The Design and Implementation of Gnu Compiler Generation Framework

Uday Khedker

GCC Resource Center,
Department of Computer Science and Engineering,
Indian Institute of Technology, Bombay

January 2010

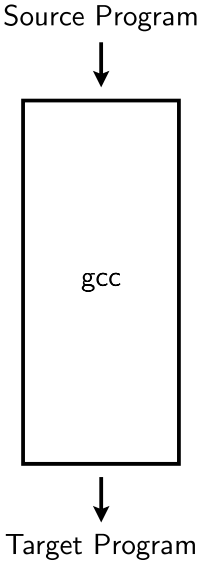
Outline

- GCC: The Great Compiler Challenge
- Meeting the GCC Challenge: CS 715
- Configuration and Building

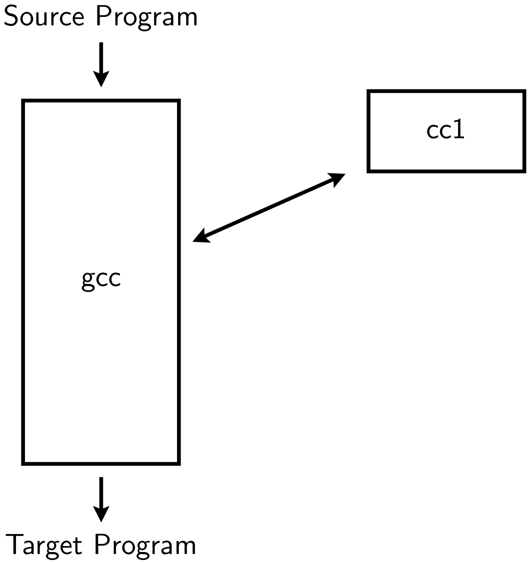
Part 1

GCC $\equiv$ The Great Compiler Challenge

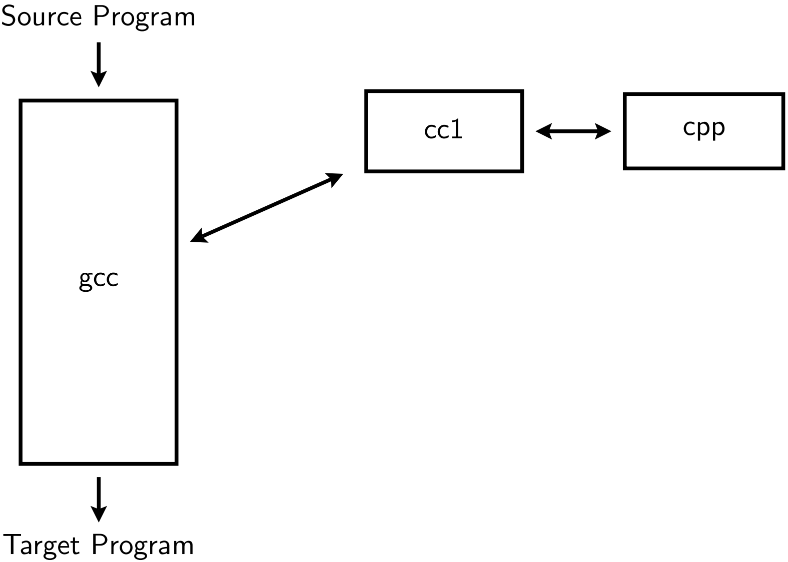
The Gnu Tool Chain



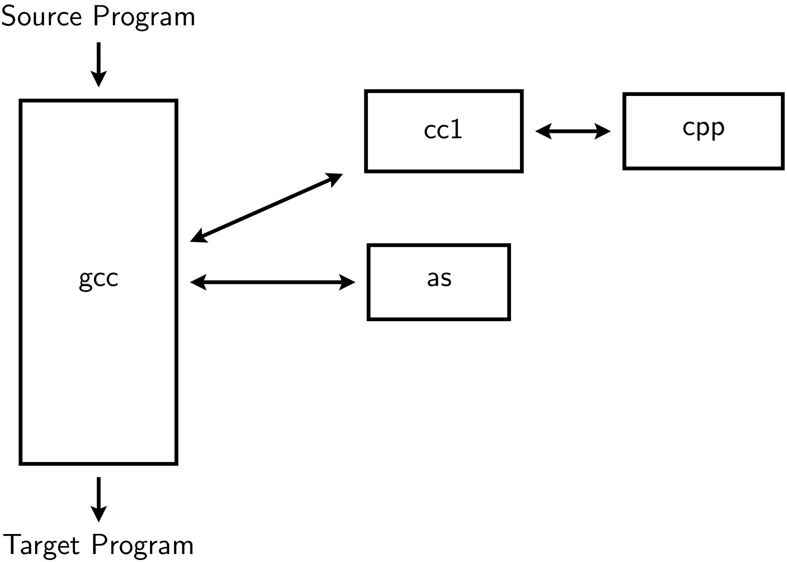
The Gnu Tool Chain



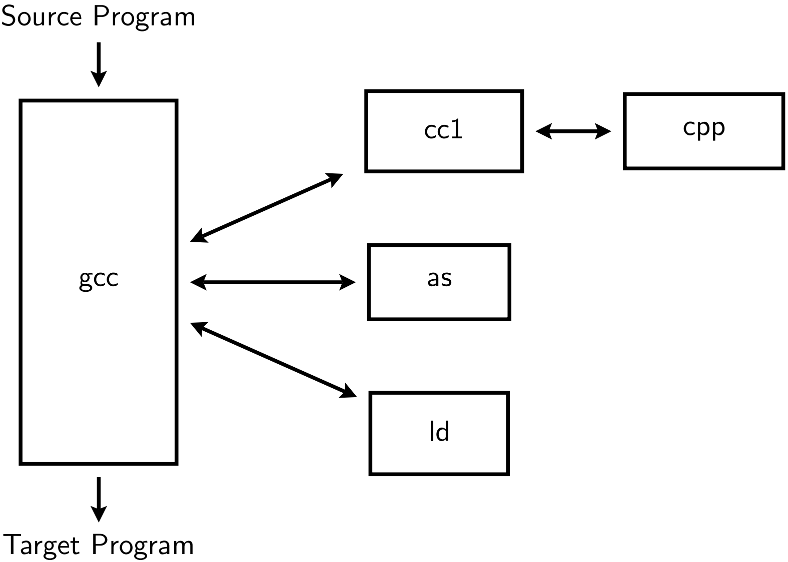
The Gnu Tool Chain



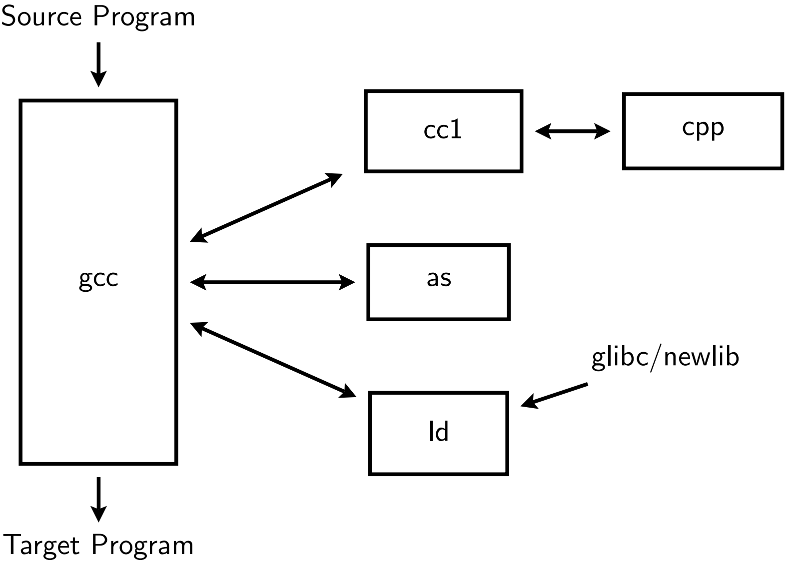
The Gnu Tool Chain



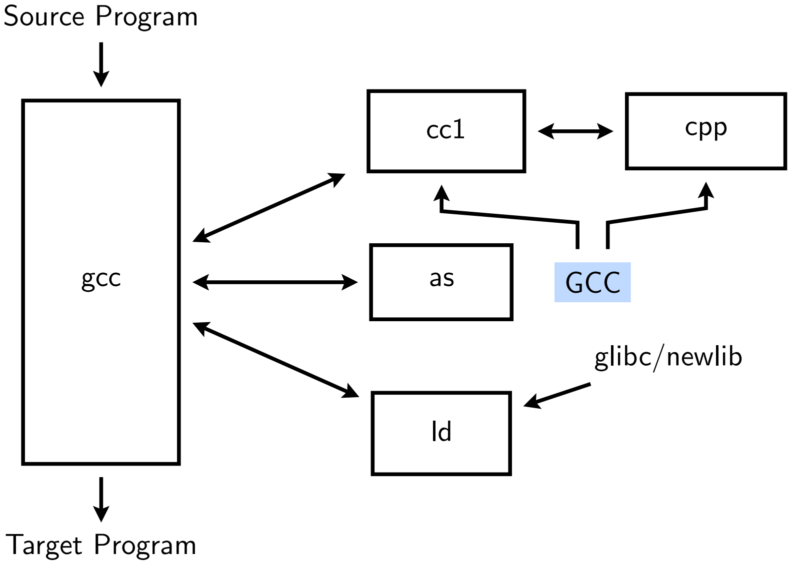
The Gnu Tool Chain



The Gnu Tool Chain



The Gnu Tool Chain



Why is Understanding GCC Difficult?

Some of the obvious reasons:

- Comprehensiveness

  GCC is a production quality framework in terms of completeness and practical usefulness

- Open development model

  Could lead to heterogeneity. Design flaws may be difficult to correct

- Rapid versioning

  GCC maintenance is a race against time. Disruptive corrections are difficult

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86),
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC,
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa,
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze, MSP430,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze, MSP430, Nios II and Nios,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze, MSP430, Nios II and Nios, PDP-10,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze, MSP430, Nios II and Nios, PDP-10, TIGCC (m68k variant),

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze, MSP430, Nios II and Nios, PDP-10, TIGCC (m68k variant), Z8000,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze, MSP430, Nios II and Nios, PDP-10, TIGCC (m68k variant), Z8000, PIC24/dsPIC,

Comprehensiveness of GCC 4.3.1: Wide Applicability

- Input languages supported:
  C, C++, Objective-C, Objective-C++, Java, Fortran, and Ada
- Processors supported in standard releases:
  - Common processors:
    Alpha, ARM, Atmel AVR, Blackfin, HC12, H8/300, IA-32 (x86), x86-64, IA-64, Motorola 68000, MIPS, PA-RISC, PDP-11, PowerPC, R8C/M16C/M32C, SPU, System/390/zSeries, SuperH, SPARC, VAX
  - Lesser-known target processors:
    A29K, ARC, ETRAX CRIS, D30V, DSP16xx, FR-30, FR-V, Intel i960, IP2000, M32R, 68HC11, MCORE, MMIX, MN10200, MN10300, Motorola 88000, NS32K, ROMP, Stormy16, V850, Xtensa, AVR32
  - Additional processors independently supported:
    D10V, LatticeMico32, MeP, Motorola 6809, MicroBlaze, MSP430, Nios II and Nios, PDP-10, TIGCC (m68k variant), Z8000, PIC24/dsPIC, NEC SX architecture

Comprehensiveness of GCC 4.3.1: Size

Source Lines	Number of lines in the main source	2,029,115
	Number of lines in libraries	1,546,826
Directories	Number of subdirectories	3527
Files	Total number of files	57825
	C source files	19834
	Header files	9643
	C++ files	3638
	Java files	6289
	Makefiles and Makefile templates	163
	Configuration scripts	52
	Machine description files	186

(Line counts estimated by the program `sloccount` by David A. Wheeler)

Open Source and Free Software Development Model

The Cathedral and the Bazaar [Eric S Raymond, 1997]

Open Source and Free Software Development Model

The Cathedral and the Bazaar [Eric S Raymond, 1997]

- Cathedral: Total Centralized Control
  Design, implement, test, release

Open Source and Free Software Development Model

The Cathedral and the Bazaar [Eric S Raymond, 1997]

- Cathedral: Total Centralized Control
  Design, implement, test, release
- Bazaar: Total Decentralization
  Release early, release often, make users partners in software development

Open Source and Free Software Development Model

The Cathedral and the Bazaar [Eric S Raymond, 1997]

- Cathedral: Total Centralized Control
  Design, implement, test, release
- Bazaar: Total Decentralization
  Release early, release often, make users partners in software development

  "Given enough eyeballs, all bugs are shallow"

Open Source and Free Software Development Model

The Cathedral and the Bazaar [Eric S Raymond, 1997]

- Cathedral: Total Centralized Control
  Design, implement, test, release
- Bazaar: Total Decentralization
  Release early, release often, make users partners in software development

  "Given enough eyeballs, all bugs are shallow"
  Code errors, logical errors, and architectural errors

Open Source and Free Software Development Model

The Cathedral and the Bazaar [Eric S Raymond, 1997]

- Cathedral: Total Centralized Control
  Design, implement, test, release
- Bazaar: Total Decentralization
  Release early, release often, make users partners in software development

"Given enough eyeballs, all bugs are shallow"
Code errors, logical errors, and architectural errors

A combination of the two seems more sensible

The Current Development Model of GCC

GCC follows a combination of the Cathedral and the Bazaar approaches

- GCC Steering Committee: Free Software Foundation has given charge
  - Major policy decisions
  - Handling Administrative and Political issues
- Release Managers:
  - Coordination of releases
- Maintainers:
  - Usually area/branch/module specific
  - Responsible for design and implementation
  - Take help of reviewers to evaluate submitted changes

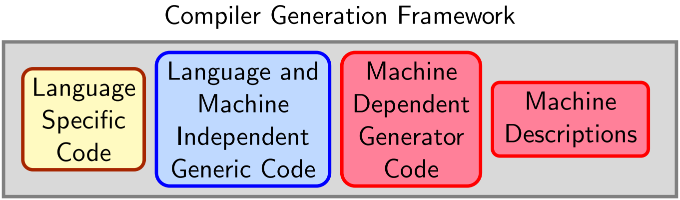
Why is Understanding GCC Difficult?

Deeper reason: GCC is not a *compiler* but a *compiler generation framework*

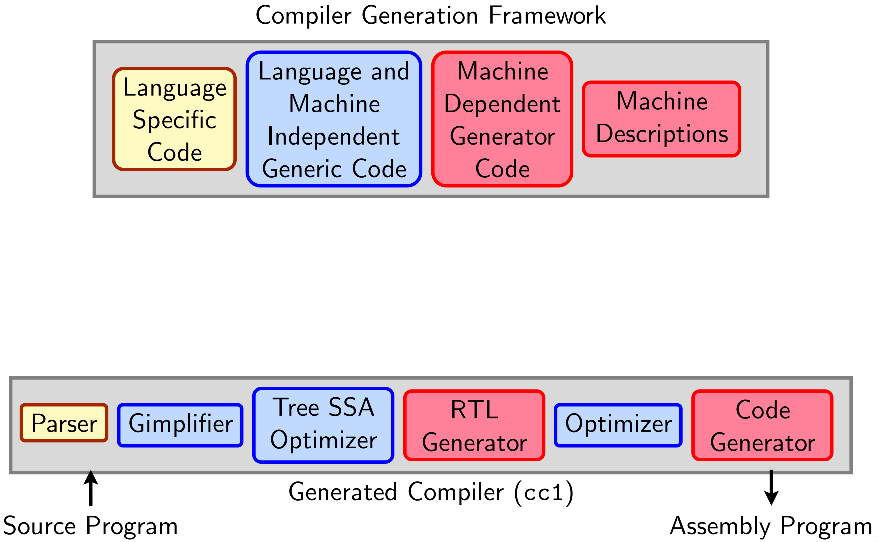
There are two distinct gaps that need to be bridged:

- Input-output of the generation framework: The target specification and the generated compiler
- Input-output of the generated compiler: A source program and the generated assembly program

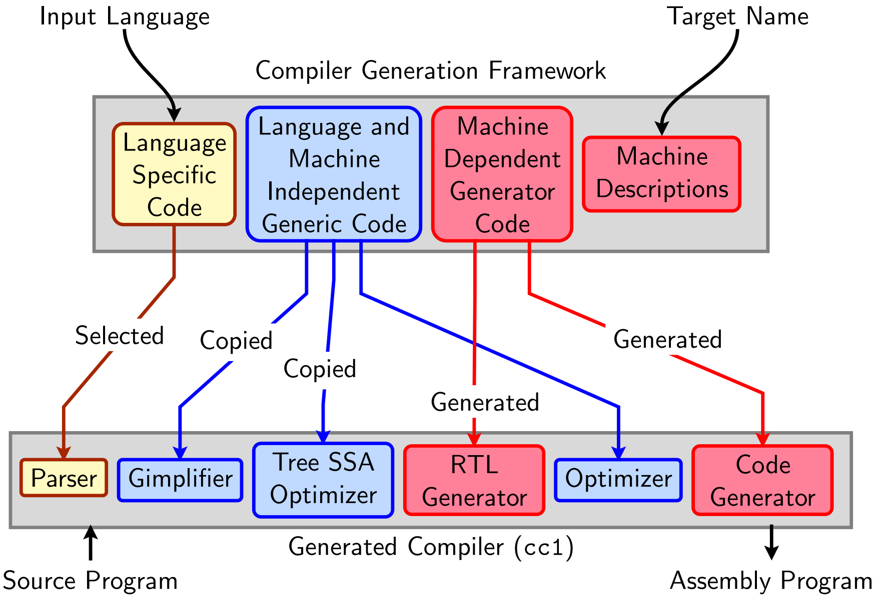
The Architecture of GCC



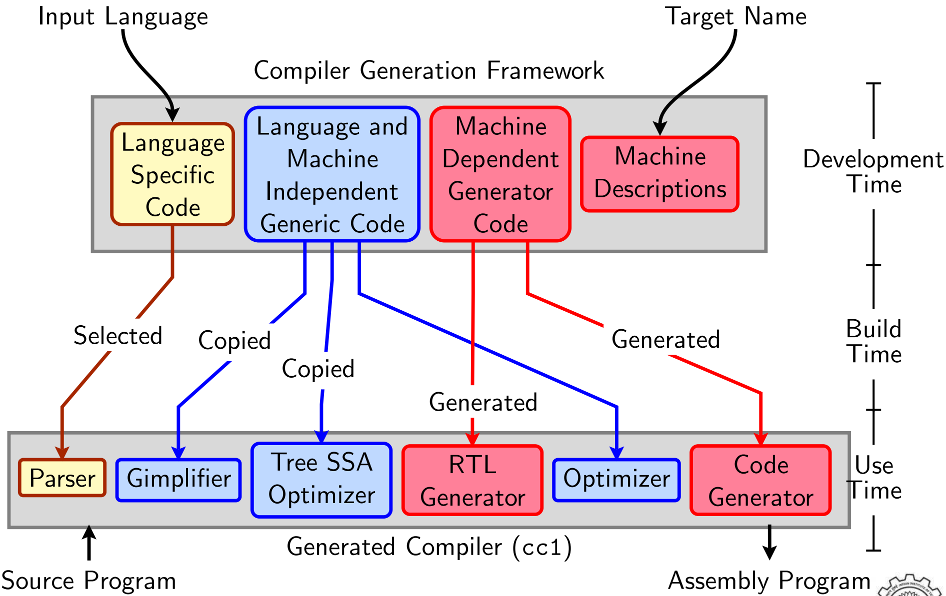
The Architecture of GCC



The Architecture of GCC



The Architecture of GCC



An Example of The Generation Related Gap

- Predicate function for invoking the loop distribution pass

```
static bool
gate_tree_loop_distribution (void)
{
  return flag_tree_loop_distribution != 0;
}
```

An Example of The Generation Related Gap

- Predicate function for invoking the loop distribution pass

```
static bool
gate_tree_loop_distribution (void)
{
  return flag_tree_loop_distribution != 0;
}
```

- There is no declaration of or assignment to variable `flag_tree_loop_distribution` in the entire source!

An Example of The Generation Related Gap

- Predicate function for invoking the loop distribution pass

```
static bool
gate_tree_loop_distribution (void)
{
  return flag_tree_loop_distribution != 0;
}
```

- There is no declaration of or assignment to variable `flag_tree_loop_distribution` in the entire source!
- It is described in `common.opt` as follows

```
ftree-loop-distribution
Common Report Var(flag_tree_loop_distribution) Optimization
Enable loop distribution on trees
```

An Example of The Generation Related Gap

- Predicate function for invoking the loop distribution pass

```
static bool
gate_tree_loop_distribution (void)
{
  return flag_tree_loop_distribution != 0;
}
```

- There is no declaration of or assignment to variable `flag_tree_loop_distribution` in the entire source!
- It is described in `common.opt` as follows

```
ftree-loop-distribution
Common Report Var(flag_tree_loop_distribution) Optimization
Enable loop distribution on trees
```

- The required C statements are generated during the build

Another Example of The Generation Related Gap

Locating the `main` function in the directory `gcc-4.4.2/gcc` using cscope

Another Example of The Generation Related Gap

Locating the `main` function in the directory `gcc-4.4.2/gcc` using cscope

```
  File             Line
0 collect2.c        766 main (int argc, char **argv)
1 fix-header.c     1074 main (int argc, char **argv)
2 fp-test.c          85 main (void )
3 gcc.c            6216 main (int argc, char **argv)
4 gcov-dump.c        76 main (int argc ATTRIBUTE_UNUSED, char **argv
5 gcov-iov.c         29 main (int argc, char **argv)
6 gcov.c            355 main (int argc, char **argv)
7 gen-protos.c      130 main (int argc ATTRIBUTE_UNUSED, char **argv
8 genattr.c          89 main (int argc, char **argv)
9 genattrtab.c     4438 main (int argc, char **argv)
a genautomata.c    9321 main (int argc, char **argv)
b genchecksum.c      65 main (int argc, char ** argv)
c gencodes.c         51 main (int argc, char **argv)
d genconditions.c   209 main (int argc, char **argv)
e genconfig.c       261 main (int argc, char **argv)
f genconstants.c     50 main (int argc, char **argv)
```

Another Example of The Generation Related Gap

Locating the `main` function in the directory `gcc-4.4.2/gcc` using cscope

```
g genemit.c        820 main (int argc, char **argv)
h genextract.c     394 main (int argc, char **argv)
i genflags.c       231 main (int argc, char **argv)
j gengenrtl.c      350 main (int argc, char **argv)
k gengtype.c      3584 main (int argc, char **argv)
l genmddeps.c       45 main (int argc, char **argv)
m genmodes.c      1376 main (int argc, char **argv)
n genopinit.c      472 main (int argc, char **argv)
o genoutput.c     1005 main (int argc, char **argv)
p genpeep.c        353 main (int argc, char **argv)
q genpreds.c      1399 main (int argc, char **argv)
r genrecog.c      2718 main (int argc, char **argv)
s main.c            33 main (int argc, char **argv)
t mips-tdump.c    1393 main (int argc, char **argv)
u mips-tfile.c     655 main (void )
v mips-tfile.c    4690 main (int argc, char **argv)
w protoize.c      4373 main (int argc, char **const argv)
```

The GCC Challenge: Poor Retargetability Mechanism

- Symptom of poor retargetability mechanism

  Large size of specifications

The GCC Challenge: Poor Retargetability Mechanism

- Symptom of poor retargetability mechanism

  Large size of specifications

- Size in terms of line counts

Files	i386	mips
*.md	35766	12930
*.c	28643	12572
*.h	15694	5105

Part 2

Meeting the GCC Challenge

Meeting the GCC Challenge

Goal of Understanding	Methodology	Needs Examining		
		Makefiles	Source	MD
Translation sequence of programs	Gray box probing	No	No	No
Build process	Customizing the configuration and building	Yes	No	No
Retargetability issues and machine descriptions	Incremental construction of machine descriptions	No	No	Yes
IR data structures and access mechanisms	Adding passes to massage IRs	No	Yes	Yes
Retargetability mechanism		Yes	Yes	Yes

What is Gray Box Probing of GCC?

- Black Box probing:
  Examining only the input and output relationship of a system
- White Box probing:
  Examining internals of a system for a given set of inputs
- Gray Box probing:
  Examining input and output of various components/modules
  - Overview of translation sequence in GCC
  - Overview of intermediate representations
  - Intermediate representations of programs across important phases

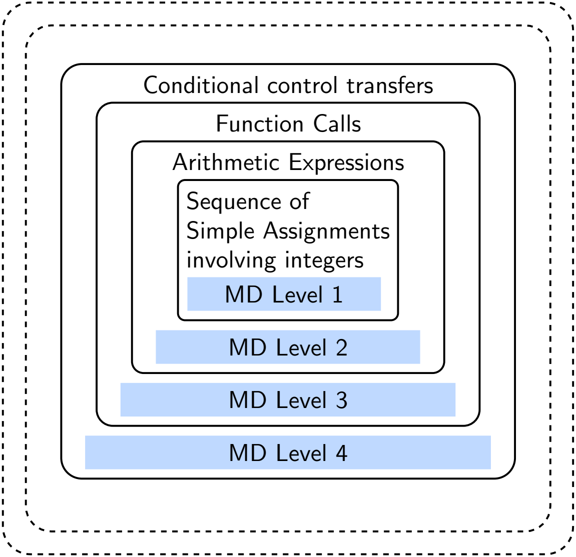
Customizing the Configuration and Build Process

- Creating only `cc1`
- Creating bare metal cross build
  Complete tool chain without OS support
- Creating cross build with OS support

Incremental Construction of Machine Descriptions

- Define different levels of source language
- Identify the minimal set of features in the target required to support each level
- Identify the minimal information required in the machine description to support each level
  - Successful compilation of any program, and
  - correct execution of the generated assembly program
- Interesting observations
  - It is the increment in the source language which results in understandable increments in machine descriptions rather than the increment in the target architecture
  - If the levels are identified properly, the increments in machine descriptions are monotonic

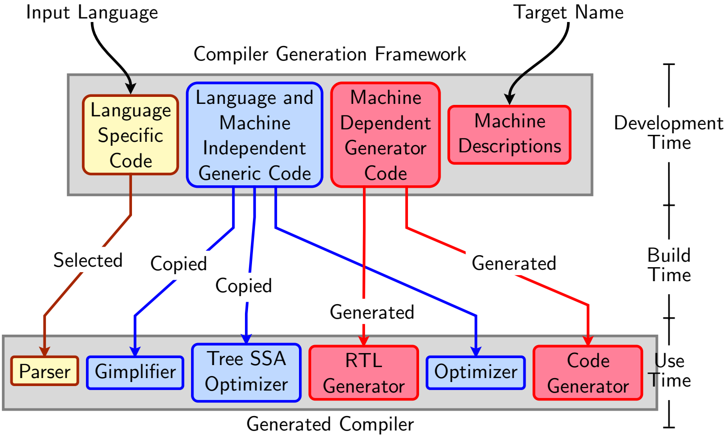
Incremental Construction of Machine Descriptions



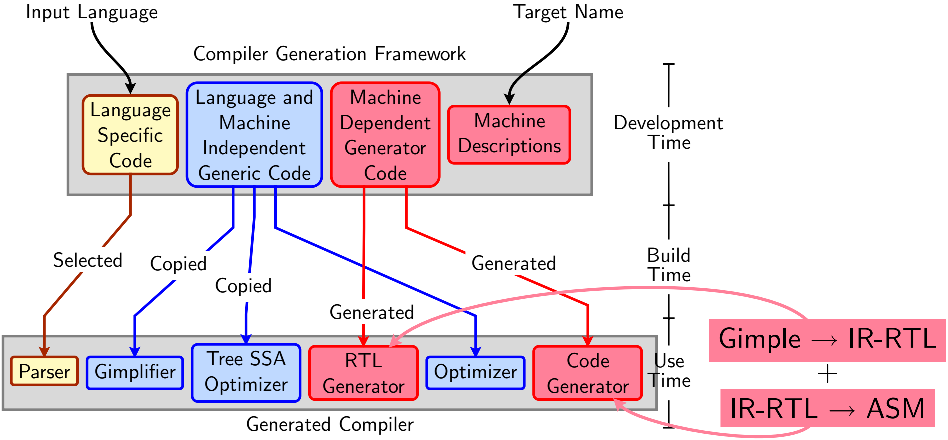
Adding Passes to Massage IRs

- Understanding the pass structure
- Understanding the mechanisms of traversing a call graph and a control flow graph
- Understanding how to access the data structures of IRs
- Simple exercises such as:
  - Count the number of copy statements in a program
  - Count the number of variables declared "const" in the program
  - Count the number of occurances of arithmatic operators in the program
  - Count the number of references to global variables in the program

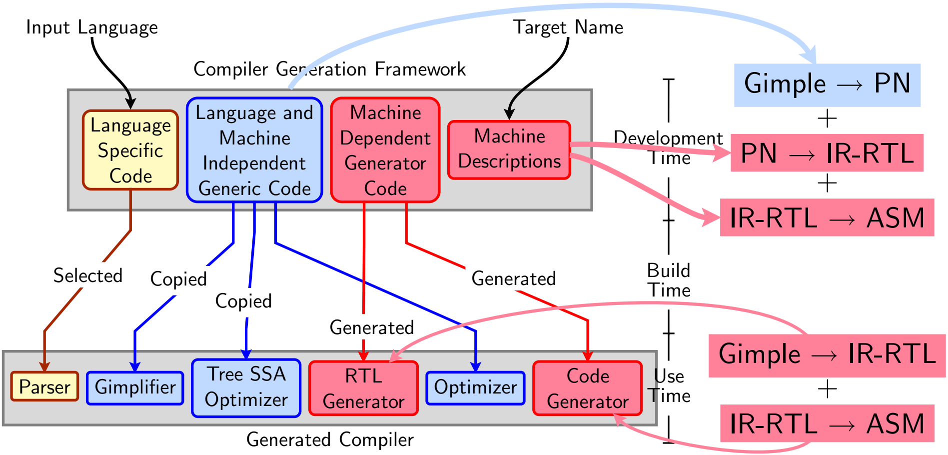
Understanding the Retargetability Mechanism



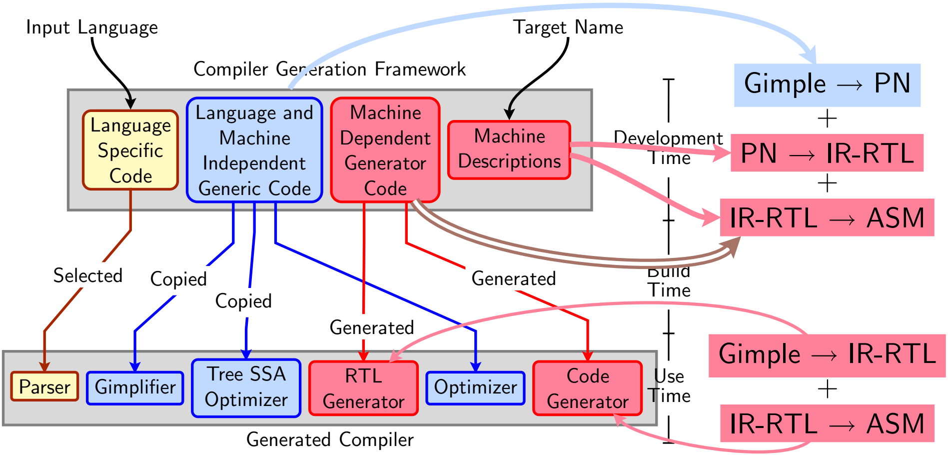
Understanding the Retargetability Mechanism



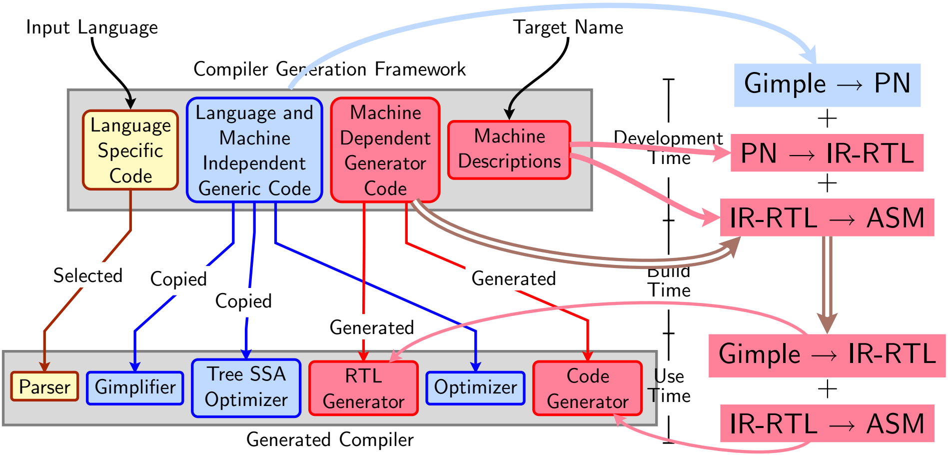
Understanding the Retargetability Mechanism



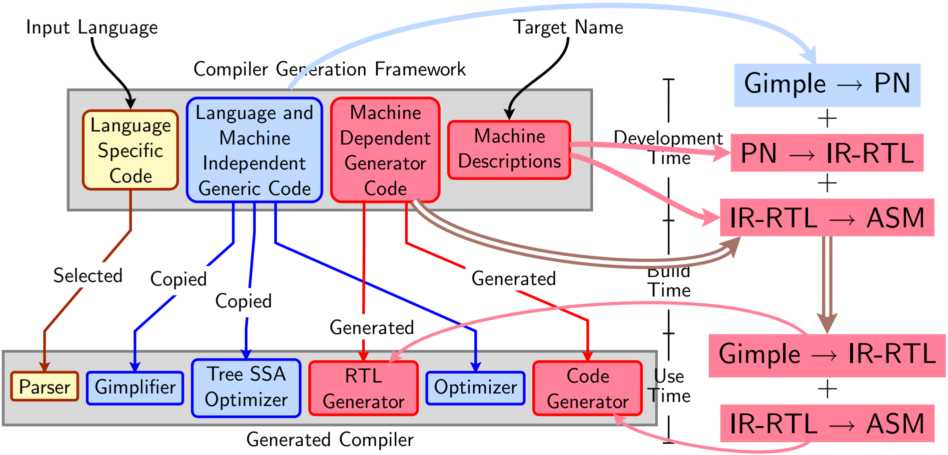
Understanding the Retargetability Mechanism



Understanding the Retargetability Mechanism



Understanding the Retargetability Mechanism



Many more details need to be explained ☹

CS 715 Coverage

Goal of Understanding	Methodology	Needs Examining		
		Makefiles	Source	MD
Translation sequence of programs	Gray box probing	No	No	No
Build process	Customizing the configuration and building	Yes	No	No
Retargetability issues and machine descriptions	Incremental construction of machine descriptions	No	No	Yes
IR data structures and access mechanisms	Adding passes to massage IRs	No	Yes	Yes
Retargetability mechanism		Yes	Yes	Yes

CS 715 Pegagogy

- Introductory lecture for each topic followed by lab work
- Many the lecture hours will be used as lab hours
- Sequence of topics
  - Configuration and building
  - Examining and manipulating Gimple IR
  - Examining and manipulating RTL IR
  - Machine descriptions

CS 715 Lab Work

- Lab exercises:
  - Pre-defined experiments
  - Ungraded
- Assignments: Graded lab work
  - Implementation to modify gcc
  - Graded
  - To be submitted in about a couple of weeks or 10 days
- Projects
  - Specific Study + Implementation
  - Graded
  - To be submitted in about a couple of months
  - Possible topics
    Extensions of GDFA, MD rewriting with newer constructs, Detailing the retargetability mechanism, MD parsers

CS 715 Assessment Scheme

- No written examination
- Marks for lab work

Head	Number	Weightage
Assignments	4	$4 \times 15 = 60$
Project	1	40
Total		100

- Assignments need not be same for all students
  However, they will be comparable and students would have the choice of opting for a particular assignment

Part 3

Configuration and Building

Configuration and Building: Outline

- Code Organization of GCC
- Configuration and Building
- Native build Vs. cross build
- Testing GCC

GCC Code Organization

Logical parts are:

- Build configuration files
- Front end + generic + generator sources
- Back end specifications
- Emulation libraries
  (eg. `libgcc` to emulate operations not supported on the target)
- Language Libraries (except C)
- Support software (e.g. garbage collector)

GCC Code Organization

Front End Code

- Source language dir: `$(SOURCE)/<lang dir>`
- Source language dir contains
  - Parsing code (Hand written)
  - Additional AST/Generic nodes, if any
  - Interface to Generic creation

Except for C – which is the “native” language of the compiler

C front end code in: `$(SOURCE)/gcc`

Optimizer Code and Back End Generator Code

- Source language dir: `$(SOURCE)/gcc`

Back End Specification

- `$(SOURCE)/gcc/config/<target dir>/`
  Directory containing back end code
- Two main files: `<target>.h` and `<target>.md`,
  e.g. for an `i386` target, we have
  `$(SOURCE)/gcc/config/i386/i386.md` and
  `$(SOURCE)/gcc/config/i386/i386.h`
- Usually, also `<target>.c` for additional processing code
  (e.g. `$(SOURCE)/gcc/config/i386/i386.c`)
- Some additional files

Configuration

Preparing the GCC source for local adaptation:

- The platform on which it will be compiled
- The platform on which the generated compiler will execute
- The platform for which the generated compiler will generate code
- The directory in which the source exists
- The directory in which the compiler will be generated
- The directory in which the generated compiler will be installed
- The input languages which will be supported
- The libraries that are required
- etc.

Pre-requisites for Configuring and Building GCC 4.4.2

- ISO C90 Compiler / GCC 2.95 or later
- GNU bash: for running configure etc
- Awk: creating some of the generated source file for GCC
- bzip/gzip/untar etc. For unzipping the downloaded source file
- GNU make version 3.8 (or later)
- GNU Multiple Precision Library (GMP) version 4.2 (or later)
- MPFR Library version 2.3.2 (or later)
  (multiple precision floating point with correct rounding)
- MPC Library version 0.8.0 (or later)
- Parma Polyhedra Library (PPL) version 0.10
- CLooG-PPL (Chunky Loop Generator) version 0.15
- jar, or InfoZIP (zip and unzip)
- libelf version 0.8.12 (or later) (for LTO)

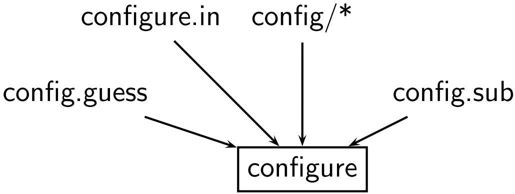
Our Conventions for Directory Names

- GCC source directory : `$(SOURCE)`
- GCC build directory : `$(BUILD)`
- GCC install directory : `$(INSTALL)`
- Important
  - `$(SOURCE)` $\neq$ `$(BUILD)` $\neq$ `$(INSTALL)`
  - None of the above directories should be contained in any of the above directories

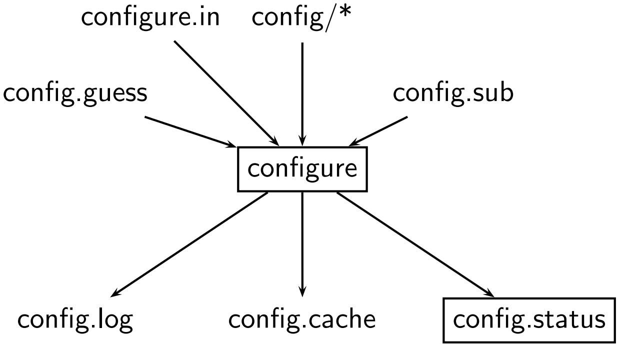
Configuring GCC

$\boxed{\text{configure}}$

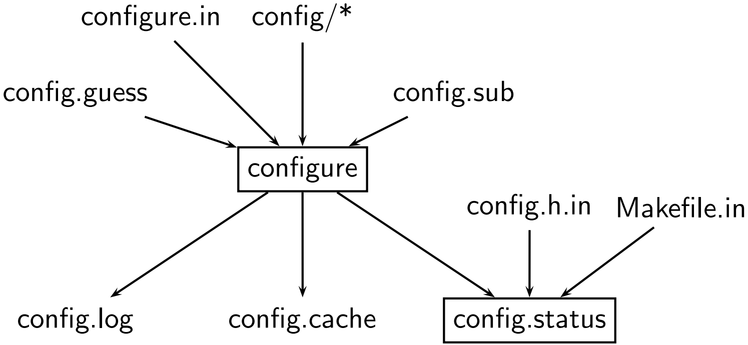
Configuring GCC



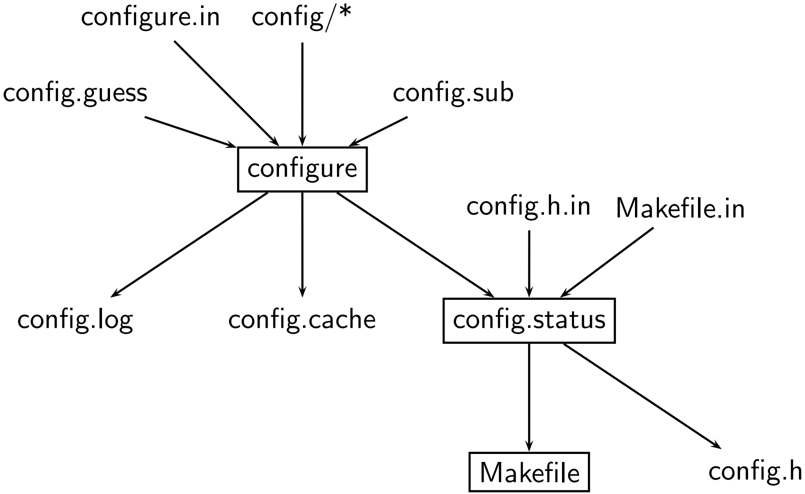
Configuring GCC



Configuring GCC



Configuring GCC



Steps in Configuration and Building

Usual Steps	
• Download and untar the source • `cd $(SOURCE)` • `./configure` • `make` • `make install`	

Steps in Configuration and Building

Usual Steps	Steps in GCC
• Download and untar the source • `cd $(SOURCE)` • `./configure` • `make` • `make install`	• Download and untar the source • `cd $(BUILD)` • `$(SOURCE)/configure` • `make` • `make install`

Steps in Configuration and Building

Usual Steps	Steps in GCC
• Download and untar the source • `cd $(SOURCE)` • `./configure` • `make` • `make install`	• Download and untar the source • `cd $(BUILD)` • `$(SOURCE)/configure` • `make` • `make install`

GCC generates a large part of source code during a build!

Building a Compiler: Terminology

- The sources of a compiler are compiled (i.e. built) on *Build system*, denoted BS.
- The built compiler runs on the *Host system*, denoted HS.
- The compiler compiles code for the *Target system*, denoted TS.

The built compiler itself runs on HS and generates executables that run on TS.

Variants of Compiler Builds

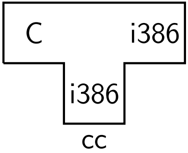
BS = HS = TS	Native Build
BS = HS ≠ TS	Cross Build
BS ≠ HS ≠ TS	Canadian Cross

Example

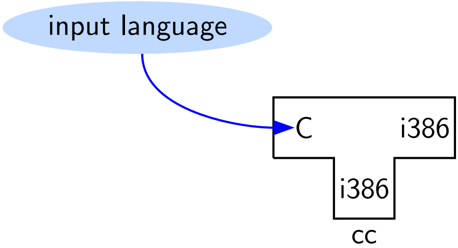
Native i386: built on i386, hosted on i386, produces i386 code.

Sparc cross on i386: built on i386, hosted on i386, produces Sparc code.

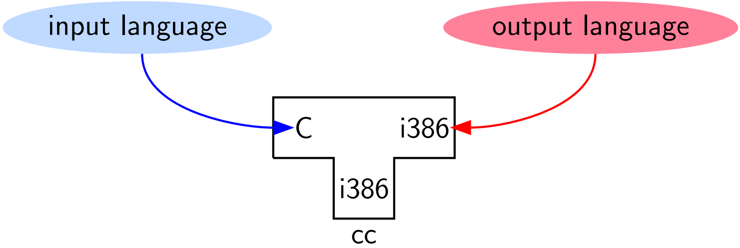
T Notation for a Compiler



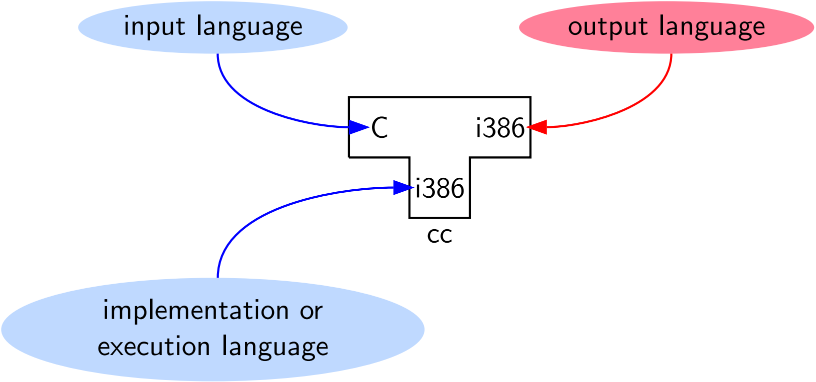
T Notation for a Compiler



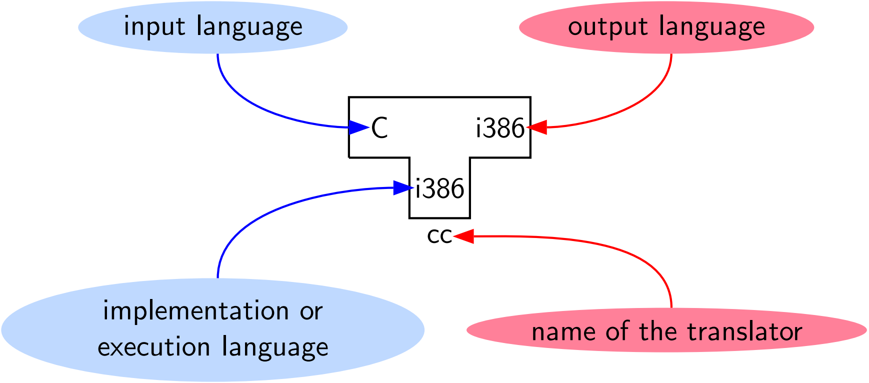
T Notation for a Compiler



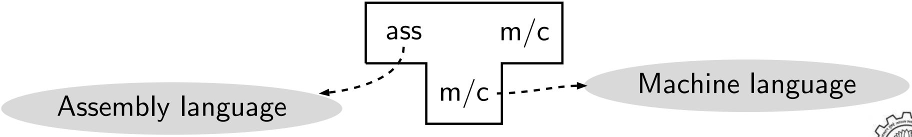
T Notation for a Compiler



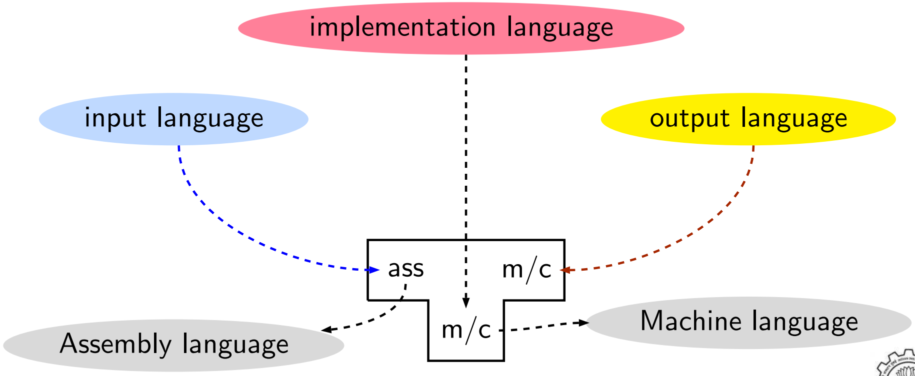
T Notation for a Compiler



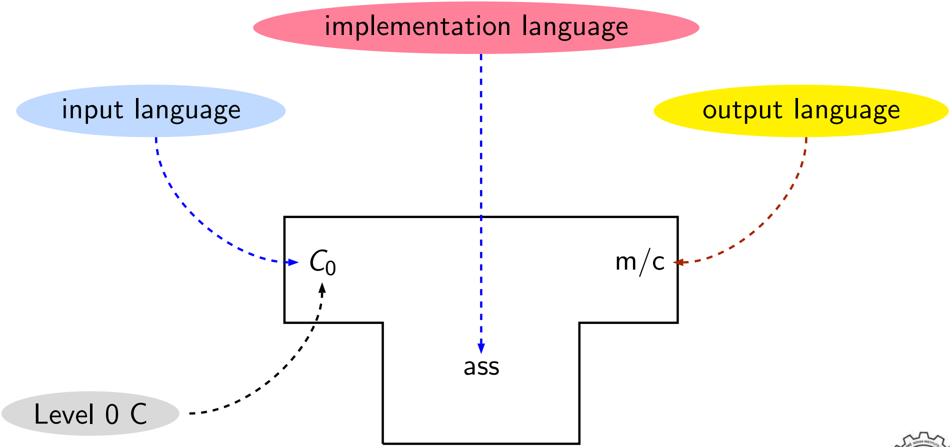
Bootstrapping: The Conventional View



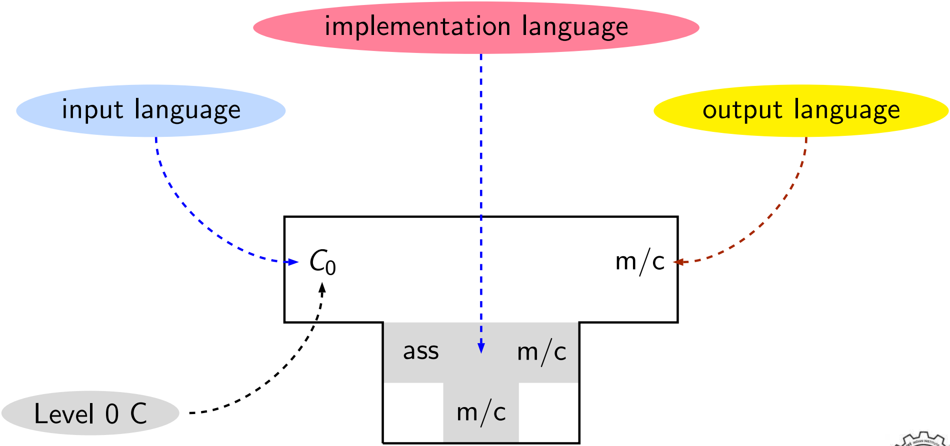
Bootstrapping: The Conventional View



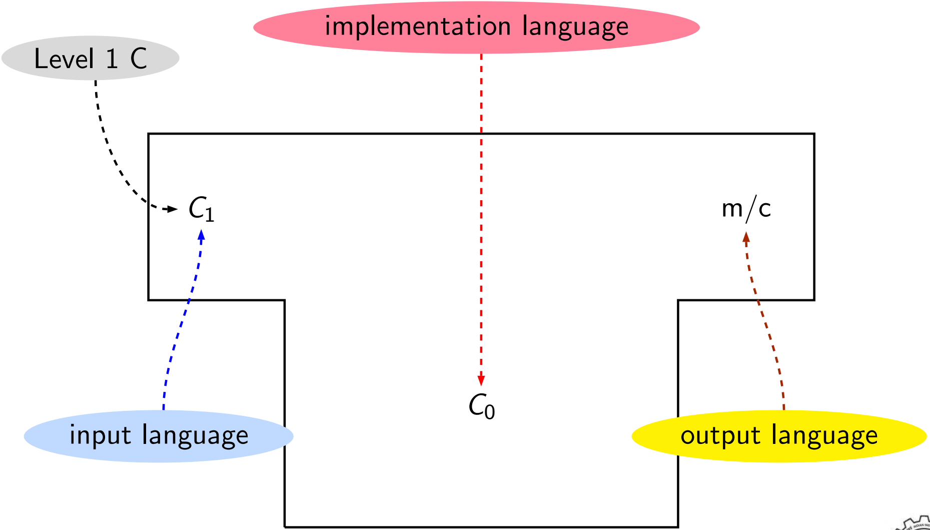
Bootstrapping: The Conventional View



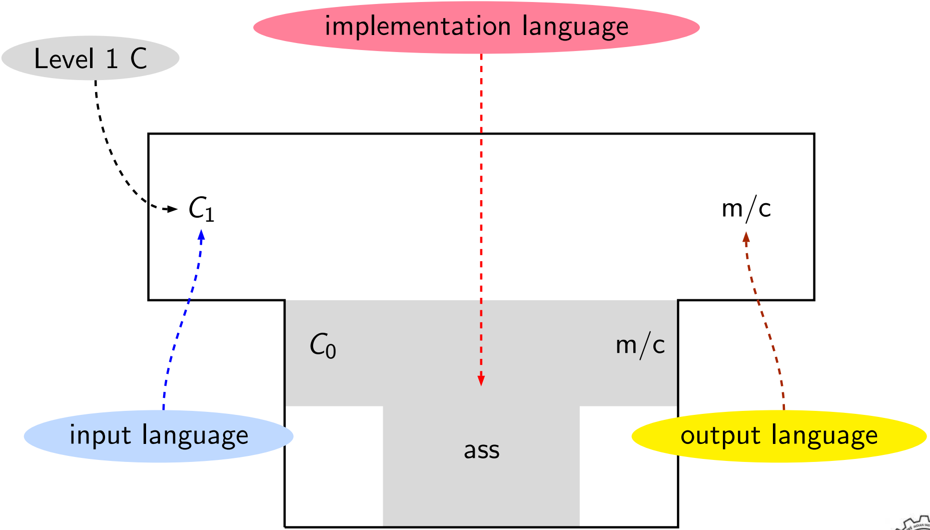
Bootstrapping: The Conventional View



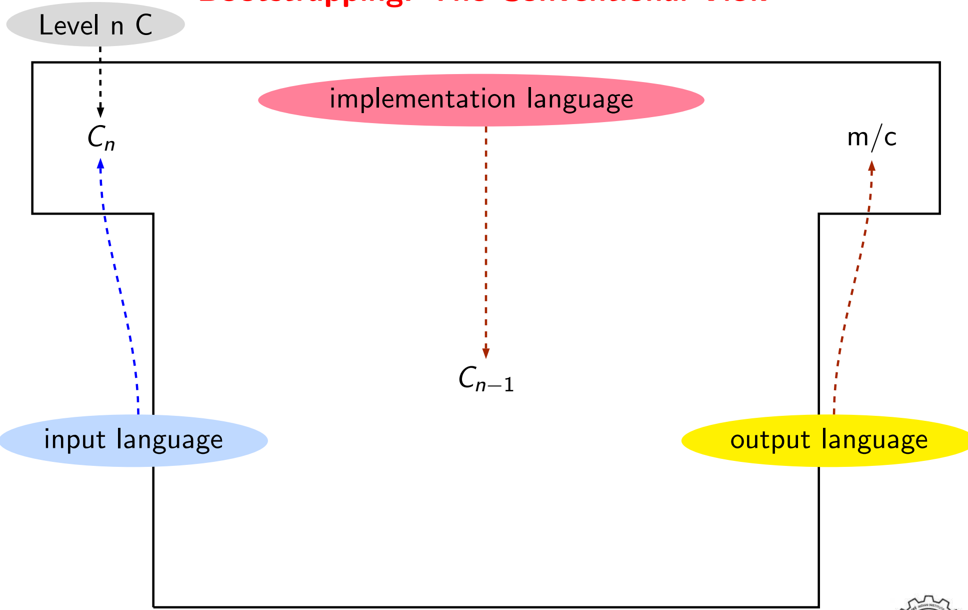
Bootstrapping: The Conventional View



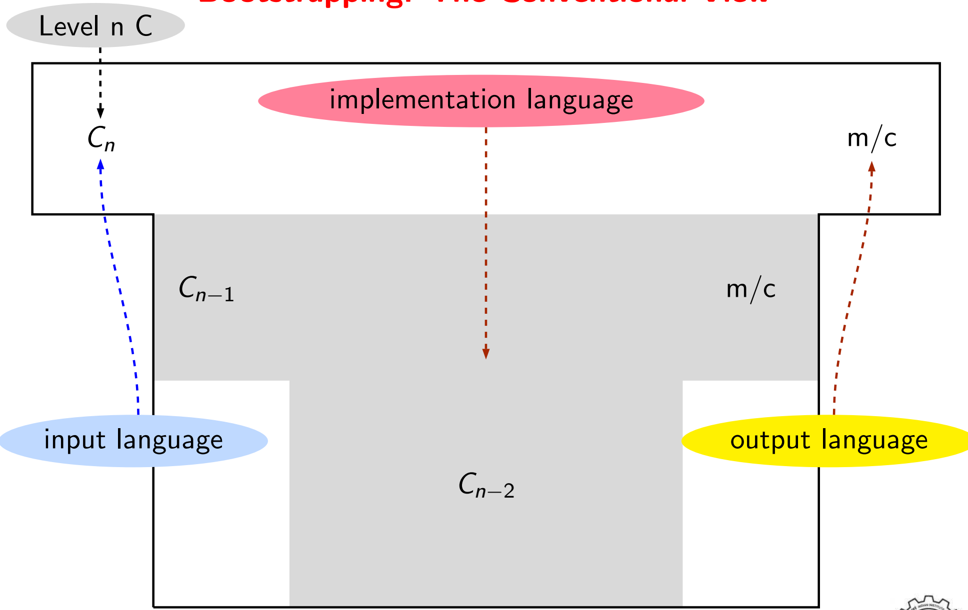
Bootstrapping: The Conventional View



Bootstrapping: The Conventional View



Bootstrapping: The Conventional View



Bootstrapping: GCC View

- Language need not change, but the compiler may change
  Compiler is improved, bugs are fixed and newer versions are released
- To build a new version of a compiler given a built old version:
  - Stage 1: Build the new compiler using the old compiler
  - Stage 2: Build another new compiler using compiler from stage 1
  - Stage 3: Build another new compiler using compiler from stage 2
    Stage 2 and stage 3 builds must result in identical compilers

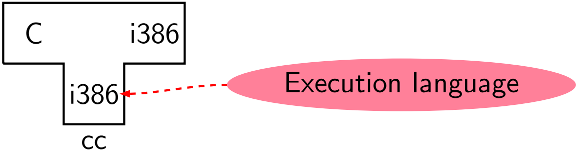
⇒ Building cross compilers stops after Stage 1!

A Native Build on i386

GCC
Source

Requirement: BS = HS = TS = i386

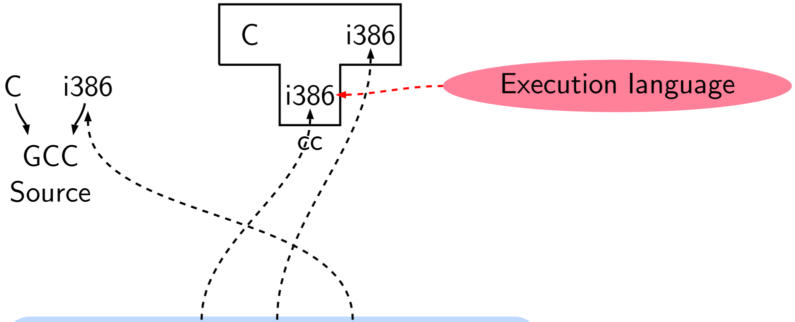
A Native Build on i386



GCC
Source

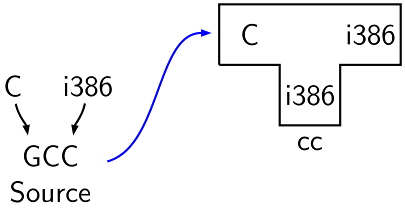
Requirement: BS = HS = TS = i386

A Native Build on i386



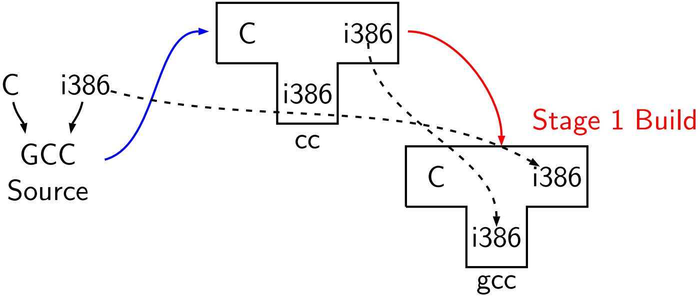
Requirement: BS = HS = TS = i386

A Native Build on i386



Requirement: BS = HS = TS = i386

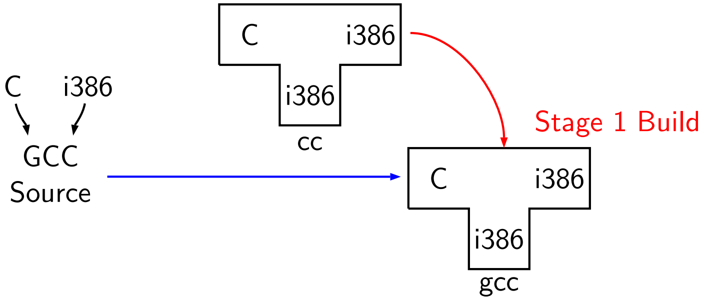
A Native Build on i386



Requirement: BS = HS = TS = i386

- Stage 1 build compiled using cc

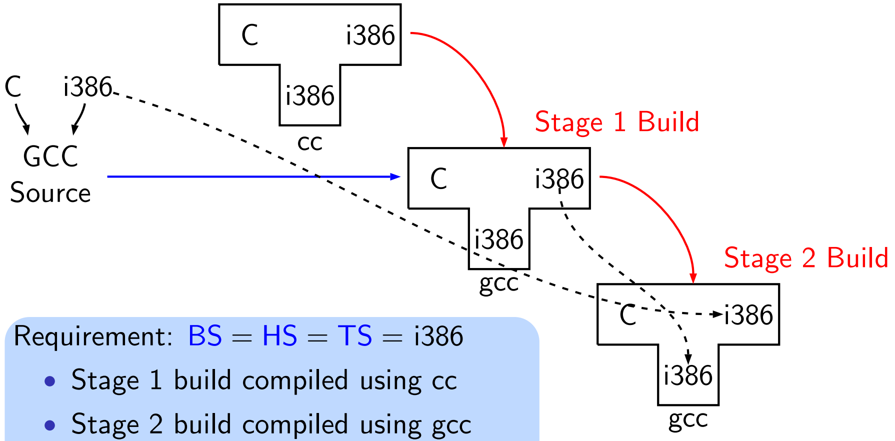
A Native Build on i386



Requirement: BS = HS = TS = i386

- Stage 1 build compiled using cc

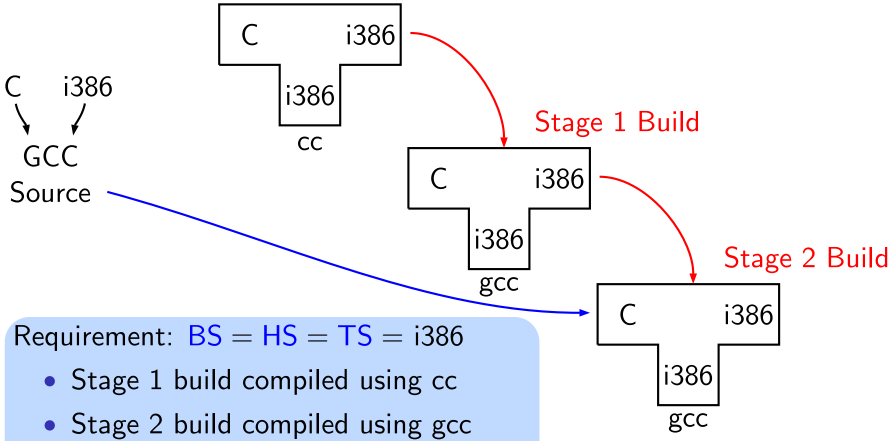
A Native Build on i386



Requirement: BS = HS = TS = i386

- Stage 1 build compiled using cc
- Stage 2 build compiled using gcc

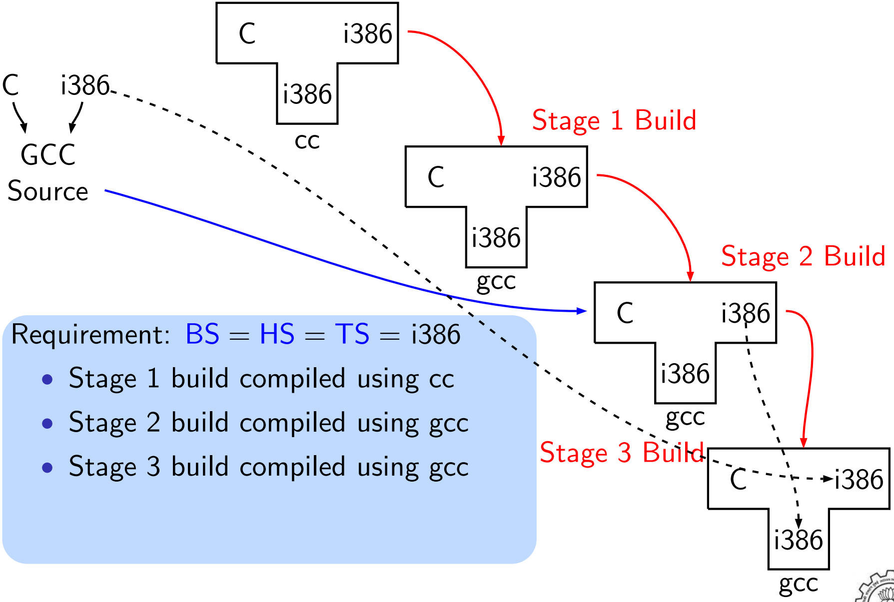
A Native Build on i386



Requirement: BS = HS = TS = i386

- Stage 1 build compiled using cc
- Stage 2 build compiled using gcc

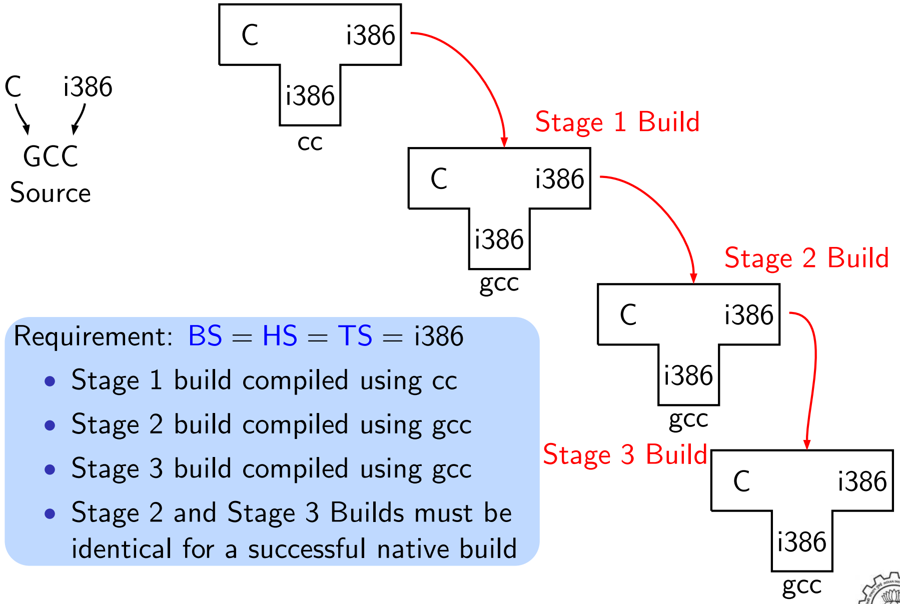
A Native Build on i386



Requirement: BS = HS = TS = i386

- Stage 1 build compiled using cc
- Stage 2 build compiled using gcc
- Stage 3 build compiled using gcc

A Native Build on i386



Requirement: BS = HS = TS = i386

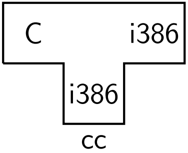
- Stage 1 build compiled using cc
- Stage 2 build compiled using gcc
- Stage 3 build compiled using gcc
- Stage 2 and Stage 3 Builds must be identical for a successful native build

A Cross Build on i386

GCC
Source

Requirement: BS = HS = i386, TS = mips

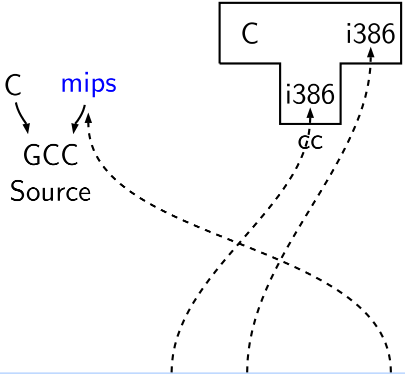
A Cross Build on i386



GCC
Source

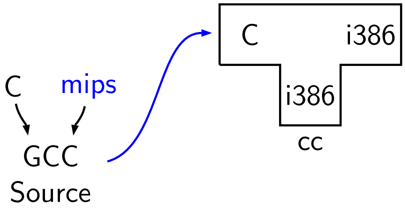
Requirement: BS = HS = i386, TS = mips

A Cross Build on i386



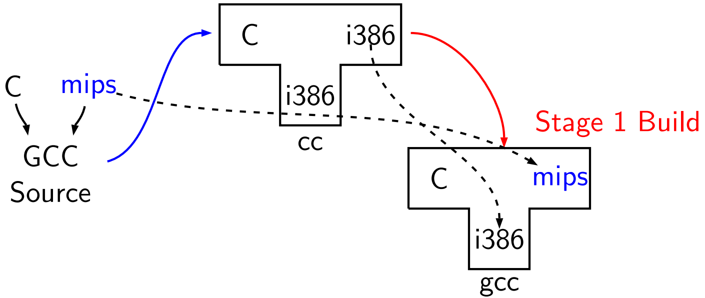
Requirement: BS = HS = i386, TS = mips

A Cross Build on i386



Requirement: BS = HS = i386, TS = mips

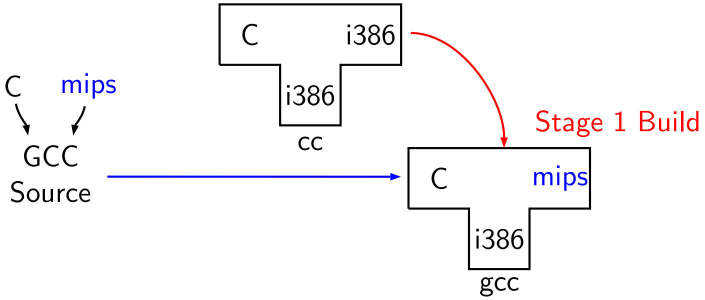
A Cross Build on i386



Requirement: BS = HS = i386, TS = mips

- Stage 1 build compiled using cc

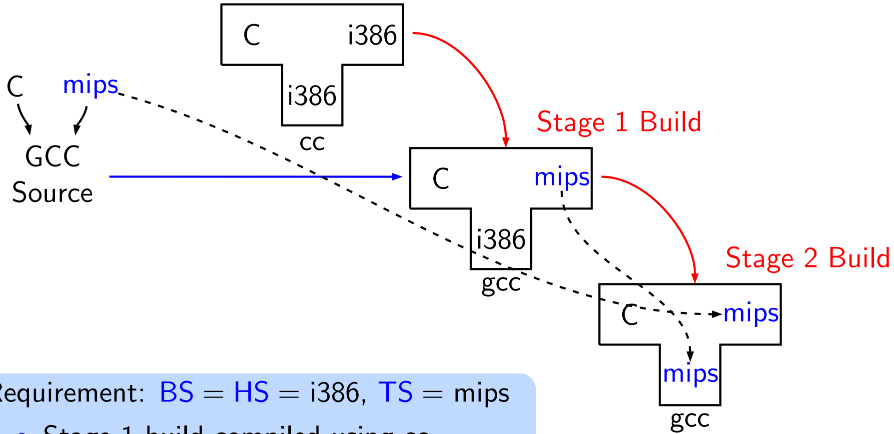
A Cross Build on i386



Requirement: BS = HS = i386, TS = mips

- Stage 1 build compiled using cc

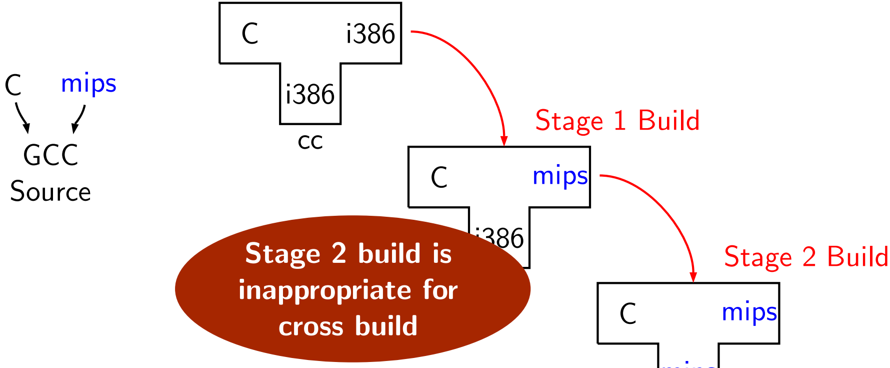
A Cross Build on i386



Requirement: BS = HS = i386, TS = mips

- Stage 1 build compiled using cc
- Stage 2 build compiled using gcc
  Its HS = mips and not i386!

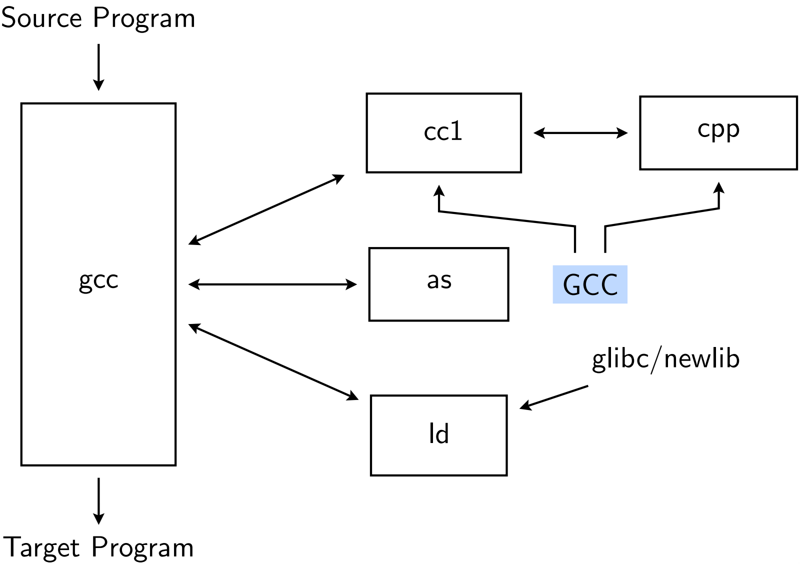
A Cross Build on i386



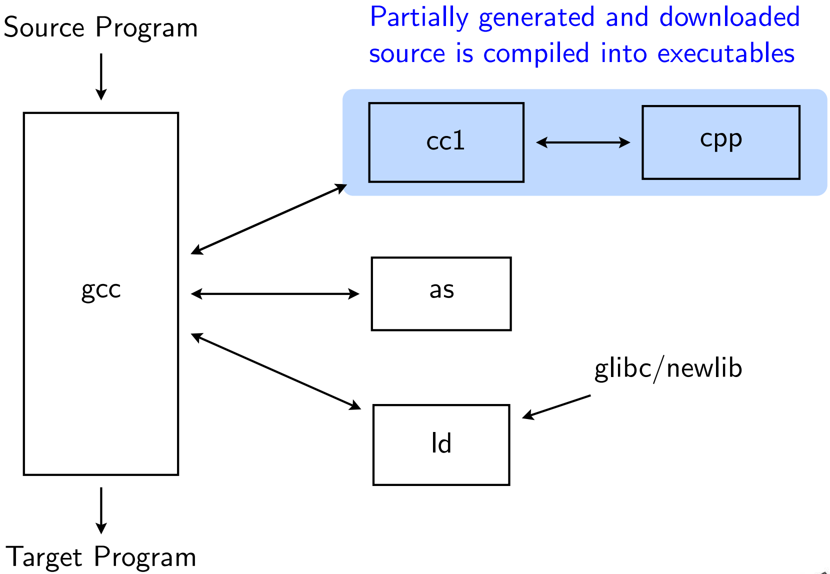
Requirement: BS = HS = i386, TS = mips

- Stage 1 build compiled using cc
- Stage 2 build compiled using gcc
  Its HS = mips and not i386!

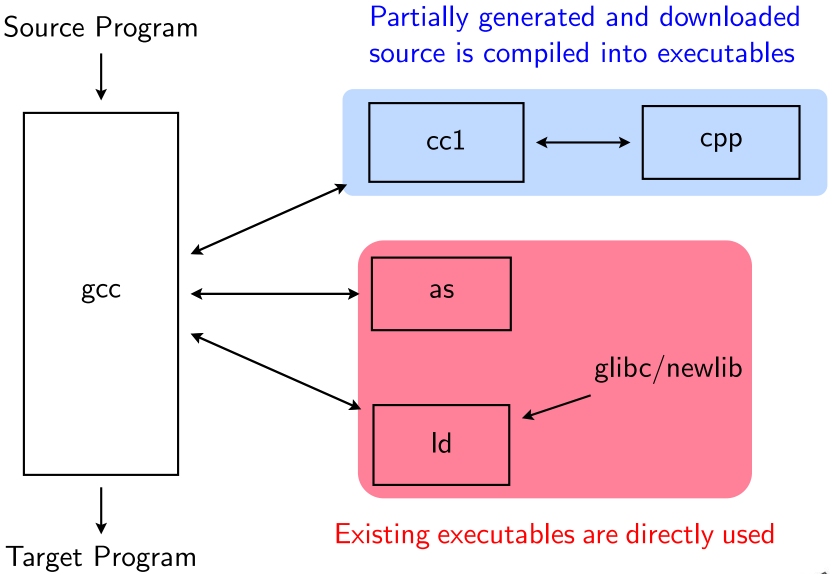
A More Detailed Look at Building



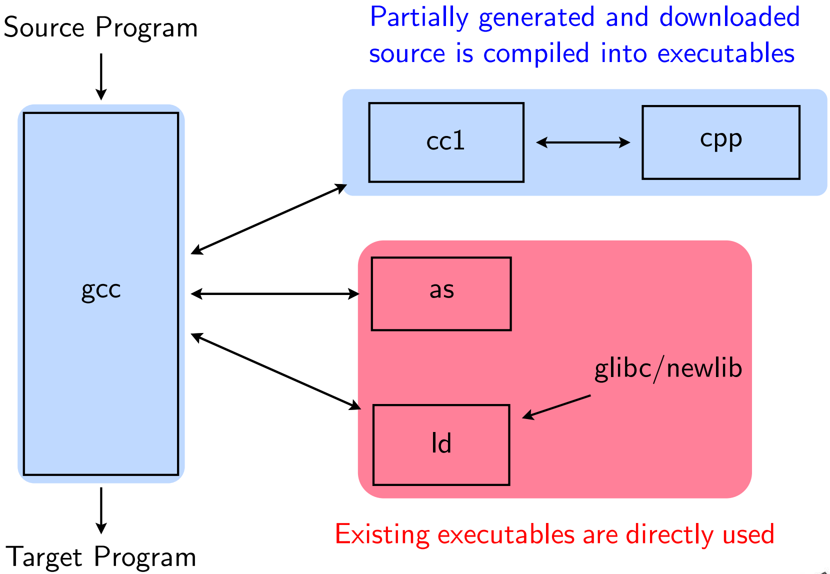
A More Detailed Look at Building



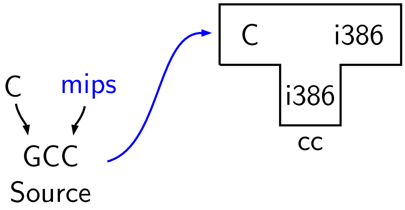
A More Detailed Look at Building



A More Detailed Look at Building

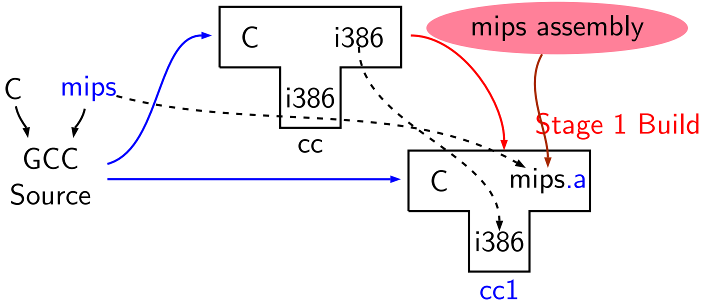


A More Detailed Look at Cross Build



Requirement: BS = HS = i386, TS = mips

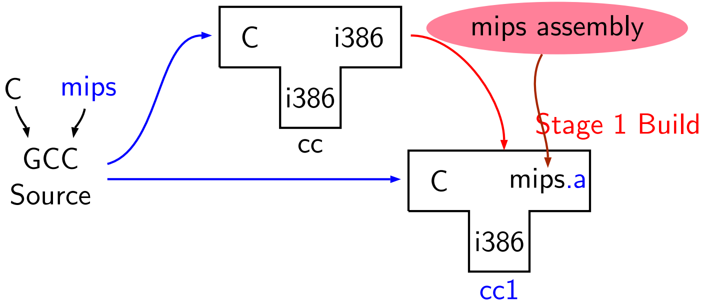
A More Detailed Look at Cross Build



Requirement: BS = HS = i386, TS = mips

- Stage 1 build consists of only cc1 and not gcc

A More Detailed Look at Cross Build

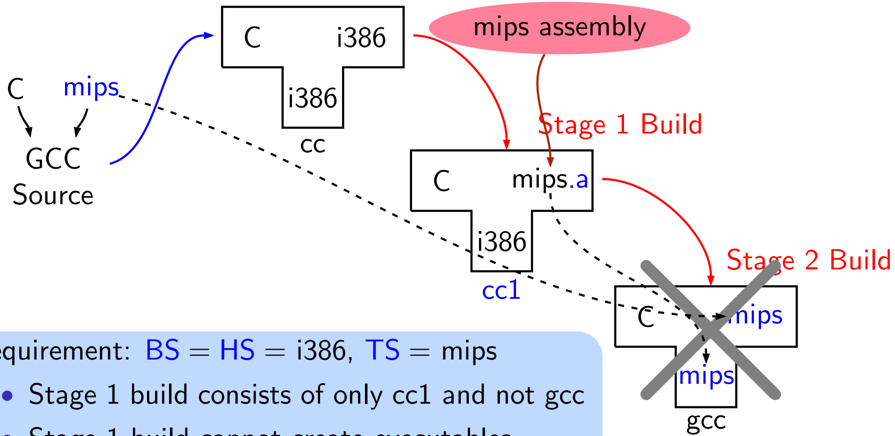


Requirement: BS = HS = i386, TS = mips

- Stage 1 build consists of only cc1 and not gcc
- Stage 1 build cannot create executables
- Library sources cannot be compiled for mips using stage 1 build

binutils
are not available
for mips

A More Detailed Look at Cross Build

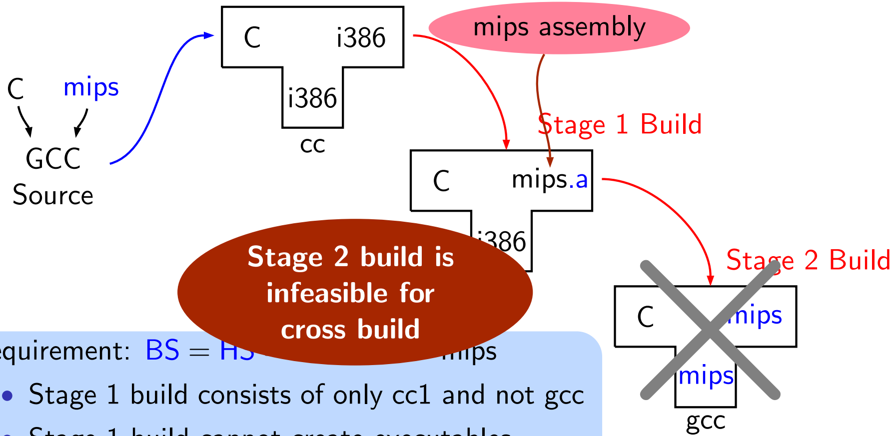


Requirement: BS = HS = i386, TS = mips

- Stage 1 build consists of only cc1 and not gcc
- Stage 1 build cannot create executables
- Library sources cannot be compiled for mips using stage 1 build
- Stage 2 build is not possible

binutils
are not available
for mips

A More Detailed Look at Cross Build



Requirement: BS = HS mips

- Stage 1 build consists of only cc1 and not gcc
- Stage 1 build cannot create executables
- Library sources cannot be compiled for mips using stage 1 build
- Stage 2 build is not possible

binutils
are not available
for mips

Cross Build Revisited

- Option 1: Build binutils in the same source tree as `gcc`
  Copy binutils source in `$(SOURCE)`, configure and build stage 1
- Option 2:
  - Compile cross-assembler (`as`), cross-linker (`ld`), cross-archiver (`ar`), and cross-program to build symbol table in archiver (`ranlib`),
  - Copy them in `$(INSTALL)/bin`
  - Build stage GCC
  - Install newlib
  - Reconfigure and build GCC
    Some options differ in the two builds

Commands for Configuring and Building GCC

This is what *we* specify

- `cd $(BUILD)`

Commands for Configuring and Building GCC

This is what *we* specify

- `cd $(BUILD)`
- `$(SOURCE)/configure <options>`
  `configure` output: customized `Makefile`

Commands for Configuring and Building GCC

This is what *we* specify

- `cd $(BUILD)`
- `$(SOURCE)/configure <options>`
  `configure` output: customized `Makefile`
- `make 2> make.err > make.log`

Commands for Configuring and Building GCC

This is what *we* specify

- `cd $(BUILD)`
- `$(SOURCE)/configure <options>`
  `configure` output: customized `Makefile`
- `make 2> make.err > make.log`
- `make install 2> install.err > install.log`

Build for a Given Machine

This is what actually happens!

- Generation
  - Generator sources (`$(SOURCE)/gcc/gen*.c`) are read and generator executables are created in `$(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)` and executables created in corresponding subdirectories of `$(BUILD)`
- Installation
  Created executables and libraries are copied in `$(INSTALL)`

Build for a Given Machine

This is what actually happens!

- Generation
  - Generator sources (`$(SOURCE)/gcc/gen*.c`) are read and generator executables are created in `$(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)` and executables created in corresponding subdirectories of `$(BUILD)`
- Installation
  Created executables and libraries are copied in `$(INSTALL)`

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

Build failures due to Machine Descriptions

Incomplete MD specifications	$\Rightarrow$	Unsuccessful build
Incorrect MD specification	$\Rightarrow$	Successful build but run time failures/crashes (either ICE or `SIGSEGV`)

Building `cc1` Only

- Add a new target in the `Makefile.in`

```
cc1:
     make all-gcc TARGET-gcc=cc1$(exeext)
```

- Configure and build with the command `make cc1`.

Common Configuration Options

`--target`

- Necessary for cross build
- Possible `host-cpu-vendor` strings: Listed in `$(SOURCE)/config.sub`

`--enable-languages`

- Comma separated list of language names
- Default names: `c`, `c++`, `fortran`, `java`, `objc`
- Additional names possible: `ada`, `obj-c++`, `treelang`

`--prefix=$(INSTALL)`
`--program-prefix`

- Prefix string for executable names

`--disable-bootstrap`

- Build stage 1 only

Registering New Machine Descriptions

- Define a new system name, typically a triple.
  e.g. `spim-gnu-linux`
- Edit `$(SOURCE)/config.sub` to recognize the triple
- Edit `$(SOURCE)/gcc/config.gcc` to define
  - any back end specific variables
  - any back end specific files
  - `$(SOURCE)/gcc/config/<cpu>` is used as the back end directory

  for recognized system names.

Tip

Read comments in `$(SOURCE)/config.sub` &
`$(SOURCE)/gcc/config/<cpu>`.

Testing GCC

- Pre-requisites - `Dejagnu`, `Expect` tools
- Option 1: Build GCC and execute the command
  `make check`
  or
  `make check-gcc`
- Option 2: Use the configure option `--enable-checking`
- Possible list of checks
  - Compile time consistency checks
    `assert`, `fold`, `gc`, `gcac`, `misc`, `rtl`, `rtlflag`, `runtime`, `tree`, `valgrind`
  - Default combination names
    - `yes`: `assert`, `gc`, `misc`, `rtlflag`, `runtime`, `tree`
    - `no`
    - `release`: `assert`, `runtime`
    - `all`: all except `valgrind`

GCC Testing framework

- `make` will invoke `runtest` command
- Specifying `runtest` options using `RUNTESTFLAGS` to customize torture testing
  `make check RUNTESTFLAGS="compile.exp"`
- Inspecting testsuite output: `$(BUILD)/gcc/testsuite/gcc.log`

Interpreting Test Results

- PASS: the test passed as expected
- XPASS: the test unexpectedly passed
- FAIL: the test unexpectedly failed
- XFAIL: the test failed as expected
- UNSUPPORTED: the test is not supported on this platform
- ERROR: the testsuite detected an error
- WARNING: the testsuite detected a possible problem

GCC Internals document contains an exhaustive list of options for testing

Configuring and Building GCC – Summary

- Choose the source language: C (`--enable-languages=c`)
- Choose installation directory: (`--prefix=<absolute path>`)
- Choose the target for non native builds: (`--target=sparc-sunos-sun`)
- Run: `configure` with above choices
- Run: `make` to
  - generate target specific part of the compiler
  - build the entire compiler
- Run: `make install` to install the compiler

Tip

Redirect all the outputs:

```
$ make > make.log 2> make.err
```

Exercise 1 and Assignment 1

- Exercises:
  - i386 native build for GCC-4.4.2
  - Build only `cc1`
- Assignment 1
  - Build a bare metal cross cross compiler for your choice of target
    Complete tool chain without OS support
  - Build a cross compiler with OS support for your choice of target
  - Deadline: Monday 25 Jan 2009