Bachelor & Master Projects and Theses
Chair for Software and Systems Engineering

Prof. Dr. Stefan Leue

University of Konstanz
Chair for Software Engineering

Stefan.Leue@uni-konstanz.de
http://www.sen.inf.uni-konstanz.de

Winter Term 2019/20
We offer

- ... integration in state of the art research projects
- ... if applicable, collaboration with our industrial partners
- ... interesting real-life applications and problems as well as more foundational work
Scope of Projects/Theses

- **Project (Bachelor and Master)**
  - 1 Semester
  - 9 ECTS (270h work)

- **Thesis (Bachelor)**
  - 3-6 Months ("1 Semester")
  - 12 (Thesis) + 3 (Colloquium) ECTS (450h work)

- **Thesis (Master)**
  - 6 Months (1 Semester)
  - 30 (Thesis + Colloquium) ECTS (900h work)
Formal Requirements

♀ Before you start your work
  ‣ Written proposal (≈ 1 page) containing (ideally by November 7, 2019)
    – the *topic* you want to choose
    – how well you *match the prerequisites*
    – *why you are suited* for the task.
  ‣ Schedule for the project/thesis
    – What will be achieved at which point in time.

♀ During your preparation of the thesis or the project work
  ‣ Regular consultation with your supervisor.
Deliverables

- Any models/code/data/binaries you created for the project.
- **Report** of ≥ 20 pages (Projects, Bachelor-Thesis) or ≥ 40 pages (Master-Thesis)
  - Discussing state of the art
  - Stating the problem
  - Presenting your approach and results
  - Critical discussion, own example, etc.
Chair for Software and Systems Engineering

成员国

- 教授 Dr. Stefan Leue
  - 邮箱: Stefan.Leue@uni.kn.de, 房间: PZ 902
- Dr. Georgiana Caltais
  - 邮箱: Georgiana.Caltais@uni.kn.de, 房间: PZ 913
- Martin Kölbl
  - 邮箱: Martin.Koelbl@uni.kn.de, 房间: PZ 912
- Fabian Marquart
  - 邮箱: Fabian.Marquart@uni.kn.de, 房间: PZ 912
Areas of Research Interest

- **Formal Modeling and Analysis**
  - model checking
  - SMT solving

- **System Safety and Analysis**
  - causality in systems
  - causality checking / QuantUM
  - analysis and repair for timed system models
  - safety and verification of machine-learning based systems

- **Applications**
  - automotive software architectures
  - functional safety of automotive software (ISO 26262)
  - safety of autonomous driving (SOTIF ISO PAS 21448)
  - legal tech
  - modeling of collective behavior
Projects and Theses
System Safety and Analysis
Problem Statement

- Causality Checking in QuantUM relies on trace computation
  - bottleneck: memory
- LTSmin / PINS is interface to symbolic model checking engine
  - hope: more memory efficient

Project Tasks

- integrate QuantUM/Causality Checking into LTSmin / PINS
- direct logic encoding of causality checking in symbolic BDD data structures [MP/MT]

Prerequisites

- programming, discrete structures
- for [MP/MT]: (symbolic) model checking an advantage
Causality Checking for Programs [MP/MT]

Programs

- the assignment of certain values to variables can cause a program to crash
- which variable assignments and which values are causal for a program failure?

Tasks

- selection of a program analysis framework (other than testing)
  - for instance, symbolic execution, static analysis
- development of a causality notion for program executions
- prototype implementation and case study

Prerequisites

- good understanding of logic, program semantics, foundations of computing
Formal Modeling and Analysis
Constraint Relaxation for Timed Systems [MP/MT]

♦ Motivation
  ‣ real-time constraints can be unnecessarily tight

♦ Analysis to Relax Time Constraints
  ‣ encode timed system (trace)
    ‐ SMT2, horn clauses
  ‣ encode analysis candidates (e.g. \( x \leq 1 + \Delta d \))
  ‣ check for weaker constraints (e.g. \( \Delta d = 2 \))
    ‐ Craig interpolation, SMT2
  ‣ is the functionality of the system changed?

♦ Related Work
  ‣ analysis of parametric timed systems

♦ Requirements
  ‣ advanced model checking
  ‣ advantageous: course on SMT solving
Repair for Parametric Timed Automata [BP/BT] [MP/MT]

♦ Parametric Timed Automata
  ‣ literature survey
    – starting points
      • Minimal-Time Synthesis for Parametric Timed Automata
        É. André et al., 2019
      • What’s decidable about parametric timed automata?
        É. André, 2015
    – tools? case studies?
  ‣ relationship to repair analysis
    – based on SMT solving
    – tool TarTar @UniKN
    – paper
      • M. Kölbl, S. Leue, T. Wies,
        Clock Bound Repair for Timed Traces,

♦ Prerequisites
  ‣ ideally, Advanced Model Checking, but not mandatory...
From SysML to Model Checkers [BP/BT][MP/MT]

From Design to Code
... filling the gap...

SysML State-Machine

ATL Transformation

```
prectype C{
    Q_A_init:
    do
        a-b -> goto Q_B;
        q-r -> goto R_A_init;
        q-e' -> goto R_E';
    od
    Q_B: [...]
    Q_E: [...]
    R_A_init:
    do
        a'-b' -> R_B;
    od
    R_B: [...]
    R_E:
    do
        break;
    od
    D:
    do
        break;
    od
}
```

How much of the SysML State-Machines can we handle?
To what model-checkers can we translate?
Are the transformations correct?
...

♦ Co-supervised by Dr. Georgiana Caltais
Run-Time Causality Checking [MP/MT]

♦ Runtime Verification
  ‣ observe and assess running system
  ‣ often: monitoring

♦ Run-Time Causality Checking
  ‣ observe system behavior
  ‣ detect occurrence of events at run-time as causal for undesired system behavior
  ‣ learn for the future

♦ Tasks
  ‣ study various run-time verification approaches, in particular run-time model checking
  ‣ analyze, what causality can mean in this context
  ‣ adapt causality checking

♦ Prequequisites
  ‣ one model checking course
  ‣ advantageous: machine learning, data mining
Causality Checking Concurrent Code [MP / MT]

CHESS: Systematic Concurrency Testing

Microsoft Research

♦ CHESS
  ‣ tool for finding and producing bugs in concurrent programs (C,C++,C#)

♦ Task
  ‣ transfer the idea of Causality Checking to testing / code analysis
  ‣ apply it to the CHESS tool / environment
  ‣ implement prototype
  ‣ perform case studies
Topic Area

Applications
Objective

- assess the suitability of formal description techniques to model emergent behavior of biological collectives
  - look at stochastic model checking
  - look at spatio-temporal logics
- context
  - cluster *Center for the Advanced Study of Collective Behavior*
- perform concrete case study
  - cooperate with the Jordan Lab @ Uni KN (biology / Max-Planck)
    - behavior of schools of fish
  - select method and tool

Prerequisites

- willingness to perform inder-disciplinary research
- readiness to familiarize oneself with formal modeling and analysis techiques / tools
- model checking courses are an advantage, but not a must...
Analysis Methods for SOTIF [MP/MT]

◆ Safety of the Intended Function
  ▪ ISO PAS 21448 SOTIF
  ▪ how to ensure safety of an autonomous vehicle in the presence of malfunctioning machine learning components

◆ Objective
  ▪ analysis, where semi-formal and formal modeling and analysis can be used in SOTIF
  ▪ approaches to be considered
    – e.g., probabilistic contracts

◆ Prerequisites
  ▪ interest in machine learning
  ▪ ideally combined with seminar "Formal Verification and Testing of Deep Neural Networks"

Figure 6: Screen shot of the simulator in interactive mode. See Section 7.1 for explanation of the performance metrics. The green area on the left is unknown because of the viewpoint transformation. The highlighted wide rectangle below the horizon is the area which is sent to the CNN.


Bachelor / Master Projects and Theses, Winter 2019/20
Explaining Faults with Machine Learning [MP/MT]

♦ Explaining Faults with Machine Learning
  ‣ Model Checking: thousands of counterexamples with hundreds of events
  ‣ Use Machine Learning (ML) to learn & explain counterexamples
    – Learn compact representation of counterexamples
    – Extract patterns

♦ Goals
  ‣ Tool to explain a set of counterexamples of Model Checker (SPIN)
    – Implementation in Python
    – Decision Tree Learning (scikit learn)
  ‣ Case study on selected Promela Models

♦ Requirements
  ‣ Strong programming skills (e.g. C++, Java, Python)
  ‣ Ability to work independently
  ‣ Basic Machine Learning knowledge
... either one of us any time!

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  - Email: Martin.Koelbl@uni.kn, Room: PZ 912