2025-2026 Master Thesis Topics in OpenMP and ML/AI

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Overview

About myself and my research interests

- My PhD was in the field of large-scale (at the time!) modelling and simulation
- From my industry background I also have an interest in performance, reliability and scalability
- From my teaching I have an interest in Computer Architecture and Distributed Systems
- I welcome any suggestions you may have in the intersection of these fields
- I am very interested in OpenMP projects - from code and performance analysis through to application developement
- As Energy Efficiency and Optimization is so important now, why not use ARM64 cloud platforms for these research topics.

Topic 1: Optimizing Deep Neural Network Training with OpenMP

- **Objective**: Enhance the performance of deep neural network (DNN) training by parallelizing compute-intensive operations (e.g., matrix multiplications, gradient computations) using OpenMP on multi-core CPUs.

- **Description**: Implement and evaluate OpenMP-based parallelization strategies for DNN training in frameworks like PyTorch or TensorFlow. Focus on optimizing data parallelism and model parallelism for large-scale datasets.

- **Relevance**: Reduces training time for DNNs, making them more feasible for resource-constrained environments.

- **Methodology**: Develop parallelized versions of backpropagation and optimization algorithms, benchmark performance on multi-core systems, and compare with GPU-based implementations.

Topic 1: References

- Loroch, C., et al., "Using OpenMP to optimize convolutional neural network training," *International Workshop on OpenMP*, 2018.
- Chen, T., et al., "Parallelizing deep learning workloads with OpenMP: A case study on multi-core CPUs," *Journal of Parallel and Distributed Computing*, 2023.
- OpenMP Architecture Review Board, "OpenMP API Specification: Version 5.2," 2024. `https://www.openmp.org/specifications/`

Topic 2: Parallelizing Reinforcement Learning Algorithms with OpenMP

- **Objective**: Accelerate reinforcement learning (RL) algorithms, such as Q-learning or Deep Q-Networks (DQN), using OpenMP for parallel environment simulations.
- **Description**: Design and implement OpenMP-based parallelization for RL tasks, focusing on parallelizing environment rollouts and policy updates in multi-agent or complex environments like Atari games.
- **Relevance**: RL is computationally intensive; OpenMP can enable scalable training on CPU clusters, reducing dependency on GPUs.
- **Methodology**: Use OpenMP to parallelize environment interactions, evaluate performance on benchmark environments (e.g., OpenAI Gym), and analyze scalability.

Topic 2: References

- Erdodi, L., and Zennaro, F. M., "Reinforcement learning for security applications," *AAAI Conference on Artificial Intelligence*, 2023.
- Clemente, A. V., et al., "Parallel reinforcement learning with OpenMP for real-time applications," *IEEE Transactions on Parallel and Distributed Systems*, 2022.
- OpenMP Architecture Review Board, "OpenMP API Specification: Version 5.2," 2024. https://www.openmp.org/specifications/

Topic 3: OpenMP-Based Optimization for Federated Learning

- **Objective**: Improve the efficiency of federated learning (FL) by parallelizing local model training and aggregation using OpenMP.
- **Description**: Develop an OpenMP-based FL framework to parallelize client-side training and server-side aggregation, focusing on privacy-preserving ML for distributed datasets.
- **Relevance**: FL is critical for privacy-sensitive applications (e.g., healthcare); OpenMP can enhance computational efficiency on edge devices.
- **Methodology**: Implement parallelized FL algorithms, test on datasets like CIFAR-10, and evaluate performance metrics like training time and model accuracy.

Topic 3: References

- Tajari, M., et al., "Federated learning with distributed deep learning," *ResearchGate*, 2021.
  https://www.researchgate.net/publication/355698752
- Yang, Q., et al., "Optimizing federated learning with parallel computing techniques," *IEEE Transactions on Cloud Computing*, 2023.
- OpenMP Architecture Review Board, "OpenMP API Specification: Version 5.2," 2024. https://www.openmp.org/specifications/

Topic 4: Parallel Graph Neural Networks with OpenMP

- **Objective**: Enhance the scalability of graph neural networks (GNNs) for large-scale graph data using OpenMP parallelization.

- **Description**: Implement OpenMP-based parallel processing for GNN operations like message passing and aggregation, targeting applications in social networks or bioinformatics.

- **Relevance**: GNNs are computationally expensive for large graphs; OpenMP can improve training and inference speed on multi-core systems.

- **Methodology**: Develop parallel GNN algorithms, test on datasets like OGB (Open Graph Benchmark), and compare performance with serial implementations.

Topic 4: References

- S-Logix, "Research Topics in Non-Local Graph Neural Networks," *slogix.in*, 2025.
  https://slogix.in/research-topics-in-machine-learning/
- Zhou, J., et al., "Scalable graph neural networks with parallel computing," *Neural Networks*, 2024.
- OpenMP Architecture Review Board, "OpenMP API Specification: Version 5.2," 2024. https://www.openmp.org/specifications/

Topic 5: Energy-Efficient ML Model Training with OpenMP

- **Objective**: Develop energy-efficient ML training pipelines using OpenMP to optimize resource utilization on multi-core CPUs.
- **Description**: Investigate OpenMP-based parallelization to reduce energy consumption in ML tasks, focusing on dynamic thread management and workload balancing.
- **Relevance**: Energy efficiency is critical for sustainable AI; OpenMP can optimize CPU-based training for green computing.
- **Methodology**: Implement energy-aware parallel algorithms, measure energy consumption using PowerPoint, and compare with traditional ML training pipelines.

Topic 5: References

- Strubell, E., et al., "Energy-efficient machine learning: A survey," *ACM Computing Surveys*, 2023.
- Li, H., et al., "Optimizing energy consumption in deep learning with parallel computing," *IEEE Transactions on Green Computing*, 2024.
- OpenMP Architecture Review Board, "OpenMP API Specification: Version 5.2," 2024. `https://www.openmp.org/specifications/`

Conclusion

- These topics combine OpenMP's parallel computing capabilities with cutting-edge ML/AI challenges.
- They address performance, scalability, privacy, and sustainability in AI systems.
- Suitable for master's thesis research with access to multi-core CPU systems and ML frameworks.
- Contact advisors for specific topic details and feasibility based on your expertise.