

## STATUS OF THE ZEUS EXPERT SYSTEM (ZEX)

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The expert system ZEX is supporting the shift crew in operating the ZEUS detector. It helps to increase both efficiency and reliability of experiment operation while reducing the required experience and expertise of the shift crew. The task of the expert system is to detect anomalous behavior in any part of the experiment, to trace errors to their origin, and to recover or help to recover the system as quick as possible. ZEX is based on the commercial expert system shell RTworks. The large number of human experts in the ZEUS environment requires the knowledge to be stored in an intuitive way, and a rule based system was considered to be the only appropriate way of knowledge storing. ZEX is put on top of existing systems, and the layered structure of ZEX reflects the structure of the online system. The Slow-Control sub-expert system is running since 1994, several parts of the DAQ and the DQM sub-expert systems have been implemented since then.

### 1 Introduction

The ZEUS detector is controlled and read out by a highly parallel distributed online system<sup>1</sup>. To increase both efficiency and reliability of experiment operation and at the same time reduce the required efforts and expertness of the shift crew, an expert system project was launched by the ZEUS collaboration in July 1992<sup>2</sup>. The goal was to automatically detect anomalous behavior in any part of the experiment, to trace errors to their origin, and to help to recover the system as quick as possible.

In a first step, an expert system prototype (ZEX-P) was created which processed monitoring information from a subsystem of the data acquisition system, the Eventbuilder<sup>3,4</sup>. The prototype was designed using SA/SD-methods, and was implemented in the programming language C, based on syntactic pattern-recognition algorithms. Experience regarding feasibility and performance was encouraging, however it became clear that keeping a full-blown expert system maintainable would require for dedicated programming languages and development tools<sup>5</sup>. ZEX-P was therefore re-engineered in a rule-based approach, before it was finally decided to implement ZEX based on the commercial expert-system shell RTworks<sup>6,7</sup>.

### 2 Overview of ZEX

#### *General Overview*

Fig. 1 shows the architecture of ZEX. The structure of ZEX was chosen to reflect the structure of the online system. Three dedicated sub-expert systems evaluate and thus encapsulate knowledge of distinct domains, while a top-level module analyses the output of the sub-expert systems to derive the overall system characteristics.

The different modules communicate through a global hierarchical data structure called blackboard. The blackboard is hierarchically organized into information

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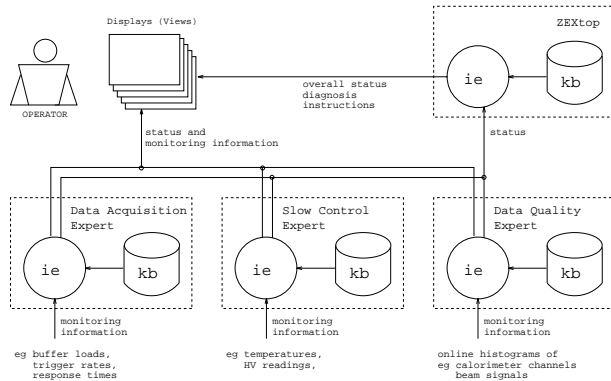


Figure 1: Architecture of the ZEUS Expert System (ZEX).

levels corresponding to levels of data processing, which range from raw monitoring information to derived system status information. The problem-solving knowledge is modularized and encapsulated in so-called Knowledge Sources, thus partitioning the Expert System according to the structure of the experiment. The majority of the Knowledge Sources is implemented as rules, however the Blackboard architecture has enabled us to include some of the pattern recognizers which have been developed for ZEX-P <sup>8</sup>

### *Sub-Expert Systems*

The slow control sub-expert-system monitors the basic hardware of the experiment. It surveys the states of power supplies, racks, crates, photomultipliers, temperature and radiation sensors, cooling, etc. Based on this information, it decides if efficient data taking is possible, and proposes what to do to regain an acceptable state.

The data quality sub-expert-system tries to ensure high quality of the data written to tape. It monitors the beam quality and background rates, and it checks the data from the major components for miscalibration, dead channels, etc. The data flow sub-expert-system surveys the data taking. It monitors the central components of the data acquisition system (ie front-end systems, trigger stages, data storage task) for data rates, deadtime, response times etc. At the top level, ZEX is combining the information about the subsystems to an overall system understanding. It selects the most important information and presents it to the shift crew.

### *Status of ZEX and Experience*

The Slow-Control Expert was the first sub-expert system to be put into operation during the 1994 data taking period. Its functionality has been expanded steadily. Finally, first parts of the other subsystems have been added.

For the 1995 data taking period, ZEX is tuned to speed up the procedure of expanding and modifying the knowledge of the system, thus enabling fast reactions



Figure 2: The ZEX Slow-Control display.

to changes in the run conditions, and preparing ZEX to handle short-term conditions in the ZEUS environment.

Development of ZEX started only after the experiment was put into operation, hence ZEX had to be put on top of existing systems. The major constraint for the development of ZEX was not to interfere with the operation of the online system, which introduces difficulties since very often information which is essential for an accurate reasoning has shown to not be accessible to ZEX.

### 3 Impact on future experiments

In a fast-changing environment like a HEP experiment, where experts are not always available at the location of the experiment and are frequently changing their positions, an expert system provides a central knowledge repository, which makes information available to anybody whenever (maybe also wherever) it is needed. Parts of the experiment operation (eg data acquisition operation, readout configuration etc) can even be automated with an ES.

A mandatory condition for successful operation is the availability of monitoring information from and access to the different detector parts, their readout and the trigger system. It is thus beneficial to incorporate an expert system already at very early stages into the experiment design (protocols, network layout etc).

Knowledge engineering and artificial intelligence are branches of computer sci-

ence which are mostly alien to high-energy physicists. It should thus be considered to involve computer scientists into the design and development of expert systems in HEP.

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