Modeling the Implementation of Stated-Based System Architectures

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

Peter H Feiler
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State-based Systems Are Everywhere

What is a state-based system
  • State: discrete, continuous, large, small
  • State transition: change, delta, command, event
  • Transition conditions & actions

Types of systems
  • Control systems
  • Autonomous systems
  • Communication systems
  • Resource management systems

What do they do
  • Communication of state
  • Coordination of state
Voluminous State Systems

State of physical environment
  • Example: Tracking of object close to space station

Communication of state
  • Series of state transmissions vs. sequence of change transmissions
  • Data stream perspective
    – State: High data volume, incomplete stream ok => tolerant to transient transmission failures
    – State change: low volume, complete stream critical => requires guaranteed delivery

AADL Modeling
  • Sampling of data ports for state vs. queuing event data ports for state change
  • Data stream & protocol QOS properties
  • Deployment to hardware

Fail-safe operation by mixing state & deltas
Embedded Control Systems

Observe and affect state of physical systems

Continuous time state
- Time sensitive data
- Setpoints in absolute vs. relative terms (state vs. delta)
- Periodic sampling of state
- Up/down sampling of data stream across harmonic tasks
- Ordering of send & receive, write/read patterns => frame-level jitter in data stream
- Missed sample => aged data

AADL Modeling
- Data ports & periodic threads
- Devices as sensors/actuators
- Input-Compute-Output model (data consistency)
- Deterministic sampling patterns (immediate, delayed)
- End-to-end flows

Shared variables vs. port-based flow architecture

Time sensitivity of state impacted by scheduling & sampling communication
Embedded Discrete State Systems

Examples

- Hybrid control systems
- Systems with operational modes
- Discrete state observations in periodic systems

Left leader
Right leader
Dual operation
Sampled Processing of Discrete State Systems

Coordinated state transitions
- Hand shaking protocols
- Replicated distributed state machine

Discrete states in control system
- Predictability of periodic task loads
- Sampled observation of events & binary states due to truth tables & Simulink
- Non-deterministic sampling leads to missed event/state change observations

Mirrored state machines
- Watch for external transition events vs. successful state change of “fraternal twin” (fail-safe)

AADL Modeling
- Events vs. sampling of states
- Modes & synchronized mode transitions
- Failure propagation modeling
Adaptive Systems

Workloads & service levels
- Supervisor
- Observes workload (global system state)
- Controls subsystem service level (assignment of resources)

Service levels as state machines
- Fully connected state machine (goto service level X)
- Linear progression through service level (Increment/decrement request)

Communication of service request
- State change requests: sampled commands => repeated action
- Target state: repeated transfer ensures fail-safe sampling
- Coordinated state transition => transient transition period

AADL Modeling
- Modes & transitions
- State as shared variables vs. communication through data ports
- Deployment, resource capacities & budgets

Fail-safe operation by periodic sampling of target state
Autonomous Systems

Multi-layered interacting state machines

- Presentation Layer
  - Operator interface and tools
  - Human decisions & planning
  - Longest time-scales

- Planning Layer
  - Deliberative planning
  - Long time-scale control loops
  - Applies alternate tactics
  - Progressive problem escalation

- Execution Layer
  - Executes plan on intent timeline
  - Monitors goal achievement
  - Detects control failures
  - May handle some contingencies

- Control Layer
  - Achieves goals
  - Highly reactive behavior
  - Short time-scale control loops

Goal monitoring for early transition failure detection

Goal networks drive controller target states

Operational commands as controller modes

State variable based design of flow-based system

Time sensitive control loops

Discrete state & event observations

Component vs. task hierarchy
Hierarchical AADL modes
Reusable reference architecture
Summary

What matters about the state behavior

- Large vs. small state
- Continuous time vs. discrete state
- State vs. state change
- Absolute vs. relative reference points
- Target state vs. action steps of transition path
- Identical vs. mirrored distribution of state machine

What matters about implementation

- Sampling vs. queued events & message
- Determinism of sampling
- Guaranteed & ordered delivery
- Ports & shared data
- Fail-safe replication, distribution, mirroring
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