Unmanned Aerial Systems for Pipeline Inspection, Monitoring, and Landscape Analysis

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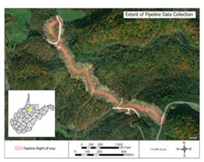
Executive Summary:

The Appalachian region of the United States has experienced significant growth in the production of natural gas. Developing the infrastructure required to transport this resource to market creates significant disturbances across the landscape, as both well pads and transportation pipelines must be created in this mountainous terrain. Midstream infrastructure, which includes pipeline rights-of-way and associated infrastructure, can cause significant environmental degradation, especially in the form of sedimentation. The introduction of this non-point source pollutant can be detrimental to freshwater ecosystems found throughout this region. This ecological risk has necessitated the enactment of regulations related to midstream infrastructure development. Weekly, inspectors travel afoot along new pipeline rights-of-way, monitoring the reestablishment of surface vegetation and identifying failing areas for future management. The topographically challenging terrain of West Virginia makes these inspections difficult and dangerous to the hiking inspectors. We evaluated the accuracy at which unmanned aerial vehicles replicated inspector classifications to evaluate their use as a complementary tool in the pipeline inspection process. We investigated the use of various sensors to determine the most cost-effective methodology for performing pipeline monitoring and analysis in Appalachia. We found RGB and multispectral sensor collections combined with a support vector machine classification approach to be effective at predicting vegetation cover. Using inspector defined validation plots, our research found comparable high accuracy between the two collection sensors. This technique displays the capability of augmenting the current inspection process, though it is likely that the model can be improved further. The high accuracy thus obtained suggests valuable implementation of this widely available technology in aiding these challenging inspections. The UAV-based remote sensing approach can aid in the inspection of erosion and sediment control features as well as support overall pipeline safety, inspection, and management.

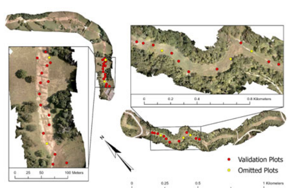
Study Area:



DJI Matrice 200 V2 equipped with Sentera 6X Multispectral sensor

RGB orthomosaic of the study area displayed over satellite imagery
Approximately 2.3 km of natural gas pipeline used as study area for the UAV based evaluation of vegetation success in Northern West Virginia, USA. a) The full extent collected along the pipeline, with the area of vegetation assessment marked with red crosshatch. b) An expanded view of area enclosed in a) to enable a detailed view of the surface at the site. Note the surface variance in vegetation and disturbance in the linear pipeline area as compared to the surrounding agricultural field.

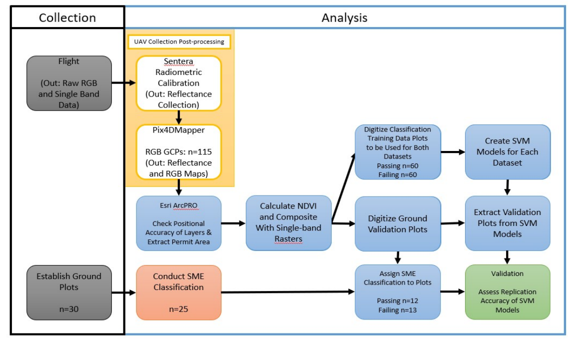
DJI Matrice 600 Pro equipped with the RedTail RTL-400 LiDAR System

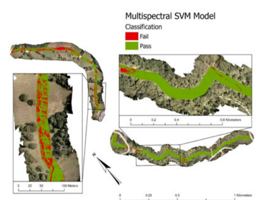


RGB Photogrammetry colorized point cloud of the pipeline right-of-way

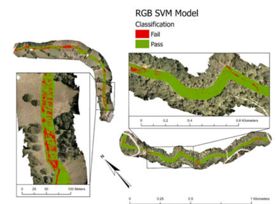
Location of the ground validation plots established in the study area. Inserts show each of the allowed access areas of the pipeline. Red indicates plots used for validation and yellow indicates omitted plots

Work Flow:

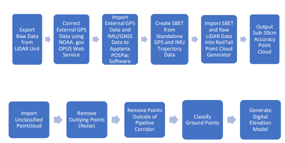


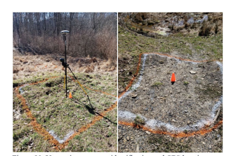


SVM classification model of the multispectral dataset using blue, green, red, and NIR bands with NDVI included. Green and red pixel color indicate passing or failing respectively as determined by the model. Inserts are included for a more detailed look at the extent available for validation plots. Spatial resolution of this model is 0.042 m



SVM classification model of the RGB dataset. Green and red pixel color indicate passing or failing respectively as determined by the model. Inserts are included for a more detailed look at the extent available for validation plots. Spatial resolution of this model is 0.063 m



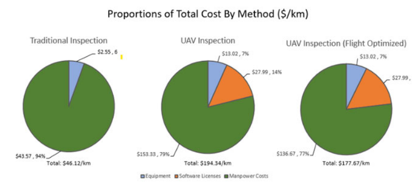


Vegetation coverage identification and GPS location

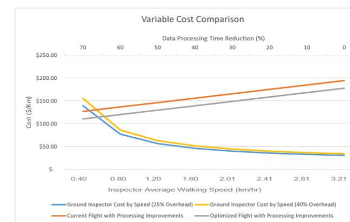
Conclusion:

With an explosion of innovative use cases within academia, government, and industry, we find that UAV-based remote sensing systems and their array of valuable data outputs display an immense opportunity to increase safety, efficiency, and accuracy within the oil and gas industry. In addition, limitations of these remote sensing systems and their outputs in an oil and gas setting are defined. Further technological advancements, improvements in U.S. FAA UAV and airspace policy, and continued research has shown to increase widespread implementation of these systems. Augmentation of foot inspections with the application of UAVs and remote sensing systems stands to increase safety and efficiency of current methods especially when FAA visual line-of-sight laws are waived. This research inquired the utility of a suite of current UAV remote sensing technologies identifying possible applications of their data outputs. There is no doubt these technologies will change rapidly, becoming ever more advanced and practical with diminishing costs. However, we find in their current state that UAV and remote sensing systems hold significant promise regarding the support of pipeline safety, inspection, and management with the results of this study demonstrating the advantages and disadvantages of each system and approach.

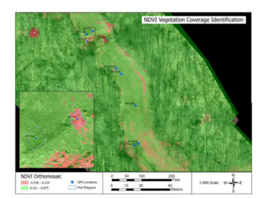
Results:



Charts depicting the proportion of each inspection method's cost categories. The three categories depicted are equipment, software licenses, and manpower in blue, orange, and green respectively. Total per kilometer costs are given below each chart



Cost trends per kilometer are shown including the variables of inspector speed and processing time reduction. Inspector speed is shown on the lower axis and increases from left to right. Data processing time reduction by percentage is shown on the upper axis and increases from right to left. Ground inspector plots show both a 25% overhead and 40% overhead in blue and yellow respectively. Similarly, drone cost with and without flight optimization are shown in grey and orange respectively. Note that the costs cross near 0.25 mph and 70% time reduction. This shows the point where cost per kilometer are lower using the drone inspection method.



UAV Multispectral NDVI Photogrammetry of pipeline right-of-way vegetation coverage