PhD Program in Civil, Chemical and Environmental Engineering

Curriculum in Fluid Dynamics and Environmental Engineering

June 2025 Call, XLI cycle - Starting date: November 1 st 2025

The research project submitted for the admission to the PhD program must be prepared in accordance with the project listed in this file. Click on the Thematic you are interested in to see the full list of projects.

Project: Detection of Objects from Satellite Images Using Inverse Design and Artificial Intelligence

Keywords: fluid dynamics, optimization, detection, neural networks, features

Brief Description:
This project focuses on the development of an advanced framework for detecting objects such as airplanes, ships, and other strategic targets from satellite imagery, leveraging the power of artificial intelligence (AI) combined with inverse design principles. The aim is to enhance the accuracy, speed, and robustness of object detection in complex and often cluttered environments, which is critical for applications in defense, maritime surveillance, and disaster response. Traditional object detection methods rely heavily on direct pattern recognition using handcrafted features or conventional deep learning. However, these approaches can struggle in scenarios with occlusions, varying resolutions, or low-contrast imagery. To address these challenges, this project introduces an inverse design methodology—a concept borrowed from physics and engineering design—where the desired output (object detection) guides the optimization of model architecture and feature representation.
The core of the system is a hybrid AI model incorporating convolutional neural networks (CNNs) and transformer-based architectures for spatial feature extraction and context-aware analysis. The inverse design loop iteratively adjusts model parameters and feature prioritization by evaluating detection performance against known object configurations and environmental conditions. Synthetic data generation and augmentation techniques further enhance the training process, allowing the model to generalize well across diverse geographies and lighting conditions.
The system will be trained and validated using publicly available satellite datasets (e.g., xView, DOTA, and SeaDronesSee) and proprietary imagery. Performance metrics demonstrate a significant improvement in detection precision and recall over baseline models, particularly in detecting small, camouflaged, or partially obscured objects.
Key innovations include:

- **Integration of inverse design principles into AI model optimization.**
- **Use of attention mechanisms for better localization in complex scenes.**
- **Adaptive learning with synthetic and real-world data to improve generalization.**

This project represents a step forward in remote sensing and automated surveillance, offering a scalable and adaptable solution for object detection from high-resolution satellite images. The methodology also provides a foundation for future applications, including environmental monitoring, border security, and search and rescue operations.

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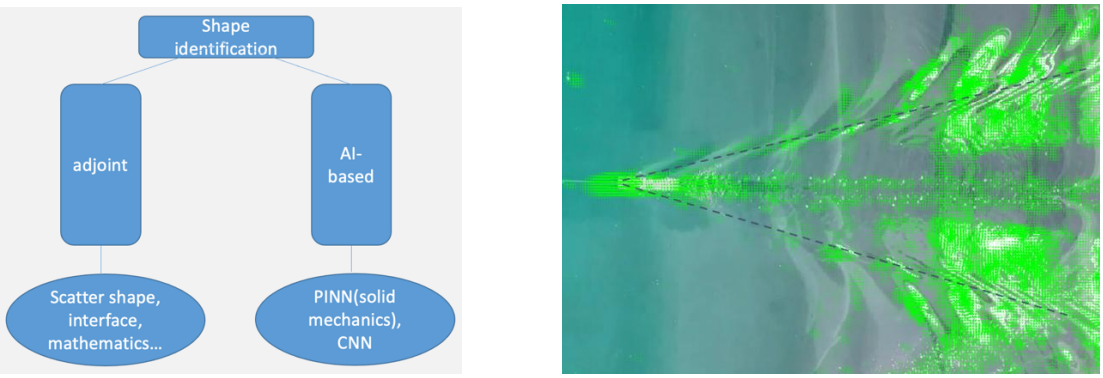

Figure: theoretical framework (left), sample of satellite image of ship wake (right)