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Coral Classification and Detection: Advancing Underwater Imaging for Biodiversity Monitoring

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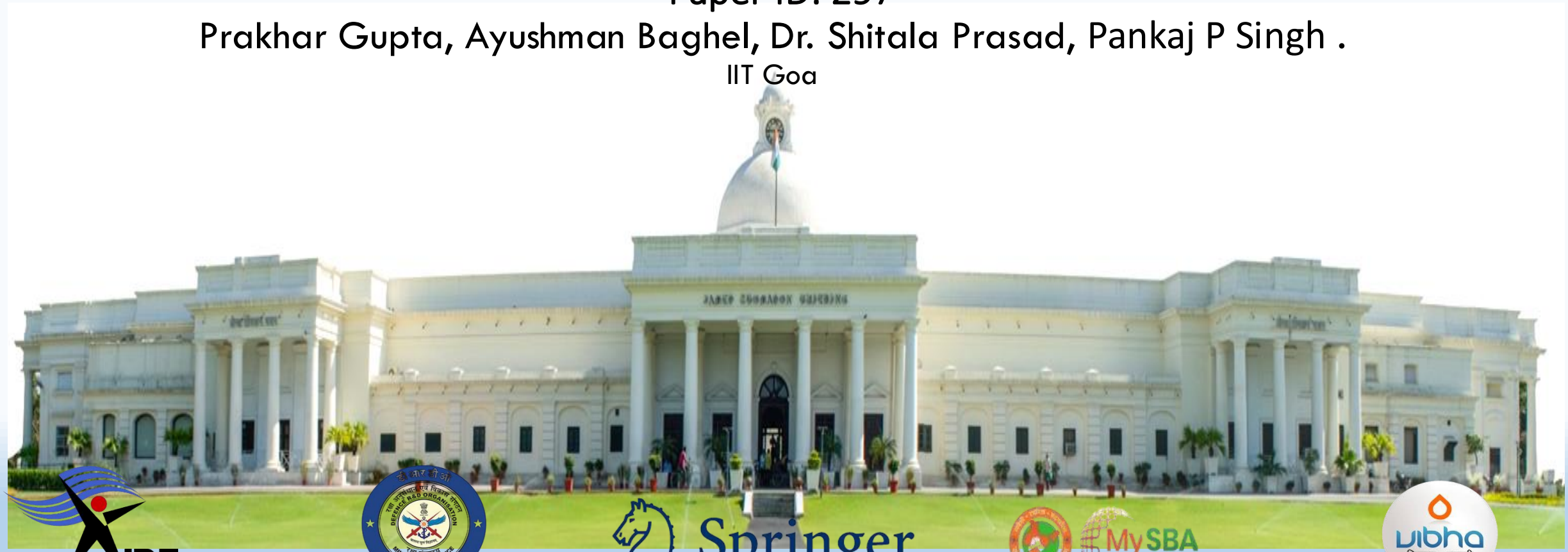


Introduction

- Coral reefs cover less than 1% of the ocean but provide habitat for over 25% of marine species [1].
- Oceans act as a net absorber of CO_2, helping regulate global climate [2].
- Coral reefs play a crucial role in coastal protection, preventing erosion and storm damage [3].
- Due to global warming and ocean acidification, coral ecosystems face severe stress [4].
- Coral bleaching is increasing due to rising sea temperatures, leading to loss of biodiversity [5].
- Monitoring and analysis are essential to track coral health and detect early signs of damage [5].
- Current coral analysis relies on expert divers, which is expensive, slow, and resource-intensive [5].
- AI-driven solutions can help automate classification, detection, and health monitoring of corals.
- Developing a robust dataset is essential for training AI models for accurate identification.
- Our research focuses on enhancing dataset quality and leveraging deep learning models for coral classification and detection.

Challenges

- Underwater images suffer from distortions, including:
  - Motion blur
  - Light absorption
  - Color shifting
- Coral species look visually similar, making classification difficult.
- Some species require electron microscopy for 100% accuracy.
- Need for high-quality, close-range images for accurate classification.
- Environmental factors like water turbulence affect image quality.
- Limited availability of annotated datasets for training deep learning models.
- Coral species exhibit variations in growth forms, adding to classification complexity.
- Real-time detection requires high computational efficiency to process images quickly.
- Imbalanced datasets cause bias in model predictions.
- Need for advanced augmentation techniques to improve training data.
- Ensuring model adaptability to different underwater conditions is challenging.
- Addressing false positives and false negatives in classification is crucial.

- Coral species although can be visual identified easily, some species need electron microscopy for 100% accurate identification.

Dataset

- We developed three datasets, each designed for a specific task.
- Data augmentation techniques used:
  - Rotation
  - Horizontal flipping
  - Brightness adjustment
- Dataset cleaning and annotation process:
  - Manual labeling
  - Removal of duplicate/misclassified images
- Goal: Develop a standard coral dataset for researchers.
- Challenges in dataset creation:
  - Underwater image distortion
  - Class imbalance
  - Lack of labeled data
- Dataset is designed for scalability to include more species.
- Future work: Collaborate with marine biologists for expert annotations.

Binary Classification	Multiclass Classification	Coral Detection
Coral: 32,187 images	27 coral species	Training set: 49,533 images Validation set: 4,372 images
Non Coral: 27,887 images	1 Marine Class, 1 Other class	Test set: 3,081 images
Total: 60,074 images	Total: 29 classes	Total: 56,986 images

Models Overview

- We tested CNNs and Vision Transformers (ViTs) for classification.
- CNN architectures used:
  - ResNet-50
  - EfficientNet-B4 & B7[10]
- ViT architectures used:
  - Google ViT-Base[9]
  - CoCa ViT[8]
- Object detection model used: YOLOv8
- CNNs excel in feature extraction from underwater images.
- ViTs are more efficient in learning long-range dependencies.
- EfficientNet models perform well with fewer parameters.
- YOLOv8 is used for object detection due to its speed and accuracy.
- Vision Transformers require large datasets for optimal training.
- Our study compares model performance across tasks (binary, multiclass, detection).

Binary Classification Results

Task: Determine whether an image contains coral or not.

Best Performing Model: EfficientNet-B7 (97.83% accuracy)

Performance of Other Models:

- ResNet-50: 96.79%
- EfficientNet-B4: 97.75%
- Google ViT-Base: 96.96%
- CoCa ViT: 97.17%

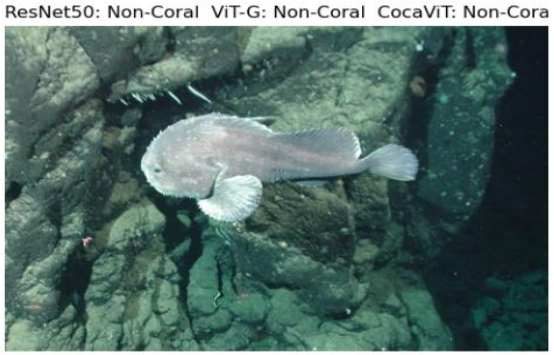
Key Observations:

- Vision Transformers (ViTs) performed competitively but required longer training times.
- EfficientNet-B7 outperformed CNNs and ViTs while being more computationally efficient.
- CoCa ViT had high accuracy but marginal improvement over EfficientNet.
- The use of data augmentation (flipping, rotation, brightness adjustment) improved performance.

Conclusion:

- EfficientNet-B7 is the best model for binary classification due to its high accuracy and efficiency.

Binary Classification Visual Results



Multiclass Classification Results

- Task: Classify images into 29 categories (27 coral species, 1 Marine class, 1 Other class).
- Best Performing Model: Google ViT-Base (95.95% accuracy)
- Performance of Other Models:
  - ResNet-50: 91.15%
  - EfficientNet-B4: 94.13%
  - EfficientNet-B7: 94.64%
  - CoCa ViT: 95.40%
- Key Observations:
  - Google ViT-Base outperformed other models, leveraging transformers' ability to learn long-range dependencies.
  - CoCa ViT performed similarly to ViT-Base, but the performance gain was not significant given its size.
  - EfficientNet-B4 and B7 were highly competitive and more efficient than ViTs.
- Conclusion:
  - Google ViT-Base is best for multiclass classification due to its high accuracy and generalization ability.

Multiclass Classification Visual Result

esNet50:Dendrogyra cylindrus ViT-G:Acropora Palmata CocaViT:Dendrogyra cylin

ResNet50:Others ViT-G:Others CocaViT:Others

ResNet50:Colpophyllia Natans ViT-G:Colpophyllia Natans CocaViT:Colpophyllia Natans

ResNet50:Montipora ViT-G:Montipora CocaViT:Montipora

ResNet50:Millepora Alcicornis ViT-G:Millepora Alcicornis CocaViT:Millepora Alcicornis

ResNet50:Pocillopora meandrina ViT-G:Pocillopora meandrina CocaViT:Montipora

ResNet50:Marine ViT-G:Marine CocaViT:Marine

ResNet50:Siderastrea Siderea ViT-G:Leptoseris CocaViT:Leptoseris

ResNet50:Porites ViT-G:Pocillopora meandrina CocaViT:Pocillopora meandrina

Object Detection Results

- Task: Detect and locate corals in underwater images.
- Best Performing Model: YOLOv8x
- Performance Metrics:
- YOLOv8n (Nano)
  - mAP@0.5:0.95 = 44.05%
  - Best for high FPS, low accuracy
- YOLOv8l (Large)
  - mAP@0.5:0.95 = 49.59%
  - Balanced performance
- YOLOv8x (Extra Large)
  - mAP@0.5:0.95 = 68.2%
  - Highest accuracy, slowest inference
- Key Observations:
  - YOLOv8x detected corals with the highest precision.
  - YOLOv8l provided the best balance between speed and accuracy, making it a strong candidate for real-time applications.
  - YOLOv8n was computationally efficient but had the lowest accuracy.
- Conclusion:
  - YOLOv8x is the best model for object detection, but YOLOv8l is preferable for real-time applications.

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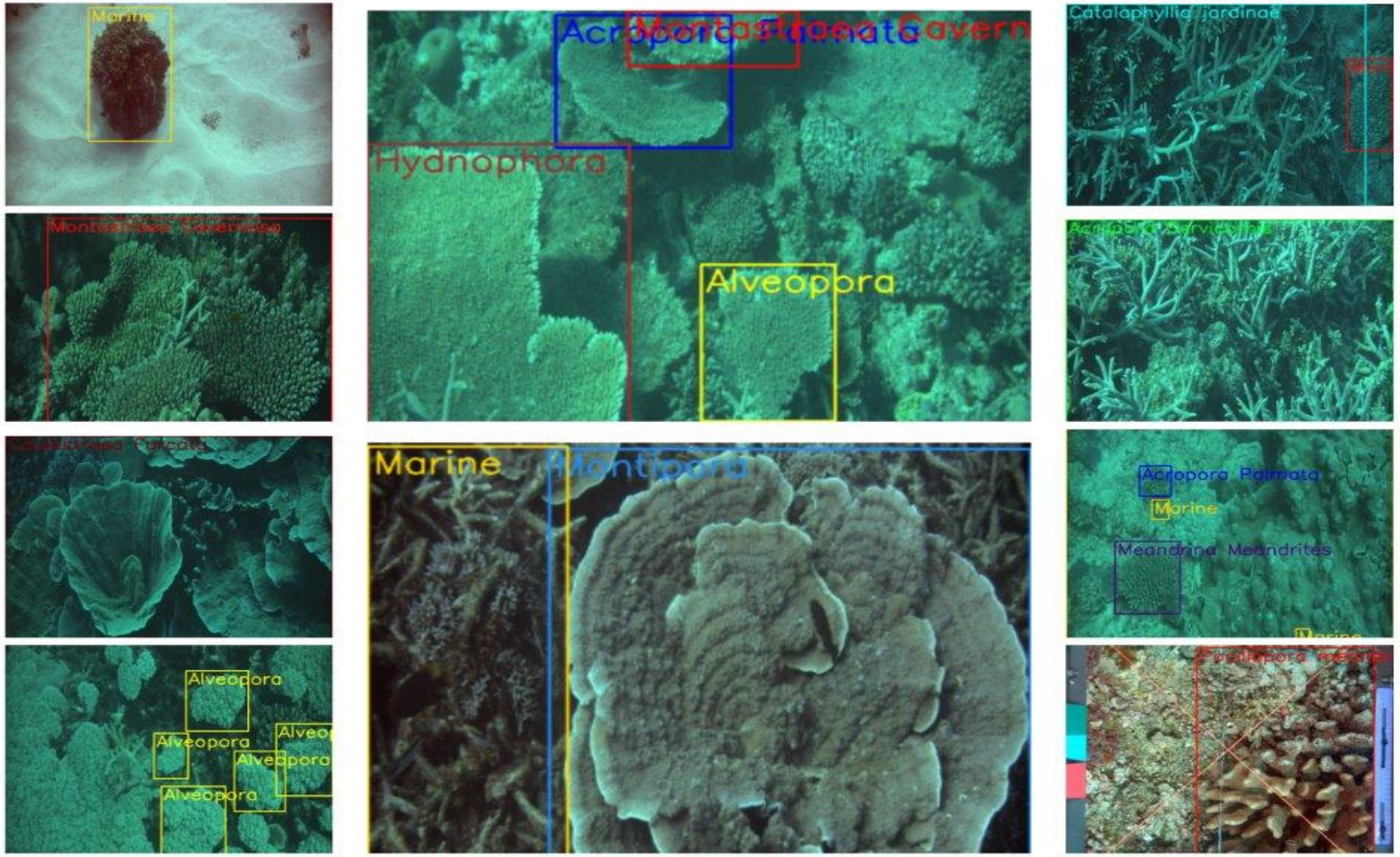
Object Detection Visual Results



Conclusion

- Key Takeaways:
  - Coral monitoring is essential for marine conservation.
  - AI can automate and enhance coral detection.
  - EfficientNet-B7 and ViT-G are strong contenders for classification.
  - YOLOv8x is best for real-time object detection.
- Next Steps:
  - Improve dataset annotation.
  - Optimize AI models for real-world deployment.
  - Explore segmentation and multimodal learning.
- Acknowledgment: Thanks to marine biologists, AI researchers, and data scientists.
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- Thank You! Questions?

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Thanks