toward multi-modal, uav-based UXO and landmine detection: development of a tetrahedral magnetic gradiometer

*Heidi Myers, University of Maryland, College Park, MD, USA*

*Vedran Lekic, University of Maryland, College Park, MD, USA*

*Daniel Lathrop, University of Maryland, College Park, MD, USA*

The global landmine, unexploded ordnance (UXO), and explosive remnants of war (ERW) crisis is a >$200B USD problem that experienced a recent fivefold increase in civilian casualties due to conflicts in places such as Ukraine. A terrain-adaptable, geophysics-based detection method is needed. Single-sensor unmanned aerial vehicle (UAV) methods often produce false flags, while current multi-sensor systems are ground-based, cumbersome to transport to remote sites, and put operators dangerously close to potential blast radii. Understanding how geologic and environmental conditions affect the geophysical signatures of buried objects is crucial for making progress and reducing false flags. We are developing a UAV-compatible, multi-sensor package that utilizes machine learning (ML) to evaluate terrain and environmental conditions, and weight onboard geophysical instrument(s) data to accurately detect anomalies and quantify detection confidence levels. One of the techniques we are incorporating is magnetometry, utilized frequently in both ground and aerial surveys. Slung-loaded total field magnetometers are commonly used in UAV-based surveys, but the lack of component information limits the ability to infer the orientation**,** burial depth**,** and magnetic moment of detected objects. Fluxgate magnetometers provide component information but suffer from calibration errors and noise due to orientation inaccuracies when used in isolation. To overcome some of the practical limitations of using a single fluxgate magnetometer, we have developed a magnetic gradiometer system consisting of four triaxial fluxgate magnetometers arranged in a tetrahedral configuration. Leveraging information obtained from examining the gradients between components of each fluxgate, we are able to streamline calibration efforts, and mitigate spatial variations that result from space weather and cultural noise sources. Here we present initial results from our magnetic gradiometer system for detecting inert landmines and proxy UXO in a controlled sand bed testing site and compare them to synthetic data. We examine the utility of multiple invariants derived from the full magnetic gradient tensor and explore their merit for ML-based detection and classification. Finally, we discuss noise-reducing techniques to enable rigidly mounting the system on a UAV. We gratefully acknowledge the support of NSF Grant No. IIP2044611 and DoD NDSEG Fellowship.