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Project Title

Remote Sensing of Transportation Assets Using Drones and Artificial Intelligence

University

North Dakota State University

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Research Needs

The rapid acquisition, processing, and visualization of data can enhance the effectiveness of transportation planning, traffic operations, and incident response. Hence, agencies can benefit from data sensed remotely from transportation assets like roads, bridges, railroads, pipelines, freight yards, rights-of-way, and other essential assets such as signs and signals. So far, however, the remote sensing of transportation assets has been based primarily on satellite images, video, or photography from manned aircrafts. The commercial development of unmanned aircraft systems (UAS), commonly called drones, can enable remote sensing with many advantages because drones can generate more information, faster, at lower cost, and more safely. The intersection of artificial intelligence (AI) methods and sensor packages can further enhance those advantages (Figure 1). Research at the intersection is essential to understand its potential utilities.

Drones can enhance worker safety and efficiency by remotely gathering much of the field data needed to study traffic density, land topographies, jobsite characteristics, and asset condition. Despite the potential benefits and advantages, remote sensing using drones is still in its infancy because of many complexities and uncertainties about the required technologies, deployment constraints, and operating characteristics. Furthermore, an application must use the appropriate type of *drone* and *sensor* payloads, depending on the type of transportation *asset* inspected.

Downstream data processing and model building using *artificial intelligence* (AI) methods needs customization and training to monitor different asset types. Each of the four areas shown in Figure 1 are themselves vast and complex. Therefore, the **goal** of this research is to distill and identify essential characteristics at the intersection of drones, sensors, and AI methods to advance applications in the remote sensing of transportation assets.

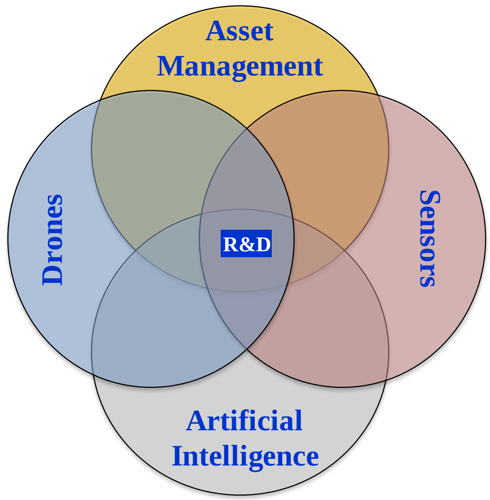

Figure 1: Intersection of research needs.

There are many operational, regulatory, and cost constraints when using drones to inspect different types of transportation assets. For example, winged aircrafts operating beyond visual line of sight (BVLOS) may work better when sensing long linear structures such as rail, roads, and pipelines because winged aircrafts can travel longer distances and carry heavier sensor payloads than rotary aircrafts (Sherrock & Neubecker, 2018). In contrast, rotary aircrafts can provide the needed maneuverability, including hovering, to inspect bridges and yard facilities, while avoiding the more restrictive and expensive BVLOS operation (Feroz & Dabous, 2021). Similarly, pattern matching algorithms using one or more methods of machine learning may work better on remotely sensed data from long linear structures whereas deep learning networks may work better on images of bridge structures and yard equipment. The image resolution available from different types of drones and sensor packages also affects the performance of different AI methods. Further research to refine and test the various hypothesis will fill knowledge gaps and guide application and standards development.

Research Objectives

The civilian market for drones is vast, rapidly growing, and has created a rather complex landscape of commercial ecosystems. Potential applications beyond remote sensing include cargo and passenger logistics for a wide variety of middle-mile and last-mile services (Kellermann, Biehle, & Fischer, 2020), law enforcement, and automated farming applications such as pesticide and fertilizer application. Therefore, research must sort out the *taxonomy* of drone applications and roadmap to focus on those that support and advance the remote sensing of transportation assets. Even so, there is a wide variety of transportation assets, each with their own set of operational considerations and constraints for software and hardware.

North Dakota is one of only seven testbeds designated by the Federal Aviation Administration (FAA) to develop strategies that will safely integrate UAS into the national airspace system. With one of the largest investments in the U.S., the state of North Dakota has invested more than $50 million on UAS infrastructure to support BVLOS operations across the entire state. This extensive BVLOS network will be the first in the nation to enable more efficient remote sensing of surface transportation assets. Therefore, this research will seek to leverage knowledge, data, and lessons learned from the unique statewide BVLOS deployment. The research team will seek expert advice from the Northern Plains UAS Test Site (NPUASTS) to further the research objectives. The NPUASTS expertise includes flight planning, operations, communications, navigation, surveillance, and aircraft command and control systems.

Although there is a potential for a deluge of data from remote sensing applications, non-proprietary datasets from remote sensing are currently scarce. Hence, the research team will seek to identify publicly available datasets of remotely sensed data from any type of transportation asset. The team will also determine the potential for data fusion with other datasets that can offer additional insights beyond the body of knowledge currently available in standalone remotely sensed data. Exploratory data analysis of those datasets will yield knowledge, experience, and insights in remote sensing. The literature review will expose knowledge gaps that the team will seek to address by applying data fusion and AI methods. The non-technical objectives are workforce development and technology transfer. Hence, the summary of research objectives are as follows:

1. Develop a taxonomy on the remote sensing of surface transportation assets
2. Classify drone technologies and their operating considerations
3. Classify relevant sensor payload technologies and their performance expectations
4. Classify AI methodologies that would be relevant to processing remotely sensed data
5. Map drone technologies, sensor technologies, and AI methodologies to each potential transportation application
6. Identify relevant datasets to fuel research in AI algorithm and model development
7. Workforce development
8. Technology transfer

Research Methods

The research methods will include several literature reviews to assess the state of the art in remote sensing, drone technology, sensor technology, and AI methods. Subsequently, the team will develop a cognitive framework that will help map technologies to applications by considering their various operating and regulatory constraints (Bridgelall & Tolliver, 2020). Stakeholder engagement with North Dakota Department of Transportation and the NPUASTS will help to identify gaps in the research. The following summarizes the research methods:

1. *Application Taxonomy*: review the literature to scope the various transportation asset management applications that can benefit from remote sensing using drones.

2. *Drone Technology Assessment*: review the literature to scope the characteristics, capabilities, and roadmap for drones with respect to their relevance in the remote sensing of surface transportation assets. Technical challenges to study will include autonomous flying capabilities, flying BVLOS, safe airspace integration, battery capacity, and data communications.
3. *Sensor Technology Assessment*: review the literature on sensor payloads that are suitable for drones and map their relevance and roadmap to applications in the remote sensing of surface transportation assets.
4. *AI Methodologies*: review the literature on artificial intelligence methodologies and map their utility to remotely sensed data of surface transportation assets.
5. *Implications*: Identify areas for standardization and future research based on the intersection of potential remote sensing applications for transportation asset management, and the capabilities and roadmaps for drones, sensors, and AI methods. Adoption challenges to study include compliance with evolving FAA regulations, threats to privacy, threats to physical safety due to potential crashes, and social or legal issues that may arise from misuse, crime, or terrorism.

Expected Outcomes

The expected outcomes are educational benefits and technology transfer to support business development and to guide future standardization activities on using UAS for remote sensing. The findings will support broad initiatives within North Dakota to expand remote sensing applications that can utilize the statewide deployment of a beyond visual line of sight (BVLOS) network. Stakeholder engagements will help to enrich the study with practical considerations based on real-world needs. Planners will gain an understanding of how the technology roadmap will affect the potential for future adoption within the state, nationally, and internationally. Planners will evaluate the identified adoption challenges and relate them to local issues that will guide policymaking to encourage adoption. Gaps identified in the literature will generate ideas for future research. The final report will serve as a reference baseline for knowledge gained in this snapshot of the technology evolution and will serve as a benchmark to evaluate impacts from future developments.

Relevance to Strategic Goals

This study relates to the strategic goal of *State of Good Repair* because the remote sensing of surface transportation assets using drones and AI will enhance the safety and efficiency of asset management practices to promote sustainability and preservation.

Educational Benefits

The project will include at least one graduate student who is working towards a Ph.D. The student will incorporate some of the methodologies and findings of the project into a dissertation. The PI will advise the student in both an academic and professional development capacity. The project will help the student hone research, presentation, and writing skills needed for advancements in the professional world. The broader educational benefits will be knowledge products and tools that feed into curricula development and laboratories in multimodal transportation systems. The PIs intend to incorporate knowledge and models from this research into curricula focused on intelligent transportation solutions.

Technology Transfer

Students will gain expertise in remote sensing technology to enhance practices in surface transportation asset management. The research team will utilize the project findings and models to prepare publications and outreach material that would encourage further adoption in the real world. Knowledge gained from the project will inform standards development with the aim to scale and reduce the cost of using drones in a variety of transportation asset management applications. Adoption of the methods will release the scarce time and expertise of professional engineers and planners for more effective use. The team will utilize traditional methods such as journal papers, conference presentations, project reports, web page postings, and other marketing or outreach materials. In addition, the team will engage stakeholders throughout the project to review intermediate findings and to suggest future research directions. The PIs will notify the progress-reporting system (PPPR) of any publications generated from this project, as well as technology transfer activities.

Work Plan

The work plan consists of the following tasks that the team will complete over a two-year period, with the month indicated relative to the project start date:

1. *Taxonomy of Applications*: Starts and ends in the 1st and 6th month, respectively.
2. *Drone Technology Classification*. Starts and ends in the 7th and 12th month, respectively.
3. *Sensor Payload Classification*. Starts and ends in the 10th and 15th month, respectively.
4. *AI Methodology Classification*. Starts and ends in the 13th and 18th month, respectively.
5. *Technology-Application Mapping*. Starts and ends in the 16th and 24th month, respectively.
6. *Dataset Research*. Starts and ends in the 13th and 21st month, respectively.
7. *Stakeholder Engagement*. Conducted throughout the project.
8. *Final Report*. Starts and ends in the 19th and 24th month, respectively.

Project Cost

Total Project Costs:	$366,000
MPC Funds Requested:	$183,000
Matching Funds:	$183,000
Source of Matching Funds:	In-kind contributions from private sector UAV service providers, contributed time from state agency partners, and NDSU returned F&A.

References

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