AI for Coral Reefs Challenge Assignment Description

Background Information

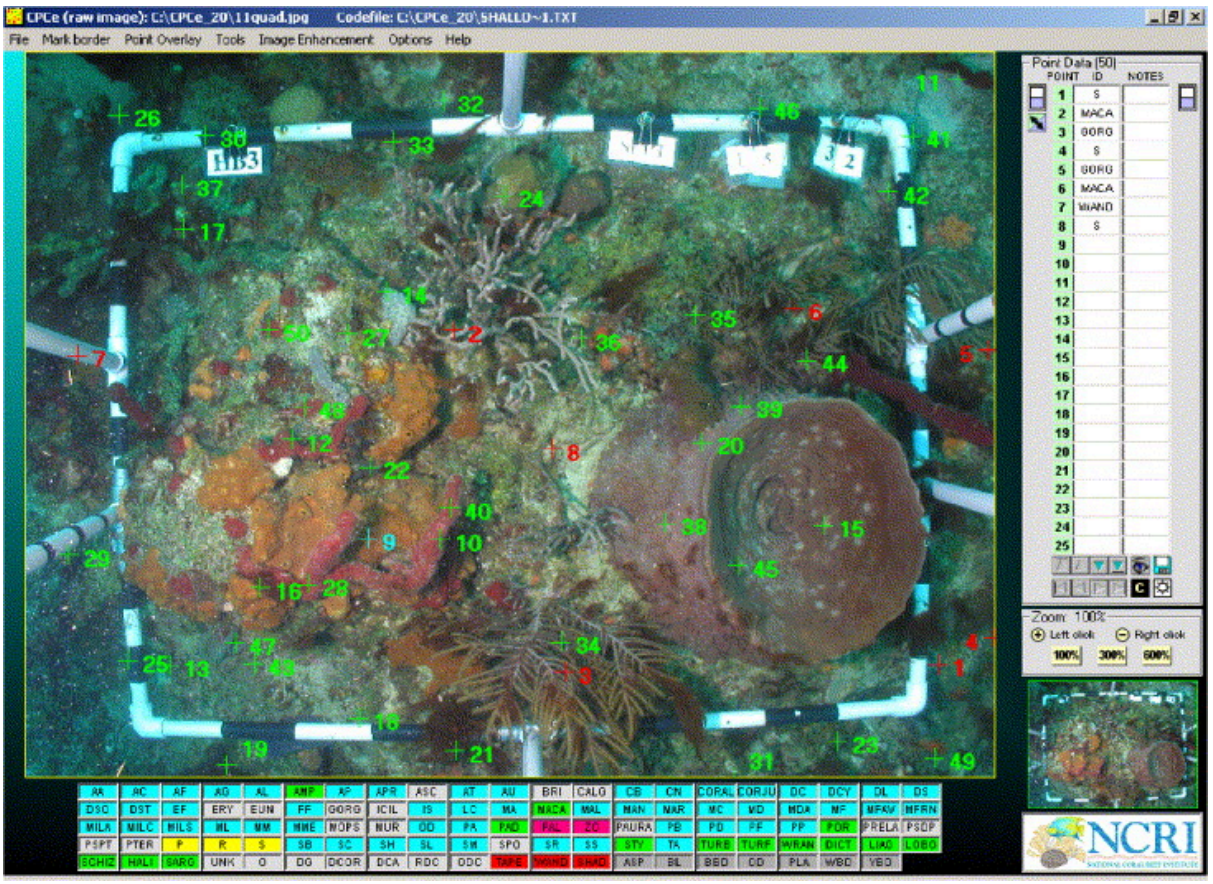
Coral reefs, despite covering only 1% of the ocean's floor, support over 25% of marine life. These vibrant ecosystems are crucial for a multitude of reasons. They protect coastlines from storms and erosion, provide jobs for local communities, and offer opportunities for recreation. Coral reefs are also a source of food and new medicines. Over half a billion people depend on reefs for food, income, and protection. Fishing, diving, and snorkeling on and near reefs add hundreds of millions of dollars to local tourism businesses. Healthy reefs act as natural barriers, protecting coastal cities, communities, and beaches from pounding ocean waves. Nearly 200 million people rely on coral reefs to shield them from storm surges and waves. Additionally, these ecosystems hold cultural significance for indigenous people around the globe.

However, these critical ecosystems are under threat from climate change, pollution, and overfishing. One of the most visible and damaging impacts is coral bleaching. This phenomenon occurs when corals are stressed by environmental changes, such as rising water temperatures, and expel the symbiotic algae living in their tissues. Without these algae, the coral loses its primary food source and its vibrant color, revealing its white skeleton. While a bleached coral is not immediately dead, it is in a weakened state and is highly susceptible to disease and mortality. The ability to quickly detect and monitor these events is critical, as timely interventions can help corals recover if conditions return to normal. Traditional methods of monitoring coral health involve labour-intensive processes, requiring extensive underwater imaging and manual analysis. Reef Support aims to improve coral reef conservation by leveraging artificial intelligence to automate and enhance the monitoring process.

Current Methods of Coral Labelling

Coral monitoring traditionally involves the use of software tools that facilitate the manual annotation of underwater images. Tools like CPCe, CoralNet, and similar solutions are commonly used by marine biologists to place points on specific features within coral reef images. These annotations are typically sparse, covering key points of interest rather than providing full image coverage. While effective for certain analyses, these methods are time-consuming and require significant manual effort.

For example, annotating a single photo-quadrat image (1m²) can take 5–15 minutes, depending on its complexity, the number of coral colonies visible and the desired amount of annotation points. Given that monitoring campaigns often collect thousands of images per site, manual annotation can require hundreds of researcher hours for just one reef survey. Scaling this process across regions and time periods quickly becomes infeasible.



Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology

The need for automation and quantitative analysis

By moving beyond the limitations of manual and point-based methods, which fail to capture the detailed spatial context and quantitative metrics essential for thorough ecological assessments, we can leverage computer vision to improve coral reef conservation.

AI-driven methods have the potential to accelerate this process dramatically. Instead of requiring hours or weeks of expert annotation, trained models can process thousands of images in a matter of minutes, producing segmentation masks, species classifications, or health (bleaching/disease) status predictions at scale. This not only reduces costs but also enables more frequent and extensive monitoring.

Crucially, the ability to quickly classify images for coral bleaching provides early warnings of stress events, allowing conservationists to intervene proactively before widespread mortality occurs. This shift from reactive to proactive strategies should enhance the preservation of coral reefs and support broader marine conservation efforts.

Challenges

You are asked to define an objective for improvement of the task involved in the analysis of underwater images of coral reefs, and provide ReefSupport with insights.

You answer your chosen objective by designing and implementing a solution which you evaluate adequately, e.g., with comparison to a baseline, and to requirements of the domain and the stakeholders. This solution

- typically, it can be an improved model learning pipeline derived from the existing baseline resulting in another model which you compare qualitatively and quantitatively to the baseline model,
- but it can also focus on a part of the original pipeline (e.g., only feature extraction or only model learning) which you compare qualitatively and quantitatively to the corresponding part of the baseline analysis,
- or an entirely different approach which is justified based on literature analysis (requirements of the domain, technical literature) and whose properties are compared to the properties of the baseline.

Here are different example problems that can be addressed by your project:

1. **Coral Bleaching Classification:**
    - **Context:** Coral bleaching is a clear sign of environmental stress, primarily caused by rising sea temperatures. A bleached coral is still alive but is in a weakened state, vulnerable to disease and death. The ability to monitor and classify coral health (healthy, bleached, or dead) is critical for timely conservation efforts. Traditional methods of manual surveys are slow, labor-intensive, and often difficult to scale. Computer vision offers a way to automate this process.
    - **Importance:** An automated coral health classification system would enable rapid, large-scale monitoring of coral reefs, allowing marine biologists and conservationists to quickly identify at-risk areas. Early detection of bleaching events is crucial for implementing targeted interventions to protect and restore these ecosystems. Such a system would reduce the reliance on manual fieldwork.

2. **Coral Surface Area Estimation**
    - **Context:** Accurately measuring the surface area of coral colonies is vital for assessing their growth, health, and overall contribution to the reef ecosystem. Traditionally, this is done through time-consuming manual measurements or complex 3D modeling, which are often not feasible for large-scale monitoring. A more efficient method is to use a known reference object, such as a measuring stick, placed within the image. This allows for the calibration of pixel-to-real-world dimensions. You can use this object to estimate the area of the coral in an image
    - **Importance:** A solution for coral surface area estimation would help marine biology and conservation efforts. It would enable scientists to rapidly and accurately quantify changes in coral size, which is a key indicator of reef health. This would facilitate large-scale monitoring projects, allowing for a more precise understanding of the impact of climate change, pollution, and conservation interventions on coral reefs.

3. **Coral Segmentation**
    - **Context:** Coral reefs are incredibly complex ecosystems, and accurately mapping them is a critical step in conservation. Coral segmentation provides a detailed view of their distribution and health. However, underwater images present significant challenges due to variable lighting, water turbidity, and the intricate, often overlapping, structures of different coral species.
    - **Importance:** Precise segmentation masks can provide invaluable data for marine biologists, enabling them to quantify coral cover, track changes over time, and identify areas of degradation or recovery. This level of detail is essential for developing targeted and effective conservation strategies. An automated segmentation solution would greatly accelerate the analysis of large-scale underwater surveys, making it possible to monitor vast areas of the ocean more efficiently.

Data description

The datasets provided in this course reflect real-world challenges, where marine biologists currently do the work by hand.

To support this, you are given access to different types of coral reef datasets, representing tasks that marine scientists face in practice:

1. **Benthic Datasets (benthic_datasets):** These image datasets provide point-based labels and segmentation masks for corals and other benthic features.
    - **Seaview Survey Photo-quadrat and Image Classification Dataset**
        - Contains over one million standardized, downward-facing images (~1m² each), collected from 860 transects worldwide (2012–2018). A transect is a path along which diver counts and records corals. Each image is paired with human-provided point annotations, you can see an example image on the previous page. It has been widely used in research for developing coral reef monitoring models.
    - **Reef Support Segmented Seaview Subset**
        - A smaller subset of Seaview images where Soft and Hard corals are fully segmented at the pixel level, with blue segmentation masks representing soft corals and red masks representing hard corals.
2. **Coral Bleaching Datasets (coral_bleaching)**
    - **Reef Support Bleaching Dataset**
        - A labeled dataset curated for this course, containing coral health states (healthy, bleached, dead) with corresponding segmentation masks. Healthy corals are segmented in red, bleached in blue and dead are kept black. This dataset was labeled by hand by marine biologists
    - **External Bleaching Datasets**
        - Additional bleaching datasets collected from various external sources. They come in different formats and label structures, requiring preprocessing.

Please take note of the data structures in each dataset, the number of images, and the label formats. In this course, we deliberately allow the datasets to be "messy" to show real-world scenarios you may encounter as a data scientist. Part of the challenge is learning to structure and process the data so that you can effectively train and evaluate different approaches.

Benthic image and its segmented mask

Resources Provided

01_data - Google drive containing all the data provided by ReefSupport. You're free to download, or shortcut to your own drive to work in Colab.

dataloader_example_masks.ipynb - Notebook with examples on how to load and process the data from the benthic_datasets folder with mask labels. This notebook also contains an example baseline model for coral segmentation.

Visualize_point_labels_SEAVIEW.ipynb - Notebook to showcase how to view the point labels that were created by the marine biologists.

Seaview Survey Data Portal - Data portal for the Seaview dataset that also contains detailed descriptions of the data gathering.

Stakeholder

Reef Support focuses on marine ecosystem monitoring and conservation. Our mission is to take practical action and support the blue economy with technology and sustainable travel through the global Reef Rangers network.

Our core product, MariMap, is being developed as a central platform for marine conservation, bringing together field surveys, Earth observation, and AI into one decision-support system. The vision is to give organisations (from NGOs to policymakers)

map-based tools for monitoring, restoration planning, and reporting. You can find more about MariMap on our documentation site.

We are also building Coral AI, a tool for reliable pixel-level segmentation of reef imagery. The aim is to make coral cover estimation, substrate classification, and benthic mapping faster and more consistent, with assisted labelling directly inside MariMap.

Alongside technology, Reef Rangers is already active, offering training and conservation travel programs with partners worldwide. Volunteers and students can join projects for 1–8 weeks, combining diving, research, and restoration while directly supporting marine conservation.

With a growing global network of 30+ partner organisations, Reef Support is working towards scalable tools and community-driven solutions to protect our oceans.

Communication

Student - Tutors/Stakeholders communicate through Slack

To join the slack channel you need to follow this link and create an account. After you joined the channel we will assign you to your group channel where you can communicate with your tutor throughout the semester.