On Real-Time Requirements in Specification-Level UML Models

Risto Pitkänen and Tommi Mikkonen
Tampere University of Technology
Finland
{risto.pitkanen,tommi.mikkonen@tut.fi}

Motivation for high-level modeling
- Abstraction is a powerful thinking tool
- High-level models
  - Better grasp of system as a whole
  - Early validation and verification
- Real-time systems should be no exception
- Inherent behavioral complexity
- High-level facilities for expressing time-related issues largely missing from UML

Use cases
- Requirements/specification level modeling in UML
  - E.g. Unified Process
- Serious handicaps from the point of view of real-time specification:
  - Use case interaction is not supported
  - Use case A cannot require that use case B has been executed
  - No explicit time constructs

Our approach: joint action

Formalization of use cases
- Catalysis [D'Souza and Wills 1999]
  - Use case = joint action
  - Joint actions originate from DisCo

action assign_mentor(subject: Instructor, watchdog: Instructor)
post subject.mentor = watchdog and
let ex_mentee = watchdog.mentee@pre in
ex_mentee <> null ==> ex_mentee.mentor = null

Layered Action Diagrams (LADs)
Properties of LADs

- Simple LADs are superposed onto each other to form a total system
- Aspect-oriented structuring of a model
- Semi-executable:
  - Generate all joint action instances whose preconditions hold true in present state
  - Pick one, modify participant states such that postcondition becomes true

Extending LADs with real-time issues

- LADs provide a suitable high-level modeling formalism also for real-time systems
- We want to be able to express real-time dependencies between joint actions
- Aim: easy and natural formalization of requirements such as “When gas valve is opened, it must be closed within 5 seconds unless the burner is ignited successfully.”

Generalized Railroad Crossing (GRC)

- System controls gate at a railroad crossing

**Requirements:**
- **Safety:** Whenever there is at least one train in the crossing, the gate must be down.
- **Utility:** When there is no train in the crossing, the gate must be raised within a reasonable time.

Real-time semantics

- Global clock Omega, typed Real, initialized to 0.0.
- Initially empty set Delta of deadlines.
- In each joint action, an implicit parameter now: Time.
- Each joint action has an implicit precondition
  - now <= Omega and now <= Delta - minimum_deadline()
- and an implicit postcondition
  - Omega = now@pre
- In effect, this causes time to grow monotonically never exceeding the minimum deadline currently in Delta

GRC with LADs: Trains

Semantics of a real-time constraint
Another way of putting it

A records minimum separation and deadline in common per/qpair

B checks minimum separation

C adds deadline to Data

(not remember that time cannot proceed beyond minimum deadline)

Controller

Validation and Verification

- Either theorem proving (using TLA) or model checking (timed automata) can be used for verification and validation
- An equivalent GRC DisCo model has been model checked using the Kronos tool after mapping it to timed automata
- Theorem proving applies to generic models, model checking currently only to specific instances (e.g. two trains)

Conclusions

- Successful application of earlier RT modeling results and techniques in a UML profile based setting
- New approach for expressing real-time requirements for formalized use cases (joint actions)
- Real-time constraint associations
- Methodological and notational support for separating real-time issues from the underlying control logic