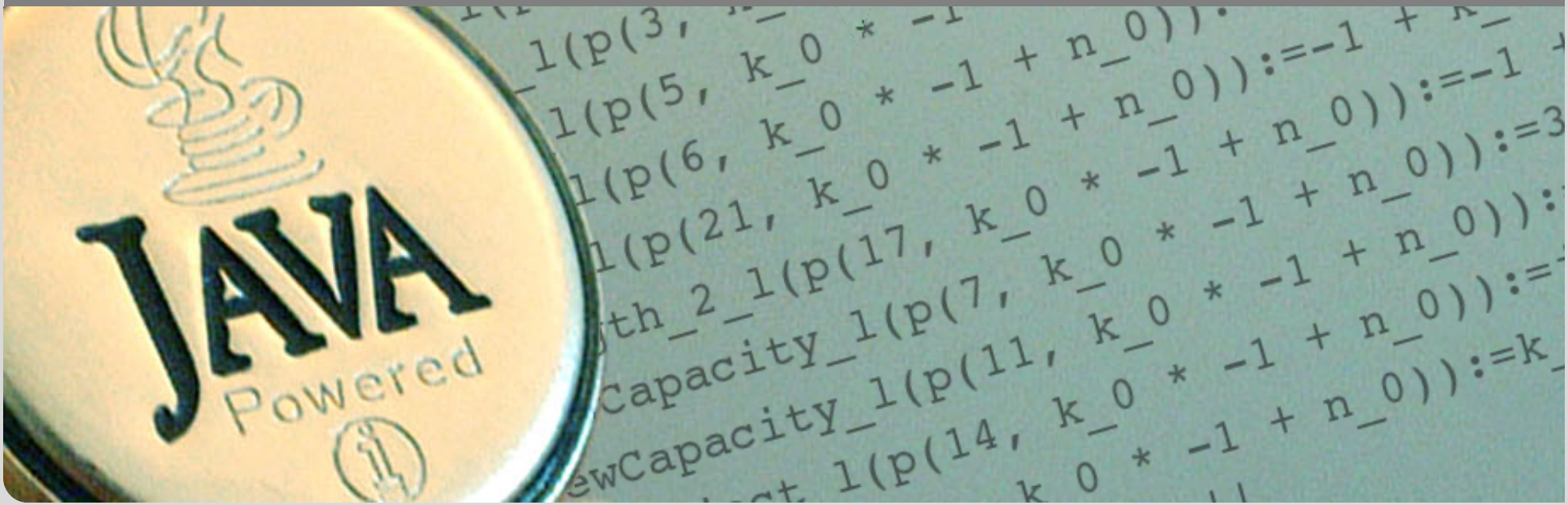
# Formale Systeme II: Anwendungen

## Organisatorisches

Bernhard Beckert · Mattias Ulbrich | SS 2017

KIT – Institut für Theoretische Informatik



# Organisatorisches

**Prof. Bernhard Beckert**

**Dr. Mattias Ulbrich**

**Dr. Carsten Sinz**

# Organisatorisches

## Webseite zur Vorlesung

**http://formal.iti.kit.edu/teaching/FormSys2SoSe2017/**

Alle für die Vorlesung relevanten Informationen und Materialien:

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

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## Zielgruppe

Master Informatik

## Vertiefungsfächer

- Theoretische Grundlagen
- Softwaretechnik und Übersetzerbau

## Module

- Atomares Modul: „Formale Systeme II: Anwendung“
- Nach alter PO auch: „Formale Methoden“

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# Organisatorisches

## Umfang und Struktur

- 3 SWS = ∼20 Doppelstunden im Semester
- ∼6 Einheiten/Themen mit je Vorlesungen und Übungen

## Übungen

- Verfahren werden anhand konkreter Verifikatiossysteme praktisch erprobt
- „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

$\sim$20 Termine von den 28 möglichen, sind noch festzulagen
(keine Vorlesung am 26.05: Brückentag)

$\Rightarrow$ Bekanntgabe in der Vorlesung und auf der Webseite

# Organisatorisches

## Vorlesungseinheiten

| | | |
|---|---|---|
| 1 | Funktionale Eigenschaften imperativer und objekt-orientierter Programme | Java Modeling Language Dynamische Logik |
| 2 | Bug Finding für imperative Programme | Software Bounded Model Checking |
| 3 | Formale Systemmodelle | Verfeinerung, Event-B |
| 4 | Informationsfluss-Eigenschaften | Dynamische Logik, Typsysteme |
| 5 | Temporallogische Eigenschaften | Model Checking |
| 6 | Echtzeiteigenschaften | Timed Automata, UPPAAL |
| ⋮ | ⋮ | ⋮ |

# Verwandte Vorlesungen

- **Formale Systeme** (Beckert)
- Formale Systeme II: Theorie (Beckert/Ulbrich)

- Modellgetriebene Software-Entwicklung (Reussner et al.)
- Theorembeweiser und ihre Anwendungen (Snelting et al.)
- Model Checking (Sinz et al.)

Karlsruhe Institute of Technology

# Formal Systems II: Application

## Introduction

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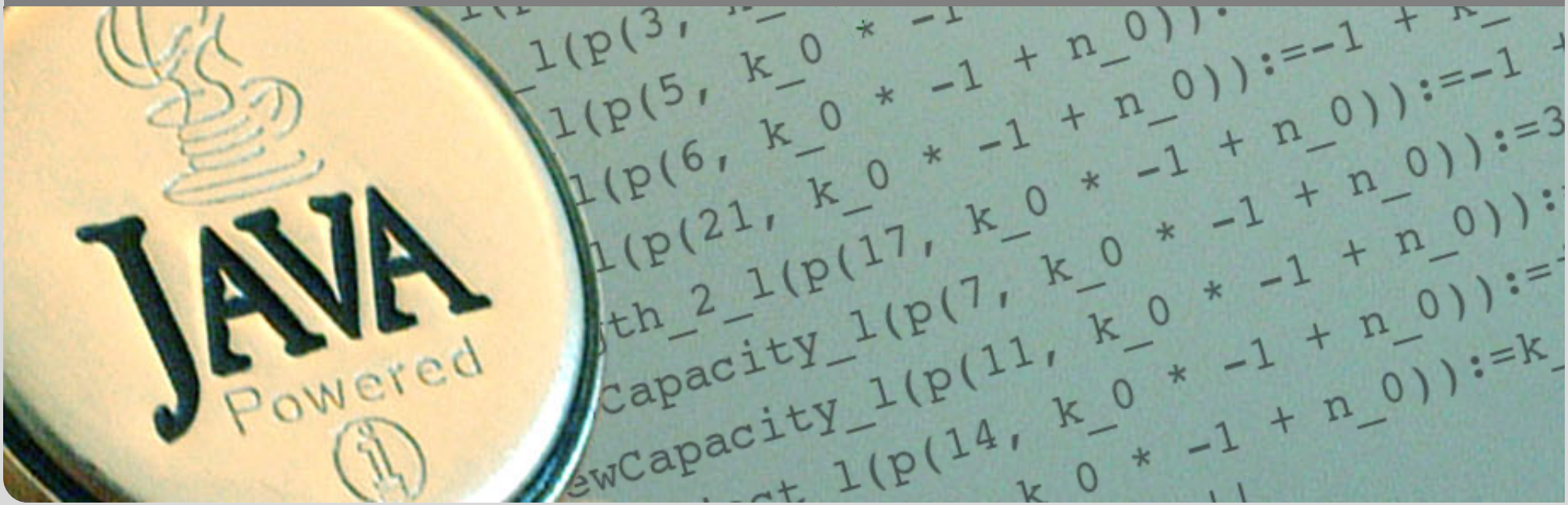

# Motivation: Software Defects cause BIG Failures

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 dateline bug (2007)
- Pentium FDIV bug (1994)
- Northeast blackout (2003)
- Debit card bug (year 2010 problem)
- MS Zune bug (2008)

# 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*

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# Achieving Reliability in Engineering

## Some well-known strategies from civil engineering

- Precise model:
  calculations/estimations of forces, stress, etc.
- 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 Is Not Easy 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

- Can *ensure* certain *properties* of the model and the system
- Complement other analysis and design methods
- Are good at finding bugs
  (in code and specification)
- Reduce development (and test) time
- 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, no buffer overflow
  - Liveness properties
    Something good will happen eventually
- General properties of concurrent/distributed systems
  - deadlock-free, no starvation, fairness
- Security properties
  - non-interference, information flow
  - access control
  - availability
- Non-functional properties
  - Runtime, memory, usability, . . .

# Various Properties (cont.)

## (Require Different Verification Techniques)

- Full behavioural specification
  - Code satisfies a contract that describes its functionality
  - Relational: Code does the same as other code, program equivalence
  - 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 $\mu$-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 $\Rightarrow$ efficiency
- Avoid clerical errors, etc.
- Verifiable proof artefacts
- Cope with large/complex programs
- Make verification certifiable