

DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics

**Combatting the Precision Loss of Partial
Contexts in Abstract Interpretation**

Felix Sebastian Kraye

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Contexts in Abstract Interpretation**

**Bekämpfung des Präzisionsverlust durch
partielle Kontexte in Abstrakter
Interpretation**

Author:	Felix Sebastian Kraye
Supervisor:	Supervisor
Advisor:	Advisor
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I confirm that this bachelor's thesis in informatics is my own work and I have documented all sources and material used.

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Felix Sebastian Kraye

Acknowledgments

Abstract

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1 Introduction

"[Goblint is] a static analyzer for multi-threaded C programs, specializing in finding concurrency bugs." (Copypaste from <https://goblint.in.tum.de/>) Analyzing interprocedural programs poses a certain difficulty. A function can be called in many different places in a program, where the (possible) values of not only formal arguments but also the global variables can be very different. Even a call in the same line of code can happen in very different contexts of such parameters and globals. Therefore one would like to analyze the function multiple times, each time with a different starting state of formal arguments and global variables or 'contexts'. However due to the high or potentially infinite amount of different calling contexts, this can be very costly.

An approach to reduce this cost is to only analyze the function in question for some few joint contexts, where multiple possible starting states are joined into a single context representing all of them. This however comes with the price of precision, especially when tracking values or relations between variables: The joint context needs to represent multiple different states. This means that the resulting context needs to represent everything that the states describe about each variable, leading to a less precise state. For example (assuming an interval analysis), if it is known in some context that $x = 5$ and in another that $x = 3$ before the call, then the starting state of the context needs to map x to the Interval $[3, 5]$.

Now even if a variable is not changed during the call and therefore also its state in the bigger state has not changed, the precision loss is still propagated to the state after the call. This is because when combining caller and callee state, it is not known whether this particular variable was updated or not. For unreachable variables by the callee the caller state can be kept, however this does not apply to globals and variables reachable by the callee. In the above example, assuming x is a global or reachable variable, the state of x after the call will be the interval $[3, 5]$, when x has not been altered in the call. To reduce this loss of precision, it would be helpful to know which variables have been altered by the call. Then, when combining the states, only the states of variables which have been altered need to be updated with the state returned after the call, while the states of other variables can be kept from the caller state before the call.

To gain the information of which variables have been altered, we will present a new analysis keeping track of this in chapter 3. Citation test [Lam94].

2 Background

2.1 Related Work

3 Main Contributions

3.1 Taint analysis

3.1.1 Fromal description

$$\mathbb{D} = 2^{\{\text{lval}\}}$$

$$[u] \in \mathbb{D}$$

Edge $e = (u, A, u')$ introduces the constraint $[u'] \sqsupseteq \llbracket A \rrbracket^\#(\text{get } [u])$

$$\llbracket x = y \rrbracket^\# \text{lv} = \text{lv} \cup \{x\}$$

$$\llbracket *x = y \rrbracket^\# \text{lv} = \text{lv} \cup \text{MayPointTo}(x)$$

$$\text{enter}^\# \text{lv} = \emptyset$$

$$\text{combine}^\# \text{lv}_{\text{cr}} \text{lv}_{\text{ce}} = \text{lv}_{\text{cr}} \cup \text{lv}_{\text{ce}}$$

3.1.2 Implementation

3.2 Benefiting other Analyses

In this section we will use the new taint analysis to improve a context insensitive analysis. For this let's choose an analysis that maps Lvalues to Rvalues. When combining the contexts of the caller before the call with the one returned by the callee there are a few aspects to keep in mind:

- All mappings of Lvalues, which are not tracked in the caller (i.e. map to top), but have a concrete value within the callee need to be added to the combined context. This is for Lvalues which are newly initialized inside the callee.
- (All mappings which are not in the callee context but have been in the caller context need to be removed. This can happen in multithreaded programs, if in the caller a mutex was held, that then was unlocked by the callee, deleting the information protected by the mutex)

- for all other Lvalues present in both contexts, the Rvalues mapped to by Lvalues not in the tainted set can be kept. We are sure that these variables are unchanged, even if they have a less precise record in the callee's context. For Lvalues present in the tainted set, it is necessary to take the Rvalue from the callee context, as the old Rvalue mapped to by the caller is incorrect.

formal:

$$\text{combine}^\# \eta_{cr} \eta_{ce} = \text{let } \eta'_{cr} = \eta_{cr} \setminus lv_{ce} \text{ in} \quad (3.1)$$

$$\text{let } \eta'_{ce} = \eta_{ce} \cap lv_{ce} \text{ in} \quad (3.2)$$

$$\eta'_{cr} \cup \eta'_{ce} \quad (3.3)$$

4 Evaluation

4.1 Testing

4.2 Benchmarking

5 Conclusion

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Bibliography

- [Lam94] L. Lamport. *LaTeX : A Documentation Preparation System User's Guide and Reference Manual*. Addison-Wesley Professional, 1994.