Component-Based Design of Embedded Control Systems

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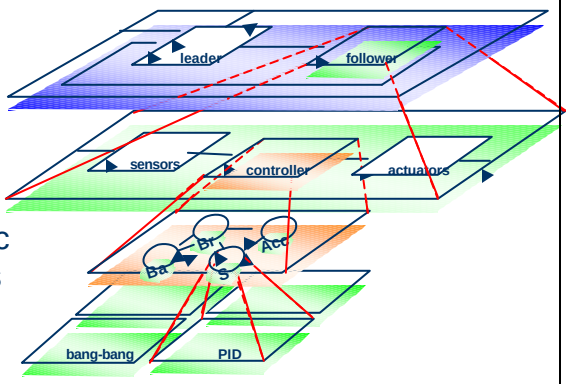
Hierarchical, Heterogeneous Modeling and Design

A model of computation governs the interaction of components at each level of the hierarchy. A submodel exposes a domain-polymorphic interface that governs the inter-domain semantics.



Ptolemy II

Ptolemy II –

- Java based, network integrated
- Many domains implemented
- Multi-domain modeling
- XML syntax for persistent data
- Block-diagram GUI
- Extensible type system
- Code generator on the way

http://ptolemy.eecs.berkeley.edu

Domains Status

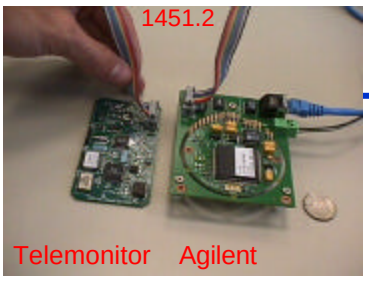
- Domains we understand well:
  - Dataflow
  - Process networks
  - CSP
  - Discrete events
  - Continuous time
  - Synchronous reactive
  - Finite state machines
- Domains we are working on:
  - Publish & subscribe
  - Time triggered

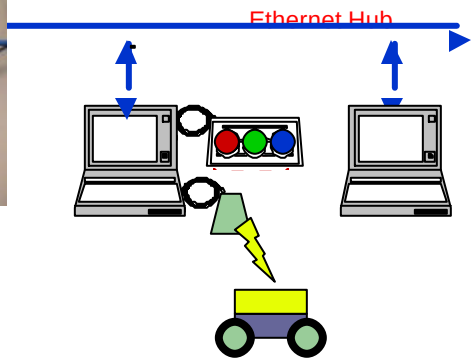
Our focus is particularly on how these domains support real-time QOS

Concept Demonstration

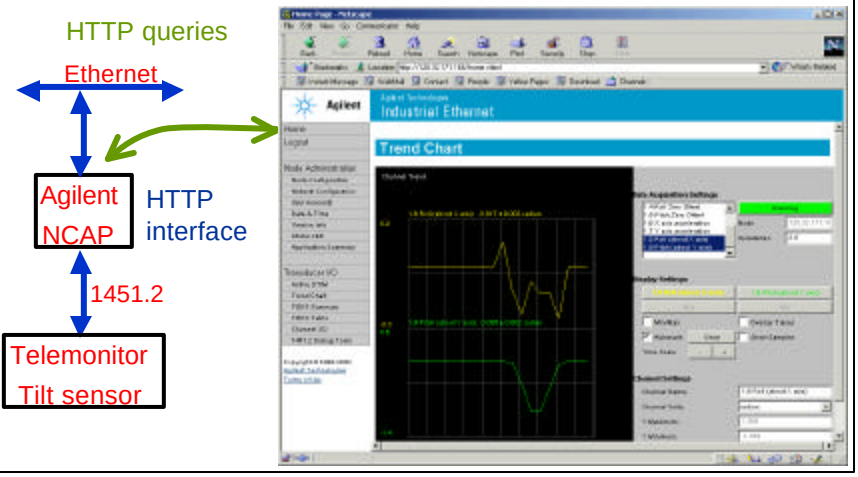
- Networked sensors and actuators
- Multiple, networked controllers, controllees
- Hierarchical, heterogeneous design
- Domain polymorphic components
- Discovery
- Mutable systems

Experimental Setup

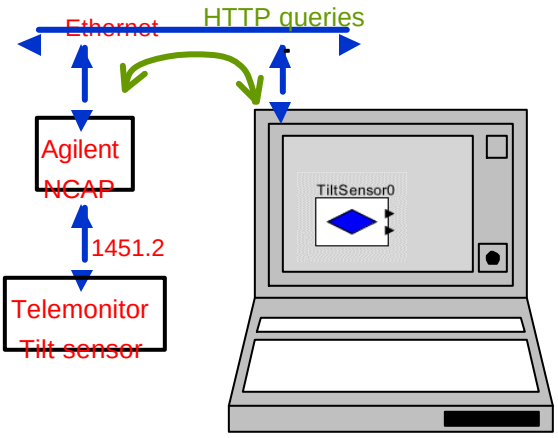




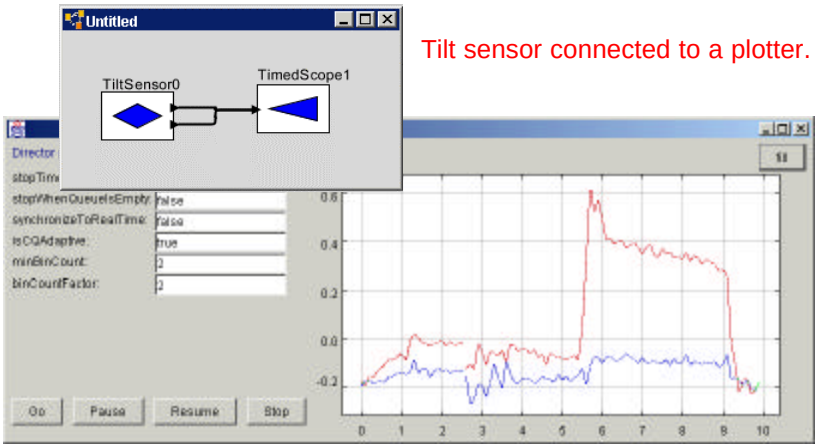
Networked Smart Sensors



Abstraction of the Sensor as a Software Component



Smart Sensor + Ptolemy II

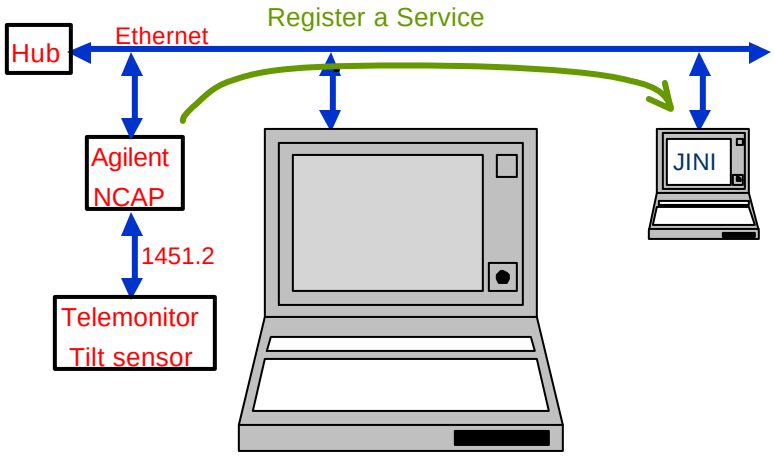


Tilt sensor connected to a plotter.

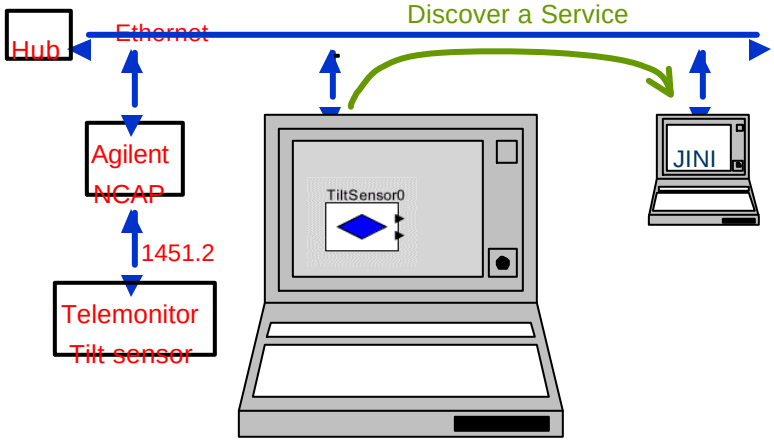
Issues Raised

- Concurrency management with I/O
  - Separate thread handles communication
  - Rendezvous with computational thread
  - How to maintain time consistency?
  - How to ensure no deadlock?

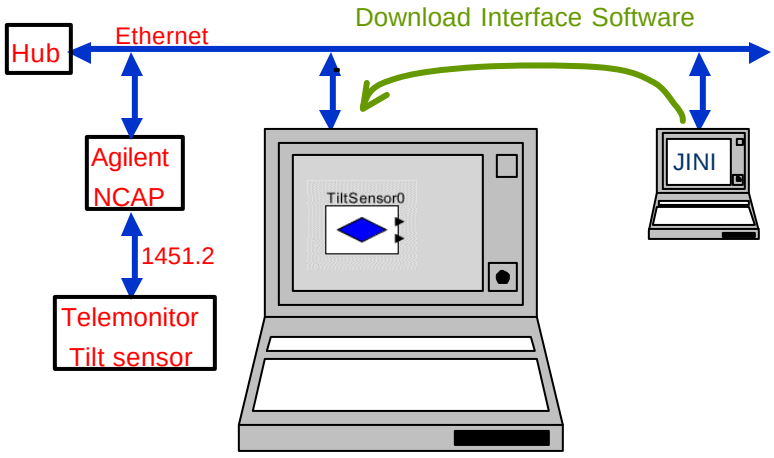
Planned - Discovery



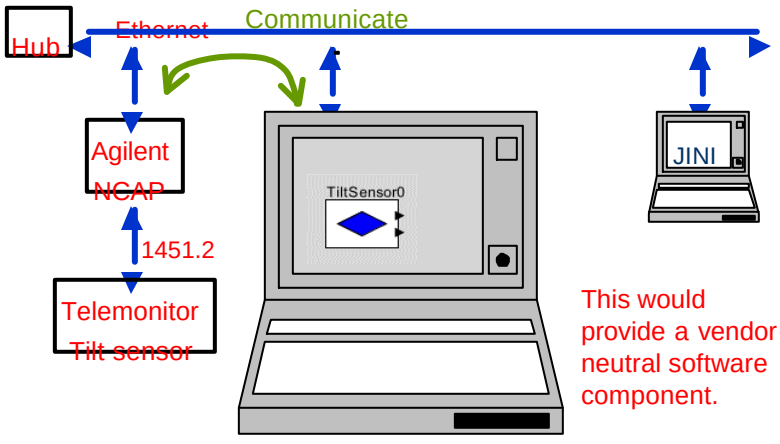
Planned - Discovery



Planned - Discovery

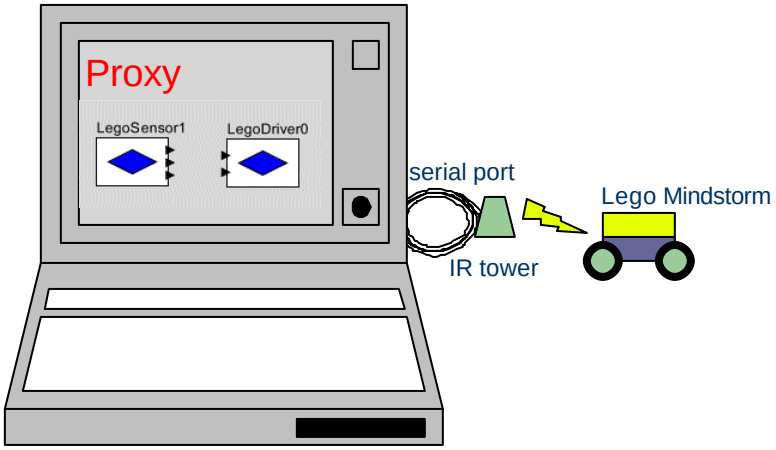


Planned - Discovery

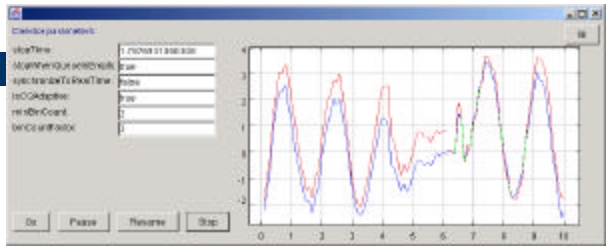


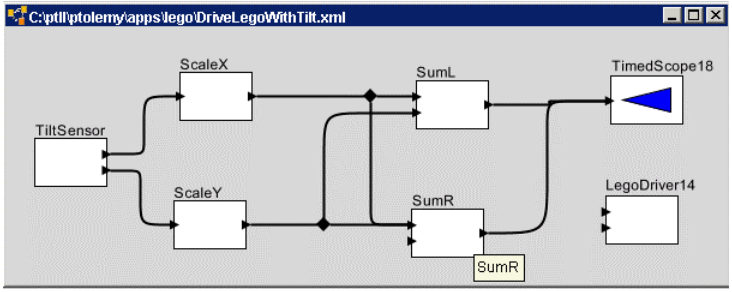
This would provide a vendor-neutral software component.

Actuator Setup



Linking the Tilt Sensor and Actuators





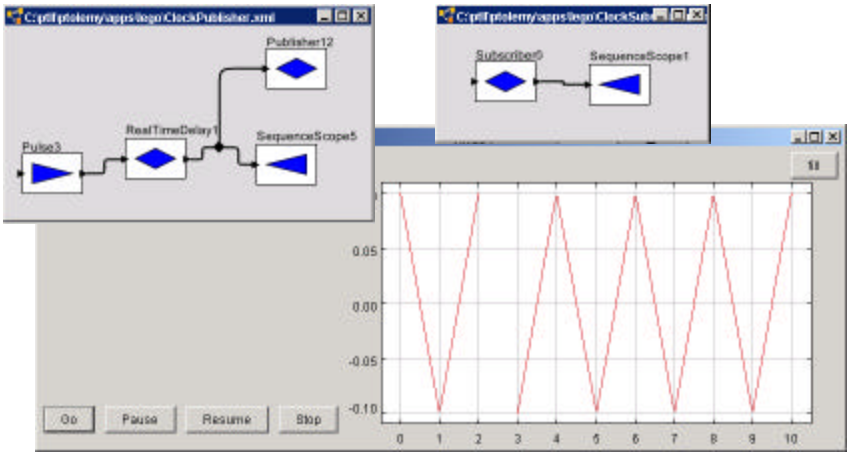
Mutations – Dynamic Structural Changes to the Model

- Thread-safe Ptolemy II kernel
  - Mutual exclusion protocol in the Workspace object.
- Domains control when mutations are committed.
  - Mutations are queued with the Manager object.
  - Manager executes mutations between *iterations*.
  - Meaning of "*iteration*" is domain-dependent.
- In this example:
  - The event thread in the UI queues mutation requests
  - The executing model commits the mutations at safe points.

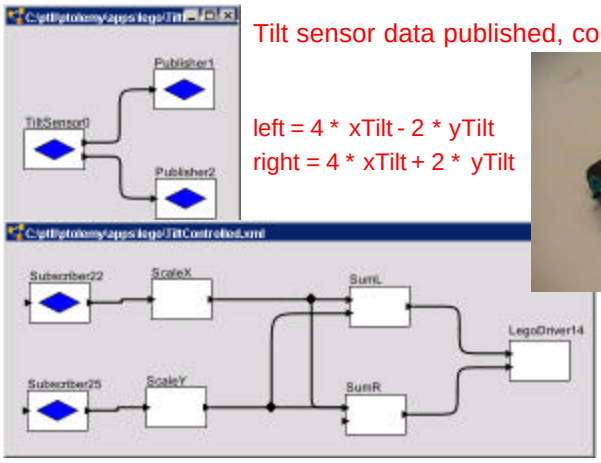
Publish and Subscribe

- Use Jini to discover the publish/subscribe fabric.
  - Our current realization returns a JavaSpaces interface.
  - Future realization will use OCP
- Real time
  - Prioritized delivery, handling
  - QOS is not part of JavaSpaces.

Clock Publisher/Subscriber



Distributed Lego Controller



Tilt sensor data published, controller subscribes.

left = 4 * xTilt - 2 * yTilt
right = 4 * xTilt + 2 * yTilt

Other Examples We Have Implemented

- Other Lego models:
  - Modal controller for navigation
  - Feedback of sensor data
- Hybrid systems:
  - Car tracking example
  - Helicopter multi-modal controller
- Pioneer robot control
  - Multi-agent coordination
  - Jini discovery of robots
  - Publish-and-subscribe task distribution

Styles of Publish and Subscribe Interactions

- time stamped events?
- globally time stamped?
- reliable delivery?
- ordered delivery?
- signal coordination?
- synchronous delivery?
- blending of multiple publishers?
- dynamic redirection/resourcing?
- persistence?
- history?

A Key Idea

- We need a variety of interaction mechanisms.
- In the prototype,
  - Jini delivers an interaction mechanism service by delivering code that realizes that interaction mechanism.
- A "meta OCP" could similarly deliver any of several interaction mechanisms.

Example 1

- Component says:
  - "I need a reliable stream-based delivery mechanism to get sampled data from here to there."
- Meta-OCP says:
  - "OK, here's some code for you and the recipient of your data."
- Delivered code uses TCP/IP and sockets, bypassing any central infrastructure.
  - E.g., Transporting audio data.

Example 2

- Component says:
  - "I need a shared data repository visible to a number of components."
- Meta-OCP says:
  - "OK, here's some code for you and the recipient of your data."
- Delivered code interacts with a Linda-style tuple space.
  - E.g., reading the current temperature from a sensor.

Example 3

- Component says:
  - "I need to send time-stamped data that must be delivered and dealt with within 3 msec."
- Meta-OCP says:
  - "OK, here's some code for you and the recipient of your data."
- Delivered code interacts with TAO.
  - E.g., deliver motion control data.

Next Steps

- OCP integration
- Define publish and subscribe semantics
- Discovery of sensor/actuator services
- Abstraction of sensor/actuator services
- Real-time QOS
- Time-driven domain (Masaccio)
- Multi-robot coordination
- Improved UI (particularly to help debugging)

The Demo Builders…

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