THE ATLAS BARREL ALIGNMENT READOUT SYSTEM

R. Hart, H. v/d Graaf, H. Groenstege, NIKHEF, Amsterdam, Netherlands
F. Bauer, CEA-IRFU, Saclay, France
P.F. Giraud, CERN, Geneva, Switzerland

Abstract

The readout system of the barrel alignment system of the ATLAS muon spectrometer is described. It consists of 5812 optical channels, each built up of a camera, a light source, a coded mask and a lens. Three layers of multiplexing are applied controlled and monitored by eight PCs, each one equipped with a frame-grabber, which grabs the pictures to be analyzed. Analyzed results are stored into a database for off-line corrections of the muon tracks. Controlling the multiplexers and frame-grabber is performed by a dedicated server *Rasdim*. PVSS uses the server and is been integrated into the overall Finite State Machine (FSM) of the ATLAS detector. The communication between the server and PVSS is performed by DIM, a distributed management system, providing a transparent inter-process communication layer. A full cycle to read and analyze all channels takes about ten minutes.

INTRODUCTION

The main part of the muon spectrometer of the ATLAS detector (an LHC experiment) consists of about 1200 MDT (Monitored Drift Tube) chambers. The alignment system provides the position of the chambers such that an accuracy of 50 µm can be achieved on the track sagitta, which is needed for the muon track reconstruction. The MDT chambers are divided into two groups: the *barrel* part (surrounding ATLAS and parallel to the beam) and the *endcap* at both ends (perpendicular to the beam). Both parts have approximately the same amount of chambers. The readout system of the barrel is handled in this article. The endcap alignment system is based on a different technology and not covered. After an overview of the hardware, the control part is described.

GENERAL DESCRIPTION

An alignment channel is defined as an optical line with a lens, a coded mask, a light-source (RasLed) and a sensor (RasCam). The sensor is a camera without a lens. Figure 1 shows the basic setup. The channels are connected to a multiplexer, which is controlled by a PC by means of its serial port. The images are obtained (grabbed) by a frame-grabber. The system is also known by its acronym Rasnik (Red Alignment System NIKHEF).

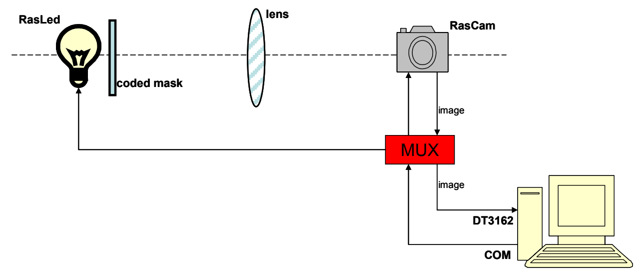

Figure 1: Rasnik channel readout.

The light source (RasLed) is a small PCB (Printed Circuit Board 42x50 mm) containing nine infra-red LEDs and when switched on it illuminates the coded mask. The camera (RasCam) is a similar PCB with a CMOS sensor and array size of 392 times 292 pixels. Figure 2 shows a picture of a RasLed (left) and a RasCam (right).

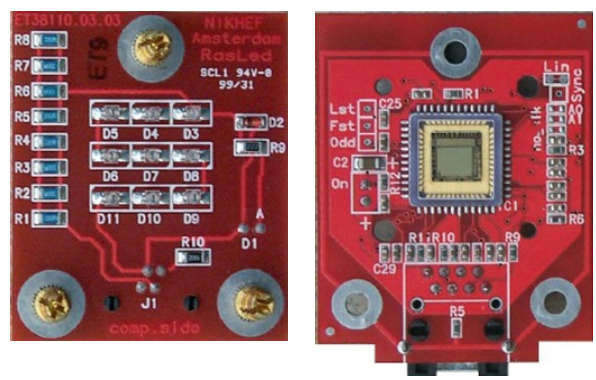

Figure 2: RasLed and RasCam.

The coded mask is the heart of the Rasnik system. It is closely mounted to the RasLed. Two types of masks are applied: the *Rasnik* type, a chessboard pattern with encoded edges and the *Spot* type, a mask with four holes (spots). The Rasnik type was the original type when Rasnik was developed (for more details see [1] and [2]). Figure 3 shows an example of the Rasnik type (left) and the Spot type (right). In total 5296 channels are of type Rasnik (91.2%) and 516 channels are of type Spot (8.8%). The squares on the mask as applied in ATLAS have a size of 120 µm. Rasnik and Spot images are treated by two distinct analysis modules (available as dynamic link library .dll).

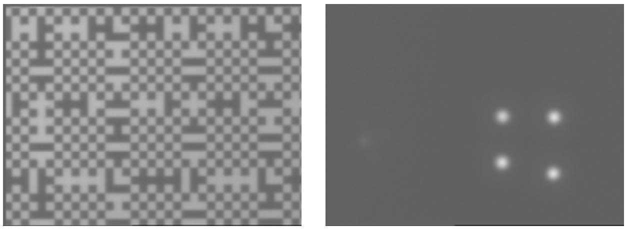

Figure 3: Rasnik and Spot mask.

The alignment system measures the position and deformation of the MDT chambers [3]. The channels are mounted on the chambers and are connected to the readout system by a three-layer multiplex scheme. At the lowest level a device called RasMux is applied. The devices are mounted on the chambers and have a fan-out of eight RasCams and RasLeds. The intermediate level consists of a so called MasterMux, with a fan-out of sixteen. These are mounted at strategic locations in the ATLAS cavern. In USA15 (ATLAS counting room) eight TopMuxes are mounted in one rack, which are connected by 100 m long cables to a maximum of eight MasterMuxes in the cavern. The scheme is drawn in Fig. 4.

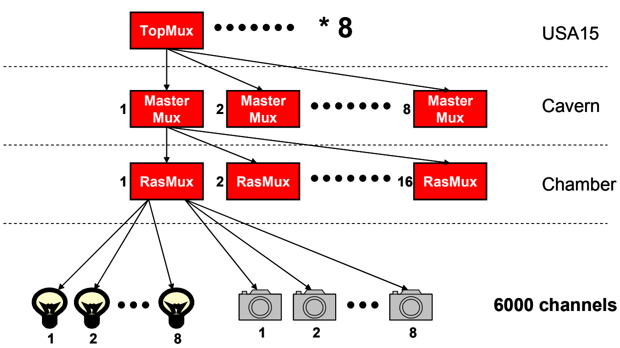

Figure 4: Multiplexer scheme.

The alignment devices as used in the cavern are radiation tolerant as defined by the ATLAS environment conditions. Each TopMux is interfaced by a 19’’ rack-mountable PC (W-XP) by means of the serial COM port. A simple lightweight protocol is used to communicate between the PC and the embedded micro-processor of the TopMux. Besides switching on and off the RasLeds and RasCams, a variety of settings, like the gain and exposure time, are optionally set by means of the I^2C bus. Whenever the sensor and corresponding light-source is switched on, the video-signal is connected to the frame-grabber of the PC. The Data-Translation DT3162 PCI card is used for this purpose. In total eight PCs are used to monitor and control the TopMuxes. Two additional PCs are used respectively as super-visor (holding the FSM part) and as spare. The PCs and TopMuxes are mounted together in one 19’’ rack in USA15.

CONTROLS

A dedicated software module is developed with Visual C++, to control both the serial port as well as the frame-grabber. Its name is *Rasdim*, an acronym made of Rasnik and DIM (DIM is the client/server communication protocol). After start-up and initialization of the serial port and frame-grabber, the server waits for a command. Rasdim controls the serial port and frame-grabber on the PC it is running on. Figure 5 shows the flow of a typical Rasdim command.

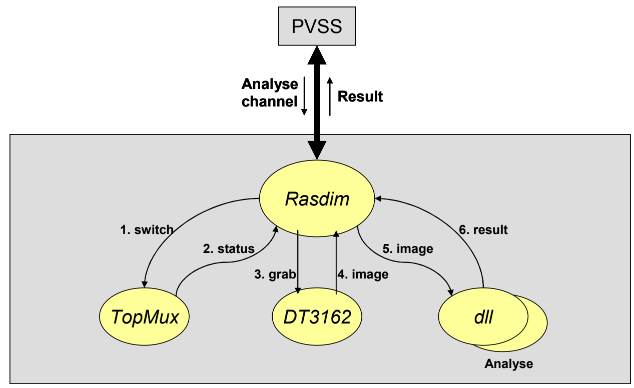

Figure 5: Rasdim control flow.

The following steps are performed after receiving a command (including the necessary parameters):

1. Switch the desired led and camera on. Optionally any I^2C setting is set as well.
2. If the previous step was unsuccessful, return the status to the client, otherwise continue.
3. Issue the grab image command.
4. Grab the image.
5. Submit the image to the appropriate analysis module.
6. Fetch the result and send it to the client.

In the original setup it was possible to have *mixed-channels*, i.e. the RasCam and RasLed were behind a different PC/TopMux combination. It made the system complex and slow. The only benefit was a simpler cabling scheme. The concept of mixed-channels was abandoned. At the moment it is mandatory that the RasCam and corresponding RasLed are connected to the same PC.

Among the parameters of the command, one can find the addressing variables of the led and camera, the I^2C parameters and last but not least the parameters belonging to this channel for the analysis module. In total a common analyze channel command contains 114 parameters. The result sent back contains the four major identifiers (including their error margins):

1. Translation x with respect to the optical axis z
2. Translation y with respect to the optical axis z
3. Rotation angle θ_z between mask and optical sensor
4. Magnification of the optical system (or z)

PVSS II [4], a commercial SCADA (Supervisory Control and Data Acquisition) product by ETM, is chosen by CERN to be used on all LHC experiments. Typical SCADA functionality, like archiving, alarm handling and man-machine-interface are supported. Its main characteristic is the *datapoint* concept, the basic data-container of a variable which could be everything from being a simple type (integer, float, etc) or a complex type like an array, structure or reference to another datapoint. Each optical channel has a corresponding datapoint defined in the PVSS system. Besides its name, it holds the 114 parameters and the result of the last measurement. In Fig. 5 PVSS is acting as the Rasdim client.

The main task of the alignment system, supervised by PVSS, is to analyze all channels in an infinite loop as fast as possible. The results are stored into a database (CERN is using Oracle), used off-line for track reconstruction. The database contains also the configuration data, i.e. the parameters of the channels. Regenerating the datapoint structure from scratch requires connectivity to the database.

DIM (Distributed Information Management) [5] provides a lightweight platform independent communication protocol. Its use is easy and does not require any knowledge of the TCP/IP protocol. The Rasdim server handles the requests completely synchronously and makes the grabbed images available for other applications, in particular for debugging a channel. A dedicated application, known as the *PVSS00dim* manager, adds the DIM-functionality to PVSS. It takes care of the client part and holds both the command and result datapoint.

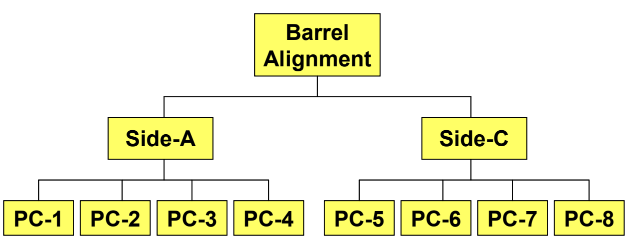

Figure 6: Barrel alignment FSM hierarchy.

The barrel alignment system is fully integrated into the ATLAS-FSM control tree and it is part of the MDT leaf which itself resides under the MUON leaf. Alignment is in general passive, i.e. no commands are implemented and only its status is relevant. The FSM structure for the barrel alignment is shown in Fig. 6. It is split into two main parts: barrel side A and side C, complying with the general partitioning of ATLAS. Each of them has four DUs (Device Units), which are actually the running PVSS projects on the alignment PCs. PC[1-4] have only channels on side A, PC[5-8] only channels on side C. On PC9, the supervisory computer, a dedicated *Watchdog* PVSS-manager is running, determining the state and status of the DUs and CUs (Control Unit) above, based on for instance the average amount of analysis errors, the ability to write to the database, etc. Figure 7 shows a snapshot of the panel as used in the ATLAS Control Room.

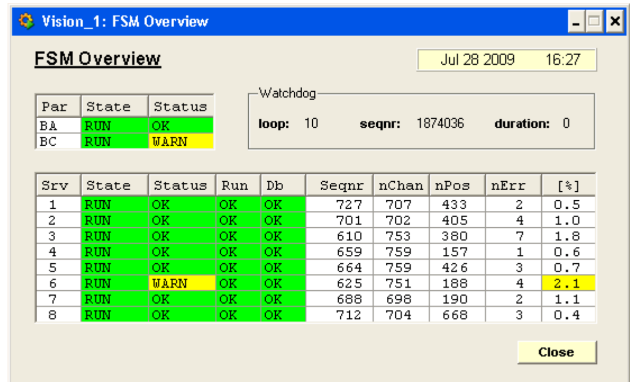

Figure 7: Barrel alignment FSM panel.

STATUS AND CONCLUSION

The first barrel alignment channel was analyzed in December 2005. The complete system however became operational in spring 2007 and has already written more than 367,000,000 entries into the database. The readout system has proved to be stable, robust and reliable.

The driver of the DT3162 frame-grabber is written in compliance with the Windows Driver Model (WDM) which implies the Rasdim server cannot be started remotely, e.g. not via remote desktop, nor as a service. In that case, the grabbing of the images fails due to a timeout, because somehow the video signal is virtually not there. As a consequence, the system has to be restarted manually, which requires physical presence in USA15.

Considering the age of the PCs and frame-grabbers, a choice of replacement has to be taken in the near future. Modern rack-mountable PCs do not support the old standard PCI boards anymore; hence a comparable frame-grabber has to be found.

REFERENCES

[1] H. Dekker et al., Proceedings of the 3rd International Workshop on Accelerator Alignment, Annecy, France, 28-20 September 1993, p. 147.

[2] The Rasnik, H. Groenstege et al., ATLAS Muon Note 63 (1994).

[3] C. Guyot e.a., “The alignment system of the ATLAS barrel muon spectrometer”, ATLAS Note ATL-MUON-PUB-2008-007.

[4] PVSS II von ETM; http://www.pvss.com.

[5] DIM; http://dim.web.cern.ch/dim/.