XGCD July 28, 2025: Real-time Control

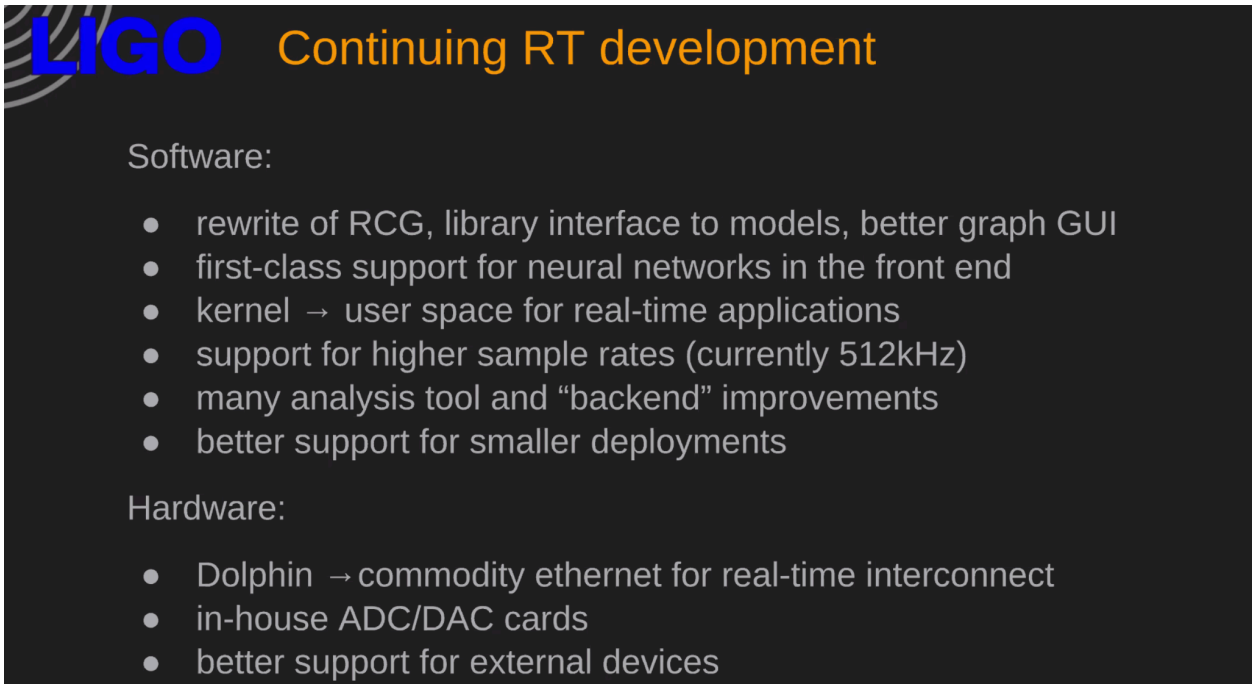
40 participants

Presentation by Jamie Rollins

Evolution of LIGO system with next generation facilities needs in mind

Overview of LIGO real-time control
Duncan – question about timing system, to be discussed later

Main improvements to the LIGO system:



In particular, way more flexible now – can support neural networks and user space library

Standalone configurations running in several labs around the world

Potential Challenges/new needs for XG:

- Longer arms – affect on ISC design?
- Faster loops?
- Possibility of incorporate FPGA-based control

Data delivery system for low latency under redesign

LIGO is overhauling of its stream processing and data distribution infrastructure, with the following goals:

- Focus on stream processing as primary for science goals.
- Lower latency data delivery.
- Modernize everything: use industry standard tools and protocols
- Unify data access methods: online/offline access with the same interface.
- Publish “derived” data streams that are immediately discoverable and accessible.
- Auto discovery of data, current and past, across all domains (federation).
- Lower barrier to entry: enable broader development of stream processing applications.

New architecture under development for low-latency, to be deployed for O5 — this is a LIGO thing only for now, but very relevant to LVK, discussion in progress

Data mesh - data management and distribution concept
Facilities can they manage their own data systems, but they need to agree on common protocols and interfaces for access,

Duncan Brown: commercial DAC/ADC so far? Yes (from General Standards), some development for in house DAC/ADC (by Daniel Sigg), mostly to reduce cost and support higher density of channels. Daniel Sigg: in-house DAC work, R&D project done, first batch of cards done, better noise performance as well; they have time receiver built in

Edwige Tournefier – faster loops? Which loops are you thinking about?
Daniel – 10 kHz, maybe 100 kHz as maximum

Presentation by Bas Swinkels

Instrument control – nice cartoon which shows different types of loops
Different groups came up with different solutions for digital control, opportunity to choose modern solutions

DAQ crates

- Most control hardware consist of some sort of 19-inch crate with plug-in boards
- Virgo does everything propriety:
  - DAQboxes from LAPP Annecy for detection electronics and auxiliary suspensions
  - Pisa DSPs crates for local control of main mirror suspensions
  - home-built slow ADC for temperature sensors
- LIGO uses mostly commercial solutions:
  - PCI expansion crates with commercial ADCs/DACs from General Standards
  - EtherCAT hardware from Beckhoff for slower controls (up to ~ 1kHz?)
- Other possibilities
  - MicroTCA: already used for Pisa DSPs, LISA phase-meter (Hamburg)
  - Commercial: NI/Dspace/SpeedGoat/MokuLab/…
    usually too noisy for critical applications
- My ideal:
  - commercially available open standard crate (no vendor/group lock-in), flexible to upgrade
  - commercial ADC/DAC/IO boards for non-critical signals
  - custom ADC/DAC/FPGA boards for the critical photodiodes/mirror actuators, possibly integrate ADC/DAC directly into analog front-end

Custom built ADC/DAC (Annecy) and DSP (PIsa)
Problem with some components being obsolete, some redesign to make spares

Timin system being redesigned at Nikhef

Real time computing elements

- FPGA for fastest computations:
  - main use at Virgo is digital demodulation of RF photodiode signals (400 MHz decimated down to 400 kHz, Nikhef's phasecam does 500 MHz down to 16 kHz)
- DSPs:
  - at Virgo used for all suspension controls
  - used in DAQbox for decimation (e.g. 1MHz down to 10 kHz)
  - handful of fast loops: laser frequency stabilization at 500 kHz (hand-coded assembler)
- Real-time PCs:
  - off-the-shelf fast Linux server with real-time kernel patches
  - control algorithms with arbitrary complexity
  - fast control loops need to run on single core!
  - typically runs at 10 kHz (64 kHZ at LIGO?), not sure if this can be scaled up a lot

We should not forget all of the monitoring tools and software needed to look at the data in the control room

Virgo → ET could be evolution of current hardware with some improvements, but not major breakthroughs needed

Possible areas of collaboration

- Requirements for ET and CE should be pretty similar
- Same hardware would be ideal, but not sure if possible due to preference/experience of engineers, availability on local hardware market and tendering rules. Still desirable to not reinvent the wheel and be flexible enough to exchange parts and technology
- Frame format, sample rates and distribution framework:
  avoid unnecessary conversions in common data analysis
- Real-time algorithm design interface: ideally most of the control algorithms can be exchanged, 'compiler' takes care of differences in hardware. Allows easier exchange of personnel between sites
- Similar SCADA system would allow easy exchange of tools for automation, data viewing, monitoring/alarming, channel/configuration databases …
- Agree on standards at IGWN level?

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Completely using the same hardware might be difficult as operating in different markets

Jan: criteria for selection of a new system, what are the critical features?

Duncan: this is basically the output of the current effort for CE

Daniel Sigg: you need to think at your software first – you don't want to use new hardware that requires the software to be redesigned, because it is harder to re-do the software than purchasing new hardware

Matt: nice to have a lot in common, but there are only a few things that we actually MUST have

Jamie: limitation is the rate at which data are accumulated (LIGO will be at 1/16s, Virgo will most likely be at 1s, but not really fundamental)

Ruslan: Is it reasonable to keep graphical interfaces?
Daniel: it is useful to have a graphical interface because many people can use it – this is very important

Ruslan: why don't stay with commercial solutions for ADC and DAC?
Daniel: having only one vendor is a liability, cost also an issue, not really a lot of development;

Duncan Brown: is ET thinking about milestones of the digital system for the construction process?

Agree on writing a sort of white paper which says what are the things that CE and ET must agree upon, and what would be nice to have (for example common software tools, example guardian code that was deployed in Virgo) – Jamie and Bas will take the lead on this.