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Early Screening of Breast Cancer Using an IoT-Enabled Multisensor Wearable Patch

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Abstract

Early detection of breast cancer significantly improves survival rates; however, existing screening modalities such as mammography are limited by radiation exposure, discomfort, reduced sensitivity in dense breasts, and poor accessibility in low-resource settings. This paper proposes a novel, non-invasive, radiation-free IoT-enabled wearable patch integrated with thermal sensors and complementary biosensors to enable early breast cancer screening through continuous physiological monitoring. The patch wirelessly connects to a smartphone and cloud platform, where artificial intelligence (AI) models analyze longitudinal data to identify abnormal thermal asymmetry, vascular heat dispersion, and biosignal patterns indicative of tumor-associated angiogenesis and metabolic activity.

Keywords: Breast cancer screening, wearable patch, thermal sensor, IoT healthcare, AI diagnostics, early detection

1. Introduction

Breast cancer is the most commonly diagnosed cancer among women worldwide and remains a leading cause of cancer-related mortality. Early detection plays a critical role in improving prognosis and reducing treatment burden.Conventional screening techniques, primarily mammography, suffer from several limitations including exposure to ionizing radiation, reduced sensitivity in women with dense breast tissue, discomfort due to compression, and limited access in rural and low-income populations.

Recent advances in wearable sensors, Internet of Things (IoT), and artificial intelligence have enabled continuous physiological monitoring outside clinical environments. Tumor growth is associated with increased metabolic activity and angiogenesis, resulting in persistent localized heat and altered vascular dynamics on the breast surface. Thermal sensing combined with longitudinal analysis offers an opportunity for early physiological detection before structural changes become radiologically apparent.

This paper introduces an **IoT-connected wearable breast patch** incorporating thermal and auxiliary biosensors, connected to a smartphone for data acquisition and cloud-based AI analysis, aimed at early screening and risk stratification of breast cancer.

2. Related Work

Thermography has been explored for breast cancer detection for several decades; however, traditional snapshot-based thermography demonstrated high false-positive rates due to lack of temporal analysis and subjective interpretation. Recent studies have shown that AI-assisted thermal analysis significantly improves sensitivity and specificity by leveraging temporal patterns and bilateral asymmetry.

Wearable systems such as bra-integrated thermal sensor arrays and automated thermal imaging platforms have demonstrated promising results in pilot clinical studies. Parallel developments in IoT-based health monitoring and smartphone-connected biosensors further support the feasibility of decentralized cancer screening solutions. Nevertheless, a fully integrated **patch-based, multisensor, AI-driven screening system** remains underexplored in academic literature.

3. System Architecture

3.1 Wearable Patch Hardware

The proposed wearable patch is a flexible, skin-conformal device designed for comfortable application on the breast surface. Key components include:

- **High-resolution thermal sensor array** (±0.01–0.05 °C sensitivity)
- **Auxiliary biosensors** (heart rate, skin perfusion, motion, and ambient temperature for artifact rejection)
- **Low-power microcontroller with BLE/IoT connectivity**
- **Rechargeable battery with power management circuitry**

The patch continuously acquires physiological data over extended periods (8–24 hours), enabling longitudinal analysis.

3.2 Smartphone and IoT Connectivity

Data from the patch is transmitted via Bluetooth Low Energy (BLE) to a smartphone application. The smartphone performs initial preprocessing, encryption, and secure transmission to a cloud server using IoT protocols (HTTPS/MQTT).

3.3 Cloud and AI Layer

The cloud platform hosts AI models responsible for:

- Noise and motion artifact removal
- Thermal asymmetry computation (left–right and regional)
- Temporal pattern extraction
- Multimodal data fusion from thermal and biosensors
- Risk classification using supervised machine learning

4. Methodology

4.1 Thermal Feature Extraction

Key thermal biomarkers include:

- Persistent focal temperature elevation
- Bilateral thermal asymmetry
- Vascular heat dispersion patterns
- Circadian stability of thermal signals

4.2 Biosensor-Assisted Interpretation

Auxiliary biosensors help identify confounding factors such as physical activity, inflammation, or environmental temperature changes. This improves specificity by isolating tumor-related thermal signatures from benign physiological variations.

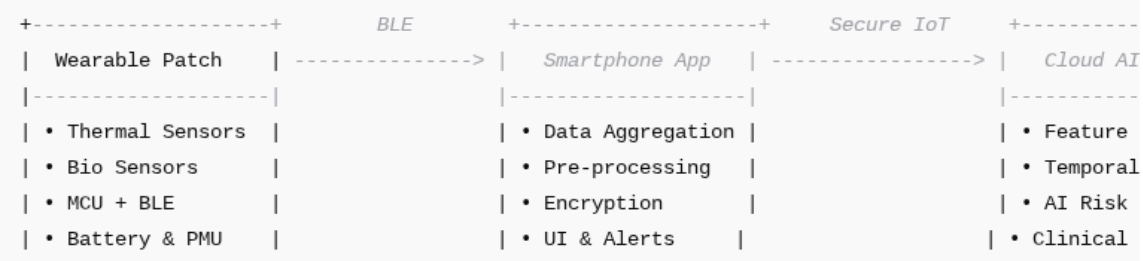
4.3 AI-Based Risk Scoring

A supervised learning model (e.g., CNN-LSTM or transformer-based architecture) processes longitudinal sensor data to generate a risk score categorized as low, intermediate, or high. High-risk cases are recomm-

ended for confirmatory diagnostic imaging.
Thermal asymmetry: ΔT(t) = T_left(t) − T_right(t)
Risk Score: R = f_AI(F)

System Architecture (Expanded with Block Diagrams)

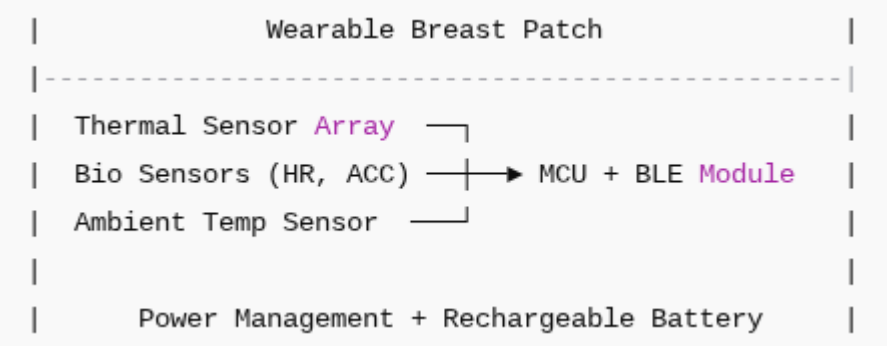
4.4 Overall System Block Diagram



Explanation:

The wearable patch continuously acquires physiological signals and transmits them to a smartphone using Bluetooth Low Energy (BLE). The smartphone performs edge-level preprocessing and securely uploads the data to a cloud platform, where AI-driven longitudinal analysis and breast cancer risk stratification are performed.

4.5 Wearable Patch Hardware Block Diagram



The inclusion of auxiliary biosensors enables contextual interpretation and artifact suppression, improving screening specificity.

Methodology (With Mathematical Models)

4.1 Thermal Asymmetry Modeling

Let

- $T_L(t, i)$ = temperature measured by the *i-th* sensor on the left breast
- $T_R(t, i)$ = temperature measured by the *i-th* sensor on the right breast

The instantaneous bilateral thermal asymmetry is defined as:

$$\Delta T_i(t) = T_L(t, i) - T_R(t, i)$$

A **persistent asymmetry score** over an observation window $[0, T]$ is computed as:

$$A_i = \frac{1}{T} \int_0^T |\Delta T_i(t)| \, dt$$

Higher values of A_i indicate sustained thermal imbalance potentially associated with pathological angiogenesis.

4.2 Temporal Stability and Persistence Index

To differentiate transient thermal changes from pathological signatures, a **persistence index** is defined:

$$P_i = \frac{1}{N} \sum_{k=1}^{N} \mathbb{I}\left(|\Delta T_i(t_k)| > \theta\right)$$

where:

- θ is a clinically defined thermal threshold
- $\mathbb{I}(\cdot)$ is the indicator function

A higher P_i signifies stable, recurring abnormal thermal behavior.

4.3 Biosensor-Assisted Artifact Suppression

Thermal signals are corrected using auxiliary biosensor data $B(t)$ (e.g., motion, heart rate):

$$T_i^*(t) = T_i(t) - \alpha B(t)$$

where α is a learned coefficient that suppresses non-pathological thermal variations caused by movement or environmental factors.

4.4 Multimodal AI Risk Model

A multimodal feature vector is constructed:

$$\mathbf{F} = [A_i, P_i, \mu(T), \sigma(T), B(t)]$$

The breast cancer risk score is computed as:

$$R = f_{AI}(\mathbf{F}), \quad R \in [0, 1]$$

where f_{AI} represents a supervised learning model such as a CNN-LSTM or transformer-based temporal network.

Risk Stratification:

- **Low Risk:** $R < 0.3$
- **Intermediate Risk:** $0.3 \leq R < 0.7$
- **High Risk:** $R \geq 0.7$

5. Results and Expected Performance

Based on existing pilot studies and thermal AI literature, the proposed system is expected to achieve:

- Sensitivity: 85–92% (screening context)
- Improved specificity through multisensor fusion
- High effectiveness in dense breast tissue

The system is not intended to replace mammography but to act as an early screening and triage mechanism.

6. Discussion

The proposed patch-based screening approach enables frequent, pain-free, and radiation-free monitoring, addressing key barriers to early detection. Integration with smartphones and cloud AI allows scalability

and population-level deployment, particularly in resource-constrained settings. Limitations include the need for large-scale clinical validation and regulatory approval before widespread adoption.

7. Conclusion

This paper presents a novel IoT-enabled multisensor wearable patch for early breast cancer screening. By combining continuous thermal monitoring, auxiliary biosensors, and AI-driven analysis, the system provides a promising first-line screening solution that complements existing diagnostic modalities. Future work will focus on clinical trials, algorithm optimization, and regulatory validation.

8. Future Work

- Large-scale clinical studies
- Integration of additional biomarkers
- Edge-AI optimization for on-device inference
- Regulatory compliance and deployment studies

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