Collaborative Data Collection with BLU-ICE

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Overview

Architecture of the Distributed Control System
- Life cycle of a DCS message.
- Collaboration features.

Hybrid Software Development Strategy
- XOS library for platform-independent C/C++ code.
- Tcl/Tk for platform independent GUI development.

Users’ Favorite Features in BLU-ICE
- GUI focuses on the experiment.
- Simple data collection set up for advanced MAD experiments.

Scripted Devices
- All operations may be scripted in BLU-ICE.
- Same scripts may be run within the DCS server.
- Supports virtual motors with parent-child relationships.
Architecture of the Distributed Control System

- A single server process per beam line centralizes control.
- Multiple hardware servers are hosted on same or different computers.
- Multiple user interfaces can be started at beam line, in staff offices, and at remote locations.
- All user interfaces are kept synchronized and prevented from sending conflicting instructions.
Life Cycle of a Motor Control Command

- User issues a move command for a specific motor (e.g. phi).
- DCSS receives command and forwards it to the DHS responsible for the motor of interest.
- DHS handles the communication with the hardware controller.
- Motor begins motion.
Response to Control Command

- DHS monitors motor position and sends position update messages to DCSS.
- DCSS receives these messages and forwards the new motor positions to all user interface clients.
- All users see current motor position changing in real time as it moves.
- The motor position updates from DHS continue until the motor stops moving.
Portability of High Performance C/C++ Server Processes Based on Cross-Operating System (XOS) Library

Supports multithreaded, distributed programs
- Much simplified TCP socket object for rapid network application development.
- Thread creation and synchronization with mutexes and semaphores.
- Memory mapped files.
- Interthread communication.

Portability
- Compile code on Digital Unix, IRIX, OpenVMS, 32-bit Windows.
- Easy to port to new platforms similar to any of the above.

Compile-time approach
- Header file xos.h loads appropriate, system-dependent include files
- Native system calls on each platform for maximum performance
- No runtime overhead for platform independence

Reliability
- Simpler APIs for more reliable code.
- Less need to study different platforms.

New C++ version under development
- Object oriented, STL based, with error handling via C++ exceptions.
- Cross-platform user authentication and permissions-based file I/O.
- Generalized communication streams for uniform network communication, interthread messaging and file I/O with transparent encryption, compression, etc.
- Cross-platform, cross-vendor, database interface.
Tcl/Tk Features Are Key to the Development of BLU-ICE

Platform Independent
- Tcl/Tk runs on any Unix, VMS, Mac, and 32-bit Windows computer.
- Scripts can also be bundled with Tcl/Tk binaries.

Rapid Development
- Required only a fraction of the code necessary if written in C, C++, or Java.
- Easy maintenance critical at the beam lines.

Object Orientation
- The [Incr Tcl] extension to Tcl provides object-orientation.
- Migration to [Incr Tcl] is simplifying the BLU-ICE code.

Active Canvas
- Binding of events to canvas objects facilitates highly graphical, very interactive user interfaces.

Event based concurrency
- Much simpler than multithreading models for GUI development.

Command Prompt with Scripting
- Command prompt and a full featured programming language for scripting.
- User can script any operation in BLU-ICE using control structures, variables, procedures, file I/O, even classes.

Extensible in C/C++
- Tcl was designed to be extended readily in C. Extensions can be loaded dynamically.
- High performance code, multiple threads and so on are best implemented in extensions.
Extending the GUI Building Philosophy to Support Users
Collaborative Data Collection Control with BLU-ICE

Intuitive MAD Data Collection
- Multiple runs can be defined and started together.
- Supports multiple energies, inverse beam, and wedges.

Run Sequence Preview
- Lists details of data frames to be collected for each run.
- Changes as data collection parameters are edited.

Robust Pause/Restart Capability
- Data collection may be paused at any time.
- Next frame to collect may be selected in sequence window.

Supports Multiple Instances
- Multiple instances of BLU-ICE may monitor data collection.
- All instances show run definitions being edited.
- New diffraction images are displayed on all instances.
- Data collection continues even if all BLU-ICE instances exit.
Example Scripted Device: TABLE_VERT

proc table_vert_move { new_table_vert } {

    # import device variables
    variable table_pitch

    # move the two motors
    move table_vert_1 to [ table_vert_1_calculate $new_table_vert $table_pitch ]
    move table_vert_2 to [ table_vert_2_calculate $new_table_vert $table_pitch ]

    # wait for the moves to complete
    wait_for_devices table_vert_1 table_vert_2
}

proc table_vert_1_calculate { tv tp } {

    # import device variables
    variable table_pivot
    variable table_v1_z
    variable table_pivot_z

    # calculate position of table_vert_1 given vertical height and pitch
    return [ expr $tv + ( $table_v1_z - $table_pivot_z ) * tan ( [ rad $tp ] ) ]
}
DCSS Scripting Engine: Server-side Motion Control Scripting

Scripting capability of BLU-ICE embedded in DCSS
- [Incr Tcl] interpreter executes as one thread within DCSS.
- Interpreter runs the non-GUI portions of BLU-ICE.
- Scripting Engine can run any scripts developed within BLU-ICE.

Scripting Engine connects to DCSS core twice
- Once as a Hardware Server serving “Scripted Devices.”
- Once as a “User Interface Client.”

Scripted device command routing
- Request for a move of a scripted device is routed to the Scripting Engine hardware server interface.
- Scripting Engine runs a script that issues move requests for the child motors.

Children motors may also be scripted devices with their own children!
Response messages flow backwards.

- Real-motor position updates go to all User Interface clients.
- Scripting Engine runs scripts that calculate new position of the Scripted Device and sends updates to DCSS Core.
- DCSS Core forwards the updated Scripted Device positions to all User Interface client.
- BLU-ICE gets a continuous stream of updated positions for both real motors and scripted devices.
- System works recursively, handling nested Scripted Devices.

Possible Uses for Scripted Devices Unlimited

- Sophisticated device control with many intermediate states.
- Complex limit checking for collision avoidance.
- New data collection schemes.
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