilot would take immediate action to reduce or eliminate increased control forces” and “trained flight crew memory procedures shall be followed to address and eliminate or mitigate the failure”. This did not occur. The alerts and indications did not cause the pilots to act immediately (NTSB, 2019). The flight crew of Lion Air flight 610 also did not have the procedures memorized, instead referring to a printed manual (Baker, 2019).

Viewing MCAS as the single-point failure in the Boeing 737 MAX 8 accidents is a catastrophic mistake. Considering other factors involved in these accidents will provide greater understanding of the system breakdown leading to the Boeing 737 8 MAX accidents. Factors from the aircraft design, certification, and assumptions on pilot response significantly contributed to the accidents. To support this argument, I will use documents such as the "Preliminary Summary of the FAA's Review of the Boeing 737 MAX" and the NTSB accident report.

Drawing on Actor Network Theory (ANT), MCAS in conjunction with the previously stated factors led to the Boeing 737 MAX accidents. Connecting social and non-social factors, ANT analyzes how network builders combine human and non-human actors to accomplish goals (Cressman, 2009). Utilizing ANT will allow the reader to understand the flaws in selecting a specific factor as a single-point failure. The breakdown of a system or network, not of one technology, caused these systems failures/accidents involving the Boeing 737 8 MAX.

Conclusion

Throughout this paper, the importance of both social and technical factors when designing integrated systems has been emphasized. The role of autonomous systems will likely continue to grow. Effective communication and resilient systems will become increasingly important as systems are integrated. To improve communication and facilitate human-machine teaming, a design of a visual representation for human operators of a drone constellation has been proposed. This visual representation will display information on the drone constellation, as well as the phone signals it detects. Improving teamwork and building off the strengths of both humans and drones will make SAR operations more efficient. Additionally, the importance of considering multiple points of failure will be analyzed using the Boeing 737 MAX 8 accidents as a case study. Actor Network Theory will be used in this analysis, helping showcase how decisions can propagate throughout a system, leading to disastrous outcomes.

Ultimately, more complex systems are more error prone. Assigning blame of a system failure to an autonomous system may seem like the simplest solution. However, system failures are rarely caused completely by a single-point failure. Searching for a single-point failure can hinder analysis, preventing potential necessary changes from being discovered and implemented. Humans and autonomous systems must work together as a team and communicate effectively with each other. As autonomous systems are given more responsibility, the importance of considering the entire system increases exponentially. Creating a visual representation that clearly communicates information to the human operator from the drone constellation enhances teamwork while reducing error.

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