Computing with coupled relaxation oscillators

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Phase and frequency synchronization in a system of coupled oscillators is a universal and omnipresent natural phenomenon. From the synchronized blinking of millions of fireflies, to the circadian cycles of plants and mammals to the synchronization of neural oscillators in our nervous system – these are several examples of coupled oscillatory systems exhibiting rich non-linear dynamics. In this talk, we will explore whether a useful computational model can be mapped to a system of coupled relaxation oscillators exploiting their synchronization dynamics.

For the last six decades, CMOS-based Boolean logic has been the cornerstone of the information technology industry. A class of problems, related to associative processing such as object recognition, requires massive computational resources in the CMOS-based Boolean framework [1]. While this has motivated the development of faster and more efficient algorithms, they are mapped back to the Boolean hardware, which ultimately limits their energy-performance metric. Fundamentally, this "Boolean bottleneck" arises from the requirement of a large number of power-intensive multiply–accumulate (MAC) operations, common to many associative-processing algorithms. This encourages the development of a non-Boolean approach utilizing coupled oscillatory systems [2-10]. Through experiments, models and simulations we demonstrate a non-Boolean non-von-Neumann computing fabric that performs pattern matching by exploiting the synchronized oscillations performed by low-power, compact and scalable complex oxide based oscillators. Specifically, we will show that the synchronization dynamics enables fast and efficient calculation of a "fractional distance norm" in the analog domain that is suitable for pattern matching in high dimensional space [11].

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