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AI-Driven Approaches to Landslide Prediction with Satellite Data

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Abstract:
Heavy rain, earthquakes, and soil wetness are some of the natural causes of landslides in mountainous regions. Human actions, such as haphazard building, may also contribute to this problem. Effective forecast systems might lessen the impact of these catastrophes, which can cause severe property damage and loss of life. Recently, ml algorithms have been used for autonomous landslip detection and prediction. The semi-automatic identification of landslides has made use of satellite data and a variety of feature extraction and classification methods. Still, there's a ways to go before completely automated detection can compete with human precision. One of the biggest challenges is finding a trustworthy training database that produces accurate testing results. In order to find where the current research is lacking, this study reviews all the methods that have been employed to date for landslip categorisation and detection using satellite imagery. It also suggests a new model for landslip forecasting. The accuracy and categorisation methods used in these articles are examined, providing a window into the present and potential future. To further develop the application of ml, especially CNN models, for landslip detection from satellite images, the suggested prototype employs dl models to enhance landslip detection and classification.
Keywords: AI, Landslide, Satellite Data

Introduction

In today's era, the atmost importance is to protect life and infrastructure from natural disasters like landslides and earthquakes. As more mountain areas are getting populated, there is an increase in national initiatives towards the safety of lively beings in the landslide susceptible areas. Landslides can cause tremendous amounts of damage to life as well as property. Landslides pose significant demographic and economic concerns in diverse countries, underlining the need for proactive risk management and international collaboration to avoid disaster-related losses. In India, 12.6% of covered land except snow-covered areas is prone to landslides. About 0.32 million sq. km area falls under the Himalayan range which is further categorized into Northeast Himalaya and North West Himalaya. Darjeeling and Sikkim fall under the North East Himalayas and cover 0.18 million sq. km area prone to landslides. NorthWest Himalaya covers Uttarakhand, Himachal Pradesh and Jammu and Kashmir comprising 0.14 million sq. Km. Western Ghats cover Tamil Nadu, Kerala, Karnataka, Goa, and Maharashtra contributing 0.09 million sq. km and Eastern Ghat contributes 0.01 sq. km of total landslide-prone area. Himalayan range lies in earthquake Zone IV and V, these areas are susceptible to landslides initiated by earthquakes. The estimated loss of infrastructure due to landslides is 1-2 % of the gross national product in most developing countries. Estimating and minimizing the damage caused by landslides is a challenging task for the government authorities and technical teams in developing countries as approximately 80% of the casualties due to landslides are reported from these countries.

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Developing counties follow a steep increase in construction. Remote areas are connected to roads, railway tracks, bridges, tunnels etc. Constructions in the morphological area cause a problem in the ecosystem environment and create hazards like landslides. The danger of landslides along road alignments in North Sikkim Himalayas is evaluated by geospatial analysis utilizing thematic weighting. The results show that 65.3% of landslides occur in very high-hazard zones, which informs construction design to reduce the likelihood of future disasters. A landslide is a natural and manmade disaster that causes loss of life. Being a developing country, construction cannot be stopped and natural parameters that trigger landslides cannot be controlled. Therefore, an early alarm system can save lives from such hazards. Satellite image databases can be pre-processed to extract the feature to train the model for the detection of landslides with artificial intelligence. AI and machine learning are essential in the digital age for utilizing a variety of data sources and supporting spatial information analysis for catastrophe risk reduction. Recurrent and convolutional neural networks, for example, have achieved above 90% accuracy in their analyses.

Landslide classification has three main stages, the first stage is the collection of images or creating datasets from satellite data. Initially, a landslide-prone area is selected, and satellite images of landslides and non-landslides related to those areas are collected and created a database. There are few ready-to-use data sets available for training and testing algorithms. The next step is to preprocess the collected data by removing noise, increasing brightness, and segmenting the area of interest. The image segmentation process is an important step in image pre-processing. The result of segmentation depends on the quality of the images. Highresolution images and machine learning algorithms provide reliable results of segmentation that are useful for selecting interest objects.

Satellite remote sensed data is highly effective for theprediction of landslides and reducing the risk of disaster. Data acquired by remotely sensed satellites help in support of keeping inventories of landslides, majorly in periods of risk assessment and during the prevention of landslides. Satellite data is also useful for creating an alert during emergencies and observing current ground situations. Machine learning can allow easy, yet accurate classification and prediction of landslides based on satellite images. Timely prediction of landslide incidents can help the disaster management team to save human lives and avoid loss of property. Machine Learning techniques are extensively used for landslide susceptibility mapping due to the complex relationships between landslides and causative factors. Many ML techniques achieve high reliability in generating susceptibility maps, with an Area Under the Curve (AUC) value exceeding 0.90.

Landslide detection have traditionally relied on a combination of geological surveys and satellite imagery analysis.

The major primary objectives of this article are as follows.

1. To analyze and categorize different machine and deep learning techniques and compare them in terms of performance with diverse types of datasets and types of satellites from where data is collected with accuracy.
2. To identify the research gap from the literature on machine learning classification of landslides available in the last few years.
3. To test and verify whether artificial intelligence techniques can provide a better classification for landslide and non-landslide data.
4. To propose a prototype of a new artificial intelligencebased technique for the classification of landslides with better accuracy.

This study identified several key concerns regarding this work, which encompass

1. Selecting appropriate and latest articles from the available literature.
2. Identify common ground and parameters for evaluating and comparing performances of existing solutions.
3. Use a common strategy to compare different machine learning techniques.

In this article, we have selected 50 research papers based on machine learning techniques for automatic and semiautomatic classification of landslides from various sources such as IEEE Explore, Springer, Remote Sensing Journal, landslide Journal, IEEE and Science Direct etc. Enough care is taken to ensure that the research articles cover a variety of datasets from various landslide-prone countries all overthe world. This will allow the researcher to understand the changing trend of datasets and techniques so that a new robust technique can be developed to predict the landslide from any dataset accurately.

The contribution of this article lies in the performance analysis of different classification techniques from recent literature followed by comparison and discussion with respect to accuracy for identifying research gaps, and guiding new researchers in the field of landslide classification using satellite images. The article also contributes by proposing an effective prototype of the landslide classification approach based on the gap identified.

We can see the objective below:

The development of an advanced landslide recognition model is crucial in mitigating natural disasters and their impacts on communities. This study aims to improve the accuracy of landslide classification by leveraging modified machine learning techniques. The proposed system is designed to enhance landslide recognition capabilities, providing more reliable and timely warnings. One of the key challenges in landslide detection is the availability and quality of data. Inaccurate classifications and limited labeled datasets can hinder the performance of traditional models. This work focuses on addressing these challenges by incorporating advanced data augmentation techniques and refining the model's ability to distinguish between different types of terrain, ultimately leading to improved prediction accuracy and reliability.

The proposed approach offers significant advantages in early warning systems for landslides, contributing to disaster risk reduction and effective mitigation strategies. By improving the model's classification accuracy and overcoming data limitations, this research aims to provide a reliable solution for early landslide detection. This advancement can significantly benefit disaster response teams, government agencies, and communities by minimizing potential damage and loss of life, thus making disaster preparedness more efficient and proactive.

EXISTING SYSTEM

Landslide detection using satellite imagery has been a crucial research area, with various machine learning techniques being explored for accurate classification. Methods such as Support Vector Machines (SVM), Genetic Algorithm-based SVM (GA-SVM), K-Nearest Neighbors (KNN), Multi-Layer Perceptron (MLP), Bayesian learning, and Statistical Region Growing (SRG) segmentation have been widely applied. These approaches aim to enhance the precision of satellite image classification by extracting relevant features that differentiate landslide-affected areas from non-affected regions.

Despite the advances in machine learning, landslide detection through satellite images presents significant challenges. One of the primary issues is noise interference in satellite images, which can arise due to atmospheric conditions, varying resolutions, and sensor limitations. Additionally, selecting relevant features from the vast amount of data is complex, as different landscapes and terrains exhibit diverse characteristics that must be accounted for in the classification process. The efficiency of the model largely depends on its ability to filter out irrelevant features while maintaining the accuracy of landslide detection.

To overcome these challenges, researchers are working on developing fully automated and robust models that minimize human intervention and enhance classification accuracy. Advanced deep learning architectures, such as Convolutional Neural Networks (CNNs), and hybrid techniques that combine traditional machine learning with deep learning approaches are gaining popularity. By improving noise reduction, optimizing feature selection, and enhancing the generalizability of the

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models, researchers aim to create a more efficient and automated landslide detection system. Such advancements will contribute significantly to disaster management, allowing for timely responses to mitigate the impact of landslides on human lives and infrastructure.

Disadvantages of Existing System:

1. **Access to Up-to-Date Information** – Selecting the latest articles ensures that the research is based on the most recent advancements, leading to more accurate and relevant conclusions.
2. **Comprehensive Understanding** – Reviewing diverse literature provides a broader perspective on existing methods, their strengths, limitations, and potential improvements.
3. **Identifying Research Gaps** – A thorough literature review helps in recognizing unexplored areas, allowing researchers to focus on novel contributions.
4. **Standardized Comparison** – Using a common strategy to compare different machine learning techniques ensures fairness, consistency, and reliability in evaluation.
5. **Performance Benchmarking** – A structured comparison allows for a clear assessment of the effectiveness, efficiency, and accuracy of different machine learning models in landslide detection.
6. **Optimized Model Selection** – Comparing various techniques helps in identifying the most suitable machine learning model for landslide detection, improving overall performance.
7. **Enhanced Decision-Making** – A systematic approach provides well-validated insights, allowing researchers and decision-makers to select the best methods for real-world applications.
8. **Facilitating Future Research** – A well-documented comparison of machine learning techniques serves as a foundation for future studies, helping researchers build upon previous findings and develop more advanced detection models.

PROPOSED SYSTEM

Landslide classification involves a three-stage process, beginning with the collection and creation of datasets using satellite imagery. Initially, landslide-prone regions are identified, and both landslide and non-landslide satellite images from these areas are gathered to build a comprehensive database. While a few pre-existing datasets are available for training and testing machine learning algorithms, additional data collection is often necessary for improved accuracy. The next step involves preprocessing the collected images, which includes removing noise, enhancing brightness, and segmenting the area of interest. Image segmentation plays a crucial role in identifying landslide-prone regions, and its effectiveness largely depends on the quality and resolution of the images. High-resolution images, combined with advanced machine learning techniques, improve the segmentation process, ensuring that only relevant features are selected for analysis.

Satellite remote sensing data has proven to be a powerful tool for landslide prediction and monitoring, significantly aiding in disaster prevention and risk assessment. By continuously capturing high-resolution imagery of vulnerable regions, satellite technology helps maintain an updated landslide inventory. This data is essential for understanding patterns and predicting high-risk zones, particularly in areas prone to frequent landslides. Furthermore, satellite data plays a crucial role in emergency response, enabling authorities to quickly assess affected areas and take necessary actions to mitigate damage. The ability to monitor ground movement in real time can significantly enhance disaster response strategies and preparedness.

The integration of machine learning techniques has further improved landslide detection and prediction. Machine learning models can analyze complex relationships between landslide occurrences and causative factors such as rainfall, soil type, elevation, and land use. These models can process vast amounts of data, identify patterns, and generate accurate landslide susceptibility maps. Early prediction of landslides is critical in reducing the impact of disasters, helping authorities implement timely evacuation plans and mitigate property damage. The continuous

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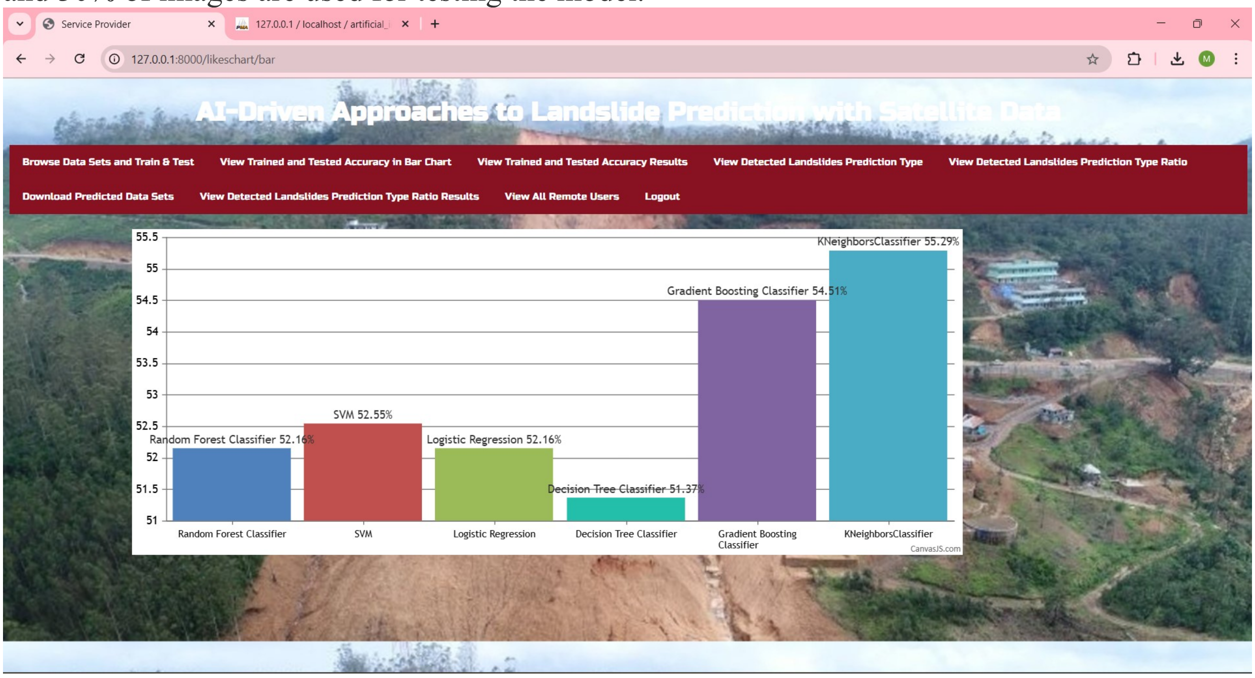
advancements in deep learning models, such as convolutional neural networks (CNNs), have significantly improved classification accuracy, achieving up to 96.88% accuracy in some cases.

Advantages of Proposed System:

1. **High Detection Accuracy** – The use of a deep learning model like ResNet improves classification accuracy, achieving a high-performance rate of 96.88% accuracy in landslide detection.
2. **Early Disaster Prediction** – The system enables early detection of landslide-prone areas, allowing authorities to take preventive measures and minimize loss of life and property.
3. **Automation & Efficiency** – By leveraging machine learning, the system can automatically analyze large datasets of satellite images, reducing manual efforts and human errors in landslide detection.
4. **Real-time Monitoring** – With remote sensing technologies, the model enables real-time monitoring, allowing for quick responses to potential disaster events.
5. **Cost and Time Efficiency** – Traditional ground surveys for landslide assessment are expensive and time-consuming. Machine learning automates the process, making it faster and more cost-effective.

Results

Dataset plays an important role in deep learning CNN algorithms. In the proposed work we select Bijie Landslide dataset. This dataset is first open remote sensing dataset based on landslide and non-landslide images [33] This dataset contains images of Bijie City, China and covers 26,853 square km area. These images were from TripleSat satellite with 0.8m resolution. More than 2770 images were classified into two sets, the landslide set contains 770 images and the non-landslide images contain 2003 images. In our experiment, 70% images from the Bijie dataset are used for training and 30% of images are used for testing the model.



Conclusion

This article analyses, and provides detailed comparison of different machine and deep learning techniques using various datasets of satellite images for landslide detection. Among the selected articles, 22% articles used active sensor based satellite database and 70% used passive sensor based satellite database. The accuracy in selected articles was found between 90% to 95%. The research

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gap is identified and a prototype model is proposed. The proposed model uses deep learning CNN network ResNet101 as the backbone to produce the best landslide recognition effect with an accuracy value of 96.88% and obtain the highest precision index of 96.4% with well-thought-tuned hyperparameters. Thus, the results yielded conclude that the proposed technique can provide classification of landslide data with better accuracy.

Of course, there are a few limitations in this work. To alleviate the restrictions future research could combine satellite image processing with meteorological data and provide more accurate understanding of landslide detection and prediction. The environmental parameters such as soil moisture, precipitation, and seismic activity can also be incorporated in the feature vector for better accuracy of prediction. The attention mechanism helps to focus on essential characteristics of satellite photos as well as environmental factors.

References

[1] B. Koley, A. Nath, S. Saraswati, S. Bhattacharya, B. C. Ray, T. Choudhury, and J.-S. Um.(2024) “Landslide hazard zones differentiated according to thematic weighting: Road alignment in North Sikkim Himalayas, India.” *Spatial Information Research*, vol. 32, no. 1, pp. 29–46, Feb. 2024. DOI: 10.1007/s41324-023-00533-1.

[2] A. Goel, A. K. Goel, and A. Kumar.(2023). “The role of artificial neural networks and machine learning in utilizing spatial information.” *Spatial Information Research*, vol. 31, no. 3, pp. 275–285, June 2023. DOI: 10.1007/s41324-022-00494-x.

[3]A. Sharma, K. K. Sharma, and S. G. Sapate.(2022). “A prototype model for detection and classification of landslides using satellite data.” *Journal of Physics: Conference Series*, vol. 2327, no. 1, 2022. DOI: 10.1088/1742-6596/2327/1/012029.

[4]M. M. Jaber, M. H. Ali, S. K. Abd, M. M. Jassim, A. Alkhayyat, B. A. Alreda, A. R. Alkhuwaylidee, and S. Alyousif. (2022). “A machine learning-based semantic pattern matching model for remote sensing data registration.” *Journal of the Indian Society of Remote Sensing*, vol. 50, no. 12, pp. 2303–2316, Dec. 2022. DOI: 10.1007/s12524-022-01604-w.

[5] Ado, M., Amitab, K., Maji, A. K., & Jasiń, E. (2022). "A machine learning-based semantic pattern matching model for remote sensing data registration." *Journal of the Indian Society of Remote Sensing*, 31(1), 16-29. DOI: 10.1007/s12524-022-01604-w.

[6] Jaber, M. M., Ali, M. H., Abd, S. K., & Alyousif, S. (2022). "A machine learning-based semantic pattern matching model for remote sensing data registration." *Journal of the Indian Society of Remote Sensing, 14*(13), 3029. DOI: 10.1007/s12524-022-01604-w.

[7] Ado, M., Amitab, K., Maji, A. K., & Jasiń, E. (2022). "Landslide hazard zonation and prediction using geo-spatial technology." *Remote Sens.*, *14*(13), 3029. DOI: 10.3390/rs14133029.

[8] Sharma, A., Sharma, K. K., & Sapate, S. G. (2022). "A prototype model for detection and classification of landslides using satellite data." *Journal of Physics: Conference Series, 2327*(1), 012029. DOI: 10.1088/1742-6596/2327/1/012029.

[9] Singh, N., Gupta, S. K., & Shukla, D. P. (2020). "Analysis of landslide: A case study of Kotrupi landslide, Mandi, Himachal Pradesh, India." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-3*, 137–142. DOI: 10.5194/isprs-archives-XLII-3-W11-137-2020.

[10] Pollock, W., & Wartman, J. (2020). "Human vulnerability to landslides." *GeoHealth, 4*(10). DOI: 10.1029/2020GH.2019.004568.

[11] Petley, D. (2018). "Global patterns of loss of life from landslides." *Geology, 40*(10), 70. DOI: 10.1007/s41062-018-0175-y.