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Investigating machine learning solutions for a 256 channel TCSPC camera with sub-70 ps single photon timing per channel at data rates > 10 Gbps.

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The development of a Time Correlated Single Photon Counting (TCSPC) camera with 256 channels has enabled several applications where single photon sensitivity is crucial, such as LiDAR, Fluorescent Lifetime IMaging (FLIM) and Quantum Information Systems. The microchannel plate-based Multi-Anode Photo-Multiplier Tube (MAPMT) is a 16 × 16 array of 1.656 mm pitch pixels with an active anode area of 26.5 × 26.5 mm^2. Each pixel can time single photons with an accuracy of 60 ps rms at a maximum photon rate of 480 KHz.
The timing electronics are capable of measuring 120 Mcps, producing huge volumes of data for processing, in the region of 10 Gbps per detector. Limitations in algorithmic data analysis techniques are critical for this application so in this paper we demonstrate a machine learning (ML) model which can determine the photon event coordinates with the objective of processing each one photon per ˜10 µs. The model applies calibrations for the detector and electronics such as amplitude walk, and charge measurement and channel to channel threshold variation. Optimisation of the model is detailed within the paper, including training hyperparameters, the clustering of coincident events and compression of the model through pruning techniques.
The ML model is trained and tested on a simulation of the microchannel plate (MCP) PMT with timing electronics configured for use as a TCSPC camera, utilising charge sharing techniques to further improve the spatial resolution of the detector. We assess the performance of this approach compared to algorithmic approaches and introduce statistical reasoning of the robustness of the model. Further objectives of the research are to test the model on detector data, allowing assessment on the variance of accuracy between simulated and real data.

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