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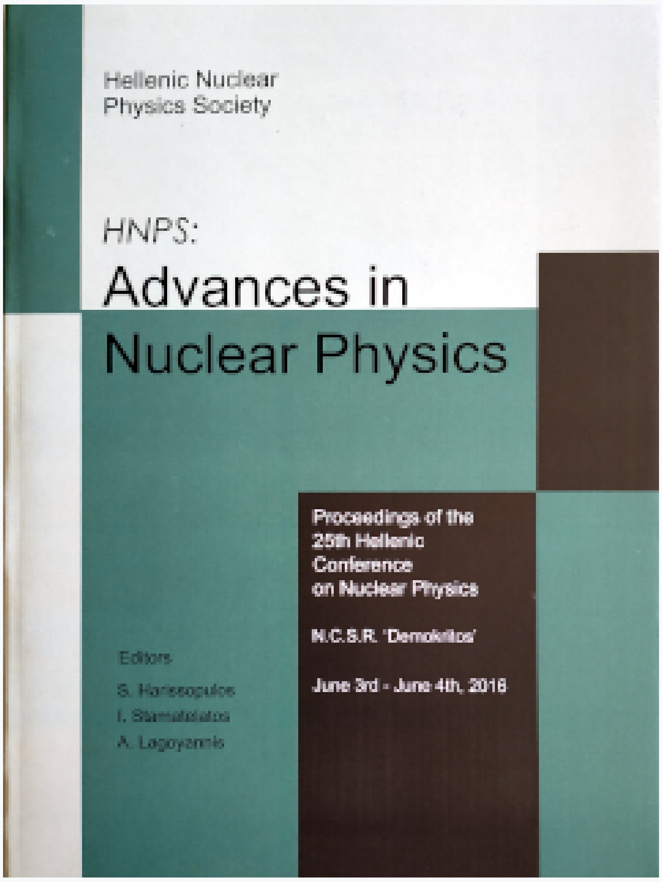


# Control System (CS) and Data Acquisition (DAQ) architecture for the radiation background monitoring of a Personnel Safety System in the ATLAS cavern

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# Control System (CS) and Data Acquisition (DAQ) architecture for the radiation background monitoring of a Personnel Safety System in the ATLAS cavern

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**Abstract** EDUSAFE is a 4-year Marie Curie ITN project, which focuses on research into the use of Virtual Reality (VR) and Augmented Reality (AR) during planned and emergency maintenance in extreme environments of high radiation background (HEP experiments, nuclear installations, space, deep sea, etc.) The scientific objective of this project is research into advanced VR and AR technologies for a personnel safety system platform, including features, methods and tools. Current technology is not efficient because of significant time-lag in communication and data transmission, missing multi-input interfaces, and simultaneous supervision of multiple workers who are working in the extreme high radiation background environment. The aim is to technically advance and combine several technologies and integrate them as integral part of a personnel safety system to improve safety, maintain availability, reduce errors and decrease the time needed for scheduled or sudden interventions. The research challenges lie in the development of real-time (time-lags less than human interaction speed) data-transmission, instantaneous analysis of data coming from different inputs (vision, sound, touch, buttons), interaction with multiple on-site users, complex interfaces, portability and wearability. The result is an integrated wearable VR/AR system and Control System which can be implemented and tested as a prototype. The LHC at CERN and its existing Personnel Safety System, requirements and protocols will be used as a test and demonstration platform. In this article the progress of the project will be presented and especially the major contribution of the NTUA team in developing and optimizing the Control System (CS) and the Data Acquisition System(DAQ).

**Keywords** augmented reality, background radiation, control system, data acquisition, wireless supervision system

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## INTRODUCTION

ATLAS is a general purpose High Energy Physics (HEP) experiment, one of the experiments at the Large Hadron Collider (LHC), constructed at CERN, to study proton-proton collisions at the unprecedented energy of 14 TeV [1]. Personnel safety, supervision and real-time monitoring are important key parameters while performing activities in risky environments and extreme environmental conditions such as the ATLAS cavern. The hazardous environments are not user friendly in terms of frequent access, performing

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regular/sudden interventions, monitoring, and supervision activities. The engineers and the personnel need to perform complex activities like installation and maintenance work in the heavy machinery. In most of the cases, it is not possible to memorize the maintenance procedures of a complex machinery. If the machines contain radioactive elements, then the situation is even more crucial for the safety of the personnel. The objective of this paper is to present the Control System (CS) and Data Acquisition (DAQ) architecture for the radiation background monitoring of a Personnel Safety System in the ATLAS cavern. This system was developed by the NTUA team during the EDUSAFE project of CERN. The goal of this project is to develop a Personnel Safety System (PSS) system based on Augmented Reality (AR) technology to improve safety, maintain availability, reduce errors and decrease the time needed for scheduled or sudden interventions in radioactive environments. AR is a technology, which aids in seeing a real scene with embedded data useful for human activities. This technology is used in wide areas namely education, health care, maintenance, construction, gaming, navigation, military, tourism etc.

The research challenges lie in the development of real-time (time-lags less than human interaction speed) data-transmission, instantaneous analysis of data coming from different inputs (vision, sound, touch, buttons), interaction with multiple on-site users, complex interfaces, portability and the goal of developing a wearable prototype. The result will be an integrated wearable VR/AR system and Control System which can be implemented and tested as a prototype. The LHC at CERN and its existing Personnel Safety System, requirements and protocols are used as a test and demonstration platform. The EDUSAFE prototype is consisted of the following independent systems also shown in Figure 1:

- The Mobile Personnel Supervision System placed on the helmet of the worker.
- The Augmented Reality (AR) glasses including a server for computer vision algorithms.
- A Gamma camera as a standalone device which connects wirelessly to the AR prototype and provides radiation hot spots in the real environment.


**Fig. 1.** First Edusafe Prototype

**CONTROL SYSTEM (CS) AND DATA ACQUISITION SYSTEM (DAQ)**

For the purposes of this project a Personnel Supervision System (PSS) module is developed to serve an automated, remote operation of a large number of sensing and mobile-autonomic application domains.

The PSS module is the host for the communication module, the safety sensors and the local intelligence for data-video treatment such as augmented reality features. It is an essential node for propagating the data from the cameras and sensors to the control system (providing supervision services to administrators and users) and vice versa from the control system to the Head Mounted Displays (HMDs). All these services are managed by a Control System (CS) and Data Acquisition System (DAQ). The basic goal of this CS and DAQ System, is to design and optimize a modular architecture, in order to firstly acquire data from safety sensors, gamma camera (device to image gamma radiation and provide localization of radioactive sources), as well as other vision cameras, secondly store them in a reliable Data Base, and thirdly display them in a User Interface to enable remote supervision of workers in the ATLAS cavern, for security purposes. The CS and DAQ architecture is designed in order to accept various types of sensors for testing in the ATLAS environment, hence the adaptation of this service-based application is a crucial goal that needs to be defined and fulfilled.

The sensor data are acquired from the Personnel Supervision System (PSS). The PSS is a wearable safety device, which combines several technologies and integrate them in a personnel safety system where data are received from different input sources (gamma camera, vision cameras, and sensors) and interaction with multiple on-site users. It is called an Augmented and Virtual reality based Personnel Transmitting Unit (PTU).

The CS and DAQ system that is developed provides the following services:

a. Sensor Data Acquisition
b. Video Streams Acquisition
c. Radiation Data Acquisition from gamma camera
d. Data-Base storage
e. User Interface development for remote supervision of workers in the ATLAS cavern for security purposes.

There are several biological sensors such as body temperature, heart beat, oxygen, fall detection and most importantly a dosimeter to calculate the dose rate (mSv/h) as well as environmental data such as temperature, humidity, $CO_2$ and barometric pressure. All of these sensor data are wirelessly acquires from the DAQ (Data Acquisition) server through JSON formatted messages. These data are stored in an Oracle Database for offline-analysis and for real-time monitoring of the worker status during the several activities in the ATLAS cavern.

## RADIATION DATA ACQUISITION

The majority of the activities that take place in accelerators such as the Large Hardon Collider (LHC) and in general in all experimental facilities that are linked with the accelerators at CERN, involve exposure to ionizing radiation including gamma, beta and particle radiation [2-4]. Therefore, it is crucial to control the dose that the personnel is accumulating by properly monitoring them during their activities. The individual dose that each person who works with ionizing radiation at CERN is receiving, is measured with personal dosimeters. Those dosimeters combine an active detector for gamma and beta radiation based on the Direct-Ion Storage (DIS) technology and a passive detector for quantifying neutron doses [2]. The operational dosimeter is crucial in activities taking place in Controlled Radiation Areas, where the radiological risk and the dose rate are above 50 μSv/h. CERN provides all staff who may work in Limited Stay Radiation Areas or High Radiation Areas with a system for active dosimetry with an alarm, in the form of a dosimeter, model DMC-2000 from MPG instruments. In our experiments we used the aforementioned operational dosimeter in order to acquire dose data with the DAQ server. The dose data are wirelessly transmitting from a XBee module that is embedded in the dosimeter and acquired from the DAQ server in JSON formatted messages. This operational dosimeter is shown in Figure 2 . In case a measurement exceeds a certain threshold an alarm is created and it is shown in the supervision interface to guide the personnel in real time.


**Fig. 2.** Operational Dosimeter DMC-2000 from MPG instruments measuring radiation data

The interaction of the collision products with the ATLAS detector and its shielding material produce many low-energy, mostly neutral particles called cavern background [3]. The background monitoring in ATLAS cavern was tested with a gamma camera developed to achieve 3D localization of the radiation hot spots. The images produced by the gamma camera are sent to the User Interface that we developed for supervision purposes.

## RESULTS AND DISCUSSION

The results of this research are a CS, a DAQ Sytem and a User Interface (EDUSS GUI) for supervision purposes in the ATLAS cavern. As it is shown in Figure 4, of testing results with the gamma camera, the system can acquire data from four HW sources and properly display them in the EDUSS GUI. These four HW sources are the Mobile Personal Supervision System (MPSS) shown in Figure 4_(1), the sensor board shown in Figure 4_(2), the Gamma radiation camera developed by Canberra shown in Figure 4_(3) and the operational dosimeter that is used to measure radiation shown in Figure 4_(4). All of the acquired data are stored in an Oracle DB for offline analysis.

The Control System (CS) and Data Acquisition (DAQ) System have been tested in the ATLAS cavern. The DAQ Server acquires data from three subsystems:

1. The Mobile Personal Supervision System (MPSS) shown in Figure 4_(1). The data that are acquired from te MPSS are wireless video, audio and radiation sensor measurements.
2. The sensor board shown in Figure 4_(2) used for environmental, biological and radiation data.
   - Acquired environmental data: environmental Temperature, Humidity, O2, CO2, Barometric Pressure.
   - Acquired Biological data: Radiation dose (Dose Rate and Dose Accumulation), Body Temperature and Accelerometer.

   These sensor data are wirelessly acquired from the new sensor board through the DAQ Server in JSON messages and are saved in the Oracle-XE 11g Database. The sampling rate of each JSON message that the server receives is 5s. The CS creates alert messages in case a measurement exceeds a certain threshold. Every measurement that comes from the sensor board has a timestamp and the Database keeps a record of every measurement (ID, Unit, Time, Value) using Oracle SQL Developer 4.0.3.
3. The Gamma Camera web interface.
   The DAQ Server acquires the gamma camera image with 3D localization of the radiation hotspots over the ATLAS environment through the IP of the gamma camera webserver. This image is then displayed on the EDUSS UI for monitoring and safety purposes. In that way, the supervisor can acquire a complete 3D mapping and radioactive source localization as shown in Figure 3. The image shown in this figure is an example of a decoded gamma image taken during the radiation background monitoring of pipes with a new generation of gamma camera developed by CEA LIST [5].


**Fig. 3.** Gamma camera image displayed in EDUSS GUI.

4. The operational dosimeter that is used to measure radiation shown in Figure 4_(4). It wireslly transmits Dose Rate and Dose Accumulation measurements to the DAQ Server.

On the left part of the following Figure 4 all the HW sources used from the DAQ system are shown and on the righ part of this Figure all the data processing and monitoring tools are represented, including the EDUSS GUI, the DAQ Server and the Oracle DB.

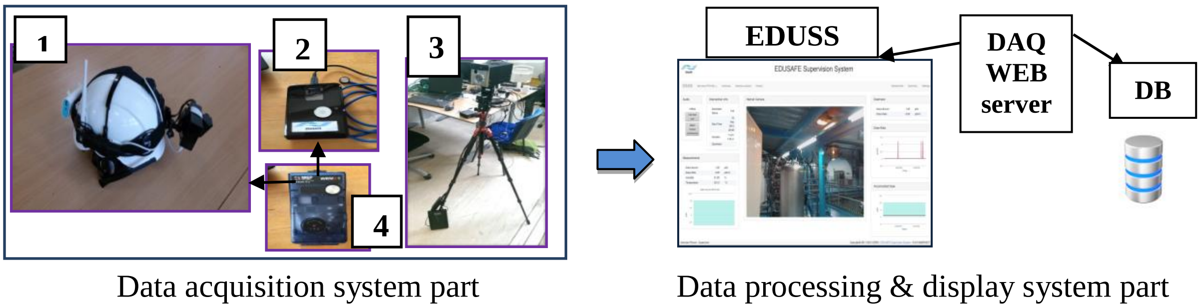


**Fig. 4.** DAQ System sources: (1) Mobile Personal Supervision System (MPSS) (2) Sensor Board (PTU) (3) Gamma radiation camera (4) Dosimeter for radiation data. The right part of the figure presents the data processing and display of the system part.

## CONCLUSIONS

A Control System and a Data Acquisition System for supervision purposes in the ATLAS cavern of CERN was presented in this paper in the framework of the EDUSAFE project. One of the main goals of this research was accomplished by wirelessly transmitting sensor, video and audio data from the supervised person to the supervisor as well as creating a User Interface (EDUSS GUI) for monitoring the activities of the personnel in a highly dynamic and challenging environment such as the ATLAS cavern. This system can be adaptable and scalable to other markets and extreme environmental conditions such as Nuclear Power Plant emergent or planned maintenance and Industrial subsea activities, accepting various types of sensors.

## ACKNOWLEDGMENTS

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