AI-DRIVEN ARCHAEOLOGICAL SITE ANALYSIS

SEMANTIC SEGMENTATION, OBJECT DETECTION, AND TERRAIN EROSION PREDICTION

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INTRODUCTION

Traditional archaeological site analysis using satellite and drone imagery depends largely on manual interpretation, which is time-consuming and prone to human error. Managing and analyzing large volumes of geospatial data also presents challenges in accuracy and efficiency.

This project applies Artificial Intelligence (AI) techniques, specifically Machine Learning and Computer Vision, to automate archaeological site mapping. Deep learning models such as U-Net for semantic segmentation, YOLO for object detection, and machine learning-based terrain erosion prediction are used to identify archaeological structures, vegetation patterns, and erosion-prone areas from aerial imagery.

PROBLEM STATEMENT

- Archaeological site identification and monitoring using satellite and drone imagery is a complex and labor-intensive process. Manual analysis of large-scale geospatial images is time-consuming, requires expert knowledge, and is prone to inconsistencies.
- Additionally, existing methods struggle to simultaneously detect archaeological structures, analyze land cover such as vegetation, and assess terrain erosion risks. The lack of an integrated, automated system limits efficient site discovery, preservation planning, and risk assessment.

PROJECT STATEMENT

- The objective of this project is to design and implement an AI-driven system for archaeological site mapping using aerial and satellite imagery. The system integrates semantic segmentation, object detection, and terrain erosion prediction to automatically identify archaeological features, vegetation cover, and erosion-prone regions.
- By combining deep learning and machine learning techniques, the proposed solution aims to improve accuracy, reduce manual effort, and support archaeologists in efficient site analysis and preservation planning.

OBJECTIVE

- To develop an AI-based system for automated archaeological site analysis.
- To perform semantic segmentation of aerial images to identify ruins and vegetation.
- To implement object detection for recognizing archaeological artifacts using YOLO.
- To predict terrain erosion risk using machine learning models.
- To integrate all modules into a single interactive application for visualization and analysis

PROPOSED SYSTEM

- The proposed system is an AI-driven archaeological site analysis platform that automates the identification and assessment of archaeological regions from aerial and satellite imagery.
- The system integrates three major components:
- Semantic Segmentation Module using U-Net to classify each pixel into ruins, vegetation, or background.
- Object Detection Module using YOLO to detect and localize archaeological structures and artifacts.
- Terrain Erosion Prediction Module using machine learning to assess erosion risk based on terrain features.
- All modules are combined into a single interactive application, enabling users to upload images and visualize segmentation results, detected objects, and erosion risk predictions in one unified interface.

METHODOLOGY

- **Data Collection:** Aerial and satellite images of archaeological regions were collected and organized for analysis. The dataset includes images representing ruins, vegetation, terrain surfaces, and surrounding land features.
- **Data Annotation & Preparation:** Pixel-level masks were prepared for semantic segmentation (ruins, vegetation, background).Bounding box annotations were created for object detection using YOLO format.Images were resized and normalized to ensure consistency during model training.
- **Semantic Segmentation (U-Net):** A U-Net model with a ResNet34 encoder was trained to perform pixel-level classification, enabling accurate segmentation of archaeological ruins and vegetation areas.
- **Object Detection (YOLO):** A YOLO-based object detection model was trained to identify and localize archaeological structures and artifacts from images using bounding boxes.
- **Terrain Erosion Prediction:** Terrain-related features such as vegetation ratio and slope score were extracted from images. A machine learning model was used to classify regions as erosion-prone or stable.
- **System Integration & Visualization:** All models were integrated into a single pipeline and deployed using Streamlit, allowing users to upload images and visualize segmentation, detection, and erosion prediction results interactively.

TECHNOLOGY USED

- Programming Language: Python
- Artificial Intelligence: Deep Learning and Machine Learning
- Semantic Segmentation: U-Net with ResNet34 encoder
- Object Detection: YOLO (You Only Look Once)
- Machine Learning Models: Random Forest / Regression-based erosion prediction
- Computer Vision: OpenCV for image processing and feature extraction
- Frameworks & Libraries:
  - PyTorch
  - Segmentation Models PyTorch
  - Ultralytics YOLO
  - NumPy, Pandas, Matplotlib
- Deployment & Visualization: Streamlit
- Development Platform: Google Colab & Local Python Environment

WORKFLOW

1. **Input Image Upload:** Aerial or satellite images of archaeological sites are provided as input to the system.
2. **Preprocessing:** Images are resized and normalized to make them suitable for model inference.
3. **Semantic Segmentation (U-Net):** The U-Net model performs pixel-level classification to identify ruins, vegetation, and background regions.
4. **Object Detection (YOLO):** The YOLO model detects and localizes archaeological structures and artifacts using bounding boxes.
5. **Terrain Feature Extraction:** Terrain-related features such as vegetation ratio and slope score are extracted from the image.
6. **Terrain Erosion Prediction:** A machine learning model analyzes the extracted features to classify areas as erosion-prone or stable.
7. **Visualization & Output:** All results—segmentation maps, detected objects, and erosion risk—are displayed through an interactive dashboard.

PERFORMANCE EVALUATION

The performance of the proposed system was evaluated using standard metrics specific to each module:

Semantic Segmentation (U-Net)

- Dice Score: Measures overlap between predicted and ground truth masks
- Intersection over Union (IoU): Evaluates pixel-level segmentation accuracy

Object Detection (YOLO)

- Mean Average Precision (mAP@0.5): Measures detection accuracy at 50% IoU
- Precision: Correctness of detected objects
- Recall: Ability to detect all relevant objects

Terrain Erosion Prediction

- Root Mean Square Error (RMSE): Measures prediction error magnitude
- R^2 Score: Indicates how well the model explains erosion behavior

These metrics collectively validate the effectiveness and reliability of the AI-based archaeological site analysis system.

OUTPUT

localhost:8501

Chat

Deploy

🏛 Archaeological Site Analysis System

✅ Models loaded successfully

Upload an archaeological image

Drag and drop file here
Limit 200MB per file • JPG, PNG, JPEG

Browse files

22679050_15.png 5.1MB

Input Image

OUTPUT

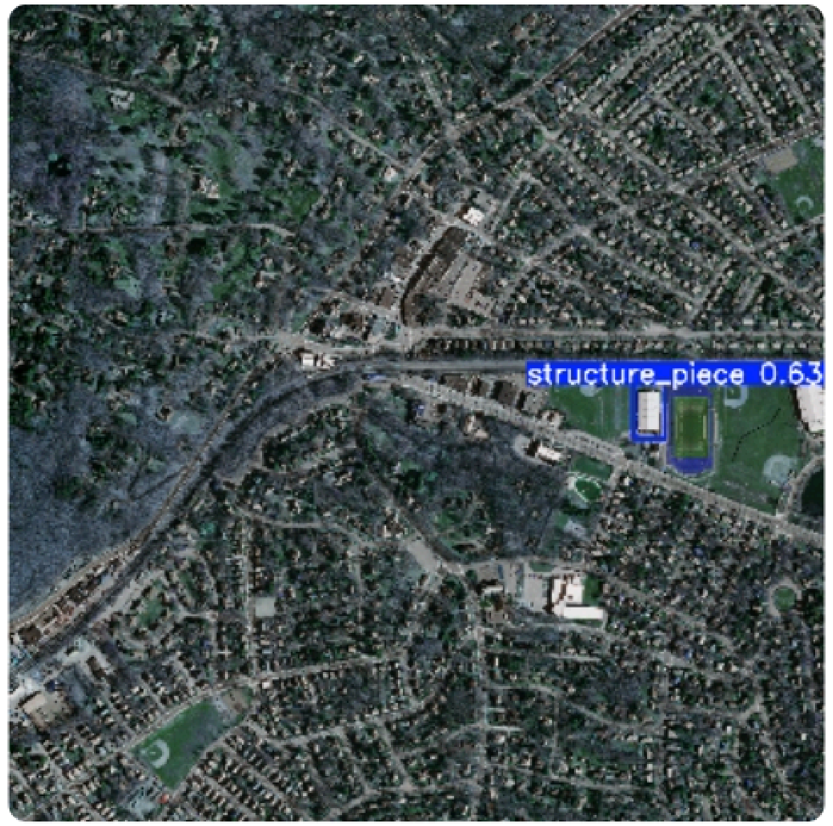
localhost:8501

Chat

Model Outputs

U-Net Segmentation

YOLO Object Detection



Terrain Analysis

Vegetation Ratio

0.3041

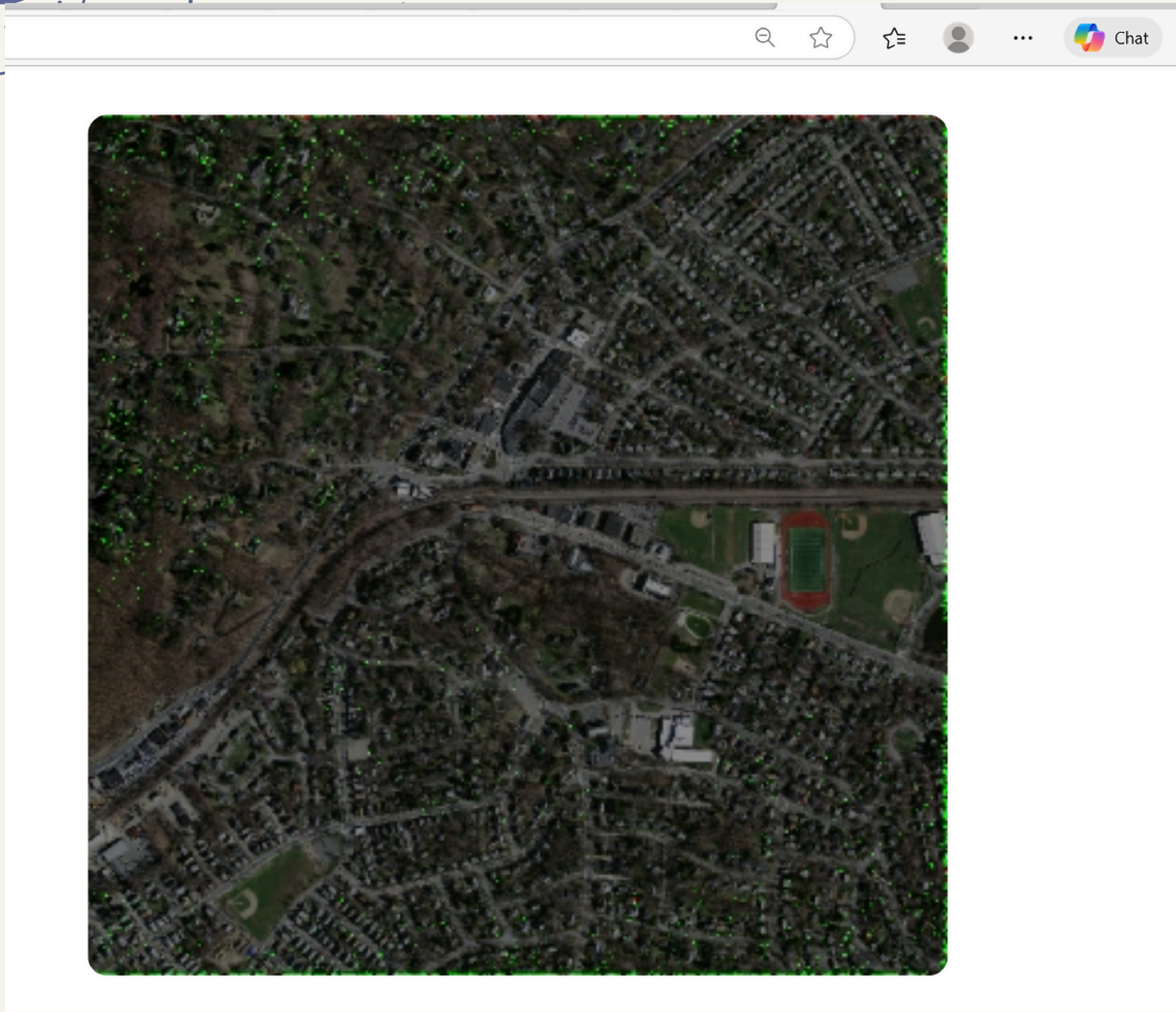
Slope Score

123.17

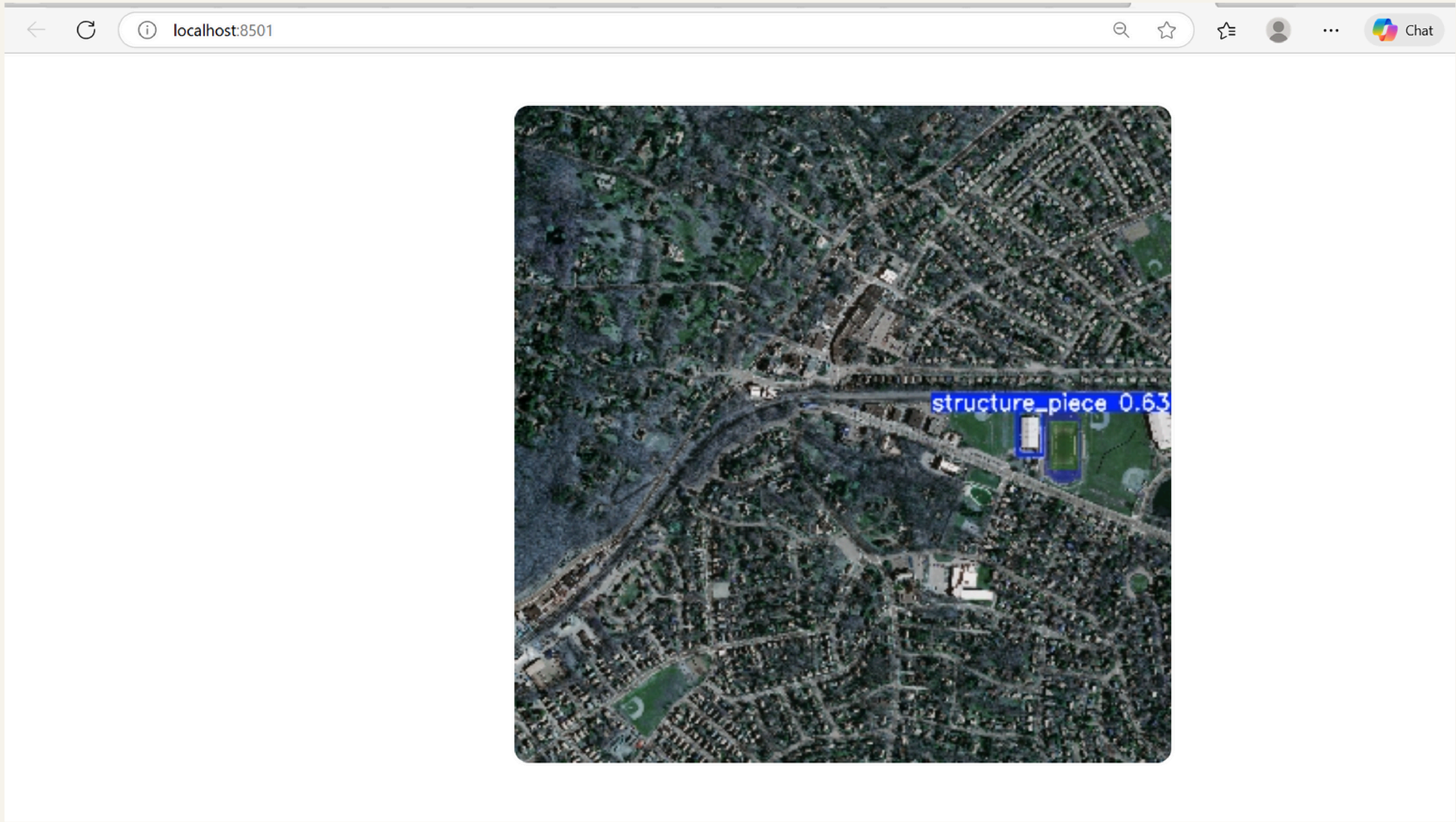
Erosion Risk

Stable

OUTPUT



OUTPUT



RESULTS AND FUTUREWORKS

Results:

- Successfully implemented AI-based semantic segmentation, object detection, and terrain erosion prediction.
- U-Net accurately segmented ruins and vegetation from aerial imagery.
- YOLO effectively detected archaeological structures using bounding boxes.
- The terrain erosion module classified regions as erosion-prone or stable based on extracted terrain features.
- All outputs were visualized through an interactive dashboard.

Future Work:

- Integrate DEM and NDVI data for enhanced terrain and erosion analysis.
- Improve detection accuracy using larger and more diverse datasets.
- Extend erosion prediction to multi-level severity classification.
- Deploy the system on a cloud platform for real-time access.
- Enable temporal monitoring of archaeological site changes.

CONCLUSION

This project successfully demonstrates the application of Artificial Intelligence for automated archaeological site mapping. By integrating semantic segmentation, object detection, and terrain erosion prediction, the system provides an efficient and accurate solution for analyzing archaeological imagery. The proposed approach reduces manual effort, improves analysis consistency, and supports informed decision-making for site preservation. The results highlight the potential of AI-driven systems in advancing archaeological research and heritage conservation.

THANK YOU