Accelerator Laboratory 2025 • Controls

Sessions: April 10 and 15, 2025
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Food for thought

We believe it is useful to provide the students of this course with a concise outline of what was said and done during the study and laboratory day. This outline contains points for reflection that each student may use as they see fit: to better remember what was said in the introductory presentation, or to delve deeper into some topic out of personal curiosity, or even – in the future – to approach a problem related to IT (*Information Technology*) with a different mindset. This is an informal document, and its reading or the use of its contents for writing the activity report is not required in any way.

How the Development of IT Systems is Changing

In software development and in the creation of hardware infrastructures, highly advanced technology is currently available, even compared to just a few years ago. This fundamentally alters both the way applications are written and how infrastructures and computing platforms are designed.
Keywords: virtual machines, dockers, containers, orchestrators, high throughput networks and storage.

Characteristics of Control Systems

Within the scope of this course, we focused on the control systems of scientific installations, based on the use of software-implemented control processes running on computers/microprocessors/FPGAs. We also said that —in essence— the control of a particle accelerator does not differ from that of an industrial or medical plant, or of other kinds. On the other hand, we also saw that there are distinct requirements in these different situations, which necessitate optimizing the control system design to make it suitable for operation in the specific context.
Keywords: reliability, scalability, flexibility, single point of failure, machine protection.

Description of Control Systems

We saw how, in facilities covering medium to large areas, distributed system architectures tend to be adopted. In these cases, control processes are implemented on physical computers located in proximity to (or even inside) the devices where low control latency is required, and on remote machines —both physical and virtual— where communication channels and the network guarantee the necessary bandwidth and latency. We saw how the architecture of a control system that needs to operate over a long time horizon must be as independent as possible from any specific hardware and/or from what are currently considered reliable standards, since they are all eventually destined for obsolescence.
Keywords: acquisition bus, VME, cPCI, µTCA (microTCA), fieldbus, Ethernet, embedded computers, virtual machines, machine learning, machine protection, AI.

Data Flow and Retention

In a system consisting of many control processes on one side (e.g., a particle accelerator facility) and many operator consoles on the other (e.g., a control room), there are many ways to organize data traffic and command forwarding.
In particular, the difference is relevant between the method based on queries (from the consoles to the control processes) and the one based on the use of a *live cache* (a volatile memory area where control processes write and consoles read). The difference between relational and non-relational databases was also described.
In addition to these architectural aspects, we also talked about how important it is to go through a virtualization process aimed at unifying families of devices that differ by brand and/or model but which perform the same function. At the end of this process, the system will operate only with virtual representations of objects (classes) which will have uniform sets of characteristics (properties) and possible actions (methods).
Speaking of how data can be represented, we saw how serialization techniques (e.g., JSON, YAML, XML) allow representing any set of data through a sequence of bytes (hence serialization) which —besides containing the data value— also describes its format. Finally, we saw what the difference is between relational and non-relational databases and how the latter are particularly suitable for accommodating serialized data.
Keywords: Relational Database, Object DB, key-value DB (e.g. memcached[1]), data serialization, JSON, BSON, XML, YAML

User Interface

User interaction (machine operators, machine physicists, external users, etc.) with the Control System must be as intuitive as possible and consistent with the WEB and smartphone interfaces that we use daily. This is one of the most challenging aspects in the development of a control system, as the creation of an ergonomic and modern human-machine interface is extremely time-consuming. On the other hand, this field is rapidly evolving (outside the scientific community), and very well-designed and functional graphical data presentation environments are starting to become available (e.g., at LNF, the open source software Grafana[2] is used extensively).
Keywords: WEB interface, GUI.

Lab activity

See the detailed document `Notes on the lab exercise.pdf` available on the INFN Agenda webpage in the April 15th slot (for both groups A and B).

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(Tutors of the "Controls" session)

[1] https://memcached.org/

[2] https://grafana.com/