FIMIL: A high-throughput deep learning model for abnormality detection with weak annotation in microscopy images

Jing Ke, Changchang Liu, Yizhou Lu 2020.02 @ HIKM2020
Overview

1. Background Introduction
2. Methodology
   2.1 Multiple Instance Learning
   2.2 Foveated Imaging based Patch Partition
   2.3 Aggregation
   2.4 Architecture
3. Experiments
   3.1 Dataset
   3.2 Evaluation
4. Conclusion
Background Introduction

Liquid-based cytology image

- Normal cell
- Abnormal cell
- Inflammatory cell
Background Introduction

- Pathologists’ annotation: highlight the suspicious region with marker pens on glass of microscopy slide

Task:
automatic computer-aided detection cancerous/tumorous?
Methodology

FIMIL: Foveated Imaging Multiple Instance Learning

detection \{ accurate \{ multiple instance learning aggregation \}
fast $\rightarrow$ foveated imaging based patch partition
Typical Multiple Instance Learning (MIL)

Multiple-Instance Learning (MIL)

positive bags

negative bags

positive

negative

Traditional supervised learning

Multiple-instance learning

[Dietterich et al. 1997]
MIL

- Bag: red area
- Instance: cell

The image is {\text{abnormal}} if abnormal cells exceed a certain ratio otherwise.

red area contains multiple cells

diversity of cells and tissues unexpected dust or nonspecific staining difference between each grade of dysplasia
Foveated Imaging

- The center area of a marked region: fixation point
- Fixation point → highest resolution region of the image → more details and information
- Function: 1. concentrate on the area with highest likelihood of dysplasia;
  2. accelerate the processing by neural networks.
Foveated Imaging based Patch Partition

- Split the microscopy image into patches with different rates of magnification.
- Example: an input image of 4096×4096 is split into patches of magnification rates of 40X, 20X and 10X with patch size 256×256.

![Diagram showing the process of foveated imaging based patch partition with original image, patch partition, and multi-resolution scale.]
Aggregation

- patch scores $\xrightarrow{aggregation}$ bag score
- weighted patch scores
- bag score $>$ threshold?
Architecture
Dataset

- 49 positive and 100 negative whole slide liquid-based cytology images.
- Crop 256*256 patches of multiple magnifications rate of 40x, 20x, and 10x from the original high-resolution scanned images with a balance in normal/abnormal samples.
- Data enhancement: cropping, rotating and elastic transformation.

<table>
<thead>
<tr>
<th>Training</th>
<th>Validation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>70%</td>
<td>15%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Evaluation

- Two benchmarks are designed to evaluate the accuracy and performance acceleration of our proposed model.
- First: patch-level prediction; second: image-level prediction
- Device: NVIDIA Tesla V100
- threshold: 0.75
Evaluation

- Patches with 40x, 20x and 10x rate are fed into their corresponding networks respectively.
- 89 test patches of 40x, 183 test patches of 20x and 191 test patches of 10x

<table>
<thead>
<tr>
<th>Magnification rate</th>
<th>Precision</th>
<th>Recall</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>40x</td>
<td>0.911</td>
<td>0.837</td>
<td>0.867</td>
</tr>
<tr>
<td>20x</td>
<td>0.880</td>
<td>0.818</td>
<td>0.842</td>
</tr>
<tr>
<td>10x</td>
<td>0.842</td>
<td>0.800</td>
<td>0.817</td>
</tr>
</tbody>
</table>
Evaluation

- Take all the marked region as the input for performance evaluation.
- 90 images for test.
- Example: $4096 \times 4096$

FIMIL

40x: 16
20x: 12
10x: 12

vs.

Baseline

40x: 256
Evaluation

- Downsampling → Loss of information
- Accuracy decreases little, speed increases much
- Predication performance

<table>
<thead>
<tr>
<th>All images</th>
<th>Precision</th>
<th>Recall</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.889</td>
<td>0.833</td>
<td>0.856</td>
</tr>
<tr>
<td>Optimized partition method</td>
<td>0.867</td>
<td>0.813</td>
<td>0.833</td>
</tr>
</tbody>
</table>
### Evaluation

- **Performance speedup results**

<table>
<thead>
<tr>
<th>image size</th>
<th>No. of 10x</th>
<th>No. of 20x</th>
<th>No. of 40x</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>4096 × 4096</td>
<td>16</td>
<td>12</td>
<td>12</td>
<td>640%</td>
</tr>
<tr>
<td>6144 × 6144</td>
<td>64</td>
<td>48</td>
<td>20</td>
<td>436%</td>
</tr>
<tr>
<td>8192 × 8192</td>
<td>64</td>
<td>48</td>
<td>48</td>
<td>640%</td>
</tr>
<tr>
<td>10240 × 10240</td>
<td>64</td>
<td>48</td>
<td>84</td>
<td>816%</td>
</tr>
<tr>
<td>5120 × 4096</td>
<td>32</td>
<td>16</td>
<td>14</td>
<td>516%</td>
</tr>
<tr>
<td>6144 × 5632</td>
<td>48</td>
<td>44</td>
<td>16</td>
<td>489%</td>
</tr>
<tr>
<td>7168 × 6144</td>
<td>32</td>
<td>16</td>
<td>36</td>
<td>800%</td>
</tr>
<tr>
<td>10240 × 8192</td>
<td>96</td>
<td>72</td>
<td>56</td>
<td>571%</td>
</tr>
</tbody>
</table>
Conclusion

- We propose a novel **FIMIL** model for abnormality detection and classification in microscopy image with weak annotations.

- With foveated imaging based patch partition algorithm, multi-scale processing is performed for the classification network.

- The architecture is applicable to arbitrary size of the annotated regions.

- Experimentally, the proposed model can output high-throughput predictions with high accuracy in the cytology microscopic image analysis.
Acknowledgement

- Thanks for Professor Jing Ke.
- Thanks for Shanxi Tumor Hospital for the supplement of digital cervical cytology images, as well as the labels and annotations from cytologists.
Thank you!

Q&A