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Identifying Diabetes in Mice using Optical Coherence Tomography Angiography Images of the Ears and Deep Learning

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Abstract: Using optical coherence tomography angiography images from mouse ears, a convolutional neural network successfully recognized diabetes with an accuracy of 0.81 and an area under the curve of 0.90.

OCIS codes: (100.4996) Pattern recognition, neural networks, (170.4500) Optical coherence tomography, (170.1870) Dermatology.

1. Introduction

Diabetes mellitus is a chronic metabolic disorder that is linked to macro- and microangiopathies, which cause several vascular diseases such as diabetic retinopathy, nephropathy, neuropathy and arteriosclerosis.

Optical coherence tomography (OCT) is a non-invasive imaging modality that can capture high-resolution three-dimensional image data of tissue. Optical coherence tomography angiography (OCTA) as a functional extension of OCT enables visualization of the vascular network without requiring a contrast agent.

The current work aims to investigate if a deep learning algorithm can be trained to distinguish between OCTA images of the vascular network of healthy and diabetic mice.

2. Materials and Methods

Four OCT angiography images were taken from slightly overlapping regions on pinnae of six healthy (C57BL/6J) and six type 2 diabetic mice (BKS.Cg-Dock7m+/+ Leprdb/J), resulting in a data set of 96 angiography images evenly split between healthy and diabetic animals.

Optical coherence tomography images were recorded using a custom-built dermal OCT system [1]. The system uses an akinetic swept laser operating at a central wavelength of 1322 nm with a bandwidth of 62 nm. A scan lens with a focal length of 18 mm provides a lateral resolution of $\sim$13 mm. Images were acquired over square skin patches of 4.86 mm $\times$ 4.86 mm. Split-spectrum amplitude decorrelation [2] was used to obtain angiography images. En face projections of the acquired volumetric angiography images had a size of 768 px $\times$ 768 px.

A convolutional neural network using the pre-trained VGG16 [3] network followed by three fully connected layers was trained to discriminate diabetic and healthy subjects. The network was trained on patches of a size of 330 px $\times$ 330 px resized to 224 px $\times$ 224 px (2.09 mm $\times$ 2.09 mm) randomly extracted from the angiography projections after applying image augmentation. Six-fold cross-validation was employed, with each of the six folds consisting of eight images from one healthy and eight images from one diabetic mouse.

3. Results

To assess network performance, we extracted 49 overlapping patches from each image using an equally-spaced 7×7 grid. Evaluating 4704 patches in total, we achieved an accuracy of 0.81 and an area under the curve (AUC) of the receiver operating characteristic (ROC) curve of 0.90. When averaging the results of the 49 patches of each image, we obtained an accuracy of 0.89 and an AUC of 0.96. Fig. 1 gives the ROC curves for both kinds of evaluations. Sample images and corresponding predictions of the convolutional neural network can be found in Fig. 2.

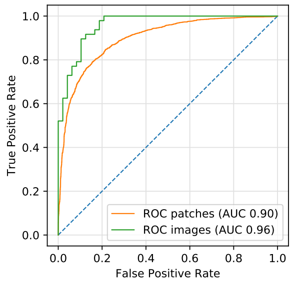
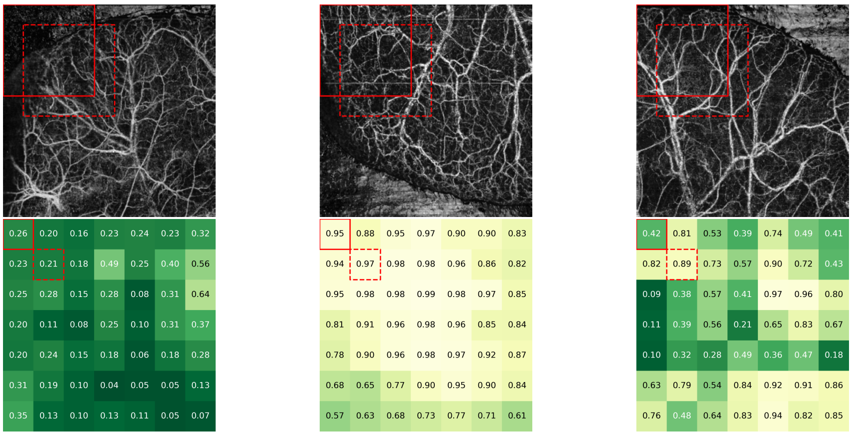


Fig. 1. Receiver operating characteristic for the detection of diabetes. *ROC patches* depicts the ROC curve for individual overlapping patches extracted from the acquired OCT images. *ROC images* gives the ROC curve after averaging over all patches of each image.



(a) Non-diabetic mouse. Correct average prediction (0.21).

(b) Diabetic mouse. Correct average prediction (0.87).

(c) Non-diabetic mouse. Incorrect average prediction (0.60).

Fig. 2. Example OCTA images with a size of 4.86 mm × 4.86 mm with corresponding predictions of the convolutional neural network. As the network was trained on smaller patches (size indicated by red rectangles), inference was performed 49 times per image on overlapping patches of this size. Predictions close to one indicate diabetes.

4. Conclusion

We demonstrated that differences between the blood vessel networks in ears of healthy and diabetic mice allow for an accurate classification using a deep learning algorithm. Future work should focus on determining an appropriate qualitative and quantitative characterisation of these differences, e.g. by analysis of vascular network properties such as vessel thickness and number of bifurcations.

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