Implementation of a complex monitoring system to track people in the ATLAS detector

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Abstract

ATLAS is one of the four large experiments at the Large Hadron Collider at CERN. The detector itself and the surrounding structures in the cavern of the experiment are accessible for people during maintenance periods. People can easily be isolated and difficult to localize in which case their safety may be compromised in this very complex environment. Therefore a dedicated system called "Finding Persons Inside ATLAS Areas" has been designed and implemented to track persons in the experimental cavern. It is based on a network of passive infrared sensors which are read out by specific front-end electronics. A complex software architecture provides active tracking of people in the cavern with the possibility to detect abnormal situations where people are possibly in danger. This paper describes the technological choices which have been made for this monitoring system and explains the implementation of the software components. This provides a tool for the operation in the control room of ATLAS to actively follow people in the cavern underground. As the system is data-driven, it can be easily adapted to other environments where similar safety problems exist.

I. INTRODUCTION

ATLAS is an experiment at the Large Hadrons Collider (LHC) at the European Organization for Nuclear Research CERN. Protons collide at an unprecedented energy of 7+7 TeV in the middle of this huge and highly complex detector (Fig 1). The ATLAS detector is 44 meter long and has a diameter of 23 meters. Its cylindrical shape is made of concentric detection layers and the outer layers are accessible to people. These spaces together with the surrounding structures of the cavern of the experiment form a complicated topology of accessible areas and confined spaces, which are used by personnel involved in the maintenance of the detector. The services like cryogenics, gas systems and high voltage supplies are a possible source of dangers and the areas, where people need to work, are often isolated.

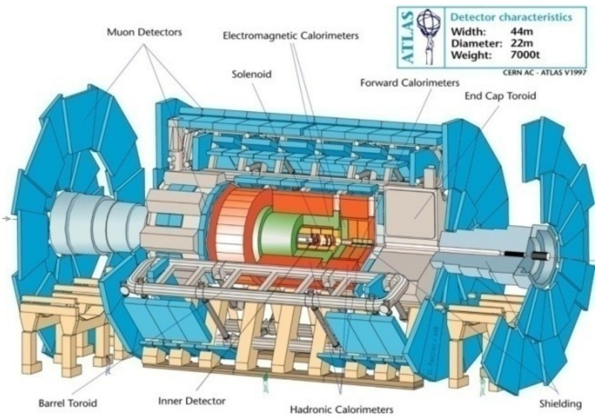

Fig. 1. Cut view of the ATLAS detector

An access system provides at any moment a list of people present in the cavern. However in case of an emergency, it can become very difficult and time consuming for the rescue team to locate a missing person in the detector areas. This is the reason why the "Finding Persons Inside ATLAS Areas" (FPIAA) system has been initiated and developed using the framework of the ATLAS Detector Control System (DCS) [1]. Its aim is to provide a detection system for people which can locate and follow persons with a fine granularity in the experimental cavern of ATLAS. This system has been designed to actively track persons even with a large number of people in the cavern. But its first goal is to follow isolated persons, a situation where it reaches its maximum of efficiency.

This paper describes the concept and the implementation of the FPIAA system for ATLAS. After a description of the hardware components in section II and the software algorithms in section III, the human interface is presented in section IV. Finally, a summary and an outlook to other possible applications are given in section V.

II. HARDWARE COMPONENTS

A first study for the FPIAA design concentrated on investigating active systems, which would be able to identify people by name. A transmitter-receiver method was studied, but all technical solutions found were either not compatible with the constraints of the environment of the experiment, or were too expensive for a large scale deployment. The study then focused on passive detection systems using as technologies ultrasonic, infrared or microwave sensors. Passive detection does not permit name identification. However in safety matter, it is not important to know who is in danger but that someone is in danger. Moreover passive detection does not require wearing a transmitter which could be forgotten or lost. After several tests [2], which took into account the constraints of a high energy physics detector like ionizing radiation, magnetic field and electromagnetic compatibility, Passive InfraRed (PIR) sensors have been chosen. This technology choice has been validated by a first pilot test in the ATLAS Toroid [3] before the full implementation.

1. *Sensors*

The PIR sensors [4] chosen for FPIAA are standard, low cost industrial components. They had to be modified to comply with the ATLAS environment: As shown in Fig. 2, a board with opto-couplers has been installed replacing the relays in order to provide the digital output signal. The opto-couplers chosen have been validated to be radiation tolerant and not sensitive to the magnetic field.

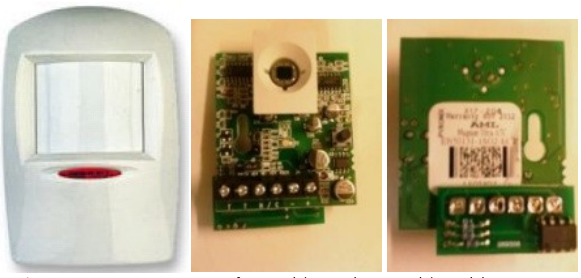

Fig. 2. PIR sensor: cover, front side and rear side with opto-couplers patched on the PCB

In total about 850 PIR sensors have been installed in the experimental cavern, covering every accessible place inside the detector and on the surrounding structures. The infrared sensitive element detects any movement of a person in its active range which covers an angle of 120 degrees and a distance of up to 10 meters. The embedded electronics provides a signal of 5 Volts to the front end electronics when a movement is detected.

2. *Front End readout electronics*

In the frame of the DCS a distributed I/O network has been installed covering the full experimental area. It is based on a dedicated electronics module called Embedded Local Monitoring Board (ELMB) [5]. This is a credit-card-sized PCB comprising a CAN controller, 64 analog inputs (16 bit resolution), 16 digital inputs and 8 digital outputs. The ELMB is widely used for control applications of the LHC experiments because of its flexible I/O capabilities and of its robustness.

Fig. 3 shows the fully assembled readout box. It contains an ELMB and its motherboard, the connectivity modules for the 16 digital inputs to read out the PIR sensors and the necessary power distribution for the sensors, 15 Volt for the PIR itself and 5 Volt to drive the drain of the opto-couplers. In addition 3 analog inputs of the ELMB are used to monitor the PIR sensor voltage supplies and the temperature in the box. Two D-Sub 9 connectors are installed on the front side of the box for the connection of the ELMB to a CAN field bus.

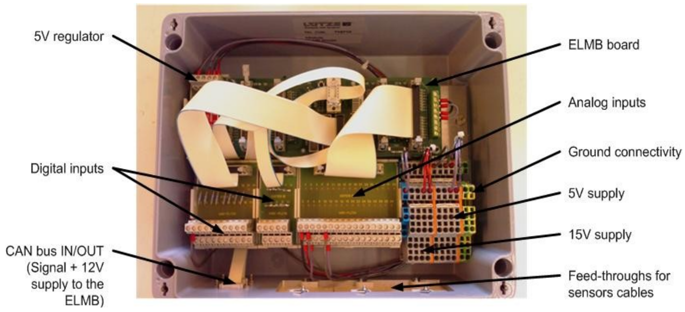

Fig. 3. Front-end readout box

Particular care has been taken in the choice of the materials used in the box to comply with the ATLAS-specific environment. All mechanical pieces are made of aluminum, which is insensitive to the magnetic field of ATLAS and all plastic materials are halogen free.

The 5 Volt for the PIR sensors are provided by a regulator installed in the box. As these cannot be operated in magnetic field, all regulators are placed outside the toroid area and the 5 Volt lines are daisy-chained from box to box.

3. *Data acquisition*

The ELMB embeds a CAN controller and the industry standard software protocol CANOpen is used to transfer the data to the front-end computer located in the underground counting room USA15 Level 1. 80 boxes are read out by 11 CAN buses, each serving a specific area of ATLAS.

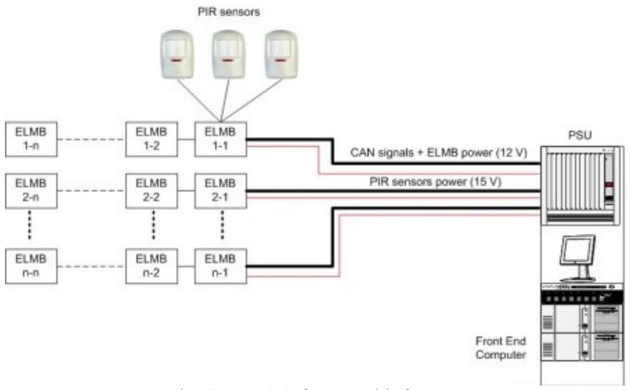

Fig. 4. FPIAA front-end infrastructure

Fig. 4 shows the layout of the front-end components. The front-end computer houses 3 PCI - CAN bus interfaces [6], each driving up to 4 CAN buses. A Power Supply Unit (PSU) equipped with 12 Volt and 15 Volt modules provides the power to the ELMB and to the PIR sensors. This PSU is also controlled and monitored by the computer via CAN bus.

The FPIAA must provide the operator in charge of safety in the control room of ATLAS with a view of all movements of people in the cavern in quasi-real time. Therefore the data acquisition design is event-driven to guarantee a real time response, i.e. each movement detected results in sending a CAN message.

III. SOFTWARE

The DCS uses a commercial, device-oriented and event-driven control software package, PVSS II [7]. The FPIAA is an application in this DCS software environment.

1. *PIR-to-cell definition*

FPIAA monitoring is based on a hierarchically organized structure in which the experimental cavern of ATLAS is divided into areas. The cavern is subdivided in 8 zones: The toroid magnet (inside the detector), the arches (on top of the detector), the Big Wheels and the structures on the four walls of the cavern.

These zones are divided into sub-zones and finally in cells, which are the lowest layer of the structure. A cell can contain several PIR sensors depending on its size and complexity. An abstraction of the hardware is made by building a logical view in software which defines this hierarchy and associates the sensor(s) to the corresponding cell (Fig. 5). The state of the cell is the combination of the state(s) of the attached sensor(s).

In total, the 850 PIR sensors have been organized in about 500 cells which cover every accessible place in the experimental cavern. A meticulous commissioning process has taken place to ensure that each PIR-to-cell matching has been done correctly.

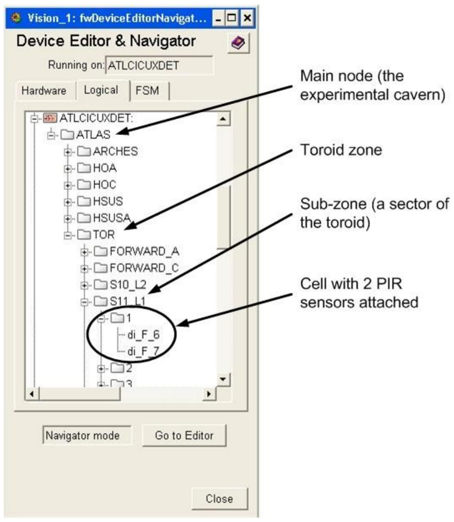

Fig. 5. Logical view, which links the software to hardware elements

2. *Active tracking of people*

FPIAA is not only a supervising tool for movements of people in the experimental cavern of ATLAS, but it also offers a tracking algorithm to generate alerts if someone "disappears" from the system. In order to perform this active tracking, each person who enters in the experimental cavern triggers a control script.

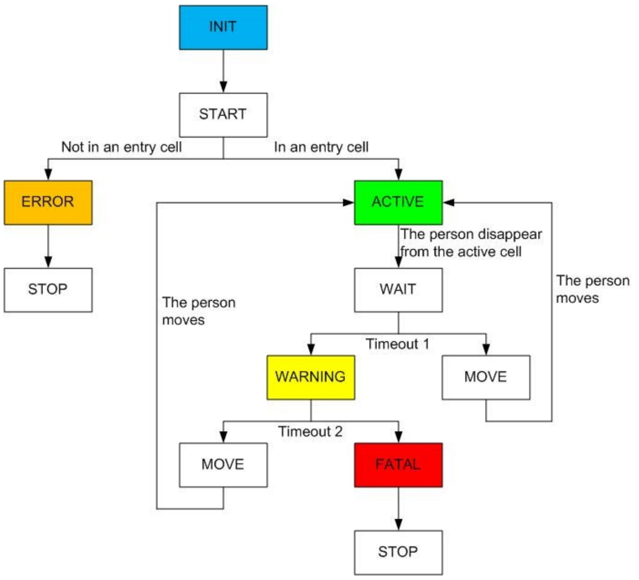

Fig. 6. Flow diagram of FPIAA tracking algorithm

Fig. 6 shows a simplified diagram of the tracking algorithm. After the initialization sequence (INIT), each person entering triggers a control loop (START), which defines a tracking case to be treated.

If the start point is not a cell which is declared as an allowed entry in the system, the algorithm considers this as an unexpected movement (ERROR) and closes the case (STOP).

This mechanism is intended to avoid false alerts coming from hardware faults or badly oriented sensors.

If the start point is a regular entry cell, the algorithm starts the tracking in this cell (ACTIVE). As soon as the person disappears from the cell, the algorithm loads the list of the neighbors of this cell and waits for movement (WAIT). If the person appears in an adjacent cell or again in the cell itself (MOVE), this cell is defined as active cell and the algorithm loops back.

If no movement is detected after a first timeout (Timeout 1, 3 minutes), a first level of alert is generated and transmitted to the control room of ATLAS (WARNING). Finally, either the person appears in one of the adjacent cells before a second timeout (Timeout 2, 2 minutes), or a higher level of alert is generated and transmitted to the control room (FATAL). This alert stays until the situation is understood by the operator and is acknowledged.

In addition to the baseline of the tracking algorithm, several cases have also been taken into account in the implementation. A time-out period of three minutes is set at the initialization, during which all cells are considered as entry cells. This mechanism allows to (re)start the control script while people are already in the controlled area. A mechanism has been implemented to cover cases where the paths of two persons cross. In such a situation two tracking cases become one and the algorithm waits for one of two possible outcomes. Either the persons move together and, after a timeout, the algorithm considers that the crossing cell is empty; or the persons continue separately and the algorithm continues to track them separately.

3. *Databases and configuration tool*

The tracking algorithm uses a large amount of configuration data for the cell definitions like neighbor mappings and entry cells, which must be stored centrally to ease the maintenance. These cell definitions are stored in the ATLAS configuration database which provides the facility to manage system configurations on a central Oracle database. This configuration database works with recipe mechanisms holding predefined values for sets of parameters.

For FPIAA, several neighbor mapping configurations are needed because the topology in the experimental cavern can change. Detector parts can be moved in order to give access for maintenance operations. This creates new accessible areas which must be covered by FPIAA. The recipe mechanism of the configuration database allows the operator to load configurations adapted to the current topology in the cavern.

In order to ease the maintenance of the neighbor mapping, a specific tool has been developed to create new recipes, or to modify existing ones (Fig. 7).

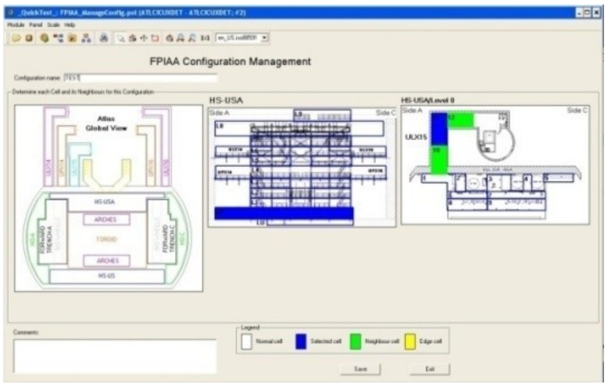

Fig. 7. Configuration management tool

It provides an intuitive way to build a configuration file by navigating in the experimental cavern. The expert selects a cell which then appears in blue (or yellow if it is set up as an entry cell) and then clicks on the cells which should be defined as neighbors, which then appear in green. A second click on the firstly selected cell validates the changes which are stored in a local buffer. When the configuration is finished, all changes are saved to the corresponding recipe in the database.

IV. USER INTERFACES

1. *Online monitoring*

FPIAA is one of the tools allocated to the safety desk in the control room of ATLAS. A human interface has been developed to provide to the operator with a simple way to navigate in the experimental cavern and to follow people for online monitoring.

110 panels have been implemented to display every sector of the toroid, every level of the surrounding structures, and all access paths to the cavern. The panels have been included in the Finite State Machine (FSM) [1] mechanism of ATLAS. Fig. 8 shows the hierarchically organized structure of the FSM which allows the user to navigate down in a tree in order to display any zones/sub-zones of the cavern from the global view. People's movements are indicated by blue cells.

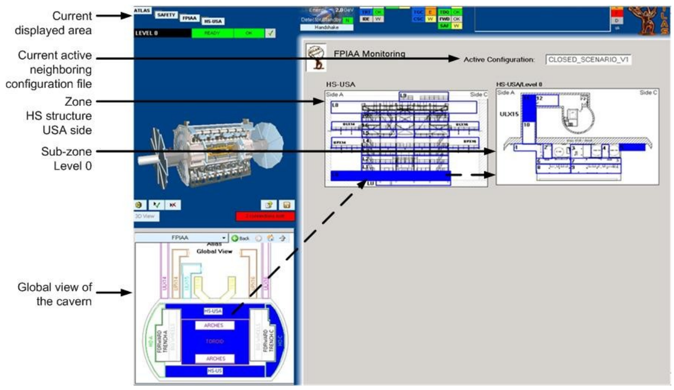

Fig. 8. FSM panel for online monitoring

FPIAA uses the standard FSM state/status mechanism. The status (OK, warning, error, fatal) of each individual cell is set by the tracking algorithm (see section III) and is propagated up to the top node of the FSM tree. Therefore, when an alert is generated, the operator will see it on the ATLAS top node of the FSM and can navigate down in the tree in order to find out the details.

The overall state of the FPIAA (ready, not ready, unknown) is constructed from the states of its components:

- The states of all ELMB involved in FPIAA. Checks are made whether they respond properly and do not generate errors.
- The state of the power supplies which provide the power to the PIR and to the ELMB.
- The operational parameters of the ELMB boxes (5 Volt supply, temperature in the box).

The FPIAA system can be switched ON/OFF from the FSM panel. The operator can send commands to start/stop all the power supplies or one of them individually.

2. *Replay tool*

An additional user interface has been implemented to replay the activity of people in the cavern. All online data are stored in a database which is accessed by this tool (shown in Fig. 9) to replay at real or accelerated speed the movements logged and the alerts generated for any time period.

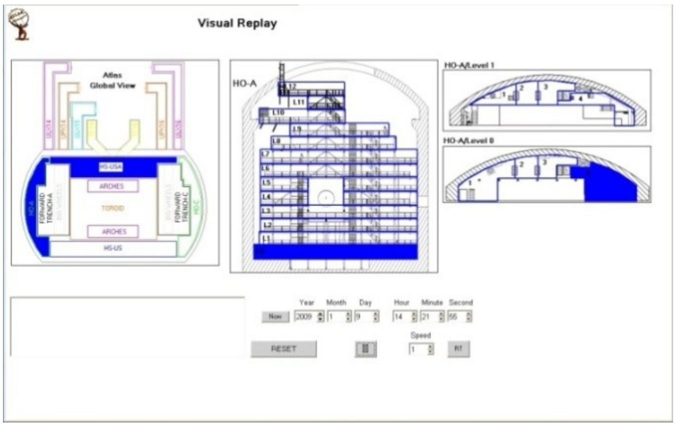

Fig. 9. Replay tool

V. PRESENT DEVELOPMENTS AND CONCLUSIONS

FPIAA is presently in its final development state. The last hardware components are being installed and the parameters of the tracking algorithm are being tuned to minimize false alerts. FPIAA is presently under final validation and works already with quite an acceptable number of false alerts. It is already used in the control room as a supervising tool and the aim is to activate the tracking and the alert system at least in the toroid area for the next maintenance period of ATLAS.

The FPIAA system has been developed for a very specific application in the environment of an experiment of particle physics. But the choice of industrial off-the-shelf hardware and software components and the flexible way it has been built make the tracking system easily portable to any industrial environment.

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