CS780 Discrete-State Models

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Office hours: Mon,Wed 3-5 pm

Today:

Introduction & Overview

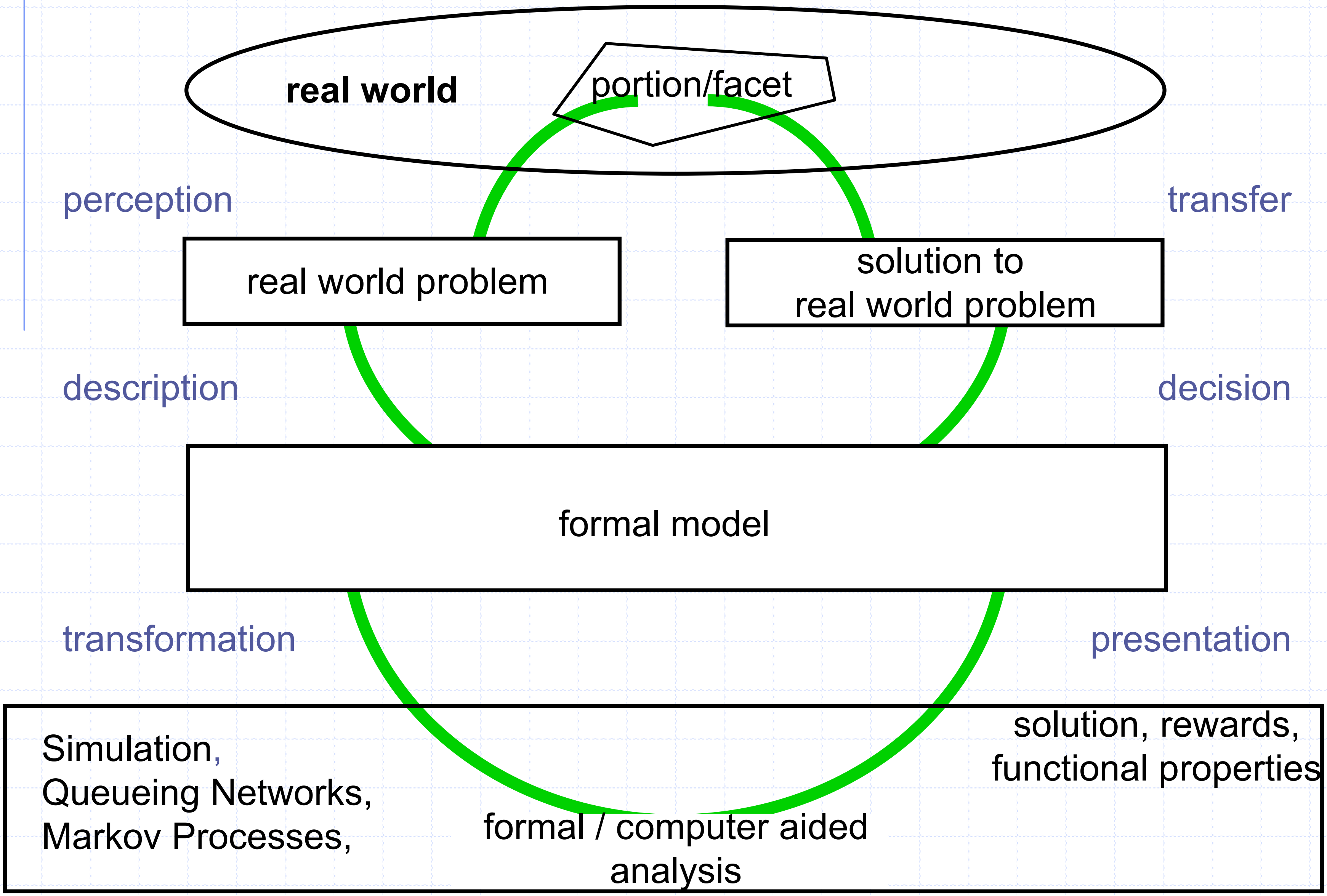
Quick Reference: (Handout)

Yu-Chi Ho, Introduction to special issue on dynamics of discrete event systems

Proceedings of the IEEE

Volume 77, Issue 1, Jan 1989 Page(s):3 - 6

Model-based Analysis of Systems



Overview – this is the plan

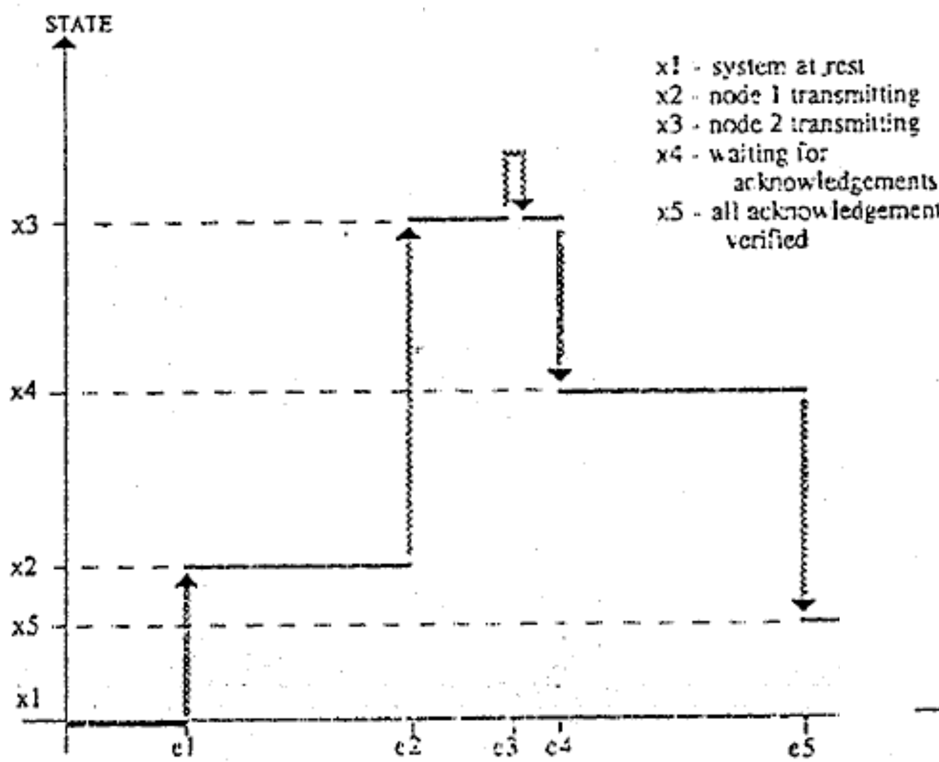
- CVDS vs DEDS
- Modeling formalisms
  - Automata, Stochastic Automata, Weighted Automata
  - Process Algebra: CCS, PEPA
  - Petri nets, GSPNs, Stochastic automata networks
  - …
- Composition operations:
  - Action sharing, State Variable Sharing, Message passing
- Analysis:
  - Simulation
  - State space exploration:
    - Explicit, Symbolic ,… with corresponding data structures
  - Modelchecking:
    - Logics: LTL, CTL, CSL, … with corresponding algorithms & ds
  - Performance analysis, dependability analysis
    - Simulation, Numerical solution of Markov chains
  - Reduction & Comparison
    - Bisimulations of various kinds, lumpability

Tools:
- Mobius

Discrete Event Systems vs Continuous Dynamic Systems

- Dynamic System: changes over time
- Continuous Variable Dynamic System (CVDS):
  - System state changes gradually as time evolves
  - Well described by differential equations
  - Well Established across a number of disciplines and used for describing dynamics in the physical world
- Discrete Event Dynamic System (DEDS):
  - Abrupt, discontinuous changes of a system state happen due to occurrences of events
  - Various formalisms, notations, modeling techniques, methods and tools …
  - Wide area of applications, mostly applied to man-made systems
    - Computer science
    - Engineering: Manufacturing and production systems, logistics
    - Biology

Graphics from Ho: DEDS vs CVDS



e1 - message 1 received;
e3 - repeat message ;
e5 - acknowledgements received;
e2 - message 2 received;
e4 - transmission complete
e6 - shut down system

Fig. 1. Example of a DEDS trajectory

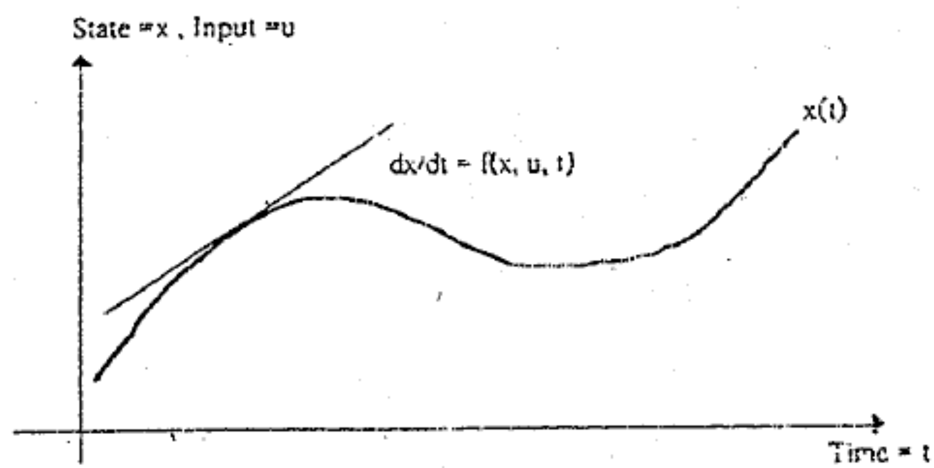


Fig. 2. Example of a CVDS trajectory.

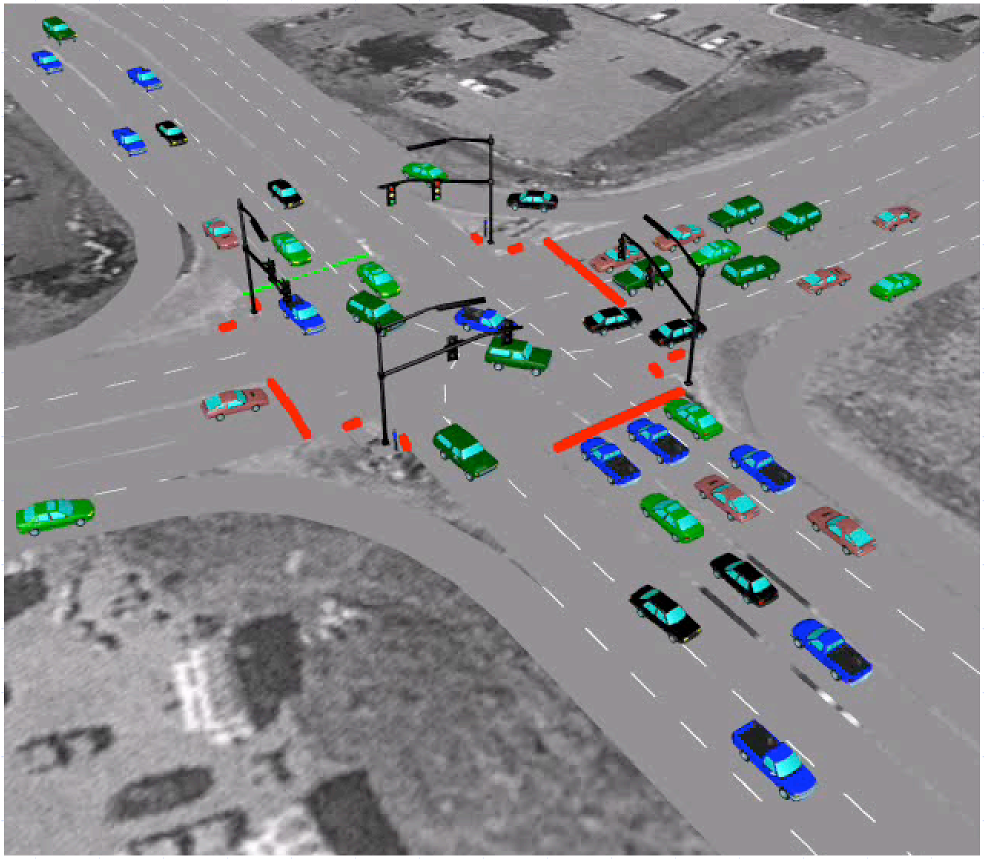
Modeling desiderata for DEDS according to Ho

- Discontinuous Nature of Discrete Events
- Continuous Nature of most Performance Measures
- Importance of Probabilistic Formulation
- Need for Hierarchical Analysis & Structure
- Presence of Dynamics
- Feasibility of Computational Burden
- Need for Experimental and Theoretical Components

DEDS

- Untimed, qualitative behavior
  - Possibility of certain states or sequences of events
  - Equivalence among models, e.g. spec and implementation
  - Emphasizes "state sequence", ignores "holding times"
  - Interested in "correctness" issues
- Timed behavior
  - Interested in Performance/Dependability/Reliability/Availability issues
  - Integrates time into behavior
  - Deterministic or Stochastic

DEDS or CVDS ???



Overview – this is the plan

- CVDS vs DEDS
- Mobius
- State Space Exploration
- Modelchecking
- Process Algebras
- Equivalence, Bisimulation, Reduction
- Weighted Automata
- Stochastic Automata
- Numerical Analysis of Markov chains
- Simulation
- Trace Analysis
- Runtime Verification

Tools:
- Mobius

Mobius

- Multiformalism - Multisolution Framework
- Formalism
  - Automata
  - Stochastic Activity Networks
  - Stochastic Process Algebra
  - Fault Trees
- Composition
  - Sharing state information:
    - Hierarchical/Tree-type: Rep-Join Mechanism
    - Graph
  - Action sharing, synchronization of events
- Analysis
  - Simulation
  - Numerical solution of Markov chains

State Space Exploration

- Explicit
  - Exact, straight forward
  - Approximative: Bitstate hashing, supertrace method
- Symbolic
  - Decision diagrams of various kinds
    BDDs, MTBDDs, MDDs, EVDDs, …
- Kronecker representations
  - Modular, hierarchical

Modelchecking

- According to data structure that represents state space
  - Symbolic data structures
  - Kronecker representations
  - Explicit, …
- According to the formal description of the property of interest:
  - Modal logic

    LTL: Linear time logic

    CTL: Computational tree logic (a branching time logic)

    CTL*

    CSL: Continuous stochastic logic

Equivalence, Reduction

- Bisimulations of various kinds
  - Strong bisimulation
  - Weak bisimulation
  - Inverse bisimulation
  - Exact Lumpability
  - Ordinary Lumpability
  - …
- For particular formalisms
  - Process algebras like CCS, PEPA, …
  - Automata with action synchronisation
- Wrt to quantitative information
  - Stochastic Automata, Markov chains
  - Weighted Automata

Analysis of Stochastic Models

- Numerical analysis of Markov chains
  - Steady state analysis
    - Algorithms: Power method, Jacobi, GS, CGS and projection methods, …
    - Data structures:
  - Transient analysis
    - Algorithms: Randomization
- Data structures
  - Symbolic representations: MTBDDs, MxDs, …
  - Kronecker representations
- Formulation of measures of interest
  - Rate rewards
  - Impulse rewards
  - Path-based rewards
  - Terms of a stochastic modal logic like CSL
- Discrete event simulation

Analysis based on the observed behavior

- Discrete event simulation
  - Single and long run to produce set of samples
  - Many separate independent runs to produce set of samples
  - Statistics based on sampled "observations"
- Trace analysis
  - Evaluates a trace of observed behavior
  - Trace may result from simulation
  - Trace may result from observing running system
    - Monitoring
    - Runtime verification

How to get an A for CS 780 ?

- Required work and grading

40% Project (requires programming)

30% In class presentations (requires prep of a lecture)

10% Active participation in class
(requires reading papers, providing a summary,…)

20% Take home exam