Hybrid Systems: Theoretical Contributions Part II

Edited and presented by

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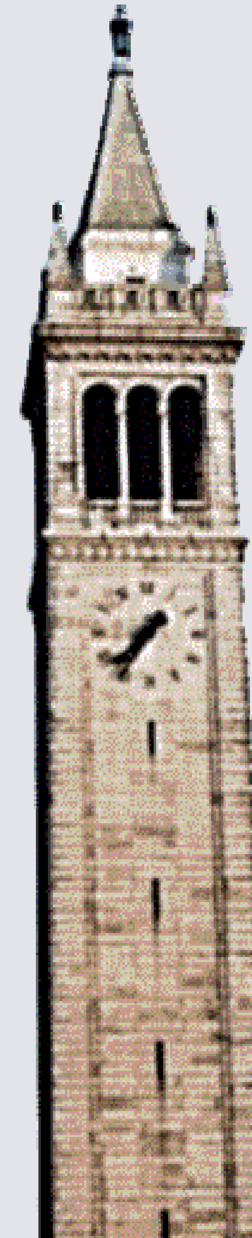
Chess Review
October 4, 2006
Alexandria, VA



More Research Samples

- Henzinger's group:
  - Robust Hybrid Systems
  - Timed Games
  - Compositional Real-Time Systems
  - Interface Theories
- Sangiovanni's group:
  - Petri Net Scheduling

A Quantitative Theory of Timed and Hybrid Systems

- Models are approximations
  - Sensor errors, estimations, uncertainties
  - Need theories that are robust w.r.t. small perturbations
- How close are two models?
  - Traditional: B may or may not match (or refine) A
  - Quantitative: B may match A "better" than B' does
- Quantitative (bi)simulation relations:
  - H, Majumdar, Prabhu 2005

A Quantitative Theory of Timed and Hybrid Systems

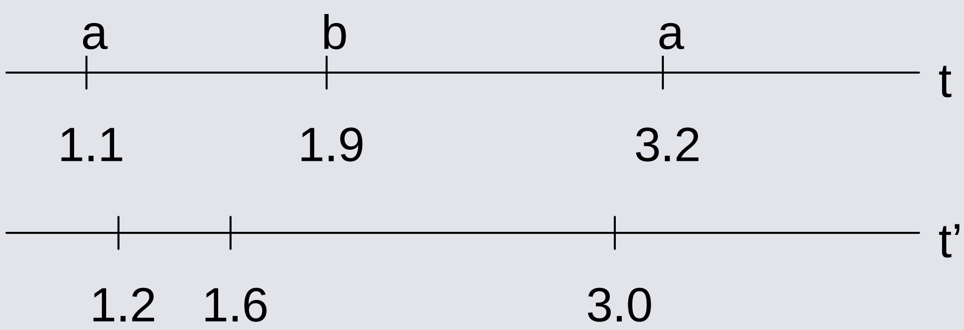
1. Quantitative models:
   - What is the distance between two models?

2. Continuity of specifications:
   - Close models satisfy close specifications

3. Quantitative specifications:
   - View formulae as real-valued functions on states

A Quantitative Theory of Timed and Hybrid Systems

1. Distance between traces d(t,t'):
   - sup of timing mismatches



d(t,t') = 0.3

2. Trace distance between states D(s,s'):
   - $\sup_{t \in L(s)} \inf_{t' \in L(s')} d(t,t')$
   - Game interpretation: adversary chooses trace from s', and we try to match it as well as possible from s

A Quantitative Theory of Timed and Hybrid Systems

- Traditional theory:
  - s refines s' iff L(s) µ L(s')
  - Efficient sufficient condition: s simulated by s'

- Quantitative theory:
  - D(s,s') not computable
  - Computable upper bound: ***SD***(s,s',0) where

    $SD(s,s',\delta) = \sup_{\varepsilon} \inf_{\varepsilon*} \{ \max(\delta, SD(r,r',\delta + |\varepsilon - \varepsilon*|)) : s\ !_{\varepsilon}\ r,\ s'\ !_{\varepsilon*}\ r' \}$

A Quantitative Theory of Timed and Hybrid Systems

Continuity theorem for TCTL:

If SD(s,s',0) · ε and s 2 ϕ, then s' 2 relax(ϕ, 2ε).

Example:

ϕ: 9}$_{.5}$ p

relax(ϕ,ε): 9}$_{< 5 + \varepsilon}$ p

So, if we want a model to satisfy 9}$_{< 5}$ p and the modeling error is estimated at most ε, then we should model check 9}$_{< 5 - 2\varepsilon}$ p.

A Quantitative Theory of Timed and Hybrid Systems

- CTL:

  [8} p](s) = 0 if p can be avoided forever from s
  1 otherwise

- QCTL:

  [8} p](s) = β^t where t is the longest time that can be spent avoiding p from s

  $0 < \beta < 1$ ... discount factor

A Quantitative Theory of Timed and Hybrid Systems

$[p](s) = 1$ if s ² p

$[p](s) = 0$ if not s ² p

$[:\phi](s) = 1 - [\phi](s)$

$[\phi_1$ Ç $\phi_2](s) = \max([\phi_1](s), [\phi_2](s))$

$[\phi_1$ Æ $\phi_2](s) = \min([\phi_1](s), [\phi_2](s))$

$[9\}\ \phi](s) = \sup_{t2\ L(s)} \sup_{\delta}\ \beta^{\delta}$ ¢ $[\phi](t@\delta)$

$[8\}\ \phi](s) = \inf_{t2\ L(s)} \sup_{\delta}\ \beta^{\delta}$ ¢ $[\phi](t@\delta)$

$[9$□ $\phi](s) = \sup_{t2\ L(s)} \inf_{\delta}\ \beta^{\delta}$ ¢ $[\phi](t@\delta)$

$[8$□ $\phi](s) = \inf_{t2\ L(s)} \inf_{\delta}\ \beta^{\delta}$ ¢ $[\phi](t@\delta)$

We have been able to show only the computability of a subset of QCTL over timed automata; the general model checking question remains open.

A Quantitative Theory of Timed and Hybrid Systems

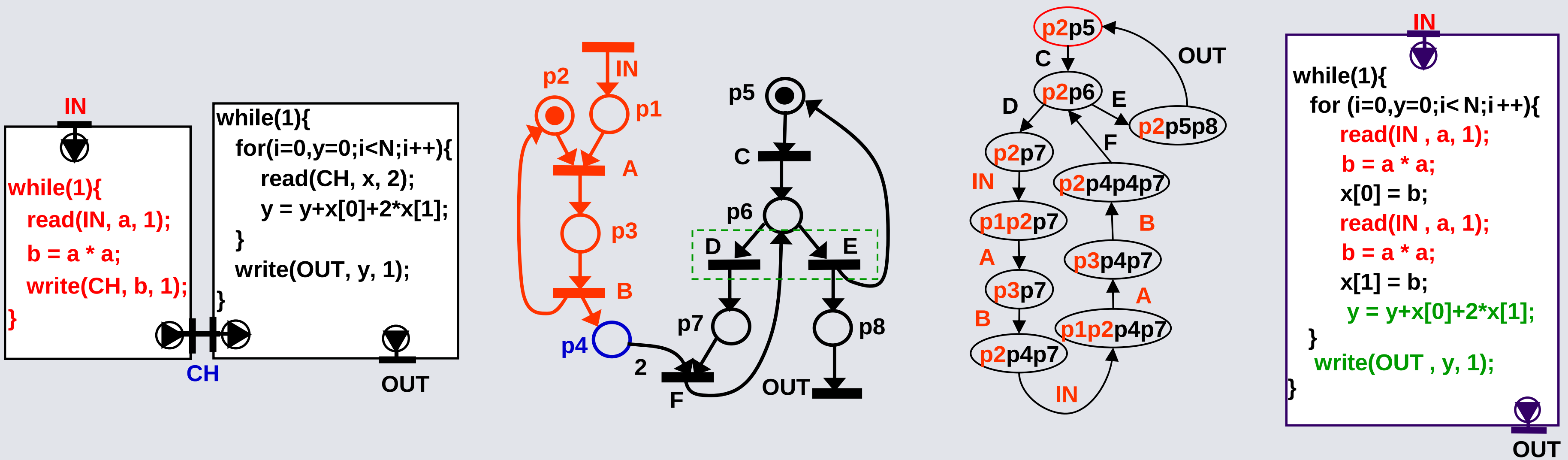
Quantitative Continuity Theorem:

Let k be the number of nested temporal operators in ϕ.
If $D(s,s',0) \cdot \varepsilon$, then $| [\phi](s) - [\phi](s') | \cdot (k+1)$ ¢ $(1 - \beta^{2\varepsilon})$.

This bounds the specification error in terms of the model error.

Quasi-Static Scheduling

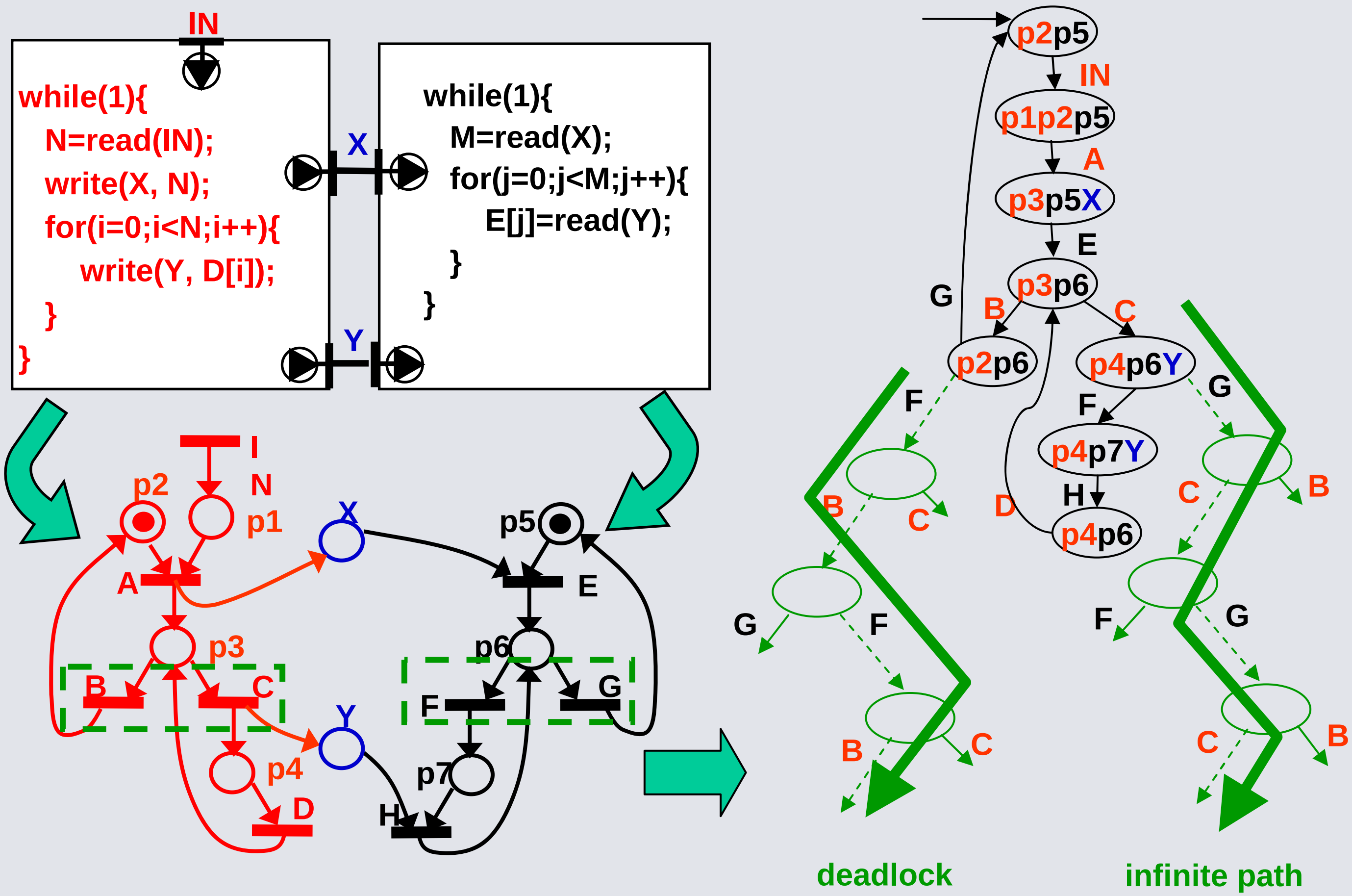
- Petri nets have been successfully used in quasi-static scheduling of concurrent programs.



[Liu, Sangiovanni-Vincentelli, Watanabe, Kondryatev]

Motivational Example

- Petri nets generated from interesting applications are often unschedulable.



Our Approach

- Question:

  Is a given Petri net schedulable?
  Is a given Petri net not schedulable?

- One Solution: Try to construct a schedule (very time consuming)

- Our approach: Employ necessary conditions for schedulability which are based on the Petri net structure and hence efficient to decide.
  - Checking cyclic dependence of transitions using linear programming
  - Checking a rank condition of the incidence matrix using linear algebra

Experiments

- Experiments from real applications show effectiveness and efficiency of our approach.
  - PVRG-JPEG encoder [Hung 93]
  - Motion-JPEG encoder [Lieverse 01]
  - Philips MPEG2 decoder [Wolf 99]
  - XviD MPEG4 encoder [Broekhof 04]

	#P	#T	#Arc	#FCS	Rank	CDC	Scheduler
JPEGenc1	26	27	64	6	<0.01s	0.19s	>24hr
MJPEGenc	117	124	330	25	<0.01s	0.04s	>24hr
MPEG2dec1	116	144	358	38	<0.01s	0.25s	>24hr
MPEG4dec	72	72	184	15	<0.01s	0.16s	>24hr