Smart Satellite Monitoring: Detecting Illegal Mining in Ghana with CNNs and FCNs

Research Proposal
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Summary of the Proposal

This project provides an innovative way to prevent unlawful small-scale mining (galamsey) in Ghana by combining modern artificial intelligence and satellite imagery analysis. The primary goal is to create an automated system capable of detecting, monitoring, and alerting authorities to galamsey activities in near real time over wide geographic regions. The system will employ Convolutional Neural Networks (CNNs) and Fully Convolutional Networks (FCNs) to evaluate high-resolution satellite images, detecting land-use changes and vegetation loss caused by unlawful mining. Data collection and preprocessing, AI model construction, change detection analysis, real-time monitoring and alerting, and an interactive dashboard for visualization and decision-making assistance are all critical components. The project's goals are to increase detection skills, allow proactive monitoring, optimize resource allocation, and deliver data-driven insights to Ghanaian authorities.

Introduction

Illegal mining, also known as galamsey in Ghana, has caused severe environmental deterioration, such as deforestation, soil erosion, and water pollution. [5] Detecting and monitoring galamsey operations across wide geographical regions is difficult for local authorities because of limited resources and the remoteness of many mining locations. However, advances in artificial intelligence (AI) and remote sensing technologies have provided a feasible answer. The purpose of this project is to develop an automated system for detecting, monitoring, and alerting authorities to high-risk regions where galamsey operations are taking place. By leveraging Convolutional Neural Networks (CNNs) and Fully Convolutional Networks (FCNs) trained on satellite imagery, this project aims to develop an automated system capable of identifying and monitoring high-risk areas.

Background

Illegal mining is a pervasive issue in Ghana, severely impacting the environment, public health, and local economies. [5] Galamsey activities have led to widespread deforestation, water pollution, soil erosion, and loss of biodiversity, threatening the livelihoods of communities dependent on farming and fishing. Many rivers, such as the Pra, Ankobra, and Offin, have turned muddy and unsafe due to toxic chemicals like mercury and cyanide used in galamsey, further complicating access to clean water. [5] The scale of the problem is massive suggesting following:

- An estimated number of 40,000 to 50,000 people are directly involved in galamsey activities, while nearly 3 million rely on it for their livelihoods. [5]
- The environmental impact of galamsey is severe and far-reaching. Illegal mining activities have polluted 60 percent of the country's major water bodies, according to recent reports from the Ghana Water Company Limited (GWCL). [1]
- Turbidity levels have skyrocketed to an average of 14,000 NTU (nephelometric turbidity units), far exceeding the 2,000 NTU capacity of water treatment systems. [1]

- This pollution has led to water scarcity and increased the risk of waterborne diseases in affected communities. Deforestation is another significant consequence of galamsey. The Forestry Commission of Ghana has reported that illegal mining has affected 34 out of the country's 288 forest reserves, resulting in the devastation of 4,726 hectares of forest land. [2]

- This loss of forest cover not only impacts biodiversity but also contributes to climate change and soil erosion. The agricultural sector, specifically cocoa production, has also suffered severe impacts. Ghana Cocoa Board data shows that cocoa production, currently at 429,323 tons, is less than 55 percent of its seasonal output, mainly due to illegal mining. [2] In the Mankurom community alone, Galamsey has wiped out over 100,000 acres of cocoa farms. [2]

Over the years, both the government of Ghana and various stakeholders have taken several steps to combat galamsey. The following are just a few examples of these steps:

- In 2013, the establishment of a joint task force with military and other security personnel resulted in the deportation of 4,500 Chinese miners. [2]

- In 2017, the government of Ghana launched Operation Vanguard, a military-led initiative aimed at curbing illegal mining activities. Military and police personnel deployed the task force to mining hotspots across the country to dismantle illegal mining operations and arrest perpetrators. Though the initiative initially showed promise, challenges with sustainability and enforcement hampered long-term success. [2]

- In 2021, the government adopted a bold strategy by setting fire to excavators and other mining equipment utilized by galamsey operators. This intervention aimed to send a strong message about the government's commitment to ending illegal mining. [4] While this move was controversial—eliciting mixed reactions from the public—it underscored the gravity of the issue and the desperate need for decisive action. However, critics argued that burning excavators without addressing underlying socio-economic issues was unsustainable and could fuel further tensions. [5]

- On September 21, 2024, Democracy Hub, a local organization, launched a three-day protest to pressure the government into enforcing measures to stop galamsey. The protesters demanded direct intervention from President Akufo-Addo, including a presidential order to stop all illegal mining activities, particularly in forest reserves and along key rivers.[3] The "Stop Galamsey Now" protests led to the arrest of 53 individuals, including a 62-year-old woman and a 10-year-old girl. [3] This action by the authorities sparked further outrage and debate about the right to protest and the government's commitment to addressing the galamsey issue. [3]

The persistence of Galamsey despite numerous government interventions and civil society actions underscores the complexity of the issue. Factors contributing to the problem include corruption, lack of political will, and the involvement of influential figures in illegal mining activities. [2] There are concerns that strictly enforcing anti-galamsey laws could damage the ruling party's electoral prospects, particularly in mining communities. Given these challenges, there is a clear need for innovative, technology-driven solutions to complement existing efforts. The proposed AI-powered satellite imagery analysis system offers a promising approach to detect and monitor galamsey activities more effectively. By leveraging CNNs and FCNs, this system can provide near-real-time monitoring of large areas, enabling authorities to identify and respond to illegal mining activities more quickly and efficiently. The urgent need to protect Ghana's environment, water resources, and agricultural lands from the devastating effects of galamsey motivates this research. By providing authorities with advanced tools for detection and monitoring, the proposed system can support more targeted and effective interventions, potentially breaking the cycle of failed enforcement efforts and contributing to the long-term sustainability of Ghana's natural resources.

Goal and Objectives

We aim to achieve the following objectives:

- Develop an automated AI model to analyze satellite imagery, identifying land-use changes and vegetation loss specifically associated with illegal mining activities.

- Establish a centralized alert system to alert law enforcement to any suspicious mining activity.
- Establish a user-friendly dashboard for visualization and trend analysis, supporting efficient decision-making.

Methodology

Data Acquisition and Preprocessing

We will collect high-resolution satellite images for Ghana's mining-prone regions from sources such as Sentinel, Landsat, or commercial providers. We will update these images weekly or monthly to enable near-real-time analysis of land changes. Image preprocessing steps include:

- **Geo-rectification:** Align images to a consistent coordinate system for accurate spatial analysis.
- **Filtering:** Use noise reduction filters to enhance the clarity of images and emphasize important features such as vegetation and exposed soil.
- **Change Detection Preparation:** Align images of the same location across different time periods to enable effective change detection analysis.

Model Selection

The proposed model is a CNN-based architecture optimized for satellite imagery, such as FCNs specifically designed for pixel-level image classification.

Training the Model

We will train the CNN on a labeled dataset that features a variety of land uses, such as vegetation, water bodies, exposed soil, and mining sites.

Labeled Data: The training dataset will include annotated samples that illustrate pre-mining and post-mining conditions, allowing the model to learn patterns associated with mining activities.

Data Augmentation: Data augmentation techniques such as rotation, flipping, and scaling will ensure robustness to satellite image variations in angle and lighting.

Results

- We wish to establish a baseline from initial satellite imagery analysis to monitor changes over time.
- Detecting Changes in Land Use and Vegetation Loss.
- Compare images at the pixel level over time to detect vegetation loss or new exposed soil indicative of mining activities.
- Leverage vegetation indices like the Normalized Difference Vegetation Index (NDVI) to identify reductions in vegetation cover.
- After identifying changes, the model categorizes them according to their type (such as vegetation loss, newly exposed soil, or water contamination) to determine if they are indicative of illegal mining activity.

Model performance evaluation and optimization

To optimize the model performance, we will periodically fine-tune it with new data, improving accuracy and reducing false positives.

Accuracy Metrics: Evaluation metrics like precision, recall, and F1-score will measure the model's ability to detect illegal mining sites accurately.

Human-in-the-Loop Validation: Experts will periodically review flagged images to validate mining activity, feeding corrections back into the model to refine its accuracy over time.

Integration with Additional Data Sources: Integrate additional data sources, such as drone footage and ground-level imagery, to validate and cross-reference satellite data findings, increasing overall accuracy.

Real-Time Monitoring and Alert System

Remote Sensing Integration: We will link the trained model to a remote sensing system, enabling automatic updates with new satellite images.

- Automated Alerting: The system will automatically flag significant changes, such as vegetation loss or exposed soil, and notify enforcement authorities through an alert system.
- Interactive Dashboard: A centralized dashboard will allow authorities to visualize flagged areas, monitor land-use trends, and prioritize investigations. Key dashboard features may include:
- Mapping the detected mining sites using the Geographic Information System (GIS).
- Time-series analysis of vegetation loss in high-risk areas.
- Historical data to identify patterns and forecast trends.

Conclusion

This proposal outlines a comprehensive strategy to address galamsey, utilizing AI-powered picture identification through CNNs and FCNs, which excel in pixel-level classification and land-use segmentation. This strategy promotes proactive monitoring and enforcement by recognizing plant loss and exposed soil as indicators of unlawful mining to assist Ghana in protecting its environment and natural resources.

References

[1] Africanews. Nationwide lockdown looms as ghana battles illegal mining crisis. *Africanews*, September 2024.

[2] Enoch Randy Aikins. Ghana must stop galamsey before it sinks the country. *ISS Today*, September 2024.

[3] Citinewsroom. Three-day 'citizens against galamsey' demo to commence today. *Citinewsroom*, October 2024.

[4] Ministry of Lands and Natural Resources. Lands minister seeks media support as gov't ramps up radical measures in renewed fight against galamsey. *Ministry of Lands and Natural Resources*, 2024.

[5] Wikipedia contributors. Galamsey. *Wikipedia, The Free Encyclopedia*, 2024. Accessed 31 October 2024.