**Abstract**

**Drone + A.I. Integration Assessment of Bridge Infrastructure**

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Aging bridges across the United States face increasing risks from **structural fatigue, corrosion, and environmental degradation**, placing public safety and economic stability at stake. Traditional bridge inspection methods, which rely heavily on manual assessments, are labor-intensive, time-consuming, and limited in precision. To address these challenges, this project develops an **AI-integrated drone inspection framework** designed to **detect, classify, and quantify structural anomalies** with greater speed, accuracy, and scalability.

At the core of this system is a **phased inspection pipeline** that integrates advanced imaging, computer vision, and machine learning techniques:

* **Phase A — Manual Image Assessment:** High-resolution RGB images are combined with thermal data to establish baseline conditions. Using **Python-based visualization tools**, anomalies such as cracks and rust patches are manually identified for model training.
* **Phase B — Quantitative Defect Metrics:** Custom algorithms measure **crack width, length, and rusted surface area**, producing quantitative indicators for risk scoring.
* **Phase C — RGB + Thermal Hotspot Overlays:** RGB imagery is fused with **simulated thermal hotspot data** to highlight regions of potential structural compromise.
* **Phase D — CNN + LLM Integration:** A **hybrid deep-learning approach** leverages **Convolutional Neural Networks (CNNs)** for segmentation and an **LLM-driven reasoning layer** to enhance classification, creating an adaptive framework for anomaly detection and severity categorization.
* **Phase E — Quality Assurance & Risk Scoring:** Outputs are validated using structured **Excel-based classification logs** and expert annotations, while a multi-factor scoring model classifies anomalies as **low, medium, or high risk** based on **size, intensity, and frequency**.

All processes are consolidated into a **Jupyter-based pipeline** for reproducibility and scalability, enabling seamless future integration into **autonomous drone operations**. Beyond immediate academic objectives, this research lays the groundwork for **real-time bridge health monitoring**, supporting predictive maintenance strategies and improving infrastructure resilience.

By merging **RGB and thermal analytics** with **AI-driven anomaly detection**, this project demonstrates a transformative approach to bridge inspection. It reduces operational costs, minimizes safety risks to inspection personnel, and accelerates the identification of high-priority repairs. This work represents a vital step toward **next-generation infrastructure monitoring systems** capable of supporting both **civil engineering applications** and potential **DoD-aligned missions** requiring advanced drone-based intelligence.