ASIPP EAST

Development of Local-Imaging and High-Speed Visible Diagnostics for Real-Time Plasma Boundary Reconstruction of EAST

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ABSTRACT : Fast plasma boundary reconstruction is usually used for real-time control of tokamak plasma. In EAST experiment, the time consuming for boundary reconstruction should be within 1ms to meet the need of real-time control. Fast evolution of cameras in recent years has made them promising tools for diagnostics of Tokamak. The solution presented in this paper consists of a prototype of high-speed visible image acquisition and processing system (HVIAPs) dedicated for EAST shape and position control. The optical system can be applied in high-speed camera diagnostics, due to its large relative aperture (1:1.5). Three visible cameras, which are mounted outside the EAST at a distance of 3.4 m, are all controlled via optical fibers over QSFP+ (40 Gbit/s data rates) interfaces. As each new frame comes in from the camera, it is stored in main memory of the server by direct memory access (DMA). In order to meet the needs of real-time storage, the acquired image data is cached in main memory and written to Solid state drive (SSD) after one shot discharged. 16 frames per second are chosen from the cached data and sent to another server for displaying by using website. GPUs and FPGAs are typically used as accelerators and co-processors in addition to a CPUs. Such a heterogeneous computing system can combine the advantages of its individual components. The offline image process results are compared to offline EFIT, with an average error of 1.5 cm. The total processing time for one frame is less than 0.2 ms.

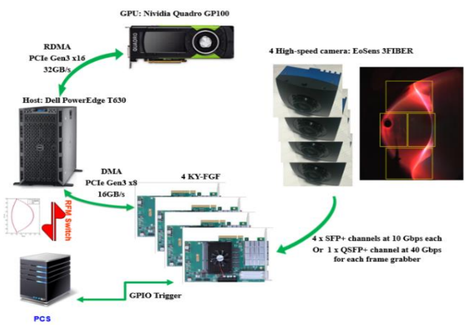
Introduction

- ◆ Low plasma current result in weak magnetic signals.
- ◆ Large distance to the magnetic pick-up coils also result in weak magnetic signals.
- ◆ Large scale of transients of the flux distribution make magnetic reconstruction problematic.
- ◆ The camera data do not suffer from drift.
- ◆ The camera data contains much information: plasma boundary, filament structures, ELMs, and hot spots of PFCs, etc.

Image acquisition and processing hardware & software

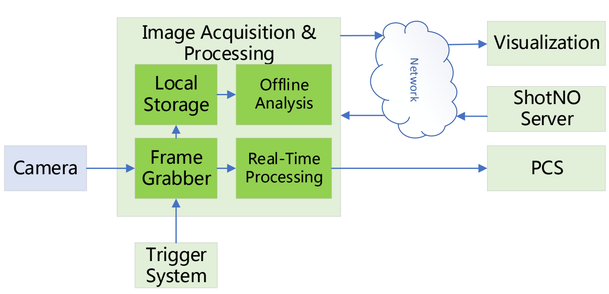
Hardware:

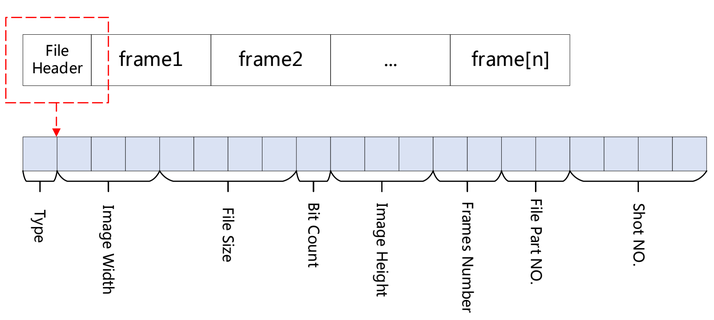
- ◆ 4 high-speed cameras, 4 dedicated frame grabber boards based on FPGA
- ◆ 1 NVIDIA Quadro GP100
- ◆ 1 host server
- ◆ 1 DAQ machine



Software:

- ◆ KAYA grabber API functions were used in IAPs to provide high speed acquisition rate and low-latency data transform by DMA memory copy.
- ◆ The sample time of all grabbers is synchronized by PCS hardware signal.
- ◆ The acquired image data is cached in main memory and written to disk in special format after one shot discharged.
- ◆ Operating system of DAQ machine has been patched Preempt-RT to improve the performance of real-time.
- ◆ This image acquisition and processing system can acquire 10,000 FPS with 8bit@320*210.

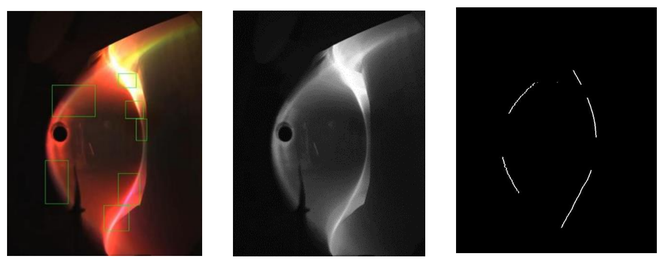




Edge detection algorithm

Online:

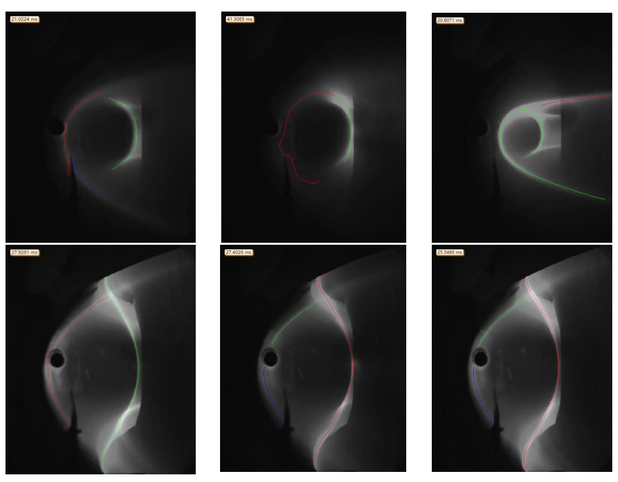
- ◆ Step1: Appoint Regions Of Interest (ROIs)
- ◆ Step2: Three-channel color digital images to gray image
- ◆ Step3: Plasma edge extraction (algorithm based on global contrast)



Offline:

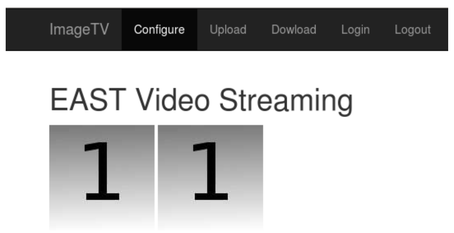
- ◆ Step1: Mean filtering
- ◆ Step2: Threshold segmentation
- ◆ Step3: Morphological filtering
- ◆ Step4: Second-order gradient global edge extraction based on Gauss algorithm

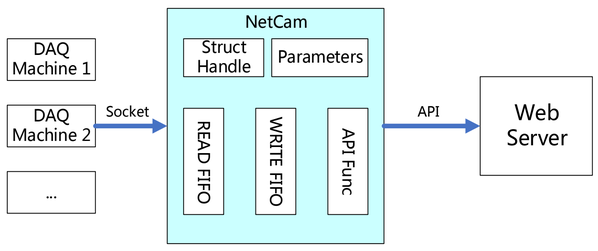
$$G(x,y,s) = \frac{1}{2ps^2} exp(-\frac{x^2+y^2}{2s^2})$$



GUI

- ◆ Host server connect with DAQ machines through TCP/IP
- ◆ A web server were built on host server and can receive 16 frames per second from every DAQ machine
- ◆ A module which named NetCam was used in web server to manage received image data
- ◆ User can uses the GUI from browser





Conclusions

- ◆ Through Optics, plasma shape reconstruction can be achieved in real-time
- ◆ By reducing the number of reconstruction points, the minimum reconstruction time consuming can be less than 60 microseconds
- ◆ Have potential for faster single point reconstruction, like for VDE
- ◆ FOV of single optical path is not enough for the whole plasma imaging
- ◆ The brightness of plasma imaging region varies greatly, and the single optical path can not meet the demand

Acknowledgements

This work is supported by the National Natural Science Foundation of China (Grant No:11775262).
Development of plasma current fiber current sensor for EAST superconducting tokamak device

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