Advancing Particle Track Imaging with Machine Learning Applications for Modern Modular Bubble Chamber

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Introduction & Background:

The Standard Model offers a unified framework delving into subatomic particle interactions including the strong force binding quarks, employing methods like particle scattering to validate predictions. Simultaneously, experimental prediction methods for these cross-section calculations strive to optimize machine learning for interpreting intricate particle track patterns in Modern Modular Bubble Chamber (MMBC) photos, tailored for DUNE. Additionally, we can explore the Raspberry Pi 4 Model B's economical potential for external-input image retrieval; while triggering captures and initial reconstructions, offline reconstruction mainly drives the process, with an MNist assessment due to camera limitations gauging its effectiveness..

Purpose:

Employing computer-based triggering, the MMBC's event selection will be enhanced, outperforming previous methods involving trained calculators. By harnessing image learning with the Raspberry Pi, a robust, self-contained single-board computer, the potential to replace costly camera equipment in a cold vacuum environment emerges, presenting a cost-effective solution for a proof of concept device while advancing particle track accuracy and reconstruction efficiency.

Methods & Procedure:

- Configure the Raspberry Pi 4 Model B as a trigger and evaluate its suitability as a data acquisition system.
- Investigate the capabilities of the single circuit board in the realm of machine learning, to determine its potential.
- Utilize the MNist database repository to assess the training duration on the Raspberry Pi.
- Conduct a test of machine learning by employing the software to gather camera information from the MMBC.
- Evaluate the accuracy and efficiency of the trained model.

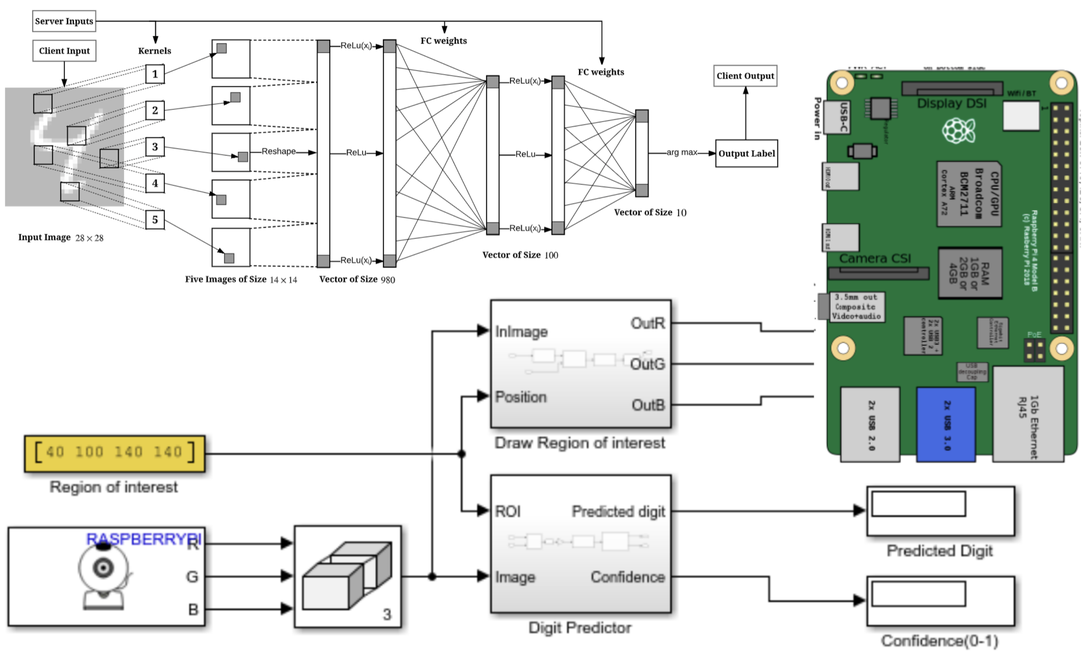
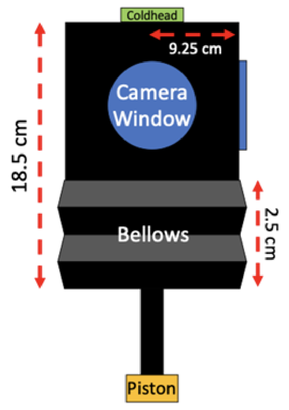


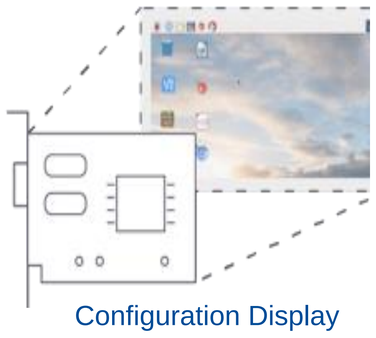
Fig 1: Distributed Learning Framework for Raspberry Pi 4 Model B

(Ulutas, A.; AI/ML CNN Model Pathway)



Proposed MMBC Pressure Vessel Prototype

Pressure Vessel Vacuum Device in MiniBooNE Hall for MMBC Development

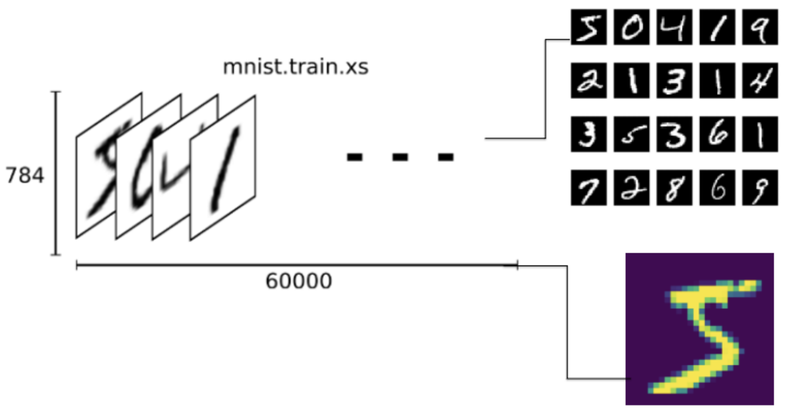


Configuration Display

Image Generated from Raspberry Pi Camera Module V2-8

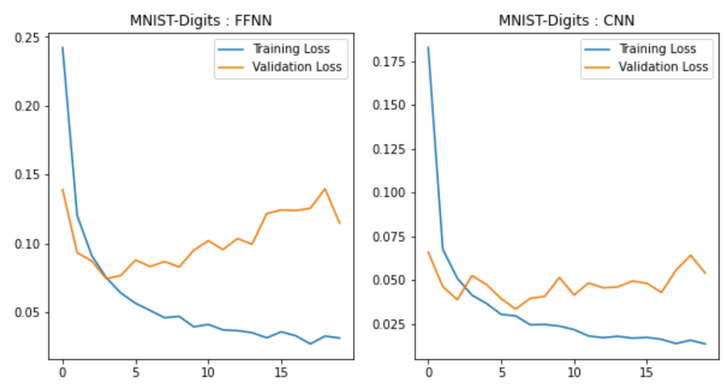
Results & Analysis:

Fig 2: Testing and Training Mnist Dataset



An MNist dataset can train and test machine learning capabilities for identifying handwritten digits exploring algorithms and techniques and evaluating its performance on a test set.

Fig 3: Training and Validation Loss & Accuracy Plots of MNist Recognition



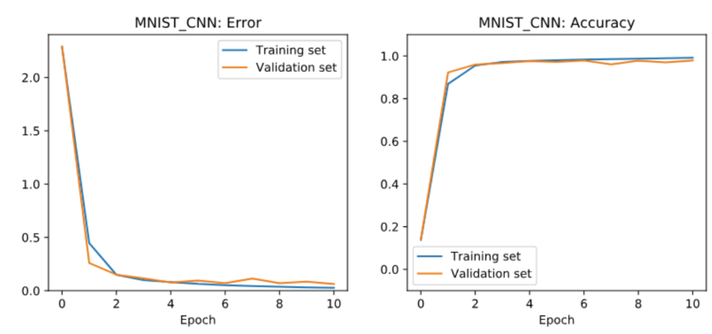
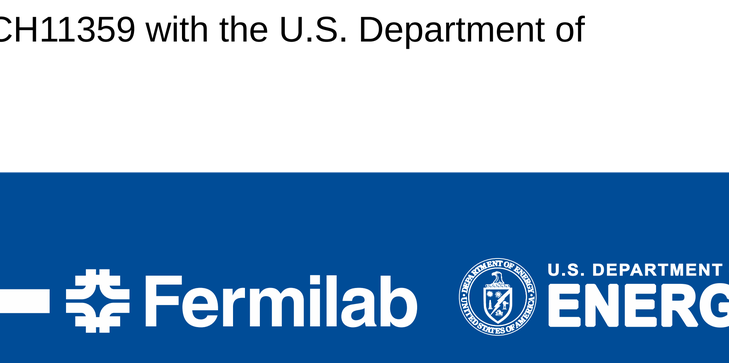


Fig 4: Test of ML Computational Efficiency



After running the MNist model, there is potential for efficient and accurate model pruning techniques for the Pi, opening up new possibilities for resource-constrained parameters.

Conclusion & Future Research:

Leveraging machine learning processing on a single circuit board device can greatly optimize MMBC imaging for neutrino cross-section research. In the future, attaching a camera for simulation processing can increase efficiency.

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