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Abstract

The purpose of this study was to develop a computer-aided diagnosis (CAD) system for the classification of malignant and benign breast masses using ultrasonography based on a convolutional neural network (CNN), a state-of-the-art deep learning technique.

From the clinical data obtained in a previously conducted large-scale clinical trial, we collected images of 1536 breast masses (897 malignant and 639 benign) confirmed by pathological examinations, with each breast mass captured from various angles. We constructed an ensemble network by combining two CNN models (VGG19 and ResNet152) fine-tuned on training data and used the mass-level classification method to enable the CNN to classify a given mass using all views. To visualize the regions detected by the CNN models to classify breast masses, we performed a heatmap analysis.

For an independent test set consisting of 154 masses (77 malignant and 77 benign), our network showed outstanding classification performance with a sensitivity of 90.9% (95% CI 84.5–97.3), a specificity of 87% (79.5–94.5), and area under the curve of 0.951 (0.916–0.987). In addition, our study indicated that not only the breast masses but also the surrounding tissues were important regions for correct classification.

Collectively, this CNN-based CAD system is expected to assist doctors and improve the diagnosis of breast cancer in clinical practice.

Introduction

Ultrasonography has been recommended as an adjunctive modality to mammography. Ultrasonography has the disadvantage of being operator dependent and requiring proficiency in reading ultrasound images.

Figure 1. Examples of breast masses on ultrasound images

(a) Benign (b) malignancy

Figure 2. Structure of a CNN

Intro 2

- A computer-aided diagnosis (CAD) system was developed to assist doctors
- A CAD system automatically classifies the breast lesions in ultrasound images into malignant or benign, which helps doctors in providing a more accurate diagnosis.
- Convolutional neural networks (CNNs), a deep learning technique, have attracted considerable attention as a powerful tool to extract and learn efficient features directly from a data set.

![Figure 2. Structure of a CNN](image-url)
Computer-aided diagnosis system for breast ultrasound images using deep learning

Hiroki Tanaka¹, Shih-Wei Chiu², Takanori Watanabe³, Setsuko Kaoku⁴, Takuhiro Yamaguchi²

1 Division of Pharmaceutical, JAPAN TOBACCO INC, Tokyo, Japan; 2 Tohoku University Graduate School of Medicine; 3 National Hospital Organization Sendai Medical Center, Sendai, Miyagi, Japan; 4 National Hospital Organization Osaka National Hospital, Osaka, Japan

Abstract

Introduction

Results

Discussion

Conclusion

Method

Method 1: Image collection and datasets

- 1536 breast masses (897 malignant and 639 benign) used in this study were collected from a previously conducted large-scale clinical trial in Japan.
- Breast masses were identified by pathological examination.
- The dataset was randomly divided by mass in an 8:1:1 ratio into a training set, a validation set and a test set.

Method 2: data argumentation

- In this study, we applied data augmentation for the training set.
- Data augmentation is a technique for synthetically generating new samples from an original training data.

Example)

Original

The number of training images increased from 6712 to 136,160 images.

Method 3: CNN models

- We constructed an ensemble model by combining two CNN models called VGGNet19 (Simonyan et al 2015) and ResNet152 (He et al 2016). This number indicates the number of layers.
- This model combines the predictions of the trained VGGNet and ResNet to enhance the classification performance.

Figure 3. Ensemble model

Figure 4. VGGNet19

Figure 5. ResNet152
Methods

Method 3: Procedure to classify masses

- For each mass, there were multiple ultrasound images because each breast mass was captured from various angles.
- In practice, doctors evaluate some views in ultrasound images and make a diagnosis per mass (patient) and not per view.
- Therefore, it is desirable for a CNN to perform its diagnosis accordingly.

Method 4: Software

- SAS® Visual Data Mining and Machine Learning 8.3 / SAS® Viya® 3.4
- DLPy 0.7, the high-level Python APIs designed to efficiently apply the deep learning methods in SAS Visual Data Mining and Machine Learning
  - Easy to code CNN models and Image processing such as data augmentation.
  - Can visualize the process of the CNN models with heat map analysis.
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Abstract

Introduction

Results 1

Results 2

Discussion

• The classification performance of the ensemble model were evaluated using the test set consisting of 154 masses (77 benign and 77 malignant).

Table 1. Classification performance of the ensemble model

<table>
<thead>
<tr>
<th>Accuracy (95%CI)</th>
<th>Sensitivity (95%CI)</th>
<th>Specificity (95%CI)</th>
<th>AUC (95%CI *)</th>
</tr>
</thead>
<tbody>
<tr>
<td>89.0% (84.0–93.9)</td>
<td>90.9% (84.5–97.3)</td>
<td>87.0% (79.5–94.5)</td>
<td>0.951 (0.916–0.987)</td>
</tr>
</tbody>
</table>

* 95% confidence interval

Figure 7. Example where ResNet detected the mass
Figure 8. Example where ResNet did not detect the mass

Discussion

• In a large-scale clinical trial where screening was combined with mammography and ultrasonography, sensitivity was shown to 91% and specificity was 87% (Ohuchi et al 2016).

• Our model provided equivalent results.

• Thus, we believe that our model might provide a second opinion to doctors and might assist doctors in decision making regarding diagnosis.

Table 2. Detection rate for overall masses in randomly selected test patches

<table>
<thead>
<tr>
<th>Model</th>
<th>Detection rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGGNet 19</td>
<td>47.7%</td>
</tr>
<tr>
<td>ResNet 152</td>
<td>37.0%</td>
</tr>
</tbody>
</table>

Conclusion

• In summary, it is expected that our system will be useful for doctors as a supplemental modality for screening women with breast masses.

Acknowledgments

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References


• Simonyan K and Zisserman A 2015 Very deep convolutional networks for large-scale image recognition Int. Conf. on Learning Representation (ICLR)