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Computer-aided diagnosis system for breast ultrasound images using deep learning

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Abstract
Introduction
Methods
Results
Discussion
Conclusion

Main Author：
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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 87.0% (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

Intro 1

- 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.

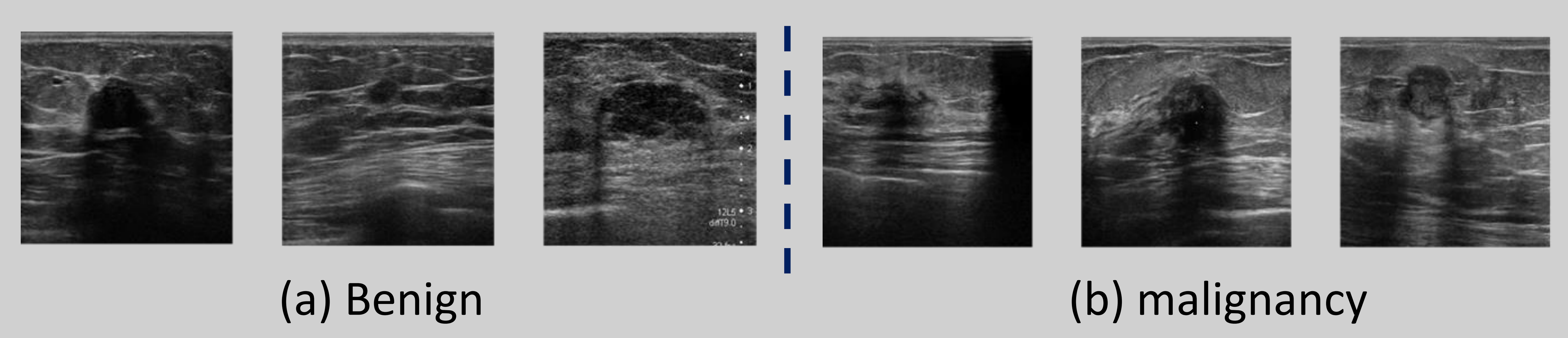


Figure 1. Examples of breast masses on ultrasound images

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.

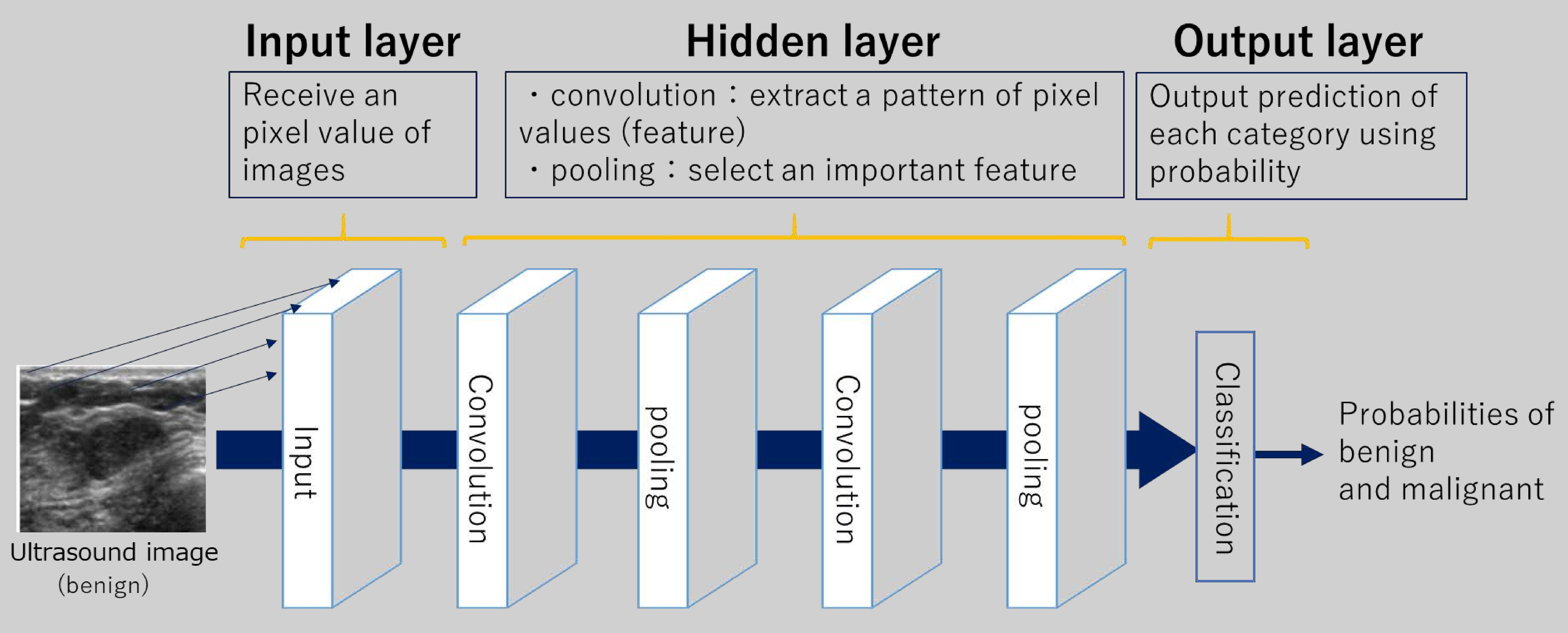
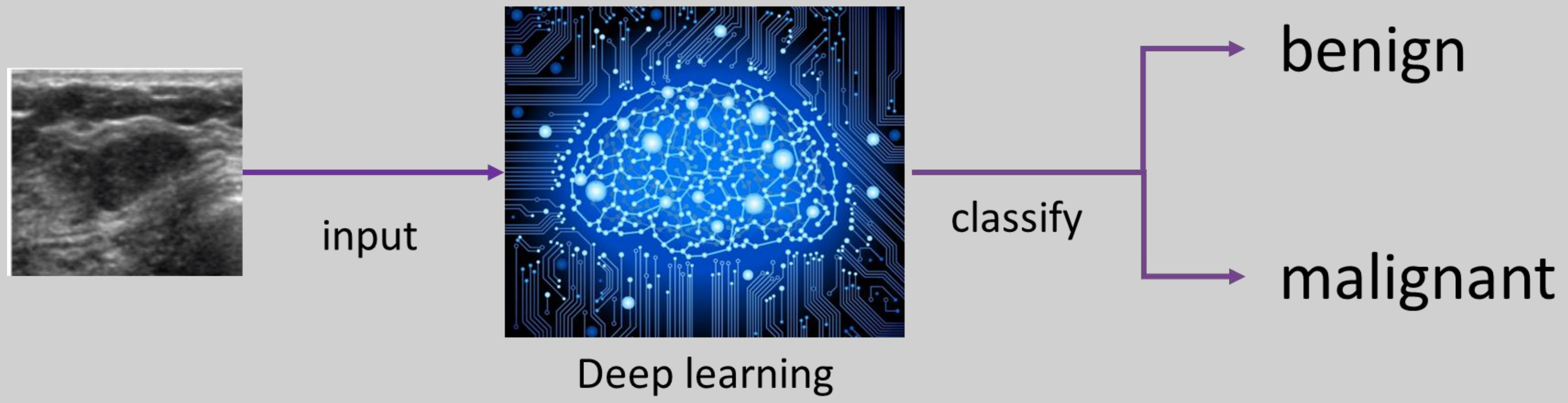


Figure 2. Structure of a CNN

Objective

- This study aimed to develop a CNN-based CAD system to automatically classify the breast masses using all related ultrasound images by using a large-scale dataset.



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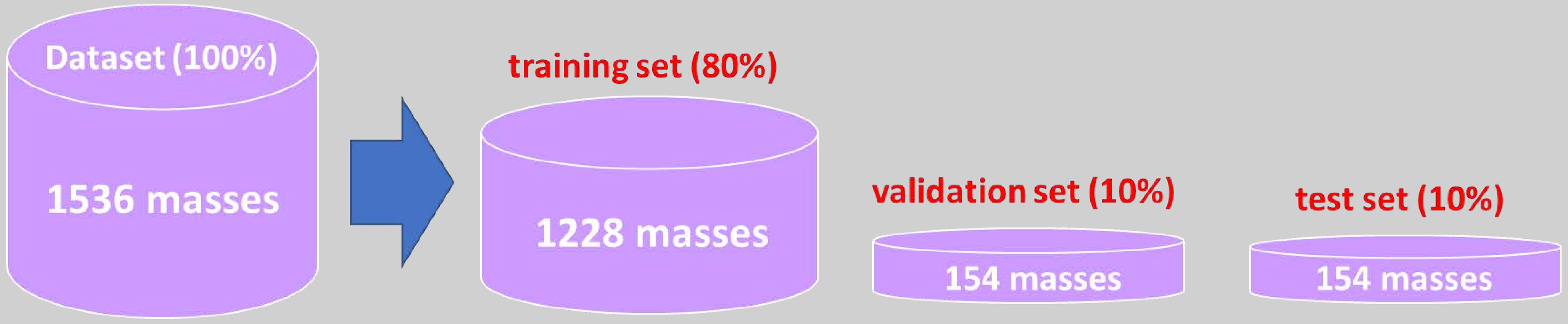
Methods

Method 1：Image collection and datasets

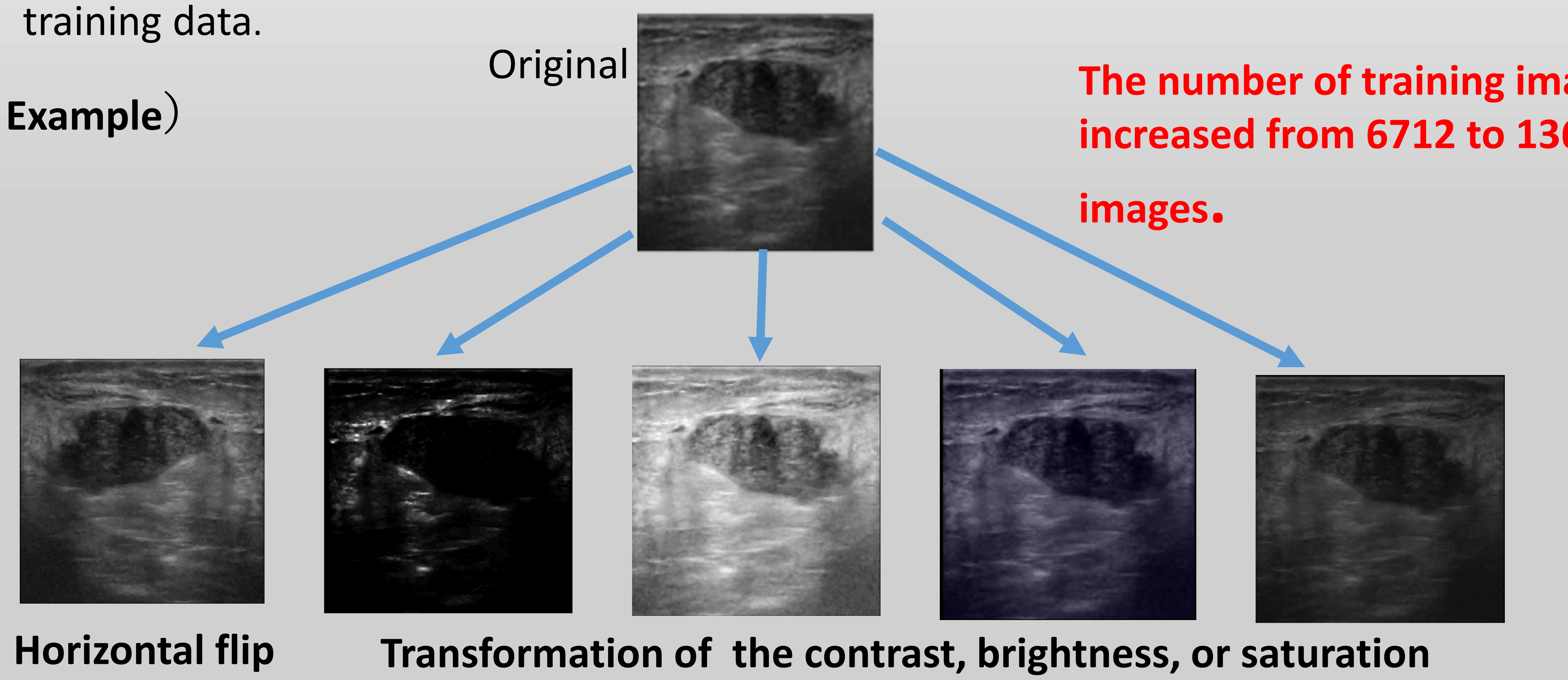
- 1536 breast masses (897 malignant and 639 benign) used in this study were collected from a previously conducted large-scale clinical trial in Japan.
- Breast masses were identified by pathological examination.
- The dataset was randomly divided by mass in an 8:1:1 ratio into a training set, a validation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



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

Method 3：CNN models

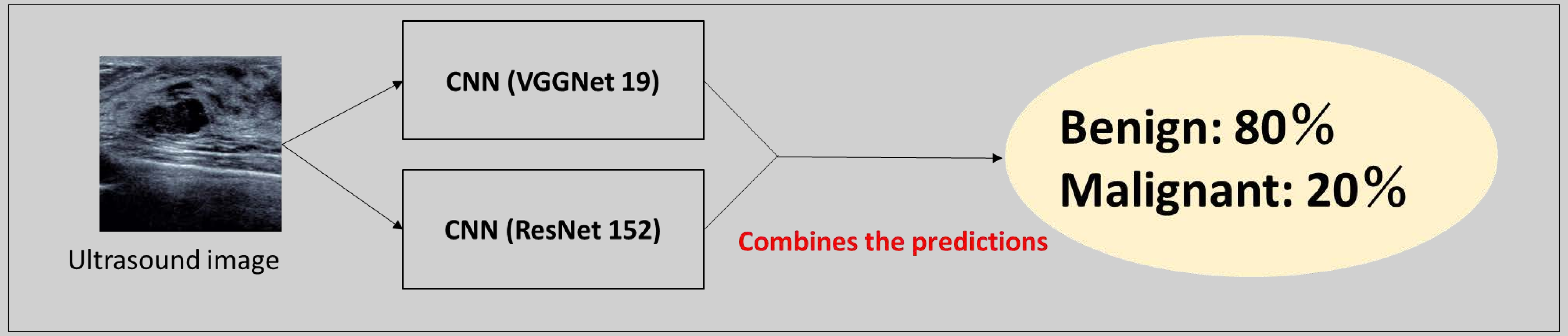


Figure 3. Ensemble model

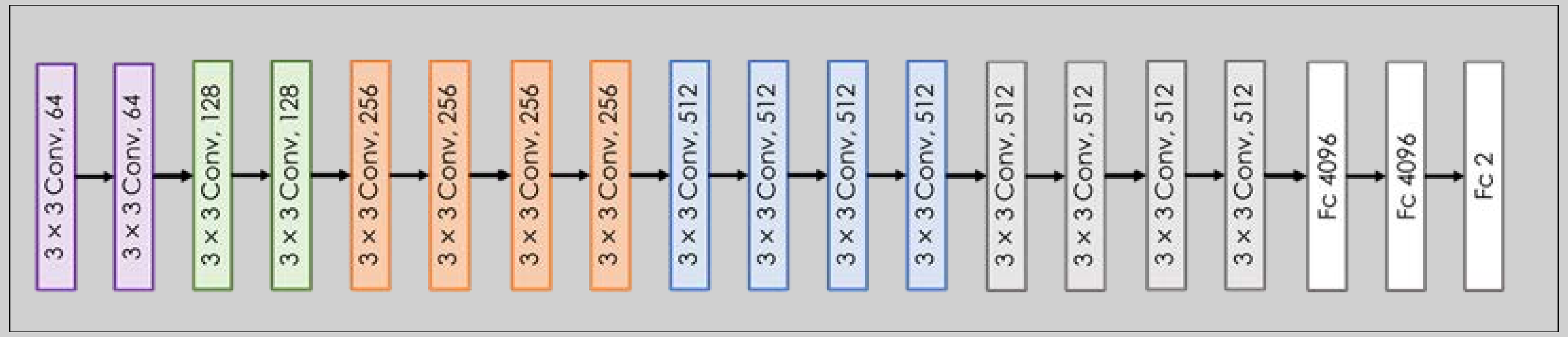


Figure 4. VGGNet19

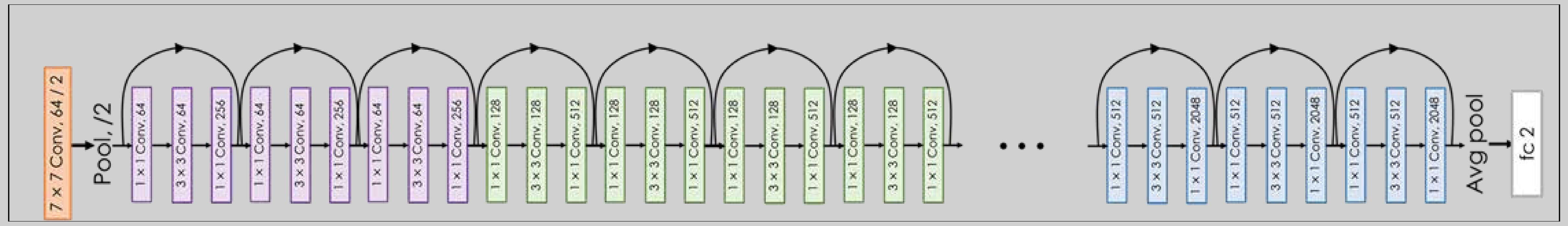


Figure 5. ResNet152

- 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.

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Method 3 : Procedure to classify masses

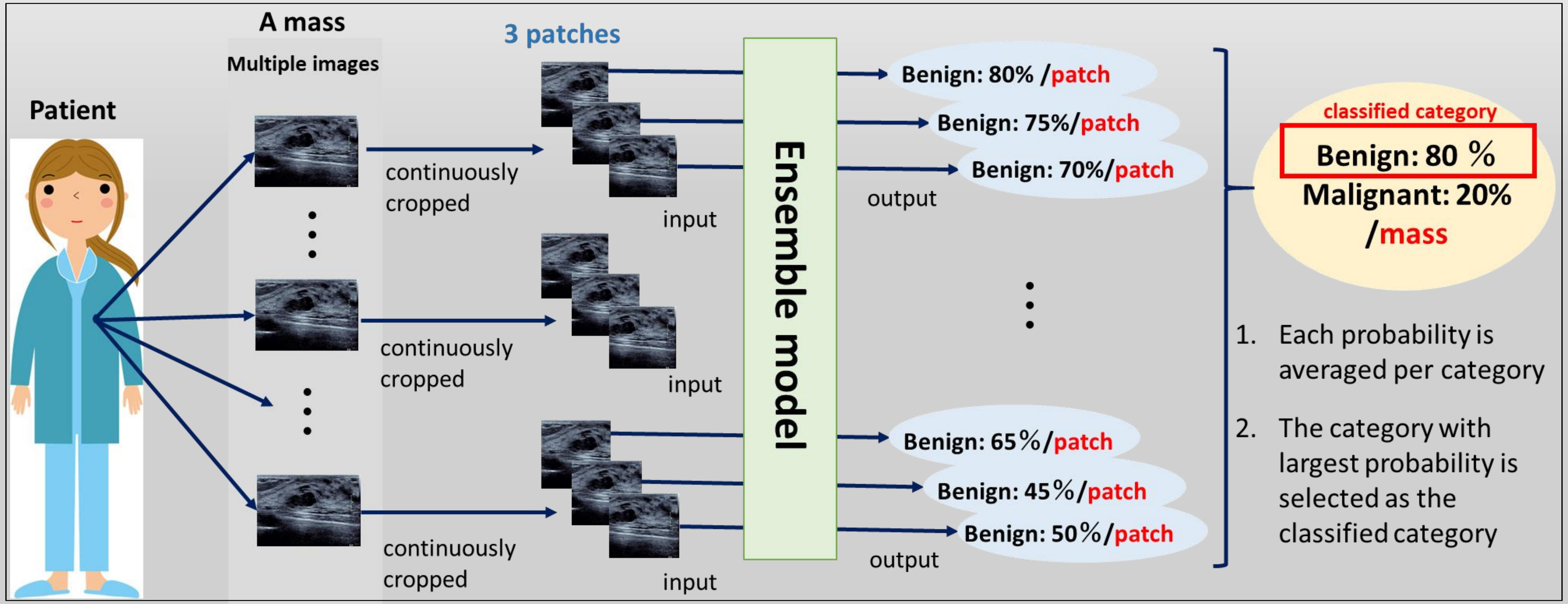
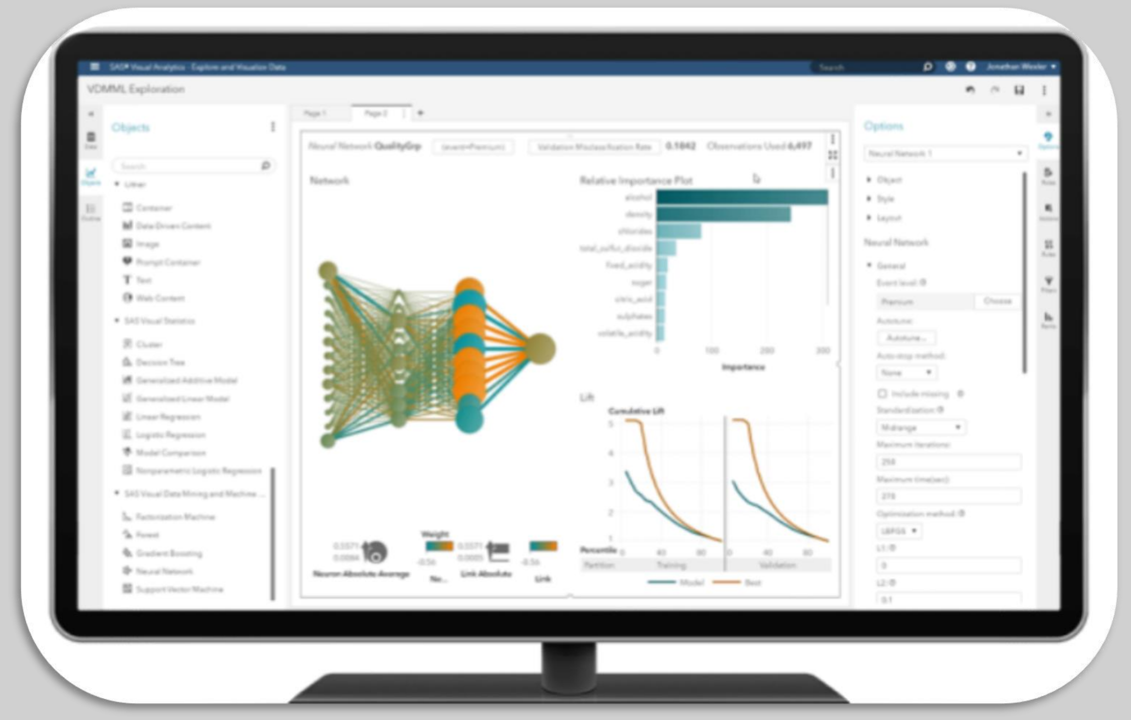


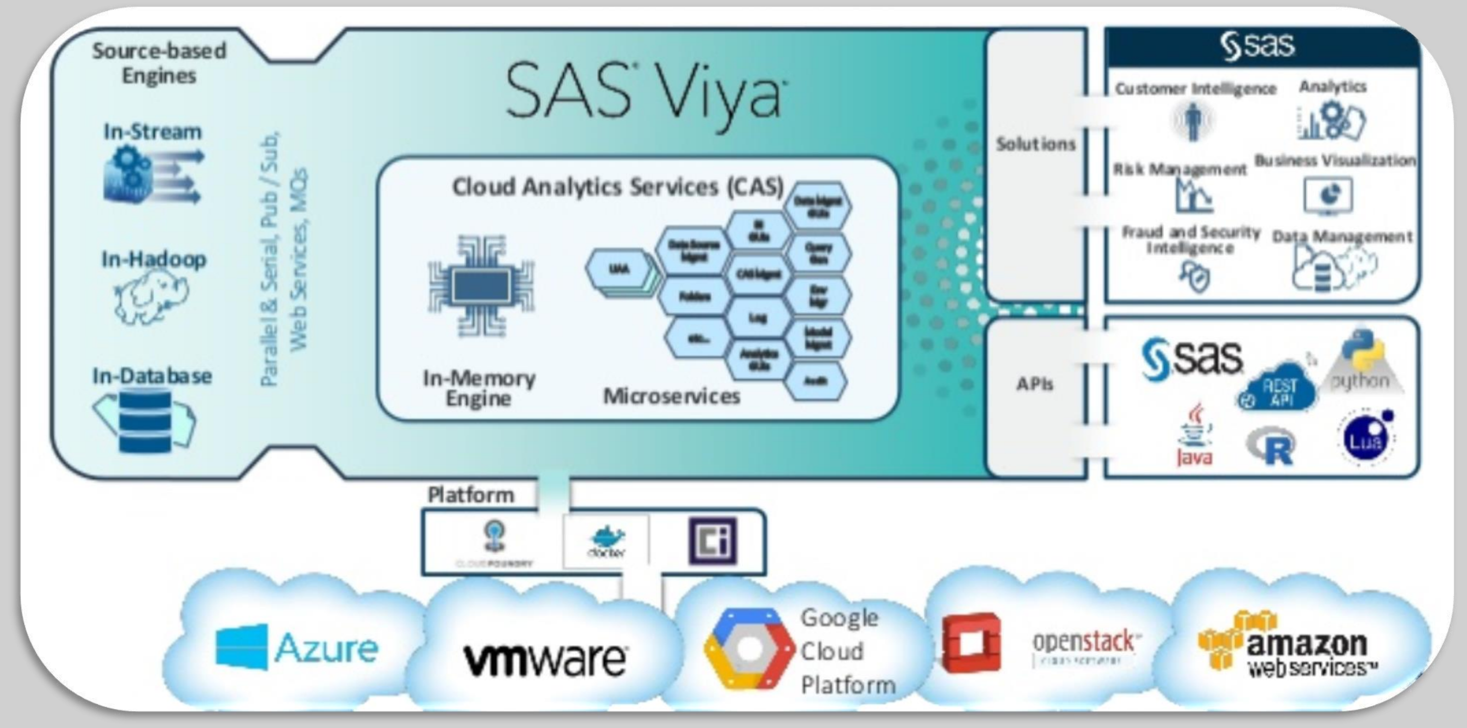
Figure 6. Illustration of procedure to classify masses

- 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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Result 1 : classification performance

Table 1. Classification performance of the ensemble model

Accuracy (95%CI)	Sensitivity (95%CI)	Specificity (95%CI)	AUC (95%CI *)
89.0% (84.0–93.9)	90.9% (84.5–97.3)	87.0% (79.5–94.5)	0.951 (0.916–0.987)

* 95% confidence interval

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

Result 2 : heat map analysis

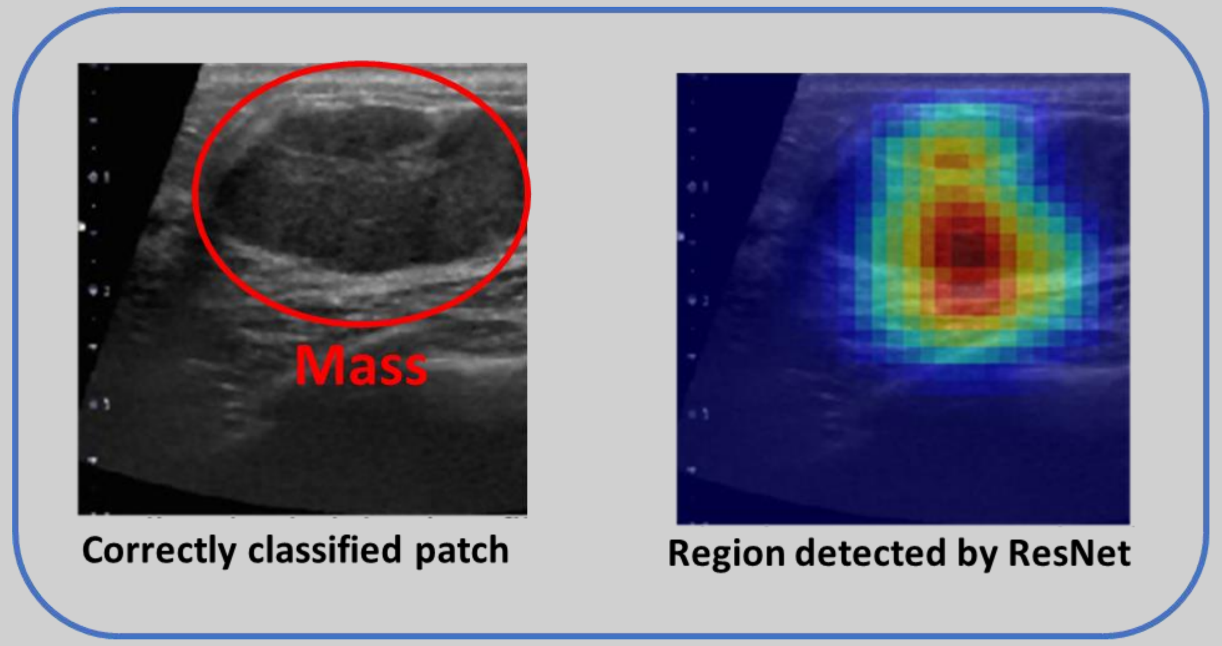

Figure 7. Example where ResNet detected the mass

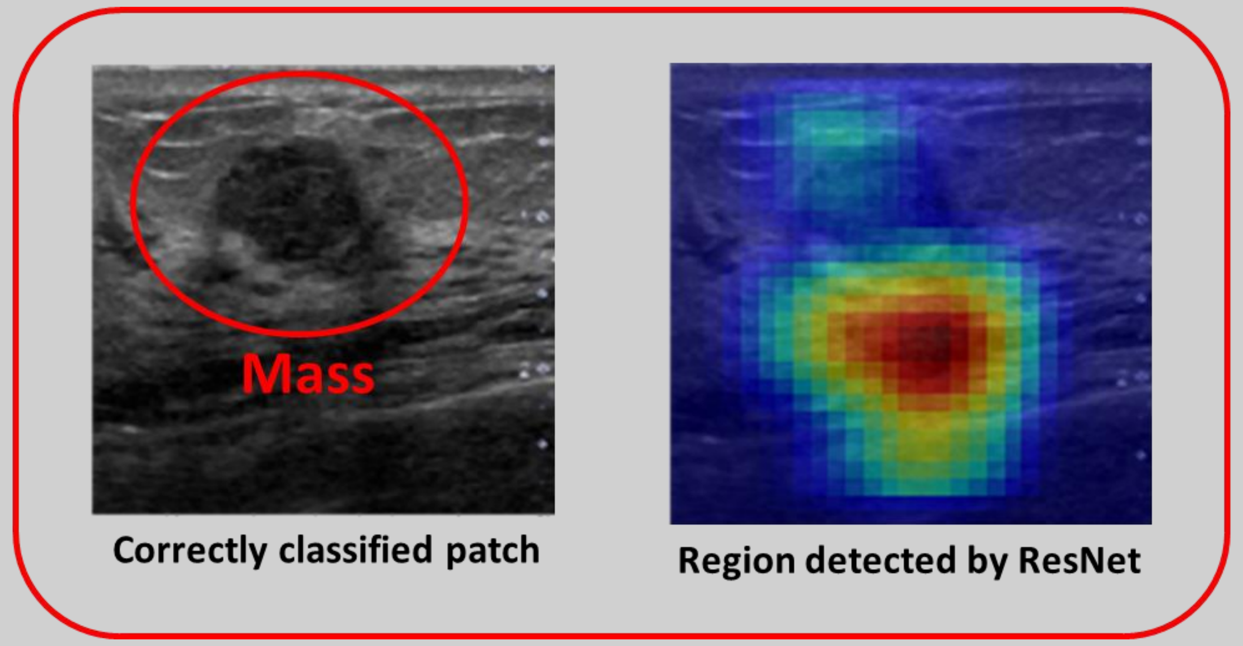

Figure 8. Example where ResNet did not detect the mass

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

	mass detection rate = Number of detected masses/number of randomly selected 50 test patches
VGGNet 19	47.7 %
ResNet 152	37.0 %

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.

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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