**Title:** Development of a Biomimetic Spiking Neural Network Model for Multidimensional Tactile Perception

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**Abstract:** Implementing an artificial tactile system that approaches the human perception level has proven to be a formidable challenge. This work proposes a biomimetic tactile perception model based on a Spiking Neural Network (SNN) that addresses this challenge. Designed to mimic the tactile pathway from fingertip mechanoreceptors to primary somatosensory cortical neurons, the proposed model utilizes a multi-layered SNN architecture, with each layer representing a distinct component of the tactile pathway. The first layer comprises Slowly Adapting-1 (SA-1) and Rapidly Adapting-1 (RA-1) afferent neurons, which receive tactile stimuli from mechanoreceptors stochastically. The second layer processes the information derived from SA-1 and RA-1 afferents in separate streams, simulating the functions of the cuneate nucleus (CN). This layer follows the neuronal circuit mechanisms intrinsic to the cuneate nucleus, particularly the dynamic interaction between excitatory and inhibitory neural circuits that facilitate lateral inhibition for minimizing noise accumulation and maintaining the fidelity of spatial information. The final layer, wherein inputs from Slowly Adapting-1 (SA-1) and Rapidly Adapting-1 (RA-1) afferents converge, is constructed to emulate the primary somatosensory cortex. This layer utilizes a diverse combination of excitatory and inhibitory fields for the encoding of various stimulus properties. The layered organization of the SNN enables simultaneous processing of multiple physical features of tactile information, thereby enhancing the efficiency of information processing. Throughout the course of this investigation, the model was successfully subjected to a two-point discrimination test, displaying a capacity akin to human tactile discrimination in distinguishing two separate points of pressure stimulation at a distance of 3mm or greater. This outcome aligns closely with the human perceptual threshold, marking a significant accomplishment in the realm of artificial tactile intelligence. Moreover, the model demonstrated adeptness in handling static stimuli, accurately identifying and responding to angular stimuli ranging from 0 to 180 degrees in increments of 10 degrees. This was realized by examining the neural activity patterns of a mere four output neuron groups. Utilizing a Support Vector Machine (SVM) in conjunction with this approach resulted in a classification accuracy of 90.1%. These outcomes not only reinforce the model's competency in mimicking biological tactile processes but also provide substantial implications for prospective enhancements in the architecture and evolution of tactile intelligence systems.

(기존 내용)To evaluate the model's performance, separate experiments were conducted, wherein it was tasked with the representation of an extensive variety of both static (e.g., pressure and shape) and dynamic (e.g., vibration frequency and slip) tactile stimuli. The subsequent analysis focused on two aspects: the classification accuracy achieved by the model, and its ability to identify tactile features within the output layer in response to various stimuli. The results validate the model's ability to replicate the intricate process of biological tactile information processing, as demonstrated by a broad spectrum of neural responses to various tactile features. These findings not only enhance the current state of artificial tactile systems but also hold significant implications for the future design and development of tactile intelligence.