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Proposal : Enhancing the DeepLense Pipeline with State-of-the-Art Vision Transformers for Improved Dark Matter Substructure Identification

Synopsis

This proposal aims to enhance the DeepLense pipeline by incorporating state-of-the-art (hybrid) vision transformers for efficient and improved dark matter substructure identification in strong gravitational lensing images. Building upon the existing work from the previous year, I plan to explore, compare, and develop various vision transformer models tailored to the DeepLense data and the lenstronomy library. This will extend the existing functionalities and ultimately provide a more accurate understanding of the underlying nature of dark matter, while augmenting the performance of DeepLense algorithms.

Insights from Tasks

1. Pre-trained models followed by fine-tuning often provide better performance than training from scratch.

2. Advanced CNN architectures (ResNet50) and vision transformers (Google's ViT-base-16) achieve comparable ROC-AUC scores, indicating their potential for improving dark matter substructure identification.

3. Exploring hybrid vision transformers (LambdaNet), which combine both CNNs and vision transformers, can be a promising direction.

4. Hyperparameter tuning can be time-consuming and challenging, especially for transformer based models.

5. Data size is crucial, as vision transformers require large amounts of data to perform well due to their reliance on self-attention mechanisms that process entire images at once.

Project Timeline

The project will be completed within 175 hours, with specific goals and milestones detailed below:

1. Community binding and Data prepartion (10 hours): Familiarize myself with the team, tools, libraries, and data. Ensure that the data is properly prepared for future analysis.

   - Milestone 0 (10 hours): Complete data preprocessing and gain access to all tools/authorizations.

2. Investigation and Review (15 hours): Review methods used in past and research additional state-of-the-art hybrid transformer architectures, such as LambdaNet and MViT, which might be suitable for the DeepLense data.

3. Model Selection and Customization (25 hours): Select multiple promising hybrid transformer model based on the research and customize it for the DeepLense pipeline.

   - Milestone 1 (50 hours): Complete the selection and customization of the hybrid vision transformer model.

4. Model Implementation and Integration (30 hours): Implement the selected and customized hybrid vision transformer model and integrate it with the DeepLense pipeline.

   - Milestone 2 (80 hours): Successfully integrate the selected vision transformer models with the DeepLense pipeline.

5. Model Training and Evaluation (70 hours): Train the model on strong lensing simulation data and evaluate its performance using ROC-AUC Scores (both OVO and OVR) on the test data.

   - Milestone 3 (110 hours): Complete initial model training and evaluation.
   - Milestone 4 (160 hours): Fine-tune the model, perform final evaluation and model comparsion

6. Documentation and Presentation (25 hours): Write comprehensive documentation on the implemented model, its integration with the DeepLense pipeline, and the achieved results.

Significance

By improving the accuracy of dark matter substructure identification, this project will advance the scientific community's understanding of the nature of dark matter. The open-source nature of the project will enable researchers and organizations worldwide to benefit from the enhanced pipeline, promoting further discoveries and development in the field of astrophysics. The project will also serve as a case study for the adoption of state-of-the-art hybrid vision transformers in scientific research, potentially inspiring new applications across across various domains.

Also, by extending the DeepLense pipeline with state-of-the-art hybrid vision transformers, we will be able to offer a more efficient and accurate tool for researchers studying dark matter substructure identification, ultimately contributing to a deeper understanding of the universe and its underlying phenomena.

Why me

I hold a Bachelor's degree in Statistics and Computer Science (University of Illinois, Urbana Champaign) and a Master's degree in Biostatistics with a specialization in Data Science (Harvard). I am currently a PhD offer holder at multiple universities' PhD programs in Data Science/ Computer Science, and I will commit to one of them (NYU, UVA, UCSD) to embark on my next academic journey. I have published multiple research papers in reputable journals, showcasing my ability to conduct thorough research and present findings effectively. My past experience with PyTorch, Keras, Python, combined with my strong machine learning research background and passion for astrophysics, make me well-suited for this project.

In addition to my academic achievements, I have been interested in contributing to open-source projects, including the development of an open-source automatic differentiation library. My work in these projects demonstrates my ability to collaborate with diverse teams and develop high-quality, well-documented software.

By incorporating advanced vision transformers into the DeepLense pipeline, I am confident in enhancing the identification of dark matter substructures, furthering our understanding of the universe, and showcasing the capabilities of advanced machine learning models in scientific research.