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Study of Retina Algorithm on FPGA for Fast Tracking

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Real-time track reconstruction in high energy physics experiments at colliders running at high luminosity is very challenging for trigger systems. To perform pattern-recognition and track fitting, artificial Retina or Hough transformation algorithms have been introduced in the field which have usually to be implemented in the state of the art FPGA devices. In this paper we report on simulated performance of Retina in a detector configuration made of concentric detection layers with high magnetic field as well as on performance of several possible firmware implementations on a Kintex-7 FPGA.

Summary

For many high energy physics experiments, like the ones at the high luminosity LHC (HL-LHC), it becomes now unavoidable to perform precise tracking at the earliest stage of the trigger system. As an example HL-LHC is expected to deliver a peak luminosity of up to 5×1034 Hz/cm2, with an average of about 140 overlapping proton-proton (pp) collisions per 25 ns bunch crossing. Such busy background increases unmanageable data volume and extremely challenges the physics-analysis capabilities of trigger system if no additional information could be provided at the earliest trigger level. High-resolution spatial information from tracking detectors is becoming mandatory, at the cost of adding a few microseconds latency, to maintain the physics performance. However, real-time reconstruction of charged particle trajectories requires major combinatorics and massive parallel pattern recognition within limited latency. In this case, the development of new algorithms able to run on hardware is desirable. A pattern-recognition algorithm named "artificial retina", inspired from neurobiology of the vision mechanism in mammals, has been recently introduced. This retina algorithm can extract specific track features from a multilayer detector data flow, map the hits with stored patterns and identify the most possible candidate among them. Its aim is to take advantage of the parallelism and decrease the number of stored patterns so that latency and hardware resources can be reduced.

In a real HEP detector, the geometry of the detector and the topology of the events are quite complicated. To start our investigation, we have used a tracker detector model made of parallel tracking planes in the space without magnetic field. To validate the algorithm and measure its performances, hardware prototypes have been designed. Our first Retina algorithm online processor embeds a Floating-Point Operator IP core and a bus standard for on-chip communication AXI, providing rapidly and easily floating-point operators that can be targeted to any of the latest Xilinx FPGA platforms. We have also implemented retina on FPGA using fixed-point data representation as well as Look-up Table (LUT) in which function values are pre-calculated at certain sample points and stored in memory. Then we have adapted our Retina algorithm to another tracker detector geometry often met at particle colliders: a multi-layer cylindrical geometry in presence of a high magnetic field. Due to the magnetic field effects, charged particle trajectories in this detector are bent and treated as partial arc. A first retina modelling of track reconstruction under the situation of particles in a magnetic field with six barrel layers tracker has been built. Some simulation results such as the momentum thresholds of particles for retina are under discussion.

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