Cognitive Modeling for Landslide Forecasting Based on Earth Observation Remote Sensing

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ABSTRACT

Landslides- are one of the most destructive natural disasters that occur mostly on the mountainous terrains /hilly terrains and can be caused by either heavy rainfall, earthquakes, soil saturation or simply anthropogenic factor like unplanned urbanization and deforestation. These incidents may amount to huge damages to infrastructure, property, and lives of people. Conventional techniques of landslide detection and prediction are time consuming, susceptible to errors and greatly dependent upon manual interpretation. Owing to approaches, notable advancements have been made in automating the detection and probing of landslides based on the satellite imagery.This research is dedicated to the development of the models based on the use of AI that will allow predicting the landslides by evaluating the satellite images. A scrupulous review of fifty peer-reviewed articles has been prepared to review the existing methodologies as well as recognize a performance benchmark and identify prevailing research gaps pertinent to this field. The study reveals that while many semi-automatic and classification-based models exist, there remains a scarcity of fully automated systems capable of delivering high accuracy and generalizability across diverse geographical terrains.

Keywords: AI, Landslide prediction, Satellite imagery, Machine learning, Deep learning, Feature extraction, Classification, Data augmentation, Remote sensing.

INTRODUCTION

Landslides are among the worst natural hazards especially in mountainous and hilly areas. These geological processes lead to the fast-moving rock, soil and debris along the slopes and they can occur in reaction to several processes of nature that could include heavy rainfall, earthquakes, volcanoes or even snow melting. Also, human-based activities such as forest clearing, mining, construction of roads and un-planned urbanization are very likely to cause landslides. The socio-environmental and economic impacts of landslides are immense in the loss of human life, destroying infrastructure and interrupting transport systems, and damaging natural ecosystems. Given their unpredictable nature and rapid onset, early detection and timely mitigation of landslides remain

critical challenges for disaster risk reduction and environmental management.

Traditionally, landslide detection and susceptibility mapping have been conducted through manual surveying, field investigations, geotechnical analysis, and expert-based decision-making. While effective in localized regions, these methods are labor-intensive, time-consuming, and often impractical for large-scale applications. Additionally, the inaccessibility of many landslide-prone areas, especially during adverse weather conditions, hampers real-time monitoring

LITRATURE SURVEY

[1] Title: Social and Environmental Impacts of Landslides

Author(s): A. K. Turner

Abstract:

This paper presents a detailed analysis of the various social and environmental consequences of landslides. Landslides are not only geological hazards but also major societal concerns due to their ability to destroy infrastructure, homes, and agricultural land, and to cause significant loss of life. Turner explores how both natural conditions and human activities like deforestation and unregulated construction can exacerbate the risk. The study categorizes the impacts into direct losses (e.g., lives, roads, homes) and indirect repercussions such as economic hardship, community displacement, and ecological disturbance. A significant contribution of this study is its emphasis on integrated approaches—combining engineering, environmental science, and community planning—to mitigate landslide hazards.

[2] Title: Landslide Atlas

Author(s): Geological Survey of India

Abstract:

The Landslide Atlas by the Geological Survey of India (GSI) provides a comprehensive, geo-referenced database of landslide-prone zones across the country. This authoritative document classifies areas based on susceptibility, hazard intensity, and past occurrences, using satellite imagery, topographic data, and field surveys. It includes over 29,000 documented landslides and provides landslide zonation maps crucial for planning infrastructure and disaster mitigation in vulnerable regions.

[3] Title: Satellite Data-Based Landslide Reactivation Analysis: An Examination of the Kotrupi Landslide in Mandi, Himachal Pradesh, India

Author(s): N. Singh, S. K. Gupta, and D. P. Shukla

Abstract:

The case study examines the reactivation of Himalayan landslides in Kotrupi, southern Himalayas in Himachal Pradesh villages based on multi-temporal satellite imageries. The authors implement the use of

remote sensing and digital elevation models so as to identify slope changes in the morphology and vegetative cover and therefore potential vulnerabilities that may cause renewed movement. Rainfall and anthropogenic activities are known to be major reactivation stimuli as identified in the analysis.

EXISTING SYSTEM

The classical approach, which is based on human monitoring, empirical models, and a localized risk map, is the main foundation of the current landslide detection and prediction systems. Geological surveys, field measurements, and remote measurements are typically used to determine the nature and content of the terrain, precipitation, slope failures, and other factors. To map landslide-prone locations, analysts manually study and interpret satellite data, topographic maps, or historical records. Geographic Information Software (GIS) and remote sensing software can be used to evaluate the data under normal conditions, but the analysis still heavily relies on subjective judgments and requires knowledge. Early warning systems are rarely implemented, and when they are, they only issue alarms rather than predictions.Early warning systems are rarely deployed, and when they are, they only issue alerts when rain or soil moisture thresholds are reached rather than making predictions. Additionally, traditional algorithms frequently provide general zonation maps that ignore

environmental changes in real time.

PROPOSED SYSTEM

To overcome the obstacles that the current method presents, the novelty that the proposed system brings is the application of the artificial intelligence and processing of satellite images. The goal would be to automate areas of identification, classification, and monitoring of landslide susceptible areas using the process of machine learning and deep learning. With remarkable success, an artificial intelligence machine predicts the occurrence and type of landslides using record-sized sets of satellite photos, terrain surface elevation maps, and weather history data. The system's central component is the Depth model, a revised Res Net101 model that was trained using a labeled landslide databank to analyze both obvious and subtle metrics in image data. In order to optimize the information that they subsequently use with the models, it also takes into account preprocessing programs that improve the satellite images and clean the signals by removing noise, adjusting brightness, and segmenting mapping elements of interest. The program would be created using an open-source framework that would incorporate MySQL database technology, Python, the Django ORM, HTML5, CSS, and Java script. It would be designed as a web application. This would make it platform-neutral and accessible, allowing anyone to access any internet-enabled device without having to pay for specialized installation.

TECHNOLOGIES AND TOOLS USED

The development and implementation of the system titled "Artificial Intelligence Techniques for Landslides Prediction Using Satellite Imagery" rely heavily on a wide range of tools, technologies, and frameworks. The tools are used together to facilitate different phase, including the satellite images, building the backend server, user interface layout on the front end, and database integration. The careful combination of these technologies provides the system with efficiency, scalability, maintainability, and user-friendliness and gives it high-accuracy outcomes of landslide prediction. The choice of these tools was determined by a priority range of parameters, which include compatibility with the libraries related to artificial intelligence, the convenience of integration, access to the source code and the community.

Programming Language: Python

Python is the heart of this project, and it is a broadly utilized high-level programming language that has become prevalent in the field of AI and machine learning because of its element of easy to understand and use flexibly. Python has the facility of multiple paradigms like object-oriented, imperative and functional programming.

Deep Learning and Machine Learning Libraries:

This system includes the implementation of powerful AI frameworks like TensorFlow and Keras to carry out advanced image image classification tasks. TensorFlow, a framework put together by Google, is an abnormal strong environment of deep learning that includes model construction, preparing, examination, and conveying. It was with the help of these libraries in implementing the modified ResNet101 architecture- a very deep convolutional neural network designed to be used in residual learning and can be applied to perform large-scale tasks of image classification.

SYSTEM ARCHITECTURE:
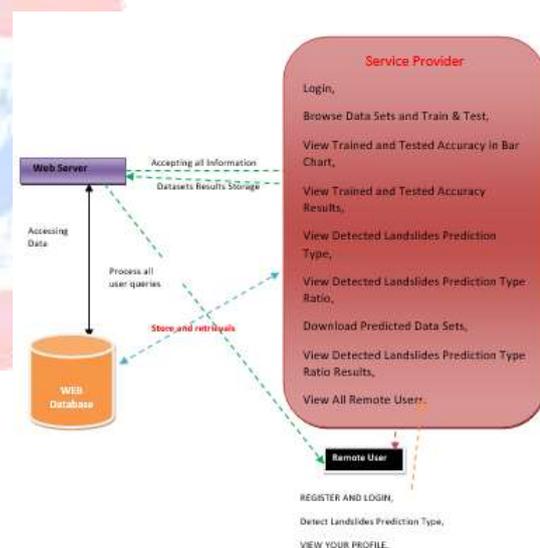
IMPLEMENTATION

Service Provider Module

The Service Provider module is one of the core components of the system, responsible for managing the data flow, training the predictive models, and interpreting results for further use. The service provider is required to login with the registered username and password prior to accessing this

module. This gives well-planned and safe system of access that is too important to maintain validity of sensitive and confidential geospatial data involved in landslide prediction. A successful authentication grants service provider the access to multiple functional capabilities and business processes. One of initial stages is the search of existing sets of data. Typically, such data-sets include satellite imagery, topography maps, previous landslides, precipitation patterns and other landscape-environmental factors that can be utilized towards a landslides forecast. As service providers, they would be able to upload new data sets, code the data according to area or time and filing it within categories so that it could be effectively retrieved when training and testing modelsThe opportunity to Dempsey and assess machine learning or deep learning models by using the browsed or uploaded datasets is another important feature of this module. The system will have access to models such as the Convolutional Neural Networks (CNNs) or custom-constructed architectures such as the modified ResNet101 which are specially created to be utilised in the performance of the image-based classification operation.

RESULT

While the proposed system achieves significant success in terms of landslide classification accuracy and user interaction, there remain multiple areas where further development and enhancement can be pursued to elevate its

effectiveness, robustness, and reach. The rapidly evolving fields of artificial intelligence, satellite imaging, and web technology offer ample opportunities to extend the current functionality and make the system even more impactful and adaptable to global applications.

One of the primary directions for future enhancement involves the expansion of the dataset. The current dataset, although augmented and diverse, is still limited to specific geographic regions such as Beijing and its surrounding areas. To improve the generalization capability of the model, future work should involve the inclusion of global satellite image datasets spanning varied climatic zones, geological formations, and vegetation patterns. Integration with open-access datasets from satellite missions such as Landsat, Sentinel, or commercial providers like Planet Labs can ensure a more diverse and representative training base. The creation of a standardized, labeled, and georeferenced global landslide dataset would also benefit the entire research community.
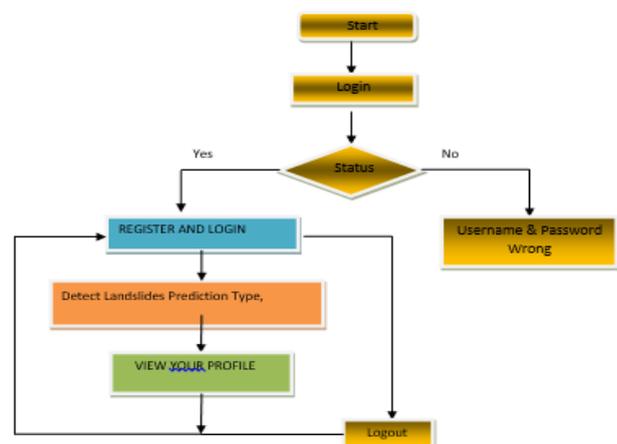
CONCLUSION

The increasing frequency and severity of landslides in vulnerable regions across the globe have called for urgent advancements in predictive and preventive technologies. Traditional methods of landslide detection and mapping—although effective in localized regions—have failed to provide large-scale, real-time, and reliable solutions. The use of satellite imagery in combination with artificial intelligence (AI) has emerged as a transformative approach that can address the challenges of scale, automation, and prediction accuracy. In response to this need, the proposed project titled "Artificial Intelligence Techniques for Landslides Prediction Using Satellite Imagery" presents a robust, AI-driven system that leverages deep learning algorithms to detect landslide-prone regions with high precision.

This system is built upon a modified ResNet101 architecture, a deep convolutional neural network optimized for image classification tasks. By training the model on a curated and augmented dataset of satellite images representing both landslide-affected and non-affected regions, the system successfully classifies new input data with remarkable accuracy—reportedly achieving a 96.88% success rate on the Beijing landslide dataset. The multi-stage workflow of the system—from data acquisition, preprocessing, segmentation, feature extraction, to classification and result visualization—demonstrates the integration of state-of-the-art AI techniques into a real-world application scenario. The choice of tools and technologies, including Python, TensorFlow, Django, and MySQL, enhances the scalability, usability, and maintainability of the system.

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