Ministry/Organization Name/Student Innovation: **Indian Space Research Organisation (ISRO)**

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Problem Statement Title: **Change detection due to human activities.**

Team Name: **Fuzion 2.0**

Team Leader Name: **Dhruba Jyoti Das**

Institute Code (AISHE): **U-0052**

Institute Name: **Gauhati University**

Theme Name: **Space Technology**

Team Member Details

Team Leader Name: Dhruba Jyoti Das

Branch: BTECH Stream: ECE Year: IV

Team Member 1 Name: Anushuya Ghatak

Branch: BTECH Stream: BET Year: IV

Team Member 2 Name: Tonuj Pritam Deka

Branch: BTECH Stream: ECE Year: IV

Team Member 3 Name: Subarna Saikia

Branch: BTECH Stream: CSE Year: II

Team Member 4 Name: Anubhav Dey

Branch: BTECH Stream: ECE Year: IV

Team Member 5 Name: Gautam Hazarika

Branch: BTECH Stream: CSE Year: II

Table of Contents

Literature Review

1. ***"Change Detection Based on Artificial Intelligence: State-of-the-Art and Challenges:"***
   Author: Wenzhong Shi, Min Zhang, Rui Zhang, Shanxiong Chen, Zhao Zhan
   This review presents the latest methods, applications, and challenges of the AI-based change detection techniques. For beginners, the implementation process of AI-based change detection is introduced. Considering that the validity of training data is one of the major challenges, the commonly used data sources and existing datasets used for change detection were fully surveyed. Although the current public datasets have increased significantly, openly labelled datasets for change detection are still scarce and deficient, which requires the joint efforts of the RS community. The systematic analysis of the general network frameworks and commonly used networks in AI adopted for change detection shows that great progress has been made in the combination of AI for change detection, but there are still many challenges in change detection with heterogeneous big data processing, unsupervised AI, and the reliability of AI. This means that further research needs to be pushed forward. This review offers a clearer organization and will help researchers understand this field.
2. ***"Change Detection using Deep Learning and Machine Learning Techniques for Multispectral Satellite Images"***
   Author: Vignesh Thangathurai, Thyagharajan K K
   In our study focused on change detection using multispectral images, we employed a combination of deep learning and machine learning algorithms to address this challenging task. We also explored the potential for defect prediction prior to change detection. Leveraging multi-instance learning, we successfully recognized patterns in the multispectral data, allowing us to identify changes in the input dataset. Notably, in the context of machine learning, a crucial feature extraction phase was required to enhance the accuracy of change detection. However, when utilizing deep learning algorithms, a separate feature extraction phase was rendered unnecessary. The classification accuracy of change detection was found to be contingent on the choice of algorithms and the resolution of the images. Our comprehensive analysis revealed that deep learning algorithms consistently outperformed traditional machine learning techniques, underscoring their superior accuracy in the domain of change detection from multispectral images.
3. ***"Detection of Objects in Satellite images using Supervised and Unsupervised Learning Methods:"***
   Author: Chaitanya Malladi
   This study delves into the vital task of extracting valuable information from satellite imagery, which inherently holds a wealth of data. To this end, we employed two distinct object recognition approaches, one supervised and the other unsupervised, based on their prior performance in established studies. Our evaluation, conducted on satellite images, revealed that support vector machines outperformed k-means clustering in the context of a two-object dataset, using normalized values as the metric. Consequently, our findings suggest that the supervised approach of support vector machines holds greater promise for object recognition in satellite imagery, highlighting its superior suitability compared to the unsupervised k-means clustering method.
4. "***Geographic Resources Decision Support System for land use, land cover dynamics analysis"***
   Author: T. V. Ramachandra ,Uttam Kumar
   Holistic decisions and scientific approaches are required for sustainable development of the region. Change detection techniques using temporal remote sensing data provide detailed information for detecting and assessing land cover and land use dynamics. Different change detection techniques were applied to monitor the changes. The change analysis based on two dates, spanning over a period of four years using supervised classification, showed an increasing trend (2.5 %) in unproductive waste land and decline in spatial extent of vegetated areas (5.33 %). Depletion of water bodies and large extent of barren land in the district is mainly due to lack of integrated watershed approaches and mismanagement of natural resources.

Introduction

Change detection, a pivotal aspect of remote sensing and geospatial analysis, plays an increasingly vital role in monitoring, understanding, and mitigating the impacts of human activities on our environment. This methodological framework, based on a fusion of satellite imagery and cutting-edge artificial intelligence (AI) technologies, empowers us to detect, assess, and respond to alterations in land cover, infrastructure, and various other dimensions with unprecedented precision and efficiency.

In a world where urbanization, industrialization, and other human-driven developments continuously transform the Earth's surface, the need for accurate and real-time change detection has become paramount. It enables us to observe and react to critical events and changes such as urban sprawl, deforestation, infrastructure expansion, and disaster response. Such insights are indispensable for sustainable development, resource management, and environmental conservation.

A defining aspect of our research is its specific focus on changes attributed to human activities. As we look at the Earth's evolution, we seek to unravel the intricacies of transformations resulting from human interventions. This includes the detection of man-made objects like buildings, roads, vehicles, and aircraft. Understanding the dynamics of these changes is fundamental for a multitude of applications, including urban development monitoring, infrastructure management, and disaster response preparedness.

Central to this research endeavour is the application of AI and machine learning. These technologies serve as our guiding stars, illuminating the path towards automated, accurate, and efficient change detection. In particular, Convolutional Neural Networks (CNNs) have emerged as powerful tools for extracting meaningful features from satellite imagery. CNNs excel in their ability to decipher two-dimensional data and preserve spatial relationships, much like the human visual system. Our exploration of AI in the context of change detection is imbued with immense potential for driving innovation and achieving superior accuracy.

Our mission in this research is twofold:

1. First, we aim to create an AI/ML-based model that can automatically detect changes related to human activities from remote sensing images, with a primary focus on Sentinel-2 and LISS-4 satellite data.
2. Second, we aspire to demonstrate the real-world applications and benefits of this technology for diverse domains, ranging from urban planning to disaster management. By bridging the gap between AI, satellite imagery, and change detection, our objective is to revolutionize the way we monitor and interpret human-induced changes in the world.

As we embark on this journey of change detection due to human activities using satellite imagery and AI technologies, it is essential to recognize the profound implications of our research. By accurately identifying and interpreting human-made changes in our environment, we contribute to the holistic and sustainable development of our regions. The chapters that follow will delve into the intricate methodologies, challenges, and outcomes of our research. Our hope is that this exploration not only furthers the frontier of geospatial analysis but also informs and empowers decision-makers, researchers, and change agents to address the complex issues of our dynamic world.

Data

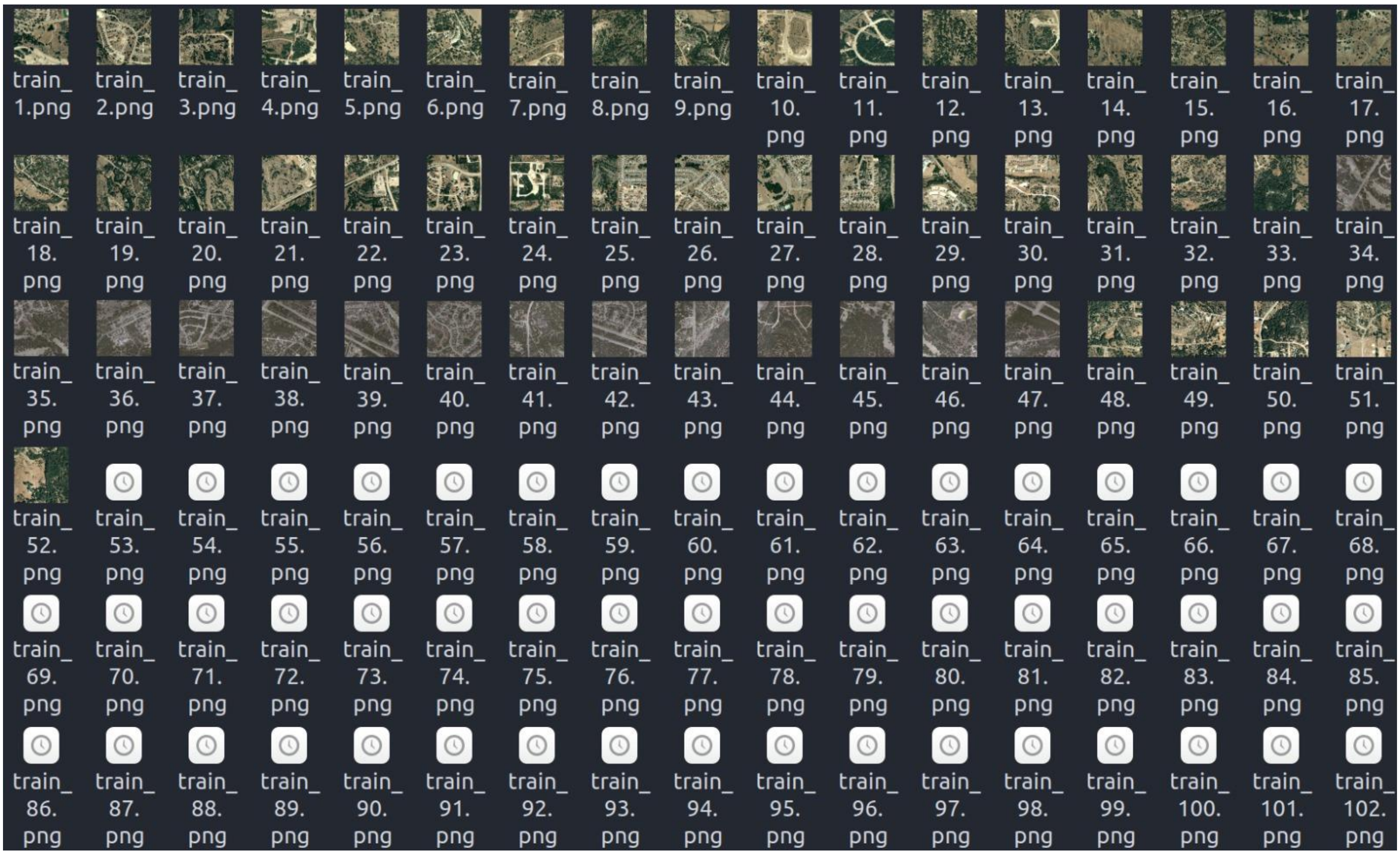


Table 1: Train Data

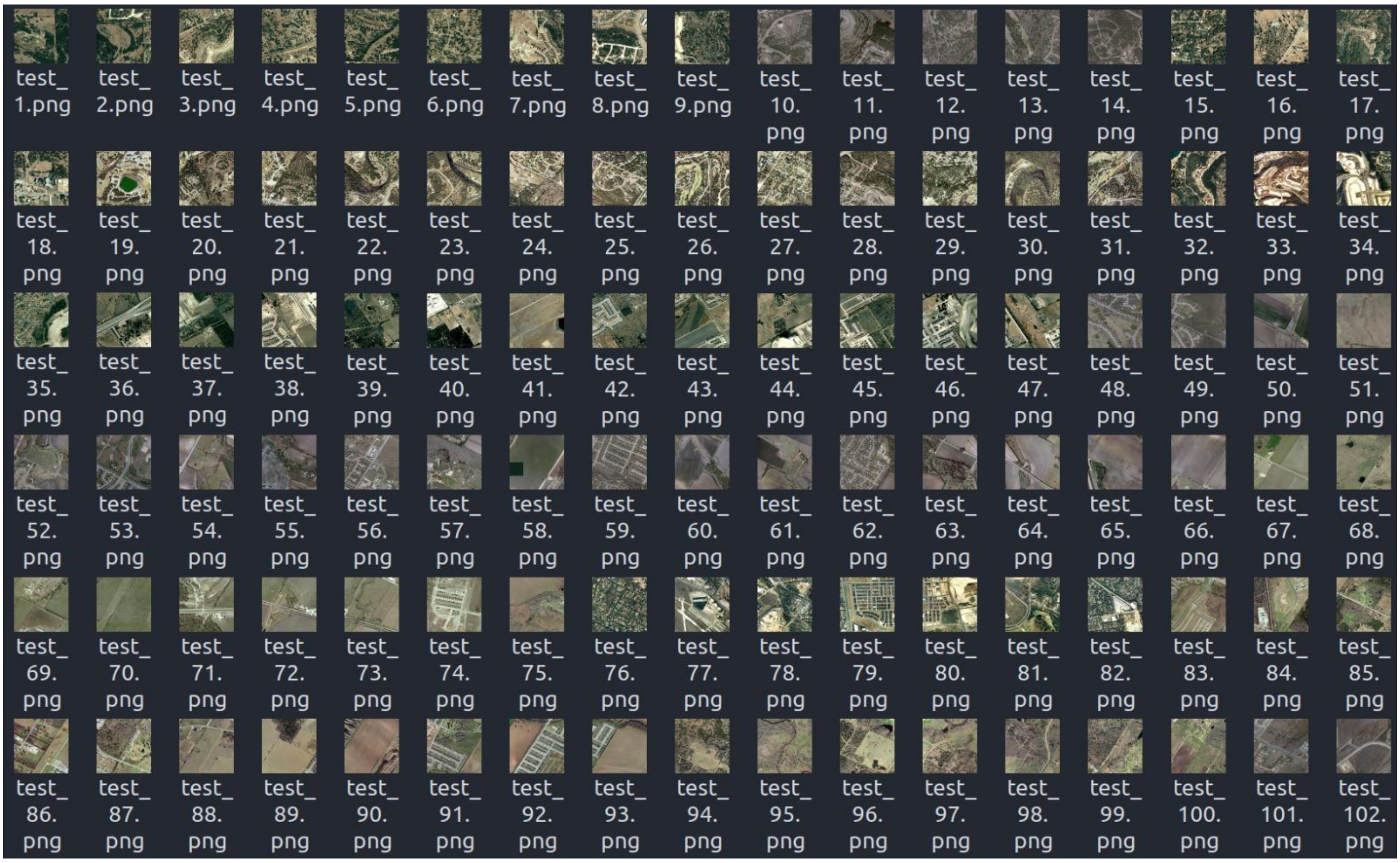


Table 1: Test Data

Use Cases and Business Prospect:

1. **Urban Expansion Monitoring:**
   Our solution assists city planners in monitoring urban expansion by detecting changes in building footprints, road networks, and infrastructure. This data can be invaluable for assessing the rate of urban growth and optimizing resource allocation.
2. **Disaster Response and Recovery:**
   During natural disasters, our technology can quickly identify changes in affected areas, such as damaged buildings, blocked roads, or altered landscapes. This information is crucial for coordinating disaster response efforts and evaluating recovery progress.
3. **Environmental Conservation:**
   The project aids environmental conservation efforts by identifying illegal logging, land encroachments, or changes in protected areas. Conservationists can use this data to better protect ecosystems and wildlife habitats
4. **Infrastructure Development:**
   Our solution is beneficial for tracking large-scale infrastructure projects like highways, bridges, or airports. By detecting changes in construction progress, stakeholders can ensure projects stay on schedule and within budget.
5. **Agricultural Monitoring**
   Farmers and agriculture experts can utilize our technology to monitor crop health and changes in agricultural land. This information helps optimize farming practices, detect diseases, and improve crop yields.
6. **National Security:**
   Our technology plays a pivotal role in national security by detecting suspicious human activities in border regions or remote areas. It helps authorities monitor potential security threats and respond proactively.

These use cases demonstrate the versatility and significance of our solution in various domains, making it a valuable tool for change detection due to human activities in satellite imagery.

What makes our product Unique?

Our Tongucometer is a unique and innovative product in several ways:

- **AI-Powered Accuracy:** Our solution leverages state-of-the-art AI and machine learning techniques, especially Convolutional Neural Networks (CNNs), to achieve exceptional accuracy in change detection. This technology allows us to distinguish human-made changes from natural variations with high precision.
- **Multi-Satellite Compatibility:** We offer compatibility with multiple satellite sources, such as Sentinel-2 and LISS-4. This versatility ensures that our solution can adapt to various data inputs, making it widely applicable.

- **Real-Time Capability:** Unlike many traditional change detection methods that require extensive manual intervention, our solution offers real-time change detection. This means that changes can be identified and reported promptly, enabling timely responses.
- **Wide Range of Applications:** Our product caters to a diverse range of applications, from urban planning to environmental conservation, disaster response, infrastructure development, agricultural monitoring, and national security. This versatility makes it a valuable asset across industries.
- **User-Friendly Interface:** We've designed our solution with a user-friendly interface, allowing non-technical users to access and interpret the data effectively. It empowers professionals from various backgrounds to utilize our technology.

Our Vision

Our vision is to revolutionize the way the world perceives and manages human-induced changes to the environment through cutting-edge technology. We aspire to be at the forefront of change detection in satellite imagery, driven by Artificial Intelligence and Machine Learning, and to set a new standard for accuracy, efficiency, and real-time insights.

we aim to create an intelligent system capable of analysing satellite images to identify changes made by human activity. Our focus includes detecting human-made structures like buildings, vehicles, roads, and aircraft. The target satellite imagery sources are Sentinel-2 and LISS-4.

Our objective is to harness the power of artificial intelligence and machine learning to develop a computer program. This program will automatically pinpoint any new man-made objects or alterations brought about by people within these satellite images. Such a solution has wide-ranging applications, from tracking urban development and infrastructure changes to aiding in disaster response efforts.

Proposed Solution

In our solution, we leverage the power of Convolutional Neural Networks (CNNs) to automatically detect changes in satellite imagery related to human activities. CNNs excel in extracting significant features from images, and they play a pivotal role in our project.

1. ***One-Dimensional vs. Two-Dimensional Data:***
   In our project, we primarily work with two-dimensional data, which preserves spatial relationships within the images. This approach is crucial for accurately detecting changes caused by human activities like buildings, roads, and vehicles.

2. ***CNN Architecture Selection:***
   We adopt well-established CNN architectures like VGGNet, CaffeNet, SegNet, UNet, InceptionNet, and ResNet, tailoring them to our specific change detection needs.

3. ***Adaptive Layer Integration:***
   Our system integrates key CNN layers, including convolutional layers for feature extraction, pooling layers for dimension reduction, activation functions, and fully connected layers for classification. These layers are carefully adapted to our change detection tasks.

4. ***Enhanced Techniques:***
   We employ advanced techniques such as Region CNN (R-CNN) modifications for precise object region prediction and PCANet for noise reduction in SAR images. Additionally, we utilize kernel PCA convolution for extracting spatial-spectral features from remote sensing images in an unsupervised manner.

CNNs are the backbone of our solution, enabling us to automatically and accurately identify changes related to human-made objects in satellite imagery. While they have significantly advanced change detection technology, we continue to explore innovative ways to design and train CNNs for remote sensing applications, ensuring our solution remains at the forefront of this field.

Methodology

It encompasses data processing, machine learning, and post-processing techniques to automate change detection in satellite imagery.

1. **Data Collection**: Our first step is to collect satellite imagery data from sources such as Sentinel-2 and LISS-4. This data provides the foundation for our change detection system.

2. **Data Preprocessing**: We perform essential preprocessing tasks on the collected data, including radiometric and geometric corrections. These adjustments ensure data consistency and accuracy, making it suitable for analysis.

3. **Data Labelling**: Accurate data labelling is crucial. To train our machine learning model, experts will annotate the data, identifying regions in the images where human activities have caused changes. This step provides labelled examples for the model to learn from.

4. **Feature Extraction**: We extract meaningful features from the images, such as spectral information, texture, and spatial characteristics. These features serve as inputs to our machine learning model.

5. **Model Selection**: To perform change detection, we select an appropriate machine learning model. Convolutional Neural Networks (CNNs) are common choices for image analysis tasks, and we may explore pre-trained models for efficiency.

6. **Model Training**: Using the labelled data, we train the selected model. The model learns to distinguish changes related to human activities from the features extracted in the previous step.

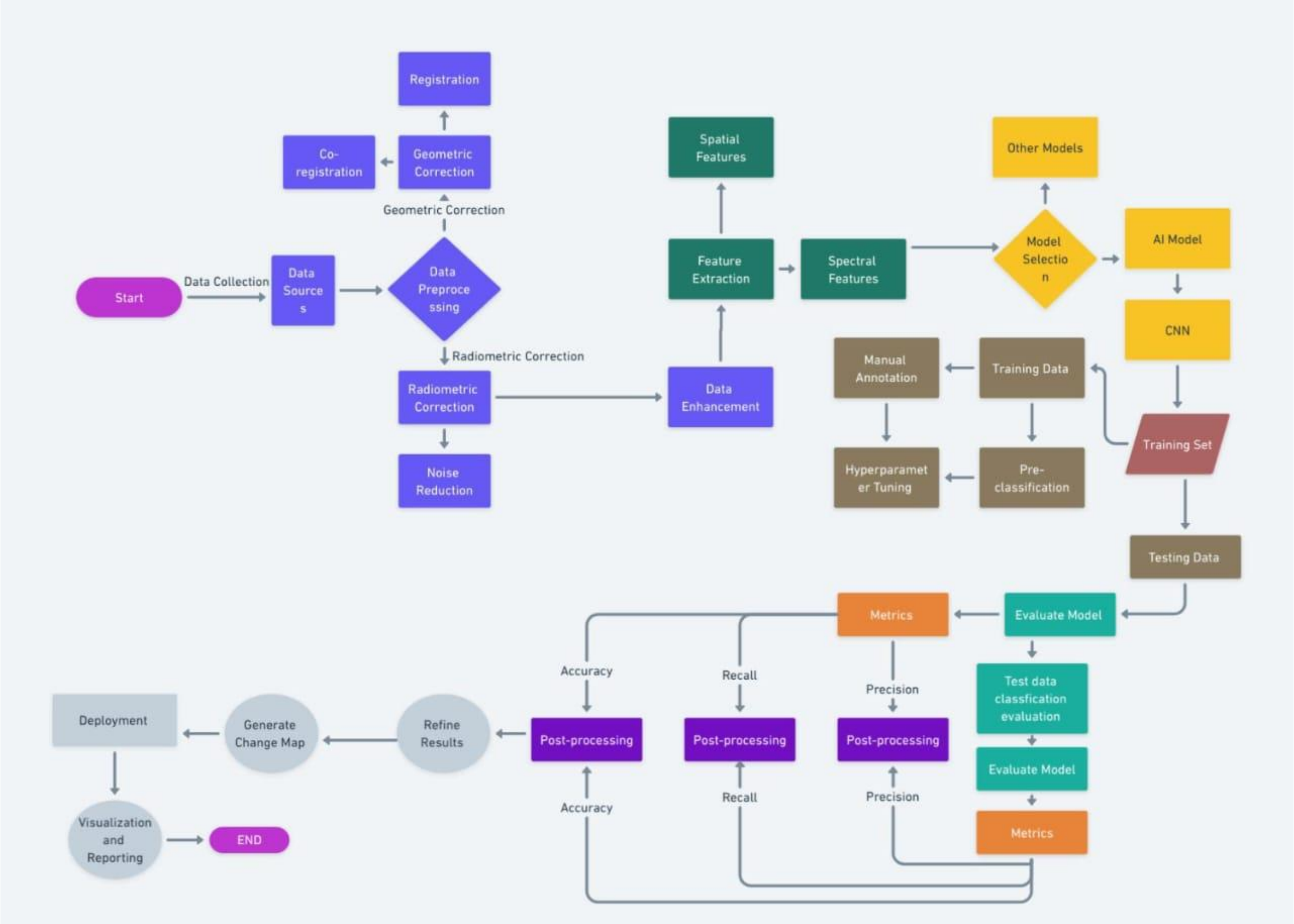
7. **Hyperparameter Tuning**: We fine-tune the model's hyperparameters, experimenting with learning rates, batch sizes, and architectural variations. This process helps optimize the model's performance.

8. **Validation and Evaluation**: We evaluate the model's performance on a validation dataset using relevant metrics such as accuracy, precision, recall, F1 score, and Intersection over Union (IoU). This step ensures that the model is performing well without overfitting.

9. **Testing**: The model is tested on a separate testing dataset to assess its real-world performance. This step ensures that the model can generalize to unseen data effectively.

10. **Post-processing**: Post-processing techniques are applied to the model's output to refine the detection results. This may include removing false positives, improving change masks, and enhancing the overall accuracy.

Process Flow:



Challenge in existing solution:

Existing change detection techniques have traditionally focused on multi-temporal hyperspectral and high-spatial-resolution images, predominantly relying on conventional methods. These techniques can be categorized into various groups:

1. **Visual Analysis:** Change maps are manually interpreted, offering reliable results based on expert knowledge but are time-consuming and labour-intensive.
2. **Algebra-Based Methods:** Change maps are generated through algebraic operations on multi-temporal data, such as image differencing, regression, ratioing, and change vector analysis (CVA).
3. **Transformation:** Data reduction techniques, like PCA and Tasseled Cap, are used to reduce correlated information and emphasize variance in multi-temporal data.
4. **Classification-Based Methods:** Changes are identified through post-classification comparisons or trained classifiers.
5. **Advanced Models:** Complex models, such as spectral mixture models, are used to convert spectral reflectance values into physically based parameters, providing more intuitive and meaningful results but requiring additional time and complexity.

6. **Others:** Hybrid and knowledge-based methods, spatial statistics, and integrated GIS and RS techniques are also utilized.

In recent years, traditional change detection has seen a shift towards the integration of AI techniques. Both traditional and AI-based approaches start with data acquisition, aiming to generate change detection maps. While traditional methods involve data preparation, homogenization, and change detection, AI-based approaches require additional steps, including training set generation and AI model training for change detection. In AI-based approaches, the key components revolve around the use of AI techniques.

This transition toward AI techniques enhances the efficiency and accuracy of change detection, aligning with our solution's focus on automating the process using AI and machine learning.

Dependencies

1. **High-Dimensional Datasets**:
    - The proliferation of platforms and sensors has introduced high-dimensional datasets with features like high spatial resolution and hyperspectral information.
    - These complex data structures, characterized by nonlinear and overlapping distributions, present challenges in terms of robust feature extraction and classification.
    - Managing the nonlinear optimization problem, often with high computational complexity, is a key challenge, particularly when handling multi-source data. This can be considered a hurdle in processing heterogeneous big data effectively.
2. **Data Acquisition for Supervised Learning**:
    - Supervised AI methods rely on large volumes of training samples, which are typically obtained through time-consuming and labour-intensive processes.
    - Human interpretation of remote sensing products and field surveys are common means of data collection, making it challenging to build robust AI models when faced with limited training samples.
    - There's a need to explore and develop unsupervised AI techniques to alleviate the data scarcity issue.
3. **Choosing Efficient AI Models**:
    - While a variety of efficient and accurate AI models and frameworks are available, the continuous evolution of new AI-based change detection approaches poses the challenge of selecting the most suitable model for specific applications.
    - Ensuring that the chosen AI model maintains high accuracy and reliability in diverse applications is a significant consideration for practical implementation.

Tech Stack

We'll harness the power of deep learning with **TensorFlow** and **PyTorch**. These frameworks offer comprehensive support for neural network development, simplifying the implementation **of Convolutional Neural Networks (CNNs).**

OpenCV is a crucial component for image processing and computer vision tasks. It will facilitate satellite image pre-processing, feature extraction, and data augmentation.

Scikit-learn is an essential library for traditional machine learning algorithms. It provides tools for data analysis and model evaluation, which is valuable for our comprehensive approach to change detection.

GDAL and **Fiona** are indispensable for handling geospatial data and satellite imagery. These libraries enable us to manage different satellite image formats and perform geospatial operations.

Database is stored in **SQLite**

Django, a high-level Python web framework, is an excellent choice for rapid development and scalability.

Target Audience

1. Environmental Agencies and NGOs
2. Urban Planners and Municipal Authorities
3. Disaster Management Agencies
4. Agriculture and Land Management
5. Remote Sensing and GIS Professionals
6. Research Institutions and Academia
7. Government Agencies and Geospatial Authorities
8. Commercial Enterprises
9. General Public and Community Activists
10. AI and Data Science Enthusiasts

Future Roadmap

Some of the plans and features we would like to add in the future are:

- Continuously enhance our AI/ML models to improve accuracy, speed, and adaptability to different satellite data sources.
- Explore the integration of advanced deep learning techniques to further boost performance.
- Collaborate with more satellite providers to access a broader range of high-resolution data
- Focus on optimizing the system's scalability and performance to handle a larger volume of data and users, ensuring swift results and efficient processing.
- Integrate predictive analytics into the platform to forecast future changes, offering invaluable insights for urban planning and environmental management.
- Cloud-based AI/ML: Shift towards cloud storage and cloud computing for running AI/ML models, allowing seamless integration of new models without modifying the software.

Conclusion

In conclusion, our project represents a significant leap in the realm of change detection due to human activities, powered by AI. With an unwavering commitment to innovation, our solution opens new horizons for diverse applications. The future is marked by endless possibilities, and we are poised to make a lasting impact.

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