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Master's Thesis

## **A Data-flow Analysis Framework for Graal IR**

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The goal of this project is to develop a general data-flow analysis framework for Graal IR. The framework should implement the required tools for tracking sparse, conditional data flow information and iterating over the graph in an efficient manner until a fixed point is reached. It should be simple to instantiate the framework with different analysis domains to express various analyses without having to touch the general framework code.

The framework should be general enough to allow efficient implementations of at least the following analysis domains:

- Sparse conditional constant propagation (and folding): track which values in the graph are constant, fold arithmetic operations with known constant inputs. A specific implementation of this was already done in a previous student project. This master thesis aims to build and expand upon this approach.
- Value range analysis: track the possible ranges of values for values in the graph, use stamp machinery to evaluate arithmetic operations over ranges
- Pentagonal analysis: track value range information plus sets of symbolic " $x < y$ " constraints (maybe some flavor of flow-sensitive pointer analysis, just to have something that's not a numeric domain).

Domains should maybe be able to specify which nodes they are interested in, so that we don't have to analyze irrelevant parts of the program. For example, the main use of pentagonal analysis is for folding away array bounds checks. Only integer computations that are used by bounds checks should have to be analyzed for this, so most of the program could be ignored by the analysis, causing a significant speedup. This is a form of "program slicing". A direct combination with data flow analysis might be novel.

The work's progress should be discussed with the supervisor at least every 2 weeks. Please note the guidelines of the Institute for System Software when preparing the written thesis. The deadline for the written thesis is 30.9.2025.

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