Static Methods for Quantitative Program Analysis

Introduction

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`https://moves.rwth-aachen.de/teaching/ws-1819/qpa/`

Software Modeling and Verification Chair

RWTH AACHEN UNIVERSITY

Outline

What Is It All About?

Static (Program) Analysis

Static analysis is a general method for reasoning on artefacts such as requirements, design models, and programs.

Here, “static” means: based on source code, not on (dynamic) execution
(in contrast to testing, profiling, or run-time verification)

Overview

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(Main) Applications

Optimising compilers: exploit program properties to improve runtime or memory efficiency of generated code

- dead code elimination, constant propagation,...
- usually fully automated

Software validation: verify program correctness

- bytecode verification, shape analysis, functional correctness, ...
- varying degrees of automation

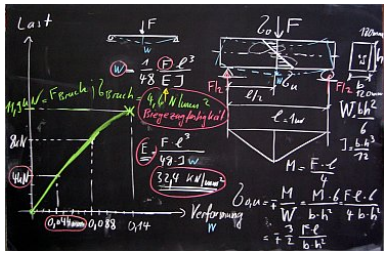
Overview

Dream of Program Analysis

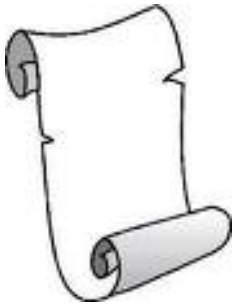
Program

```
                print "ncfiles: Socket error (%s) for host %s (%s)" % (errno,
for h3 in page.findAll("h3"):
    value = (h3.contents[0])
    if value != "Afdeling":
        print >> txt, value
        import codecs
        f = codecs.open("alle.txt", "r", encoding="utf-8")
        text = f.read()
        f.close()
        # open the file again for writing
        f = codecs.open("alle.txt", "w", encoding="utf-8")
        f.write(value+"\n")
        # write the original contents
```

Analyzer



Result



Property specification

Why “Quantitative”?

Classical setting

Addresses “yes/no problems”:

- Is control location c reachable?
- Is the value of variable x always positive?
- When we send a request to the server, will we eventually get an answer?

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Thomas A. Henzinger [Comp. Sc. – Research and Development 28(4), 2013]

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Interesting quantitative aspects

- Execution time
- Resource consumption (energy, heap space, ...)
- Probabilistic properties (reliability, expected execution time, ...)
- Note: many “qualitative” properties pose “quantitative” questions
  - e.g., balancedness of trees refers to height information

Outline

Aims of this Seminar

Goals

Aims of this seminar

- Independent understanding of a scientific topic
- Acquiring, reading and understanding scientific literature
  - given references sufficient in most cases
- Writing of your own report on this topic
  - far more that just a translation/rewording
  - usually an “extended subset” of paper
    - “subset”: present core ideas and omit too specific details (e.g., extension of partial to total correctness)
    - “extended”: more extensive explanations, examples, ...
    - discuss with supervisor!
- Oral presentation of your results
  - can be “proper subset of report”
  - generally: less (detailed) definitions/proofs and more examples

Requirements on Report

Your report

- Independent writing of a report of 10–15 pages
- First milestone: detailed outline
  - not: “1. Introduction/2. Main part/3. Conclusions”
  - but: overview of structure (section headers, main definitions/theorems) and initial part of main section (one page)
- 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 “standard” page layout
- Language: German or English
- We expect the correct usage of spelling and grammar
  - $\geq$ 10 errors per page $\Longrightarrow$ abortion of correction
- LaTeX template will be made available on seminar web page

Requirements on Talk

Your talk

- Talk of 30 minutes
- Available: projector, presenter, [laptop]
- Focus your talk on the audience
- Descriptive slides:
  - $\leq$ 15 lines of text
  - use (base) colors in a useful manner
  - number your slides
- Language: German or English
- No spelling mistakes please!
- Finish in time. Overtime is bad
- Ask for questions
- Have backup slides ready for expected questions
- LaTeX/beamer template will be made available on seminar web page

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Important Dates

Deadlines

- 5 November: Detailed outline of report due
- 3 December: Full report due
- 14 January: Presentation slides due
- 29 January (?): Seminar

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Missing a deadline causes immediate exclusion from the seminar

Selecting Your Topic

Procedure

- You obtain(ed) a list of topics of this seminar.
- Indicate the preference of your topics (first, second, third).
- Return sheet here or by Sunday (14 October) via e-mail (`noll@cs.rwth-aachen.de`) or to secretary.
- We do our best to find an adequate topic-student assignment.
  - disclaimer: no guarantee for an optimal solution
- Assignment will be published on web site next week.

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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

The Topics

Worst-Case Execution Time Analysis [Noll]

Goal

Analysis methods for establishing (safe and tight) timing constraints for (embedded) software, e.g. for ensuring schedulability

- challenge: execution times of instructions dependent on the execution history (caches, pipelines, speculative execution, ...)

The Topics

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Topics

1. Timing Analysis by Integer Linear Programs [B]
2. Timing Analysis by Abstract Segment Trees [B]
3. Power-Aware Worst Case Execution Time Analysis [B]
4. Timing Analysis by Abstract Interpretation
5. Semantics-Based Worst Case Execution Time Analysis

The Topics

Heap Resource Analysis [Matheja]

Goal

Logical methods for reasoning about memory resources (variables, heap)

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Topics

6. Introduction to Separation Logic [B]
7. Reasoning about Complexity of Data Structure Operations [B]
8. Permission Accounting for Concurrent Threads [B]
9. Graph-Based Reasoning about Relational Properties of Data Structures [B]
10. Variables as Resources [B]
11. Dataflow Analysis for Quantitative Properties of Tree Data Structures

The Topics

Static Analysis of Probabilistic Programs [Kaminski]

Goal

Reasoning about (expected) values of quantities such as reliability, termination and sizes of data structures in the presence of probabilistic behaviour (e.g., failures)

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Topics

12. Quantitative Separation Logic [B]
13. Abstract Interpretation of a Probabilistic λ-Calculus [B]
14. Estimating Probabilities of Program Assertions [B]
15. Static Quantitative Reliability Analysis [B]
16. Probabilistic Invariants and Almost-Sure Termination [B]
17. Abstract Interpretation of Imperative Probabilistic Programs I
18. Abstract Interpretation of Imperative Probabilistic Programs II

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