Automated Offline Smartphone-Assisted Microfluidic Paper-Based Analytical Device for Biomarker Detection of Alzheimer's Disease

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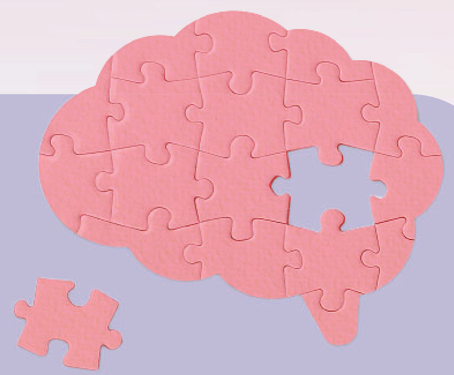
ABSTRACT

This paper presents a smartphone-assisted microfluidic paper-based analytical device (μPAD) applied to detect Alzheimer's disease (AD) biomarkers, especially in resource-limited regions. This device implements deep learning (DL)-assisted offline smartphone detection, eliminating the requirement for large computing devices and cloud computing power. In addition, a smartphone-controlled rotary valve enables a fully automated colorimetric enzyme-linked immunosorbent assay (c-ELISA) on μPADs.

INTRODUCTION



Alzheimer's disease (AD) is a progressively deteriorating neurological disease without effective treatment.

- Early detection and timely intervention could control the progression of AD [1, 2].
- Our platform implements an automated high-accuracy c-ELISA for early detection of AD, with the advantages of rapid detection, low cost, and ease of operation.
- Our platform realizes offline detection of smartphones, and can implement real-time monitoring and rapid detection, even in areas with poorly developed communications.

METHODS

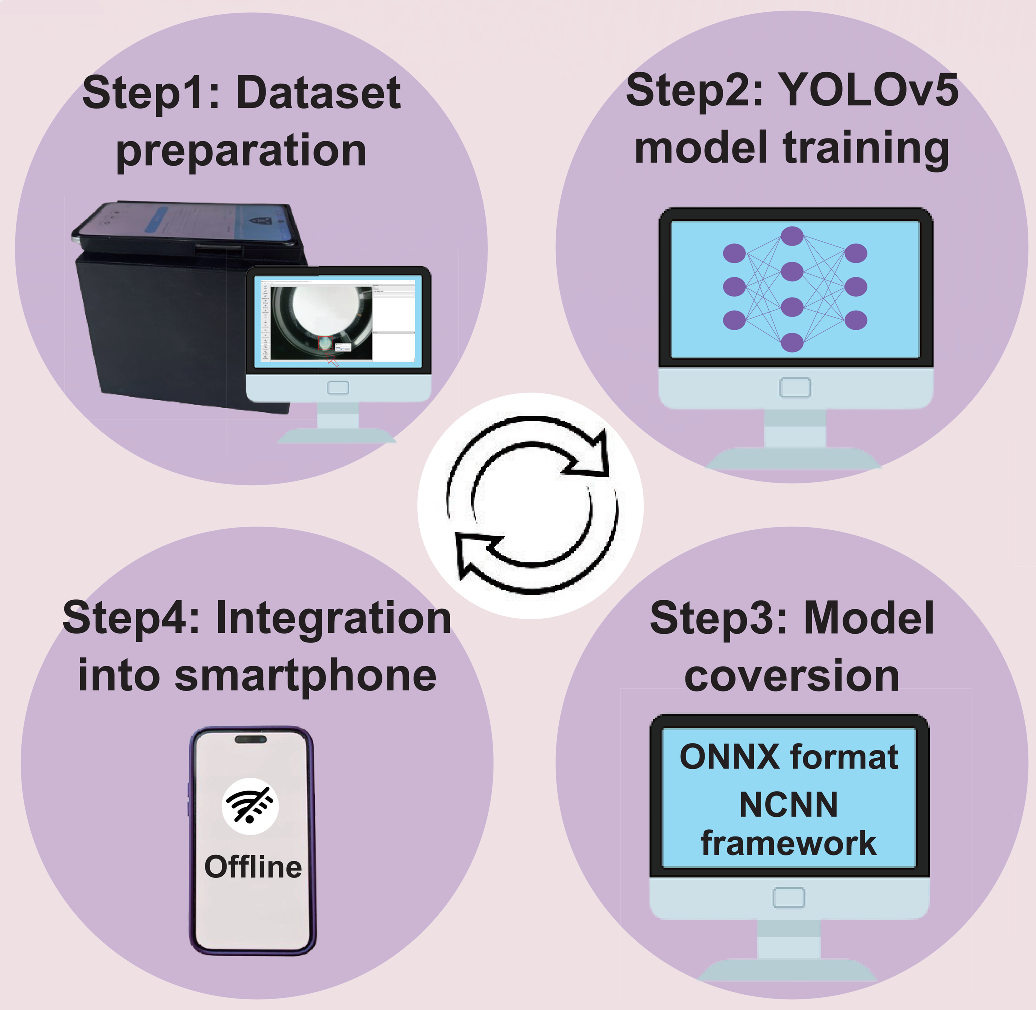


Fig. 1. The flow chart of implementing smartphone-based offline detection on μPAD.

- Prepared a dataset by conducting sandwich c-ELISA of Aβ 1-42 samples on our device (Fig. 2).
- Used the prepared dataset to train the YOLOv5 model on the computer side.
- Deployed the traind YOLOv5 model to the smartphone using the NCNN framework.
- Developed an Android application under the integrated development environment Android Studio (Google, U.S.A.).

Automated μPAD with mechanical rotary valves (Fig. 3)

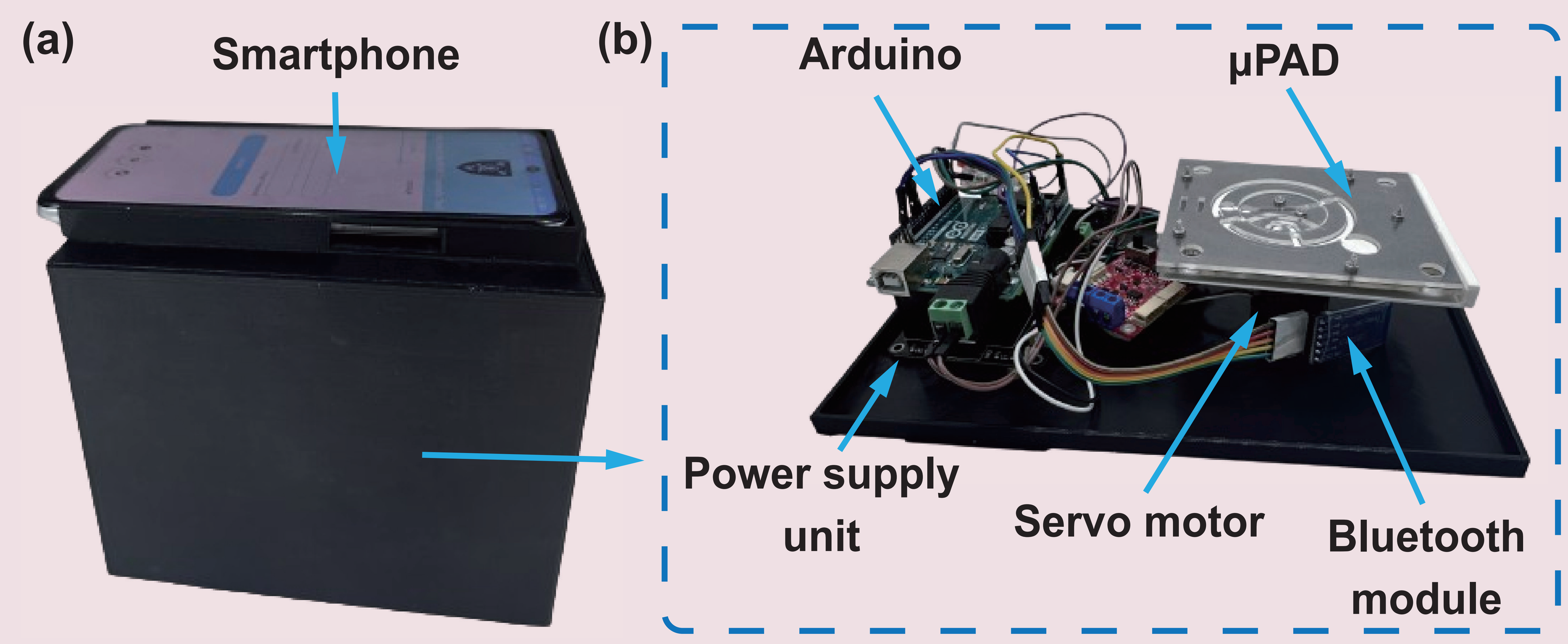


Fig. 2. (a) The photo of smartphone-assisted μPAD. (b) The photo of μPAD and other components.

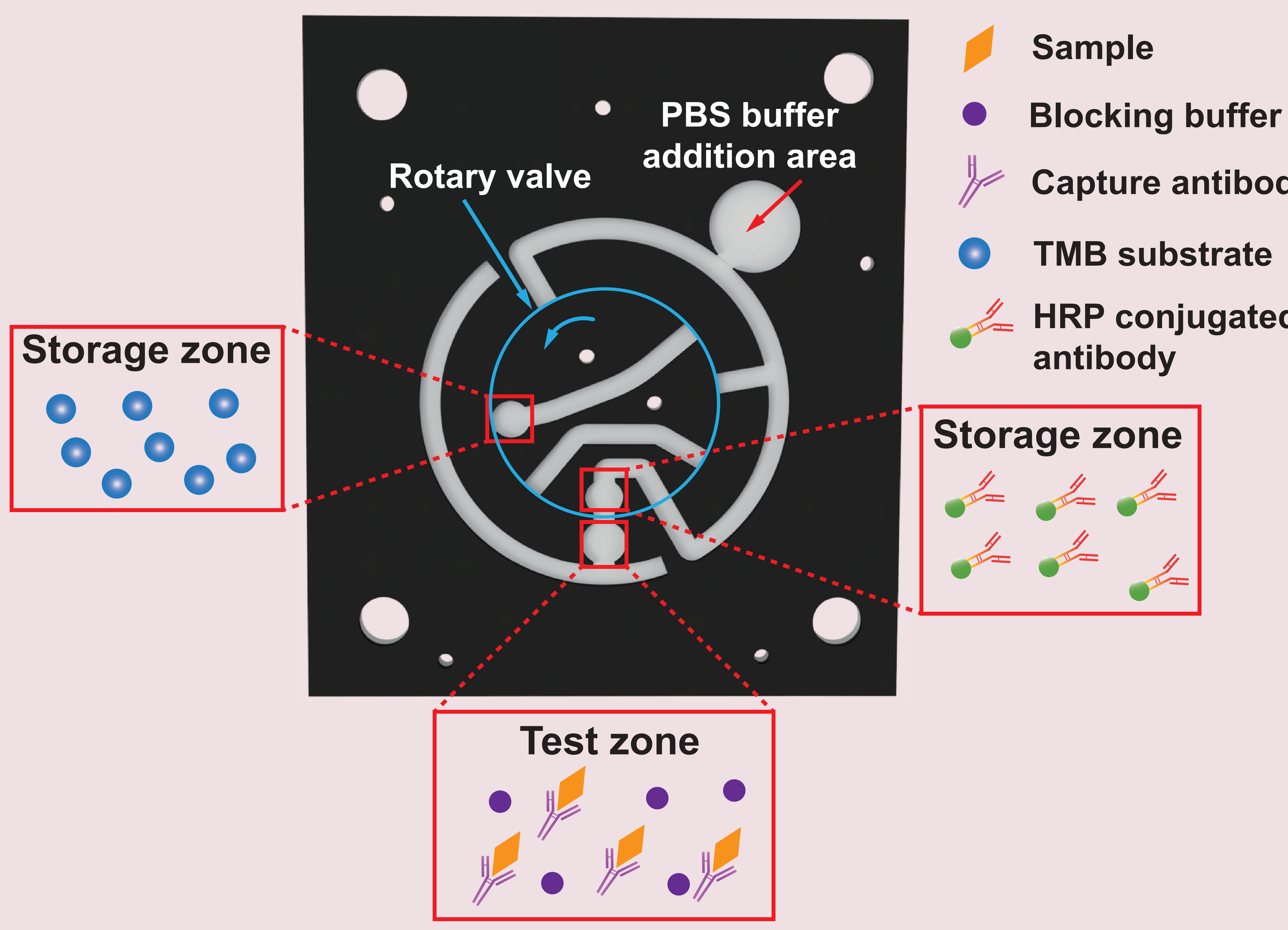


Fig. 3. The schematic diagram of the design of μPAD.

RESULTS

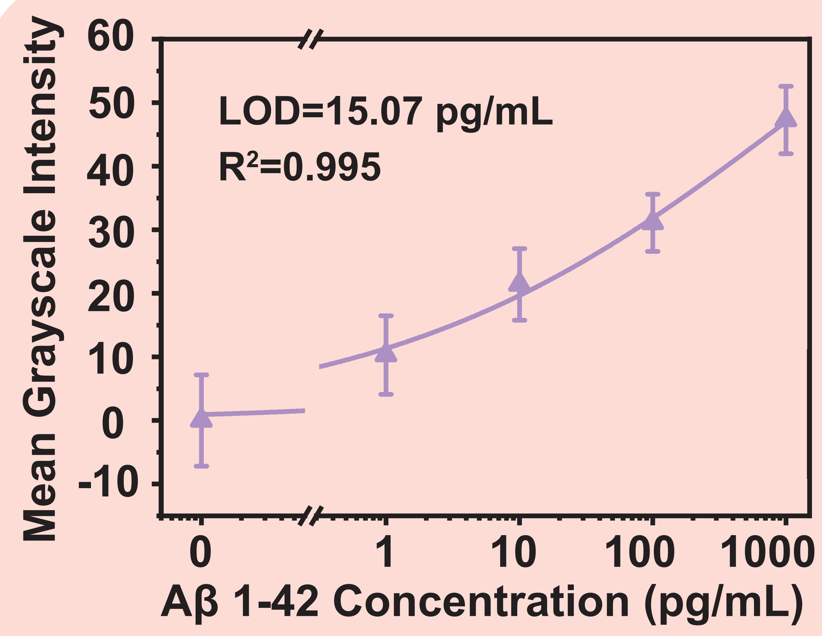


Fig. 4. The calibration curve of sandwich c-ELSIA detection (n=5).

Detected Aβ 1-42 peptide in artificial plasma (Fig. 4):
LOD = 15.07 pg/mL
R^2 = 0.995

- Constructed the dataset for training the YOLOv5 model by testing 30 human serum samples (healthy: 15, unhealthy: 15).

The YOLOv5 model achieved an accuracy of 88.5%, outperforming the ImageJ analysis, which had an accuracy of 76.67%.

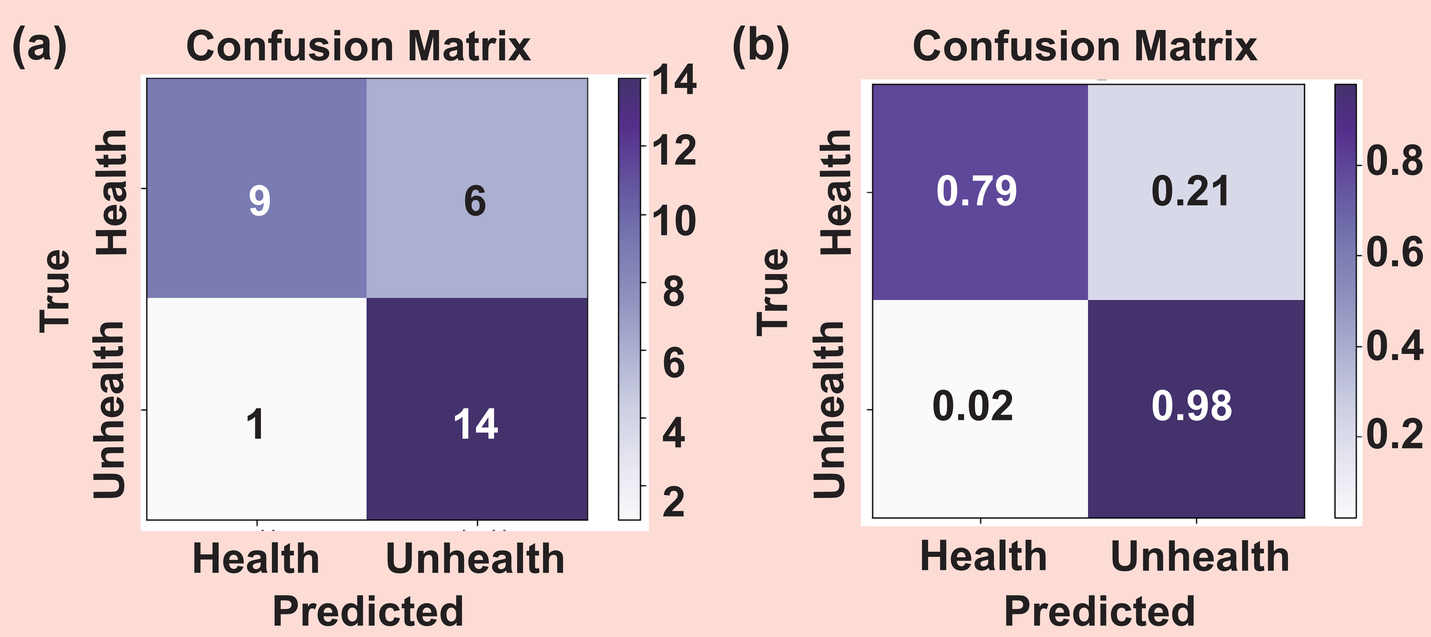


Fig. 5. The confusion matrix of (a) conventional method (ImageJ analysis). (b) YOLOv5 model.

CONCLUSION

This paper introduced a fully automated μPAD, controlled by a smartphone enhanced with DL, for accurate offline detection of AD biomarkers (Aβ 1-42).

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