A SUMMARY OF THE IEEE REAL TIME 2005 CONFERENCE HELD AT STOCKHOLM

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ABSTRACT

Bi-annually, the Nuclear and Plasma Sciences Society of IEEE sponsors the Real Time conference. At this conference it is mostly physicists that present their developments around the online systems in these fields. These presentations are focused mainly on real-time applications but nevertheless the whole range of control systems for detectors is covered, which is similar to the ICALEPCS conference. Even though the topics covered are quite similar the participants tend to be different with only a few people attending both events.

Therefore, this paper will summarize and highlight the key presentations of the Real Time conference where they are interesting for the ICALEPCS community. Such topics are “system architecture”, “front-end signal processing”, “trigger and data acquisition”, “online databases”, and “online processing farms”.

INTRODUCTION

The 14th IEEE-NPSS Real Time conference held at the AlbaNova University Centre in Stockholm gave a very broad overview of technologies used in online systems for physics and medical experiments, as well as particle accelerators. 160 papers have been presented orally or as posters in this interdisciplinary conference to all participants, as all sessions are plenary session in the conference series. Additionally this year short 3 minute “teaser” talks have been given for the posters, which was generally seen as a success.

The author goes along with the praise of the conference chairman, Richard Jacobsson, for the format of sessions grouped by the type of application and not field of research, which underlined the character of Real Time, bringing apparently very different subjects together and showing their similarities and possible synergies.

This paper tries to summarize the conference by pointing out the key technologies which were presented and their application. Of course, this is a personal summary by the author, even though put together after some discussions with other participants.

The complete conference record, including presentations and originally submitted papers, can be found in [1]. Selected papers will be published after a peer review process in the IEEE Transactions of Nuclear Science.

GENERAL OVERVIEW

At the beginning of the Real Time Conference there were two short courses covering two topics which also emerged to be the key issues addressed during the conference: high speed networking for Data AcQuisition (DAQ) systems, and programming of Field Programmable Gate Arrays (FPGAs).

In contrast to dedicated controls conferences like ICALEPCS, Real Time covers all aspects of online systems (controls, DAQ, electronics, trigger, and alike) as far as they have a connection to real-time applications. This approach gathers experts from sometimes very much separated fields together in one conference and helps very much for the understanding between the various fields and possible synergies.

Each morning was started by an introductory talk on very different topics and approaches to tackle the problems experimenters are faced with. The first introductory talk covered the use of off-the-shelf computing hardware for a highly complex solar telescope. Apart from a very complete introduction to solar astronomy, the talk covered the issues related to the use of commodity computing hardware, and pointed out the advantages of this approach for small development teams for the complete online system. The longer time-allocation for the introductory talks also allowed for reviews of wider subjects, like the talk of the second morning, which covered “Techniques and Technologies for the Transport of Digital Data in Recent Physics Experiments”. The speaker gave a thorough overview and discussion of the technologies used so far, as well as technologies on the horizon to be used in coming

experiments. Apart from applications in the field of physics experiments, medical applications are an important fraction in the use of real-time systems. In recent years, this is reflected more and more in new systems, especially in the field of medical imaging. The third morning's introductory talk presented one of these applications, a Positron Emission Tomography (PET) scanner, already in use for seven years at the Gesellschaft für SchwerIonenforschung (GSI) at Darmstadt. The last introductory talk addressed the hot topic of standardization in instrumentation and high availability control systems. By giving design goals and design principles, as well as discussing existing standards, a broad overview of techniques was given that might influence future design approaches at large.

Specific topics can be found in the following section, but it became clear already the first day of the conference, that the way most developments go is towards the use of FPGAs wherever fast and reliable control or dataflow is needed. Some of the applications combine FPGAs with older technologies, such as digital signal processors (DSPs), or even implement them inside FPGAs, or application-specific integrated circuits (ASICs), but those less flexible chips loose ground substantially, while FPGAs grow to more powerful, sophisticated devices that sometimes contain implementations of complete micro-processors. The second main topic was the use of special network topologies for data acquisition, event building, and trigger systems. This goes as far as reading out detectors at interaction rates or even trigger-less DAQ. With faster and more reliable commodity network hardware available also at very low cost, and computing power in farms being extremely scalable, even very big experimental setups read out at megahertz rates are envisaged, and sometimes already being implemented. Last but not least, it became very clear that large systems – especially real-time systems – cannot be managed without powerful and intelligent databases holding the information for setup, configuration, and monitoring. Many developments are currently ongoing, and the next Real Time conference will without any doubt have this as a major topic.

This overview would not be complete without mentioning the two student awards newly introduced at Real Time. The first went to Lana Abadie from CERN in Geneva for her work on representing dataflow and routing tables using a database [2], the second to Peter Hofverberg from the Royal Institute of Technology at Stockholm for his original development of a data acquisition system for an educational air shower array for schools [3].

MAIN TOPICS

This list of main topics follows the tracks inside the conference. The conference does not distinguish between applications for controls systems, data acquisition, trigger, …, but on the approaches and technologies applied or tested. Tests of new or emerging technologies are implicit in many presentations, but only a few in-depth tests have been presented. This is not a real disadvantage, as pure tests can be found from various other sources, but the real test is the usage inside an application, where also the compatibility with other – mainly established – approaches is probed. This section can only give an overview, pointing out the main technologies with some remarks.

Real Time System Architectures and New Technologies

This track is the most specific on emerging technologies, even though many novel ideas are presented in the other tracks, together with some existing applications. Apart from new communications technologies like PCI Express or SpaceWire [4], the re-usage of bus technologies that are already introduced in other areas seems to be very promising. Large readout networks face similar requirements as telecom networks, and so it is quite natural to look for ideas and solutions in this field [5]. The second issue stressed very much here, as well as in existing applications, is the introduction of FPGA-based solutions in areas where flexible behaviour, determinism, and reliability is of great importance. Studies and solutions using FPGAs presented in this track range from complete applications in particle physics, e.g. for the ANTARES and CMS experiments [6], via applications in the medical field for the control and data acquisition of PET scanners, e.g. [7], to nearly all-purpose DAQ controllers [8].

Not really meant as the bottom-line of the conference topics, but very well bringing it to a conclusion, a presentation on contributions of high-energy physics electronics techniques for the medical imaging field [9] concluded this track.

Signal Processing and Readout Electronics

Complete systems for signal processing and mainly readout electronics have recently been designed and implemented for the various LHC experiments and are also studied and prototyped for the detectors at future colliders. A comprehensive overview of the readout system of a complex sub-detector has been given by ATLAS [10]. LHCb presented a very interesting approach for implementation and simulation of VHDL code by co-designing C and VHDL code [11], and STAR presented a full readout-chain for a precision vertex tracker with commercially available components like FPGAs and Ethernet [12].

Furthermore, signal processing plays a major role in medical imaging, so a number of applications for PET [13] and other three-dimensional image data processing [14] were shown.

Feedback and High Speed Synchronous Control

While feedback systems are mainly used for control of fusion experiments, which are also well represented at Real Time, high speed synchronous control systems are very common at modern accelerators, where among others trigger information has to be distributed to many destinations within a very tight time window. The system used at LHC – Timing, Trigger, and Control (TTC) – was presented with its applications e.g. for CMS [15]. In another paper a similar approach for a fusion experiment was presented [16].

Feedback systems took the largest space in this track, and it is difficult to pin-point only a few papers for a mention here. In addition to the many applications presented orally, a large number of posters deal with the subject. It seems that in this area DSPs play the major role, see e.g. [17].

Control, Monitoring, GUIs, and Online Databases

Real-time systems also need to have so-called “slow-control” counterparts for items which need to be monitored and visualized, and this data also has to be kept for further analysis in databases. Consequently, one of the longest tracks in the conference was dedicated to this complex. It was opened by a presentation on a widely used tool for large experiment automation [18], which – integrated with a SCADA system – forms the basis of the LHC experiment controls systems. Several other talks referred to this powerful combination, its application but also aspects like deployment and support. Especially here, a widely visible tendency to the use of common frameworks for controls and monitoring was presented w.r.t. several applications. These ranged from smaller application frameworks using LabVIEW [19] or even JAVA, to very much universally usable packages based on powerful SCADA systems like PVSS [18].

Apart from the pure controls, monitoring, and visualization aspect, controls systems require infrastructure in hardware and underlying database technologies. One very appealing approach has been presented by LHCb: the usage of distributed intelligence on single-board PCs close to the controlled hardware. These are even powerful enough to upload programmes into FPGAs and by that decentralization play a major role in load-balancing [20]. Also several models and applications of database techniques to online systems have been presented. From a novel approach to use databases for network setup in terms of routing and dataflow [2], to the discussion of first experience using configuration and conditions databases for LHC experiments, many aspects have been covered and the strong momentum in this issue has been made clear.

Algorithm Implementation

Essentially all of the application presentations in the conference contained descriptions of the implementation of various algorithms to tackle the very specific problems faced there. A short, but impressive session was nevertheless dedicated to the more generic implementation of algorithms, showing some novel ideas on how to use techniques already very much in use in the offline world. Especially here, the power of FPGAs can be seen. In one implementation of the Hough transform for track reconstruction, the authors presented a simulation that showed the processing time in the range of 10 to 100 µs [21].

Data Acquisition Systems

Data acquisition is the central real-time part of most experiments, and consequently the three sessions in this track showed together with a large number of poster presentations a snapshot of the state of the art in data acquisition and handling systems.

From very small but powerful systems, where the “on-detector” part can be carried by a rat [22], to space and weight-constrained systems for space experiments [23], to highly complex architectures for LHC experiments [24], almost all possibilities have been presented. These presentation made it very clear that novel technologies and algorithms are needed to cope with the problems of modern data acquisition systems, and that approaches only just being thought about in some fields are already implemented and even established in others.

Trigger

Low-level trigger systems of experiments are intrinsically real-time, and even though they are about to be made obsolete by faster and faster readout networks that acquire the data at interaction rate, are constantly upgraded and make use of highly sophisticated hardware and software algorithms. The track mostly presented overviews of complex trigger architectures and their testing, e.g. [25]-[27], but also the use of commodity solutions for high performance detectors [28] was covered.

Fast Networks and Event Building

As already pointed out several times, fast networks and fast event building play an important role in modern data acquisition architectures. Established technologies like gigabit Ethernet render custom implementations nearly obsolete. In several talks it was shown that the use of gigabit Ethernet essentially solves the major problems of this field, see e.g. [29] and [30].

Online Processing Farms and High Level Triggers

Whilst in the last generation of experiments large computing farms did not play a role in the online architecture, now even remote real-time computing farms are an issue [31]. However, computing farms do not only solve problems but they also bring up new challenges. One of the foremost of these is the number of infrastructure services, mainly cooling, they need [32].

Concentrating on the orally presented papers, the impressive work shown in the poster sessions should not be forgotten. They could not fit into a short summary of a week-long conference, but the reader of this paper is encouraged to have a look at the posters and the underlying papers which are included in the conference record [1].

CONCLUSIONS

Real-time applications are central to modern detector and accelerator systems and the Real Time conference again presented the online community with established implementations as well as novel and emerging technologies to improve the performance of the systems. The trends in technology are going in two very different directions, placing higher level algorithms already into hardware, and skipping most of the established real-time electronics by powerful readout networks and relocating former hardware tasks like trigger and event-building to big computing farms. The commissioning and running of LHC experiments will show the performance of the systems presented in real life. Maybe afterwards both trends will be put together again, by implementing the computing farms in real-time hardware on FPGAs?

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