Department

Department of Computer Science (Computer Vision)

Project Title

Disaster Insight: Deep Learning for Remote Sensing of Natural Disaster Affected Areas

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Project Objective or Aim

The primary aim of this research is to develop and refine deep learning models for analyzing satellite and aerial imagery of regions affected by natural disasters. The project will address key questions such as: How effectively can convolutional neural networks (CNNs) identify and classify disaster-affected regions? What improvements can deep learning bring to disaster impact prediction and recovery planning? By leveraging advanced remote sensing and machine learning techniques, this study seeks to enhance our understanding of disaster impacts and inform disaster management strategies.

Project Background and Significance

Natural disasters impact ecosystems and communities, leading to widespread human, environmental, and economic consequences. Natural disasters, specifically hurricanes, have personally affected me and my community back home in Fort Myers, FL. In 2022, category 4 Hurricane Ian hit Fort Myers bringing 20ft+ storm surge and catastrophic damage to the city. My goal is to mitigate the damage from these types of storms in the future by using remote sensing data and machine learning techniques.

This project investigates the intersection of artificial intelligence and remote sensing to enhance disaster detection and assessment. Remote sensing, as highlighted by Yu et al. (2020), enables the monitoring of environmental phenomena such as trans-Atlantic dust patterns, showcasing its potential for large-scale data collection and analysis. When combined with advanced machine learning algorithms, such as those discussed by Habib (2020), this technology becomes a powerful tool for processing vast datasets and predicting disaster impacts.

Convolutional neural networks (CNNs) are a cornerstone of image analysis. Studies like Sen and Keles (2020) emphasize their effectiveness in remote-sensing applications, making them ideal for this research. These frameworks will be applied to classify areas affected by disasters, distinguishing between impacted and non-impacted zones with high precision.

Additionally, this research incorporates the secure handling of data, a critical consideration when transmitting and storing sensitive satellite images. Techniques like chaotic cellular automata, as outlined by Jeelani (2020), will ensure robust encryption and data integrity. Furthermore, advancements in Earth topography mapping, such as those demonstrated by Dubayah et al. (2020), will inform this study's exploration of the physical and ecological impacts of disasters.

The project's outcomes could significantly improve disaster preparedness and response, aligning with global goals for sustainability and resilience. By integrating remote sensing with machine learning, this research aims to develop an innovative approach to mitigate the effects of natural disasters.

Research Methods

1. **Pre-Data Model Training and Evaluation(June):** Utilizing CNNs, as recommended by Sen and Keles (2020), train models for image classification with previous natural disaster images to ensure a smooth transition to current imagery and scans.
2. **Data Collection (June-October)**: Obtain satellite and aerial imagery datasets from public and private sources, such as NASA and Google Earth Engine. The data will include pre- and post-disaster images.
3. **Preprocessing (September-October)**: Clean and prepare the datasets for analysis by applying techniques such as noise reduction and data augmentation. Jeelani's (2020) methods for image encryption will ensure data security during this stage.
4. **Model Training and Evaluation (September-October)**: Utilize previously trained CNN architectures, as recommended by Sen and Keles (2020), to train models for image classification with current imagery. The training will involve classifying disaster-affected areas with metrics like precision and recall measuring accuracy as previously defined from earlier model training.
5. **Impact Analysis (October)**: Evaluate the ecological and infrastructural effects of disasters by classifications of images using data insights. Techniques such as GEDI laser-based topography mapping (Dubayah et al., 2020) from the research provided LiDAR system will guide this analysis. Mapping of topography before and after natural disasters will be used to then classify areas as *high-affect*, *mid-affect,* or *low-affect*. The classification of each image and map will be fed to the model to determine similar characteristics of each map in each classification of affected area.
6. **Dissemination (November)**: Share results via a scholarly journal article, a poster presentation, and community outreach events.

Timeline (Depends on Hurricane Season

- June: Pre-data model training and evaluation of previous imagery
- June-October: Data collection
- September-October: Preprocessing of imagery
- September-October: Model training and evaluation of current imagery
- October: Evaluation and impact analysis
- November: Finalize deliverables

Expected Outcome

The project will produce several deliverables:

1. A comprehensive report detailing the CNN-based image classification framework and its applications to disaster-affected regions. Applications will include data and mapping of effects of a natural disaster before and after on an area, and data providing insight on mitigations of effects on an area.
2. A scholarly journal article for publication in a remote sensing, artificial intelligence, or environmental science journal.
3. A poster presentation for UCF's undergraduate research conference.

The project will contribute new knowledge to the fields of machine learning, environmental science, and provide new and/or advanced applications of UAVs in remote sensing. It will enhance the accuracy and efficiency of disaster response systems, benefiting UCF's research community by demonstrating the practical applications of interdisciplinary research. Specifically, the outcome of this research is meant to understand why certain areas are more prone to the effects of a natural disaster. It will also observe the effects of an environment/landscape after a natural disaster through remote sensing and UAV imagery applications. These insights will inform policies and tools for global disaster mitigation strategies, while also giving insight to how areas can be reconstructed after a natural disaster. This data will be helpful to civil engineers, environmental engineers, and residents in the affected community, to ensure future disasters can be mitigated and the areas can be successfully reconstructed.

Literature Review

1. Yu, Hongbin, et al. *"Satellite Remote Sensing Observations of Trans-Atlantic Dust Transport and Deposition: A Multi-Sensor Analysis."* IEEE IGARSS, 2020, doi:10.1109/igarss39084.2020.9324325.
2. Habib, Maki K. *"International Journal of Artificial Intelligence and Machine Learning (IJAIML)."* 2020, doi:10.4018/IJAIML.20200701.
3. Sen, O., Keles, H.Y. *"On the Evaluation of CNN Models in Remote-Sensing Scene Classification Domain."* PFG, 2020, doi:10.1007/s41064-020-00129-6.
4. Dubayah, Ralph, et al. *"The Global Ecosystem Dynamics Investigation: High-resolution Laser Ranging of the Earth's Forests and Topography."* Science of Remote Sensing, 2020, doi:10.1016/j.srs.2020.100002.
5. Jeelani, Zubair. *"Digital Image Encryption Based on Chaotic Cellular Automata."* IJCVIP, 2020, doi:10.4018/IJCVIP.2020100102.
6. Xin, M., Wang, Y. *"Research on Image Classification Model Based on Deep Convolution Neural Network."* J Image Video Proc., 2019, doi:10.1186/s13640-019-0417-8.

Preliminary Work and Experience

As a Computer Science major, focusing on computer vision and machine learning, I have a strong background in topics to prepare me for this project. I have successfully completed projects involving data encryption, machine learning, and image processing. Although these projects have not been directly tied to computer vision for natural disasters, they have fortified my technical skills for techniques required to complete the project. Additionally, I have conducted preliminary research on public satellite imagery datasets and experimented with preprocessing techniques such as image cleaning for 3D reconstruction. Outside of academics, I will be interning at the aerospace engineering company, Urban Sky, this summer as a software engineer. There I will be working on their sensors' software and radar capabilities, expanding my knowledge and experience of remote sensing and image processing techniques. This foundational work ensures that I have the skills and knowledge required to complete this project successfully.

IRB/IACUC Statement

This project does not require IRB or IACUC approval as it does not involve human or animal subjects.

Budget

- **UAV pilot**: $300
- **LiDAR (Image range sensor)**: $500
- **Software licenses (e.g., MATLAB, ArcGIS)**: $400
- **Conference travel and materials**: $300

  Total: $1,500