BHARATIYA ANTARIKSH HACKATHON 2024

Innovation partner H2S

Team Name: **AWAY FROM KEYBOARD**
Name of College(s)/University(s): **DELHI TECHNOLOGICAL UNIVERSITY**
Team Members Details:

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3. Devdeep Paul
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Step 1: Data Preparation

Data collection and Annotation:

- Use tools like *labelImg* or *VGG Image* annotator for manual annotation
- Acquire Images - Obtain high resolution images from the *OHRC*.
- Annotation: Manually annotate these images with bounding boxes for craters and boulders. Each annotation includes the coordinates and class labels.

Organize data:

- Structure: Organize the data into directories for training, validation, and test sets.
- Format: Convert the annotations into *YOLO format('<class_id> <x_center> <y_center> <width> <height>')*

Step 2: Advance Data Augmentation

- Use *Albumenatations* for applying a variety of transformation: Apply transformations such as rotation, scaling, flipping, brightness adjustments, and adding synthetic noise to make the model robust.

Step 3: Model Setup

- Install required libraries.
- Configure *YOLOv8*: create a configuration file specifying model parameters, paths to data and training settings.

Step 4: Model Evaluation and Hyperparameter Tuning

- Evaluate model: Calculate precision, recall, F1-score etc., on the *validation set.*
- Hyperparameter tuning: Use Grid search or random search to find the optimal hyperparameters(*e.g., learning rate, batch size, no. of epochs*) and use automated optimization tools like *Optune* to fine tune the model.

Step 5: Ensemble Learning

- Train multiple models : Train multiple YOLO models with different architectures or hyperparameters.
- Combine Model Predictions

Step 6: Post- processing and output

- Post Processing : Calculate *selenographic* position and diameter.
- Advance post processing techniques used like Soft-NMS, etc.

Step 7: Interactive Map with folium (*output shapefile*)

- Install folium
- Create Interactive map using *folium* and *geopandas* library.
- Enhance interactivity:
- Add markers, Heatmap visualization

Step 8: Deployment and Interface

- Deploy the model : Ensure the deployment environment can handle the processing requirements.
- Run Interface (*Interactive shapefile*)

Tools and Technology Used (50 words)

- **Python**: Core programming language for the entire solution.
- **PyTorch**: Framework for building, training, and optimizing the YOLOv8 model.
- **Optuna**: Tool for hyperparameter optimization.
- **LabelImg**: Tool for annotating images.
- **Albumentation**s: Library for advanced data augmentation.
- **Geopandas, Shapely**: Libraries for handling and generating geospatial data and shapefiles.
- **Folium, Dash:** Libraries for creating interactive visualizations and user interfaces.
- **OpenCV**: Library for image processing tasks.
- **ONNX, TensorRT, CoreML**: Tools and frameworks for optimizing and deploying models.
- **Jupyter Notebook**

How different is it from any of the other existing ideas?

- **Advanced Data Augmentation for better generalization.**
- **Automated Hyperparameter Optimization for optimal performance.**
- **State-of-the-Art Architectures and Transfer Learning for improved accuracy and efficiency.**
- **Ensemble Learning to reduce variance and increase robustness.**
- **Advanced Post-Processing for more accurate object localization.**
- **Interactive and Detailed Visualization for better user experience and insights.**
- **Robustness Techniques to handle various data conditions.**
- **Computational Efficiency for real-time.**
- **Additional Attribute Prediction for richer information.**
- By integrating these advanced features and methodologies, Our model is positioned to be more accurate, robust, efficient, and user-friendly than many others, making it highly competitive in various applications and competitions.

How will it be able to solve the problem?

- Our model addresses the problem of detecting craters and boulders from OHRC data and quantifying their attributes. Here's how it systematically solves this problem:
- Data Preparation and Augmentation: **Challenge**: Limited and homogeneous data can lead to poor generalization.
- **Solution**: Advanced data augmentation techniques are applied to create a diverse and robust dataset, exposing the model to a wide variety of scenarios and enhancing its ability to generalize.
- Model Training: **Challenge**: Training a model that accurately detects objects and minimizes false positives/negatives.
- Solution: Leveraging YOLOv8 architecture and pre-trained weights, along with hyperparameter optimization and transfer learning, ensures the model is both efficient and accurate.
- Post-Processing and Attribute Calculation: **Challenge**: Accurately localizing objects and extracting relevant attributes.
- **Solution**: Implementing advanced post-processing techniques like Soft-NMS and WBF improves localization accuracy. Additionally, calculating selenographic positions and diameters provides valuable information about detected objects.
- Interactive Visualization: **Challenge**: Making the detection results interpretable and useful for end-users.
- **Solution**: Generating interactive shapefiles and maps with detailed tooltips and dynamic overlays allows users to explore and analyze the results effectively.
- Efficiency and Deployment: **Challenge**: Ensuring the model is deployable in real-time applications and on resource-constrained devices.
- **Solution**: Applying model compression and optimization techniques reduces inference time and resource consumption, making the model suitable for real-time.

USP OF THE PROPOSED SOLUTION -

- **Robust Data Augmentation:** Improved generalization through diverse and augmented datasets.
- **Automated Optimization**: Enhanced performance via systematic hyperparameter tuning.
- **Cutting-Edge Architecture**: High detection accuracy with YOLOv8 and pre-trained models.
- **Ensemble Learning**: Reliable predictions through model ensemble techniques.
- **Refined Post-Processing**: Accurate object localization with advanced NMS methods.
- **Interactive Visualization:** User-friendly maps and detailed shapefiles for easy analysis.
- **Generalization**: Robust performance across different datasets and conditions.
- **Efficiency**: Optimized for real-time applications.

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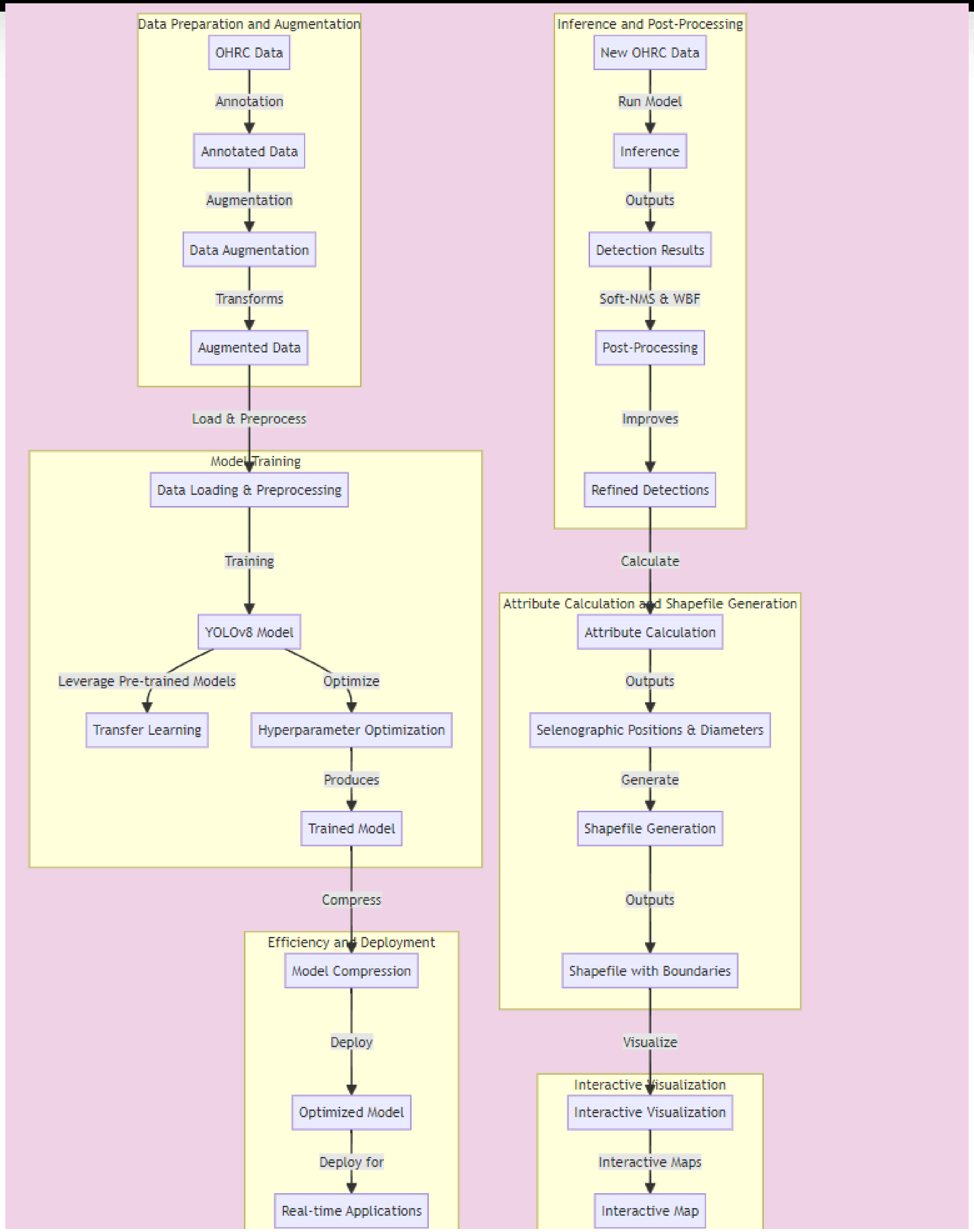
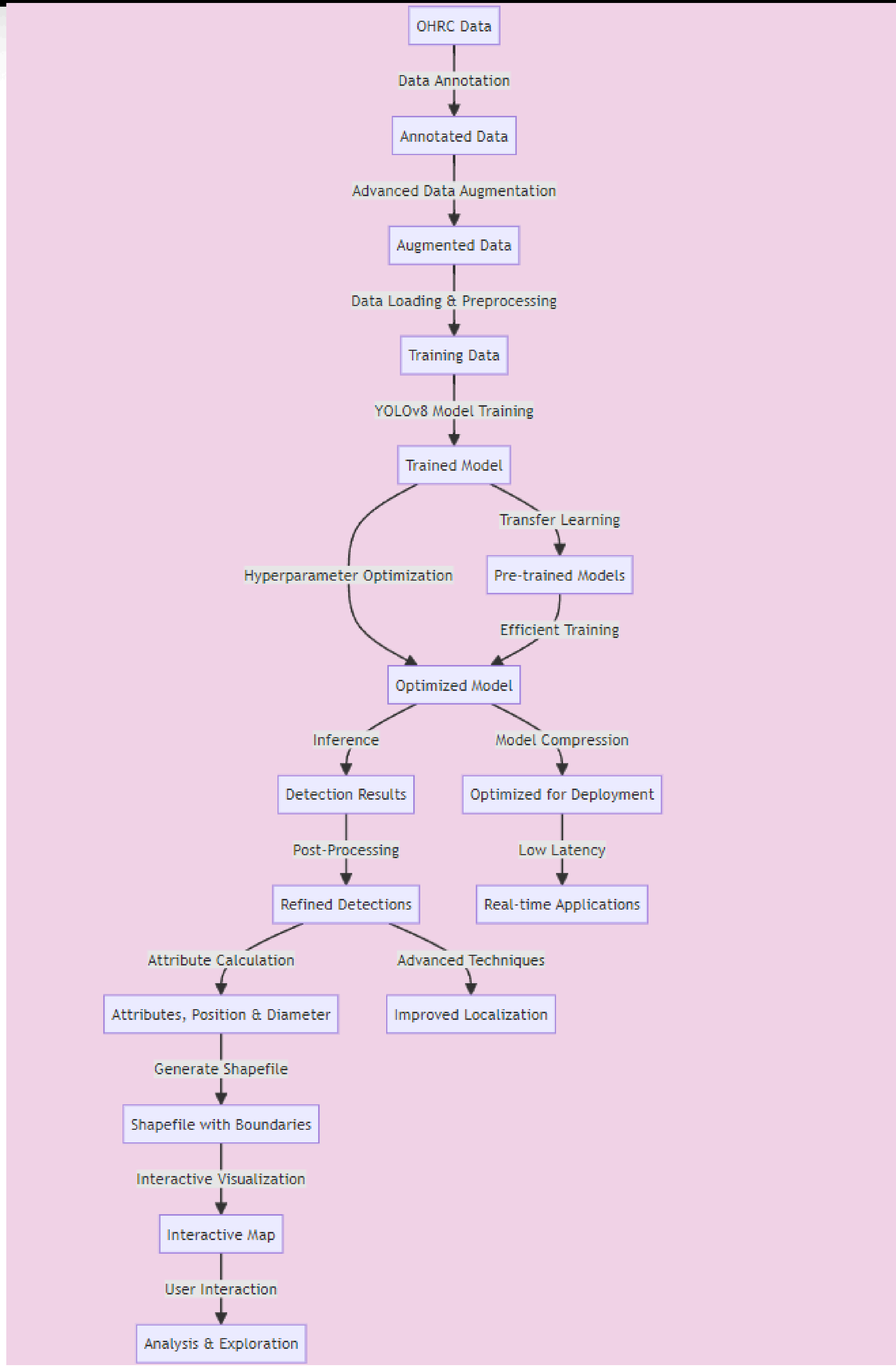
Proposed architecture/user diagram



Features Offered by the Solution

1. Advanced Data Augmentation:
    - Techniques like random cropping, cutout, mixup, and mosaic to create a diverse dataset.
    - Increases model robustness and generalization ability.
2. State-of-the-Art YOLOv8 Model:
    - High accuracy and speed for object detection.
    - Real-time processing capabilities.
3. Transfer Learning:
    - Utilizes pre-trained models to accelerate training.
    - Enhances performance with limited data.
4. Hyperparameter Optimization:
    - Automated tuning using tools like Optuna.
    - Ensures optimal model performance.
5. Post-Processing Techniques:
    - Soft-NMS and Weighted Boxes Fusion (WBF) for improved localization.
    - Reduces false positives and negatives.
6. Attribute Calculation:
    - Computes selenographic positions and diameters of detected craters and boulders.
    - Provides valuable geospatial information.
7. Shapefile Generation:
    - Outputs results in a shapefile format with boundaries and attributes.
    - Compatible with GIS software for further analysis.
8. Interactive Visualization:
    - Creates interactive maps using tools like Folium or Dash.
    - Allows users to explore and analyze detection results.
9. Model Compression and Optimization:
    - Reduces model size and improves inference speed.
    - Suitable for deployment on edge devices.
10. Monitoring and Maintenance:
    - Implements mechanisms to monitor model performance.
    - Facilitates periodic updates for continuous improvement.

Process flow diagram or Use-case diagram



Solution Brief (Overall)

Objective:

To develop an AI/ML solution that accurately detects and analyzes craters and boulders from OHRC (Orbiter High-Resolution Camera) data, providing detailed and interactive information for scientific and practical applications.

Key Components:

The solution begins with data preparation and augmentation, where high-resolution OHRC images are collected and manually or semi-automatically annotated to label craters and boulders. Advanced data augmentation techniques such as random cropping, cutout, mixup, and mosaic are employed to diversify the dataset, enhancing the model's robustness.

For model training, the annotated and augmented data undergo efficient loading and preprocessing before being used to train a YOLOv8 model. This training leverages transfer learning from pre-trained models to accelerate the process and improve accuracy. Automated hyperparameter optimization, using tools like Optuna, ensures the model achieves optimal performance.

During inference and post-processing, the trained model is run on new OHRC data to detect craters and boulders. Advanced post-processing techniques like Soft-NMS (Non-Maximum Suppression) and Weighted Boxes Fusion (WBF) are applied to refine the detection results, leading to precise object localization.

The solution also includes attribute calculation and shapefile generation. The selenographic positions and diameters of the detected objects are calculated, and detailed shapefiles are generated, including boundaries and attributes. For interactive visualization, tools like Folium or Dash are used to create dynamic maps.

To ensure efficiency and suitability for deployment, the model undergoes compression techniques such as pruning and quantization to reduce its size and enhance computational efficiency. The optimized model is then prepared for real-time applications and effective processing.

Unique Selling Propositions (USPs):

This solution's USPs include advanced data augmentation to enhance model generalization, automated hyperparameter optimization for optimal performance, and the state-of-the-art YOLOv8 architecture known for high precision and recall. The use of transfer learning and ensemble methods improves training efficiency and accuracy, while sophisticated post-processing techniques enhance localization accuracy and reduce false positives. Detailed and interactive shapefiles with enriched attributes and user-friendly visualization further distinguish this solution. Its robustness ensures reliable performance across varied datasets, and its efficiency makes it suitable for real-time applications.

In summary, this comprehensive solution offers an accurate and interactive approach to crater and boulder detection from OHRC data, making it highly competitive and effective for various applications.

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