Supplementary Note 2: MorphoExplainer Manual

2.1 Install MorphoExplainer

To install MorphoExplainer, first launch QuPath, then drag the plugin file **qupath-extension-MorphoExplainer.jar** into the QuPath interface or install it via *Extensions →
Install extension.* The JAR file can be downloaded from [Github](#). After installation, QuPath needs to be restarted. Once restarted, the MorphoExplainer panel will be visible in the menu or sidebar.

2.2 Loading GeoJSON Files

MorphoExplainer reads **GeoJSON files** that contain overlay information for both attention heatmaps and spectrum-based explanations. Each GeoJSON file corresponds to a single WSI.

2.2.1 GeoJSON File Schema

Each WSI is saved as one GeoJSON FeatureCollection that contains three logical parts, as illustrated in Figure 8.

Figure 8 GeoJSON file schema used by MorphoExplainer

The first part is Model predictions for the WSI, which records the model's four-class prediction outputs for the given slide. Because the model used in this study performs a four-

class classification task, this array contains four elements, each corresponding to one disease subtype. For each element, the attribute **prediction** specifies the subtype label, **confidence** stores the model's predicted probability for that subtype, and **classificationsets** records the morphologic clusters that the model's high-contribution patches were mapped to for that subtype. Within each entry of **classificationsets**, **name** denotes the cluster identifier (for example, Endo_hc_2), and **descr** provides a concise textual description of the cluster's morphologic characteristics (for example, Glandular pattern with squamous metaplasia). The cluster identifiers listed here are referenced by the morphologic spectrum features described later.

The second part, Attention heatmap results (per tile), stores tile-level information for the model's attention visualization. Each element within the **features** array represents one tile from the WSI. The spatial boundary of the tile is defined in the **geometry** field as a polygon described by its pixel coordinates. Within the **properties** field, **prediction** indicates which of the four predicted classes this tile belongs to, and **objectType** is set to "tile." The **measurements** subfield contains the tile's attention weight (**attention**), which quantifies the relative contribution of that tile to the model's prediction. The **metadata** field records the associated slide identifier (**slide_id**) and, when available, the tile identifier (**tile_id**).

The third part, Morphologic spectrum interpretability results (per tile), also appears under the **features** array but represents the model's spectrum-based explanations. Each feature again corresponds to an individual tile, with its spatial boundary defined in the same **geometry** format as above. In the **properties** field, **prediction** specifies the subtype to which this tile contributes, and **objectType** is set to "annotation." The **name** attribute identifies the cluster element, while **color** defines the RGB color used to display the tile on the WSI. The **classification** subfield stores the tile's morphologic cluster assignment, where **name** corresponds to the cluster identifier that matches one of the entries in the top-level **classificationsets**, and **color** provides the display color for that cluster. The **measurements** array contains quantitative information such as tile width, tile height. Finally, the **metadata** field again records the slide and tile identifiers.

The GeoJSON files containing these interpretability results for each WSI can be automatically generated using the code provided with this study; implementation details and scripts are available on the project's GitHub repository.

2.2.2 Import GeoJSON into MorphoExplainer

To import a GeoJSON file: Open the corresponding WSI in QuPath, launch MorphoExplainer, and click the Select GeoJSON File button. In the file selection window, choose the GeoJSON file you wish to import. Once selected, the file will be automatically loaded into the plugin and its contents displayed in the corresponding visualization panels.

2.3 Interactive Annotation for Visualization and Rating

MorphoExplainer provides three interactive panels—**Heatmap**, **MorphoSpectrum**, and **MorphoSpectrum Cluster**—that allow users to explore the model's attention heatmaps and morphologic spectrum–based explanations, as well as to provide corresponding annotations and ratings.

2.3.1 Heatmap Panel

Clicking the **Heatmap** tab enters the Heatmap Panel (Figure 9), which visualizes the model's attention heatmap on the whole-slide image. To begin, users should click the **Attention Heatmap Select** button, prompting the plugin to read the attention-related information stored in the imported GeoJSON file and overlay the corresponding heatmap on the WSI.
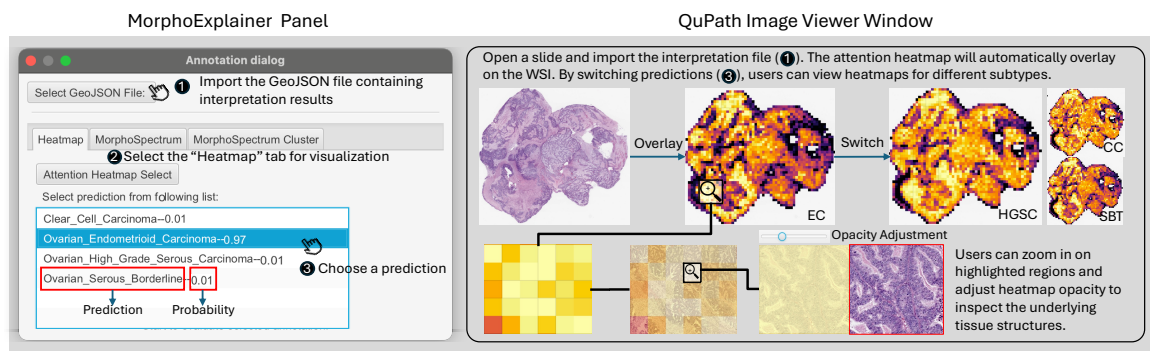
Figure 9 Interface and workflow of the Heatmap panel in MorphoExplainer

In the blue box below the panel, the plugin lists all possible predictions together with their associated predicted probabilities. Selecting one prediction will automatically update the QuPath viewer to display the attention heatmap corresponding to that subtype. The heatmap highlights the regions that contributed most strongly to the model's decision. Using QuPath's opacity slider in the viewer toolbar, users can adjust the transparency of the heatmap layer to better visualize the underlying histologic structures. Users can also zoom in on the highlighted areas to closely inspect tissue morphology corresponding to high-attention regions.

At the bottom of the panel (Figure 10), three structured questions are presented for the annotator to evaluate the interpretability and diagnostic usefulness of the attention heatmap. Annotators can select their responses corresponding to each question. After completing the ratings, clicking **"Confirm your description"** will automatically save the annotation results.

Figure 10 Annotation interface for the Heatmap panel in MorphoExplainer

2.3.2 MorphoSpectrum Panel

Clicking the **MorphoSpectrum** tab opens the MorphoSpectrum panel (Figure 11), which visualizes the model's spectrum-based interpretability results on the WSI. After clicking the **MorphoSpectrum Select** button, the plugin reads the spectrum-related information from the imported GeoJSON file and overlays the morphologic spectrum interpretation on the slide.
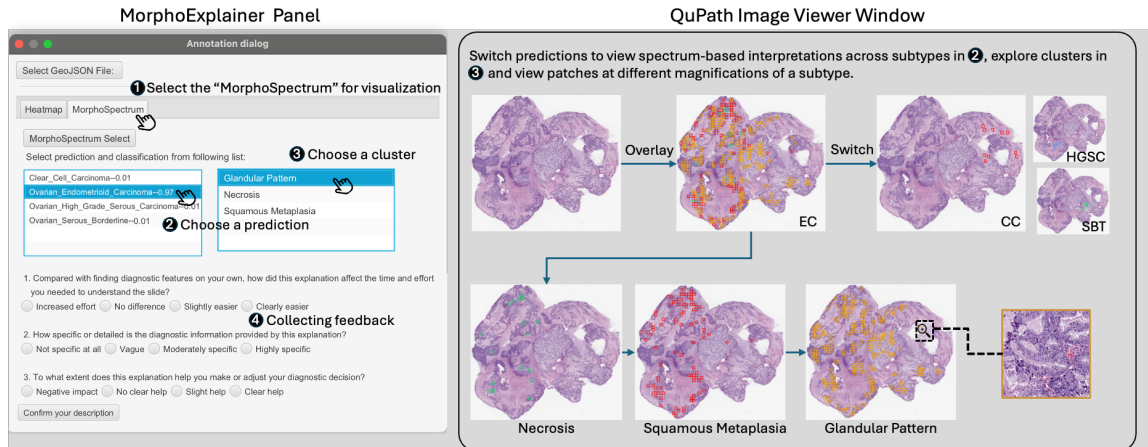

Figure 11 Interface and workflow of the MorphoSpectrum panel in MorphoExplainer

In the lower section of the panel, two blue selection boxes are provided. The left box lists all subtype predictions made by the model; users can switch between them to view the spectrum-based explanation corresponding to each subtype. The right box lists the morphologic clusters that constitute the selected subtype's spectrum, each labeled with its morphologic description (for example, Glandular pattern, Squamous metaplasia, or Necrosis). Clicking on a cluster highlights its corresponding patches on the WSI, allowing users to inspect where and how these morphologic patterns are distributed across the tissue.

At the bottom of the panel, three structured questions are provided for annotators. After completing the ratings, clicking **"Confirm your description"** will automatically save the annotation results.

2.3.3 MorphoSpectrum Cluster Panel

The MorphoSpectrum Cluster panel provides the same visualization functions as the MorphoSpectrum panel. The only difference lies in the annotation component. This panel is designed specifically for pathologists to evaluate whether the highlighted patches visually correspond to the described morphologic pattern of each cluster. At the bottom of the panel, a single structured question is provided—"Do the highlighted patches correspond to the described morphological patterns?"—with three selectable options: Consistent, Inconsistent, and Uncertain. After choosing the appropriate option, users can click "Confirm your description" to save their evaluation for the current cluster.
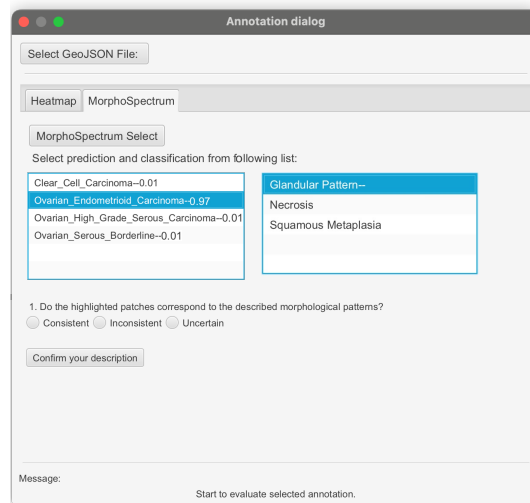
Figure 12 Interface of the MorphoSpectrum Cluster panel

2.4 Annotation Results

For each WSI, the annotations provided for both the attention heatmap and the morphologic spectrum explanations are automatically exported as a .csv file (Figure 13), which is saved in the same directory as the opened .svs file. In the exported file, the first column records the slide filename. The first two rows correspond to the annotator's ratings of the attention heatmap and the morphologic spectrum explanation regarding ease of understanding, specificity of diagnostic information, and helpfulness for diagnostic decision-making. The subsequent rows contain the evaluations for each morphologic cluster, indicating whether the highlighted patches are morphologically consistent with the described cluster pattern.

A	B	C	D	E	F
slide.svs	Heatmap		Clearly easier	Moderately specific	Slight help
slide.svs	MorphoSpectrum		Clearly easier	Highly specific	Clear help
slide.svs	MorphoSpectrum Cluster	Endo_hc_1--Squamous Metaplasia	Consistent		
slide.svs	MorphoSpectrum Cluster	Endo_hc_2--Glandular Pattern with Squamous Metaplasia	Consistent		
slide.svs	MorphoSpectrum Cluster	Endo_hc_4--Glandular Pattern	Consistent		
slide.svs	MorphoSpectrum Cluster	High_to_Endo_hc_3--Glandular Pattern			

Figure 13 Interface of the MorphoSpectrum Cluster panel