ViT-Based End-to-End Particle Reconstruction for CMS Experiment

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About Me

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Why Machine Learning for Science

I am particularly interested in applying to the Machine Learning for Science organization for this year's GSoC program as I am passionate about their projects and the impact they have on the community. Through my research, I have found that ML4Sci has an impressive record of contributing to the field of CMS experiments, which aligns perfectly with my career goals. In particular, I was caught on interest by the project of using Vision transformers for classification of high energy particles, which demonstrated their commitment to achieve competitive results using transformers instead of prevailing CNNs. I am also drawn to ML4Sci's open-source culture, which I strongly believe in. I appreciate the transparency and collaboration that comes with open-source projects, and I am excited to contribute to ML4Sci's efforts. In terms of my skills and experience, I have a relevant understanding of training a model on a large dataset and evaluating its performance on a variety of metrics .With the exercises provided by the ML4Sci's page, I went through and tried out the basic implementation of Transformer model for the classification of electron and photon datasets which gave me some insights on how my working on this project will be like and the goals it is directed towards. I believe the experience that I would receive through working on this project with my mentors would be an excellent opportunity for personal and professional growth. I am eager to learn from the experienced mentors, collaborate with other contributors, and make meaningful contributions to their projects.

Goals

The primary objectives of this project are as follows:

1. Develop a transformer-based algorithm for the classification of high-energy particles.
2. Train the model on a large dataset and evaluate its performance on a variety of metrics, including accuracy, precision, and recall.
3. Implement the model on GPUs and benchmark its performance in terms of training time and inference speed.

Benefits to Community

The field of computer vision has undergone a revolution with the development of Vision Transformers (ViT) that use the mechanism of self-attention to achieve outstanding results. However, their application to particle reconstruction in the CMS Experiment has yet to be explored. Hence this project offers a unique opportunity to contribute to the scientific community by developing and reaching towards a state-of-the-art model that could improve the accuracy of particle reconstruction and classification.

Methodology

To achieve the project's objective, I would break it down into smaller tasks and set achievable goals. I would use TensorFlow and PyTorch, and other necessary libraries for implementing the model, and I would use Git for version control.

The project will be implemented in the following tasks:

- Literature Review: A comprehensive literature review of the existing literature on Vision Transformers and their applications in computer vision.
- Data Collection and Preprocessing: The CMS dataset will be used for the training and evaluation of the model. The data will be preprocessed to remove noise and irrelevant information.
- Model Development: The transformer-based model will be developed and optimized to achieve the best results. The model will be trained using supervised learning with a cross-entropy loss function.
- Performance Evaluation: The performance of the model will be evaluated on a variety of metrics, including accuracy, precision, and recall. The results will be compared with existing state-of-the-art methods.
- GPU Implementation and Benchmarking: The model will be implemented on GPUs, and its performance will be benchmarked in terms of training time and inference speed.

Timeline

The project will be completed in two phases:

Phase 1 (175 hours):

- Literature Review: 25 hours
- Data Collection and Preprocessing: 25 hours
- Model Development: 75 hours
- Performance Evaluation: 50 hours

Phase 2 (175 hours):

- GPU Implementation and Benchmarking: 100 hours
- Documentation and Report Writing: 50 hours
- Code Review and Refinement: 25 hours

Total: 350 hours

Weekly timeline:

Week 1-2: Literature Review

- Study existing literature on Vision Transformers and their applications in computer vision
- Identify the best practices and techniques for developing transformer-based models for particle classification

Week 3-4: Data Collection and Preprocessing

- Collect and preprocess the CMS dataset for particle classification
- Explore the dataset and perform data cleaning, normalization, and augmentation

Week 5-7: Model Development

- Develop a transformer-based model for particle classification

- Experiment with different model architectures, hyperparameters, and loss functions
- Train the model on the preprocessed dataset using supervised learning

Week 8-9: Performance Evaluation

- Evaluate the performance of the model on a variety of metrics, including accuracy, precision, and recall
- Compare the results with existing state-of-the-art methods
- Identify the areas of improvement and fine-tune the model accordingly

Week 10-12: GPU Implementation and Benchmarking

- Implement the model on GPUs and optimize it for performance
- Benchmark the performance of the model in terms of training time and inference speed on different GPUs
- Fine-tune the model and optimize the hyperparameters for better performance

Week 13-14: Documentation and Report Writing

- Document the entire development process, including data preprocessing, model architecture, training, evaluation, and benchmarking
- Write a comprehensive report summarizing the findings, challenges, and future directions of the project
- Submit the report and the source code to the supervisor for review and feedback

Week 15-16: Code Review and Refinement

- Address the feedback and comments provided by the supervisor
- Refine the code, improve the performance, and fix any issues or bugs
- Make sure that the code is clean, efficient, and well-documented.

Approach

Overall, the approach I plan to take for this project is to follow a structured and iterative process that involves literature review, data preprocessing, model development, performance evaluation, GPU implementation, and documentation. I will use tools and techniques for deep learning, such as PyTorch, TensorFlow, and CUDA, to develop an efficient and accurate model for particle classification, some of which I came to know about while performing exercises provided by ML4Sci. I will also collaborate closely with the supervisor to ensure that the project aligns with the goals and requirements of the CMS experiment.

Conclusion

This project aims to develop a transformer-based algorithm for the classification of high-energy particles and benchmark its performance on GPUs. I am confident that my skills and experience in computer vision and deep learning will enable me to deliver high-quality results. I am excited about the prospect of contributing to this exciting project and look forward to hearing from you.

Thank you for considering my proposal.