EVALUATION OF SOFTWARE AND ELECTRONICS TECHNOLOGIES FOR THE CONTROL OF THE E-ELT INSTRUMENTS: A CASE STUDY

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In the scope of the evaluation of architecture and technologies for the control system of the E-ELT (European-Extremely Large Telescope) instruments, a collaboration has been set up between the Instrumentation and Control Group of the INAF-OATs and the ESO Directorate of Engineering. The first result of this collaboration is the design and implementation of a prototype of a small but representative control system for an E-ELT instrument that has been setup at the INAF-OATs premises. The electronics has been based on PLCs (Programmable Logic Controllers) and Ethernet based fieldbuses from different vendors but using international standards like the IEC 61131-3 and PLCopen Motion Control. The baseline design for the control software follows the architecture of the VLT (Very Large Telescope) Instrumentation application framework but it has been implemented using the ACS (ALMA Common Software), an open source software framework developed for the ALMA project and based on CORBA middleware. The communication among the software components is based on two models: CORBA calls for command/reply using the client/server paradigm and CORBA notification channel for distributing the devices status using the publisher/subscriber paradigm. The communication with the PLCs is based on OPC UA, an international standard for the communication with industrial controllers. The results of this work will contribute to the definition of the architecture of the control system that will be provided to all consortia responsible for the actual implementation of the E-ELT instruments. This paper presents the prototype motivation, its architecture, design and implementation.

Prototype main subsystems

The mock-up instrument, to be controlled, is a kind of multi-object (optical) spectrograph composed by the following main subsystems and components:

- One spectrographic arm with an ADC (Atmospheric Dispersion Corrector) and a dedicated CCD
- One imaging arm with a filter wheel and a dedicated CCD
- One calibration system equipped with a simple on/off lamp (e.g. Thorium-Argon lamp) and one characterized by a warm-up time required to reach the necessary stability (e.g. Deuterium lamp)

The skeleton of this prototype is representative of the components that we expect to be part of a real E-ELT instrument.

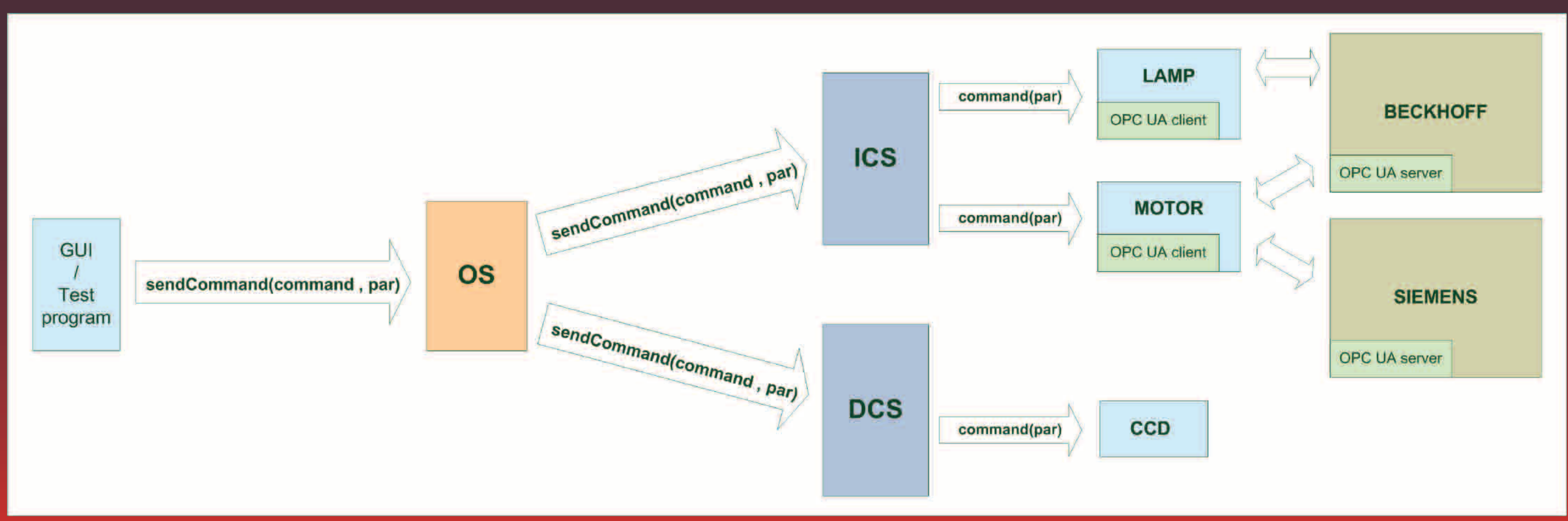
Functional requirements

We reused the work done both by ESO and INAF-OATs as part of the studies for the E-ELT Phase A instruments. Dedicated use cases were developed covering aspects like system/instrument start-up, simulation levels, handling of logs and errors and, typical of an astronomical instrument, handling of the acquisition, observation and calibration phases.

Software architecture

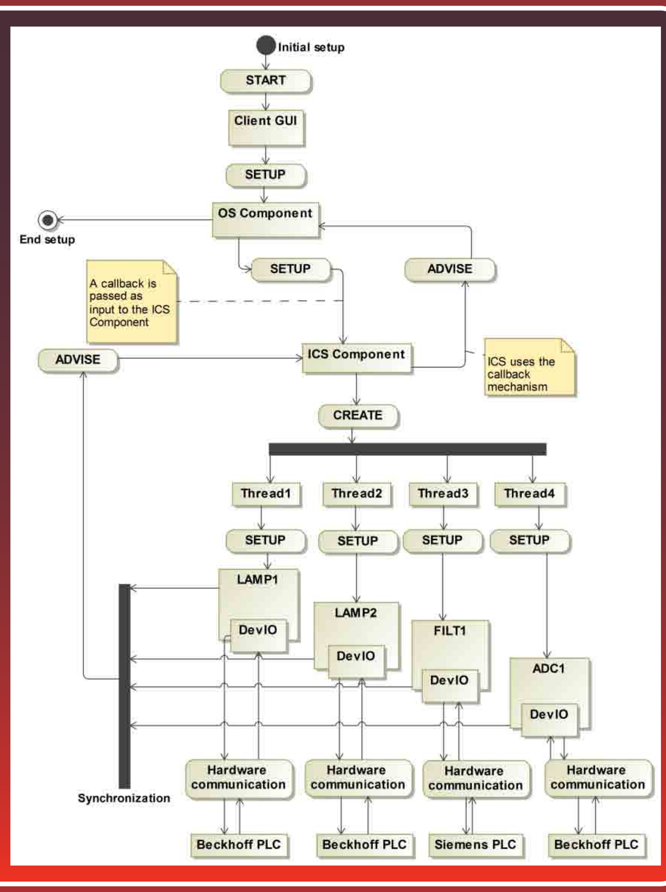
The baseline design for the prototype Control Software architecture follows a VLT-like approach. The overall architecture is composed by the following blocks/packages:

- **ICS (Instrument Control Software).** Low-level control package responsible for handling the vital part of the prototype (motorized devices and lamps)
- **OS (Observation Software).** High-level control package responsible for the coordination of activities of the detectors, low-level part and the telescope
- **DCS (Detector Control Software).** Responsible for controlling/handling all detectors



The prototype software infrastructure is based on the ACS (ALMA Common Software) framework. The ACS philosophy is to model the system as a set of collaborating components located inside one or more containers (Component/Container paradigm). In the current version of the prototype the following ACS C++ containers have been configured to host ACS Characteristic Components:

- **OS Container.** It hosts the OS Component
- **ICS Container.** It hosts the ICS Component
- **Device Container.** It hosts 4 device Components: LAMP1, LAMP2, FILT1 and ADC1
- **DCS Container.** It hosts the CCD Components CCDIMAG and CCDSPECTRO



OS and ICS General Characteristics

The system is designed and implemented to allow executing operations fully in parallel. At the subsystem level (ICS, OS, DCS), command/parameters pairs are received and the corresponding operations executed. Operations are non-blocking: at the OS level this is achieved via a callback mechanism. At the ICS level, a multi-threading paradigm is used. Parallel actions are handleld by separate threads and a thread join is used as a rendezvous point when all actions are completed.

Devices and OPC UA standard

Both ICS and DCS control hardware devices. Connection to the ICS PLC hardware is handled via OPC UA. The OPC UA is a platform-independent standard through which various kinds of systems and devices can communicate by sending messages between clients and servers over TCP networks. We implemented our own OPC UA client inside ACS by means of the ACS DevIO abstraction layer, using the OPC UA client provided by Unified Automation.

The devices controlled by ICS are:

- **LAMP1** - a simple on/off device physically controlled by a Beckhoff PLC
- **LAMP2** - a simple on/off device, with a warmp-up time, physically controlled by a Beckhoff PLC
- **FILT1** - a filter wheel with a certain number of discrete positions, physically controlled by a Siemens PLC
- **ADC1** - a rotational device physically controlled by a Beckhoff PLC

DCS controls the following devices:

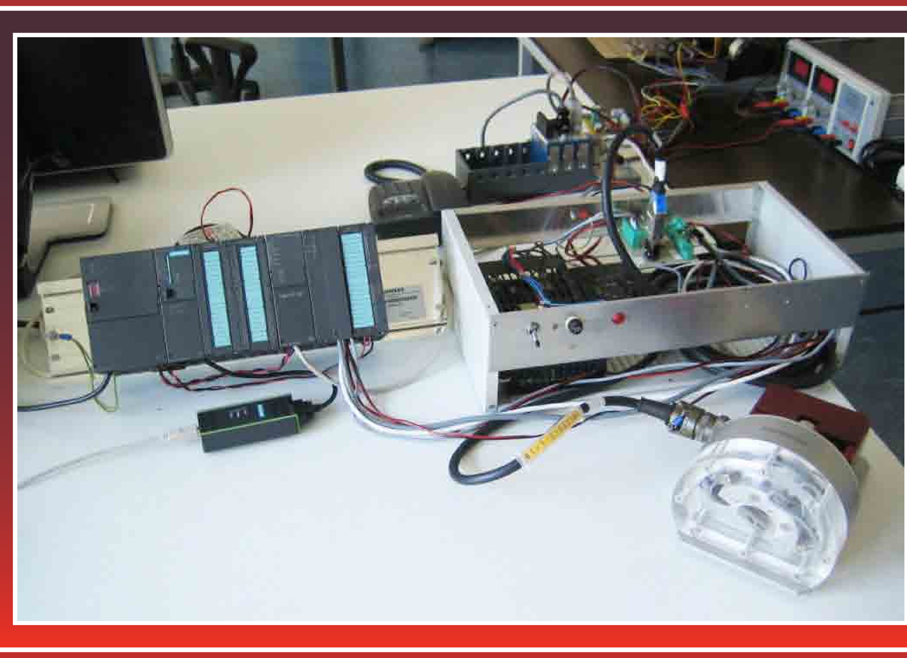
- **CCDImag** - implements the interface to a Finger Lakes Instrumentation CCD USB Camera
- **CCDSpectro** - implemented with dummy responses

Electronic architecture

Two complete hardware infrastructures have been set up at the the OATs laboratories:

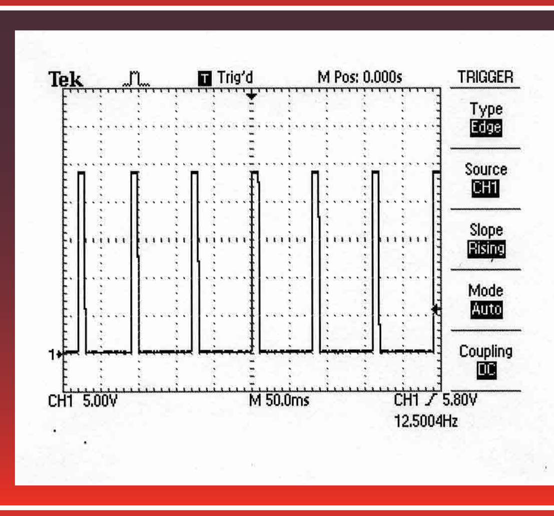
- **Beckhoff TwinCAT SoftPLC platform** - CX9000 family embedded system equipped with I/O modules (EL1002, EL1014, EL2004) and the AX5201 servo drive able to control the AM3022 brushless synchronous servomotor. The PLC software has been derived from the code developed for the ESO/VLT PIONIER instrument
- **Siemens S7-300 PLC platform** - Compact CPU (CPU 314C-2 DP) equipped with the FM354 Servo Function module able to control a custom made DC drive used in ESO/VLT instruments. Dedicated PLC code has been developed based on the Siemens FM354_354 block library

In both cases the same subset of process variables was exposed making the two platforms fully and transparently interchangeable.



Performance

Performance measurements have been done with a rotational motor connected to the Beckhoff platform (simulating an ADC). Its position depends on the coordinates of an astronomical object and must be continuously updated. A thread takes care of this and then two calls are made through OPC UA. The first call updates the target position; the second triggers the actual movement of the motor. Measurements were made by time stamping, within the ACS code, when the thread is entered, before the first OPC UA call and at the thread exit. At the PLC level, a physical output was mapped to the "move" flag and then sampled with an oscilloscope. Analysis of the measurements shows that most of the time is spent in the OPC UA communication. With our low-end CX9010 system and a 10 ms PLC cycle the average time between two consecutive thread calls is of the order of 80 ms. The actual measurements confirm that our prototype, even though based on a low performance device, is able to sustain cycles of the order of 10 Hz which is well within the requirements asked for our applications.



Conclusions

The main outcome of our work is that the selected technologies fulfil the imposed requirements and are feasible alternatives to implement instrument control software for the E-ELT. ACS strong points are the Component/Container paradigm, the transparent managing of the Component lifecycles, the DevIO interfaces and the various services offered by the framework which ease implementation (e.g. threads). The major strength in using OPC UA is the transparent hardware management. The prototype has shown that thanks to the ACS DevIO abstraction layer and a clever usage of the OPC UA standard, the overall system is unaware of the employed underlying technology/vendor products. Measurements show that performance achieved at the communication level are within specification for most astronomical requirements and therefore OPC UA, in perspective, could be further evaluated as an appealing technology to be employed for the future E-ELT instruments.

OSSERVATORIO ASTRONOMICO TRIESTE

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