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# Parallel CPU and GPU-based connected component algorithms for event building for hybrid pixel detectors

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Parallel CPU and GPU-based connected component algorithms for event building for hybrid pixel detectors

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Abstract:
Introducing the Timepix3 [6] hybrid pixel detector significantly improved particle tracking with its high spatial and temporal resolution. However, its high pixel-hit rate posed challenges for processing software [4]. This will be further enhanced by multidetector Timepix3 setups and increased hit rate capability of the next generation Timepix4 detectors [3]. Evidently, storing all pixel hits individually and processing them "offline" can be inefficient and space-intensive for such high data rates. Before being able to characterize individual particle events seen in the sensor, the pixel hits partly unsorted in both time and across the matrix must be first grouped into temporally and spatially coincident groups called "clusters". While further track analysis usually requires simple, computationally inexpensive, and fast calculations or look-up tables, the current bottleneck is fast clustering.
In the present work, we explore parallel approaches to building the clusters online, which offers the potential for online data reduction and filtering. First, we attempt to use multiple CPU cores for real-time clustering. Despite the temporal interdependence of the clusters, we achieved data throughput scaling with the number of available cores. However, due to high CPU occupancy, we faced load-balancing issues between processing and I/O, occasionally resulting in data loss.
Additionally, we propose a new highly parallel connected component labeling algorithm for pseudo-real-time processing based on a union-find data structure [2] with path compression [7]. In contrast to similar parallel connected component algorithms [1][5], our approach exploits the zero suppression data encoding.
Experimentally, the GPU parallel implementation outperformed existing CPU-based algorithms, achieving throughputs of 60 to 80 million hits per second excluding I/O, more than 20× speedup compared to a similar existing single-threaded CPU implementation (see Figures 1 & 2 attached). Moreover, offloading clustering to the GPU freed the CPU for I/O handling, minimizing the data transfer loss.
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