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Adaptative Neural Networks based on Metal-Insulator-Metal Nanostructures (Memristors)

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The rapid advancement in the field of neural network algorithms has led to their proliferation in a wide range of fields, including image and audio recognition, natural language processing, big data analytics, and decision-making. This is due to their ability to adapt and learn through methods that involve the modification of internal parameters based on input data used for training. However, due to the separation of memory and control units, the traditional Von Neumann architecture of computers poses significant challenges in effectively training these algorithms, resulting in the phenomenon known as the Von Neumann bottleneck, which is exacerbated by the increasing volume and complexity of training data.

To address this issue, a plethora of pioneering architectures have been proposed, drawing inspiration from the human brain and utilizing artificial neurons for data processing and in-memory computation, known as neuromorphic computing. One such neuromorphic architecture is the implementation of physical neural networks, which consist of interconnected artificial neurons. In recent years, there has been a significant amount of innovation in the use of memristors as memory components for these architectures.

This thesis aims to design and fabricate a functional physical neural network device utilizing metal-insulator-metal (MIM) memristors, in collaboration with INESC Lisboa and IFIMUP in Porto. The research will focus on the exceptional properties of memristors, including compatibility with complementary Metal-Oxide-Semiconductor (CMOS) technology, compact device area for high-density on-chip integration, non-volatility, swift speed, low power dissipation, and scalability, which make them an ideal choice for this application.

Keywords: Neuromorphic computing, physical neural network, memristors, Von Neuman bottleneck, artificial neurons, CMOS technology, non-volatility, scalability, high-density on-chip integration, functional device fabrication.

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