Embedded Systems Modeling and Design

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Optimizing Algorithm Performance with HBM-PIM: A Matrix Multiplication Case Study

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Evaluation, Academic Integrity and Submition

Notes on the project:

1- Evaluation

The evaluation of this project is based on the following:

a) **Algorithm Implementation (10%)**: Correctness and efficiency of the algorithm implementation.

b) **Simulation Setup (30%)**: Proper configuration and usage of the PIMSimulator.

c) **Performance Analysis (30%)**: Depth of analysis and understanding of performance metrics.

d) **Report Quality (20%)**: Clarity, completeness, and professionalism of the report.

e) **Presentation (10%)**: Effectiveness and clarity of the presentation.

2- Academic Integrity

Each student is expected to adhere to the highest standards of academic integrity. Any form of copying or plagiarism will result in severe penalties. Ensure your work is original and properly referenced.

3- Submission

The project submission guideline is as follows:

a) **Progress Reports**: Submit reports via the Courses portal until the deadline. Each delay in your submission is not acceptable.

b) **Final Report and Code**: Submit your final report and source code in a zipped folder.

c) **Presentation**: Present your findings in class during the final project meeting.

Contents

1 Project Description

1.1 Proposed of this project:

Neurodegenerative diseases, including Alzheimer's In this project you are going to deal with processing in memory (PIM) structure. For surfing in real-world application of PIM, in this project you have to run an algorithm on real PIM device and report your result that you get. Based on the lack of accessibility of real PIM hardware you are going to using PIMSimulator which is based on HBM-PIM of Samsung.

1.2 Description of HBM-PIM:

High Bandwidth Memory (HBM) is a type of memory that's made to transfer data quickly and use less energy. It's built by stacking memory layers on top of each other, which lets them connect directly and move data fast. At the base of these layers, there's a special piece that controls the flow of data to and from other parts of the computer. HBM is often used with powerful computer chips like GPUs because it can handle a lot of data at once, making everything run smoother and faster.

Inside HBM, there are separate paths for data called pseudo-channels, and each one has smaller sections called banks where data is stored. When the computer needs to read data, it picks a specific path and bank, then grabs the data from there. This process is similar to how other types of memory work, but HBM's design lets it do this much quicker and with less energy.

Samsung has made a version of HBM called HBM-PIM that's even better because it can do some data processing right inside the memory itself. This means the computer doesn't have to move data around as much, which makes things faster and saves energy. This new design fits in with how memory is usually made, so it's easy to start using in products.

Overall, HBM and its improved version, HBM-PIM, are big steps forward for memory technology. They're really important for programs that need to process a lot of data quickly, like artificial intelligence and scientific computing, because they make everything more efficient and faster.

2 Project Detaile

As it described in previous section you will use the PIMSimulator to simulate the performance of different algorithms on the HBM-PIM architecture. Each student will be assigned one algorithm to analyze. The goal is to understand how PIM technology affects the performance and efficiency of these algorithms compared to traditional memory architectures. Your task to doing this project is as follow:

2.1 Choosing Algorithm:

You have to choose one of the following algorithms to analyze and submit it in your section of project table assignment in courses portal.

Note: The priority of choosing an algorithm is with the first student which choose it.

2.1.1 Sorting Algorithms:

a) QuickSort

b) MergeSort

c) HeapSort

d) Insertion Sort

e) Bubble Sort

2.1.2 Graph Algorithms:

a) Dijkstra's Algorithm

b) Breadth-First Search (BFS)

c) Depth-First Search (DFS)

d) Prim's Algorithm

e) Kruskal's Algorithm

2.1.3 Matrix Operations:

f) Matrix Multiplication

g) Sparse Matrix-Vector Multiplication (SpMV)

IV. Machine Learning and Data Processing Algorithms:

h) K-means Clustering

2.2 Literature Review:

Each student will review existing research on HBM, PIM, and the specific algorithm assigned to them.

2.3 Algorithm Implementation:

Students will implement their assigned algorithm in a compatible programming language (e.g., C++, Python) if not already available.

2.4 Simulation Setup:

Students will set up the PIMSimulator to run their algorithms, configuring necessary parameters and optimizing the code to leverage PIM features.

2.5 Performance Analysis:

Students will run simulations to collect data on execution time, power consumption, and other relevant metrics.

2.6 Comparison:

Compare the performance of the algorithm on HBM-PIM with traditional memory architectures.

2.7 Report and Presentation:

Each student will compile their findings into a detailed report and present their results to the class.

References

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[2] Neural oscillations – interpreting eeg frequency bands. https://imotions.com/blog/learning/best-practice/neural-oscillations/.

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[4] Marin C, Vilas D, Langdon C, Alobid I, López-Chacón M, Haehner A, Hummel T, and Mullol J. Olfactory dysfunction in neurodegenerative diseases. In *Curr Allergy Asthma Rep*, volume 18, 2018 Jun 15.

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[6] T.T.K. Munia and S. Aviyente. Time-frequency based phase-amplitude coupling measure for neuronal oscillations. In *Scientific Reports 9, 12441*, 27 August 2019.

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[8] Cécilia Tremblay and Johannes Frasnelli. Olfactory and Trigeminal Systems Interact in the Periphery. *Chemical Senses*, 43(8):611–616, 07 2018.