

# Incremental Computation of Static Single Assignment Form

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**Abstract.** Static single assignment (SSA) form is an intermediate representation that is well suited for solving many data flow optimization problems. However, since the standard algorithm for building SSA form is exhaustive, maintaining correct SSA form throughout a multi-pass compilation process can be expensive. In this paper, we present incremental algorithms for restoring correct SSA form after program transformations. First, we specify incremental SSA algorithms for insertion and deletion of a use/definition of a variable, and for a large class of updates on intervals. We characterize several cases for which the cost of these algorithms will be proportional to the size of the transformed region and hence potentially much smaller than the cost of the exhaustive algorithm. Secondly, we specify customized SSA-update algorithms for a set of common loop transformations. These algorithms are highly efficient: the cost depends at worst on the size of the transformed code, and in many cases the cost is independent of the loop body size and depends only on the number of loops.

## 1 Introduction

Static single assignment (SSA) [8, 6] form is a compact intermediate program representation that is well suited to a large number of compiler optimization algorithms, including constant propagation [19], global value numbering [3], and program equivalence detection [21]. In SSA form, each variable appears as a target of an assignment at most once, so that each variable use is reached by a single definition. Special variable definitions called  $\phi$ -functions are added to the program to represent multiple reaching definitions.

This paper addresses the problem of *rebuilding* SSA form after program transformation. The traditional algorithm for building minimal SSA form [8, 18] is efficient but exhaustive. Even when program changes are small, the cost of updating SSA with this algorithm is proportional to the size of the procedure. As a result, maintaining current and correct SSA form during a multi-pass compilation process is expensive.

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