Workshop on Essential Abstractions in GCC

A Summary of Essential Abstractions

GCC Resource Center

(www.cse.iitb.ac.in/grc)

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Indian Institute of Technology, Bombay

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Part 2

Methodology

Our Padagogy

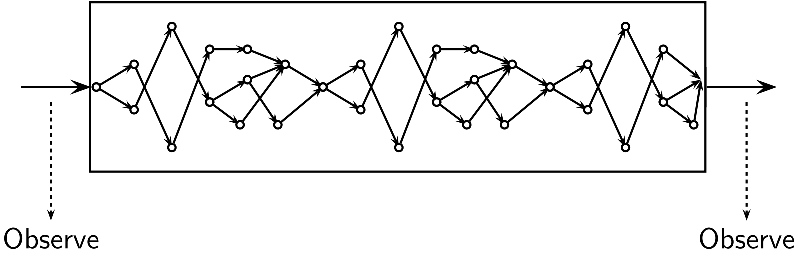
	External View	Internal View
Compiler Specifications	Machine descriptions	Front end hooks
Compiler Generator	Configuration and building	Retargetability mechanism
Generated Compiler	Gray box probing Pass structure and IR Parallelization, Vectorization	Pass structure Control flow Static and dynamic plugin mechanisms

Gray Box Probing

Black Box Probing

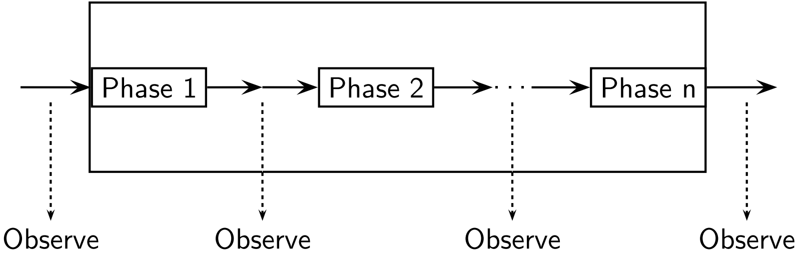
Gray Box Probing

White Box Probing

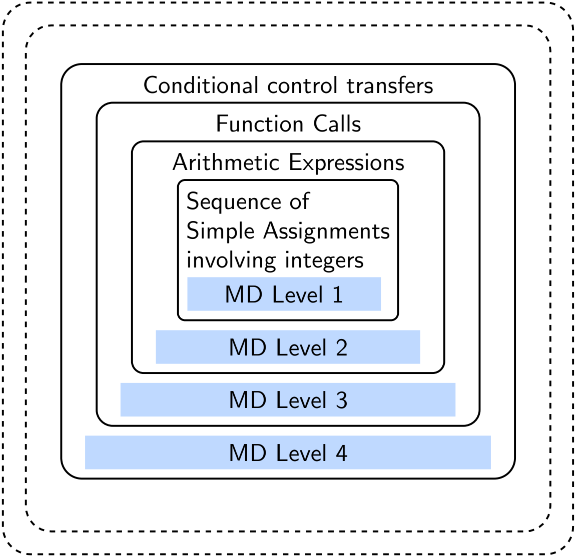


Gray Box Probing

Gray Box Probing



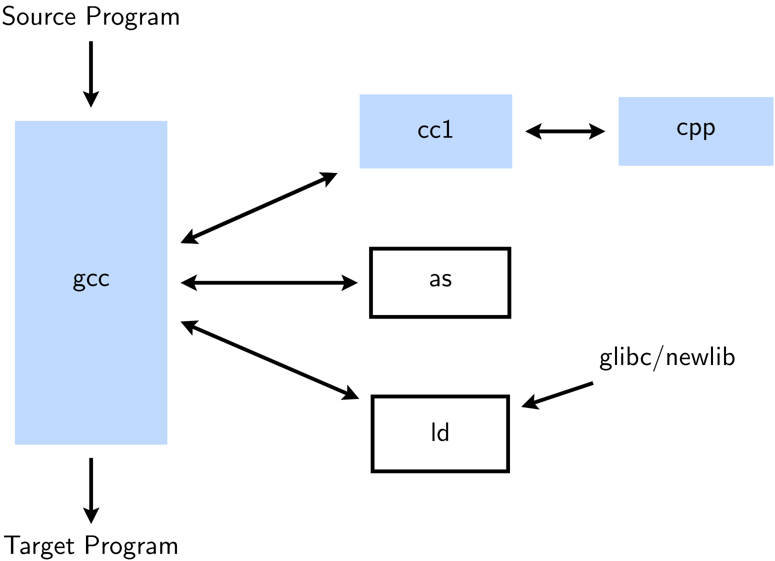
Systematic Development of Machine Descriptions



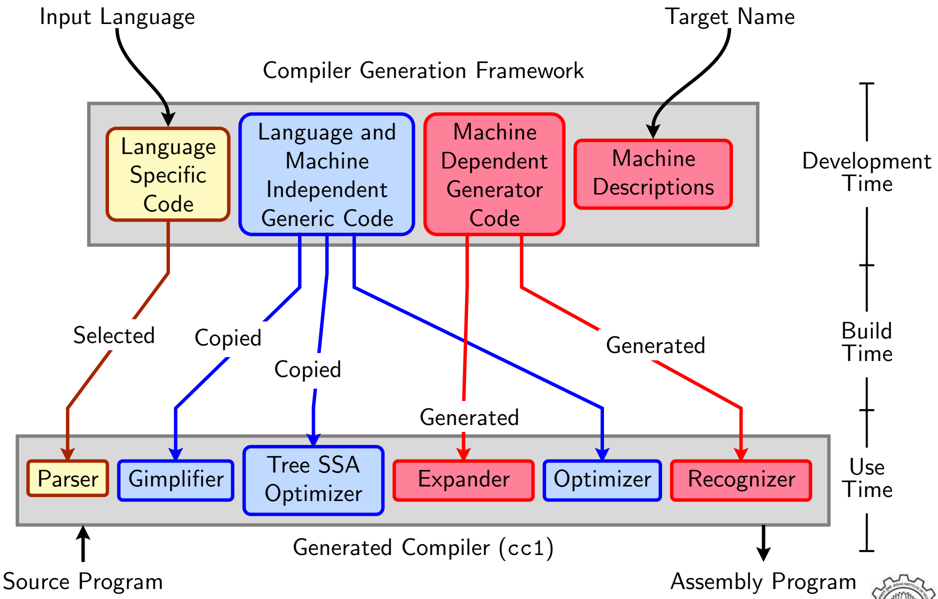
Part 3

The Framework

The GNU Tool Chain for C



The Architecture of GCC



Part 4

The Generated Compiler

Compilation Models

Aho Ullman Model

Front End → AST → Optimizer → Target Indep. IR → Code Generator → Target Program

Aho Ullman: Instruction selection

- over optimized IR using
- cost based tree pattern matching

Davidson Fraser: Instruction selection

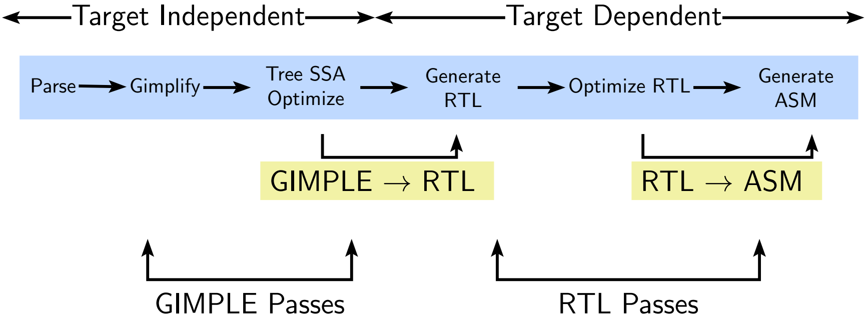
- over AST using
- structural tree pattern matching
- naive code which is
  - target dependent, and is
  - optimized subsequently

Davidson Fraser Model

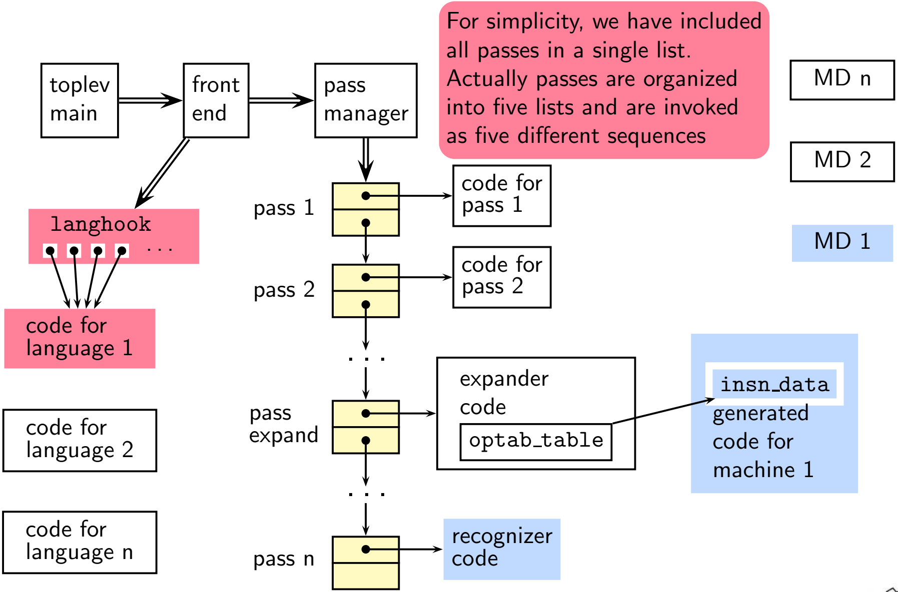
Front End → AST → Expander → Register Transfers → Optimizer → Register Transfers → Recognizer → Target Program

Basic Transformations in GCC

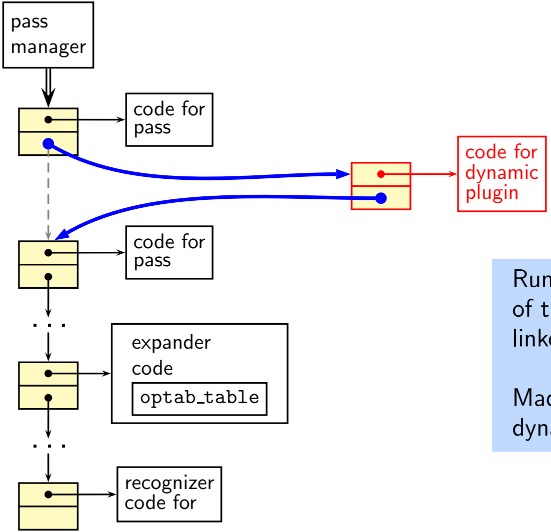
Tranformation from a language to a *different* language



Plugin Structure in `cc1`



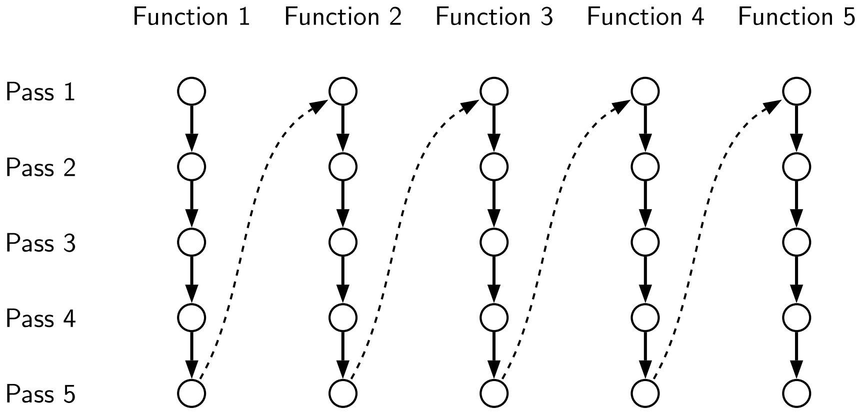
The Mechanism of Dynamic Plugin



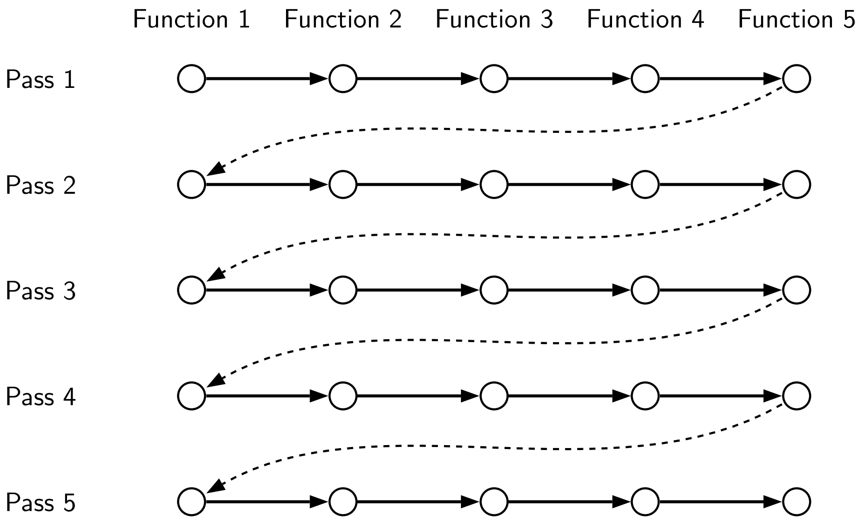
Runtime initialization of the appropriate linked list of passes

Made possible by dynamic linking

Execution Order in Intraprocedural Passes



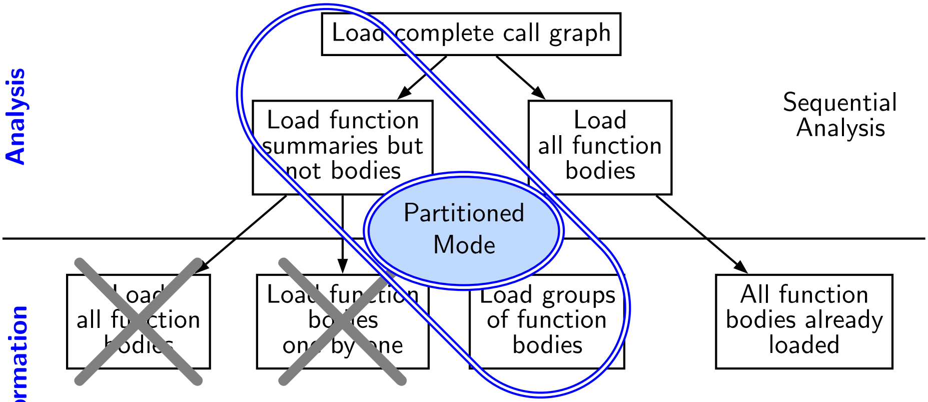
Execution Order in Interprocedural Passes



Part 5

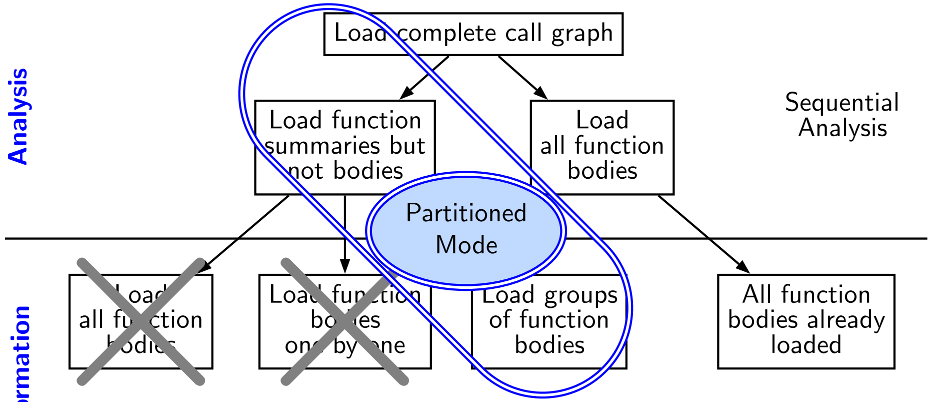
LTO

Partitioned and Non-Partitioned LTO



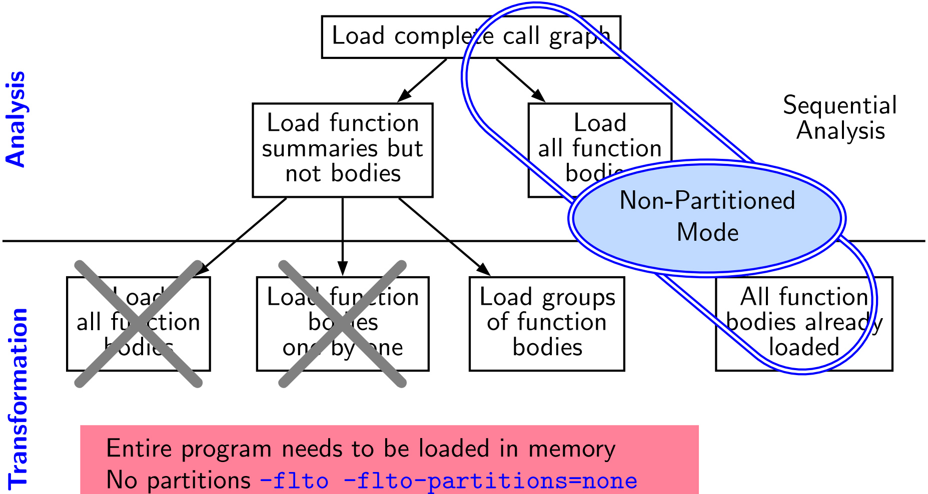
No need to load the entire program in memory
IPA possible (multiple function bodies)
Parallel transformations possible
Analysis and transformations in independent processes

Partitioned and Non-Partitioned LTO



Balanced partitions `-flto -flto-partitions=balanced`
One Partition per file `-flto -flto-partitions=1to1`
Partitions by number `-flto --params lto-partitions=n`
Partitions by size `-flto --params lto-min-partition=s`

Partitioned and Non-Partitioned LTO



- Entire program needs to be loaded in memory
- No partitions `-flto -flto-partitions=none`
- Strictly sequential transformations
- Analysis and transformations in the same processes

cc1 and Single Process lto1

```
toplev_main
...
  compile_file
  ...
    cgraph_analyze_function
```

cc1

```
cgraph_optimize
...
  ipa_passes
  ...
    cgraph_expand_all_functions
    ...
      tree_rest_of_compilation
```

cc1 and Single Process lto1

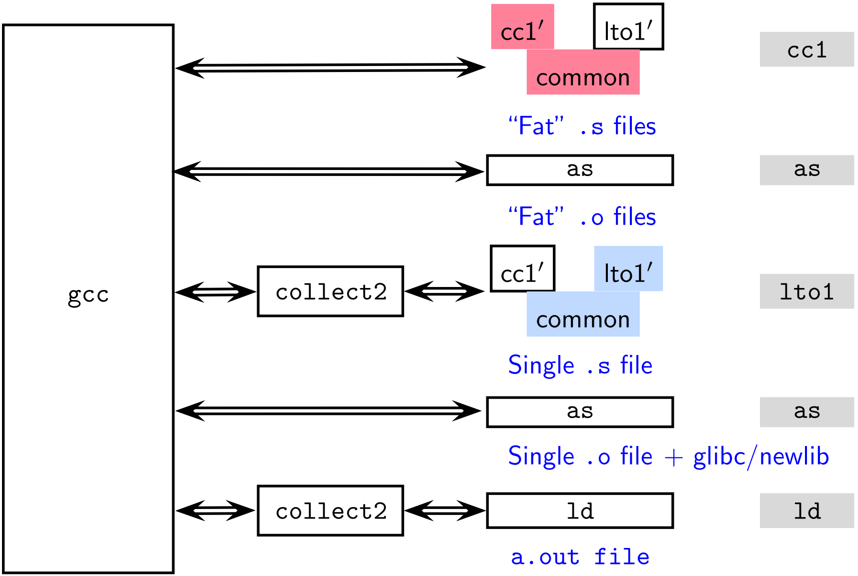
```
toplev_main
...
  compile_file
  ...
    cgraph_analyze_function
```

```
lto_main
...
  read_cgraph_and_symbols
  ...
    materialize_cgraph
```

```
cgraph_optimize
...
  ipa_passes
  ...
    cgraph_expand_all_functions
    ...
      tree_rest_of_compilation
```

lto1

The GNU Tool Chain for Single Process LTO Support



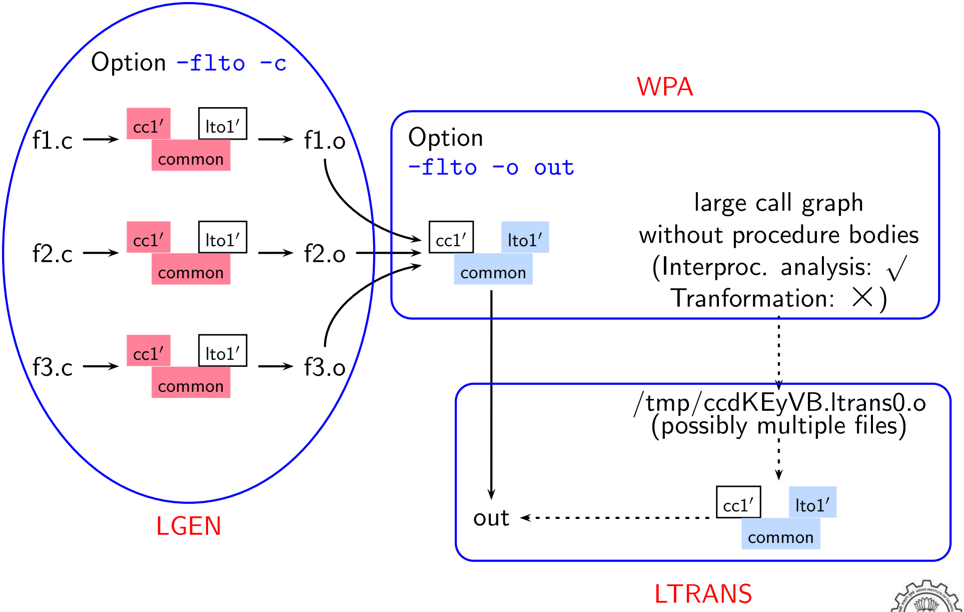
The GNU Tool Chain for Single Process LTO Support

cc1′ lto1′

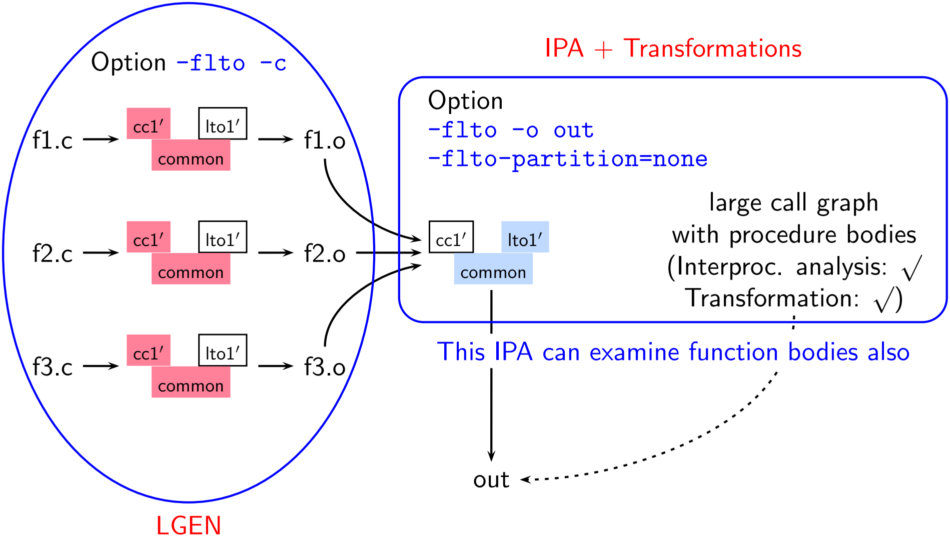
Common Code (executed twice for each function in the input program for single process LTO. Once during LGEN and then during WPA + LTRANS)

```
cgraph_optimize
   ipa_passes
      execute_ipa_pass_list(all_small_ipa_passes)/*!in lto*/
         execute_ipa_summary_passes(all_regular_ipa_passes)
         execute_ipa_summary_passes(all_lto_gen_passes)
         ipa_write_summaries
      execute_ipa_pass_list(all_late_ipa_passes)
      cgraph_expand_all_functions
         cgraph_expand_function
         /* Intraprocedural passes on GIMPLE, */
         /* expansion pass, and passes on RTL. */
```

Partitioned LTO (aka WHOPR LTO)



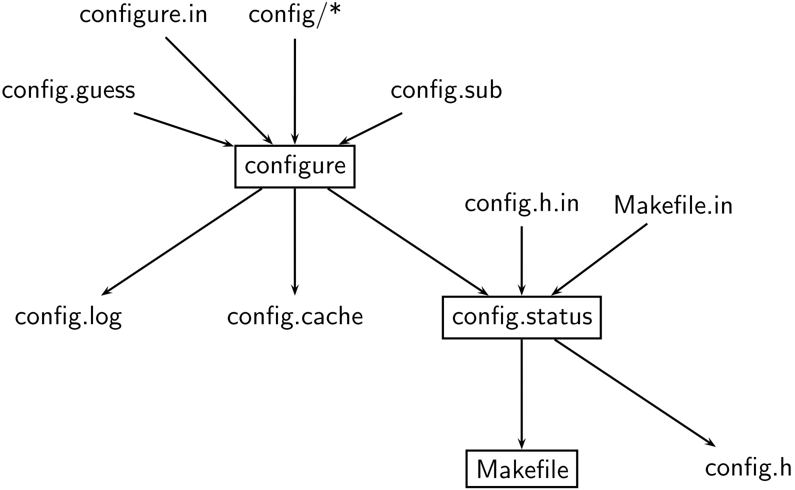
Non-Partitioned LTO



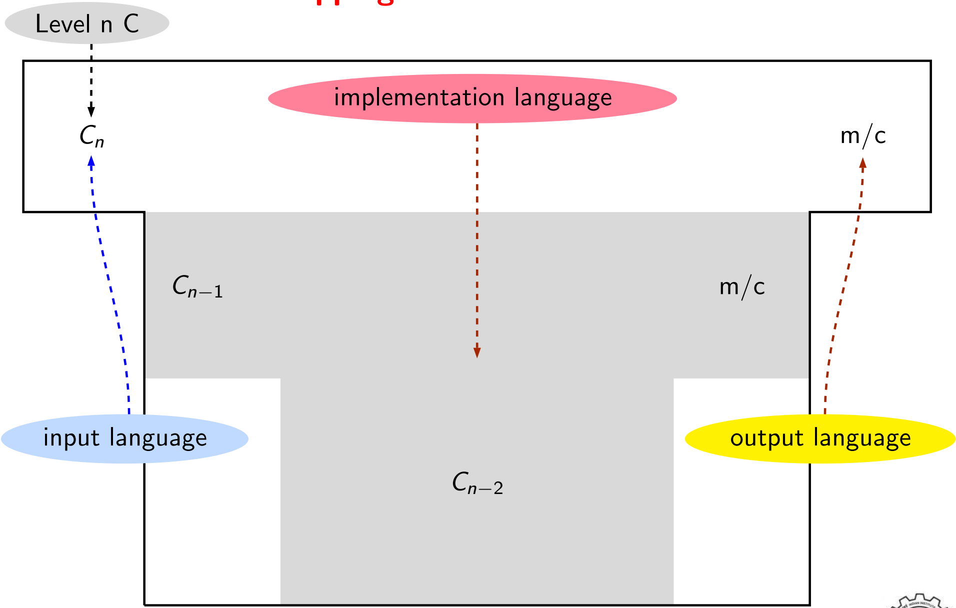
Part 6

The Build Process

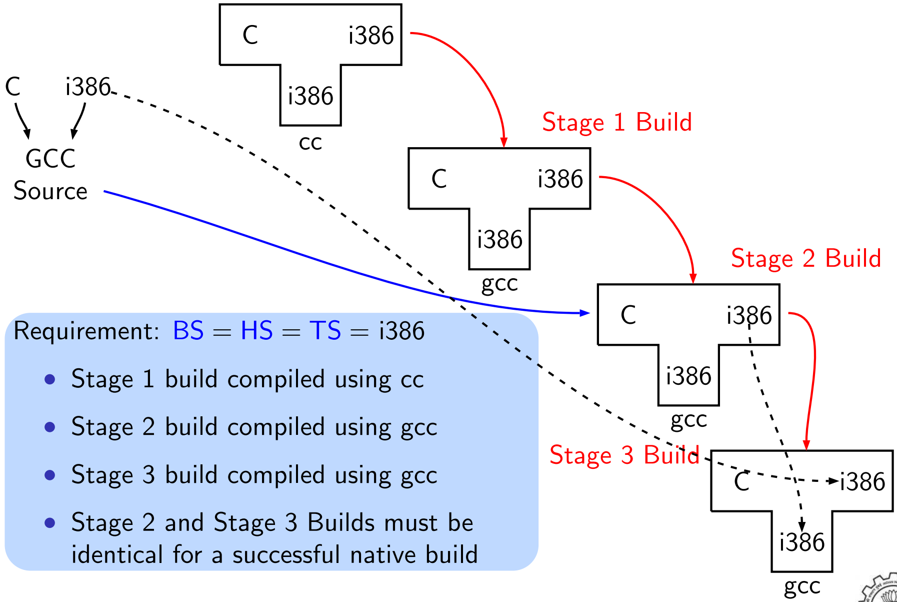
Configuring GCC



Bootstrapping: The Conventional View



A Native Build on i386



Requirement: BS = HS = TS = i386

- Stage 1 build compiled using cc
- Stage 2 build compiled using gcc
- Stage 3 build compiled using gcc
- Stage 2 and Stage 3 Builds must be identical for a successful native build

Build for a Given Machine

This is what actually happens!

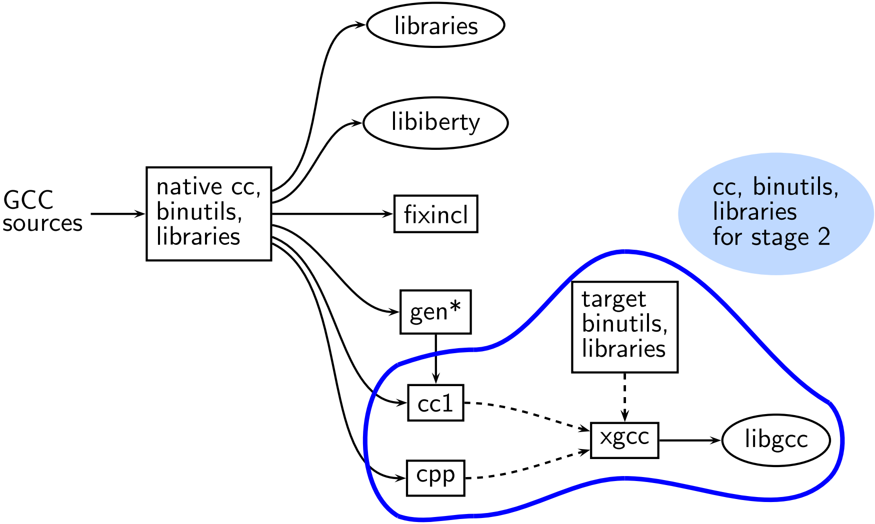
- Generation
  - Generator sources (`$(SOURCE_D)/gcc/gen*.c`) are read and generator executables are created in `$(BUILD)/gcc/build`
  - MD files are read by the generator executables and back end source code is generated in `$(BUILD)/gcc`
- Compilation

  Other source files are read from `$(SOURCE_D)` and executables created in corresponding subdirectories of `$(BUILD)`
- Installation

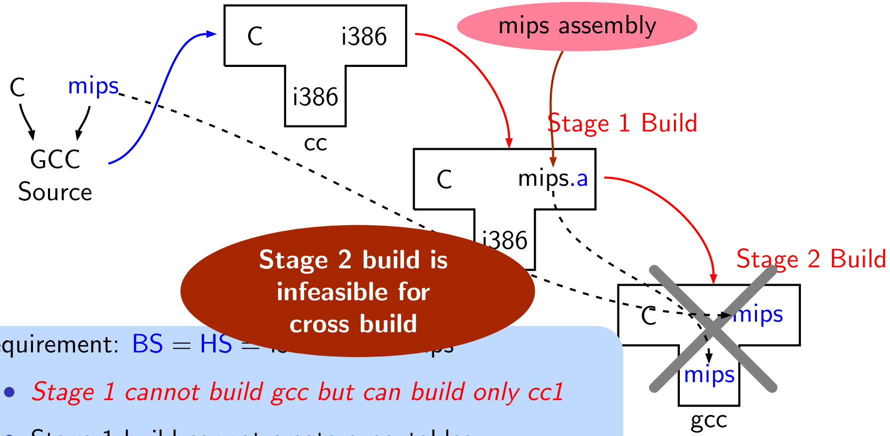
  Created executables and libraries are copied in `$(INSTALL)`

```
genattr
gencheck
genconditions
genconstants
genflags
genopinit
genpreds
genattrtab
genchecksum
gencondmd
genemit
gengenrtl
genmddeps
genoutput
genrecog
genautomata
gencodes
genconfig
genextract
gengtype
genmodes
genpeep
```

More Details of an Actual Stage 1 Build for C



Building a MIPS Cross Compiler on i386: A Closer Look

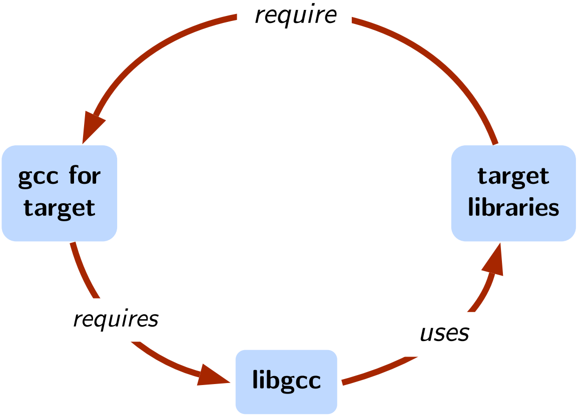


Requirement: BS = HS = ... mips

- *Stage 1 cannot build gcc but can build only cc1*
- Stage 1 build cannot create executables
- Library sources cannot be compiled for mips using stage 1 build
- Stage 2 build is not possible

we have not built libraries for mips

Difficulty in Building a Cross Compiler



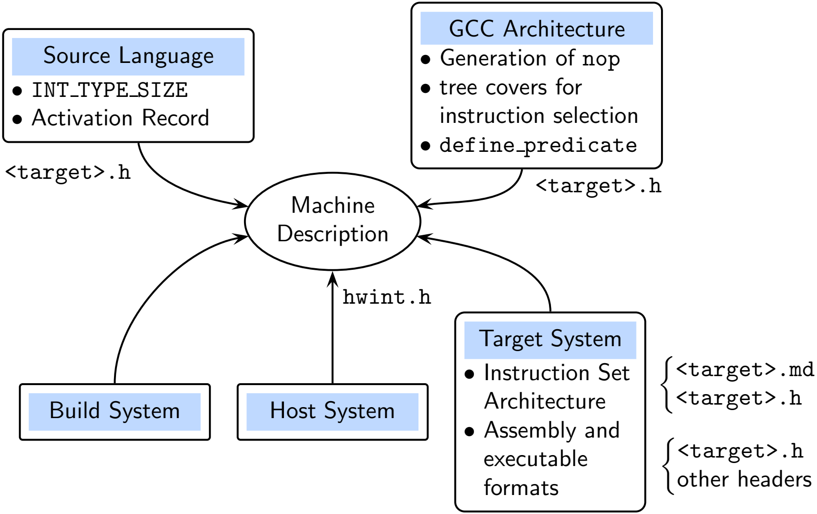
Generated Compiler Executable for All Languages

• Main driver	`$BUILD/gcc/xgcc`
• C compiler	`$BUILD/gcc/cc1`
• C++ compiler	`$BUILD/gcc/cc1plus`
• Fortran compiler	`$BUILD/gcc/f951`
• Ada compiler	`$BUILD/gcc/gnat1`
• Java compiler	`$BUILD/gcc/jc1`
• Java compiler for generating main class	`$BUILD/gcc/jvgenmain`
• LTO driver	`$BUILD/gcc/lto1`
• Objective C	`$BUILD/gcc/cc1obj`
• Objective C++	`$BUILD/gcc/cc1objplus`

Part 7

Retargetability

Examples of Influences on the Machine Descriptions

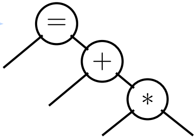


Redundancy in MIPS Machine Descriptions: Example 3

```
[(set (match_operand:m 0 "register_operand" "c0") (plus:m
     (mult:m (match_operand:m 1 "register_operand" "c1")
               (match_operand:m 2 "register_operand" "c2")))]
     (match_operand:m 3 "register_operand" "c3")))]
```

RTL Template

Structure



Details

Pattern name	m	$c0$	$c1$	$c2$	$c3$
*mul_acc_si	SI	=l*?*?,d?	d,d	d,d	0,d
*mul_acc_si_r3900	SI	=l*?*?,d*?,d?	d,d,d	d,d,d	0,1,d
*macc	SI	=l,d	d,d	d,d	0,1
*madd4<mode>	ANYF	=f	f	f	f
*madd3<mode>	ANYF	=f	f	f	0

Instruction Specification and Translation: A Recap

← Target Independent → ← Target Dependent →

Parse → Gimplify → Tree SSA Optimize → Generate RTL → Optimize RTL → Generate ASM

GIMPLE → RTL

RTL → ASM

- GIMPLE: target independent
- RTL: target dependent
- Need: associate the *semantics*

⇒GCC Solution: Standard Pattern Names

RTL Template

ASM

GIMPLE_ASSIGN

```
(define_insn  "movsi"
   [(set (match_operand 0 "register_operand" "r")
        (match_operand 1 "const_int_operand" "k"))]
   "" /* C boolean expression, if required */
    "li %0, %1"
)
```

Translation Sequence in GCC

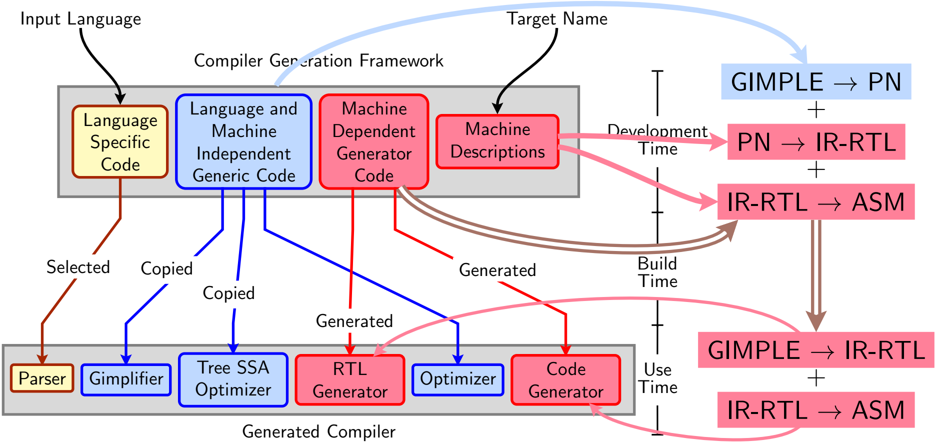
```
(define_insn
   "movsi"
    [(set
      (match_operand 0 "register_operand" "r")
      (match_operand 1 "const_int_operand" "k")
      )]
   "" /*  C boolean expression, if required */
   "li %0, %1"
)
```

Development

```
D.1283 = 10;  ⟹  (set
                     (reg:SI 58 [D.1283])
                     (const_int 10:  [0xa])
                 )  ⟹  li $t0, 10
```

Use

Retargetability Mechanism of GCC



Hooking up Back End Details