PetroSeg User Manual

Version 1.0

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Contents

1 Introduction

This manual provides a comprehensive guide to using **PetroSeg**, a Python-based graphical user interface (GUI) application. It is intended for end-users and developers who want to understand the features, installation, and usage of the app.

1.1 Purpose

The purpose of **PetroSeg** is to accelerate the process of dataset labelling in archaeological petrographic analysis through an interactive annotation tool. In this domain, constructing an accurate ground truth dataset has traditionally been one of the most significant obstacles, requiring extensive expert input and manual segmentation of inclusions within thin section images of ancient pottery.

This tool addresses that challenge by enabling machine-assisted segmentation, allowing users to interactively annotate inclusions with greater efficiency and precision. By significantly reducing the man-hour burden associated with quantitative petrographic analysis, the tool has the potential to support archaeologists in extracting meaningful insights about ceramic composition, manufacturing techniques, and the geographical origin of artefacts.

The development of this tool was driven by the following research question:

> *Petrographic analysis of thin section ancient pottery samples provides archaeologists with detailed information about the clay composition and forces applied to an artefact during its manufacture. This information can provide insight into both the geographical origin of an artefact as well as the techniques used in its creation. However, quantitative petrographic analysis traditionally demands extensive expert man-hours to accurately assess the ceramic composition.*

By integrating interactive annotation with machine-assisted segmentation, this application aims to streamline the creation of high-quality labelled datasets, thereby facilitating more scalable and reproducible research in archaeological science.

1.2 Target Audience

This manual is intended for all users of the interactive annotation tool, regardless of their level of technical expertise. While the application is designed to be accessible to a broad audience, its primary users are researchers in the field of archaeology, particularly those engaged in petrographic analysis of ancient pottery.

The tool supports archaeologists and materials scientists who require efficient and accurate methods for segmenting inclusions in thin section images. By streamlining the dataset labelling process, it enables users to focus more on interpretation and analysis, rather than manual annotation. Whether used in academic research, heritage conservation, or archaeological fieldwork, this manual provides the necessary guidance to operate the tool effectively.

2 Capabilities and Usage

PetroSeg is designed to accelerate the process of semantic segmentation in archaeological petrographic analysis by providing an interactive environment for pixel-level image an-

notation. The primary goal of the application is to generate a mask from a thin section image, where each pixel is assigned to one of three semantic classes:

- **Background** – Pixels that do not belong to the sample, typically representing the surrounding area.
- **Matrix** – Pixels that represent the clay matrix of the pottery sample.
- **Inclusions** – Pixels that correspond to inclusions embedded within the clay matrix.

This pixel-wise classification is essential for creating labelled datasets used in semantic segmentation tasks. Once the annotation process is complete, the resulting mask can be utilized in two main ways:

1. **Training AI Models:** The labelled masks serve as ground truth data for training machine learning models to automatically segment similar samples.
2. **Statistical Analysis:** With inclusions identified, researchers can extract quantitative features such as size, shape, and distribution of inclusions, enabling deeper insights into the composition and manufacturing techniques of the artefact.

PetroSeg offers a suite of advanced tools to streamline the annotation process, reducing the time and effort traditionally required for manual labelling. These tools include magnification controls, layer blending, real-time pixel information, and intuitive interaction mechanisms, all aimed at improving accuracy and efficiency for researchers.

By combining manual precision with machine-assisted segmentation, PetroSeg empowers archaeologists and materials scientists to build high-quality datasets and conduct reproducible analyses with significantly reduced man-hour investment.

3 Workflow Overview

PetroSeg is designed to guide users through a structured workflow for efficiently annotating thin section images and generating semantic segmentation masks. The following steps outline the typical usage sequence:

3.1 1. Load Image

Begin by loading the image of the thin section sample to be processed. This image serves as the basis for all subsequent annotation and segmentation tasks.

3.2 2. Set the Ruler

Define the conversion between pixel units and real-world measurements. Accurate calibration is essential for meaningful quantitative analysis, especially when measuring the dimensions of inclusions.

3.3 3. Crop Image

If the image contains irrelevant or unwanted regions, crop it to focus on the sample area. Cropping reduces the amount of data to process and improves performance during annotation and segmentation.

3.4 4. Mask the Background

Use the masking tools to identify and isolate the background region of the image. Background areas typically exhibit minimal color variation and can be easily distinguished from the sample. Proper background masking ensures that only relevant sample data is included in the analysis.

3.5 5. Find Inclusions

Utilize the available tools to identify inclusions within the clay matrix. PetroSeg offers multiple methods for this task, including an automatic edge detection algorithm. These tools assist in accurately segmenting inclusions, which are critical for both training AI models and extracting statistical features.

Each of these steps contributes to the creation of a high-quality mask, where every pixel is classified into one of three semantic categories: background, matrix, or inclusions. The resulting mask can then be used for machine learning applications or detailed quantitative analysis of the sample.

4 Installation Guide

To install and run the PetroSeg application, follow these steps:

4.1 1. Clone the Repository

Clone the GitHub repository to your local machine:

```
git clone https://github.com/StefanoGiani/PetroSeg.git
cd PetroSeg
```

Listing 1: Cloning the repository

4.2 2. Install Tkinter

Tkinter is the GUI library used by PetroSeg. It is typically included with Python, but if it's missing, install it as follows:

- **Windows:**

  ```
  pip install tk
  ```

- **macOS:**

  - If using Homebrew Python:

    ```
    brew install python-tk
    ```

  - Or install Python from `https://python.org`, which includes Tkinter.

- **Linux (Ubuntu/Debian):**

  ```
  sudo apt-get install python3-tk
  ```

4.3 3. Create a Virtual Environment (Recommended)

Creating a virtual environment helps isolate the app's dependencies.

- **Windows (CMD or PowerShell):**

```
python -m venv venv
venv\Scripts\activate
```

- **macOS / Linux:**

```
python3 -m venv venv
source venv/bin/activate
```

To deactivate the environment later, simply run:

```
deactivate
```

4.4 4. Install Python Dependencies

Ensure you have Python 3.8 or later installed. Then install the required packages:

```
pip install -r requirements.txt
```

Listing 2: Installing dependpytencies

4.5 5. Run the Application

Once all dependencies are installed, launch the application with:

```
python PetroSeg.py
```

Listing 3: Running the app

4.6 6. System Requirements

To run the PetroSeg application, users must ensure the following system requirements are met:

- **Operating System:** Compatible with Windows, macOS, and Linux (Ubuntu/Debian).
- **Python Version:** Python 3.8 or later.
- **GUI Library:** Tkinter must be installed and available.
  - **Windows:** Usually included with Python. If missing, install via:

    ```
    pip install tk
    ```

  - **macOS:** If using Homebrew Python:

    ```
    brew install python-tk
    ```

Or install Python from `https://python.org`, which includes Tkinter.

– **Linux (Ubuntu/Debian):**

```
sudo apt-get install python3-tk
```

- **Dependencies:** All required Python packages can be installed via:

```
pip install -r requirements.txt
```

- **Execution:** Run the application using:

```
python PetroSeg.py
```

5 Graphical User Interface Overview

The PetroSeg application features a user-friendly graphical interface designed to facilitate efficient image annotation and segmentation. The GUI is composed of several key components, each serving a specific function to support the user workflow:

5.1 Dropdown Menus

Located at the top of the window (see element marked with 1 in Figure 1), the menu bar provides access to core functionalities through the following options:

- **File** – for opening, saving, and exporting images.
- **Edit** – for undo/redo and annotation management.
- **Image** – for image-specific operations.
- **Mask** – for segmentation and mask manipulation.
- **Help** – for accessing documentation and support.

5.2 Image Display Area

The central portion of the window is dedicated to displaying the image being annotated (see element marked with 2 in Figure 1). Users can interact with the image directly using the tools provided in the interface.

5.3 Top Control Panel

Just below the menu bar (see element marked with 3 in Figure 1) is a toolbar that allows users to:

- Switch between image layers (Image, Mask, Mix).
- Adjust magnification using zoom controls (e.g., Zoom: 27).
- Apply or reset settings using the **Set** and **Reset** buttons.

5.4 Side Panel

On the left side of the window (see element marked with 4 in Figure 1), a vertical panel displays real-time information about the cursor position and pixel color values:

- **Coordinates:** X and Y position of the cursor.
- **Color Values:** RGB and HSV values of the pixel under the cursor.

5.5 Status Bar

At the bottom of the window (see element marked with 5 in Figure 1), the status bar provides useful information such as:

- Image dimensions (e.g., 1852 x 2400 pixels).
- Instructions or feedback related to tool usage.

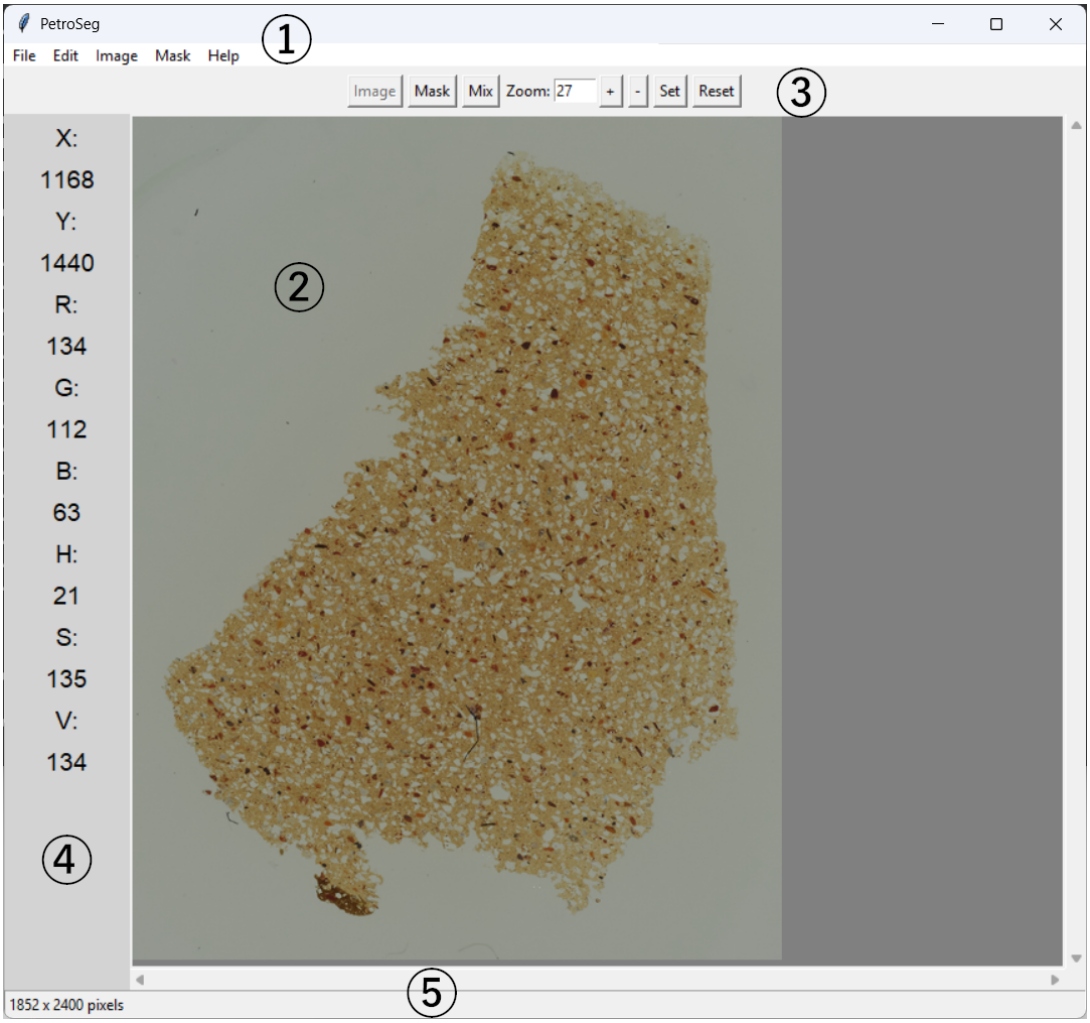

Figure 1: PetroSeg GUI showing menu bar, toolbar, image display, side panel, and status bar.

6 Toolset Overview to Manipulate Images

PetroSeg offers a range of interactive tools designed to facilitate efficient and precise annotation of thin section images. Each tool plays a specific role in the segmentation workflow, helping users label pixels according to their semantic class.

The **Crop** tool allows users to remove unwanted areas from an image, focusing only on the relevant sample. To use it, select `Image > Crop` from the menu, then draw a rectangular region with the mouse to keep. If you wish to cancel the operation, simply press `Esc`.

The **Pick Color** tool enables users to click on the image and automatically add to the mask all pixels that match the selected color and similar shades. Conversely, the **Unpick Color** tool removes from the mask all pixels of the selected color and its close variants.

The **Ruler** tool provides a virtual measuring instrument that can be dragged across the image to determine the dimensions of features. This is particularly useful for calibrating the scale and performing quantitative analysis.

To assist in identifying inclusions, the **Find Inclusions** tool applies an edge detection algorithm to automatically highlight regions that likely correspond to inclusions within the clay matrix.

The **Pick Region** tool allows users to click on the image to select a connected region based on color similarity, adding it to the mask. The **Unpick Region** tool performs the opposite action, removing a connected region from the mask when clicked.

For more refined selection, the **Pick Color Range** tool enables users to define a range of colors and select all regions within that range. This is useful for capturing subtle variations in material composition.

The **Pick Rect** tool lets users draw a rectangular region on the mask to include it in the segmentation. Similarly, the **Unpick Rect** tool allows users to deselect a rectangular region from the mask.

These tools work together to provide a flexible and powerful environment for image annotation, enabling users to create accurate segmentation masks with minimal effort.

7 Menu Overview

PetroSeg provides a structured menu system that organizes commands and tools into five main categories: **File**, **Edit**, **Image**, **Mask**, and **Help**. Each menu contains items that support specific aspects of the annotation and segmentation workflow.

7.1 File Menu

The File menu contains commands for managing projects within PetroSeg. These options allow users to create, load, and save their work, ensuring that annotation progress can be preserved and resumed as needed.

- **New Project...** – Creates a new project, initializing a fresh workspace for image annotation.
- **Load Project...** – Loads an existing project from disk, restoring previously saved images, masks, and settings.

- **Save Project** – Saves the current project, including all annotations and configurations, to the existing project file.
- **Save Project As...** – Saves the current project under a new name or location, allowing users to duplicate or version their work.

7.2 Edit Menu

The Edit menu provides essential commands for modifying the image and managing user actions during the annotation process.

- **Undo** – Reverts the most recent action, allowing users to correct mistakes or try alternative approaches.
- **Redo** – Re-applies the last undone action, restoring changes that were previously reverted.
- **Zoom in** – Increases the magnification level of the image, helping users inspect fine details more closely.
- **Zoom out** – Decreases the magnification level, providing a broader view of the image for context or navigation.

7.3 Image Menu

The Image menu provides a comprehensive set of tools for image manipulation, annotation, and analysis. These commands support the core functionality of PetroSeg and enable users to interact with the image and mask in a variety of ways.

- **Export Image...** – Saves the current image to disk.
- **Create Tiles...** – Create tiles from the image and the mask to be used to train automatic segmentation methods.
- **Crop** – Crops the image to remove unwanted areas.
- **Pick Color** – Adds to the mask all pixels of the selected color and similar shades.
- **Unpick Color** – Removes from the mask all pixels of the selected color and similar shades.
- **Pick Region** – Adds a connected region to the mask based on color similarity.
- **Unpick Region** – Removes a connected region from the mask.
- **Pick Color Range...** – Opens a dialog to select regions using a color range.
- **Pick Rect** – Selects a rectangular region on the mask.
- **Unpick Rect** – Deselects a rectangular region on the mask.
- **Ruler** – Displays a virtual ruler for measuring features in the image.

- **Pick Color Dialogue...** – Opens a dialog to configure parameters for the Pick Color tool.
- **Pick Region Dialogue...** – Opens a dialog to configure parameters for the Pick Region tool.
- **Set Ruler...** – Opens a dialog to set units and define the pixel-to-real-unit conversion.
- **Find Inclusions...** – Opens a dialog to configure parameters for automatic inclusion detection using edge detection.
- **Show H Histogram** – Displays a histogram of the H (Hue) channel.
- **Show S Histogram** – Displays a histogram of the S (Saturation) channel.
- **Show V Histogram** – Displays a histogram of the V (Value) channel.
- **Show R Histogram** – Displays a histogram of the Red channel.
- **Show G Histogram** – Displays a histogram of the Green channel.
- **Show B Histogram** – Displays a histogram of the Blue channel.

7.4 Mask Menu

The Mask menu allows users to specify which semantic class they are currently annotating. This selection determines how subsequent interactions with the image affect the segmentation mask.

- **Export Mask...** – Saves the current mask to disk.
- **Export Mix...** – Saves the current mask overlaid to the image to disk.
- **Background** – Sets the active class to background, allowing users to mark regions that do not belong to the sample. Some tools need a class to be selected in order to work, see Section 9.
- **Matrix** – Sets the active class to matrix, enabling annotation of the clay matrix within the sample. Some tools need a class to be selected in order to work, see Section 9.
- **Inclusion** – Sets the active class to inclusion, used to identify and label inclusions embedded in the matrix. Some tools need a class to be selected in order to work, see Section 9.
- **Overwrite** - Allow for already selected classes on the mask to be overwritten. Some tools are affected by the status of this option, see Section 10
- **Check Consistency...** - Check that all the pixels in the mask are asigned to a class.
- **Export Statistics...** - Dialogue to export the statistics of the inclusions.

7.5 Help Menu

The Help menu provides access to information about the application and its authorship.

- **About** – Displays a window showing credits and version information for the PetroSeg application.

8 Dialogues

8.1 Color Range Dialogue

The **Color Range Dialogue**, Figure 2, allows users to mask all pixels in the image that fall within a specified color range. This tool is particularly useful for selecting materials or features that exhibit consistent color characteristics across the sample.

Users can define the color range using either the RGB or HSV color space, providing flexibility in how color similarity is interpreted. Once the range is set, the tool scans the entire image and adds all matching pixels to the mask, regardless of their spatial connectivity.

This functionality is ideal for identifying dispersed features with similar color properties, such as inclusions or matrix elements that are not necessarily adjacent but share a common visual signature.

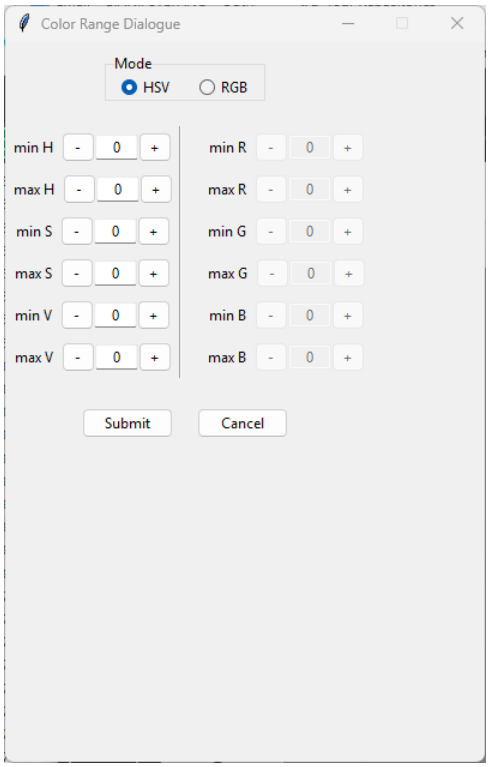

Figure 2: Color Range Dialogue – define a color range in RGB or HSV to mask matching pixels.

8.2 Pick Color Dialogue

The **Pick Color Dialogue**, Figure 3, allows users to configure the parameters for selecting pixels across the entire image based on color similarity. When a user clicks on a

point in the image, the tool identifies all pixels that are similar in color to the clicked pixel and adds them to the mask.

Unlike region-based selection, the resulting mask may include non-contiguous areas, as the similarity is evaluated globally rather than spatially. The similarity relation is defined using adjustable thresholds in either the RGB or HSV color space, allowing users to fine-tune the selection sensitivity according to the characteristics of the image.

This tool is particularly useful for identifying widespread material features that share similar color properties but are distributed across different parts of the sample.

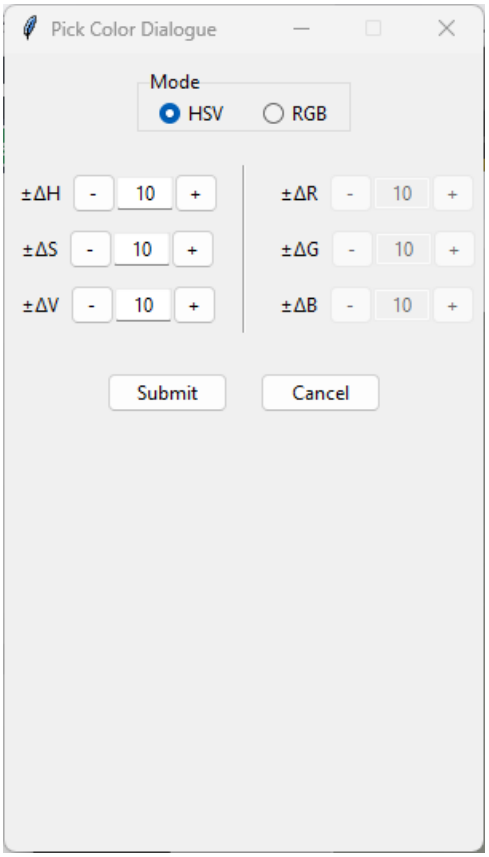

Figure 3: Pick Color Dialogue – configure global color similarity thresholds for pixel selection.

8.3 Pick Region Dialogue

The **Pick Region Dialogue**, Figure 4, allows users to configure the parameters for selecting a connected region in the image based on color similarity. When the user clicks on a point in the image, the tool identifies a region of pixels that are similar in color to the clicked pixel and adds it to the mask.

Color similarity is determined using adjustable thresholds, which can be defined in either the RGB or HSV color space. This flexibility allows users to fine-tune the sensitivity of the selection process depending on the characteristics of the image and the materials being annotated.

This dialogue is particularly useful for segmenting inclusions or matrix regions that are visually distinct but not uniform in color, enabling more accurate and efficient annotation.

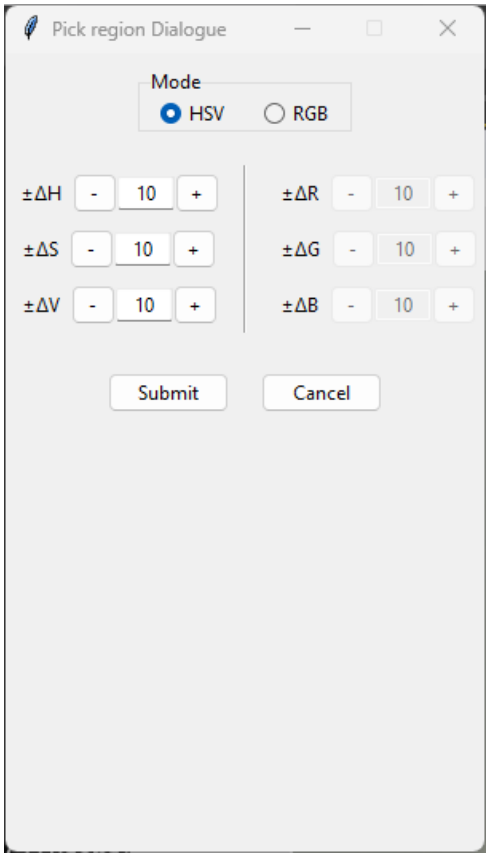

Figure 4: Pick Region Dialogue – configure color similarity thresholds for region selection.

8.4 Find Inclusions Dialogue

The **Find Inclusions Dialogue**, Figure 5, provides a configurable interface for automatically detecting inclusions in the image using edge detection techniques. This tool is designed to assist users in identifying potential inclusions with minimal manual effort by applying a series of filters and thresholds.

Several parameters can be adjusted to refine the detection process:

- **Edge Thresholds** – Define the minimum and maximum gradient values used to detect edges in the image. Lower thresholds may detect more edges, including noise, while higher thresholds focus on stronger, more defined edges.
- **Area Thresholds** – Specify the acceptable range of areas for detected regions to be considered valid inclusions. This helps filter out regions that are too small (likely noise) or too large (possibly background or matrix).
- **Ratio Threshold** – Sets a minimum value for the ratio between the area of a region and the area of its convex hull. This metric helps identify compact, well-defined inclusions by excluding irregular or elongated shapes.
- **Color Range** – Allows users to define acceptable color ranges for inclusions using minimum and maximum values for each component in either the RGB or HSV color space. This ensures that only regions with appropriate color characteristics are included.

The dialogue also includes a **Preview** button, which enables users to visualize the regions that meet the specified criteria before committing them to the mask. This feature allows for iterative refinement of parameters to achieve optimal results.

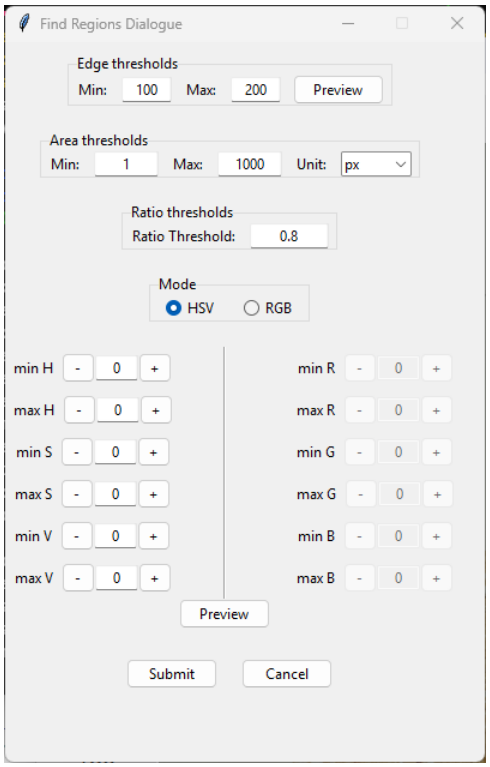

Figure 5: Find Inclusions Dialogue – configure edge, area, shape, and color parameters for automatic inclusion detection.

8.5 Find Inclusions Dialogue

The **Tile Generation Dialogue**, Figure 6, provides a configurable interface for generating tiles from the image and the mask. Such tiles can be used to train an automatic segmentation algorithm.

Several parameters can be adjusted to refine the detection process:

- **Tile Width** – Width of the tiles in pixels.
- **Tile Height** – Height of the tiles in pixels.
- **Horizontal Overlap** – Size in pixels of the horizontal overlap between consecutive tiles.
- **Vertical Overlap** – Size in pixels of the vertical overlap between tiles on consecutive rows.
- **Tiles Name** – Root name for the tiles. The algorithm adds automatically the number of the tile to the root name, and the word mask and the the number of the tile to the root name in case of tiles of the mask.
- **Output Directory** – Folder where the tiles generated from the image and mask are saved.

The dialogue also includes a **Preview** button, which enables users to visualize the regions that meet the specified criteria before committing them to the mask. This feature allows for iterative refinement of parameters to achieve optimal results.

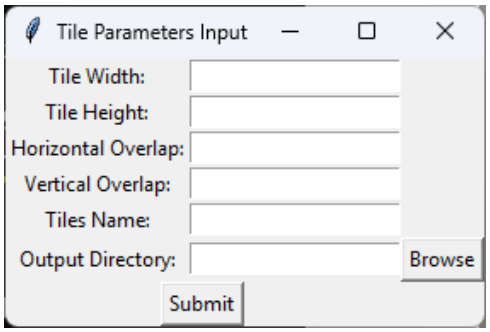

Figure 6: Tile Generation Dialogue – configure the parameters to generate the tiles form the image and mask.

8.6 Set Ruler Dialogue

The **Set Ruler Dialogue**, Figure 7, allows users to define the real-world dimensions of features in the image by establishing a conversion factor between pixels and physical units. This calibration is essential for accurate measurement and quantitative analysis of inclusions and other sample features.

Users can specify the unit of measurement—centimeters (cm), millimeters (mm), or inches—and input the known length of a feature in the image. The application then calculates the pixel-to-unit ratio, enabling all subsequent measurements to reflect true physical dimensions.

This tool is particularly useful when analyzing the size and distribution of inclusions, as it ensures that extracted statistics are meaningful and consistent with real-world scales.

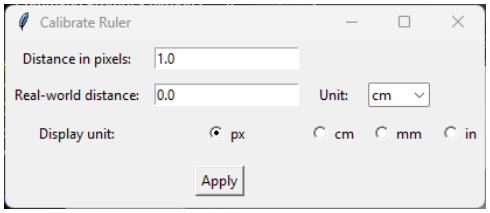

Figure 7: Set Ruler Dialogue – define pixel-to-unit conversion for accurate measurements.

9 Tools Using the Mask

The following tools act on the mask, and in order for them to work, a mask class among **Background**, **Matrix** or **Inclusions** must be selected in the Mask menu before using the tool:

- **Pick Color**
- **Pick Region**
- **Pick Rect**

- **Pick Color Range**
- **Find Inclusions**

10 Overwriting the Mask

The results of some tools are affected by the option **Overwrite** in the Mask menu to be selected or not. When the option is selected, the tools can overwrite the already existing classes in the mask, otherwise the tools will only act on pixels without a class assigned to them. The tools affected by **Overwrite** are:

- **Pick Color**
- **Unpick Color**
- **Pick Region**
- **Pick Color Range...**
- **Find Inclusions**

11 Keyboard and Mouse Shortcuts

PetroSeg supports a range of keyboard and mouse shortcuts to improve workflow efficiency and streamline the annotation process. Below is a list of available shortcuts and their functions:

- **Ctrl+N** – Create a new project and open an image.
- **Ctrl+S** – Save the current project.
- **Ctrl+O** – Load a project from disk.
- **Ctrl+Q** – Terminate the application.
- **+**, **-** – Increase or decrease the zoom level.
- **Arrow keys** – Pan the image in the corresponding direction.
- **Ctrl+Z** – Undo the previous action.
- **Ctrl+Y** – Redo the last undone action.
- **Esc** – Deselect the currently active tool.
- **Right Mouse Button** – Deselect the currently active tool.
- **1**, **2**, **3** – Switch between image view, mask view, and blended view of image and mask.
- **Left Mouse Button (drag)** – When no tools are selected, drag the image by holding down the left mouse button and moving the cursor.

11.1 Configuration Options

Explain config files or settings.

- **Issue:** App won't start
  Solution: Check Python version and dependencies.
- **Issue:** GUI elements not displaying
  Solution: Ensure correct GUI library is installed.

12 Contact and Support

For help, contact: `stefano.giani@durham.ac.uk`
GitHub: `https://github.com/StefanoGiani/PetroSeg`