AI编译器系列

LLVM架构和原理

ZOMI

Talk Overview

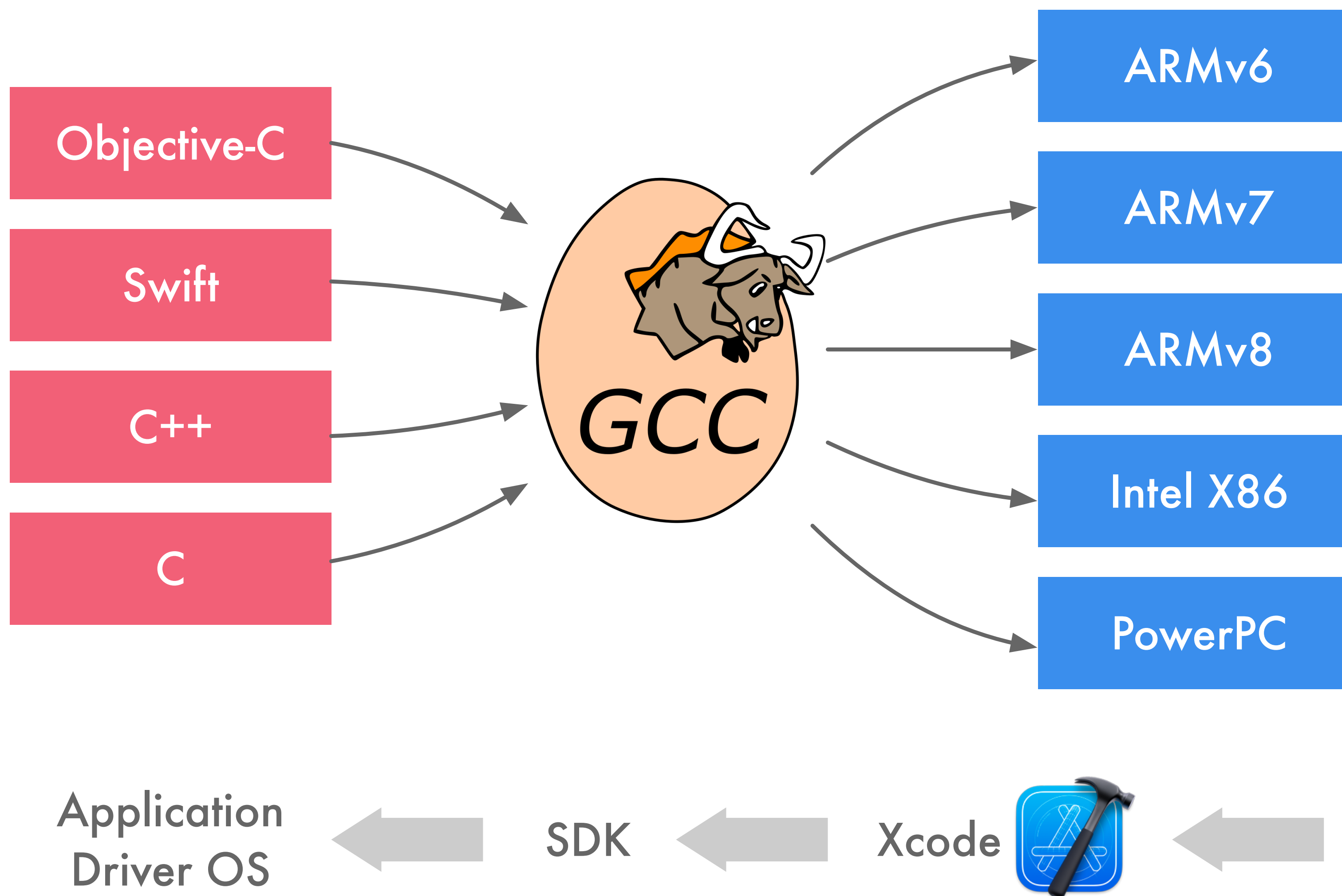
1. **传统编译器**
   - History of Compiler - 编译器的发展
   - GCC process and principle – GCC 编译过程和原理
   - LLVM/Clang process and principle – LLVM 架构和原理
2. **AI编译器**
   - History of AI Compiler – AI编译器的发展
   - Base Common architecture – AI编译器的通用架构
   - Different and challenge of the future – 与传统编译器的区别，未来的挑战与思考

Talk Overview

LLVM/Clang process and principle – LLVM 架构和原理

- LLVM 项目发展历史
- LLVM 基本设计原则和架构
- LLVM 中间表示 LLVM IR
- LLVM 前端过程
- LLVM 中间优化
- LLVM 后端生成
- 基于 LLVM 项目

Complicate Ecosystem



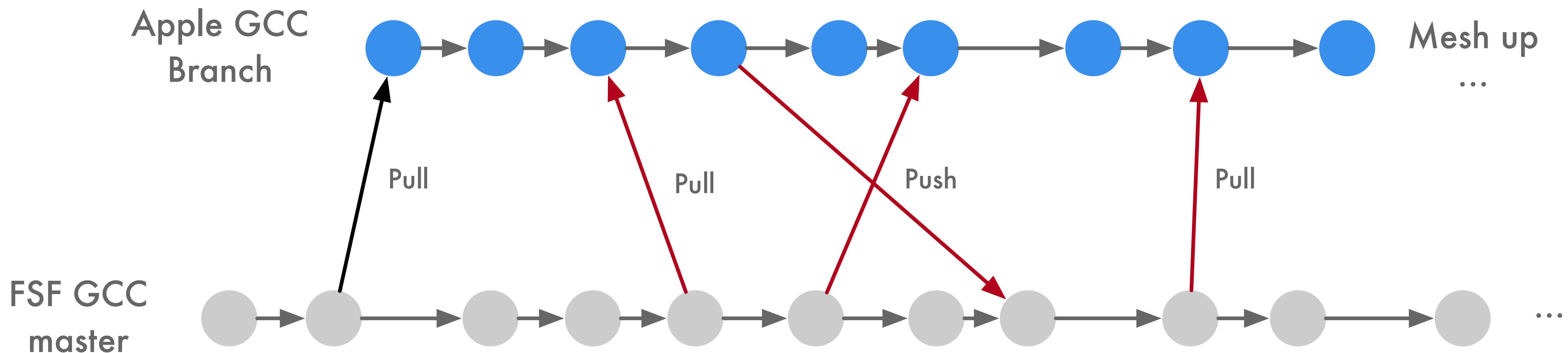
Apple needs find a way out

NeXTSTEP

1997 1997 2001

1998 Power Macintosh G3
1999 Power Macintosh G4
2000 PowerBook
2001 iPod
2002 iPod2
2003 iPod3
2004 iPod4 & Mini & Photo
2005 iPod5
iPod Shuffle
iPod Nano
Power Macintosh G5 (Intel)
2006 MacBook Pro
2007 Apple TV
iPhone
2008 MacBook Air
iPod Touch
iPhone 3G

Apple needs find a way out



GCC is developed for solving real problems,
it has no time to make a good everything perfect.

Apple met LLVM

Chris Lattner

Twitter: https://twitter.com/clattner_llvm

Website: http://nondot.org/sabre

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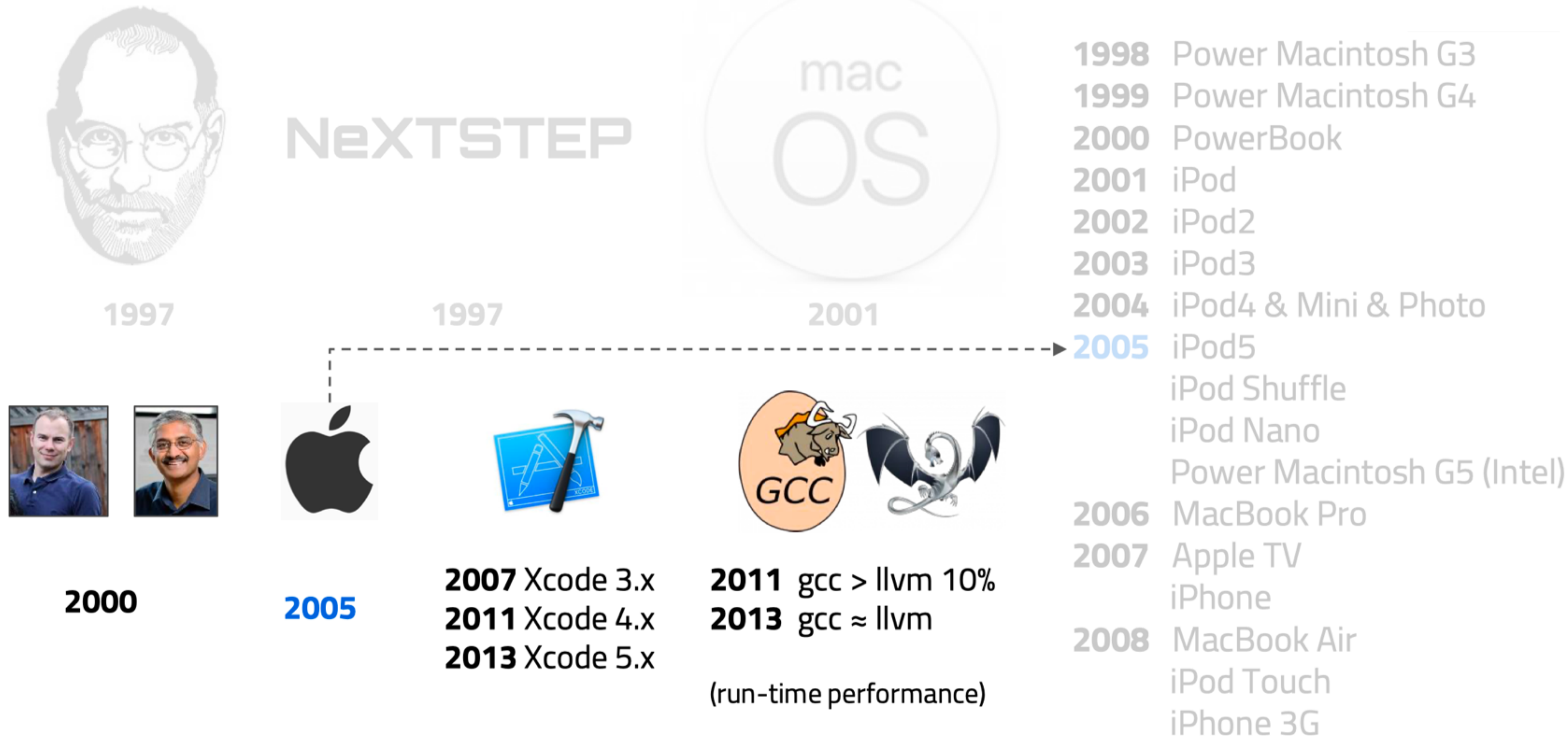
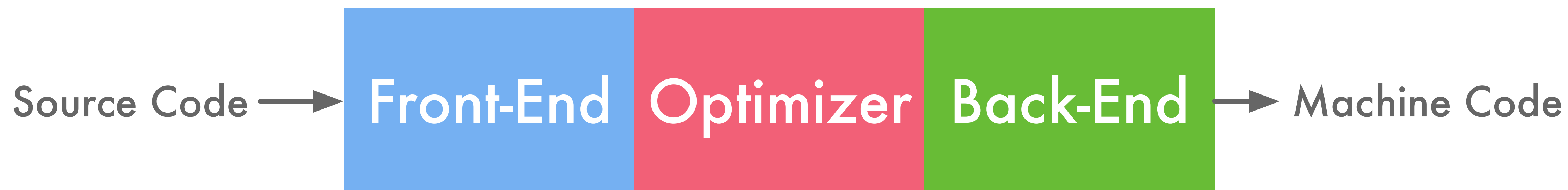
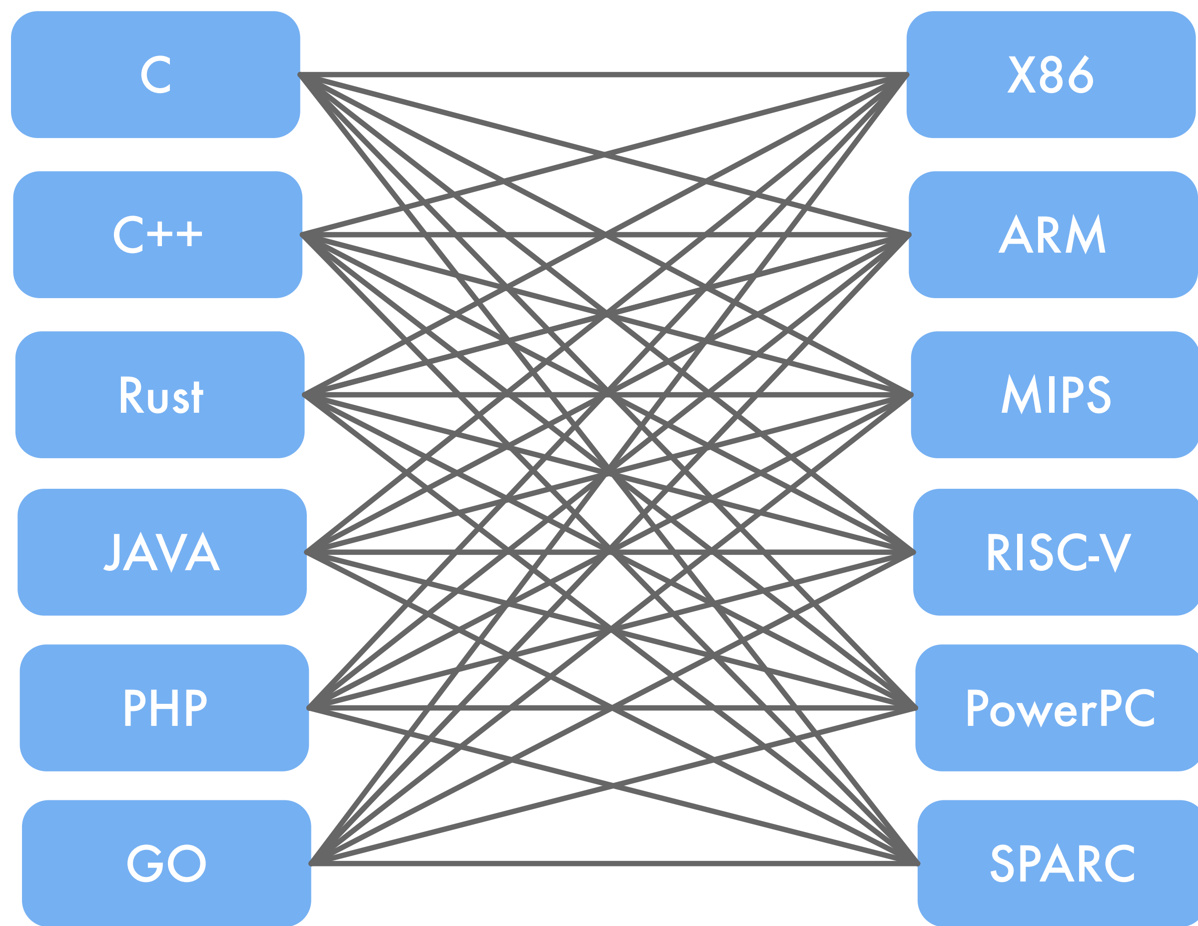
Apple met LLVM



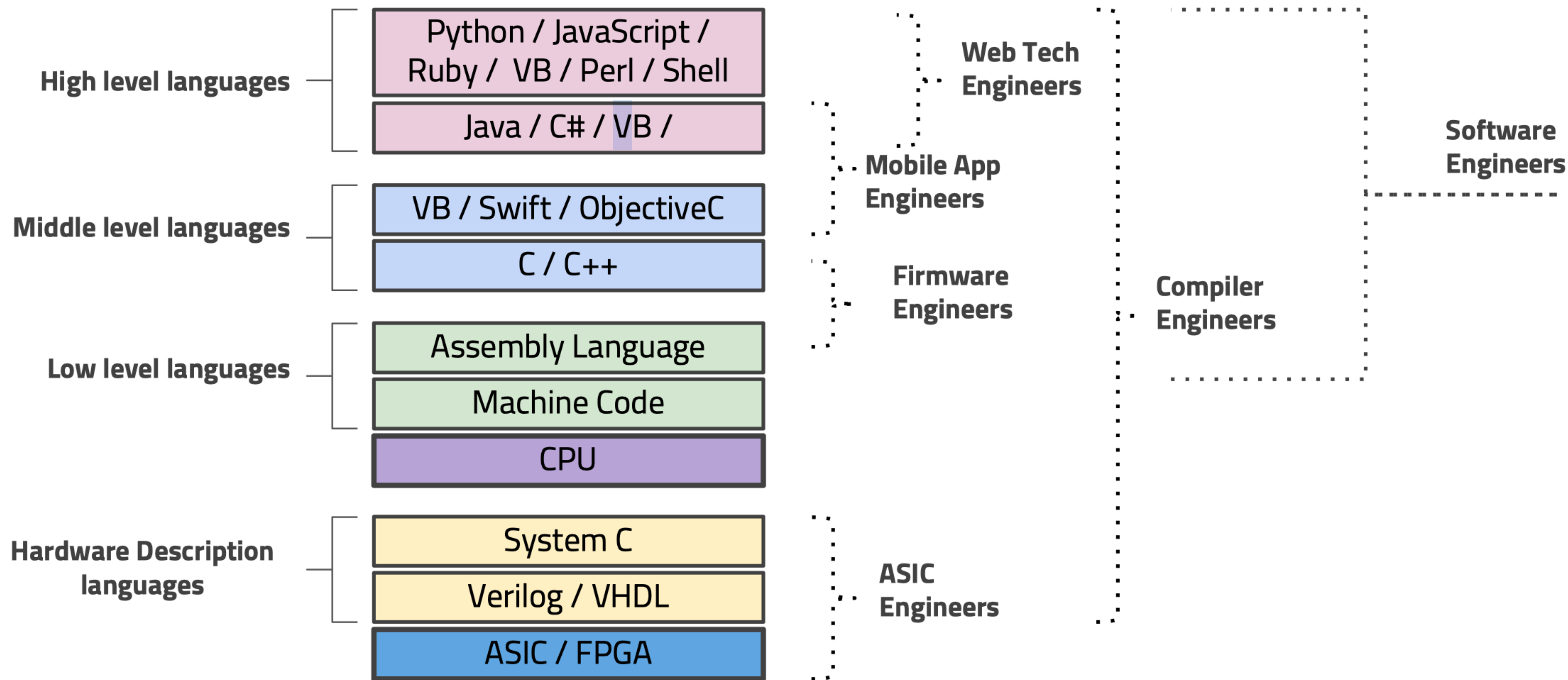
Compiler basic constitution



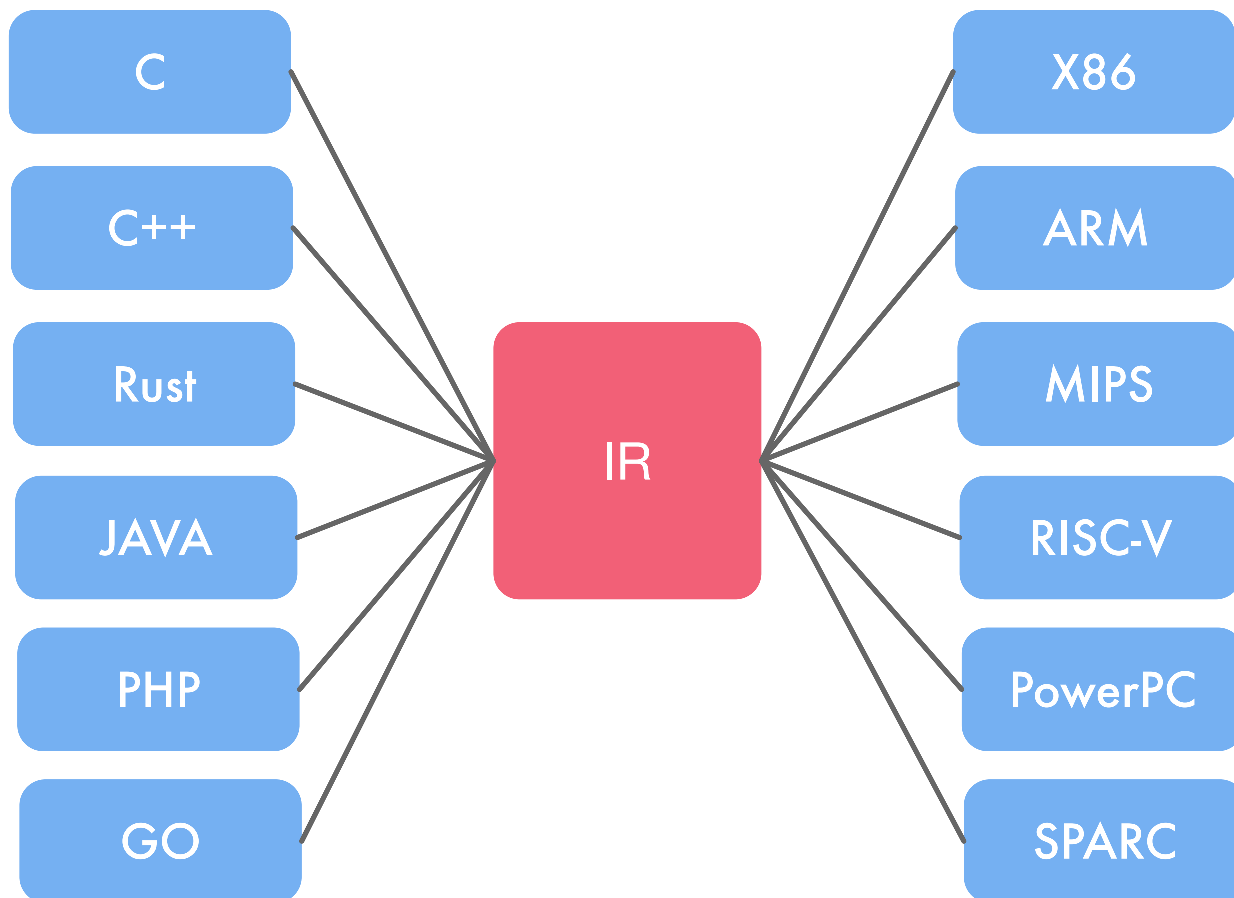
Traditional Compiler vs Modern Compiler



Computer Language stacks



Traditional Compiler vs Modern Compiler



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What is LLVM

- LLVM is a Compiler
- LLVM is a Compiler Infrastructure
- LLVM is a series of Compiler Tools
- LLVM is a Compiler Toolchain
- LLVM is an open source C++ implementation
- LLVM 项目发展为一个巨大的编译器相关的工具集合

Lib base LLVM

Lib base LLVM

LLVM Core	即 LLVM 的核心库，主要是围绕 LLVM 中间代码的一些工具，它提供了一个“源”和“目标”无关的优化器和几乎所有主流 CPU 类型的代码（机器码）生成器。
Clang	是 LLVM 项目中的一个子项目。它是基于 LLVM 架构的轻量级编译器，诞生之初是为了替代 GCC，提供更快的编译速度。它是负责编译C、C++、Objecte-C 语言的编译器，它属于整个 LLVM 架构中的，编译器前端。
Compiler-RT	项目用于为硬件不支持的低级功能提供特定于目标的支持。例如，32位目标通常缺少支持64位的除法指令。Compier-RT通过提供特定于目标并经过优化的功能来解决这个问题，该功能在使用32位指令的同时实现了64位除法。为代码生成器提供了一些中间代码指令的实现，这些指令通常是目标机器没有直接对应的，例如在32位机器上将 double 转换为 unsigned integer 类型。此外该库还为一些动态测试工具提供了运行时实现，例如 AddressSanitinzer、ThreadSanitizer、MemorySanitizer 和 DataFlowSanitizer 等。
LLDB	LLDB是一个LLVM的原生调试器项目，最初是XCode的调试器，用以取代GDB。LLDB提供丰富的流程控制和数据检测的调试功能。
LLD	clang/llvm内置的链接器。
Dragonegg	GCC插件，可将GCC的优化和代码生成器替换为LLVM的相应工具。
libc	C标准库实现。
libcxx/libcxxabi	C++标准库实现。
libclc	OpenCL标准库的实现。
OpenMP	提供一个OpenMP运行时，用于Clang中的OpenMP实现。
polly	支持高级别的循环和数据本地化优化支持的LLVM框架，使用多面体模型实现一组缓存局部优化以及自动并行和矢量化。
vmkit	基于LLVM的Java和.Net虚拟机实现。
klee	基于LLVM编译基础设施的符号化虚拟机。它使用一个定理证明器来尝试评估程序中的所有动态路径，以发现错误并证明函数的属性。klee的一个主要特征是它可以在检测到错误时生成测试用例。
SAFECode	用于C/C++程序的内存安全编译器。它通过运行时检查来检测代码，以便在运行时检测内存安全错误（如缓冲区溢出）。它可以用户保护软件免受安全攻击，也可用作Valgrind等内存安全错误调试工具。

LLVM vs GCC

- 把编译器移植给新的语言只需要实现一个新的编译前端，已有的优化和后端都能实现复用；
- 如果前后端和解析器没有相互解耦，新语言编译器需要支持 N 个目标机和 M 种语言(N*M)；

- LLVM 组件之间交互发生在高层次抽象，不同组件隔离为单独程序库，易于在整个编译流水线中集成转换和优化 Pass。现在被作为实现各种静态和运行时编译语言的通用基础结构；
- GCC 饱受分层和抽象漏洞困扰：编译前端生成编译后端数据的结构，编译后端遍历前端抽象语法树（AST）来生成调试信息，整个编译器依赖命令行设置的全局数据结构；

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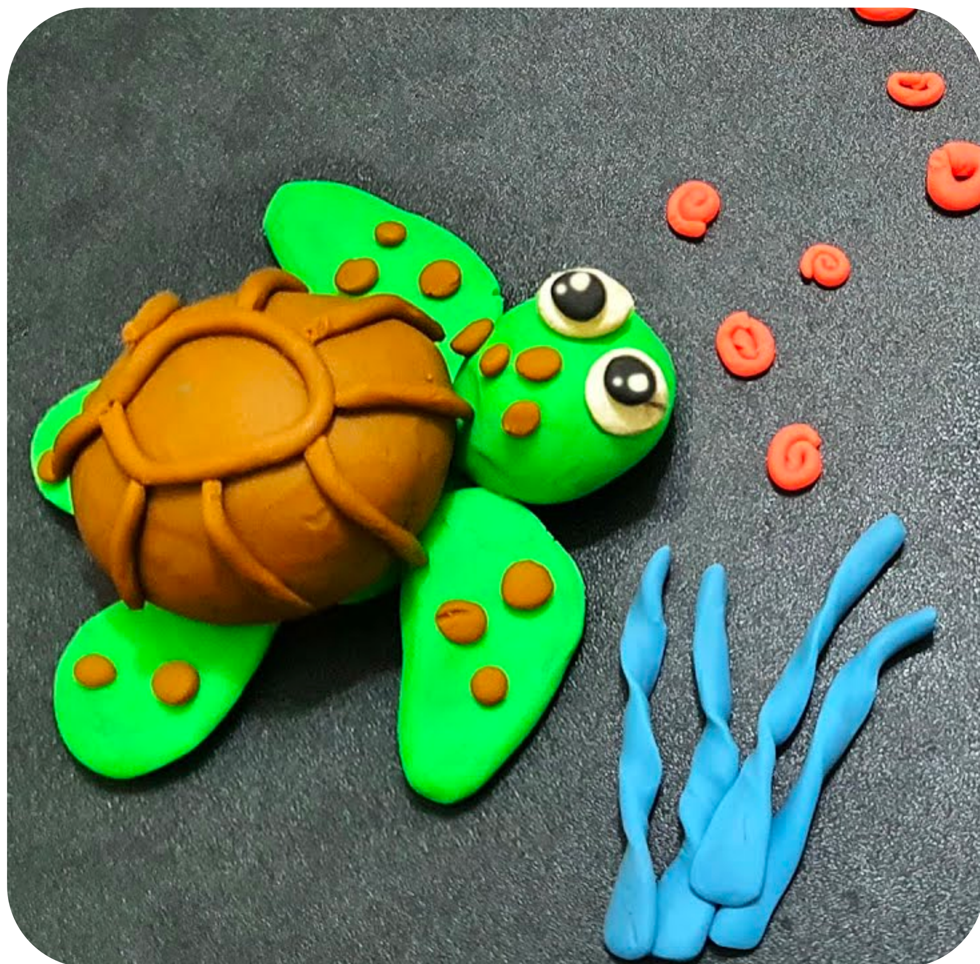
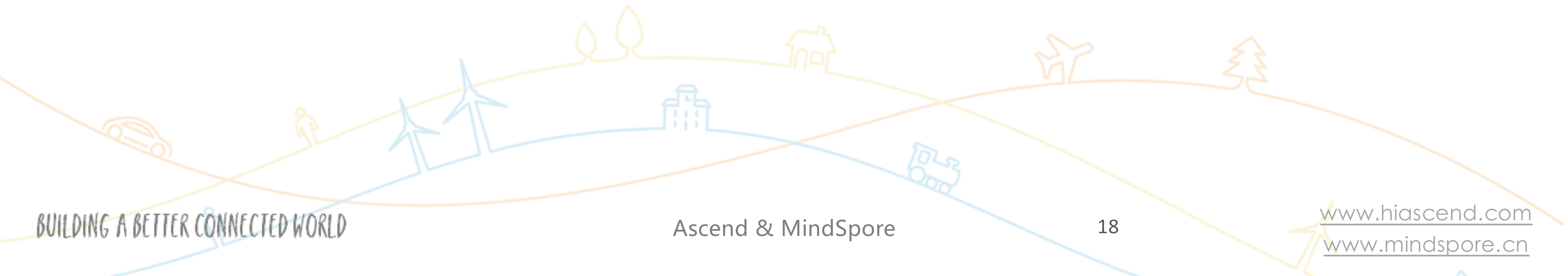
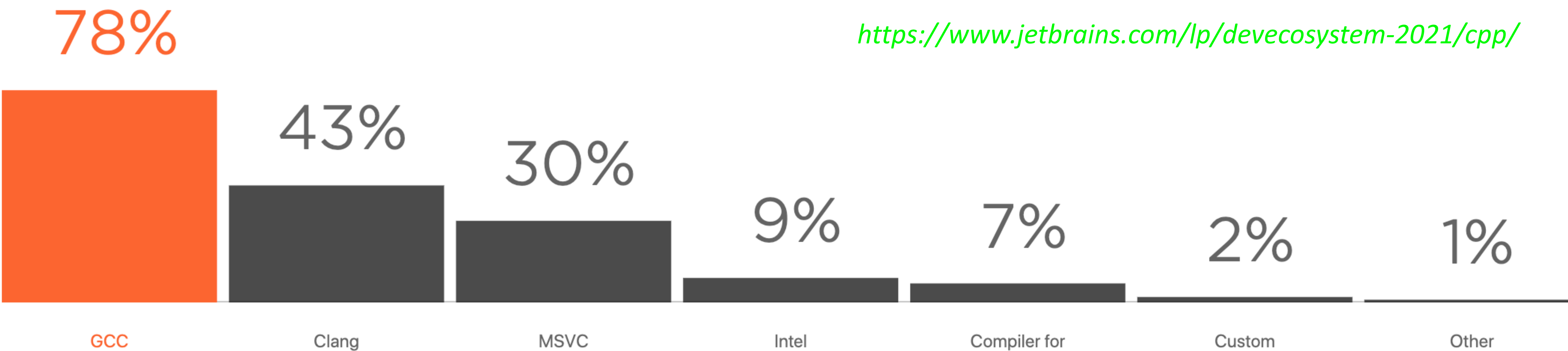
What I see the different like this ...



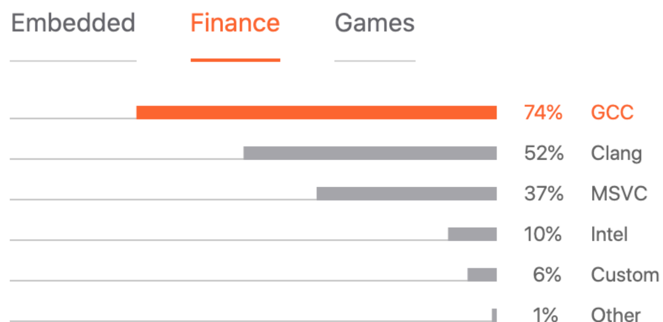
CLANG vs GCC

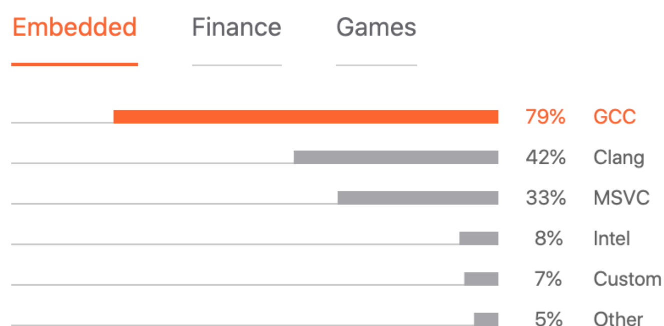


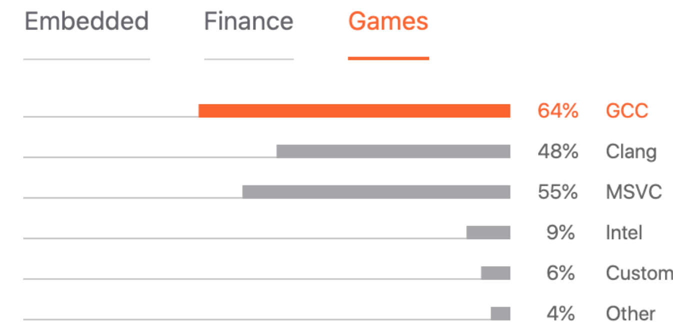
Which compilers do your regularly use?



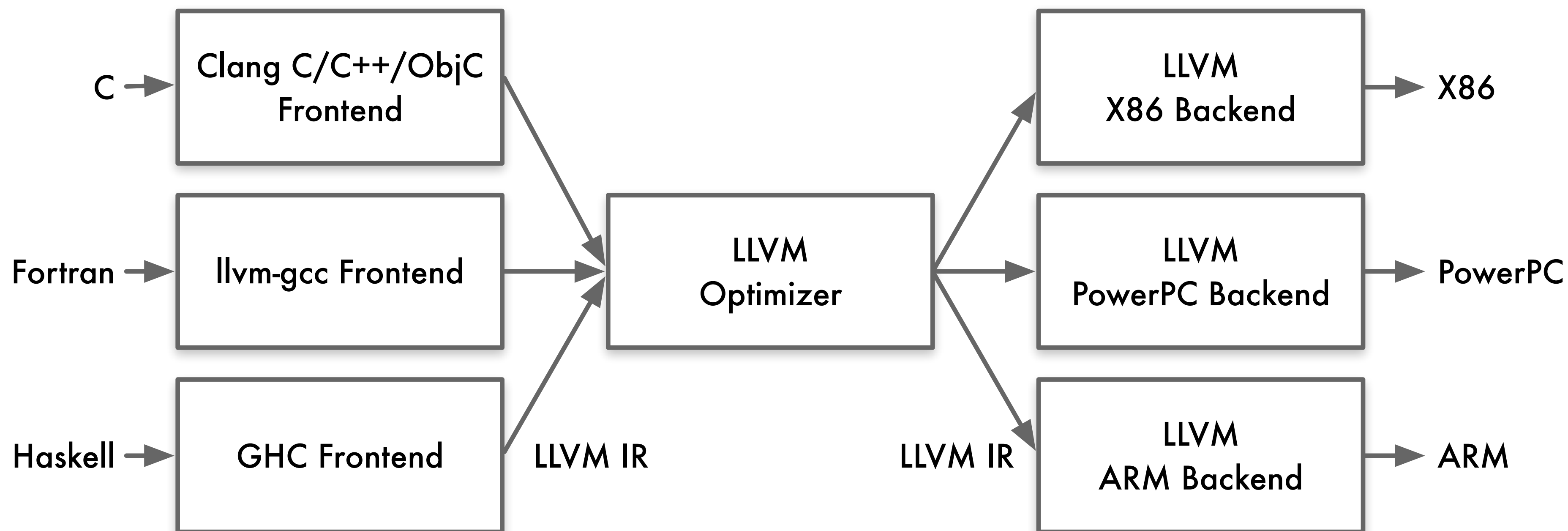
https://www.jetbrains.com/lp/devecosystem-2021/cpp/







LLVM Architecture



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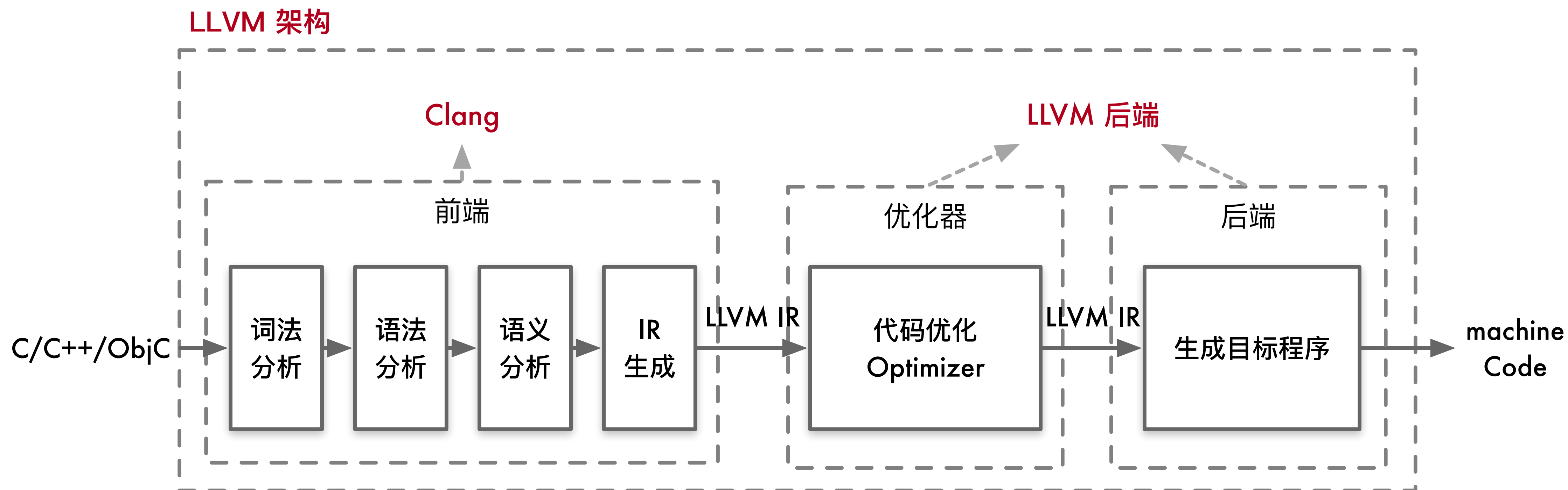
LLVM Architecture



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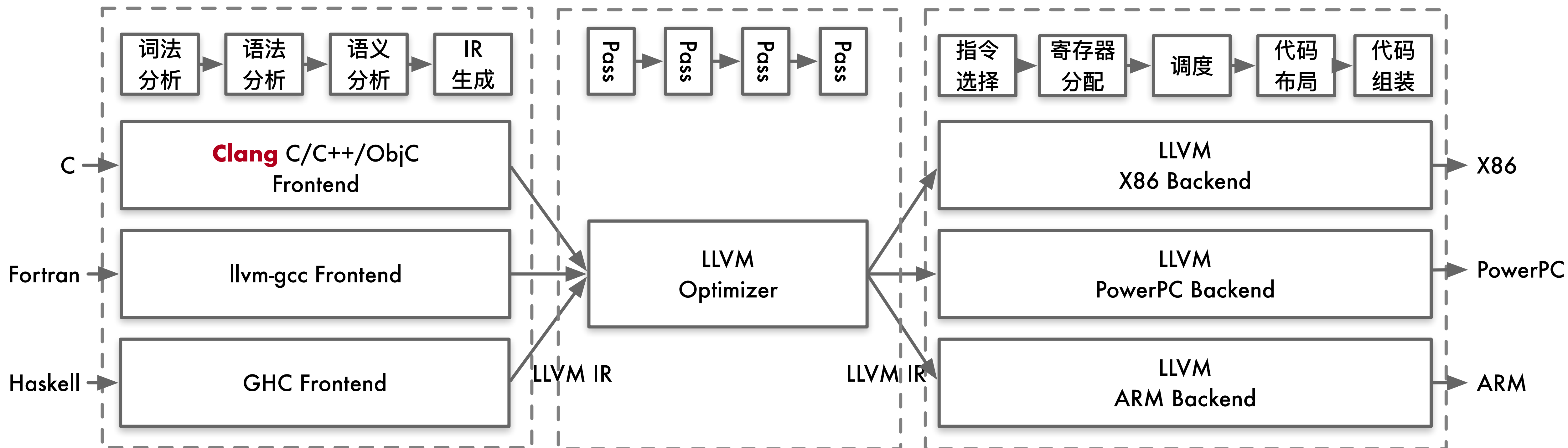
LLVM Architecture



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Pro's of GCC vs Clang

- GCC supports languages that Clang does not aim to, such as Java, Fortran, AN, Go, etc.
- GCC supports more targets than LLVM.
- GCC supports many language extensions.

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Pro's of Clang vs GCC

- The Clang ASTs and design(Modular design) are intended to be easily understandable by anyone.
- Clang is designed as an API from its inception, allowing it to be reused by source analysis tools, refactoring, IDEs as well as for code generation. GCC is built as a monolithic static compiler.
- Various GCC design decisions make it very difficult to reuse , Clang has none of these problems.
- Fast compilation speed. In Debug mode, OC compilation speed is three times faster than GCC. Small memory consumption.

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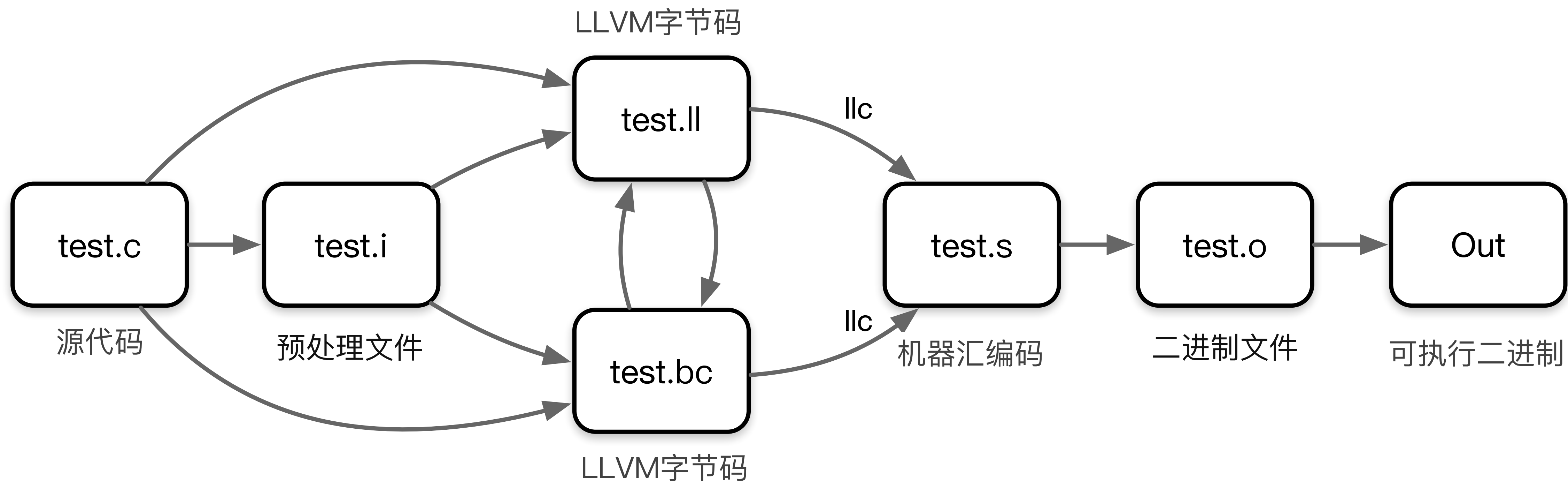
How to run...



How to Use LLVM

How to run…

- clang -E -c hello.c -o hello.i
- clang -emit-llvm hello.i -c -o hello.bc
- clang -emit-llvm hello.i -S -o hello.ll
- llvm-dis hello.bc -o hello.ll
- llvm-as hello.ll -o hello.bc

- clang -O2 -S hello.c -emit-llvm -o hello.ll

- llc hello.ll -o hello.s
- clang hello.s -o hello

How to run…

- clang -ccc-print-phases hello.c
- clang -Xclang -ast-dump -c hello.c

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THANK YOU

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