The stand-alone optimized post-processing algorithms for plasma diagnostics

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The stand-alone optimized post-processing algorithms for hot tokamak plasma diagnostics

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The article concerns the implementation of a library developed in the framework of providing fast optimized tools for plasma diagnostics for the GEM detector based acquisition system designated for WEST tokamak. The set of functions is intended to provide methods of analyzing the data in the system on the PC side in so-called post-processing. The primary objective of the implementation is to provide a benchmarking tool for evaluating hardware platforms for plasma post-processing algorithms for the deployment at WEST tokamak. Other purpose is to provide a tool for fast real-time processing of data so far conducted in MATLAB after the experiment. The ultimate goal of implementation and research is to provide optimized hardware and software solutions for the developed system. The splitting algorithm has been implemented and optimized in the library functions. The optimization techniques are presented and computation time of different approaches is shown. Further implementation in a stand-alone C++ library is considered due to promising results.

Keywords: plasma diagnostics; GEM system; data processing, optimization; data acquisition systems; fast histogramming

1. Introduction

The primary objective of the research is to meet the requirements for providing means of efficient and fast methods of plasma diagnostics and the detection of impurities in the hot tokamak plasma. The requirements led to rapid development of GEM detector based soft X-ray acquisition systems, second revision of those is planned to be deployed in WEST, Cadarache this year.

The development of second revision of the system for hot tokamak plasma diagnostics resulted in the increase of throughput and resolution in the new revision of the system [1-4]. The modified, second version has improved parameters over first revision of the system, intensively exploited in such tokamaks as JET [4, 5]. Moreover, new functionalities concerning data analysis, data transmission and methods of acquisition could be introduced to the system and evaluated [6-11].

The advancements in the systems can be seen in figures 1 and 2. The scheme of first revision of the system is depicted in figure 1 [6].

In the first revision of the system data was collected, stored and then processed offline by MATLAB in a post-processing phase, after the experiment [6-11]. Depending on the type of acquisition, a subset of following operations was performed on the PC:

- Splitting overlapping signals from the raw data and identifying events
- Sorting, grouping and merging of signals from different boards
- Conducting event and cluster recognition in special and temporal vicinity
- Calculating histograms for analyzed data

To accelerate computations of data analysis and to minimize the time required for data analysis, MATLAB mex compiled C++ functions have been implemented to provide the presented functionalities [11,12]. Due feasibility study with subsequent implementation were performed to assess the achievable throughput at which the data can be post-processed [12-15].

2. The implementation of a library

The development of electronics allowed partial implementing of algorithms, so far performed offline after the experiment in an online system. Moreover, some computations are extremely resource consuming on an FPGA side so an alternative hardware solution for a selected data analysis algorithms is sought for.

To meet the needs for the deployment at a tokamak, the stand-alone C++ library of functions was implemented to allow splitting the overlapping signals on-line. The information on algorithm can be found in [6]. The principle of operation of an algorithm is shown in figure

Fig. 1. The block diagram of first revision of the multichannel measurement system [6].
The set of stand-alone functions is a part of framework and a testing environment for utilizing coprocessors, parallelism and optimization techniques for maximizing throughput in a deployed system. The hereby presented implementation is a first step to provide a testing environment for the developed diagnostics algorithms.

In order to refrain from using MATLAB which is imposing constraints limiting throughput of data processing, a library of functions was implemented, designated to be run on Linux on the working target system. The overview of the new revision of the system to be deployed in WEST, CEA, Cadarache is presented in figure 3.

The library was included in a reference program that will be used to evaluate which of the devices will be chosen for the specific computations in the system. The set of algorithms and the possible and currently-evaluated devices is presented in figure 4.

To implement a library, there the splitting function had to be rewritten and optimized for evaluation purposes. In order to simulate the data from the FPGA, there was written a program to change the available data format from MATLAB-compatible experiment with the previous revision of the system into a binary data format compliant with the one acquired from the new revision of the system. The shift of data representation allowed lessening the storage needed for extracted the data sets.

2. The optimization

With the evaluation of the algorithm, several conclusions have been drawn. First of all, the performance of the algorithm severely depends on the memory access pattern and overall memory accesses. For instance, the computation time was reduced almost twice when the access pattern into the data was changed. The impact of memory access pattern is illustrated in figure 5 and in figure 6.
The transposition of selected dimensions of array led to accessing data in space and temporal vicinity, thereby maximizing the reusability of data in cache.

The algorithms are memory bound so the fastest speedup can be maximized by minimizing the number of memory access. The comparison of computation times is given in table 1. One can observe significant speedup over MATLAB script and mex functions. For evaluation the 3-D array of 40x128x20000 samples was chosen from the collected data during the experiment for the first revision of the system – the “SH-151113-FeBi-1” data. Moreover, the mex function was compiled for Windows environment, whereas the stand-alone library was compiled with the Gnu Compiler Collection as it is designated to be run under Linux.

Table 1. Execution times of selection of implementations of splitting algorithm – the MATLAB function, the mex function and stand-alone library function

<table>
<thead>
<tr>
<th>Serial data acquisition</th>
<th>MATLAB script</th>
<th>mex function</th>
<th>stand-alone function</th>
</tr>
</thead>
<tbody>
<tr>
<td>execution time [s]</td>
<td>16.58</td>
<td>0.79</td>
<td>0.45</td>
</tr>
</tbody>
</table>

The library is designated to be used in deployment of new revision of the system for the WEST tokamak. The stand-alone functions will be used for further optimization and benchmarking regarding parallelization of the code using selected devices – Intel Xeon Multi-Core CPU, Intel Xeon Phi ManyCore MIC, NVIDIA GPU.

3. Conclusions

The further optimization of plasma diagnostics post-processing algorithms has been reached and a reference library has been implemented for further performance tests. The stand-alone functions will be used for further optimization and benchmarking regarding parallelization of the code using CPU and PCIe coprocessors for the deployed system. The functions will be used in the target system to be deployed this year in WEST tokamak, Cadarache, France.

It is planned in future work to implement other functions of the processing pipeline, so far optimized in mex functions. The following analysis is planned to be implemented in stand-alone library: The calculation of fast histograms for different detector topologies, grouping sorting and merging the data from different boards.

Moreover, different approaches regarding the processing of the data will be evaluated to choose the optimal solution for the new version of the system. The scalability is also planned to be investigated.

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