CHESS
CENTER FOR HYBRID & EMBEDDED SOFTWARE SYSTEMS

COLLEGE OF ENGINEERING, UC BERKELEY

From PTIDES to PtidyOS: Programming Distributed Real-Time Embedded Systems

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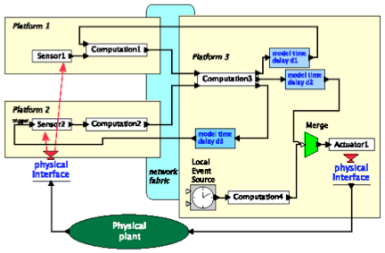
Distributed Real-Time System Implementation



Programming Model

Programming **T**emporally **I**ntegrated **D**istributed **E**mbedded **S**ystems

Based on Discrete-Event semantics

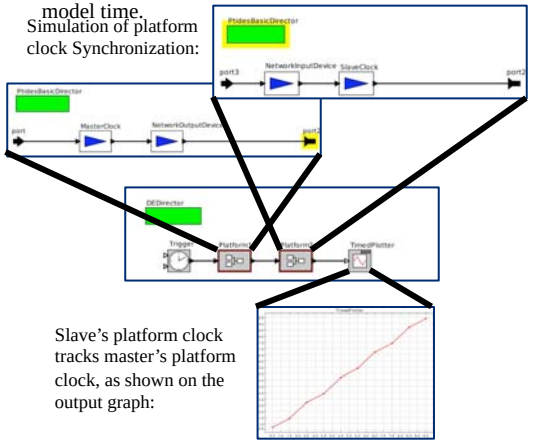
Event processing in time-stamp order

Clock Synchronization Simulation

Notions of Time:

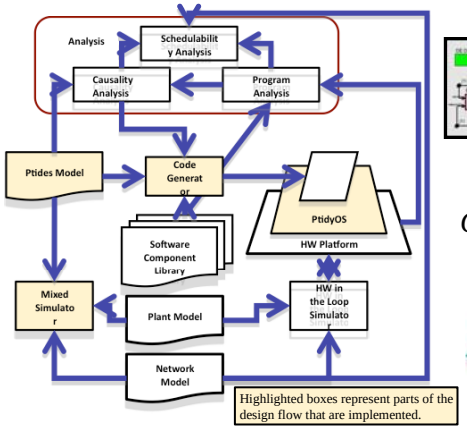
- Top level simulate real world (oracle) physical time.
- Each platform contains a clock to keep track its notion of platform physical time.
- Each Ptides director has a notion of model time.

Simulation of platform clock Synchronization:

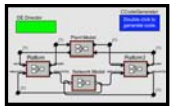


Slave's platform clock tracks master's platform clock, as shown on the output graph:

Ptides Design Flow



Highlighted boxes represent parts of the design flow that are implemented.



Code Generation

Ptides Simulator

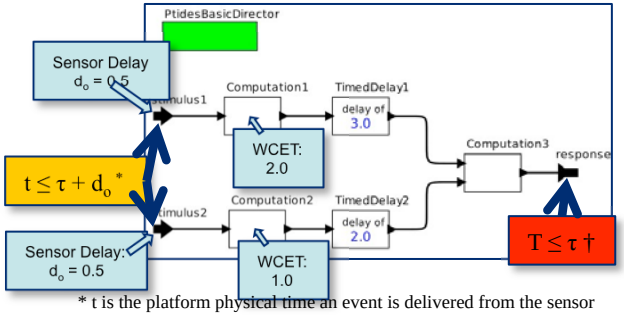
Simulate functional and real-time properties.

Function simulation :

- Same denotational semantics as DE simulation, i.e., Same functional outputs whether Ptides or DE Director is used.
- Performs safe-to-process analysis instead of DE simulation
- Currently support 2 Ptides execution strategies: Basic, PreemptiveEDF (combines Ptides with Earliest-Deadline-First).

Real-time simulation:

- Users annotate WCET and sensor delays.
- Check for deadline misses at actuators.



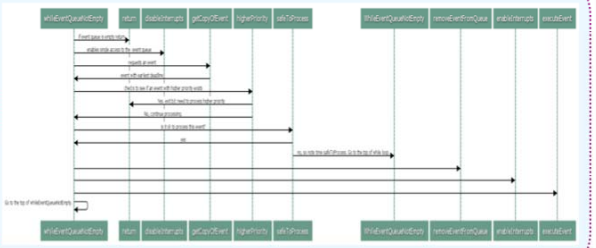
* t is the platform physical time an event is delivered from the sensor to the rest of the platform. τ is the timestamp of the sensor event.

† t is the platform physical time an actuation event is delivered to the actuator. τ is the timestamp of the actuation event.

PtidyOS

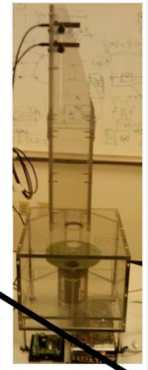
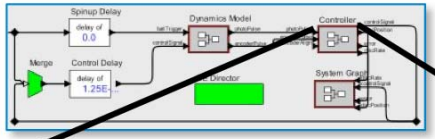
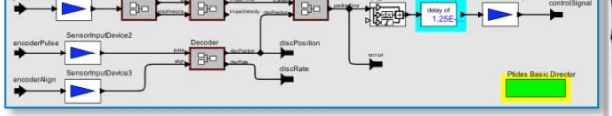
- Is a library linked against application C code.
- Implements Ptides semantics
- Local execution strategy includes a safe to process analysis and resource scheduling layer.
- Uses a Single Stack
- Steps away from threading model
- To ensure event of highest priority is always processed first, interrupts play an important role:
  - Event processing is done within Interrupt service routines
  - Reentrant interrupts
- No dynamic memory allocation.

Event Processing Algorithm Sequence Diagram



***The use of a single stack and interrupts for mutual exclusion was done in TinyOS. PtidyOS uses these concepts and introduces time semantics.**

Application: The Tunneling Ball Device

- Cyber-physical system with real-time constraints
- Event-driven signals (motor encoding, object detection)
- Parallels an automotive engine control unit (ECU)
- Timed semantics ensure:
  - Deterministic control delay
  - Data associated with the same physical time are processed together

- Balls drop above a rapidly spinning disc
- Device must adjust disc to allow ball to pass through a small hole, without stopping disc