LHCb Detector Simulation using Machine Learning

Progress Update

Zhihua Liang

LHCb Group Meeting

26-05-2024

Project Recap

- Developing machine learning models to predict charge and center of gravity of the current signal in the LHCb detector
- Goal: Streamline the simulation process and avoid re-running TCoDe simulation for each event

Dataset and Preprocessing

- Dataset: "Totaleventdata.dat" containing particle simulations in the LHCb detector
- Data conversion from raw format to HDF5 format for efficient handling
- Custom dataset class (LHCbDataset) and data loader developed for preprocessing

Model Development

- Implemented and evaluated several machine learning models:
  - Multi-Layer Perceptron (MLP)
  - Edge-Activated Adaptive Function Network (EAAFN)
- Models take particle's impact and exit points and energy as input
- Predict charge and center of gravity

Experimental Results

- Conducted experiments with different model architectures, precision settings, and techniques
- Key findings:
  - Double precision significantly improves performance, especially for charge prediction
  - EAAFN models, particularly deep architectures, outperform MLP models
  - Adding Gaussian noise slightly improves charge prediction results

Best-Performing Model

- Deep EAAFN
- Charge Prediction:
  - R2 Score: 0.9944
  - Relative MAE: 0.0125
- Center of Gravity Prediction:
  - R2 Score: 0.9368
  - Relative MAE: 0.0357

Conclusion

- Machine learning models, especially EAAFN, effectively predict charge and center of gravity in LHCb detector simulation
- Deep EAAFN models with double precision and Gaussian noise provide the best performance
- Promising approach for streamlining the simulation process and reducing computational requirements

Next Steps

Integration into LHCb simulation framework

Fine-tuning and optimization of models

Scalability assessment for larger datasets and real-world scenario

Documentation and knowledge sharing

Road Map

- Integrate trained models into LHCb simulation framework
- Leverage model predictions to streamline the overall simulation process
- Collaborate with the computing team to ensure seamless integration
- Validate the integrated simulation pipeline and assess performance gains

Acknowledgments

- Thank all team members for their valuable contributions and support
- Special thanks to Angelo for providing the dataset.

Thank You

Questions and Discussion

Zhihua Liang

zhihua.liang@ca.infn.it