Anwendung formaler Verifikation

Organisatorisches

Prof. Dr. Bernhard Beckert · Dr. Vladimir Klebanov · Dr. Mattias Ulbrich | SS 2015

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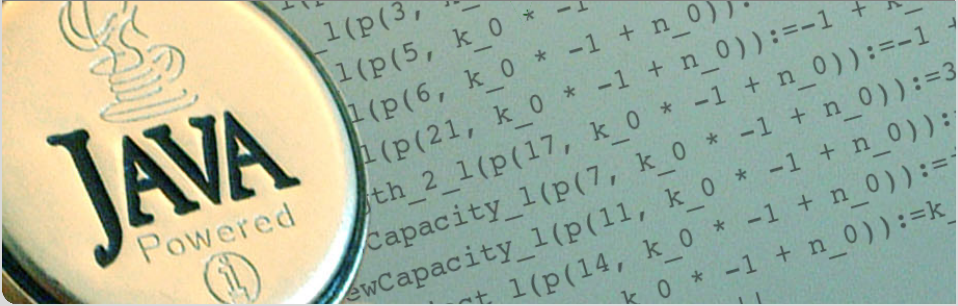

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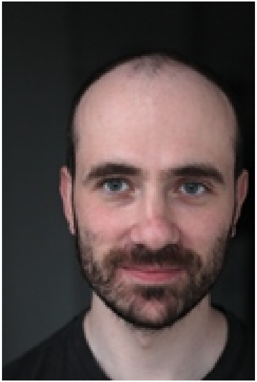

Dr. Vladimir Klebanov

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Webseite zur Vorlesung

`http://formal.iti.kit.edu/teaching/AnwendungFormalerVerifikation2015/`

Alle für die Vorlesung relevanten Informationen und Materialien:

- Termine und aktuelle Informationen
- Folien
- Tools und weitere Materialien

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Zielgruppe

Diplom Informatik, Master Informatik

Vertiefungsfächer

- Theoretische Grundlagen
- Softwaretechnik und Übersetzerbau

Modul *Formale Methoden*

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Umfang und Struktur

- 3 SWS = 21 Doppelstunden im Semester
- aufgeteilt in sechs Einheiten mit je Vorlesungen und Übungen
- Übungen: Verfahren werden anhand konkreter Verifikatiossysteme praktisch erprobt („sich die Finger schmutzig machen")
- Essentiell für den Kurs!
- Eigene Rechner mit den installierten Werkzeugen

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Termine

- Dienstags, 11:30 – 13:00
- Freitags, 11:30 – 13:00

Keine Vorlesung am 1. Mai

21 Termine von den 27 möglichen
(Hinweis in der Vorlesung, auf der Homepage)

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Vorlesungseinheiten

1	Funktionale Eigenschaften imperativer und objekt-orientierter Programme	Java Modeling Language Dynamische Logik
2	Temporallogische Eigenschaften	Model Checking
3	Nebenläufige Programme (Concurrency)	Rely/Guarantee
4	Echtzeiteigenschaften	Timed Automata, UPPAAL
5	Formale Systemmodelle	Verfeinerung, Event-B
6	Informationsfluss-Eigenschaften	Dynamische Logik, Typsysteme

Verwandte Vorlesungen

- **Formale Systeme** (Beckert/Schmitt)
- Formale Systeme II (Schmitt/Beckert)
- Spezifikation und Verifikation von Software / Formaler Entwurf und Verifikation von Programmen (Schmitt/Beckert)
- Modellgetriebene Software-Entwicklung (Reussner et al.)
- Theorembeweiser und ihre Anwendungen (Snelting et al.)
- Model Checking (Sinz et al.)
- Automatic/Static Program Checking (Taghdiri et al.)

Applications of Formal Verification

Introduction

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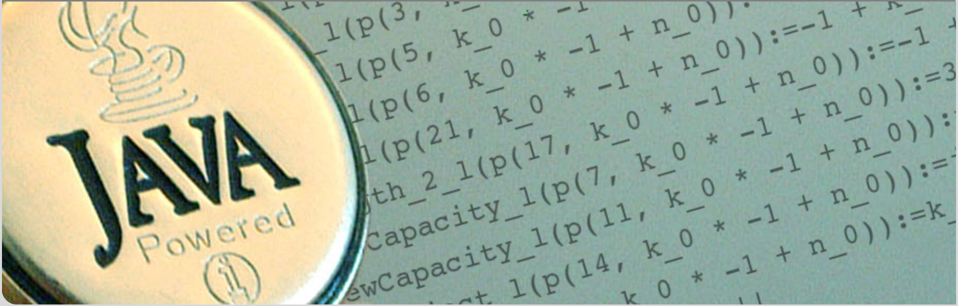
JAVA
Powered
1(p(5, k_0 * -1 + n_0)):=-1 +
1(p(6, k_0 * -1 + n_0)):=-1
1(p(21, k_0 * -1 + n_0)):=3
th_2_1(p(17, k_0 * -1 + n_0)):
Capacity_1(p(7, k_0 * -1 + n_0)):=
wCapacity_1(p(11, k_0 * -1 + n_0)):=k_
1(p(14, k_0 *

Motivation: Software Defects cause BIG Failures

Tiny faults in technical systems can have catastrophic consequences

In particular, this goes for software systems

- Therac-25 (1985–87)
- London Ambulance Dispatch System
- Patriot missile bug (1991), F-22 bugs (1992, 2007)
- Pentium FDIV bug (1994)
- Northeast blackout (2003)
- Debit card bug (year 2010 problem)
- MS Zune bug (2008), Azure bug (2012)

Motivation: Software Defects cause OMNIPRESENT Failures

Ubiquitous Computing results in Ubiquitous Failures

Software these days is inside just about anything:

- Mobiles
- Smart devices
- Smart cards
- Cars
- Aviation

⇒ *software—and specification—quality is a growing legal issue*

Achieving Reliability in Engineering

Some well-known strategies from civil engineering

- Precise calculations/estimations of forces, stress, etc.
- Hardware redundancy ("make it a bit stronger than necessary")
- Robust design (single fault not catastrophic)
- Clear separation of subsystems
  Any air plane flies with dozens of known and minor defects
- Design follows patterns that are proven to work

Why This Does Not Work For Software

- Software systems compute non-continuous functions
  Single bit-flip may change behaviour completely
- Redundancy as replication doesn’t help against bugs
  Redundant SW development only viable in extreme cases
- No clear separation of subsystems
  Local failures often affect whole system
- Software designs have very high logic complexity
- Design practice for reliable software in immature state
  for complex, particularly, distributed systems
- Cost efficiency favoured over reliability
- Extremely short innovation cycles

Limitations of Testing

- Testing shows the presence of errors, in general not their absence
  (exhaustive testing viable only for trivial systems)
- Representativeness of test cases/injected faults subjective
  How to test for the unexpected? Rare cases?
- Testing is labor intensive, hence expensive

Formal Methods: The Scenario

- Rigorous methods used in system design and development
- Mathematics and symbolic logic $\Rightarrow$ formal
- Increase confidence in a system
- Two aspects:
  - System implementation
  - System requirements
- Make formal model of both and use tools to prove mechanically
  that formal execution model satisfies formal requirements

Formal Methods: The Vision

- Complement other analysis and design methods
- Are good at finding bugs
  (in code and specification)
- Reduce development (and test) time
- Can *ensure* certain *properties* of the system model
- Should ideally be as automatic as possible

Various Properties

(Require Different Verification Techniques)

- Simple properties
  - Safety properties
    Something bad will never happen (eg, mutual exclusion)
  - Liveness properties
    Something good will happen eventually
- General properties of concurrent/distributed systems
  - deadlock-free, no starvation, fairness
- Non-functional properties
  - Runtime, memory, usability, . . .
- Full behavioural specification
  - Code satisfies a contract that describes its functionality
  - Data consistency, system invariants
    (in particular for efficient, i.e. redundant, data representations)
  - Modularity, encapsulation
  - Refinement relation

The Main Point of Formal Methods is Not

- To show “correctness” of entire systems
  What *IS* correctness? Always go for specific properties!
- To replace testing entirely
  - Formal methods work on models, on source code, or, at most, on bytecode level
  - Many non-formalizable properties
- To replace good design practices

There is no silver bullet!

- No correct system w/o clear requirements & good design
- One can’t formally verify messy code with unclear specs

But . . .

- Formal proof can replace (infinitely) many test cases
- Formal methods can be used in automatic test case generation
- Formal methods improve the quality of specs (even without formal verification)
- Formal methods guarantee specific properties of a specific system model

Formal Methods Aim at:

- Saving money
  Intel Pentium bug
  Smart cards in banking
- Saving time
  otherwise spent on heavy testing and maintenance
- More complex products
  Modern μ-processors
  Fault tolerant software
- Saving human lives
  Avionics, X-by-wire
  Computer aided surgery

Tool Support is Essential

Some Reasons for Using Tools

- Automate repetitive tasks
- Avoid clerical errors, etc.
- Verifiable proof artefacts
- Cope with large/complex programs
- Make verification certifiable