Enhancing Breast Cancer Detection through Multimodal Neural Network Integration

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Abstract

Breast cancer poses a substantial global health challenge. This project aims to integrate microwave radiometry (MWR) with traditional mammography and tomosynthesis using novel multimodal neural networks to improve early detection and monitoring of breast cancer. By employing advanced machine learning techniques, such as contrastive learning, this approach seeks to enhance diagnostic accuracy, improve generalisability and reduce clinician workload.

Introduction

Breast cancer remains a leading cause of mortality among women worldwide. Early detection is crucial for improving patient outcomes. Mammography and tomosynthesis are standard tools for detecting breast cancer, yet they primarily assess structural changes. The introduction of MWR, which measures internal tissue temperature changes due to metabolic activity, offers a complementary diagnostic tool (Smith et al., 2020, Vesnin at al. 2017). Cancerous cells, which demand increased energy as they proliferate, exhibit higher metabolic rates, leading to elevated heat generation detectable by MWR. This temperature-based assessment complements structural evaluations by providing insights into tumour growth rates.

Nevertheless, the practical challenges of evaluating multiple imaging modalities within clinical workflows necessitate innovative solutions. Neural network algorithms offer a compelling avenue by seamlessly integrating diverse data modalities, thereby enhancing diagnostic accuracy while reducing clinicians' workload.

Research Challenge

Integrating diverse data types demands innovative computational models capable of efficiently processing and analysing such complexity (Johnson & Lee, 2019). The exploration of combining MWR data with other modalities represents a promising frontier in research.

This project targets several key research challenges:

1) Data fusion: This challenge arises when integrating sparse representations of temperature measurements from MWR with dense, high-dimensional voxel data from other modalities;

2) Feature Representation: Each modality offers unique information, with the relationship between temperature data from MWR and structural abnormalities often being disjoint. Effectively capturing and representing these distinct features within the neural network poses a significant challenge; and

3) Data Alignment: Aligning non-structural MWR imaging with structural modalities presents a considerable hurdle. Achieving accurate alignment despite differences in spatial properties and information content is crucial for meaningful integration.

Data & Methodology

The project boasts an extensive dataset, comprising MWR data collected from over 20,000 patients, complemented by additional publicly available breast imaging data. Further data collection is planned to facilitate clinical evaluation. MWR data is collected from a dual-band device that monitors both infrared (skin temperature) and microwave (internal tissue temperature) emissions. The dataset is already annotated and ready to be used (Li J, 2022).

To address each of the research challenges the proposed methods are:

1) Data Fusion: A pioneering approach involves crafting a novel multi-modal neural network architecture distinguished by modality-specific encoders and a unified joint embedding space (Girdhar et al., 2023).

2) Feature Representation: Innovative contrastive learning techniques (Khosla et al., 2020) will be employed, targeting three distinct domains. These techniques will focus on contrastive learning within samples of the same modality, across different modalities, and within regions of individual cases (self-contrastive) which exploit the symmetrical properties of the breasts.

3) Data Alignment: A novel approach involves mapping the MWR data to a phantom breast model, which will subsequently be registered to mammograms (2D) and/or tomosynthesis (3D) (Boveir et al., 2020).

RRI/Ethical Considerations

The project will adhere to Responsible Research and Innovation (RRI) frameworks to ensure ethical compliance, focusing on patient confidentiality, data security, and the minimization of bias in AI models. Ethical approval will be sought from the relevant institutional review boards.

Expected Outcome & Impact

The expected outcome is the development of an effective diagnostic tool that can be integrated into existing clinical practices, enhancing the accuracy of breast cancer detection and facilitating personalized treatment strategies. This could significantly impact patient care and potentially be adapted for other medical applications (White & Thomson, 2022).

Funding and Support

This project is supported by MMWR LTD, UK, and will involve collaboration with industrial and academic partners to access necessary data and expertise.

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