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Approach Brief

Implementing a geospatial web portal that estimates rooftop solar energy potential using state-of-the-art deep learning models for building footprint extraction. This system leverages satellite data, geospatial solar datasets, and user-friendly visualization tools to provide accurate, detailed solar energy assessments at the building level.

Detailed solution and Approach

To develop a geospatial web portal for estimating rooftop solar energy potential, the approach is multi-faceted, focusing on accurate building footprint extraction and solar potential estimation.

Building Footprint Extraction:

We will deploy advanced convolutional neural networks (CNNs) such as U-Net and EfficientNet. U-Net, with its encoder-decoder architecture, excels in segmentation tasks by capturing contextual information through downsampling (encoder) and reconstructing precise object boundaries through upsampling (decoder). To enhance performance, multi-task learning will be employed. This technique simultaneously predicts building footprints and rooftop orientations (e.g., flat, east, west, north, south) using a joint loss function that combines segmentation loss (Dice Loss or Intersection over Union) and orientation classification loss (Cross-Entropy Loss). Data augmentation (rotations, flips, scaling) and preprocessing (normalization, contrast enhancement) will improve model robustness against variations in satellite imagery.

Solar Potential Estimation:

The portal will integrate geospatial solar radiation datasets including Solar Insolation, Global Horizontal Irradiance (GHI), and Direct Normal Irradiance (DNI) to provide critical solar energy data. We will use a mathematical model to estimate the potential solar energy output for each rooftop. The formula used will be:

$$E = A \times GHI \times \eta \times PR$$

where E is the solar energy, A is the rooftop area, GHI is the Global Horizontal Irradiance, η is the efficiency of the solar panels, and PR is the performance ratio accounting for losses such as shading and system inefficiencies. To handle orientation misclassification, opposing orientations (e.g., east and west) will be merged and weighted based on actual solar exposure.

Validation and Evaluation:

Model validation will be conducted using benchmark datasets such as DeepRoof and RID, with metrics including Intersection over Union (IoU) for segmentation accuracy and Mean Absolute Error (MAE) for solar potential estimation. Performance will be compared with traditional methods to highlight improvements in accuracy and efficiency.

Tools and Technology Used

Deep Learning Frameworks:

U-Net and EfficientNet: For precise building footprint extraction.

TensorFlow: To implement and train deep learning models.

Data Handling and Processing:

PostgreSQL with PostGIS

GDAL: For processing and transforming geospatial raster data.

Web Development:

Frontend: Leaflet.js for interactive mapping, D3.js for dynamic data visualization, and Vue.js for building responsive user interfaces.

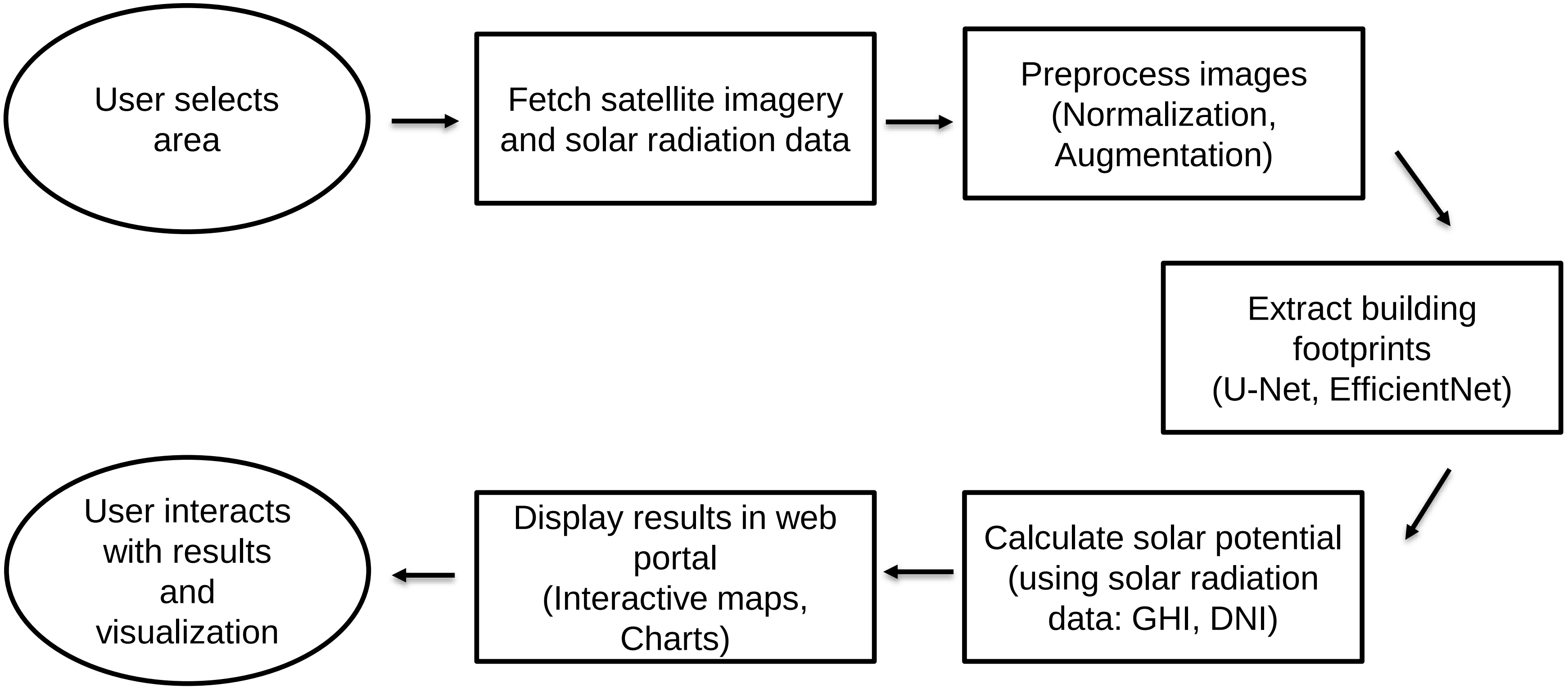
Backend: Flask for developing the server-side logic and API endpoints

Solar Data Integration:

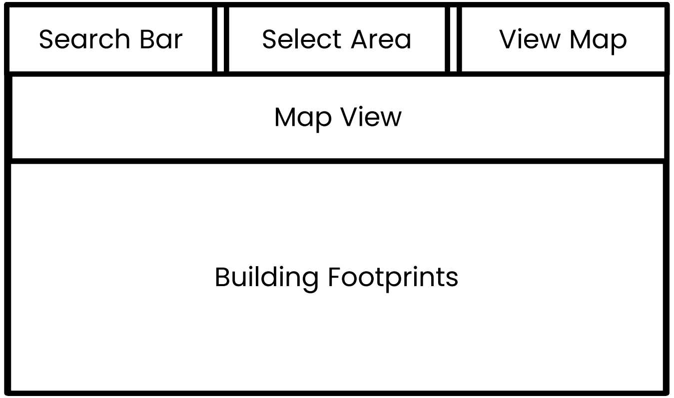
PVGIS: For accessing solar radiation data and estimating solar potential.

Python Libraries: Such as NumPy, SciPy, and Pandas for mathematical modeling and data analysis.

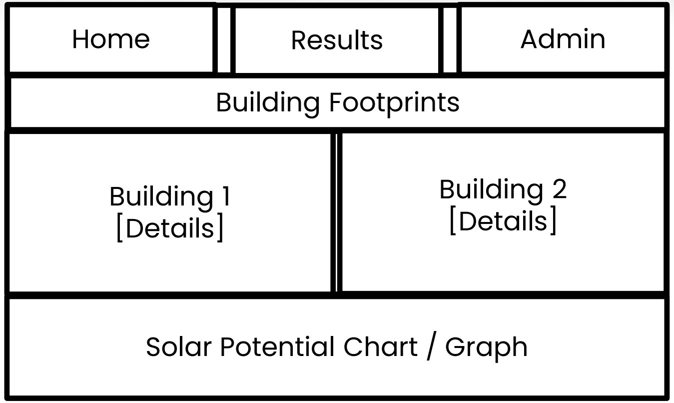
Process Flow Diagram



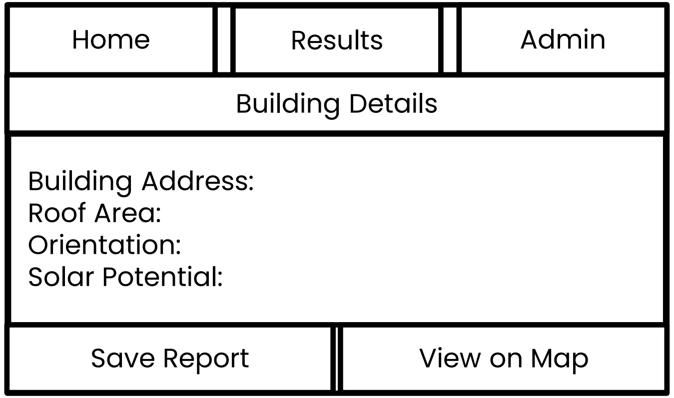
Wireframes/Mock Diagrams



Home Page



Results Page



Detail View

Solution Brief

The proposed solution aims to create a comprehensive geospatial web portal for assessing rooftop solar energy potential. This system integrates state-of-the-art deep learning techniques for building footprint extraction and combines them with geospatial solar radiation data to deliver accurate solar potential estimates.

Unique Aspects:

Advanced Deep Learning Models:

By employing U-Net and EfficientNet, we leverage robust architectures for precise segmentation and feature extraction, improving the accuracy of rooftop footprint identification.

Multi-Task Learning:

This approach simultaneously predicts both building footprints and rooftop orientations, optimizing model performance and reducing misclassification errors.

Mathematical Modeling: The integration of solar radiation data with a mathematical model provides a realistic estimation of solar potential, accounting for factors such as panel efficiency and performance ratio

Validation:

Rigorous validation using benchmark datasets (DeepRoof, RID) and performance metrics (Intersection over Union for segmentation, Mean Absolute Error for solar potential) will ensure the reliability and accuracy of the predictions. Comparative analysis with traditional methods will further demonstrate the efficiency and improvements of the proposed system.

Impact:

The portal will significantly enhance the ability of policymakers, urban planners, and residents to make informed decisions about solar energy investments. By providing detailed, localized solar potential maps and integrating advanced data analysis techniques, the solution supports the transition to sustainable energy practices and helps maximize the utilization of available rooftop spaces.

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