【Grant-in-Aid for Scientific Research (S)】

Multi-Disciplinary AI Computing Platform Based on Hyper-dimensional Vector Representation

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Project Information	Project Number : 23H05489 Project Period (FY) : 2023-2027 Keywords: Deep neuranet, Annealing, Hyperdimensional computing

Purpose and Background of the Research

●Outline of the Research

As the societal application of AI technology advances rapidly, the significant energy consumption associated with its processing is emerging as a social issue. In order to achieve a more prosperous and environmentally friendly Society 5.0, there is a need for technological innovations in information processing architecture to improve the processing efficiency of AI computing. In this context, AI computing can be understood as an intelligent information processing that supplements human intelligence, targeting the "explosion of data" that serves as the input to computer systems and the "explosion of solutions" that are generated as output.

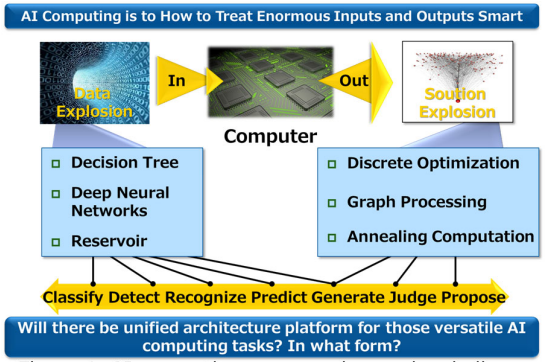

Figure 1 AI computing: an overview and a challenge.

With this awareness, this research focuses on two representative technologies: Deep Neural Networks (DNN) that handle the "explosion of data" and Annealing Computation (ANC) that addresses the "explosion of solutions." Furthermore, based on the understanding that both of these processing methods can be reconstructed using the framework of Hyperdimensional Distributed Vectors (HDV), this research aims to explore a multi-disciplinary AI computing platform that incorporates the emerging machine learning technology known as High-Dimensional Computing (HDC).

●Inspiration Based on Research Achievements

Through the previous research conducted by the PI's team on DNN and ANC, they noticed the potential for a unified understanding of these technologies in terms of parallel processing targeting HV. This realization led to the development of the research plan for this project.

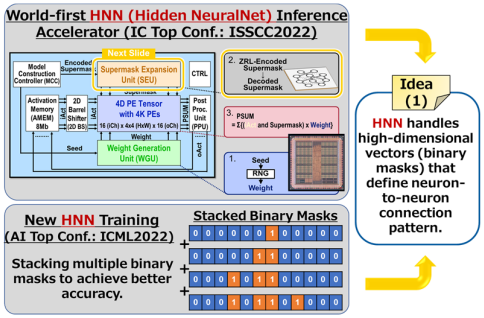

Figure 2 Hidden neuralnet research.

Idea (1)

HNN handles high-dimensional vectors (binary masks) that define neuron-to-neuron connection pattern.

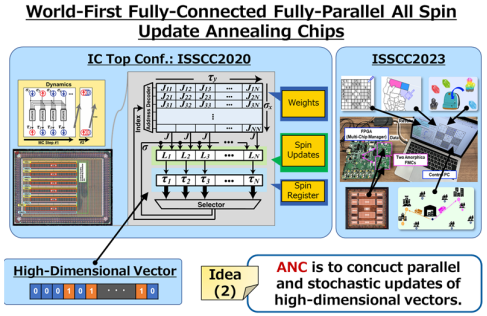

Figure 3 Annealing computation research.

●Research Organization

Will be driven by close collaboration between three teams from Tokyo Institute of Technology, Hokkaido University, and Kyoto University, each bringing different strengths and expertise. The teams will work together closely on AI computing technologies that span across both software and hardware domains, addressing both the explosions trough a cross-disciplinary and hierarchical approach.

Figure 4. Research Organization.

Expected Research Achievements

●Research Strategy

In the broader field of AI, encompassing DNN, ANC, and HDC, this research project aims to tackle ambitious themes such as the parallel and reconstructive memory-processor integrated engine mechanism for HV sets as the core, the development of DNN-HDC fusion-based machine learning techniques, DNN-HDC-ANC integrated processing architecture, efforts towards explainable AI through the reverse process of ANC and post-processing of HV sets, and the creation of an architecture foundation that integrates all of these aspects.

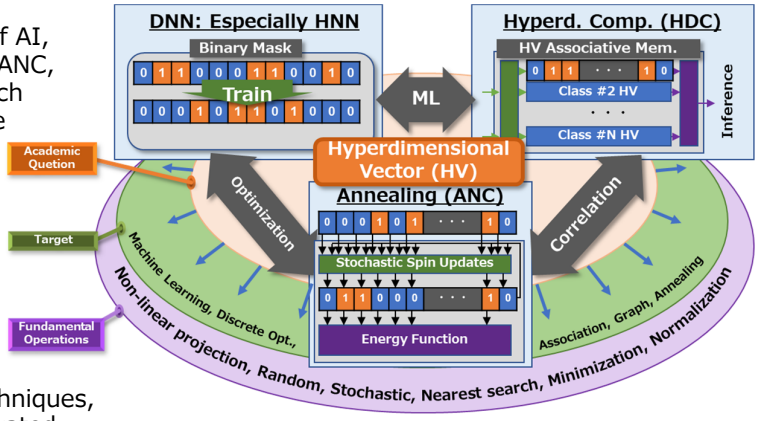

Figure 5. Research Strategy.

● Academic and Social Contributions

The title of this research project reflects the awareness of making contributions to academia and society. By establishing a common foundation for information processing based on the "Hyperdimensional Distributed Vector representation," this research aims to provide a sound computational model to in-memory integrated circuits from a top-down perspective, incorporating both traditional digital computing and new physics-inspired approaches, including future quantum computing technologies.

The term "multi-disciplinary" is important for achieving robust and versatile information processing that is not confined to individual applications, by providing a unified means to address both types of explosions mentioned earlier.

Furthermore, improving the energy efficiency of the "AI computing platform" is a significant societal need in the context of Society 5.0, and this research endeavors to promote the development of information processing architectures that support further advancements in smart societies.

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