AIRAQC: Deep Learning for Artefact Identification and Quantification in Digital Pathology

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Abstract

The quality of a whole slide image (WSI) of a histopathology slide may be impacted by artefacts introduced by fixation, processing, sectioning, and/or scanning. Artefacts in WSIs can render portions or the entirety of histopathology slides unsuitable for various types of analysis, and lead laboratory staff to create additional slides or scans that are less impacted. Quality control in preanalytical workflows to detect these artefacts is time and resource-consuming when performed manually and could lead to increased costs and slowed production timelines. In this study, we present a deep learning system trained to identify and quantify frequently occurring artefacts in WSI of H&E-stained tissues.

Methods

Nonclinical Training Data

- Stain: H&E
- WSI: 1850
- Organs: 40
- Species: 3 (rat, mouse, dog)

Clinical Training Data

- Stain: H&E
- WSI: 600
- Organs: 8 (biopsies and resections)

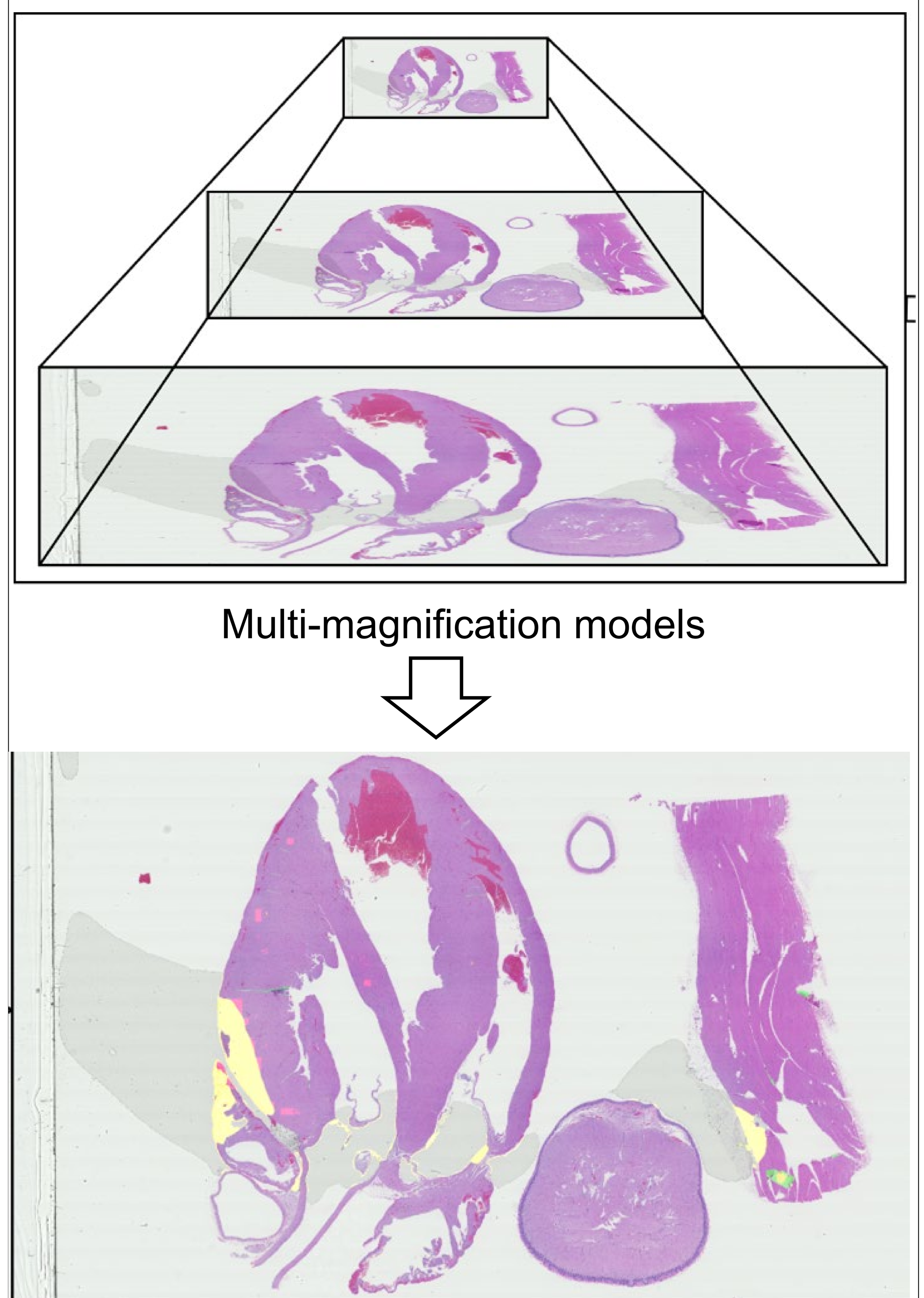
Testing Data

- Stain: H&E
- WSI: 157
- Organs: 34
- Species: 4 (rat, mouse, rabbit, dog)

This multi-model workflow analyzes each WSI at multiple magnifications, enabling identification of artefacts at different scales. Combining predictions from various magnifications yields five class segmentation masks that can quantify the percentage of tissue affected by each artefact. Model training employs multiple techniques that permit generalization across various tissue types, species, stain intensities, and scanner manufacturers.

These techniques include cross-domain active learning, semi-supervised domain generalization, and stain mix-up augmentation.

Figure 1: Algorithm workflow



We evaluated the model on 157 out of sample WSI with the following artefacts: Out-of-focus, Fold, Air Bubble, Knife Line, and Penmark/Spot. A histopathology technician contributed to the annotation of various artefacts to generate ground truth. The system was evaluated based on the tissue percentage quantified.

Results

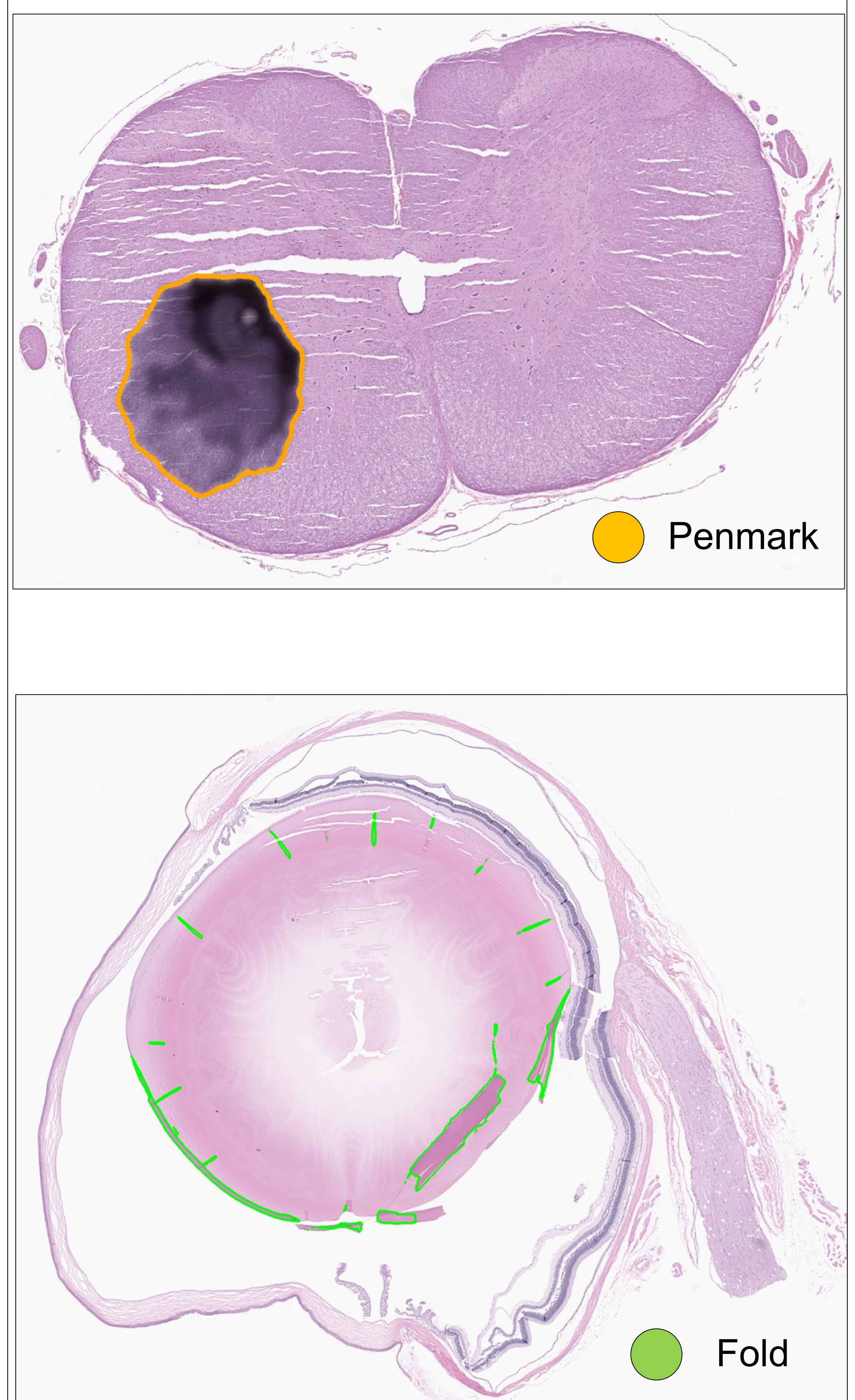
Average sensitivity and specificity for the automated solution across all artefacts was 0.96 and 0.95, respectively

Table 1: Mean sensitivity/specificity across WSI

Artefact Type	Sensitivity	Specificity
Air Bubble	NA	0.98
Out-of-Focus	0.99	0.91
Fold	0.95	0.92
Penmark/Spot	0.92	0.98
Knife Line	0.98	0.94

On NVIDIA A6000 GPU, the median testing time was 18.4 seconds.

Figure 2: Illustrative artifact detections



Discussion

- Digital Whole Slide Images (WSI) are widely used for qualitative and quantitative tissue analysis in histology workflows.
- Slide preparation and digitization may introduce artefacts that render some tissue regions unsuitable analysis.
- Quality control for qualitative analysis currently involves human review of slides.
- Quality control for quantitative analysis involves delineation and exclusion of affected regions.
- The volume of slides generated for nonclinical toxicology study evaluation (2500+ tissues per study) lends itself to automated artifact assessment.
- For laboratories operating under a formal quality system (e.g., Good Laboratory Practice) output of QC computational model offers potential to retain a quantitative quality record.
- We present computational model that detects various types of artefacts and is generalizable across species, tissue types, scanners, and image formats.

Conclusion

- A novel system is presented for detecting and quantifying artefacts in histology WSI.
- The system is intended to enhance the efficiency of digital pathology laboratories and reduce the cost of quality control.
- Output could be used to generate a histology slide quality control report to document compliance in laboratory quality system.

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