EECS 241b Project Proposal
High-Dimensional Vector Associative Memory
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We propose the design of an Associative Memory specifically tailored for the purpose of High-Dimensional (HD) Computing.

Computing in high dimensional vector spaces shows similarities with computing in the human brain. HD Computing can be used for machine learning classification tasks by encoding data samples as HD (10,000-bit) vectors and then using a distance metric between vectors as a means for classification. The statistical distribution of distances in HD vector spaces dictates that two randomly generated HD vectors almost always have normalized distance of 0.5. This makes HD computing robust to noisy data and error-prone computation.

HD computing has been shown to accurately classify text language, EMG, and EEG datasets [1] [2]. However, as these machine learning applications become more ambitious, simulation time becomes a problem. To efficiently perform operations on HD vectors, a system with a very wide datapath must be designed. In addition, an Associative Memory (AM) must be used to avoid high memory bandwidth during distance calculations between vectors. It is unlikely that any AM can support a 10,000-bit wordline, so we propose a modular approach, in which subsets of each vector are compared in series. Since the information stored in HD vectors is distributed evenly in each bit, a comparison between a subset of two vectors will return an approximate distance. As the AM iteratively compares more bits, the distance will become more and more accurate. This information can possibly be used to terminate the associative search early if the distance function converges quickly enough.

Since HD computation can tolerate errors, the AM will be functional despite device mismatch and low voltage supplies.

Reference:

[1] Abbas Rahimi et al. Hyperdimensional Computing for Noninvasive Brain–Computer Interfaces: Blind and One-Shot Classification of EEG Error-Related Potentials. ACM 2017.

[2] Abbas Rahimi et al. A Robust and Energy Efficient Classifier Using Brain-Inspired Hyperdimensional Computing. ISLPED 2016.

[3] Hans Jürgen Mattausch et al. Compact associative-memory architecture with fully parallel search capability for the minimum Hamming distance. IEEE Journal of Solid-State Circuits 37(2):218 - 227 · March 2002
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[5] N. Pavan Kumar and Sandeep Bansal. VLSI Design and Implementation of Low Power PBCAM: A Tutorial and Survey. Indian Journal of Science and Technology. 2016.
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