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AI-driven signal enhancement for energy-efficient, wearable piezoelectric tactile sensing

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Abstract

This study presents the development of a fully flexible, low-power piezoelectric tactile sensor based on the piezotronic effect, designed for applications in AI, augmented reality, and smart wearable technologies. The sensor integrates piezoelectric materials with organic field-effect transistors and β-polyvinylidene fluoride (PVDF) nanorod arrays,

which convert mechanical stress into electrical signals. The AlN thin film, positioned between titanium or molybdenum electrodes, efficiently amplifies the generated piezoelectric voltage, significantly enhancing sensitivity and responsiveness. The combined use of PVDF nanorods and AlN films boosts energy conversion efficiency, enabling high precision in pressure detection. Experimental results show superior pressure sensitivity, low detection limits, and rapid response times due to the unique structural configuration and active material selection. Additionally, the device eliminates the need for external gate voltage by employing piezotronic transistors to directly convert mechanical stimuli into electrical outputs. For intelligent signal processing, the system incorporates deep learning architectures—Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM), and Gated Recurrent Units (GRUs) with Multi-Head Attention—providing adaptive and high-fidelity interpretation of tactile data. This innovation supports advancements in flexible electronic skin (e-skin) and next-generation human–machine interfaces.

Keywords:

Signal enhancement flexible and wearable piezoelectric tactile sensors

convolutional neural networks (CNN) gated recurrent unit (GRU) multi-head attention mechanism

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the conception and design of the study, analysis and interpretation of data, drafting or critically revising the article for important intellectual content, approved the final version to be published, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved, in accordance with ICMJE authorship guidelines.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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