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Submanifold Sparse Convolutional Networks for Sparse, Locally Dense Particle Image Analysis

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From a breakthrough revolution, Deep Learning (DL) has grown to become a de-facto standard technique in the fields of artificial intelligence and computer vision. In particular Convolutional Neural Networks (CNNs) are shown to be a powerful DL technique to extract physics features from images: They were successfully applied to the data reconstruction and analysis of Liquid Argon Time Projection Chambers (LArTPC), a class of particle imaging detectors which records the trajectory of charged particles in either 2D or 3D volumetric data with a breathtaking resolution ($\sim 3\text{mm}/\text{pixel}$). The CNNs apply a chain of matrix multiplications and additions, and can be massively parallelized on many-core systems such as GPUs when applied on image data analysis. Yet a unique feature of LArTPC data challenges traditional CNN algorithms: it is locally dense (no gap in a particle trajectory) but generally sparse. A typical 2D LArTPC image has less than 1% of pixels occupied with non-zero value. This makes standard CNNs with dense matrix operations very inefficient. Submanifold sparse convolutional networks (SSCN) have been proposed to address exactly this class of sparsity challenges by keeping the same level of sparsity throughout the network. We demonstrate their strong performance on some of our data reconstruction tasks which include 3D semantic segmentation for particle identification at the pixel-level. They outperform a standard, dense CNN in an accuracy metric with substantially less computations. SSCN can address the problem of computing resource scalability for 3D DL-based data reconstruction chain R&D for LArTPC detectors.

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