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FPGA Implementation of an Artificial Neural Network for Subatomic Physics Experiment Particles Recognition

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CMOS Pixel Sensors have been used in subatomic physics experiments for tracking devices. There are large quantities of hits generated by particles that coming from the detector beam background impacting tracking efficiency and reducing system bandwidth. We propose to design a CMOS pixel sensor with on-chip Artificial Neural Network (ANN) to tag and remove hits generated by background particles based on different features of these clusters. In this paper, we show and analyze the feasibility result of this idea by FPGA device implementation of an ANN.

Summary

CMOS Pixel Sensors (CPS) are monolithic devices which integrate signal sensing and readout electronics in the same substrate. Due to the attractive balance among granularity, read-out speed, radiation tolerance and power dissipation, CPS have been used in some subatomic physics experiments for high performance particles charge detection and tracking purposes.

In the vertex detector of International Linear Collider (ILC) experiment, there are large quantities of e+/e- particles which come from the beam background impacting parameter resolution and tracking efficiency of the detector and reducing the system bandwidth.

Background particles have low momentum (10-100MeV/c) compared with particles which come from subatomic physics experiments, and with the effect of magnetic field in the detector, resulting in that background particles produce large incident angles on CMOS pixel sensors. Due to different incident angles, associated cluster shape and charge distribution are different between clusters generated by particles coming from subatomic physics experiment and those generated by background particles. We propose to classify these particles on the basis of cluster shape and charge distribution into two categories by using an on-chip Artificial Neural Network (ANN). This paper aims to use an existing CPS and a FPGA device to validate the scheme of reconstructing of incident angles by ANN.

The incident angle scan has been performed with Sr-90 β source and a CMOS pixel sensor prototype, MIMOSA18. There is a readout system for CMOS pixel sensors to collect the cluster data. Our development platform for the ANN with the pixel data preprocessing is implemented by using a Xilinx Artix development board.

We have acquired the pixel sensor data under different incident angles for the further data processing. Following structures have been implemented in FPGA device: a pixel data pre-processing, a cluster search algorithm, a main component analysis and the ANN structure. We propose use these features to present a cluster, maximum and minimum standard deviation that present the shape of a cluster, seed charge and total charge that present the charge distribution of a cluster. In the training procedure, we use input parameters of ANN and incident angle to train the connection weight by TMVA (Root) software. In the regression procedure, we use input parameters and connections weight to calculate corresponding incident angles in the FPGA device.

We show the recognition result of ANN implemented in FPGA device, it is basically the same as software (TMVA) regression results reported in this paper. We verify the feasibility of hardware ANN to reconstruct incident angles, detailed describe the algorithm of cluster search and the structure of ANN. In the future, we

need to develop the accuracy of recognition result, optimize connections weight and structure of ANN, design an efficient algorithm for the cluster search which can be integrated with pixel matrix in a sensor device.

Author: ZHAO, Ruiguang (university of strasbourg)

Co-authors: BESSON, Auguste Guillaume (Institut Pluridisciplinaire Hubert Curien (FR)); GUO HU, Christine (Centre National de la Recherche Scientifique (FR)); PEREZ PEREZ, Luis Alejandro (Institut Pluridisciplinaire Hubert Curien (FR)); Mr JAASKELAINEN, Kimmo (Institut Pluridisciplinaire Hubert Curien); GOFFE, mathieu (IPHC CNRS); Prof. HU, Yann (Institut Pluridisciplinaire Hubert Curien); WINTER, Marc (Centre National de la Recherche Scientifique (FR))

Presenter: ZHAO, Ruiguang (university of strasbourg)

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