Seminar
Trends in Computer-Aided Verification
Introduction

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Outline

Formal Verification Methods

Formal verification methods

- Rigorous, mathematically based techniques for the specification, development and verification of software and hardware systems
- Aim at improving correctness, reliability and robustness of such systems

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Classifications

- According to design phase
  - specification, implementation, testing, ...
- According to specification formalism
  - process algebras, timed automata, Markov chains, ...
- According to underlying mathematical theories
  - model checking, theorem proving, static analysis, ...

Outline

Goals

Aims of this seminar

- Independent understanding of a scientific topic
- Acquiring, reading and understanding scientific literature
- Writing of your own report on this topic
- Oral presentation of your results

Requirements on Report

Your report

- Independent writing of a report of 15–20 pages
- Complete set of references to all consulted literature
- Correct citation of important literature
- Plagiarism: taking text blocks (from literature or web) without source indication causes immediate exclusion from this seminar
- Font size 12pt with "normal" page layout
- Language: German or English
- We expect the correct usage of spelling and grammar
  - $\geq$ 10 errors per page $\Longrightarrow$ abortion of correction

Requirements on Talk

Your talk

- Talk of about 45 minutes
- Focus your talk on the audience
- Descriptive slides:
  - $\leq$ 15 lines of text
  - use (base) colors in a useful manner
- Language: German or English
- No spelling mistakes please!
- Finish in time. Overtime is bad
- Ask for questions

Final Preparations

Preparation of your talk

- Setup laptop and projector ahead of time
- Use a (laser) pointer
- Number your slides
- Multiple copies: laptop, USB, web
- Have backup slides ready for expected questions

Outline

Important Dates

Talks

The seminar will be held as a weekly double feature on Mondays at 15:30 (?) starting end of November

- see `http://www-i2.informatik.rwth-aachen.de/i2/cav13/`

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Deadlines

You are requested to adhere to the following firm deadlines:

- immediately: obtain the required literature from the web or library
- eight weeks before your talk: present a table of contents
- six weeks before your talk: preliminary version of your report
- four weeks before your talk: final version of your report
- two weeks before your talk: preliminary version of your slides
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Missing a deadline causes immediate exclusion from the seminar

Outline

Selecting Your Topic

Procedure

- You obtain(ed) a list of topics of this seminar.
- Indicate the preference of your topics (first, second, third).
- We do our best to find an adequate topic-student distribution.
- Disclaimer: no guarantee for an optimal solution.
- Your topic will be published on our website by 11 October.
- Please give language preference
  - unsure $\Longrightarrow$ German

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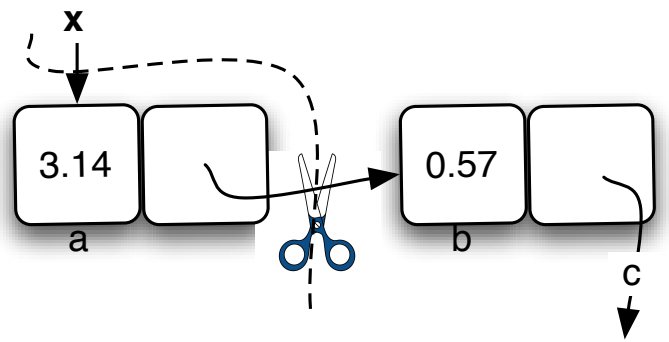
Withdrawal

- You have up to three weeks to refrain from participating in this seminar.
- Later cancellation (by you or by us) causes a not passed for this seminar and reduces your (three) possibilities by one.

Outline

1: Interprocedural Shape Analysis with Separated Heap Abstractions

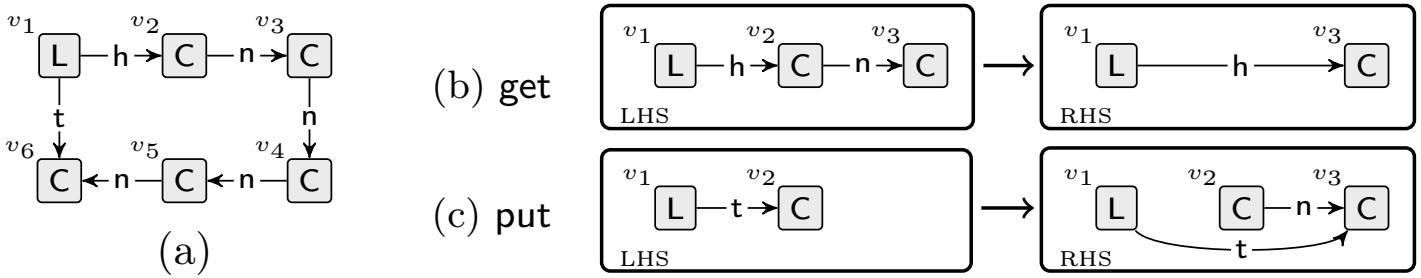
Microsoft Research



- interprocedural analysis of heap-manipulating programs
- goal: proving shape properties
- heap described by (Separation) Logic formulae
- Separation Logic: extension of Hoare Logic

2: Pattern-Based Graph Abstraction

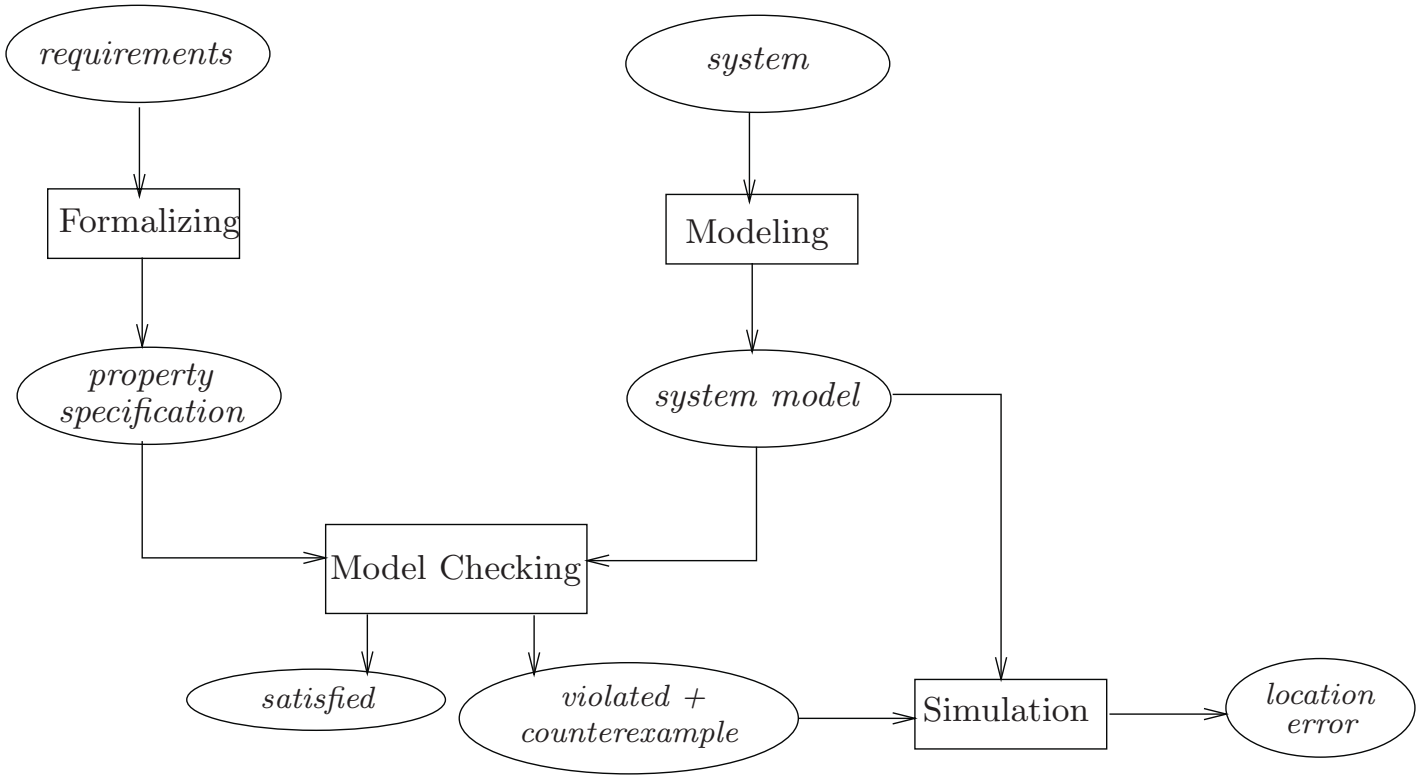
University of Twente
The Netherlands



- (abstract) state space of heap-manipulating programs
- program statements: graph transformations
- abstraction: composition of pattern graphs
- tool support: GROOVE

Outline

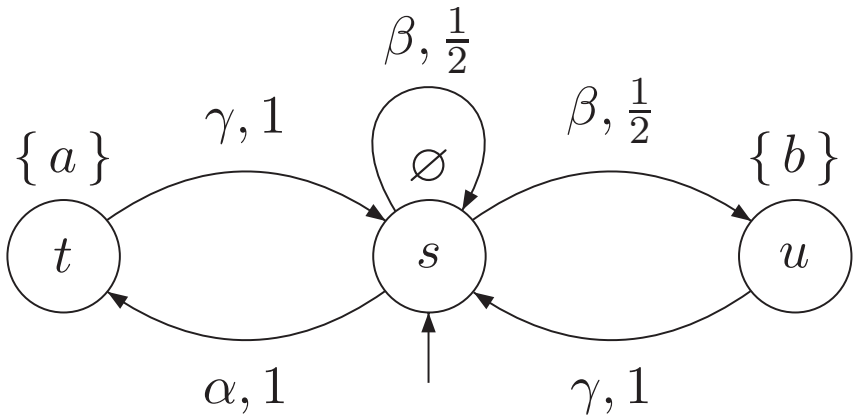
Model Checking



Extension: Probabilistic Models and Temporal Logics

3: Faster Algorithms for MDPs with Low Treewidth

Model: Markov Decision Processes



Problem: verification time consuming

Idea: exploit typical shape of models to speed-up verification

4: Assume-Guarantee Verification for Probabilistic Systems

Model: Markov Decision Processes

$$\begin{array}{ccccccccc} \mathcal{M} & = & \mathcal{M}_1 & \| & \mathcal{M}_2 & \| & \ldots & \| & \mathcal{M}_n \\ \downarrow & & \downarrow & & \downarrow & & & & \downarrow \\ \text{huge} & & \text{small} & & \text{small} & & & & \text{small} \end{array}$$

Problem: verification of full system time and memory consuming

Idea: try to verify subsystems instead

5: Pareto Curves for Probabilistic Model Checking

Model: Markov Decision Processes

$$\overrightarrow{\varphi} = \Big(\underset{\downarrow}{\varphi_1} , \underset{\downarrow}{\varphi_2} , \cdots , \underset{\downarrow}{\varphi_n} \Big)$$

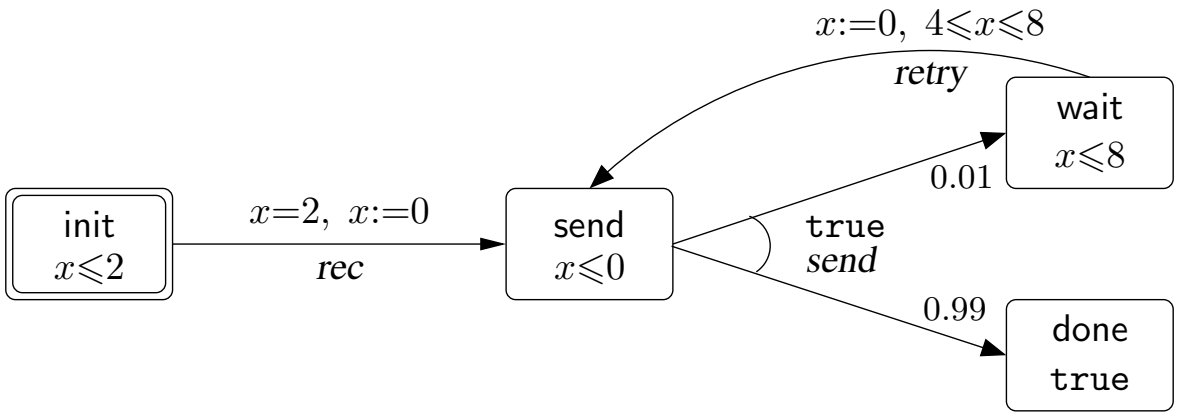
$$p(\rightsquigarrow e_1) \bowtie p_1 \qquad p(\rightsquigarrow e_2) \bowtie p_2 \qquad p(\rightsquigarrow e_1) \bowtie p_1$$

Problem: how to verify (possibly conflicting) $\overrightarrow{\varphi}$

Idea: successively approximate Pareto curve of MDP

6: Stochastic Games for Verification of PTA

Model: Probabilistic Timed Automata



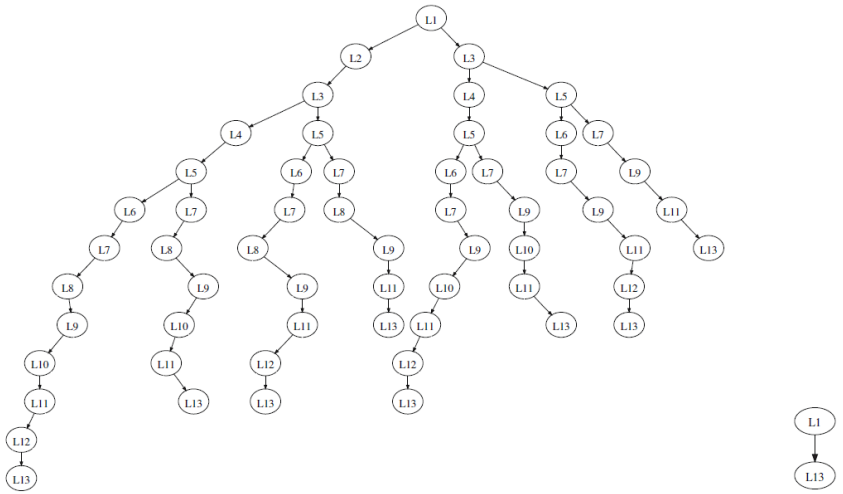
Problem: how to verify timed properties

Idea: reduce model to two-player game

Outline

7: Software Model Checking via Large-Block Encoding

Model: Abstract Reachability Tree



Problem: State space explosion

Idea: Minimize ART by minimizing control flow graph

8: Checking Safety by Inductive Generalization of Counterexamples to Induction

First completely new MC approach since McMillan's interpolation.

Base:	Initial states satisfy property
Induction:	If in property state, no transition to non-property state

Problem: unreachable states violating induction

Outline

9: Action Refinement in Conformance Testing

- In model-based testing actions are automatically generated from a formal model
- The formal model is often more abstract than the actual implementation
- Rewriting the model is error-prone and time consuming
- Solution: Action refinement, relating action from the abstract model to the concrete action of the implementation

10: Testable Properties

- Generation test-cases from the model can lead to large test suits
- One possibility to improve the practical feasibility is to use properties for deriving test-cases
- Advantage: Properties allow for selecting certain test-cases

11: Integrating Formal Verification and Conformance Testing for Reactive Systems

- Verification of formal models can be undecidable or too complex, especially for symbolic, infinite-state transition systems
- There is no guarantee that verified properties are tested at all
- This paper describes the link between verifying properties on the specification and testing them on the implementation
- Testing may detect violations of properties on the implementation that could not fully be verified on the specification

Outline

12: Zeno analysis of UPPAAL models

Zeno analysis of UPPAAL models

- Rinast, J., & Schupp, S. (2012). Static detection of zeno runs in UPPAAL networks based on synchronization matrices and two data-variable heuristics. Formal Modeling and Analysis of Timed Systems, 220-235.
- Timed automata may contain erroneous behavior: Zeno.
- Paper describes method for static analyis of such models (UPPAAL) to detect this behavior.
- Heuristics to deal with data variables.
- Algorithm implemented in tool (ZenoTool) and tested on various models, compared to existing detection methods.

13: Expected time and long-run average in IMCs

Expected time and long-run average in IMCs

- Guck, D., Han, T., Katoen, J., & Neuhäußer, M. (2012). Quantitative timed analysis of interactive Markov chains. NASA Formal Methods, 1-15.
- IMC: Model containing both non-determinism and continuous time probabilistic transitions.
- Paper describes analysis of long-run average and expected time properties of such models.
- Reduction to SSP problem for both properties.
- Implemented in the IMCA tool, expiriments with two case studies
  - Google file system
  - Workstation cluster

Outline

14: Interpolation-Based Model Checking

Interpolation (Craig, 1957)

Simple & important result from mathematical logic. Craig proved:

- Given $A \implies B$, where A and B are first-order logic formulae,
- Then $\exists C :: A \implies C \wedge C \implies B$, where $var(C) = var(A) \cap var(B)$.

Interpolant C *abstracts* A to variables shared between A and B.

Applications to Model Checking (McMillan, 2003)

McMillan showed the power of Craig's result to model checking:

- Abstracting successor-states for state space exploration.
- Abstracting the transition relation itself.

Also applications to program verification, compositional reasoning, etc.

Supervisor

Viet Yen Nguyen (nguyen@cs.rwth-aachen.de)

Outline

15: Imperative Program Synthesis

- *Andrew Ireland and Jamie Stark*, Combining Proof Plans with Partial Order Planning for Imperative Program Synthesis, 2006
- Problem: *construct* program P s.t. $\{Q\}P\{R\}$ for given Q, R
- Based on structured programming
- When to apply which rules?
- Planning heuristics on two levels
  - Proof plans
  - Partial order planning

Outline

/Users/thomasnoll/Research/D-MILS/Meetings/05_Aachen_Oct_13/W

16: Using Architecture to Reason About Information Security

- **Goal:** derivation of information flow security properties
- **Inputs:**
  - architectural abstraction of system
    - set of security domains
    - information flow relation
  - logical specification of distribution of knowledge
- **Procedure:** model checking of system architecture w.r.t. logical spec
- Possible extension of architecture by filter functions to restrict information flow
- Implementation by access control policies

17: Hyperproperties

- "Classical" properties: satisfied by traces
  - safety: "nothing bad happens" (e.g., mutual exclusion)
  - liveness: "eventually something good happens" (e.g., every server request will be answered)
- Every property representable as intersection of safety and liveness property
- Some security properties expressible as properties:
  - "system may not write to network after reading from file" (safety)
- But not all, e.g., noninterference:
  - "commands issued by users holding high clearances can be removed without affecting observations of users holding low clearances"
  - formally: whenever system contains trace t, it also contains t' without high inputs but with same low events as t

  $\Longrightarrow$ property satisfied by set of traces ("hyperproperty")
- Hypersafety, hyperliveness, representation theorem

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Some Final Hints

Hints

- Take your time to understand your literature.
- Be proactive! Look for additional literature and information.
- Discuss the content of your report with other students.
- Be proactive! Contact your supervisor on time.
- Prepare the meeting(s) with your supervisor.
- Forget the idea that you can prepare a talk in a day or two.

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We wish you success and look forward to an enjoyable and high-quality seminar!