ISBI 2019 Challenge: Classification of Normal versus Malignant Cells in B-ALL White Blood Cancer Microscopic Images

# Neighborhood-Correction Algorithm for Classification of Normal *vs*. Malignant Cells

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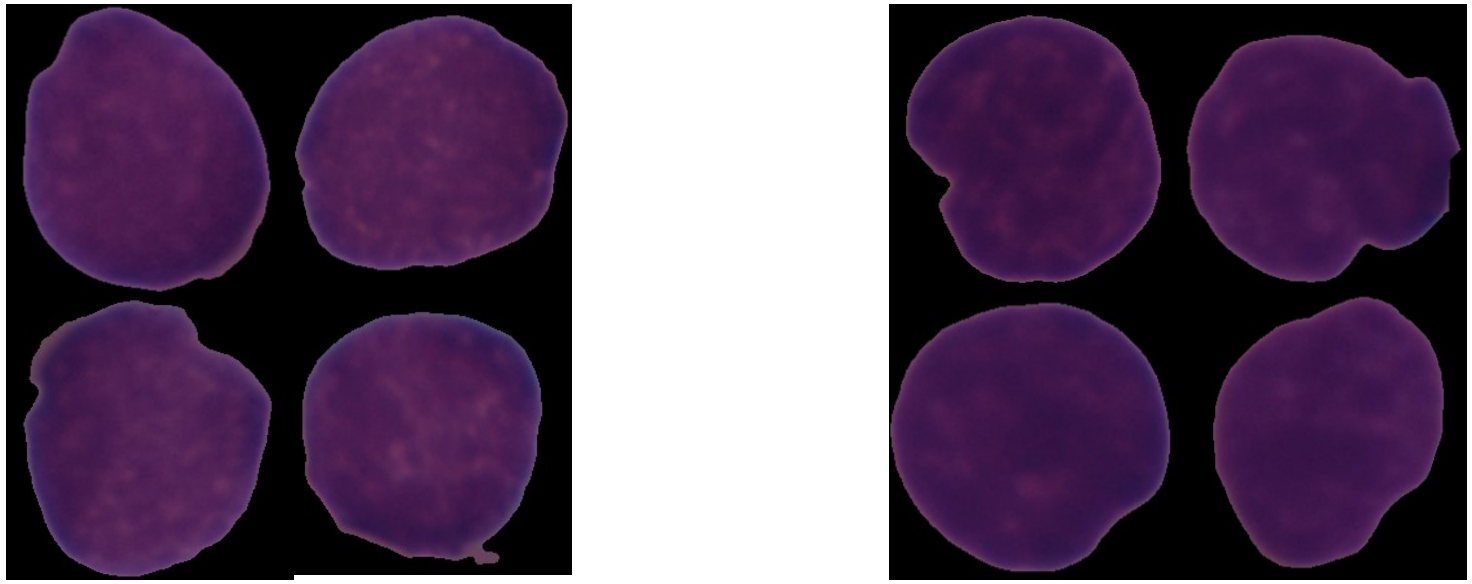
# Background and Aim

- Acute lymphoblastic leukemia (ALL): a serious health threat, mostly children with ages between 2 – 5
- Diagnosis of ALL: blood tests and bone marrow examination
- Aim: Classification of normal and malignant cells observed under a microscope for developing a cost-effective computer-aid diagnosis tool for ALL

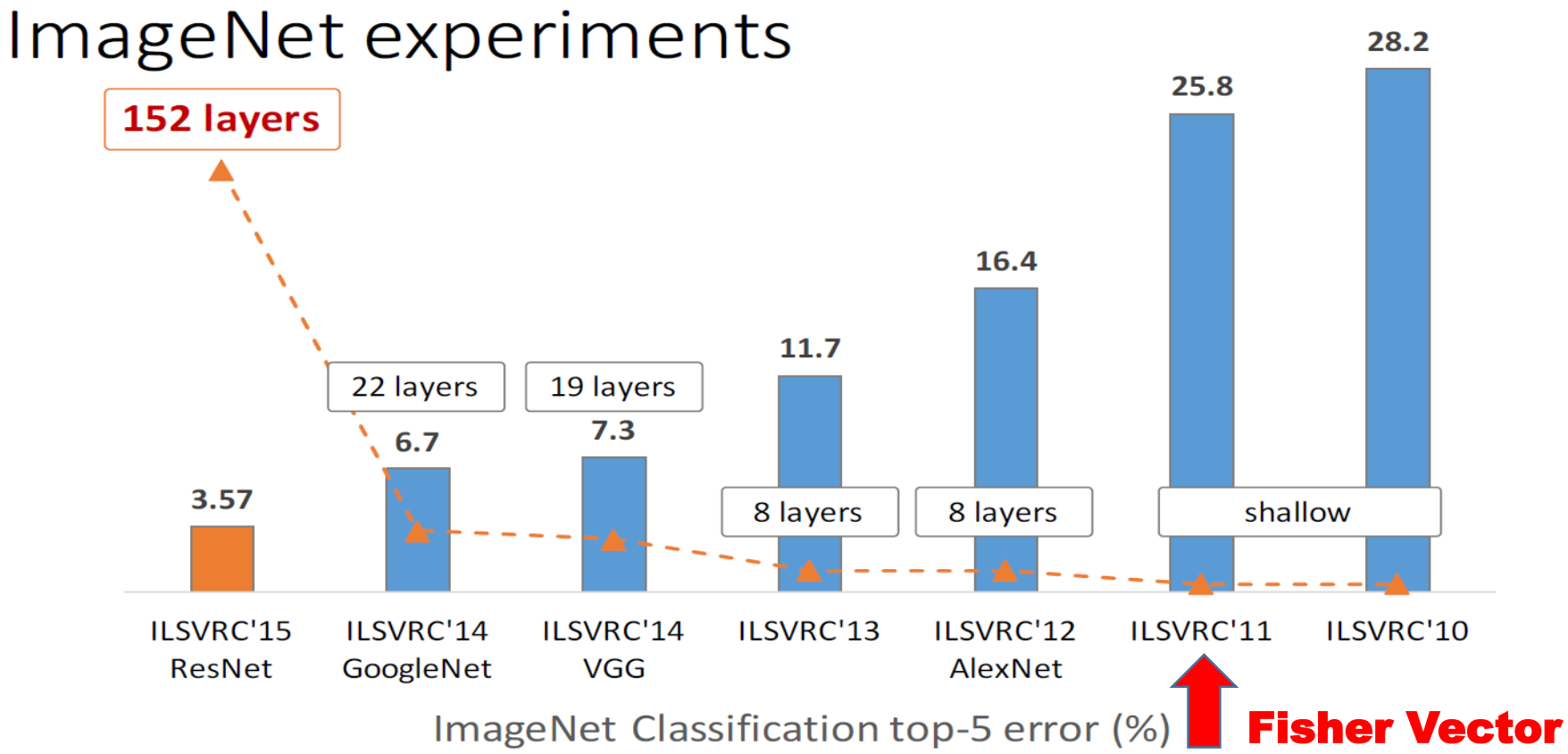


(a) Normal (b) Malignant

Fig. 1 Two cell images

# Related Work

- Fisher vector, deep convolutional neural networks, and combination




K. He, X. Zhang, S. Ren, J. Sun, Deep Residual Learning for Image Recognition. In: CVPR 2016, pp. 770-778. IEEE Press, New York. (2016)

# Related Work - Fisher Vector

- The set of local descriptors of an image: $\boldsymbol{X} = \{x \in \mathcal{R}^D; x \sim p\}$
- **Fisher Score** is the gradient of the log-likelihood $P(\boldsymbol{X}|\lambda)$

$$G_\lambda^X = \nabla_\lambda P(\boldsymbol{X}|\lambda) = E_{x\sim p} \nabla_\lambda \log u_\lambda(x) = \nabla_\lambda \int_x p(x) \log u_\lambda(x)\, dx$$

where $u_\lambda$ is the probability density function of the generative process

- **Fisher Information Matrix**

$$F_\lambda = E_{x\sim u_\lambda}[\nabla_\lambda log\, u_\lambda(x) \nabla_\lambda log\, u_\lambda(x)^{\mathrm{T}}] = L_\lambda{}^{\mathrm{T}} L_\lambda$$

- **Fisher Kernel**

$$K_{FK}(X, Y) = G_\lambda^{X^T} F_\lambda^{-1} G_\lambda^Y = \mathcal{G}_\lambda^{X^T} \mathcal{G}_\lambda^Y$$

- The **Fisher Vector** of $X$ is defined as $\mathcal{G}_\lambda^X = L_\lambda G_\lambda^X$.

# Method: Overview

- Neighborhood-correction algorithm (NCA) for classification of normal vs. malignant cells

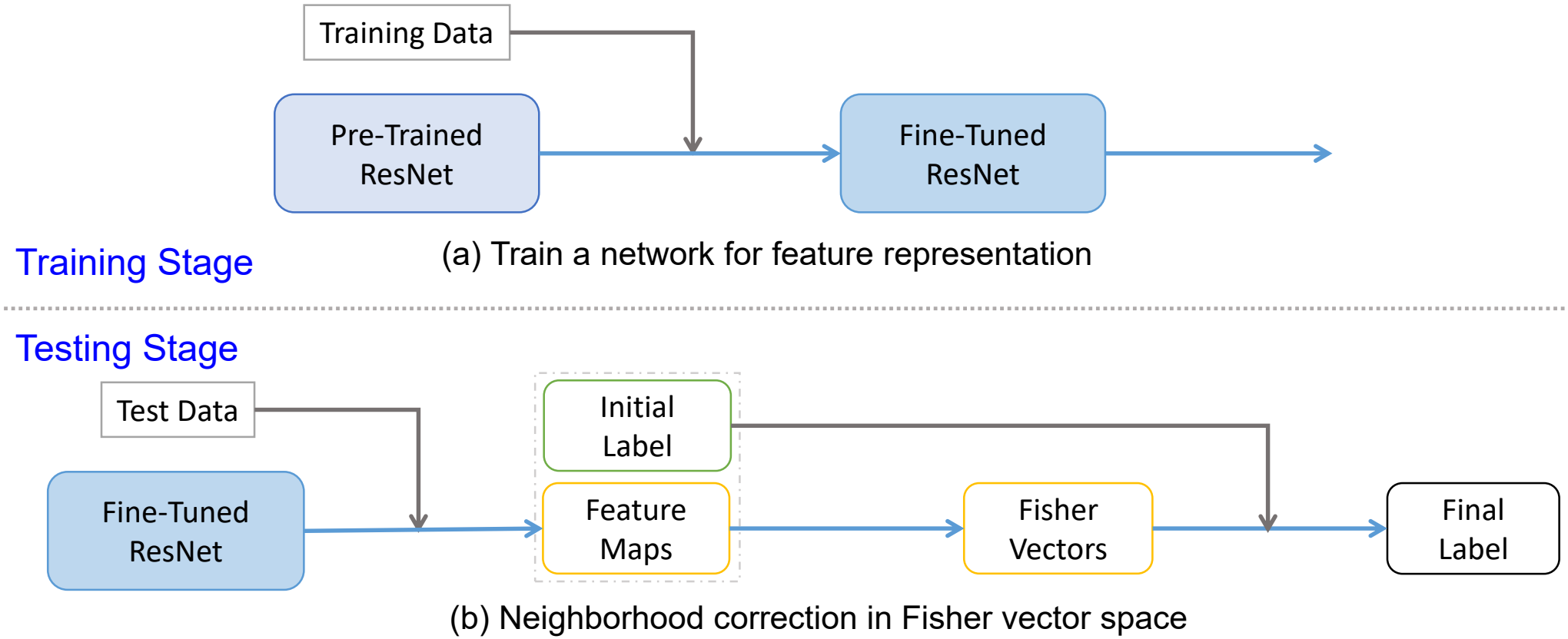



Fig. 2 Diagram of proposed NCA

# Method – Step 1 (Training)



- Data augmentation and image processing

(1) Left-right Flip

(2) Up-Down Flip

(3) Rotation

(4) Crop to 224× 224

(5) Minus mean

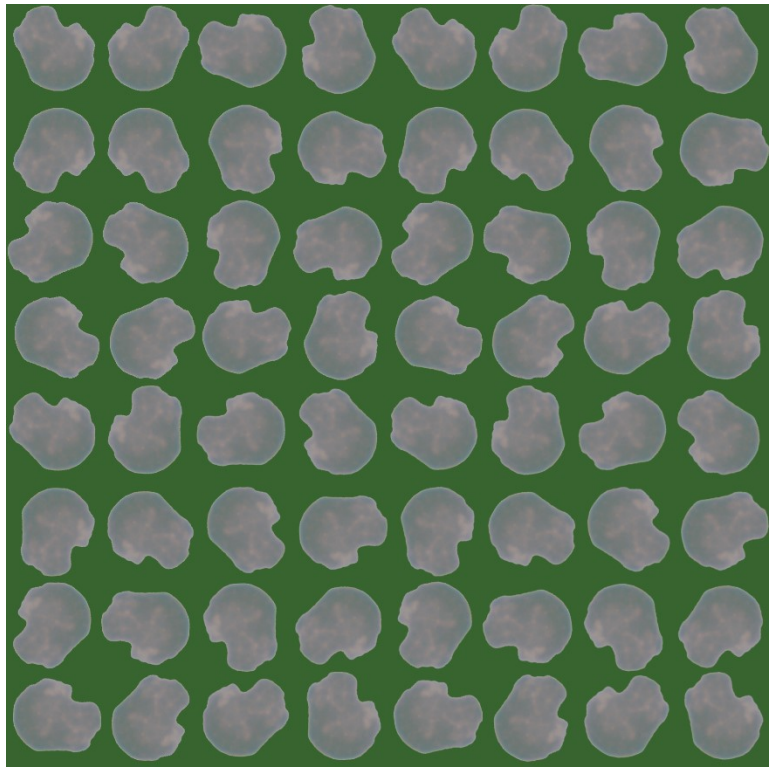


Fig. 2 Diagram of data augmentation and image processing

# Method – Step 2 (Training)

- Fine-tuning the pre-trained ResNet
  - Optimizer: SGD
  - Hyperparameters: Batch size = 32, epochs = 20, learning rate = $10^{-3}$ (first 10 epochs) / $10^{-4}$

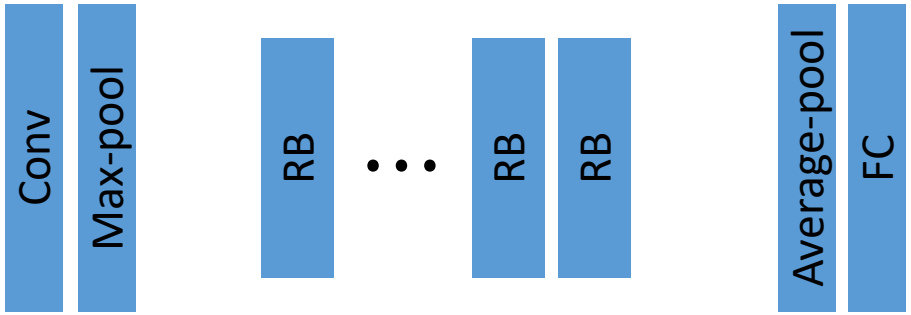



Fig.4. Diagram of ResNet (RB: Residual Block)

# Method – Step 3 (Testing)

- Applying the fine-tuned ResNet to each test image and obtaining the initial label of that image

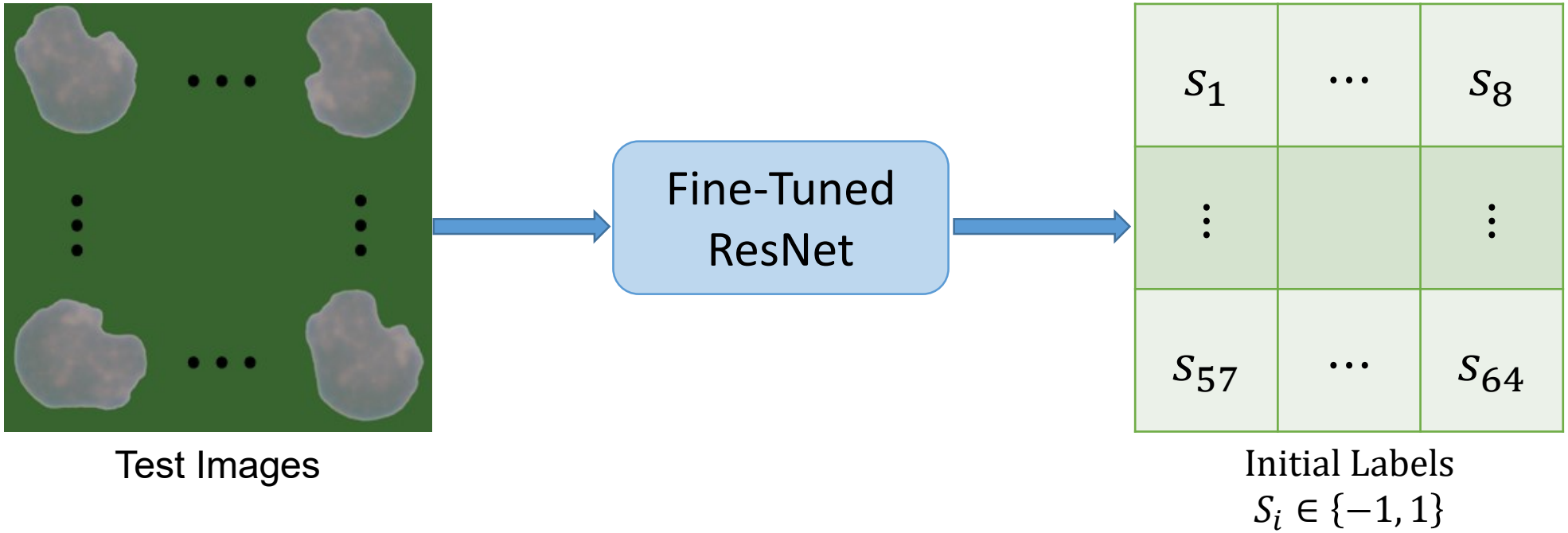
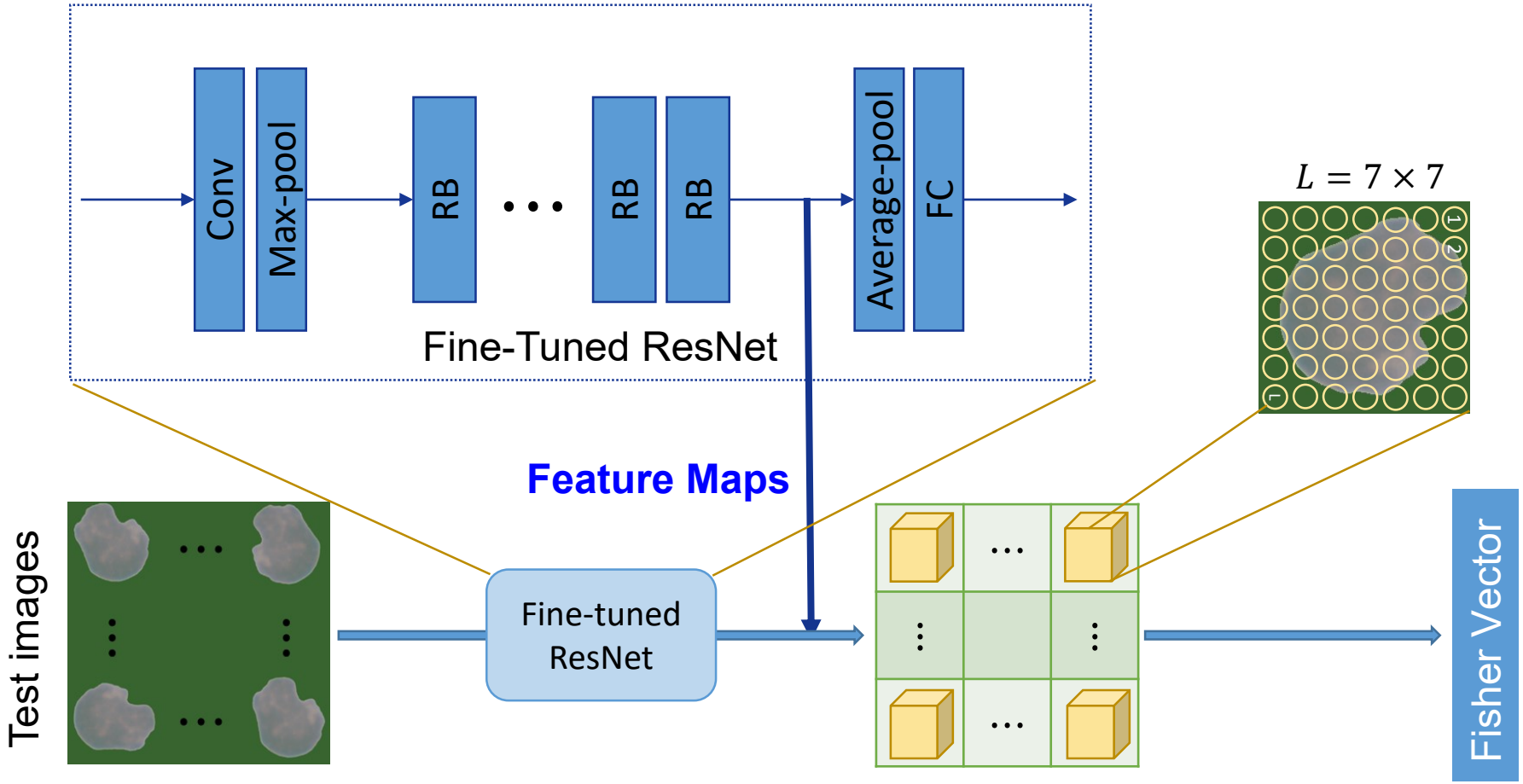



Fig. 2 Diagram of generating initial labels

# Method – Step 4 (Testing)

- Encoding the feature maps generated by the fine-tuned ResNet into a Fisher vector




Y. Pan, Y. Xia and D. Shen. "Foreground Fisher Vector: Encoding Class-Relevant Foreground to Improve Image Classification." IEEE-TIP, 2019.

# Method – Step 5 (Testing)

- Neighborhood Correction in FV Space

Let $\mathbb{B} = \{\mathcal{B}_i\}_{i=1}^{N}$ be a set of $N$ Fisher Vectors (FVs), where each FV represents a cell image. The similarity of a pair of images is

$$J(\mathcal{B}_i, \mathcal{B}_j) = \mathcal{B}_i{}^{\mathrm{T}}\mathcal{B}_j$$

Each image should be consistent with its neighbors in FV space, i.e., belong to the same category.

Suppose that $X_{i,(1)}, X_{i,(2)}, \ldots, X_{i,(K)}$ are the most similar $K$ images of $X_i$, whose initial labels are $y_{i,(1)}, y_{i,(2)}, \cdots, y_{i,(K)}$,

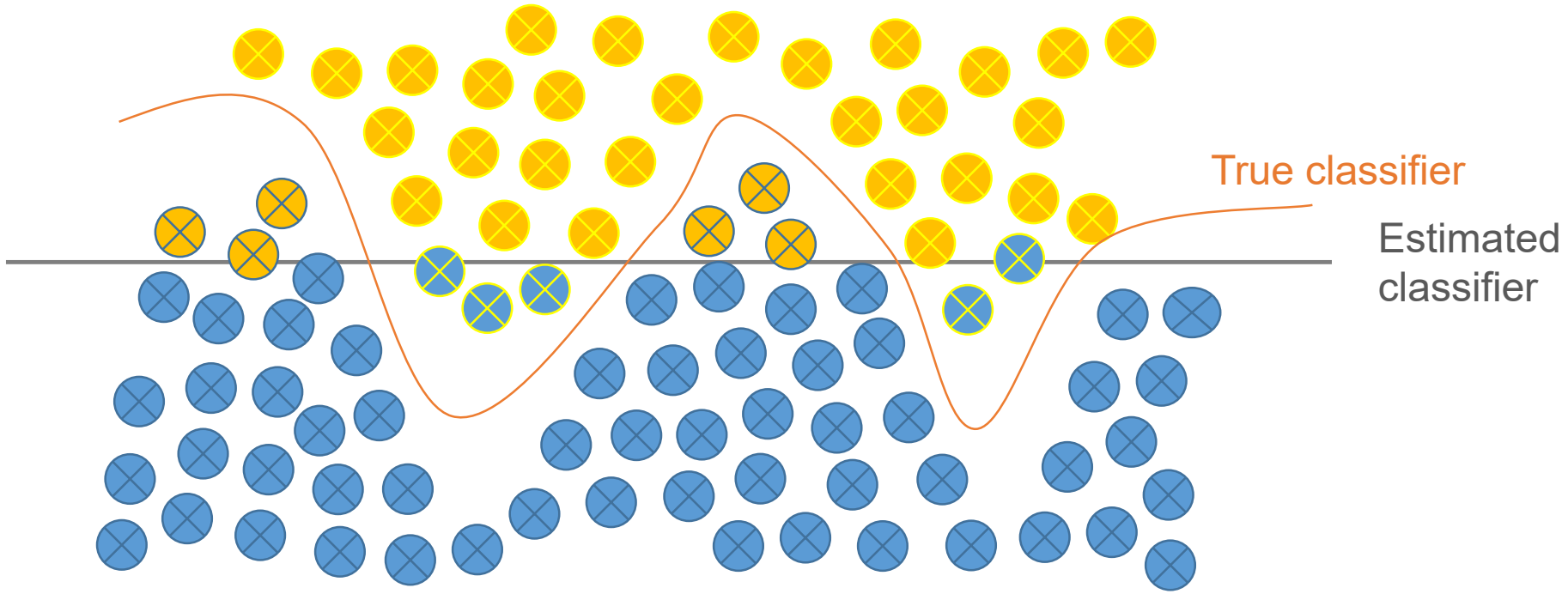
$$y_i^* = \operatorname{sign} \sum_{k=1}^{K} J(X_i, X_{i,(k)}) y_{i,(k)}$$

# Method – Step 5 (Testing)

- Neighborhood Correction in FV Space

  Most cells are correctly classified, only a small number of cells are misclassified.

  For each misclassified cell, we could probably correct it using its neighborhoods.



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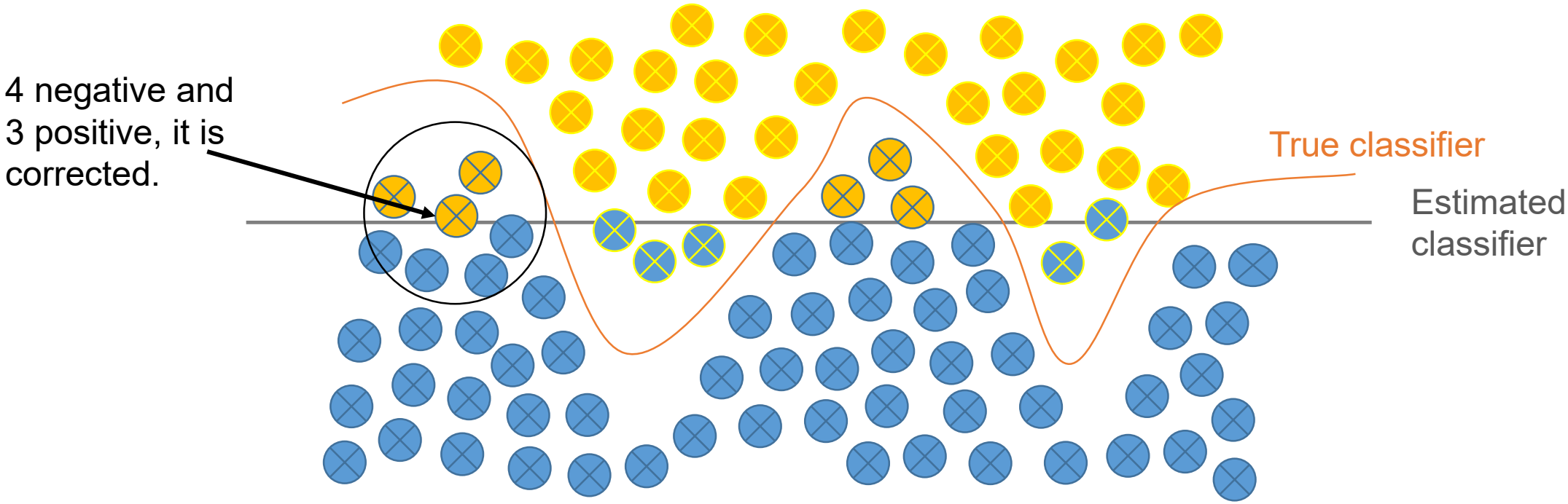

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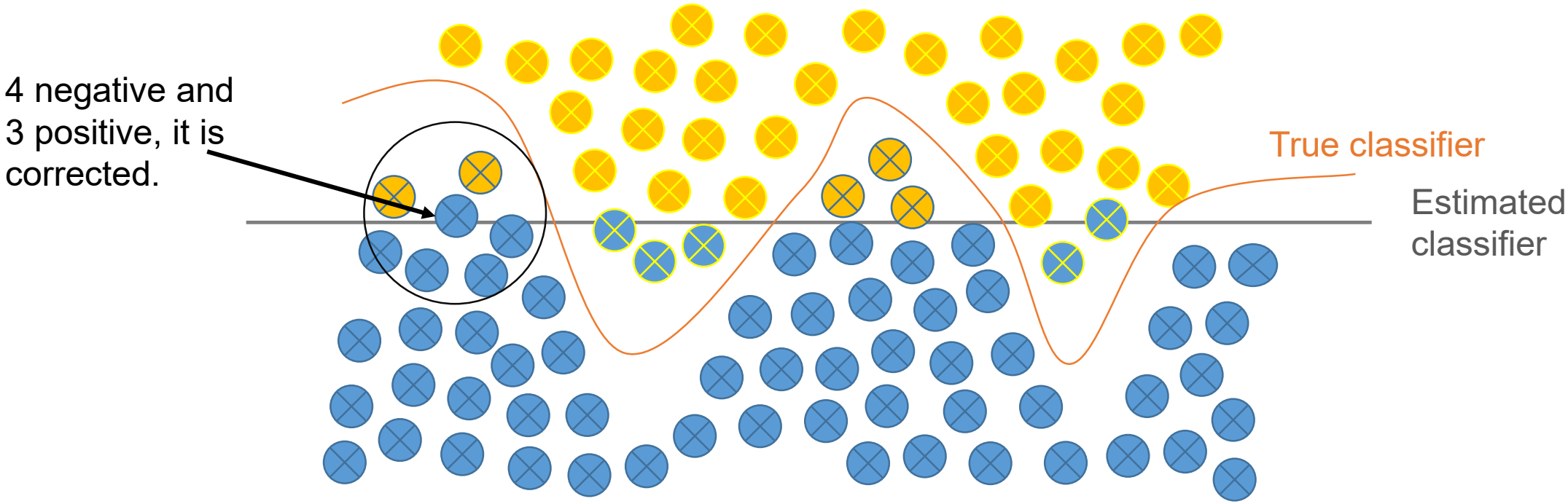

# Results in the C-NMC Challenge

西北工業大學 NORTHWESTERN POLYTECHNICAL UNIVERSITY

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

- Won the 1st Place in the Preliminary (0.9250) Test (1/60)

| # | User | Entries | Date of Last Entry | Team Name | Prediction score ▲ | Duration ▲ | Detailed Results |
|---|---|---|---|---|---|---|---|
| 1 | yspan | 177 | 01/31/19 | SAIIP-NPU & BRIC-UNC | 0.9250 (1) | 0.00 | View |
| 2 | jprellberg | 29 | 01/30/19 | | 0.8966 (2) | 0.00 | View |
| 3 | kuangrf | 174 | 01/27/19 | BUPT-CAD | 0.8955 (3) | 0.00 | View |
| 4 | yelan | 80 | 01/24/19 | | 0.8942 (4) | 0.00 | View |
| 5 | haoyuyang | 62 | 01/23/19 | Sunset Roller-coaster | 0.8929 (5) | 0.00 | View |
| ⋮ | | | | | | | |
| 59 | | | | | | | |
| 60 | | | | | | | |

# Results in the C-NMC Challenge

西北工業大學 NORTHWESTERN POLYTECHNICAL UNIVERSITY

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

- Won the 1st Place in in the Final Test (0.9104) (1/25)

| # | User | Entries | Date of Last Entry | Team Name | Prediction score ▲ | Duration ▲ | Detailed Results |
|---|---|---|---|---|---|---|---|
| 1 | yspan | 2 | 03/17/19 | SAIIP-NPU & BRIC-UNC | 0.9104 (1) | 0.00 | View |
| 2 | deepshad | 2 | 03/17/19 | | 0.8947 (2) | 0.00 | View |
| 3 | jprellberg | 2 | 03/16/19 | | 0.8891 (3) | 0.00 | View |
| 4 | kuangrf | 2 | 03/17/19 | BUPT-CAD | 0.8856 (4) | 0.00 | View |
| 5 | wendy | 2 | 03/16/19 | MIA Group | 0.8798 (5) | 0.00 | View |
| ⋮ | | | | | | | |
| 25 | | | | | | | |

- Submissions in the Final Test (with an improvement of 0.0416)

| METHOD | # | SCORE | FILENAME | SUBMISSION DATE | STATUS | ✔ | |
|---|---|---|---|---|---|---|---|
| Fine-tuned ResNet | 1 | 0.868851339 | ftcell_50_101res-cv0 1 2 3.zip | 03/16/2019 17:56:00 | Finished | | + |
| Proposed Method | 2 | 0.9104320738 | ftcell_50_101res-cv0 1 2 3 - 2.zip | 03/17/2019 23:52:55 | Finished | ✔ | + |

# Summary and Future Work



- Proposed a hybrid algorithm (deep learning + Fisher vector) for the classification of normal vs. malignant cells
- ResNet: feature extraction and initial label generation
- Fisher vector: Correction of inaccurate initial labels
- Future work
  - Using corrected class labels to refine ResNet
  - Improving ResNet and Fisher vector mutually and iteratively

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