Workshop on Essential Abstractions in GCC

A Summary of Essential Abstrations

GCC Resource Center
(www.cse.iitb.ac.in/grc)

Department of Computer Science and Engineering,
Indian Institute of Technology, Bombay

3 July 2012

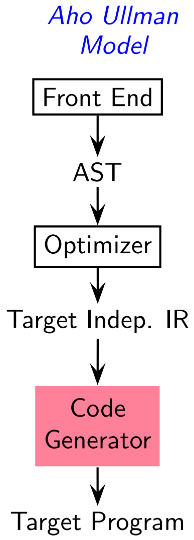
Workshop Coverage

	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 Data Flow Analysis Parallelization, Vectorization	Pass structure Control flow Static and dynamic plugin mechanisms

Workshop Coverage

Notes

Compilation Models

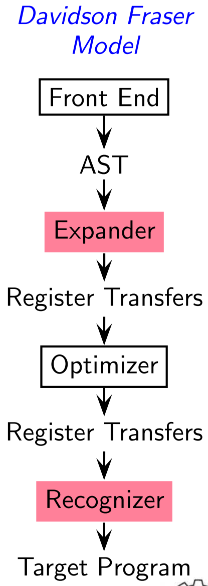


Aho Ullman: Instruction selection

- 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



3 July 2012 Essential Abstractions: Summary 2/28

Compilation Models

Notes

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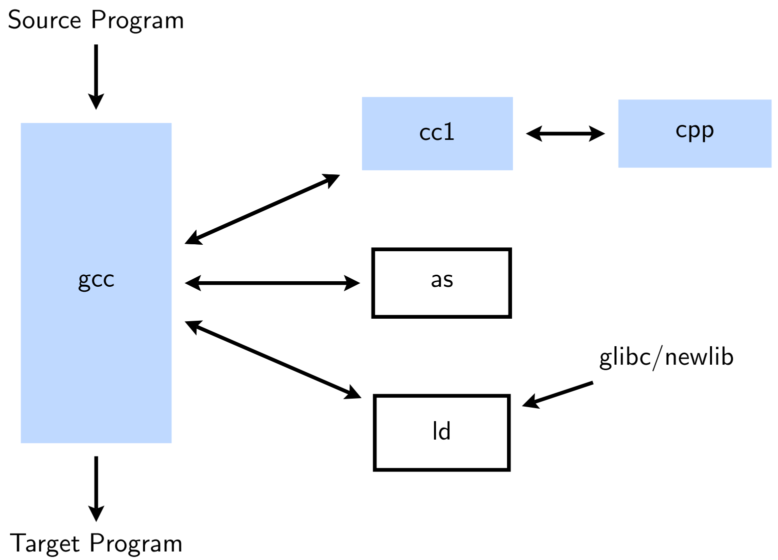
The GNU Tool Chain for C



3 July 2012 Essential Abstractions: Summary 3/28

The GNU Tool Chain for C

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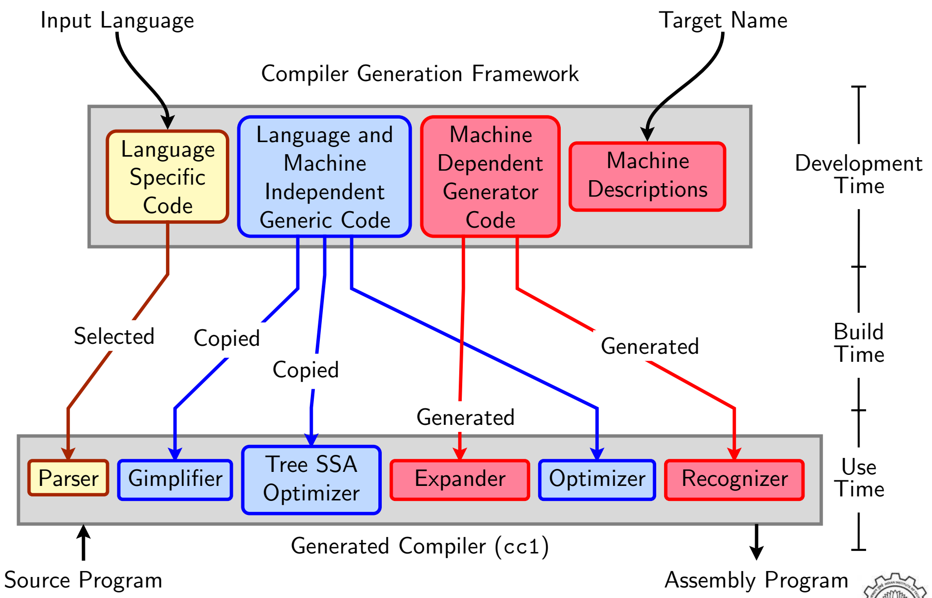
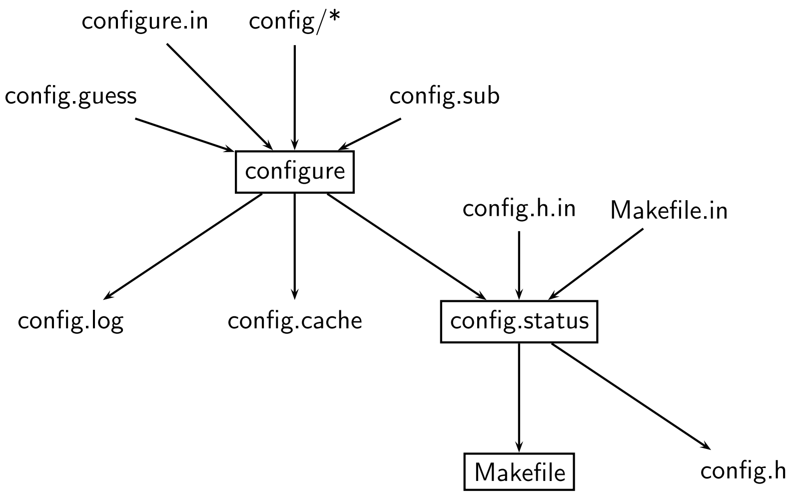
The Architecture of GCC



The Architecture of GCC

Notes

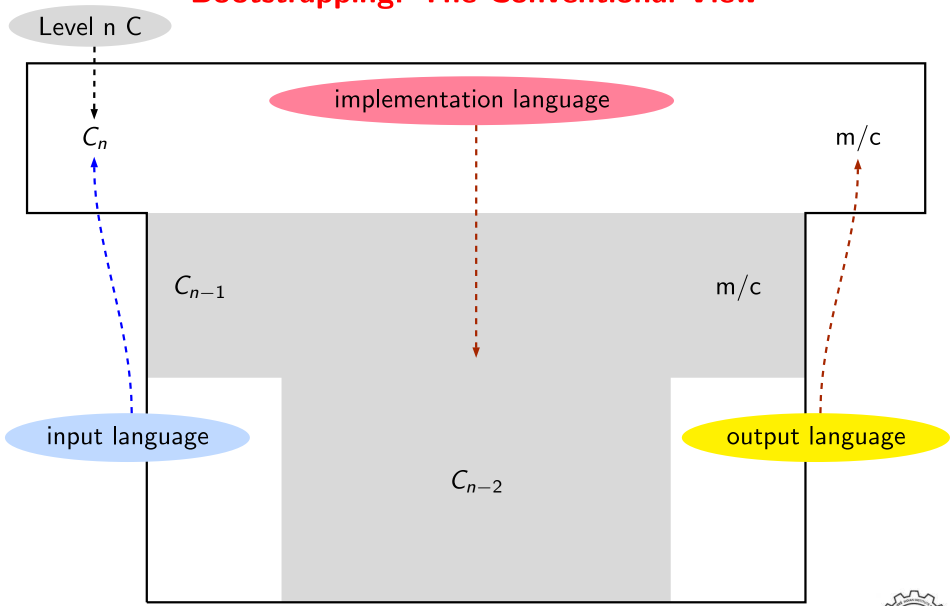
Configuring GCC



Configuring GCC

Notes

Bootstrapping: The Conventional View



Bootstrapping: The Conventional View

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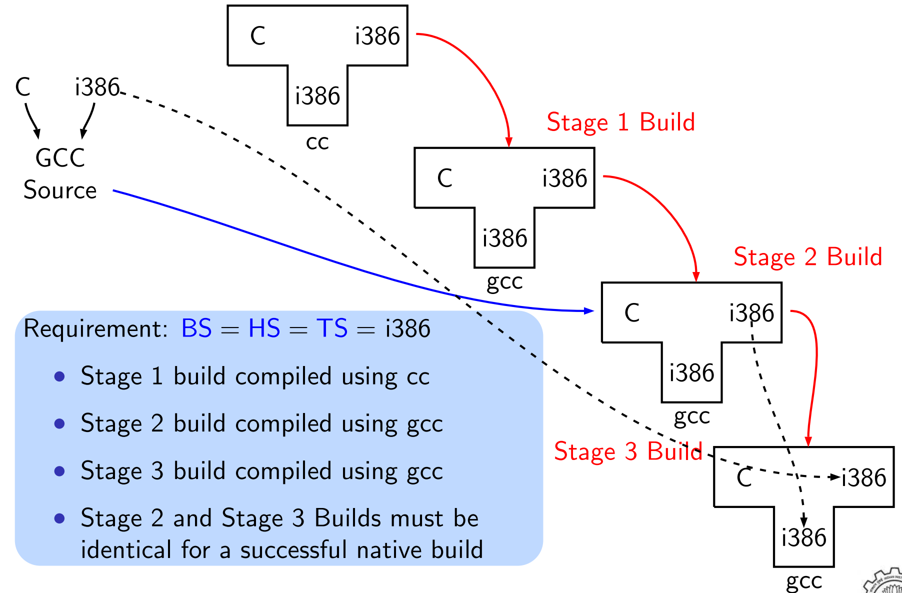
A Native Build on i386



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

A Native Build on i386

Notes

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

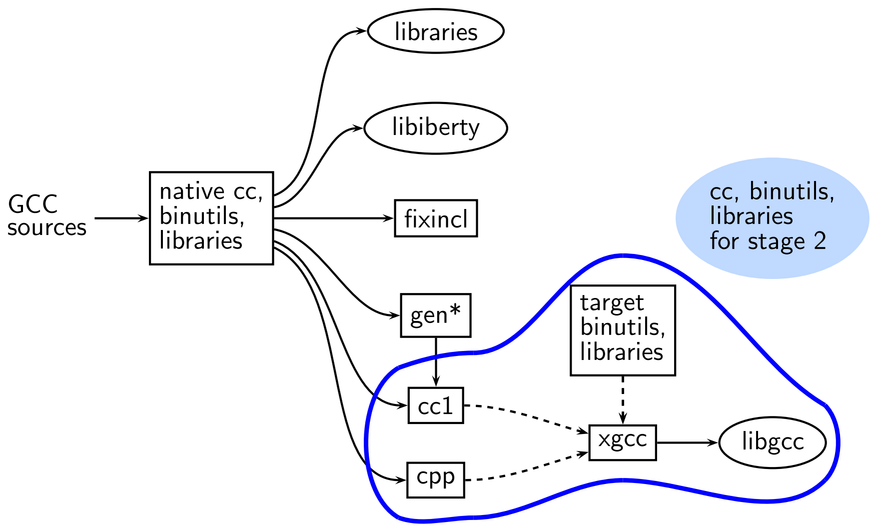
  Other source files are read from $(SOURCE_D) and executables created in corresponding subdirectories of $(BUILD)
- Installation

  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
```

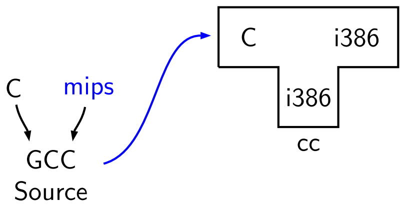

Build for a Given Machine

More Details of an Actual Stage 1 Build for C



More Details of an Actual Stage 1 Build for C

Building a MIPS Cross Compiler on i386: A Closer Look



Requirement: BS = HS = i386, TS = mips

Building a MIPS Cross Compiler on i386: A Closer Look

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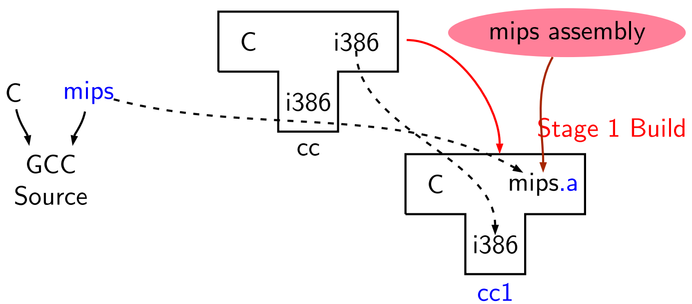

Requirement: BS = HS = i386, TS = mips

- *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

we have not built libraries for mips

Building a MIPS Cross Compiler on i386: A Closer Look

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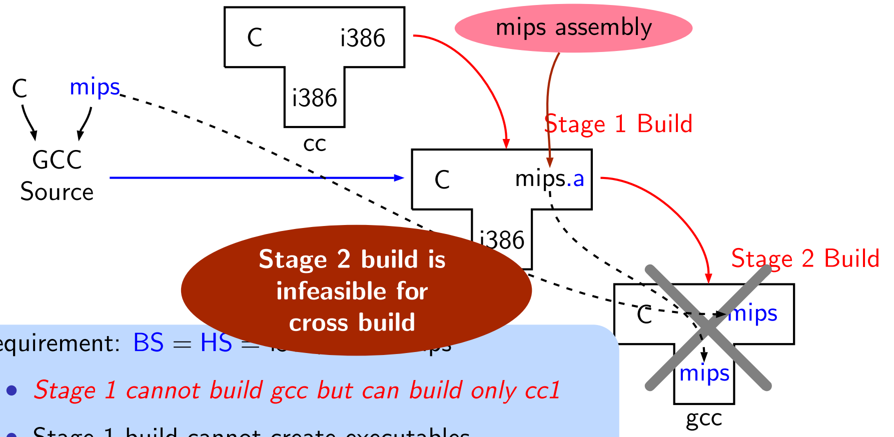
Building a MIPS Cross Compiler on i386: A Closer Look



Requirement: BS = HS =

- *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

3 July 2012 Essential Abstractions: Summary 10/28

Building a MIPS Cross Compiler on i386: A Closer Look

Notes

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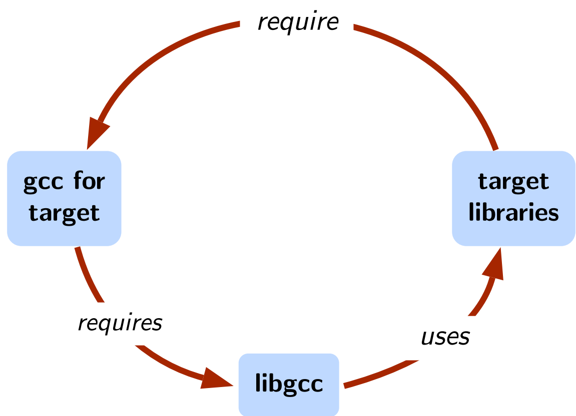
Difficulty in Building a Cross Compiler



3 July 2012 Essential Abstractions: Summary 11/28

Difficulty in Building a Cross Compiler

Notes

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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/jcl`
• Java compiler for generating main class	`$BUILD/gcc/jvgenmain`
• LTO driver	`$BUILD/gcc/lto1`
• Objective C	`$BUILD/gcc/cc1obj`
• Objective C++	`$BUILD/gcc/cc1objplus`

3 July 2012 Essential Abstractions: Summary 12/28

Generated Compiler Executable for All Languages

Notes

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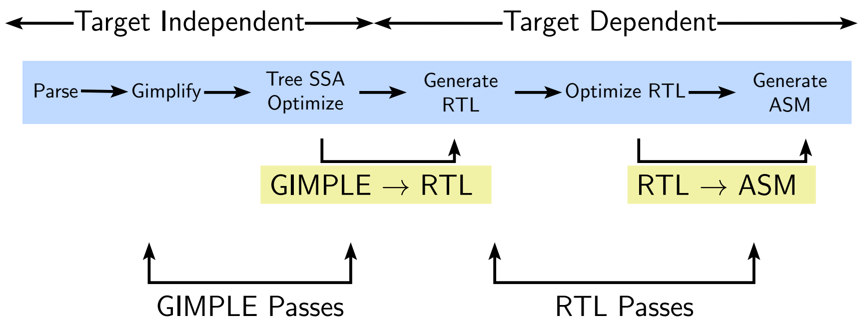
Basic Transformations in GCC

Tranformation from a language to a *different* language



3 July 2012 Essential Abstractions: Summary 13/28

Basic Transformations in GCC

Notes

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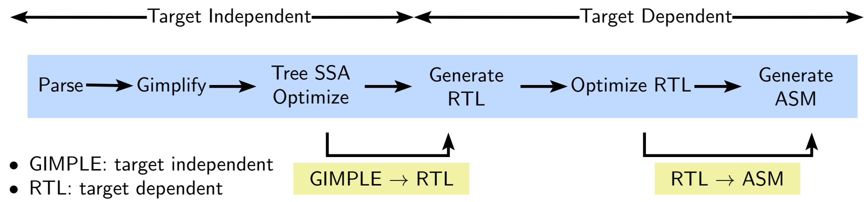
Instruction Specification and Translation: A Recap



- 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"
)
```


Instruction Specification and Translation: A Recap

Notes

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

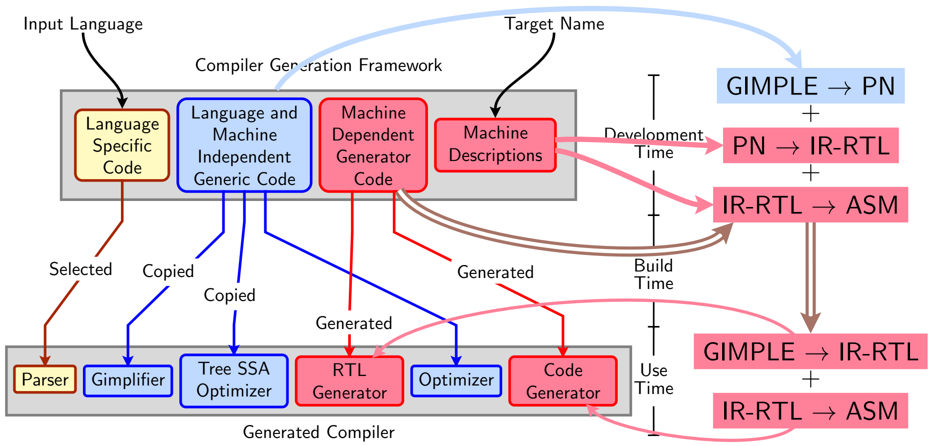
```
D.1283 = 10;  ⇒  (set
                     (reg:SI 58 [D.1283])
                     (const_int 10:  [0xa])
                 )
              ⇒  li $t0, 10
```

Use

Translation Sequence in GCC

Notes

Retargetability Mechanism of GCC



Retargetability Mechanism of GCC

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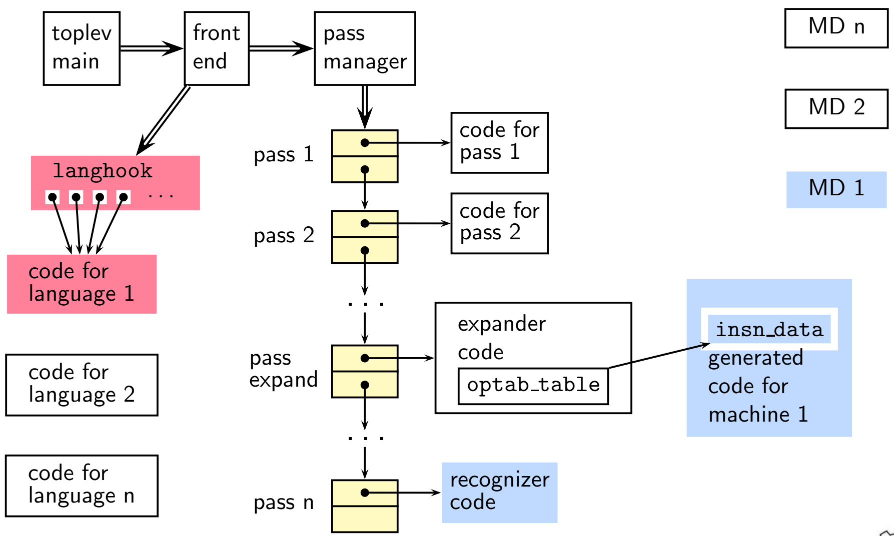
Plugin Structure in `cc1`



Plugin Structure in `cc1`

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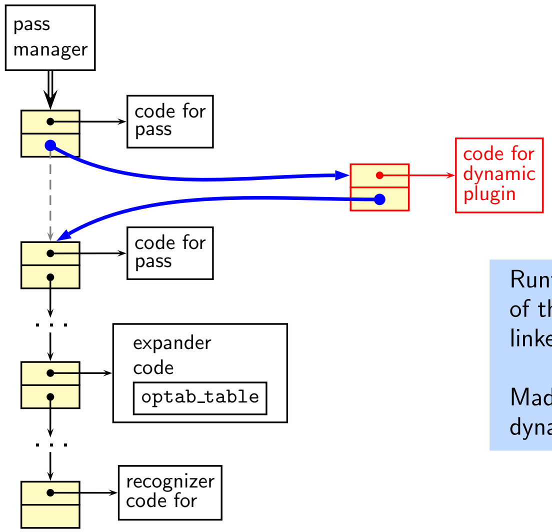
The Mechanism of Dynamic Plugin



Runtime initialization of the appropriate linked list of passes

Made possible by dynamic linking

The Mechanism of Dynamic Plugin

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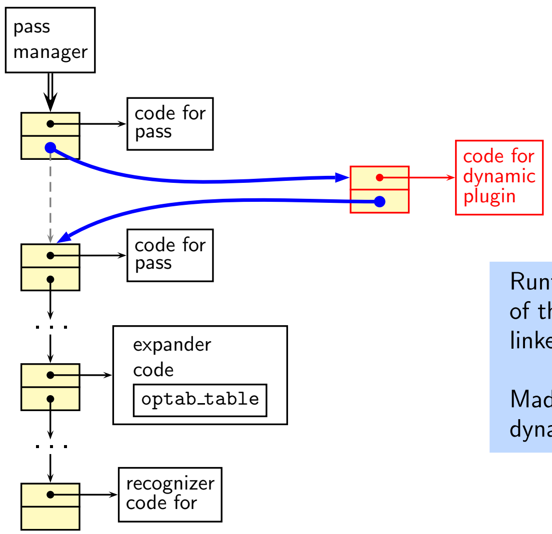
The Mechanism of Dynamic Plugin



Runtime initialization of the appropriate linked list of passes

Made possible by dynamic linking

The Mechanism of Dynamic Plugin

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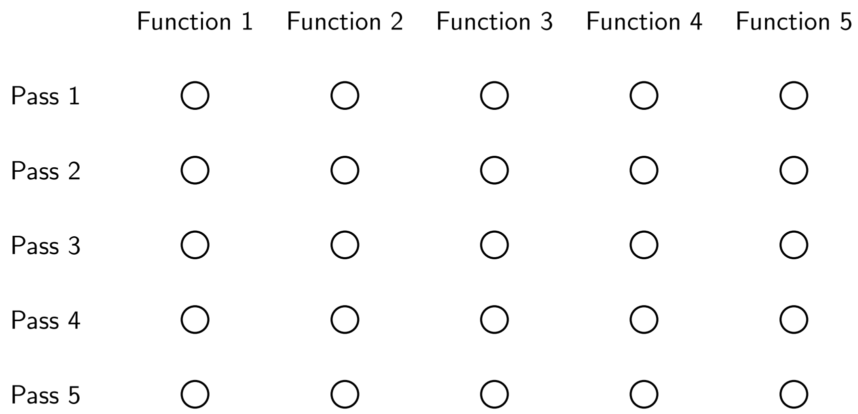
Execution Order in Intraprocedural Passes



3 July 2012 Essential Abstrations: Summary 19/28

Execution Order in Intraprocedural Passes

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3 July 2012 Essential Abstrations: Summary 19/28

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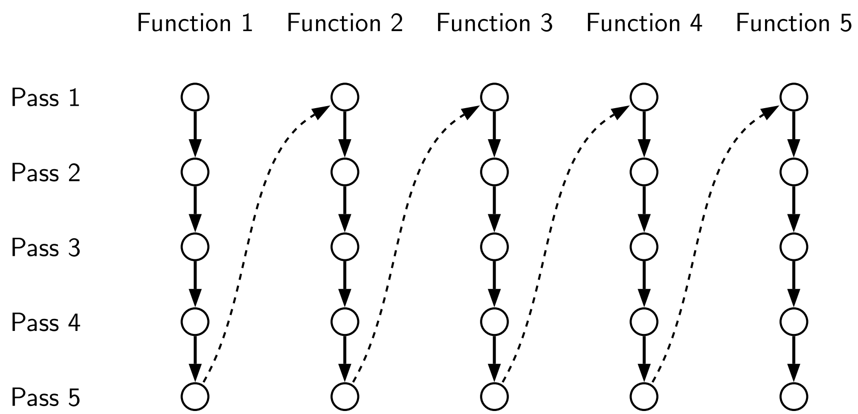

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3 July 2012 Essential Abstrations: Summary 19/28

Execution Order in Intraprocedural Passes

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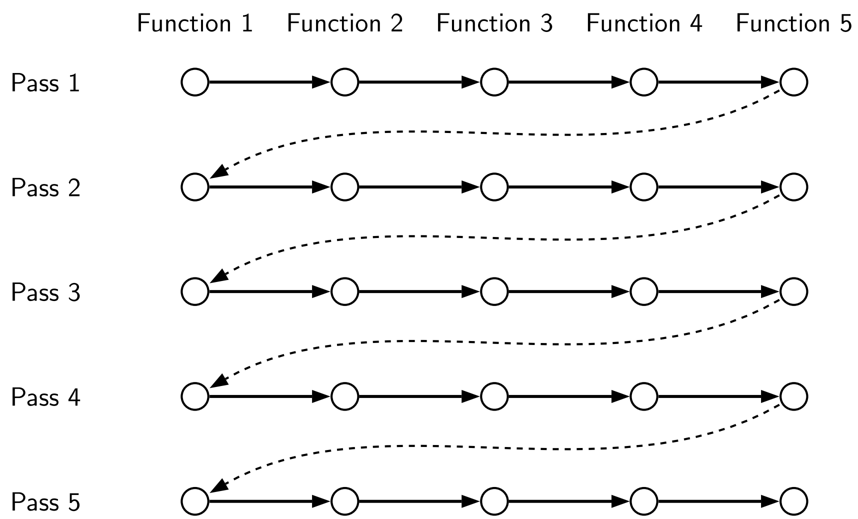

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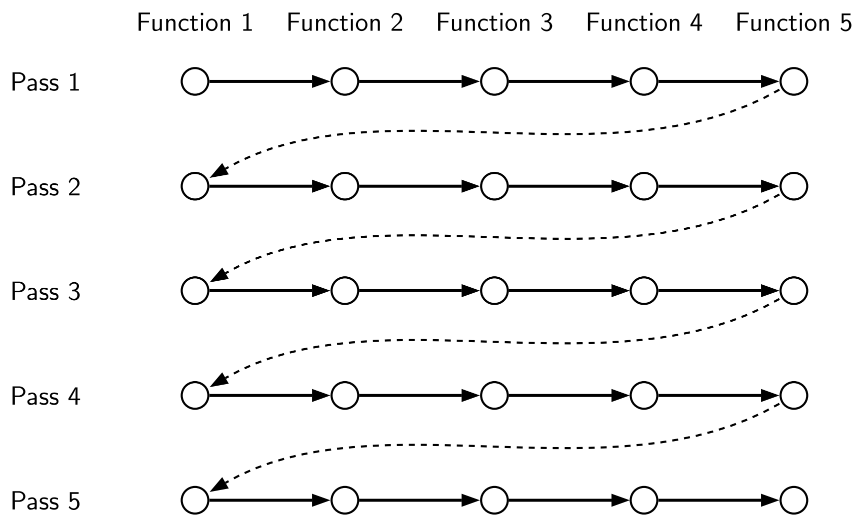


Execution Order in Interprocedural Passes

Notes

LTO Support in GCC

		Transformation		
		In the same process as that of analysis	In an independent process (possibly multiple processes)	
		Single partition of the program	Single partition of the program	Multiple partitions of the program
Whole Program Analysis	Call graph without function bodies	Not suppported	Suppported in GCC-4.6.0 ⟹	Will be suppported in future
	Call graph with function bodies	Suppported in GCC-4.6.0	Not suppported	Not suppported

`-flto` `-flto -flto-partition=none` WHOPR mode

LTO Support in GCC

Notes

`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`

Notes

cc1 and Single Process lto1

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

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

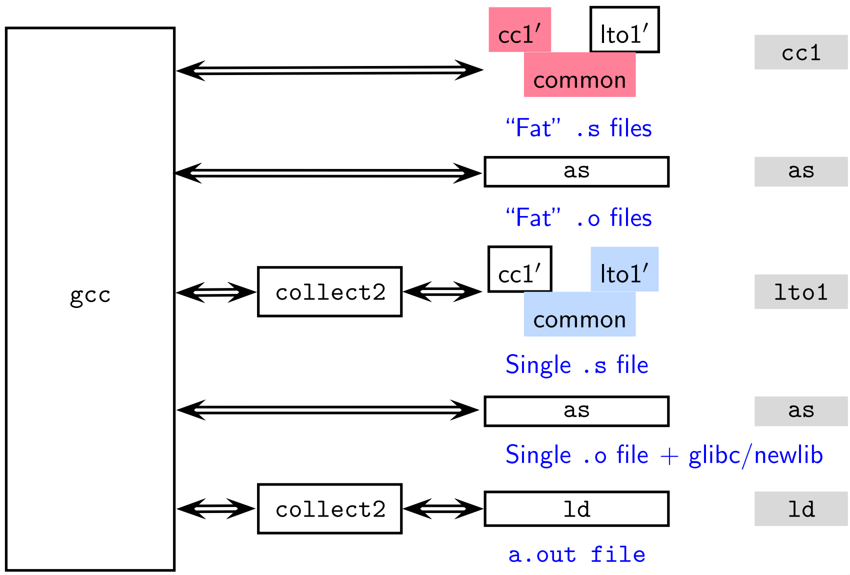
```
cgraph_optimize
...
  ipa_passes
  ...
    cgraph_expand_all_functions
    ...
      tree_rest_of_compilation
```

lto1

cc1 and Single Process lto1

Notes

The GNU Tool Chain for Single Process LTO Support



The GNU Tool Chain for Single Process LTO Support

Notes

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
      cgraph_expand_all_functions
         cgraph_expand_function
         /* Intraprocedural passes on GIMPLE, */
         /* expansion pass, and passes on RTL. */
```

a.out file

3 July 2012 Essential Abstractions: Summary 23/28

The GNU Tool Chain for Single Process LTO Support

Notes

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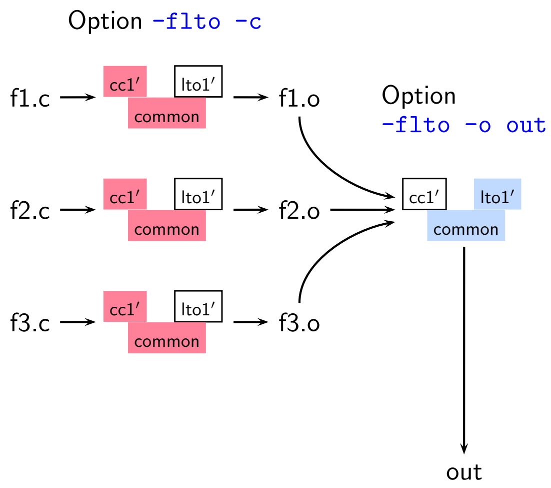
Multi Process LTO (aka WHOPR LTO)



3 July 2012 Essential Abstractions: Summary 24/28

Multi Process LTO (aka WHOPR LTO)

Notes

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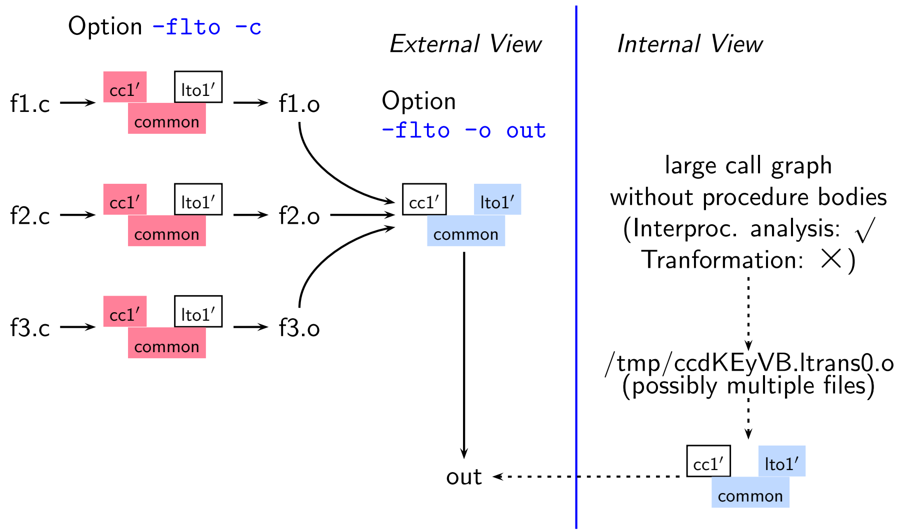

3 July 2012 Essential Abstractions: Summary 24/28

Multi Process LTO (aka WHOPR LTO)

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3 July 2012 Essential Abstractions: Summary 24/28

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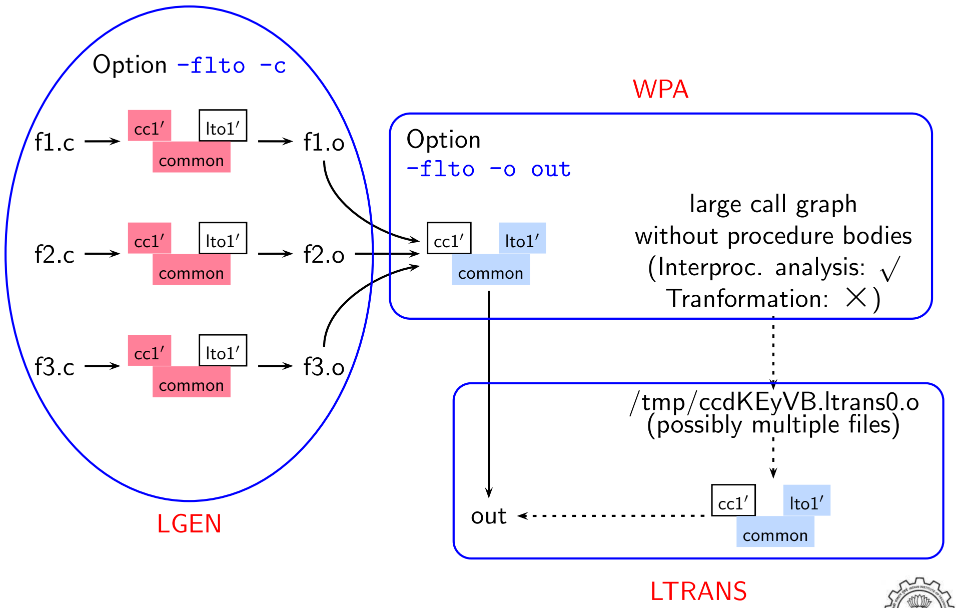

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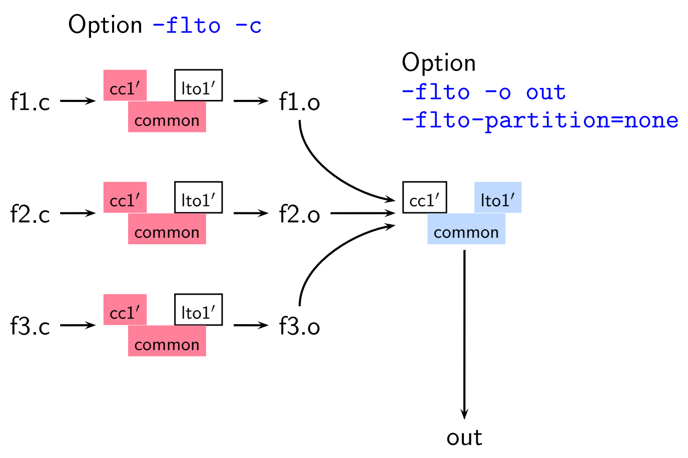
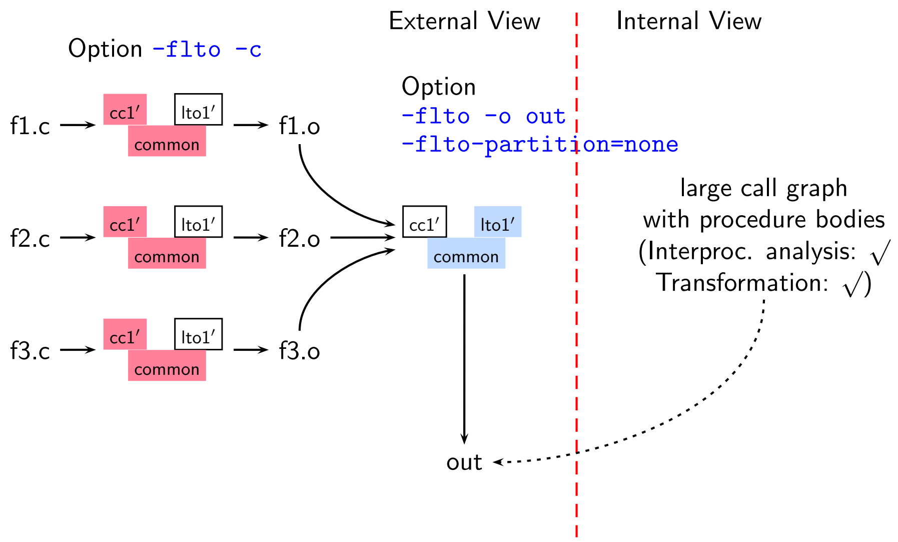
Single Process LTO



Single Process LTO

Notes

Single Process LTO



Single Process LTO

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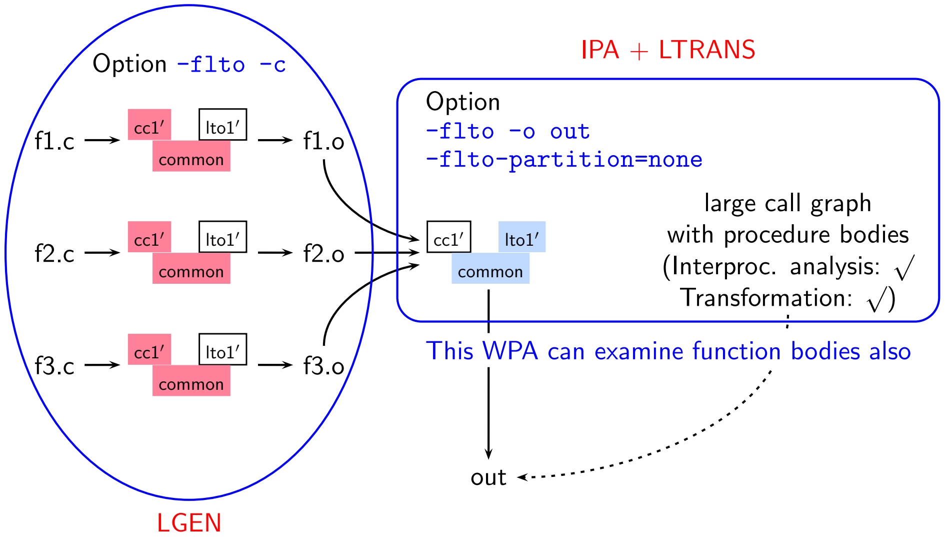
Single Process LTO



3 July 2012 Essential Abstractions: Summary 25/28

Single Process LTO

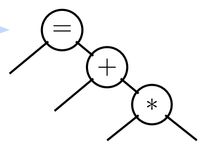
Notes

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

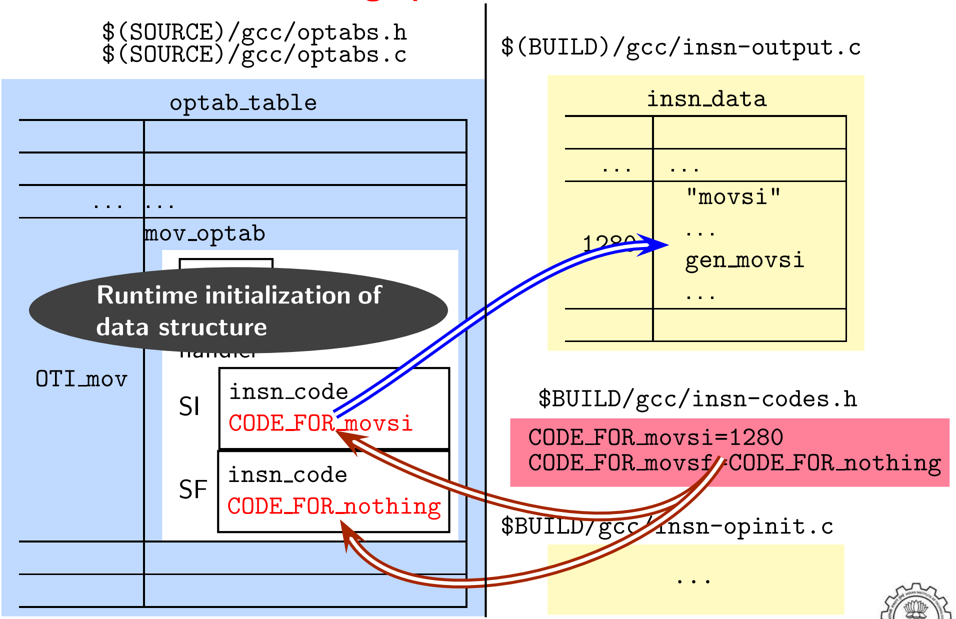
Pattern name	*m*	*c0*	*c1*	*c2*	*c3*
*mul_acc_si	SI	=l*?*?,d?	d,d	d,d	0,d
*mul_acc_si_r3900	SI	=l*?*?,d*?,d?	d,d,d	d,d,d	0,1,d
*macc	SI	=l,d	d,d	d,d	0,1
*madd4<mode>	ANYF	=f	f	f	f
*madd3<mode>	ANYF	=f	f	f	0

3 July 2012 Essential Abstractions: Summary 26/28

Redundancy in MIPS Machine Descriptions: Example 3

Notes

Hooking up Back End Details



3 July 2012 Essential Abstractions: Summary 27/28

Hooking up Back End Details

Notes

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And the final realization . . .