A Memristor-Based Edge Computing System for Accelerating Support Vector Machine

Zerui Liu[1†], Deming Meng[1†], Sushmit Hossain[1], Yudi Shi[1], Buyun Chen[1], Pan Hu[1], Hao Yang[1], Boxiang Song[2], Yunxiang Wang[1], Tse-Hsien Ou[1], Zhi Cai[3], Bofan Zhao[1], Mark Barnell[4], Qing Wu[4], Stephen Cronin[1], and Wei Wu[1]*
[1]*Department of Electrical Engineering, University of Southern California, Los Angeles, CA, 90089, USA.*
[2]*Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, Wu Han, 430074, China.*
[3] *Department of Chemical Engineering and Materials Science, University of Southern California, Los Angeles, CA, 90089, USA.*
[4]*Air Force Research Laboratory, Information Directorate, Rome, NY 13441, USA.*
* *wu.w@usc.edu*

Nowadays, as computing platform expand from the precisely regulated environments of automated manufacturing factories to the less constrained real world shared with various moving objects, the accompanying control, deploying, and perceptual tasks increase the computational load dramatically and require a range of milliseconds or smaller for the system to give action[1]. The performance of current computing systems inside robots is unable to handle the onerous computational burden in such a short time[2]. Over several decades, a lot of approaches have been proposed to address this issue. These approaches either focus on the application of artificial intelligence (AI) or making the digital computing platform more efficient, e.g., by using field programmable gates array (FPGA)[3]. Unfortunately, none of these approaches can break the limitation of time complexity of the algorithm, slowing down the computation. Therefore, the efficient computing technique to perform computations in real-time is one of the most challenging tasks in the field of the computing system.

In this study, a high-performance support vector machine (SVM)-based edge computing system is implemented using memristors to demonstrate the feasibility to revolutionize the field of computation, optimization, and decision-making. Although, as one of the most popular algorithms and AI models, SVM is widely used in the robotic domain, time complex $O(n^3)$ remains the critical bottleneck for the performance of SVM to solve real-time tasks. However, this is solved by the memristor-based computing system. This system consists of memristor-based optimization circuit, Bluetooth circuit, and digital components of the display device as shown in figure 1. SVM is inherently a quadratic programming (QP) problem which can be solved by specific designed analog circuit. The memristors enable the optimization circuit to process continuous changing external information through the reconfigurable resistance of memristors controlled by tunning circuit, which gives this platform more adaptive capacity. The characteristics of memristors are shown in figure 2. The result of the QP problem is equal to the output voltage of memristor-based optimization circuit. After obtained the result, this Bluetooth circuit will convert the result to digital signal and then send it back to the digital part via Bluetooth for further processing. By offloading computation from the digital component to the reconfigurable analog SVM solver, the time complexity is reduced from $O(n^3)$ to O (n), demonstrating a realistic way to break the limitation of time complexity and get the results within the range of microseconds. A specific case is used to demonstrate the feasibility of this idea. The SVM-based computing system is used to identify cancer and achieved accuracy of up to 93% within 35 microseconds. Implementing SVM using memristors enables the hardware to do computation itself when and where it is needed to deal with complex tasks, which demonstrates a practical way to improve the performance of the current computing system.

---

† These authors contributed equally to this work.

1. Siegwart, R., Nourbakhsh, I. R. & Scaramuzza, D. Introduction to autonomous mobile robots. (MIT press, 2011).
2. Sandamirskaya, Y. Vol. 7   eabq3909 (American Association for the Advancement of Science, 2022).
3. Murphy, R. R. Introduction to AI robotics. (MIT press, 2019).

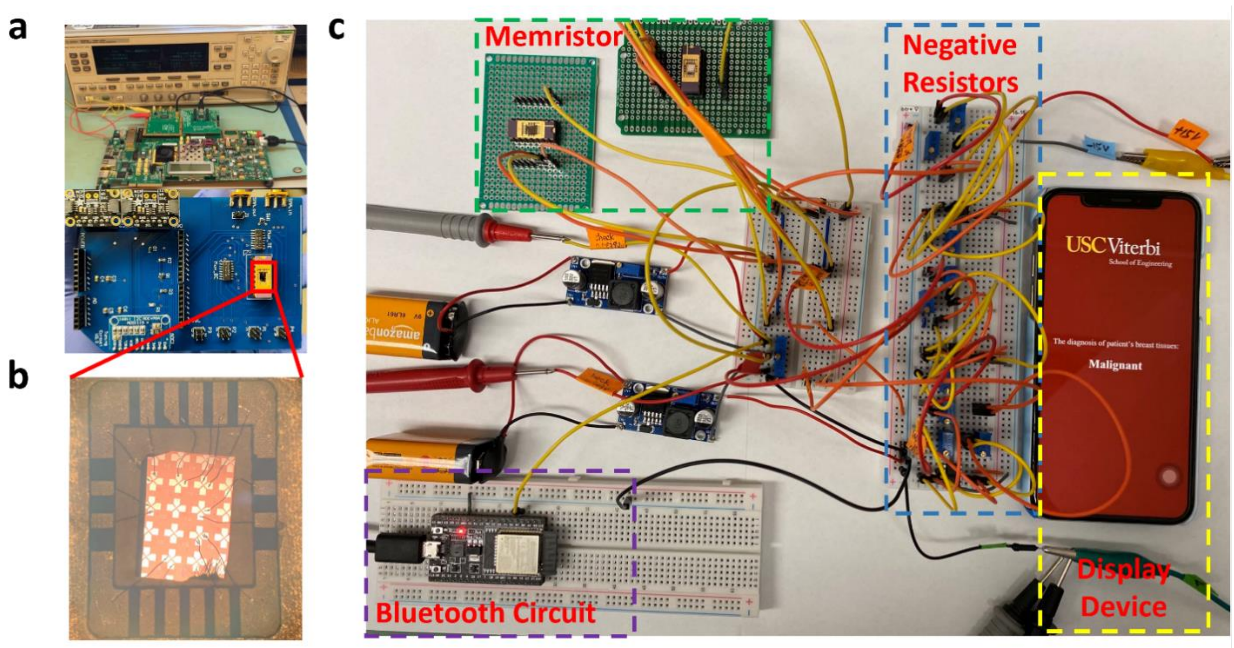

Figure 1. Experimental set up of SVM-based edge computing system for the diagnosis of breast tumor. (a) Memristor programing setup. (b) Image of memristor packaged on the chip carrier. (c) Image of SVM-based edge computing system implemented by memristors. The diagnosis of a new patient is shown through display device, which is “Malignant”.

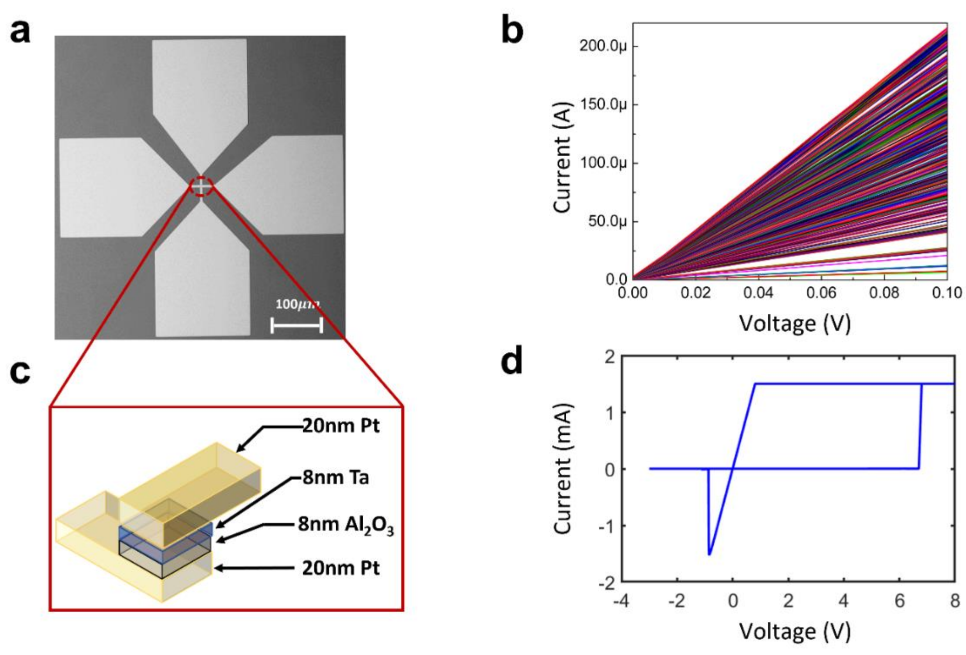

Figure 2. (a) The image of a memristor crossbar under microscope. (b) The conductance states of memristor controlled precisely using DC sweep voltages with different compliance currents. (c) The 3D visualization of cross-point area of a memristor crossbar, highlighted by red circle in (a). (d) I-V characteristics of the memristors.