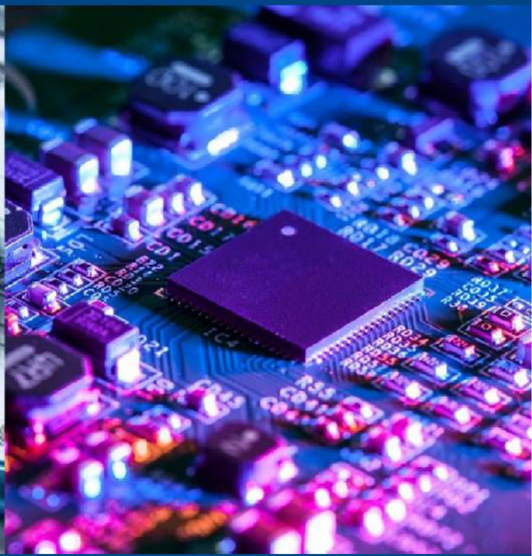
ISSN: 2582-7219

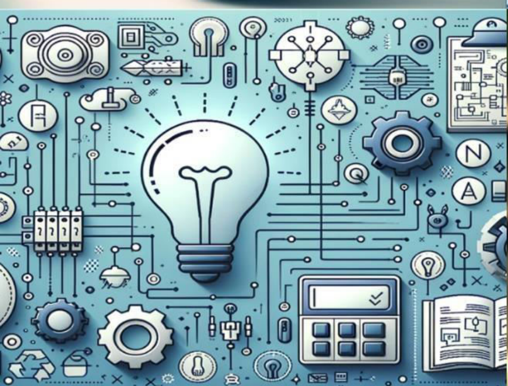




International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 8, Issue 8, August 2025

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ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

GEO-AI LANDSLIDE PREDICTION FRAMEWORK USING SHADOW PATTERN DISPLACEMENT IN MULTI-TEMPORAL SATELLITE IMAGES

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ABSTRACT: Landslides remain one of the most destructive natural hazards in mountainous regions, often occurring with little warning and causing severe loss of life and infrastructure. Conventional prediction methods primarily rely on slope stability analysis, soil properties, and vegetation cover, but they may fail to detect subtle terrain changes that precede a disaster. This project proposes a novel Geo-AI framework for landslide prediction by analyzing shadow pattern displacement in multi-temporal satellite imagery. Variations in shadows cast by slopes, when observed over time, can indicate micro-deformations or gradual terrain shifts that are otherwise undetectable in raw imagery. The framework integrates automated shadow detection using geometric modeling with displacement measurement through optical flow analysis. These shadow-based features are combined with auxiliary data such as vegetation indices, rainfall records, and digital elevation models to form a comprehensive feature set. A hybrid deep learning model incorporating convolutional and temporal layers is employed to learn spatio-temporal relationships and predict potential landslide occurrences. By focusing on shadow displacement as a primary indicator, this method aims to improve early warning capabilities, particularly in regions with limited ground-based monitoring systems. The approach has the potential to offer a cost-effective, scalable, and high-accuracy solution for proactive disaster risk management.

I. INTRODUCTION

Landslides are among the most devastating geohazards, posing serious risks to human life, infrastructure, and the environment, particularly in mountainous and hilly terrains. They are triggered by a combination of natural factors such as intense rainfall, earthquakes, and soil saturation, as well as human-induced activities like unplanned construction and deforestation. Predicting landslides with high accuracy remains a significant challenge due to the complex interplay of geological, climatic, and environmental factors.

Recent advances in satellite remote sensing have made it possible to observe large, inaccessible regions with high temporal and spatial resolution. While conventional prediction approaches focus on parameters like slope angle, soil type, and vegetation loss, subtle pre-failure surface changes often go unnoticed. One promising but underexplored indicator is the displacement of shadows cast by terrain features over time. Such variations, when detected across multiple satellite images, can signal gradual slope movement that may precede a landslide event.

This project proposes a Geo-AI framework that leverages shadow pattern displacement analysis in multi-temporal satellite imagery, combined with auxiliary environmental data, to enhance prediction accuracy. By integrating advanced image processing techniques with deep learning, the framework aims to provide a scalable, cost-effective early warning system for landslide-prone regions.

II. LITERATURE SYRVEY

Satellite remote sensing has become a vital tool for landslide monitoring due to its ability to capture large and inaccessible areas at regular intervals. Traditional optical methods, such as spectral index differencing and vegetation analysis, have been effective for post-event landslide mapping but often miss subtle pre-failure deformations. Change

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detection using multi-temporal imagery and object-based classification improves accuracy, yet remains sensitive to seasonal variations and illumination differences.

Displacement estimation techniques, including optical flow and image correlation, have been applied to track ground motion from high-resolution optical data. While these methods can detect small-scale movements, performance declines in areas with dense vegetation or inconsistent lighting. Synthetic Aperture Radar (SAR) and InSAR offer precise deformation measurements but require complex processing and may suffer from signal decorrelation. Shadows in optical imagery are generally treated as noise, though some studies note their potential as indicators of slope changes. However, systematic use of **shadow pattern displacement** for early landslide prediction remains largely unexplored. Integrating geometric shadow modeling with deep learning offers a promising path to detect pre-failure terrain shifts and improve disaster preparedness.

EXISTING SYSTEM

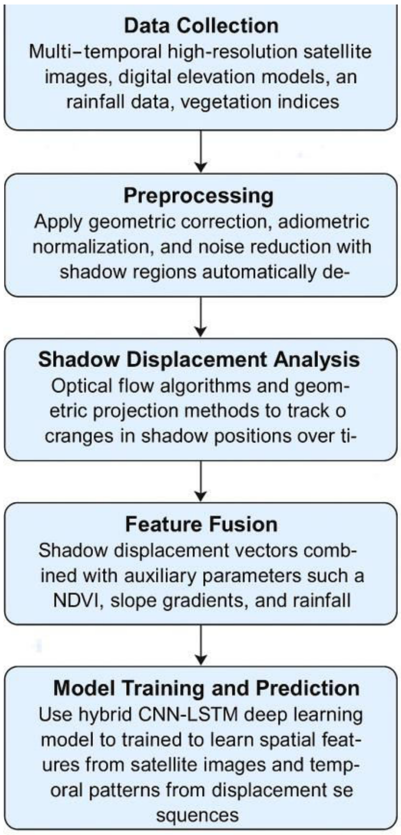
Current landslide prediction systems largely rely on satellite imagery analysis using spectral indices, vegetation cover changes, and digital elevation models. Machine learning models, such as Support Vector Machines, Random Forests, and deep learning architectures, have been applied to classify landslide-prone areas. Displacement tracking methods, including optical flow and SAR-based InSAR, are also used to monitor slope movement. While effective for mapping and post-event analysis, these systems face challenges in detecting subtle pre-failure changes. Illumination effects and shadows are often treated as noise rather than informative features, leaving a gap in utilizing shadow displacement for early landslide detection.

PROPOSED SYSTEM

The proposed system introduces a Geo-AI framework that leverages **shadow pattern displacement** in multi-temporal satellite imagery as a key indicator for early landslide prediction. High-resolution optical images of landslide-prone areas are collected over multiple time periods. Using sun-angle metadata and digital elevation models, shadows are automatically detected and segmented. Optical flow and geometric projection methods are applied to measure subtle shadow displacements that may indicate slope deformation. These shadow-based features are combined with auxiliary data such as vegetation indices, rainfall records, and topographic parameters. A hybrid deep learning model, integrating convolutional layers for spatial analysis and recurrent layers for temporal trends, is trained to predict potential landslide occurrences. This approach aims to detect early terrain instability, enabling proactive disaster management in regions with limited ground monitoring.

III. SYSTEM ARCHITECTURE

The proposed system architecture is designed to predict landslides by analyzing shadow pattern displacement in multi-temporal satellite imagery. It begins with a data acquisition stage, where high-resolution optical images, digital elevation models, rainfall data, and vegetation indices are collected from satellite sources. The preprocessing stage then corrects geometric distortions, reduces noise, and normalizes radiometric values, while extracting shadow regions using sun-angle information and elevation data. In the shadow displacement analysis stage, optical flow and geometric projection methods track changes in shadow positions across time, producing displacement vectors that indicate possible slope movements. These displacement features are fused with additional parameters such as NDVI, slope angle, and rainfall intensity to create a comprehensive dataset. Finally, a hybrid deep learning model combining convolutional neural networks for spatial feature extraction and LSTM networks for temporal sequence learning is employed to generate landslide risk predictions. The architecture supports continuous monitoring, enabling early detection of terrain instability and timely alerts for disaster management, making it a cost-effective and scalable solution for areas with limited ground-based monitoring infrastructure.



IV. METHODOLOGY

The proposed system is designed to integrate satellite image processing, feature extraction, and predictive modeling into a single workflow for early landslide detection. The design begins with identifying landslide-prone regions and acquiring multi-temporal satellite imagery along with supplementary data such as DEMs, rainfall records, and vegetation indices.

In the preprocessing stage, images are geometrically corrected, noise is removed, and radiometric values are normalized to ensure consistency across time-series data. Using sun-angle metadata and elevation models, shadow regions are detected and segmented. This is followed by the shadow displacement analysis stage, where optical flow and geometric projection techniques are applied to track positional changes of shadows over time.

Feature fusion combines these displacement vectors with other environmental indicators, forming a rich dataset for model training. The predictive component uses a hybrid deep learning approach, employing convolutional layers for spatial feature extraction and LSTM layers to capture temporal dependencies. The model is trained on labeled datasets containing both landslide and non-landslide cases, then validated on unseen data.

Implementation is carried out in Python, using libraries such as OpenCV for image processing, TensorFlow/PyTorch for deep learning, and integration with GIS tools for geospatial analysis. The final output delivers risk predictions and alerts for targeted areas.

V. DESIGN AND IMPLEMENTATION

The design of the proposed Geo-AI landslide prediction system is structured to process multi-temporal satellite imagery, detect subtle slope changes, and generate accurate risk predictions. The system begins with a data acquisition module that gathers high-resolution optical imagery, digital elevation models, rainfall data, and vegetation indices for identified landslide-prone regions. In the preprocessing module, the collected images are geometrically corrected, radiometrically normalized, and filtered to remove noise. Using sun-angle metadata and elevation data, shadow regions are identified and segmented for analysis. The core processing module applies optical flow and geometric projection techniques to track shadow displacement across different time periods, extracting motion vectors that may indicate terrain deformation. These features are combined with auxiliary environmental parameters in the feature fusion stage, creating a comprehensive dataset for prediction. The predictive modeling module employs a hybrid deep learning framework, where convolutional layers extract spatial features from imagery and LSTM layers capture temporal dependencies. Implementation is carried out in Python, using OpenCV for image processing, TensorFlow or PyTorch for model training, and GIS tools for spatial visualization. The final system delivers landslide risk assessments and alerts, enabling timely decision-making for disaster preparedness.

VI. CONCLUSION

This project presents a novel Geo-AI framework for predicting landslides by analyzing shadow pattern displacement in multi-temporal satellite imagery. By integrating geometric shadow modeling with optical flow analysis, the system is able to detect subtle terrain deformations that may precede a landslide event. The fusion of these shadow-based features with environmental factors such as vegetation indices, slope gradients, and rainfall data enhances the reliability of predictions. The use of a hybrid CNN–LSTM model allows the framework to capture both spatial and temporal patterns, making it suitable for continuous monitoring of landslide-prone regions. This approach addresses limitations in existing methods, where shadows are often treated as noise, by transforming them into a valuable predictive indicator. The proposed system has the potential to serve as a scalable, cost-effective early warning tool, especially in areas lacking ground-based monitoring infrastructure. With further refinement and testing on diverse datasets, this framework could significantly contribute to proactive disaster risk management and help reduce the loss of life and property caused by landslides.

REFERENCES

1. Bhargava, A., & Bansal, A. (2020). Crop recommendation system using machine learning algorithms. International Journal of Computer Applications, 975, 8887.
2. F. Guzzetti, A. C. Mondini, M. Cardinali, F. Fiorucci, M. Santangelo, and K.-T. Chang, “Landslide inventory maps: New tools for an old problem,” Earth-Science Reviews, vol. 112, no. 1–2, pp. 42–66, 2012.
3. L. Gariano and F. Guzzetti, “Landslides in a changing climate,” Earth-Science Reviews, vol. 162, pp. 227–252, 2016.
4. M. Behling, T. Roessner, M. Golovko, and G. Kleinschmit, “Automated landslide detection with remote sensing data using a convolutional neural network,” Remote Sensing, vol. 12, no. 4, p. 688, 2020.
5. Mondini, F. Guzzetti, M. Rossi, et al., “Landslide detection and mapping using remote sensing: A review,” Earth-Science Reviews, vol. 134, pp. 1–23, 2014.
6. K. Martha, R. Roy, et al., “Landslide detection using optical satellite imagery,” Landslides, vol. 7, no. 3, pp. 247–258, 2010.
7. Y. Chen, X. Li, Y. Zhang, et al., “Optical flow-based ground deformation measurement using high-resolution satellite images,” ISPRS Journal of Photogrammetry and Remote Sensing, vol. 150, pp. 30–44, 2019.
8. Z. Zhao, X. Lu, et al., “Deep learning-based spatio-temporal landslide prediction from multi-source remote sensing data,” Remote Sensing of Environment, vol. 237, p. 111543, 2020.
9. P. Singh, V. Kumar, and R. Choudhary, “Use of shadow information in remote sensing image analysis,” Journal of the Indian Society of Remote Sensing, vol. 48, no. 4, pp. 561–573, 2020.

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