technische universität dortmund

computer science 12

Bachelor/Master Thesis

Variable Node Size Trees in Racetrack Memory

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Recently, non-volatile memories (NVMs) have risen in popularity as competitors to the conventional memory technologies such as SRAM or DRAM. Due to its lower cost per bit and lower energy consumption, while having comparable access latencies, they have become viable as an alternative.

One such memory is racetrack memory (RTM). It features a low cost and energy consumption as well as a high integration density. One drawback of RTM is an increase in latencies due to shifts needed in response to the access patterns. A basic unit of an RTM consists of a magnetic nanowire and one ore multiple port(s). The nanowire is divided by domain walls and magnetized to represent either a 0 or a 1 in these domains. To read a domain, the nanowire needs to be shifted so the domain to read is above the port. These shifts introduce latency overhead that increases with the distance the nanowire needs to be shifted.

RTM therefore has optimization potential by manipulating the way data is stored in memory. By choosing in what order data is stored in memory, the access patterns can be influenced to reduce the overall distance the nanowire needs to be shifted to access the data. Once concrete application where such the data placement was optimized for RTM is decision trees [2]. By choosing the order in which nodes are placed, the distance the nanowire needs to be shifted can be significantly reduced, increasing performance.

[2] optimizes the placement of nodes of decision trees in RTM using an algorithm which solves a special intance of the O.L.O. problem for rooted trees [1]. Using the probabilities of each node, the algorithm optimizes the placement of the nodes to the optimal distances between nodes. However, the solution to the O.L.O. is based on the assumption that all consecutive nodes are the same distance apart. Depending on the application, this might not be true. For example, some tree datastructures have a variable node size, such as adaptive radix trees (ART) [3]. In these instances, the solution for the O.L.O. might not be optimal with regard to the shift distance.

In this thesis,[1] the student first should study the existing solutions for the O.L.O. problem as well as its existing application on tree-based structures [1, 2]. Afterwards, the solutions of the O.L.O. problem should be analyzed with regard to the influence of omitting the assumption that all elements are the same distance apart. Once a sufficient understanding of the impact has been gained, changes to the solutions should be made and implemented. These changes should then be evaluated compared to the existing solutions as well as naive baselines on real-world tree examples and hardware.

Required Skills:

- Knowledgeable of C and C++ programming.
- Willing to do theoretical analysis of a problem.

Acquired Skills after the thesis:

- Knowledge about modern memory technologies.
- Theoretical analysis of a problem.

References

[1] D. Adolphson and T. C. Hu. "Optimal Linear Ordering". In: *SIAM Journal on Applied Mathematics* 25.3 (1973), pp. 403–423. DOI: 10.1137/0125042. eprint: https://doi.org/10.1137/0125042.

[2] Christian Hakert et al. "BLOwing Trees to the Ground: Layout Optimization of Decision Trees on Racetrack Memory". In: *58th ACM/IEEE Design Automation Conference, DAC 2021, San Francisco, CA, USA, December 5-9, 2021*. IEEE, 2021, pp. 1111–1116. DOI: 10.1109/DAC18074.2021.9586167.

[3] Viktor Leis, Alfons Kemper, and Thomas Neumann. "The adaptive radix tree: ARTful indexing for main-memory databases". In: *29th IEEE International Conference on Data Engineering, ICDE 2013, Brisbane, Australia, April 8-12, 2013*. Ed. by Christian S. Jensen, Christopher M. Jermaine, and Xiaofang Zhou. IEEE Computer Society, 2013, pp. 38–49. DOI: 10.1109/ICDE.2013.6544812.

[1] Other suggestions and related topics are also welcome. Please do not hesitate to make an appointment.