Major Research Initiatives in GCC Resource Center

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Part 1

Introduction

Broad objectives

Theoretical research supported by empirical evidence

- Exploring research issues in real compilers
- Demonstrating the relevance and effectiveness (of our explorations) in real compilers

Broad Areas of Interests

- Program Analysis and Optimization
- Translation Validation
- Retargetable compilation
- Parallelization and Vectorization for SIMD and MIMD Architectures

General explorations applied in the context of GCC

Examples of Research Commitments

- Interprocedural data flow analysis
- Heap reference analysis
- Static inferencing of flow sensitive polymorphic types
- Translation validation of GCC generated code
- Increasing trustworthiness of GCC
    - Cleaner machine descriptions for GCC
    - Generating GCC optimizers from specifications

Part 2

Interprocedural Data Flow Analysis

Interprocedural Data Flow Analysis [CC2008]

- Objectives:
- Main Challenge:
- The State of Art:
- Our Breakthrough:
- The Consequences:

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- Objectives: Optimizations across procedure boundaries to incorporate
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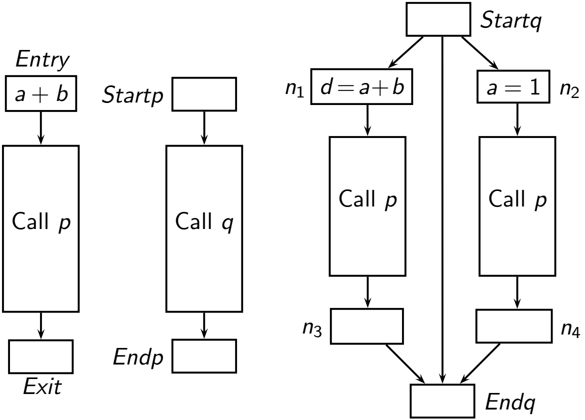

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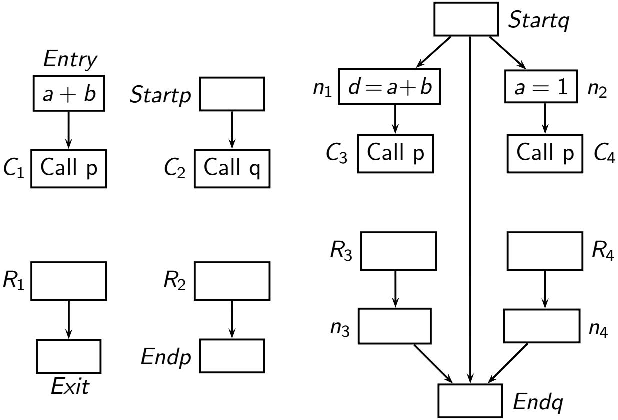

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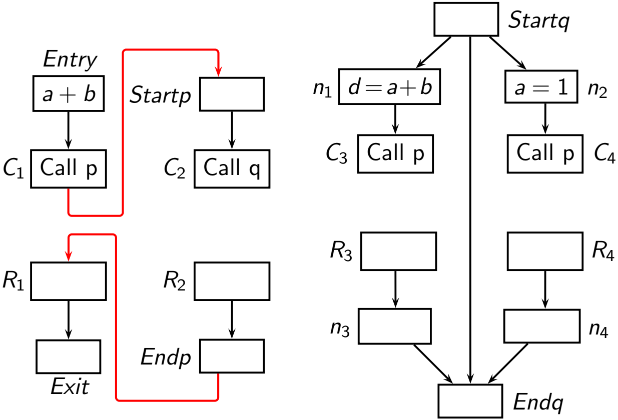

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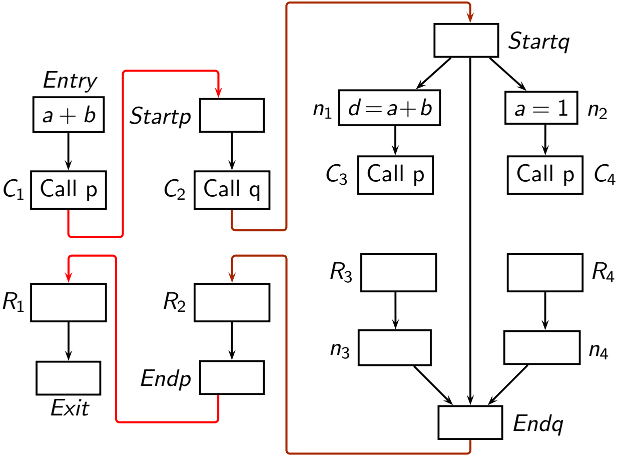

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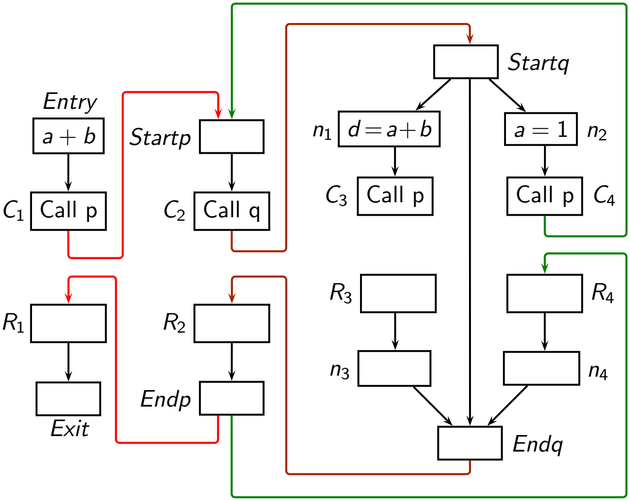

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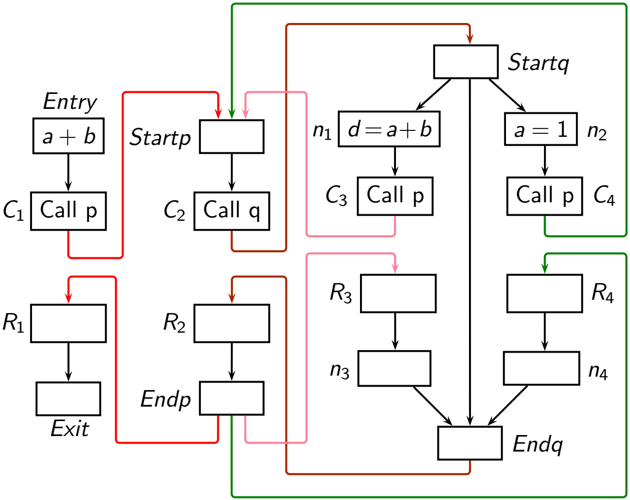

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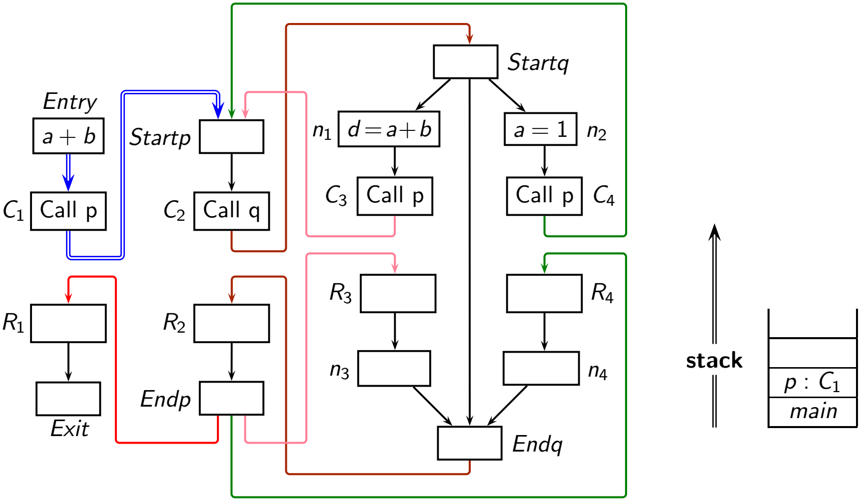

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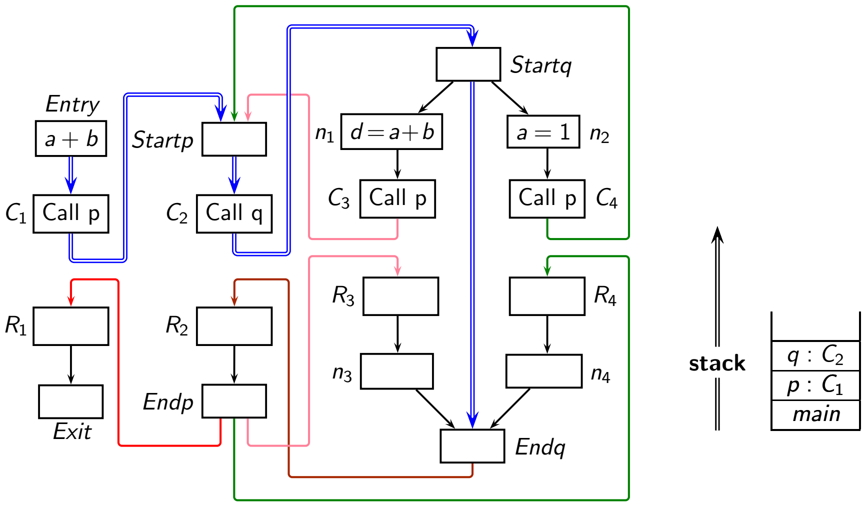

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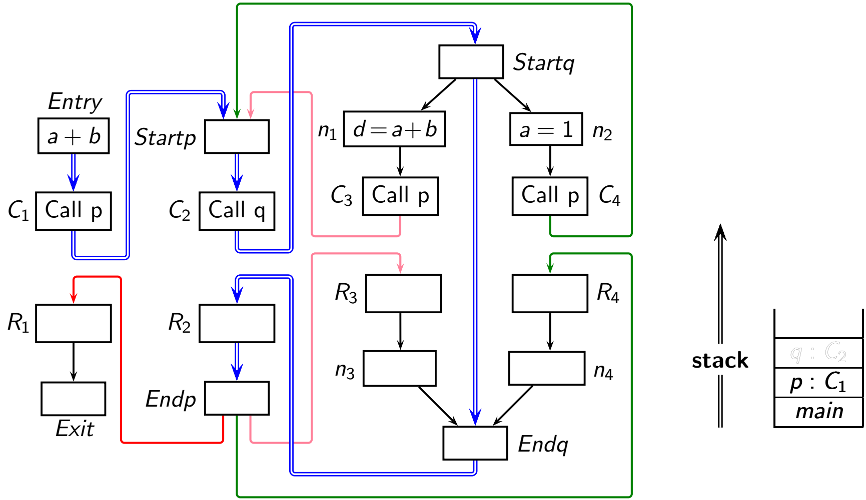

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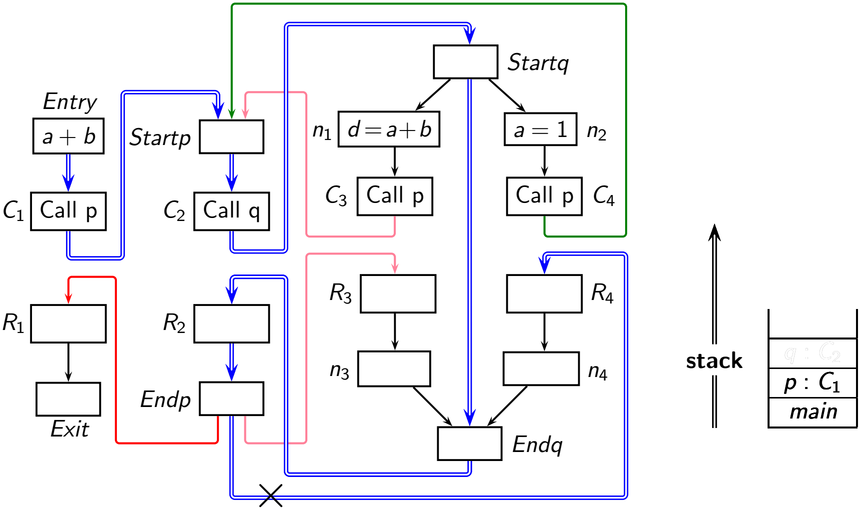

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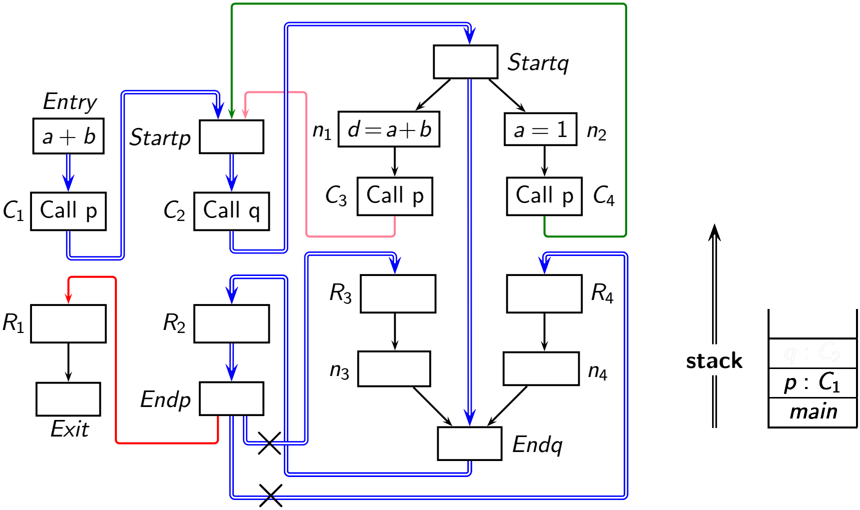

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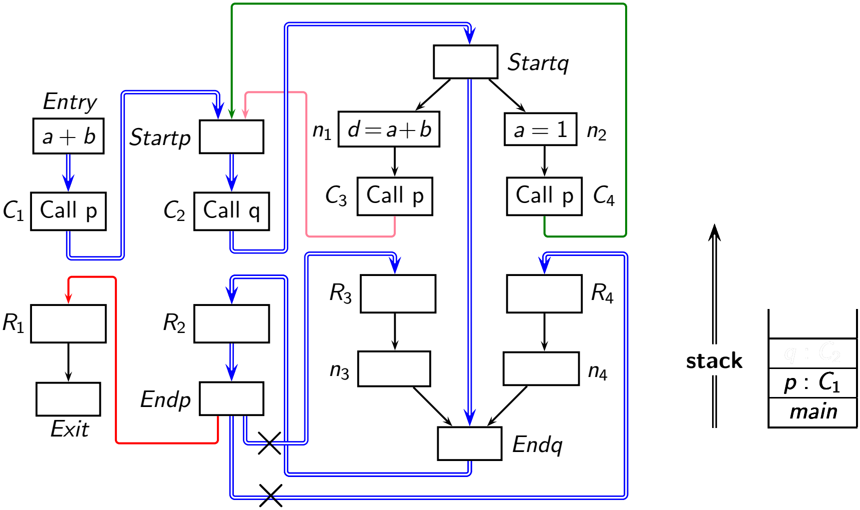

Context is defined by stack snapshot $\Rightarrow$ Unbounded number of contexts

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Part 3

Heap Reference Analysis

Heap Reference Analysis [TOPLAS 2007]

- The Problem:
- Our Objectives:
- Main Challenge:
- Our Key Idea:
- Current status:

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Which Heap Memory Nodes Can be Statically Marked as Live?

If the while loop is not executed even once.

```
w = x          // x points to m_a
while  (x.data < max)
       x = x.rptr
y = x.lptr

z = New  class_of_z
y = y.lptr
z.sum = x.data + y.data
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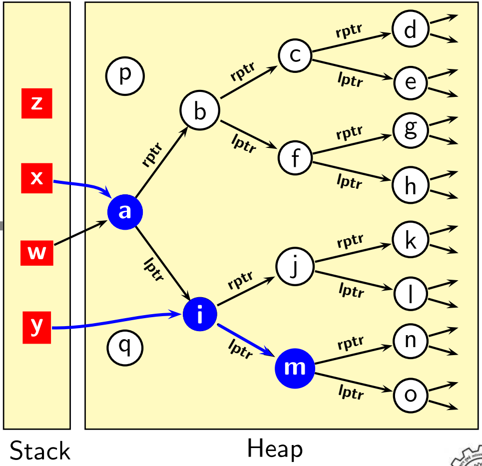

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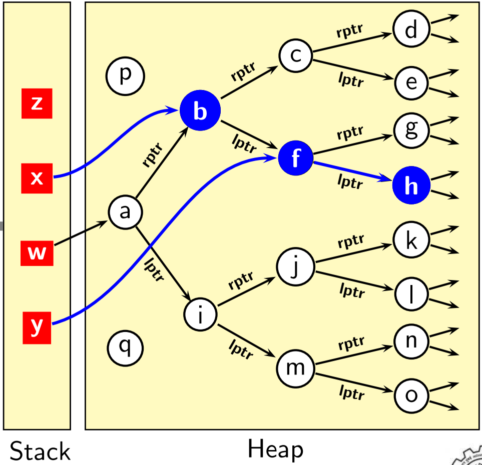

Which Heap Memory Nodes Can be Statically Marked as Live?

If the while loop is executed twice.

```
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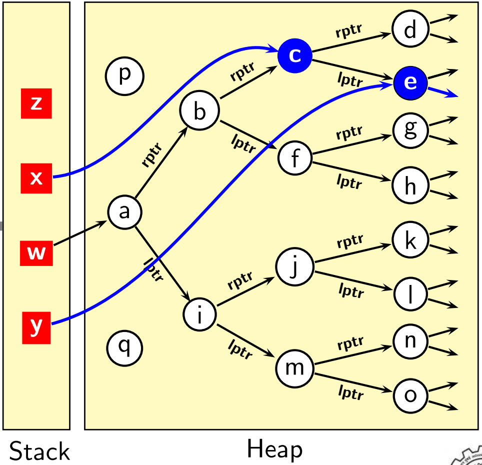

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Our Solution

		y = z = null
1	w = x	
		w = null
2	while (x.data < max)	
	{	x.lptr = null
3	x = x.rptr }	
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4	y = x.lptr	
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6	y = y.lptr	
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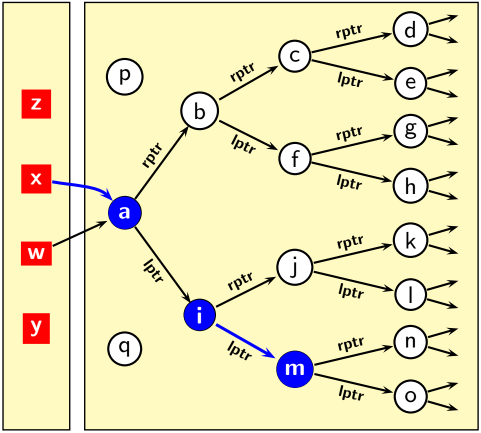

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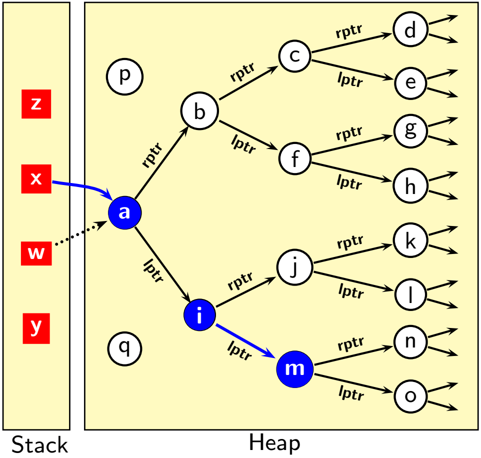

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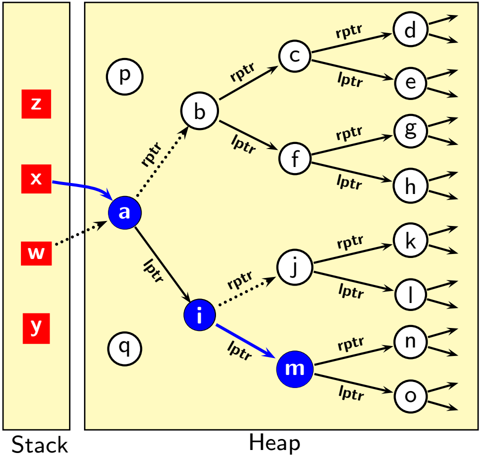

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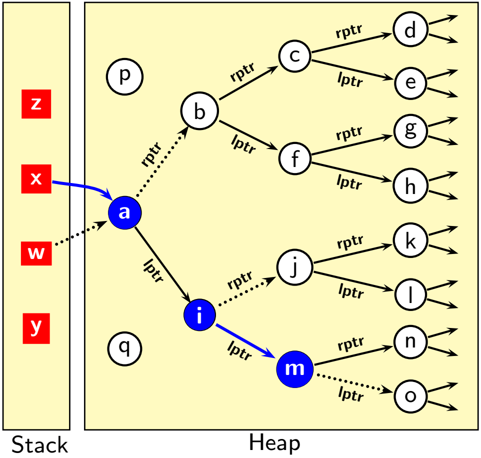

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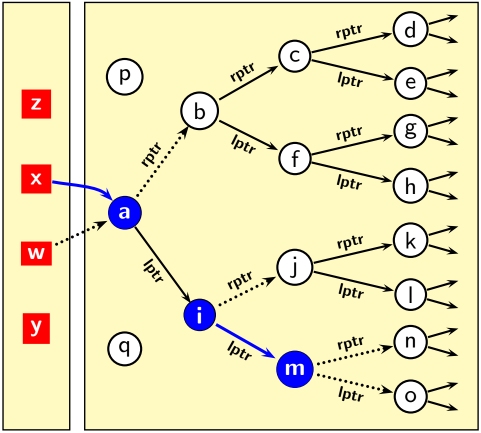

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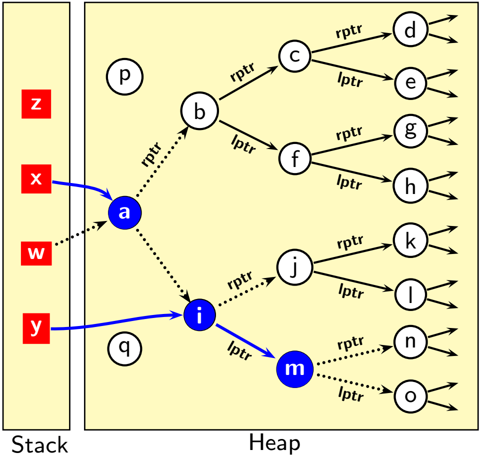

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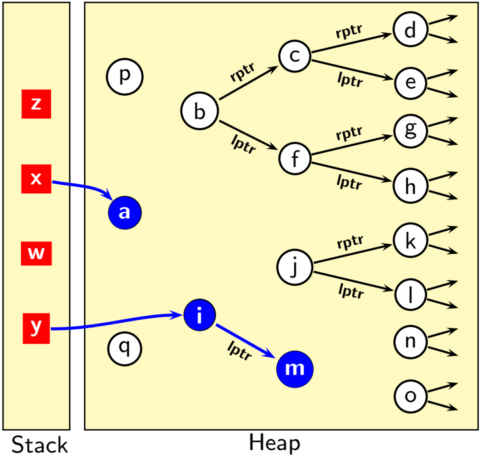

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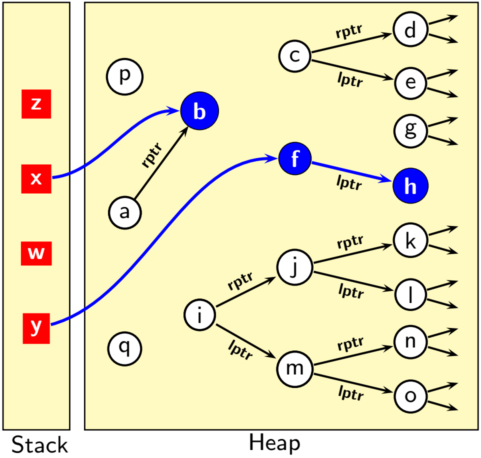

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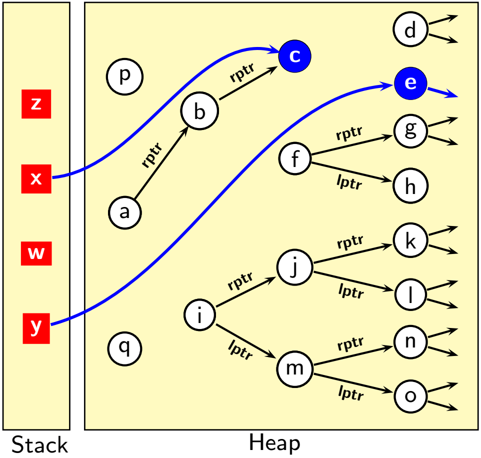

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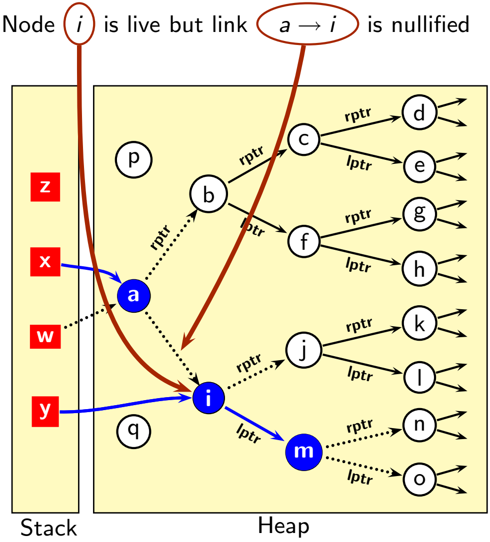

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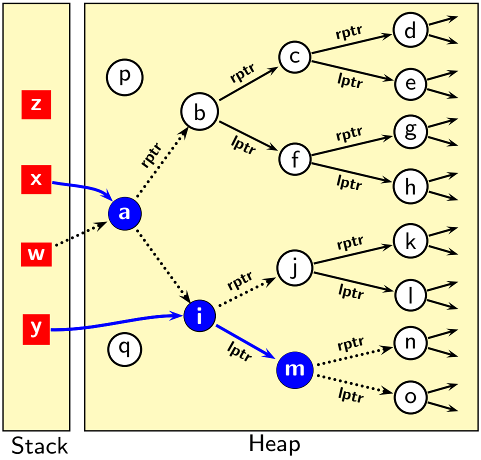
New access expressions are created.
Can they cause exceptions?



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- Our Objectives: To perform static analysis of heap allocated data for making unused data unreachable in order to improve garbage collection and plug memory leaks.
- Main Challenge: Unlike stack and static data, the mapping between object names and their addresses keeps changing at runtime for heap data.
- Our Key Idea: Represent abstractions of heap data in terms of graphs and perform analysis using these graphs as data flow values.
- Current status: Theory and prototype implementation (at the intraprocedural level) ready for Java.
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- Future Work:
  - Analysis for functional languages
  - Interprocedural implementation and Performance tuning
  - Implementation for C++

BTW, What is Static Analysis of Heap?

Static	Dynamic

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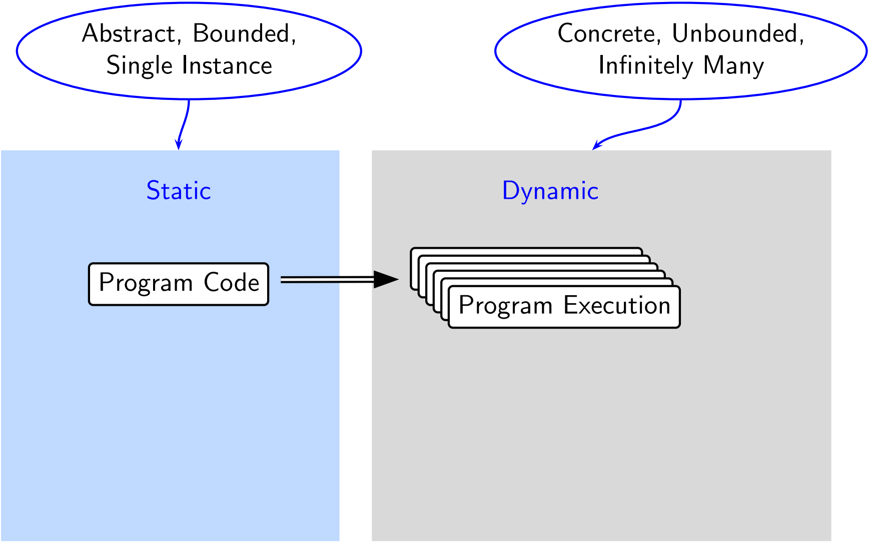

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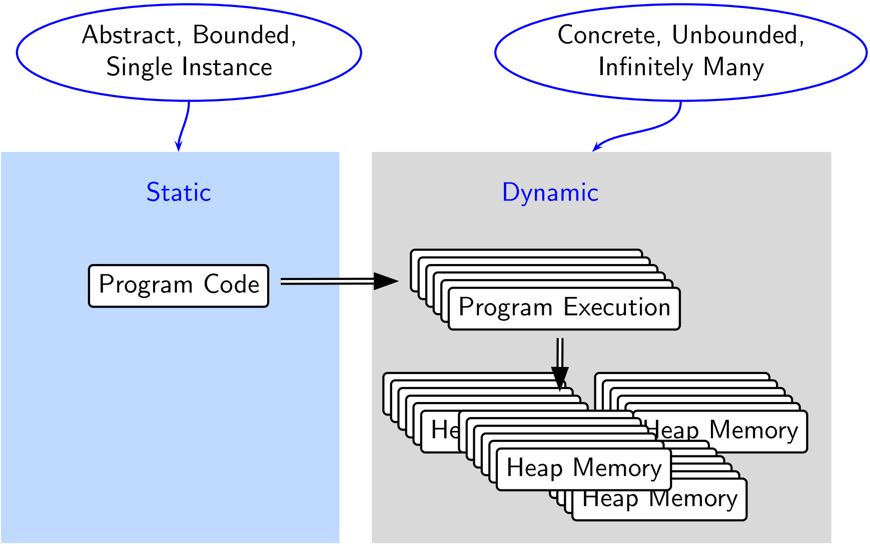

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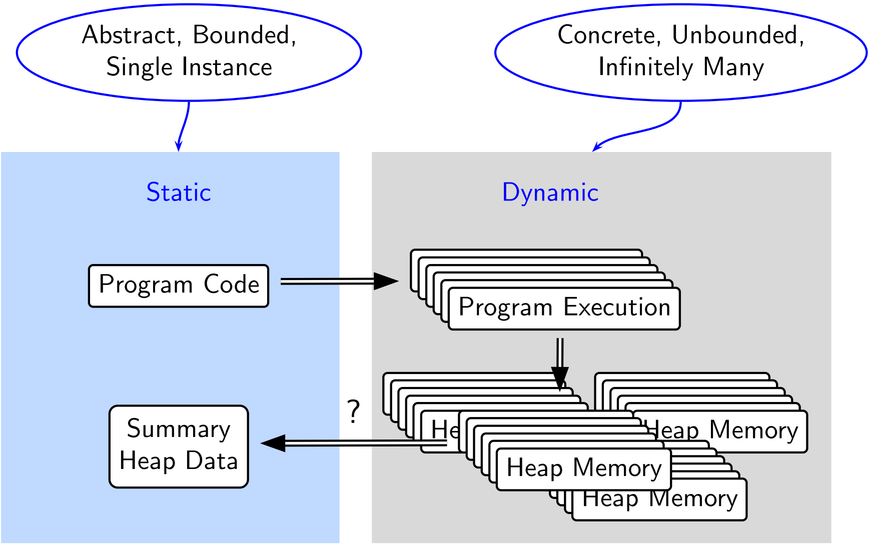

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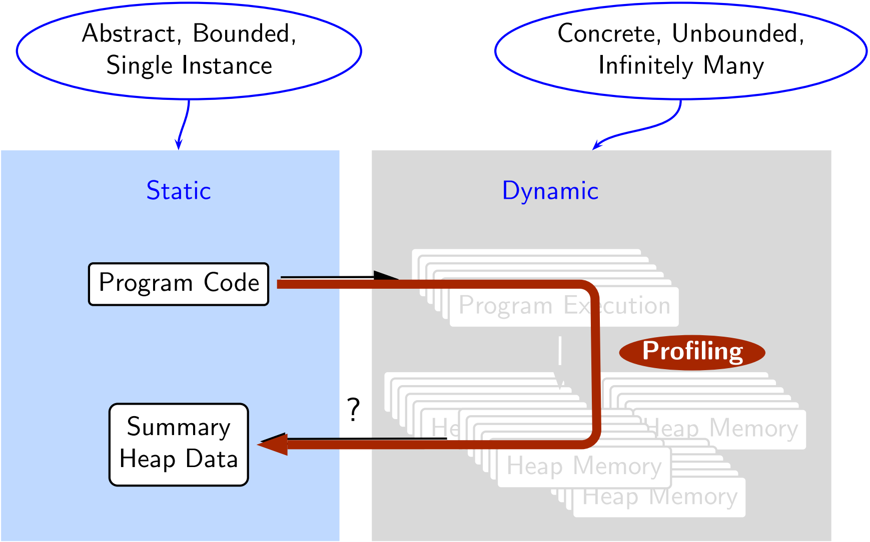

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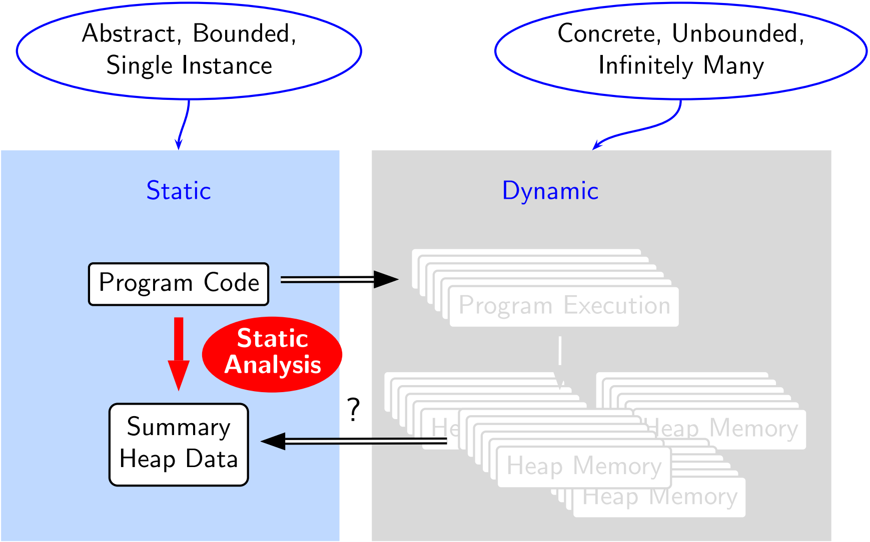
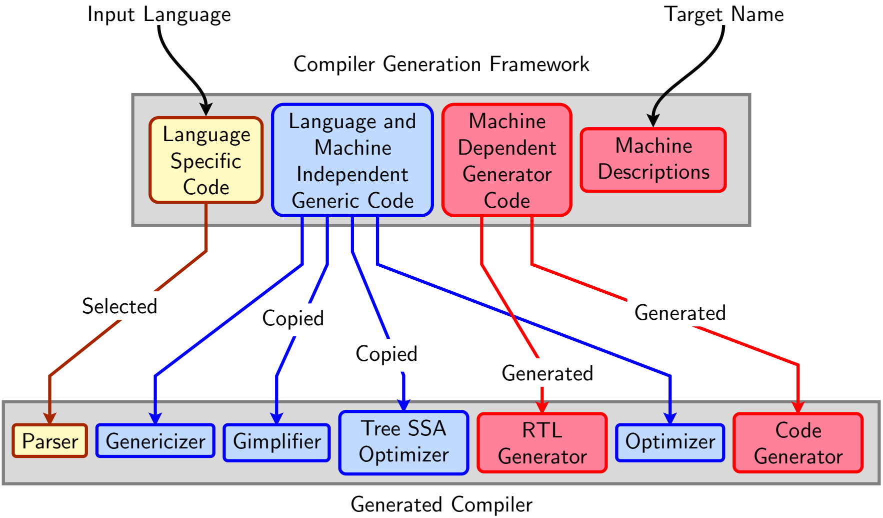


Part 4

Improving Instruction Selection in GCC

GCC : The GNU Compiler Collection



Improving Retargetability and Instruction Selection in GCC

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- The Problem: Instruction selection algorithms in GCC are very primitive (employ full tree matching instead of tree tiling).
- The Consequences:
  - A compiler developer needs to visualize and specify meaningful combinations of instructions for generating good quality code.
  - The machine descriptions are difficult to construct, understand, maintain, and enhance.
  - GCC has become a hacker's paradise instead of a clean, production quality compiler generation framework.

Improving Retargetability and Instruction Selection in GCC

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Improving Retargetability and Instruction Selection in GCC

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  - Discover the abstractions required in machine descriptions and develop a systematic methodology of constructing them.
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  - Preliminary investigations in using `iburg` seem very promising. (Only 200 rules required for `i386` instead of over a 1000!)

Part 5

Improving Optimizations in GCC

Improving Machine Independent Optimizations in GCC

- The Problems:
- Our Goals:
- Current Status:

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- The Problems:
  - Primitive algorithms and adhoc designs (too many passes, repetitive work in passes, inappropriateness of IR).
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  - Facilitate generation of optimizers from specifications.
    - Clean specifications
    - Systematic local, global, and interprocedural analysis
    - Simple, efficient, generic, and precise algorithms
    - Incremental analyses for aggressive optimizations
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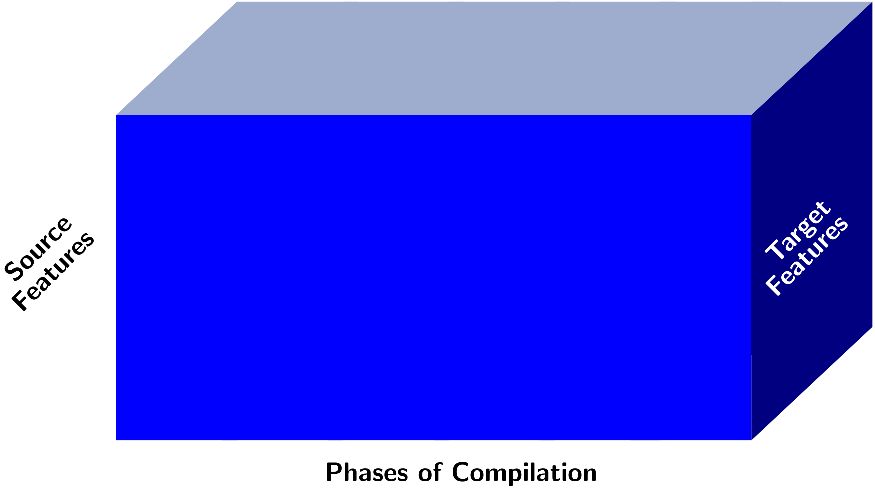
  - Algorithms and formal theory required further is in place.

Part 6

Systematic Construction of Machine Descriptions

In Search of Modularity in Retargetable Compilation



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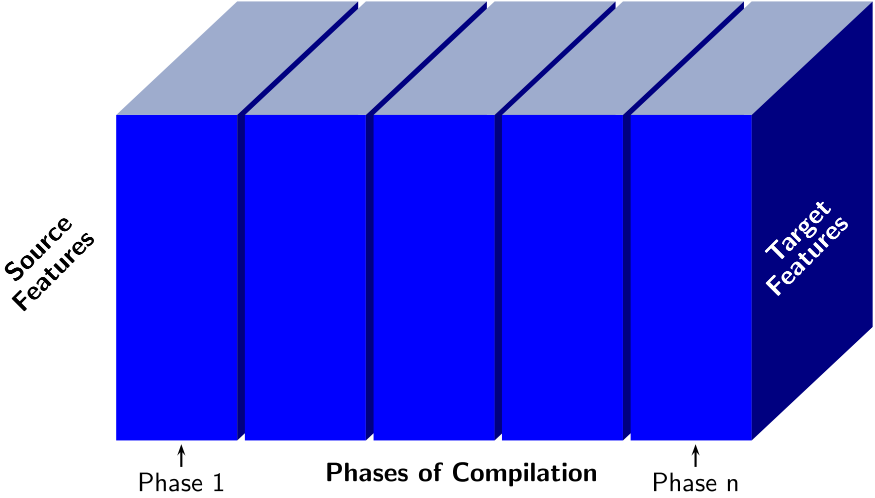

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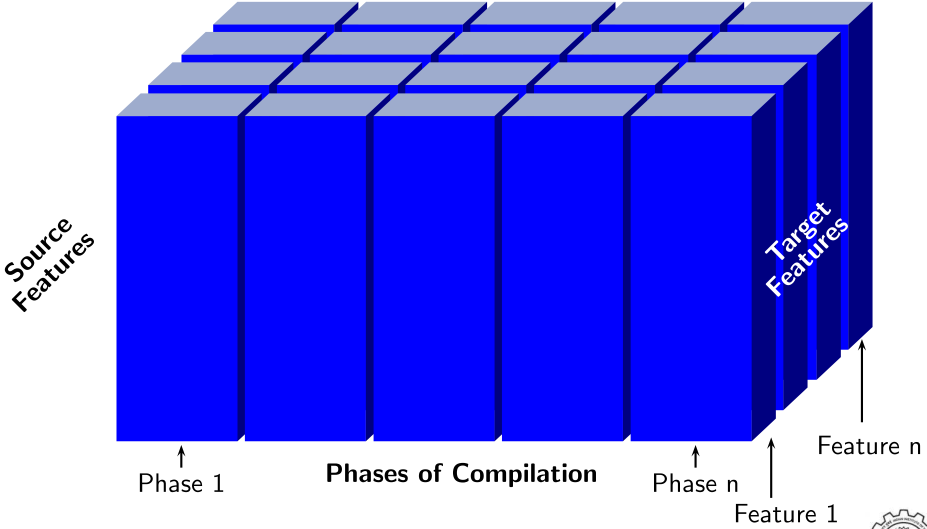

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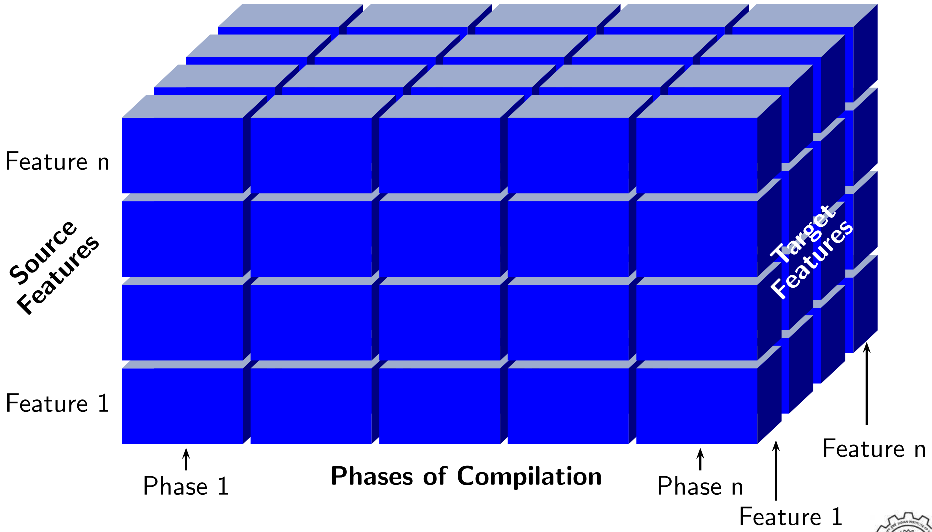

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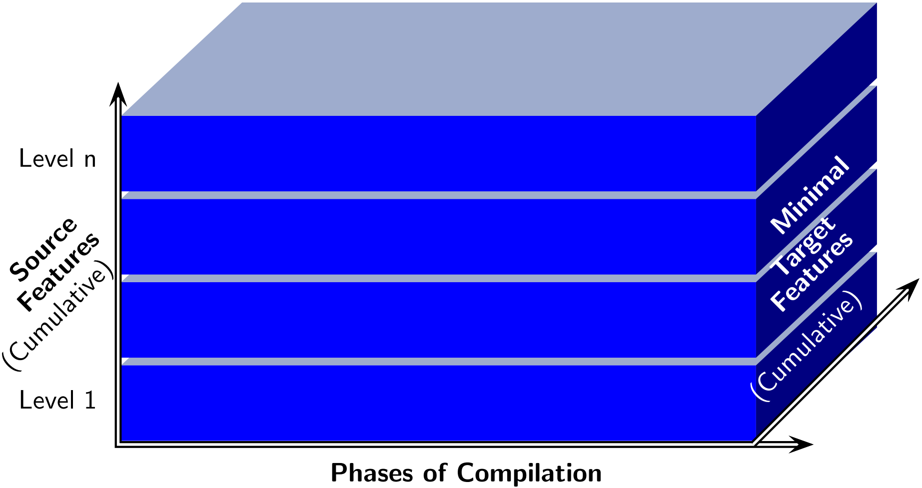
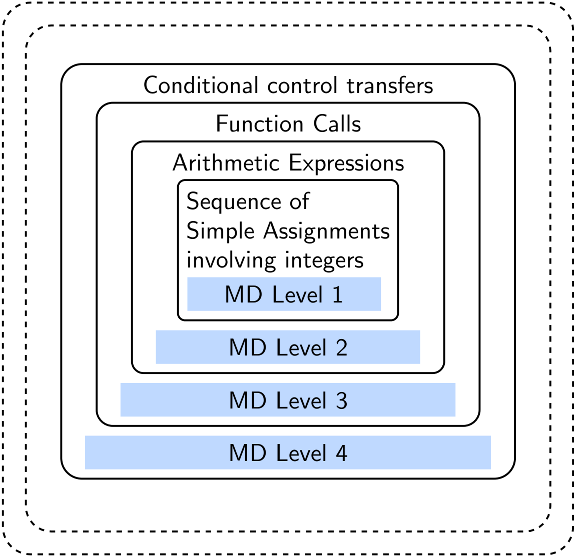


Systematic Development of Machine Descriptions [GREPS 2007]



Part 8

Translation Validation of GCC

Translation Validation of GCC

- Problem:
- Our Objectives:
- Our approach:
- Current Status:
- Future work:

Translation Validation of GCC

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  - Establishing correctness of compilers is important.
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- Future work:
  - Cleaning up the theory to systematize the termination criteria.
  - Extending the approach to include more optimizations.

Part 9

Linear Types in GCC

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  - An initial draft of the type system is in place.

Part 10

Conclusions

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  - Synergy from group activities
  - Long term commitment to challenging research problems
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- *Would you like to be a part of this dream?*

Last but not the least . . .

Thank You!