EUROFUSION WP15ER-CP(16) 15715

R. D. Krawczyk et al.

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

Preprint of Paper to be submitted for publication in Proceedings of 29th Symposium on Fusion Technology (SOFT 2016)

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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

Rafał Dominik Krawczyk[a], Paweł Linczuk[a], Krzysztof Poźniak[a], Piotr Kolasiński[a], Andrzej Wojeński[a], Grzegorz Kasprowicz[a], Ryszard Romaniuk[a], Wojciech Zabołotny[a], Paweł Zienkiewicz[a], Tomasz Czarski[b], Maryna Chernyshova[b]

[a]*Institute of Electronics Systems, Warsaw University of Technology, 15/19 Nowowiejska Street, 00-665 Warsaw, Poland*
[b]*Institute of Plasma Physics and Laser Microsynthesis, 23 Hery Street, 01-497 Warsaw, Poland*

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 it 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

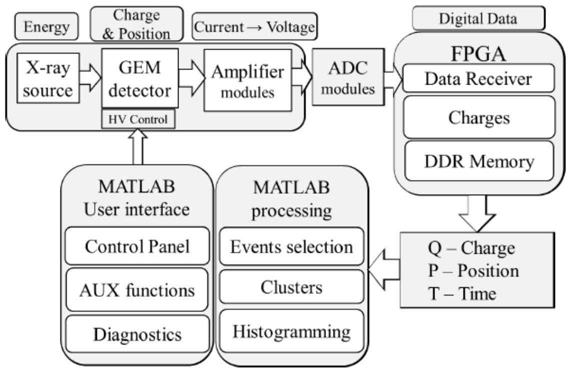

Fig. 1. The block diagram of first revision of the multichannel measurement system [6].

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

author's email: rkrawczy@stud.elka.pw.edu.pl

[5].

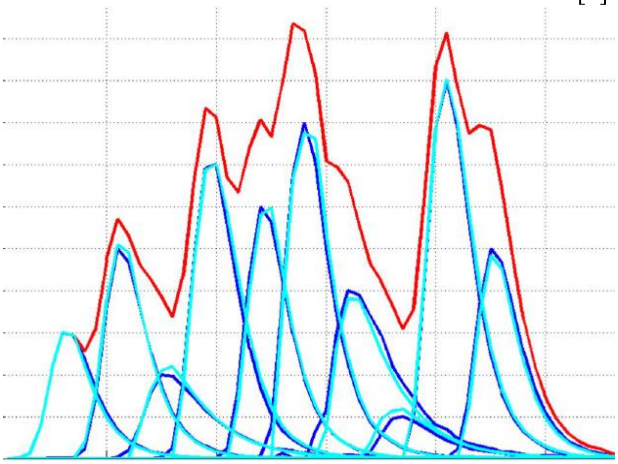

Figure 2. The principle of operation of splitting algorithm – dark blue are the original pulses, red is their sum – the input of algorithm, light blue is their reconstruction [6].

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.

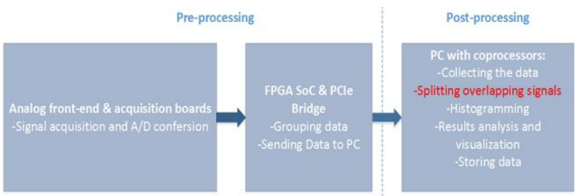

Fig. 3. The data processing schema in the new version of GEM detector based acquisition system for the deployment in WEST – the implemented library is marked in red.

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.

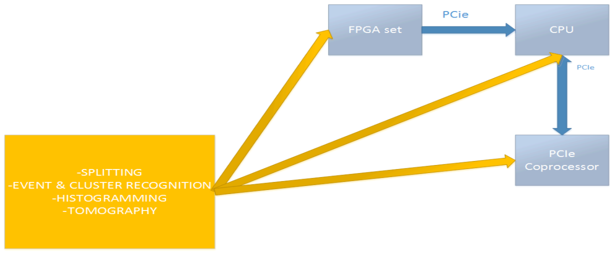

Fig. 4. The visualization of possibilities of implementations of the selection of plasma diagnostics algorithms. Algorithms are marked in yellow, hardware and communication interfaces - in blue.

Having the testing data set, the library of functions responsible for calculating auxiliary data necessary for splitting function and the splitting function has been implemented and optimized.

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.

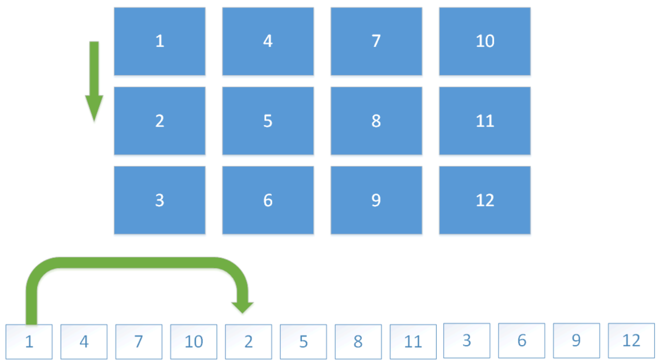

Figure 5. The inefficient memory access pattern. The 2-d array and how its layout in memory looks like along with accessing next element in an array.

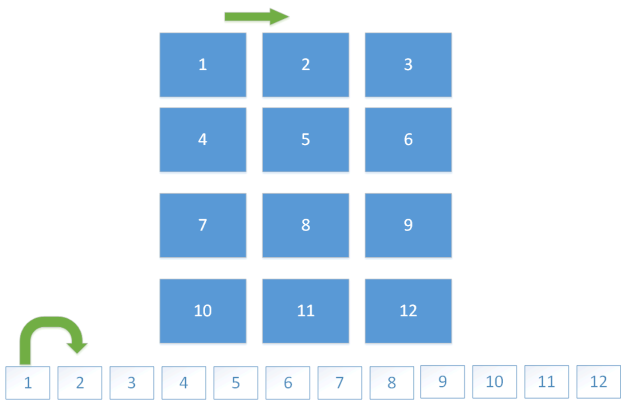

Figure 6. The efficient, stride-like memory access pattern in a transposed array. Note that subsequent elements in memory are accessed.

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

Serial data acquisition	**MATLAB script**	**mex function**	**stand-alone function**
execution time [s]	16,58	0,79	0,45

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.

Acknowledgments

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission. This scientific work was partly supported by Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the year 2015 allocated for the realization of the international co-financed project.

References

[1] Poźniak, K.T., Byszuk, A., Chernyshova, M., Czarski, T., Kasprowicz, G.H., Kolasiński, P., Krawczyk, R.D., Linczuk, M. G., Romaniuk, R., Wojeński, A., Zienkiewicz and P., Zabołotny, W. " Elektroniczne systemy pomiarowe do diagnostyki gorącej plazmy tokamakowe,j" Elektronika - konstrukcje, technologie, zastosowania doi:10.15199/13.2016.2.1, (2016)

[2] Chernyshova, M., Czarski, T., Dominik, W., Jakubowska, K., Rzadkiewicz, J., Scholz, M., Pozniak, K.T., Kasprowicz, G.H., Zabolotny, W., "Development of GEM gas detectors for X-ray crystal spectrometry," Journal of Instrumentation doi:10.1088/1748-0221/9/03/C03003, (2014).

[3] Mazon, D. , Chernyshova, M., Jiolat, G., Czarski, T., Malard, P., Kowalska-Strzeciwilk, E., Jablonski, S., Figacz, W., Zagorski, R., Kubkowska, M., Kasprowicz, G., Pozniak, K., Zabolotny, W., Larroque, S., Verger, J.-M., O'Mullane, M., Mlynar, J., Byszuk, A., and Wojenski, A., "Design of soft-X-ray tomographic system in WEST using GEM detectors," Fusion Engineering and Design doi:10.1016/j.fusengdes.2015.03.052 (2015).

[4] Chernyshova, M., Czarski, T., Malinowski, K., Kowalska-Strzęciwilk, E., Poźniak, K., Kasprowicz, G., Zabołotny, W., Wojeński, A., Kolasiński, P., Mazon, D. and Malard, P., "Conceptual design and development of GEM based detecting system for tomographic tungsten focused transport monitoring", JINST 10 (2015) 10022

[5] Rzadkiewicz, J., Dominik, W., Scholz, M., Chernyshova, M., Czarski, T., Czyrkowski, H., Dabrowski, R., Jakubowska, K.,Karpinski, L., Kasprowicz, G., Kierzkowski, K., Pozniak, K., Salapa, Z., Zabolotny, W., Blanchard, P.,Tyrrell S., Zastrow, K.-D., "Design of T-GEM detectors for X-ray diagnostics on JET", Nuclear Instruments and Methods in Physics Research A 720, (2013) 36

[6] Czarski, T., Pozniak, K.T., Chernyshova, M., Malinowski, K., Kasprowicz, G.H., Kolasinski, P., Krawczyk, R.D., Wojenski, A. and Zabolotny, W., "On line separation of overlapped signals from multi-time photons for the GEM based detection system", Proc. SPIE 9662 doi:10.1117/12.2205804 (2015).

[7] Czarski, T., Chernyshova, M., Poźniak, K.T., Kasprowicz, G. H., Zabołotny, W., Kolasiński, P., Krawczyk, R. D., Wojeński, A. and Zienkiewicz, P. "Serial data acquisition for the X-ray plasma diagnostics with selected GEM detector structures," Journal of Instrumentation doi:10.1088/1748-0221/10/10/P10013 (2015).

[8] Kolasinski, P.,Pozniak, K.T., Czarski, T., Linczuk, M., Byszuk, A., Chernyshova, M., Juszczyk, B., Kasprowicz,G.H., Wojenski A., Zabolotny W., Zienkiewicz P., Mazon, D., Malard P., Herrmann, A.,

Vezinet, D. and ASDEX Upgrade Team, "Serial Data Acquisition for GEM-2D detector," Proc.SPIE 9290 doi:10.1117/12.2075911 (2014).

[9] Kolasinski, P.,Pozniak, K.T., Czarski, T., Byszuk, A., Chernyshova, A., Kasprowicz, G.H., Krawczyk, R.D.,Wojenski, A. and Zabolotny, W., " Fast Data Transmission from Serial Data Acquisition for the GEM Detector System," Proc. SPIE 9662 doi: 10.1117/12.2205264 (2015).

[10] Czarski T., Chernyshova M., Malinowski K., Pozniak K.T.,Kasprowicz G., Kolasinski P., Krawczyk, R. D., Wojenski A., and Zabolotny W.,"The cluster charge identification in the GEM detector for fusion plasma imaging by soft X-ray diagnostics" doi:10.1063/1.4961559 (2016)

[11] Krawczyk, R. D., Czarski, T., Kolasinski, P., Linczuk, P., Pozniak, K.T, Chernyshova, M., Kasprowicz, G., Wojeński, A., Zabolotny, W. , Zienkiewicz, P. "The development of algorithms for the deployment of new version of GEM detector based acquisition system", proc SPIE vol. 10031, under printing (2016)

[12] Krawczyk, R. D., Czarski, T., Kolasinski, P., Pozniak, K. T., Linczuk, M., Byszuk, A., Chernyshova. M., Juszczyk, B., Kasprowicz, G., Wojenski, A. and Zabolotny, W., "On algorithmic optimization of histogramming functions for GEM systems," Proc. SPIE 9662 doi:10.1117/12.2205444 (2015).

[13] Krawczyk, R. D., Linczuk, P., Kolasinski, P., Wojenski, A., Kasprowicz, G., Pozniak, K. Romaniuk, R., Zabolotny, W.,Zienkiewicz, P., "The speedup analysis in GEM detector based acquisition system algorithms with CPU and PCIe cards", Acta Physica Polonica B Proceedings Supplement, DOI:10.5506/APhysPolBSupp.9.257 (2016)

[14] Krawczyk, R. D., Czarski, T., Kolasinski, P., Pozniak, K. T., Linczuk, M., Byszuk,A., Chernyshova, M., Juszczyk, B., Kasprowicz, G.H., Wojenski, A. and Zabolotny, W., " Introducing parallelism to histogramming functions for GEM systems," Proc. SPIE 9662 doi:10.1117/12.2205447 (2015).

[15] Linczuk, P., Krawczyk, R. D., Poźniak, K. T., Kasprowicz, G.H., Chernyshova, M. and Czarski,T., "Algorithm for fast event parameters estimation on GEM acquired data," proc SPIE vol. 10031, under printing (2016).