SIMATIC AX

INFORMATION TECHNOLOGY (IT)

- Standardization
- Libraries
- Unit Testing
- Debugging
- Continuous Integration
- Git Versioning

OPERATIONAL TECHNOLOGY (OT)

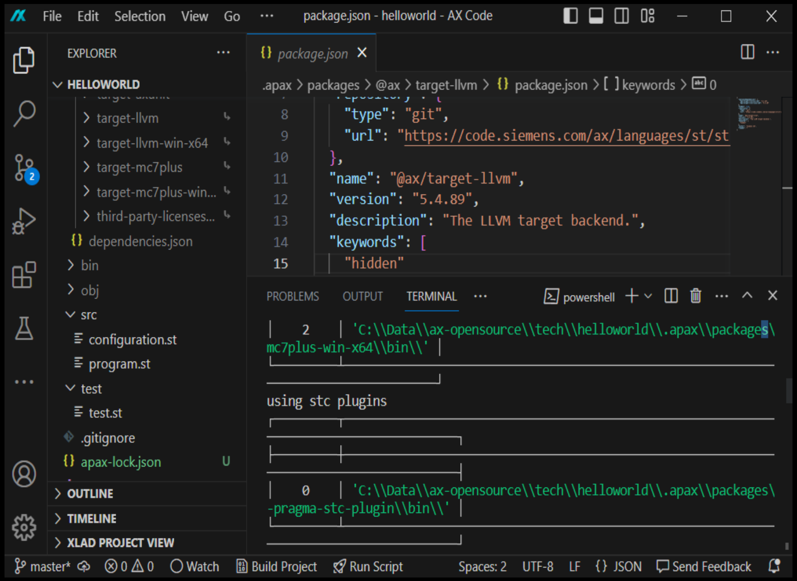
- Commissioning
- Industrial Standards e.g. IEC 61131-3
- Safety
- Industrial Communication
- Variant Management

BRINGING IT & OT CLOSER TOGETHER

What is SIMATIC AX

SIMATIC AX: Automation at the speed of software development

Based on Visual Studio Code, SIMATIC AX offers state-of-the-art IT tools in a lean development environment for programming and maintaining SIMATIC PLCs.



```
    "type": "git",
    "url": "https://code.siemens.com/ax/languages/st/st
  },
  "name": "@ax/target-llvm",
  "version": "5.4.89",
  "description": "The LLVM target backend.",
  "keywords": [
    "hidden"
```

```
│    2    │ 'C:\\Data\\ax-opensource\\tech\\helloworld\\.apax\\packages\
mc7plus-win-x64\\bin\\' │

using stc plugins

│    0    │ 'C:\\Data\\ax-opensource\\tech\\helloworld\\.apax\\packages\
-pragma-stc-plugin\\bin\\' │
```

SIEMENS

Question: How many steps does customers take to put an elephant in the refrigerator?

Human Language 😒 OT Engineer

- Open the door
- Put in the elephant [Complex task]
- Close the door

ST(Structured Text) Language

- Language nature
- Limited expressiveness
- Domain focus

LLVM 😊 IT Engineer

- Support complex feature operations of ST
- Form a kind of “runtime” libraries

SIEMENS

从 LLVM 的发展历史看未来趋势

中科院软件所PLCT实验室技术总监 邱吉

报告人简介

- PLCT 实验室 @ 中国科学院软件研究所（ISCAS）智能软件研究中心（ISRC）(2019-)：专注编译器、运行时和模拟器技术实现，推动所有开源软件将 RISC-V 接纳为 Tier-1 支持
- RISC-V International个人会员(2019-), RISC-V ambassador (2023-)
- HelloLLVM开源社区主席 (2023-)
- 博士毕业于中科院计算所微处理器研究中心龙芯团队，研究方向软硬件协同设计和优化
- 16年处理器设计(MIPS/ARM)和体系结构的软硬件适配优化经验 (MIPS/Loongson/ARM/RISC-V)

PLCT Lab 的定位和使命

程序语言与编译技术实验室（PLCT Lab）致力于成为编译技术领域的开源领导者，推进开源工具链及运行时系统等软件基础设施的技术革新，具备主导开发和维护重要基础设施的技术及管理能力。与此同时，致力于培养一万名编译领域尖端人才，推动先进编译技术在国内的普及和发展。

PLCT Lab:

ISCAS 中国科学院软件研究所 Institute of Software Chinese Academy of Sciences

Focus on Open-Source Software, promote RISC-V eco-system

- RISC-V community
  - Development partner and training partner of the RISC-V International(RVI)
  - Running RISC-V Lab, providing CI infra for all open-source communities and developers. *(Collaborate with RVI)
- LLVM
  - Standard extension support for Z*inx, Zc*, Zmmul, scalar cryptography, Zihintpause, Zbpbo
- GCC
  - Standard extension support for B/K/P/ZC*/CMO/Zmmul/Z*inx
- QEMU
  - Standard extension support for Virt memory(Svpbmt/Svinval/Svnapot), Z*inx, Scalar crypto, Zmmul, Zicond, Svadu， Zc*
- Spike
  - Standard extension support for Z*inx, CMO, Smstateen, Sscofpmf, Zc*
- OpenCV
  - Implement Wide Universal Intrinsics based on the RISC-V vector extension
- Maintaining RISC-V Backend in many more open-source projects
  - Chromium V8, Node.js, SpiderMonkey, OpenJDK, etc.
- Our contribution communities are including but not limited to the following list

- 在GNU工具链和Clang/LLVM工具链中主导或参与实现对多个扩展指令集架构支持，并将代码贡献到上游社区

扩展指令集	gcc支持情况	binutils支持情况	代码仓库源	提交者
B（位操作）	支持	支持	上游	Sifive/ISCAS/Ventana
K（密码处理）	支持	支持	上游	ISCAS
P（Packed SIMD）	支持	支持	ISCAS（等待spec更新)	ISCAS
Zc*（压缩指令）	支持	支持	OpenHW	ISCAS/Embecosm
CMO（缓存管理）	支持	支持	上游	ISCAS
Zmmul（乘法运算）	支持	支持	上游	ISCAS
Z*inx（整数寄存器浮点操作）	支持	支持	上游	ISCAS/Sifive
V(向量扩展)	支持	支持	上游	RIVAI/Sifive/Intel/ISCAS
Zfh/min(半精度浮点)	支持	支持	上游	Sifve/ISCAS
Zbf（Bf16浮点）	支持	支持	ISCAS（等待spec批准)	ISCAS

GNU 工具链 for RISC-V

扩展指令集	支持情况	代码仓库源	提交者
K（密码处理）	支持	上游	ISCAS/rivosinc
P（SIMD）	支持	ISCAS（等待spec更新)	Andes/ISCAS
ZC*（压缩指令）	支持	上游	ISCAS/Sifive/igalia
Zmmul（乘法运算）	支持	上游	ISCAS
Z*inx（整数寄存器浮点操作）	支持	上游	ISCAS/Sifive
V(向量扩展)	支持	上游	Sifive/codeplay /rivosinc/Alibaba /igalia/iscas/streamcomputin g
Zfh/min(半精度浮点)	支持	上游	Sifive/ISCAS/igalia
XCV*(corev厂商扩展)	支持	上游 & OpenHW	ISCAS/Sifive

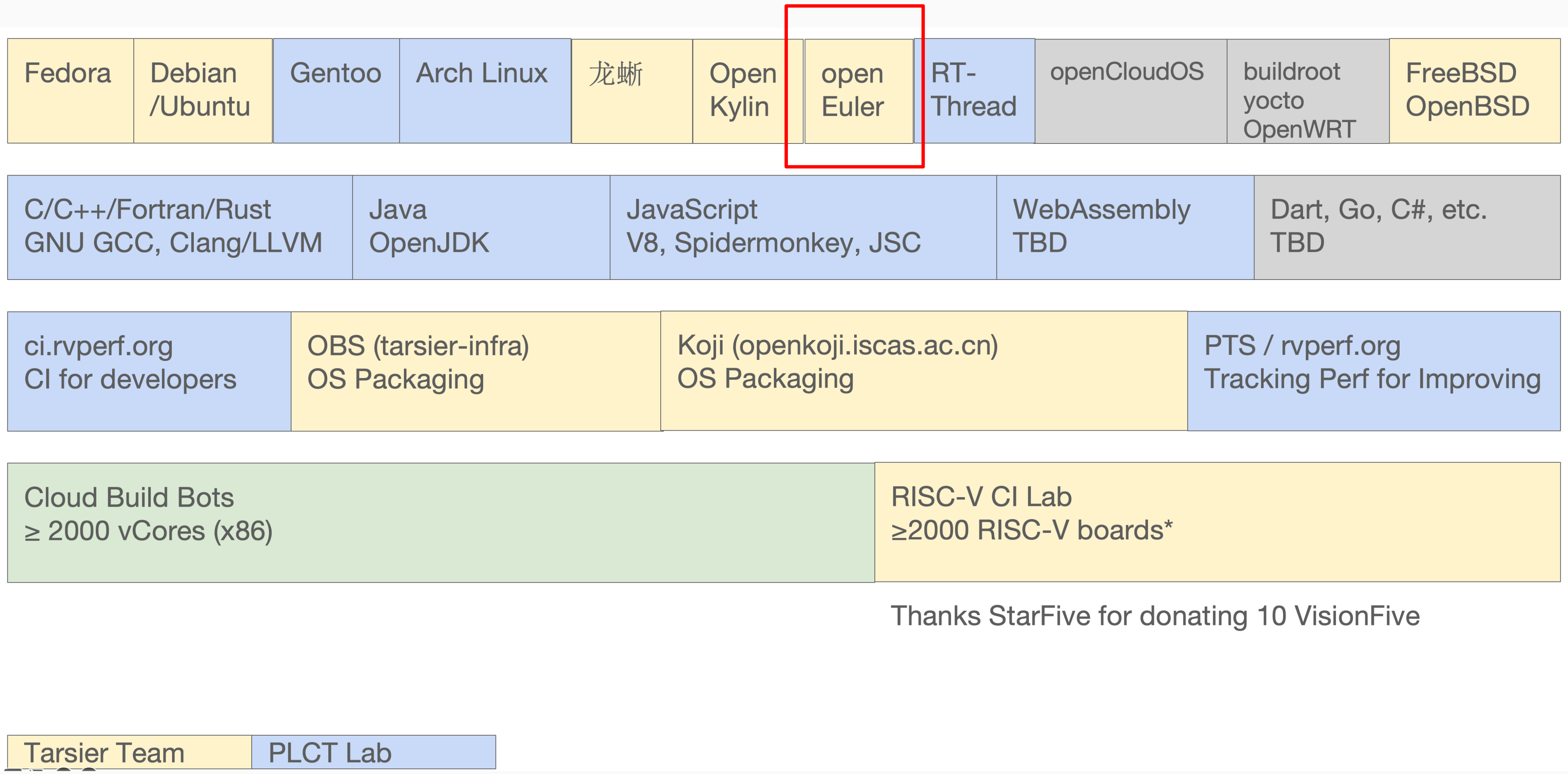
LLVM for RISC-V

LLVM 14/15的RV代码贡献量占全球 20%

中国科学院软件研究所
Institute of Software Chinese Academy of Sciences

Tarsier Project

- Make RISC-V a tier-1 support for FOSS community
- Ensure the equivalence of functionality and performance of major Linux Distro on RISC-V platforms (counterpart to X64 and ARM64)
- Strategies to 2025
  - promoting RISC-V to tier-1 target for mainstream Linux Distro (done)
  - fully support Desktop/Office user scenarios demands
  - provide full stack support for HPC fields


Fedora
Debian /Ubuntu
Gentoo
Arch Linux
龙蜥
Open Kylin
open Euler
RT-Thread
openCloudOS
buildroot yocto OpenWRT
FreeBSD OpenBSD
C/C++/Fortran/Rust GNU GCC, Clang/LLVM
Java OpenJDK
JavaScript V8, Spidermonkey, JSC
WebAssembly TBD
Dart, Go, C#, etc. TBD
ci.rvperf.org CI for developers
OBS (tarsier-infra) OS Packaging
Koji (openkoji.iscas.ac.cn) OS Packaging
PTS / rvperf.org Tracking Perf for Improving
Cloud Build Bots ≥ 2000 vCores (x86)
RISC-V CI Lab ≥2000 RISC-V boards*
Tarsier Team
PLCT Lab

Thanks StarFive for donating 10 VisionFive

LLVM 平行宇宙计划

openEuler Compiler SIG

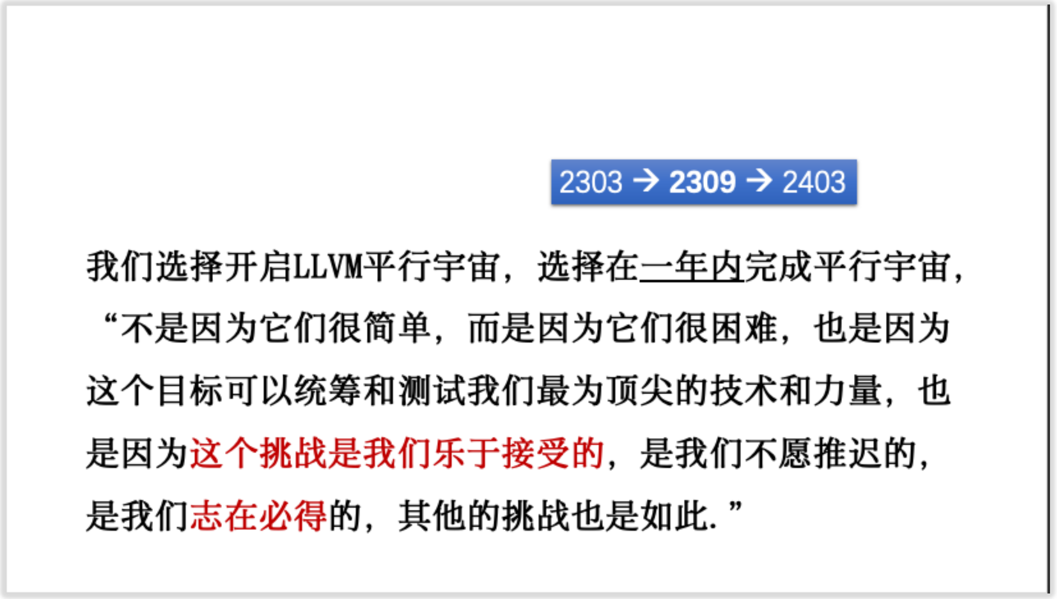
先进，再前进：RISC-V SIG 联合 Compiler SIG

推进 LLVM 平行宇宙计划

中科院软件所 吴伟

wuwei2016@iscas.ac.cn

2023-04-07 @杭州



2303 → **2309** → 2403

我们选择开启LLVM平行宇宙，选择在一年内完成平行宇宙，“不是因为它们很简单，而是因为它们很困难，也是因为这个目标可以统筹和测试我们最为顶尖的技术和力量，也是因为这个挑战是我们乐于接受的，是我们不愿推迟的，是我们志在必得的，其他的挑战也是如此. ”

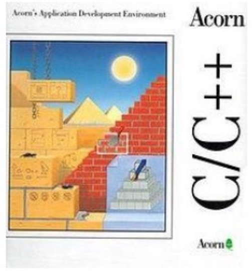
https://www.bilibili.com/video/BV1b84y1X7cD/

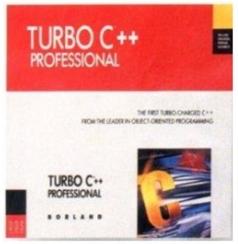
在用LLVM替换GCC道路上的付出和收获–周嘉诚

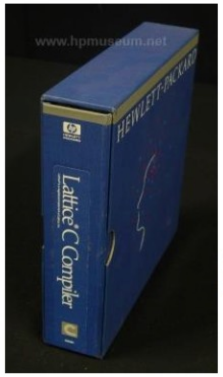
回到今天的主题：

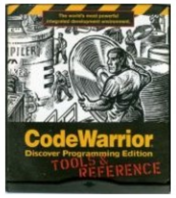
从 LLVM 的发展历史看未来趋势

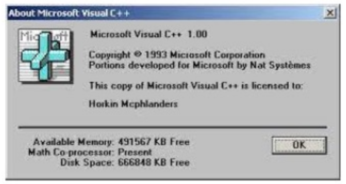
C Compilers leading into the early 90s










About Microsoft Visual C++

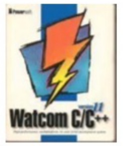
Microsoft Visual C++ 1.00

Copyright © 1993 Microsoft Corporation
Portions developed for Microsoft by Nat Systèmes

This copy of Microsoft Visual C++ is licensed to:

Horkin Mcphlanders

```
  Available Memory: 491567 KB Free
Math Co-processor: Present
       Disk Space: 666848 KB Free
```

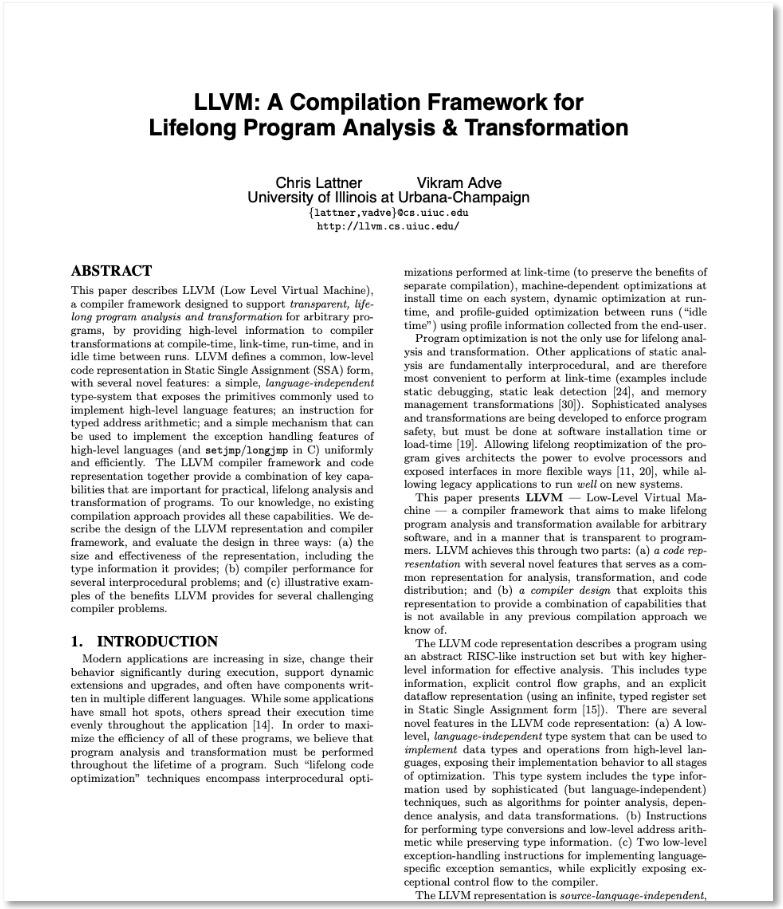


⇒ Expensive, not very compatible, inconsistencies abound

- … and didn't share any code

Also: Came in boxes, with printed manuals, often on floppy disks!

https://www.youtube.com/watch?v=4HgShra-KnY https://llvm.org/pubs/2004-01-30-CGO-LLVM.pdf



LLVM: A Compilation Framework for Lifelong Program Analysis & Transformation

Chris Lattner Vikram Adve
University of Illinois at Urbana-Champaign
{lattner,vadve}@cs.uiuc.edu
http://llvm.cs.uiuc.edu/

ABSTRACT

This paper describes LLVM (Low Level Virtual Machine), a compiler framework designed to support *transparent, lifelong program analysis and transformation* for arbitrary programs, by providing high-level information to compiler transformations at compile-time, link-time, run-time, and in idle time between runs. LLVM defines a common, low-level code representation in Static Single Assignment (SSA) form, with several novel features: a simple, *language-independent* type-system that exposes the primitives commonly used to implement high-level language features; an instruction for typed address arithmetic; and a simple mechanism that can be used to implement the exception handling features of high-level languages (and `setjmp/longjmp` in C) uniformly and efficiently. The LLVM compiler framework and code representation together provide a combination of key capabilities that are important for practical, lifelong analysis and transformation of programs. To our knowledge, no existing compilation approach provides all these capabilities. We describe the design of the LLVM representation and compiler framework, and evaluate the design in three ways: (a) the size and effectiveness of the representation, including the type information it provides; (b) compiler performance for several interprocedural problems; and (c) illustrative examples of the benefits LLVM provides for several challenging compiler problems.

1. INTRODUCTION

Modern applications are increasing in size, change their behavior significantly during execution, support dynamic extensions and upgrades, and often have components written in multiple different languages. While some applications have small hot spots, others spread their execution time evenly throughout the application [14]. In order to maximize the efficiency of all of these programs, we believe that program analysis and transformation must be performed throughout the lifetime of a program. Such "lifelong code optimization" techniques encompass interprocedural optimizations performed at link-time (to preserve the benefits of separate compilation), machine-dependent optimizations at install time on each system, dynamic optimization at runtime, and profile-guided optimization between runs ("idle time") using profile information collected from the end-user.

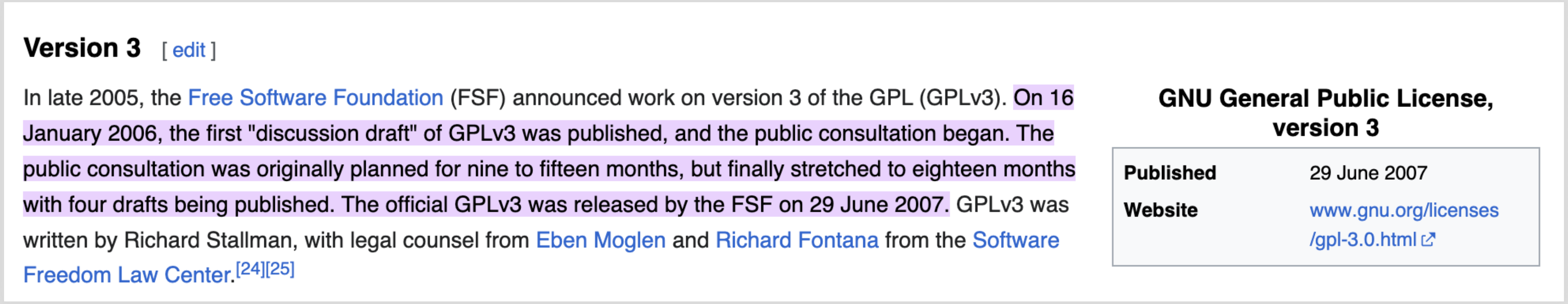
Program optimization is not the only use for lifelong analysis and transformation. Other applications of static analysis are fundamentally interprocedural, and are therefore most convenient to perform at link-time (examples include static debugging, static leak detection [24], and memory management transformations [30]). Sophisticated analyses and transformations are being developed to enforce program safety, but must be done at software installation time or load-time [19]. Allowing lifelong reoptimization of the program gives architects the power to evolve processors and exposed interfaces in more flexible ways [11, 20], while allowing legacy applications to run *well* on new systems.

This paper presents **LLVM** — Low-Level Virtual Machine — a compiler framework that aims to make lifelong program analysis and transformation available for arbitrary software, and in a manner that is transparent to programmers. LLVM achieves this through two parts: (a) *a code representation* with several novel features that serves as a common representation for analysis, transformation, and code distribution; and (b) *a compiler design* that exploits this representation to provide a combination of capabilities that is not available in any previous compilation approach we know of.

The LLVM code representation describes a program using an abstract RISC-like instruction set but with key higher-level information for effective analysis. This includes type information, explicit control flow graphs, and an explicit dataflow representation (using an infinite, typed register set in Static Single Assignment form [15]). There are several novel features in the LLVM code representation: (a) A low-level, *language-independent* type system that can be used to *implement* data types and operations from high-level languages, exposing their implementation behavior to all stages of optimization. This type system includes the type information used by sophisticated (but language-independent) techniques, such as algorithms for pointer analysis, dependence analysis, and data transformations. (b) Instructions for performing type conversions and low-level address arithmetic while preserving type information. (c) Two low-level exception-handling instructions for implementing language-specific exception semantics, while explicitly exposing exceptional control flow to the compiler.

The LLVM representation is *source-language-independent*,

GCC (>v4.2) → GPLv3+



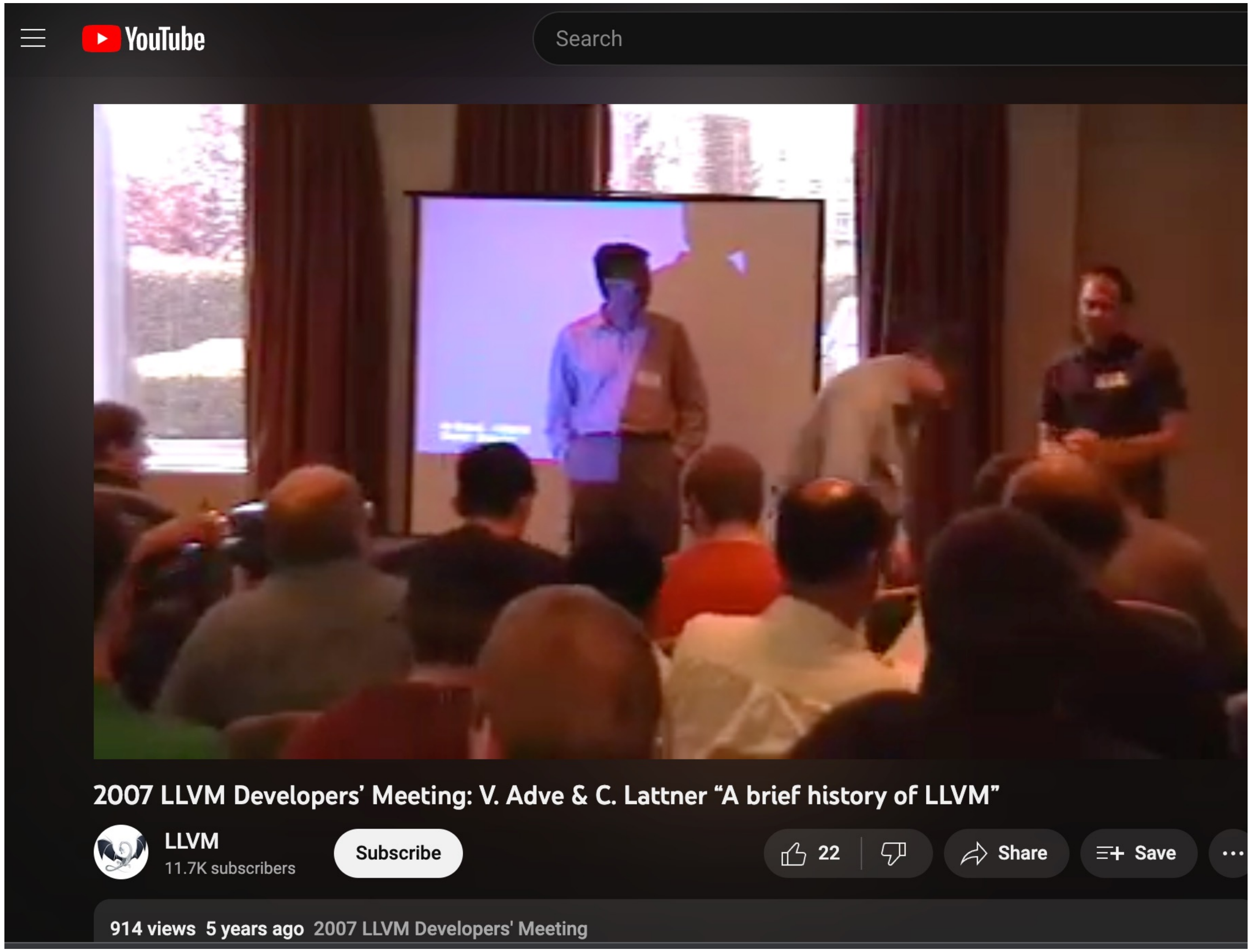
Version 3 [edit]

In late 2005, the Free Software Foundation (FSF) announced work on version 3 of the GPL (GPLv3). On 16 January 2006, the first "discussion draft" of GPLv3 was published, and the public consultation began. The public consultation was originally planned for nine to fifteen months, but finally stretched to eighteen months with four drafts being published. The official GPLv3 was released by the FSF on 29 June 2007. GPLv3 was written by Richard Stallman, with legal counsel from Eben Moglen and Richard Fontana from the Software Freedom Law Center.[24][25]

GNU General Public License, version 3

Published	29 June 2007
Website	www.gnu.org/licenses/gpl-3.0.html

Apple

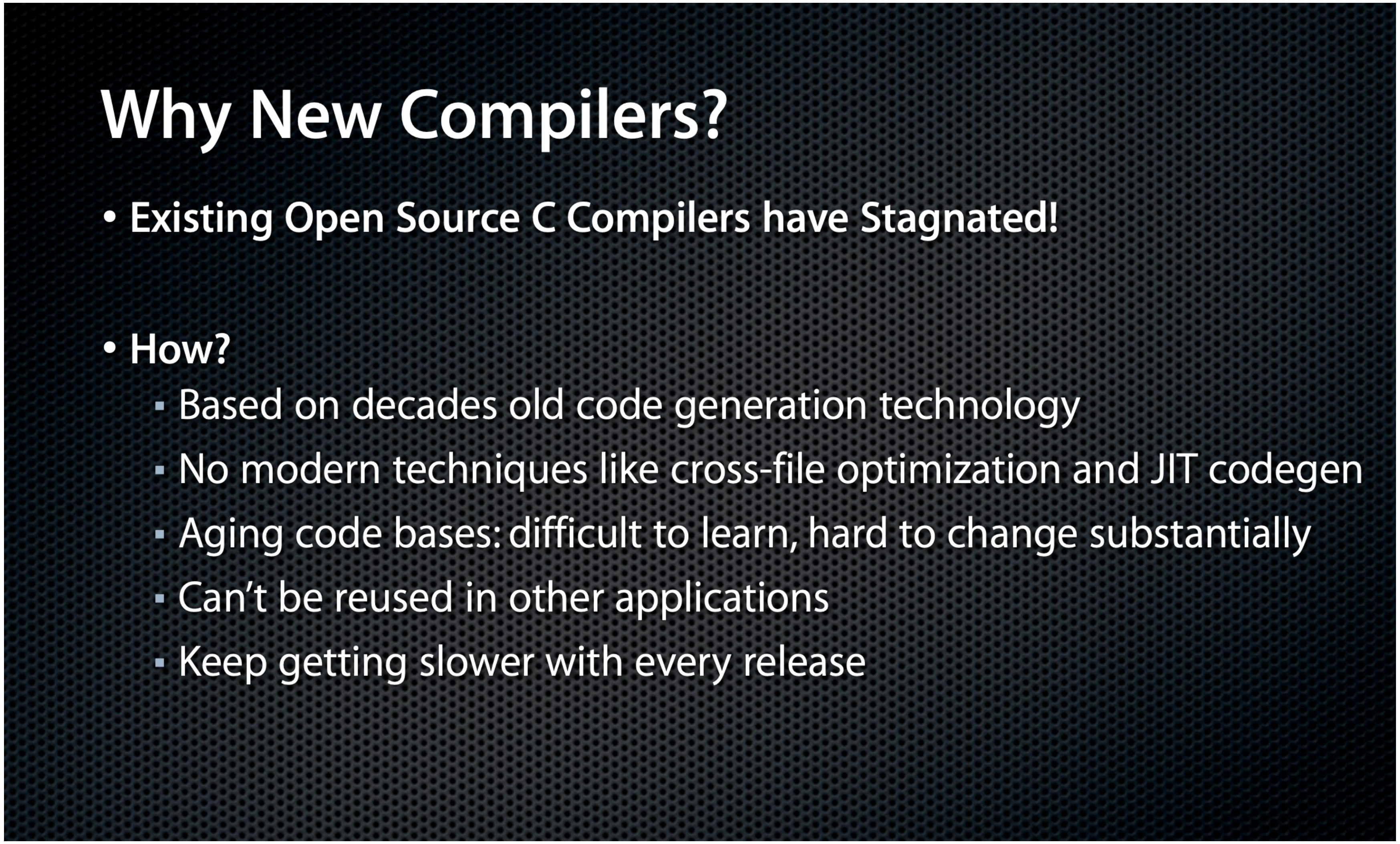


2007 LLVM Developers' Meeting: V. Adve & C. Lattner "A brief history of LLVM"

LLVM
11.7K subscribers

914 views 5 years ago 2007 LLVM Developers' Meeting

https://www.youtube.com/watch?v=FNtmemyeEHY



Why New Compilers?

- Existing Open Source C Compilers have Stagnated!

- How?
  - Based on decades old code generation technology
  - No modern techniques like cross-file optimization and JIT codegen
  - Aging code bases: difficult to learn, hard to change substantially
  - Can’t be reused in other applications
  - Keep getting slower with every release

https://indico.cern.ch/event/34666/contributions/813563/attachments/683844/939341/LLVM.pdf https://ws.engr.illinois.edu/sitemanager/getfile.asp?id=523

CS @ ILLINOIS

click!

MAGAZINE 2013, VOLUME II

LLVM: The World's Compiler

Developed by CS @ ILLINOIS

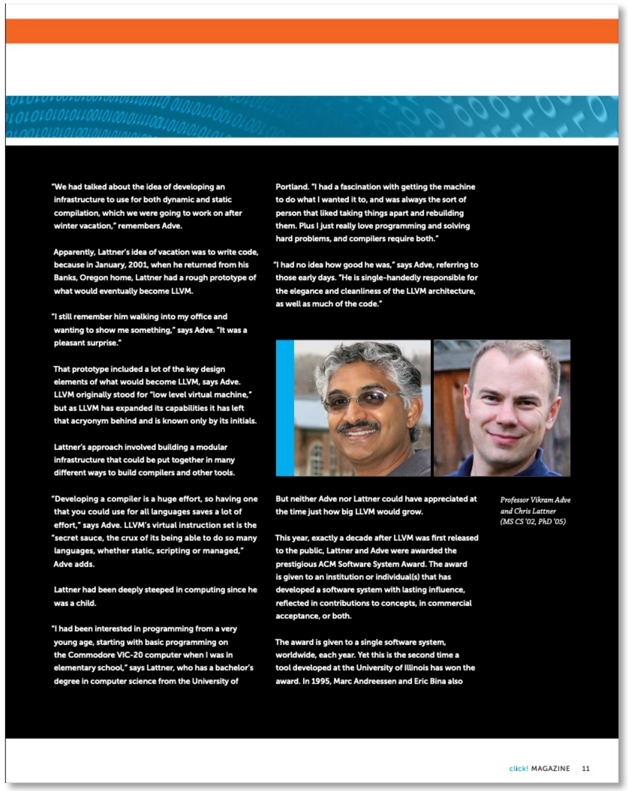
ALSO IN THIS ISSUE:

Department of Computer Science

LLVM, Starting Out as a Research Project, Hits the Big Time

BY DEB ARONSON

Vikram Adve, professor of computer science, and his first-year graduate student, Chris Lattner, made a plan for their next project. It was not a big plan, just the kind of plan a professor and a graduate student make all the time in the course of their research.


"We had talked about the idea of developing an infrastructure to use for both dynamic and static compilation, which we were going to work on after winter vacation," remembers Adve.

Apparently, Lattner's idea of vacation was to write code, because in January, 2001, when he returned from his Banks, Oregon home, Lattner had a rough prototype of what would eventually become LLVM.

"I still remember him walking into my office and wanting to show me something," says Adve. "It was a pleasant surprise."

That prototype included a lot of the key design elements of what would become LLVM, says Adve. LLVM originally stood for "low level virtual machine," but as LLVM has expanded its capabilities it has left that acryonym behind and is known only by its initials.

Lattner's approach involved building a modular infrastructure that could be put together in many different ways to build compilers and other tools.

"Developing a compiler is a huge effort, so having one that you could use for all languages saves a lot of effort," says Adve. LLVM's virtual instruction set is the "secret sauce, the crux of its being able to do so many languages, whether static, scripting or managed," Adve adds.

Lattner had been deeply steeped in computing since he was a child.

"I had been interested in programming from a very young age, starting with basic programming on the Commodore VIC-20 computer when I was in elementary school," says Lattner, who has a bachelor's degree in computer science from the University of Portland. "I had a fascination with getting the machine to do what I wanted it to, and was always the sort of person that liked taking things apart and rebuilding them. Plus I just really love programming and solving hard problems, and compilers require both."

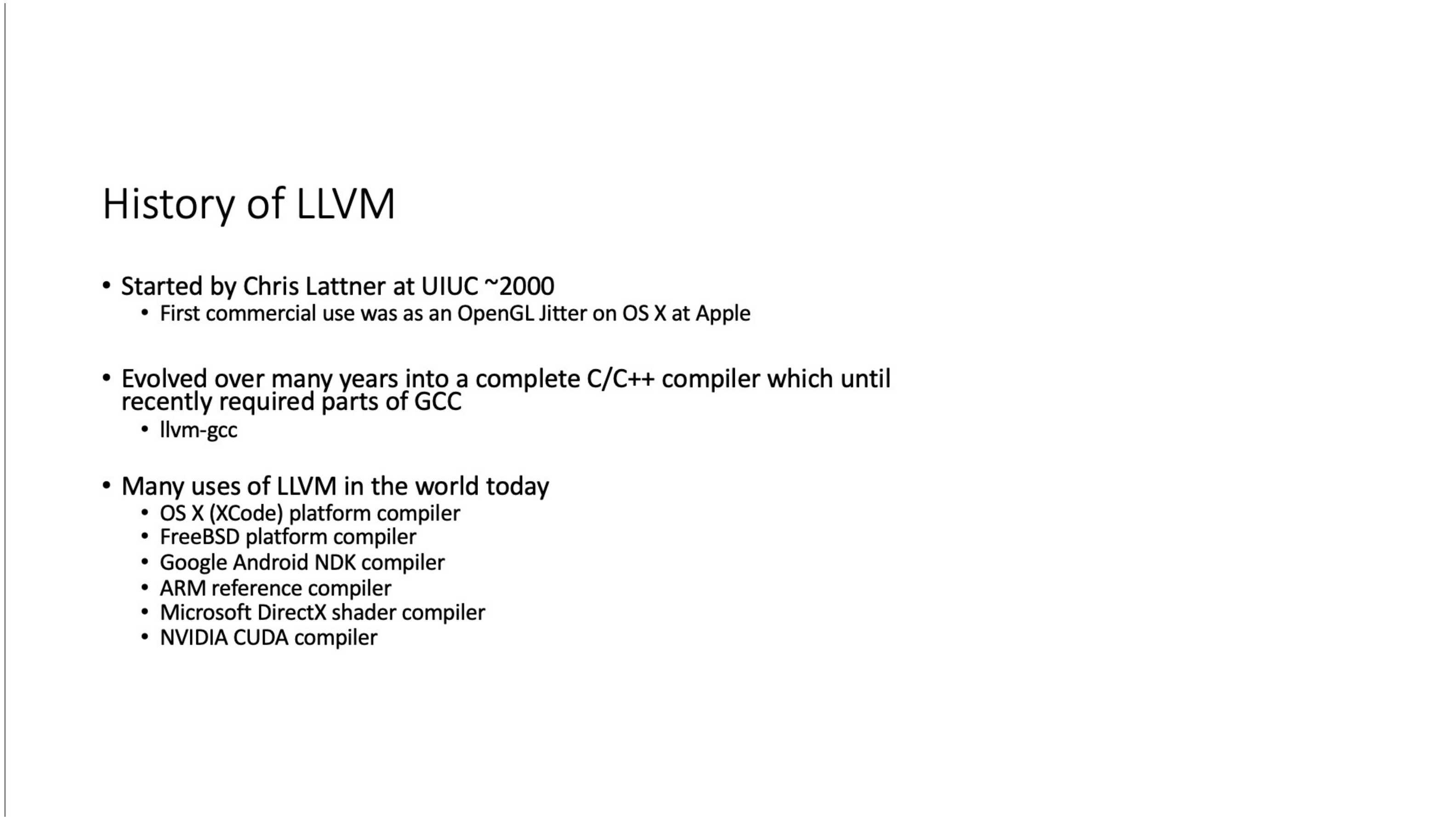
"I had no idea how good he was," says Adve, referring to those early days. "He is single-handedly responsible for the elegance and cleanliness of the LLVM architecture, as well as much of the code."

Professor Vikram Adve and Chris Lattner (MS CS '02, PhD '05)

But neither Adve nor Lattner could have appreciated at the time just how big LLVM would grow.

This year, exactly a decade after LLVM was first released to the public, Lattner and Adve were awarded the prestigious ACM Software System Award. The award is given to an institution or individual(s) that has developed a software system with lasting influence, reflected in contributions to concepts, in commercial acceptance, or both.

The award is given to a single software system, worldwide, each year. Yet this is the second time a tool developed at the University of Illinois has won the award. In 1995, Marc Andreessen and Eric Bina also https://www.inf.ed.ac.uk/teaching/courses/ct/18-19/slides/llvm-1-intro.pdf



History of LLVM

- Started by Chris Lattner at UIUC ~2000
  - First commercial use was as an OpenGL Jitter on OS X at Apple
- Evolved over many years into a complete C/C++ compiler which until recently required parts of GCC
  - llvm-gcc
- Many uses of LLVM in the world today
  - OS X (XCode) platform compiler
  - FreeBSD platform compiler
  - Google Android NDK compiler
  - ARM reference compiler
  - Microsoft DirectX shader compiler
  - NVIDIA CUDA compiler

The Golden Age of Compilers

in an era of Hardware/Software co-design

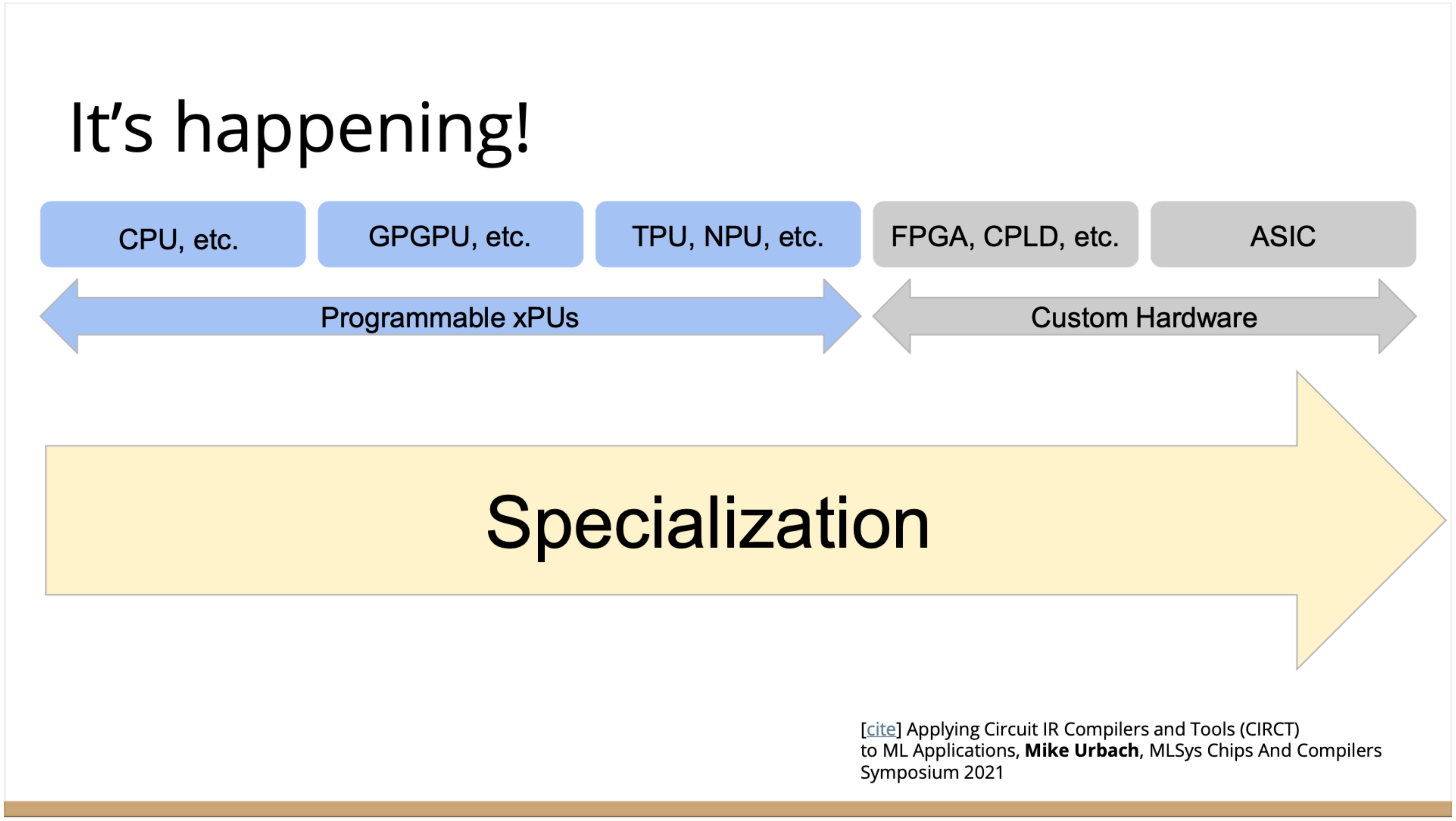
International Conference on
Architectural Support for Programming Languages and
Operating Systems (ASPLOS 2021)

Chris Lattner
SiFive Inc

April 19, 2021

YouTube Video Recording

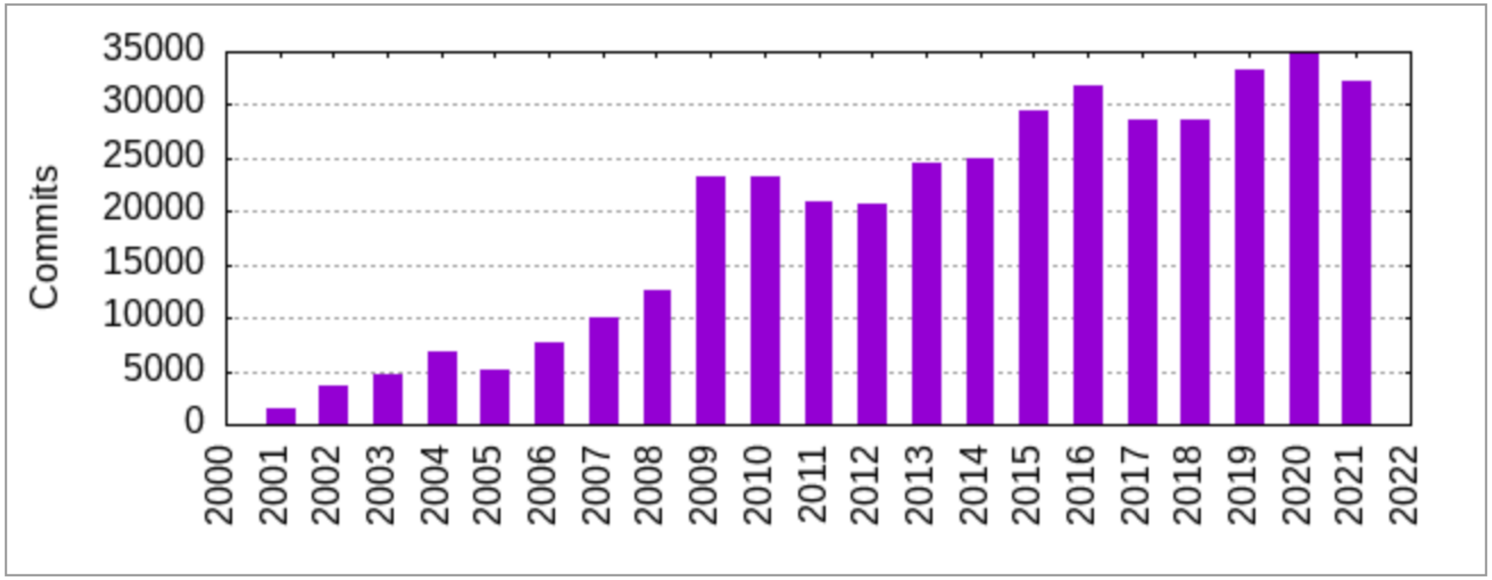
https://canvas.eee.uci.edu/courses/43849/files/17973444/

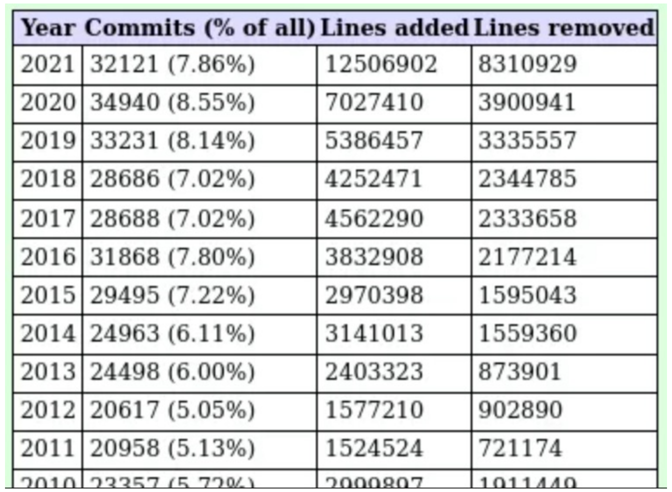


It’s happening!

[cite] Applying Circuit IR Compilers and Tools (CIRCT) to ML Applications, **Mike Urbach**, MLSys Chips And Compilers Symposium 2021

https://www.youtube.com/watch?v=4HgShra-KnY





Year	Commits (% of all)	Lines added	Lines removed
2021	32121 (7.86%)	12506902	8310929
2020	34940 (8.55%)	7027410	3900941
2019	33231 (8.14%)	5386457	3335557
2018	28686 (7.02%)	4252471	2344785
2017	28688 (7.02%)	4562290	2333658
2016	31868 (7.80%)	3832908	2177214
2015	29495 (7.22%)	2970398	1595043
2014	24963 (6.11%)	3141013	1559360
2013	24498 (6.00%)	2403323	873901
2012	20617 (5.05%)	1577210	902890
2011	20958 (5.13%)	1524524	721174
2010	23357 (5.72%)	2999897	1911449

https://www.phoronix.com/news/LLVM-Record-Growth-2021

三个基本观测（假设）

1. 摩尔定律是有极限的，而算力需求没有极限

顶端优势⬇️ | 设计成本⬇️ | 制造成本⬇️ | 设计工具⬆️ | 软件栈⬆️

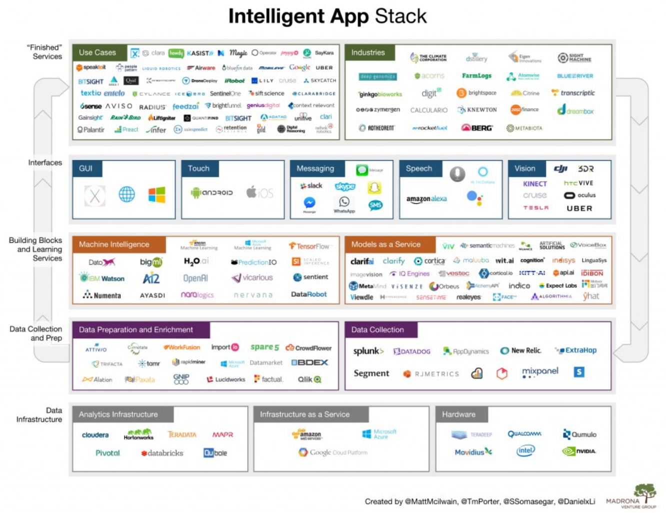
领域专属架构（DSA）时代早已来临

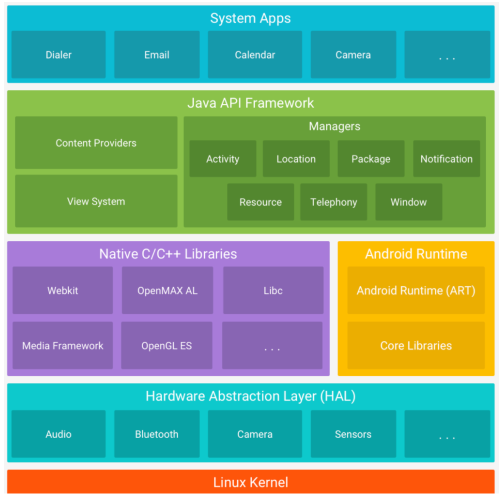
三个基本观测（假设）

1. 摩尔定律是有极限的，而算力需求没有极限
2. 软件系统的复杂度是超线性增长的

拥抱开源软件：软件吞噬世界，开源软件吞噬软件

是什么让开源不可避免？



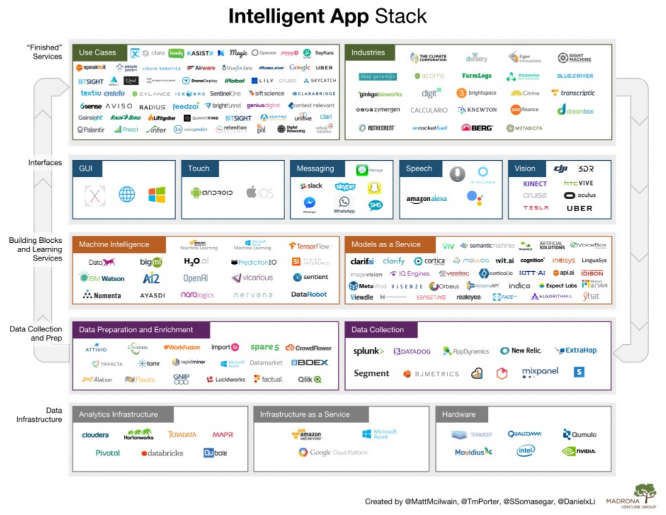


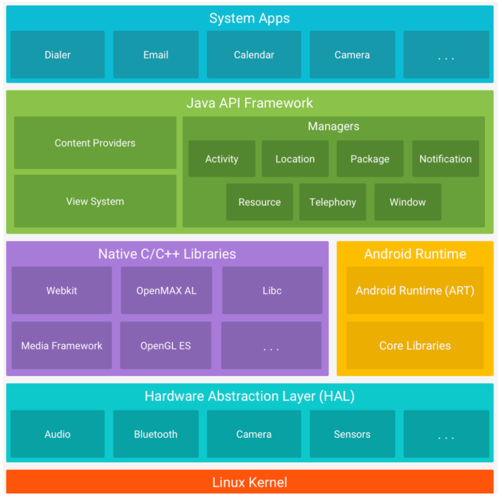
1 https://developer.ibm.com/blogs/how-open-source-software-is-eating-the-world/
2 https://algorithmia.com/blog/wp-content/uploads/2016/06/Screen-Shot-2016-06-08-at-3.35.53-PM-1024x730.png
3 https://developer.android.com/guide/platform

拥抱开源软件：软件吞噬世界，开源软件吞噬软件

是什么让开源不可避免？

软件系统的规模





1 https://developer.ibm.com/blogs/how-open-source-software-is-eating-the-world/
2 https://algorithmia.com/blog/wp-content/uploads/2016/06/Screen-Shot-2016-06-08-at-3.35.53-PM-1024x730.pnc
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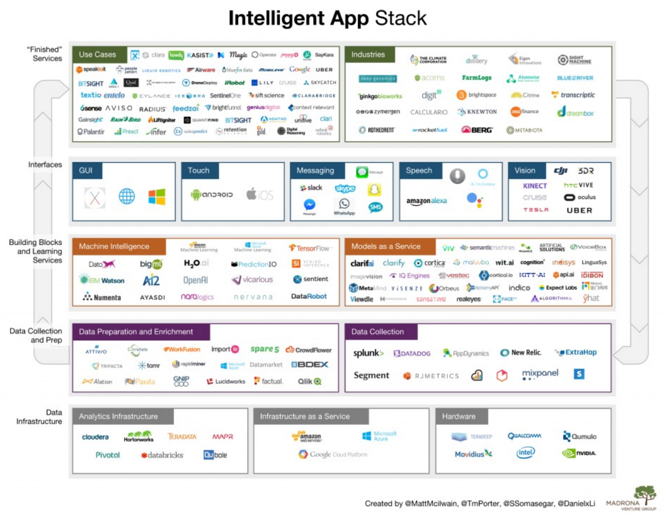
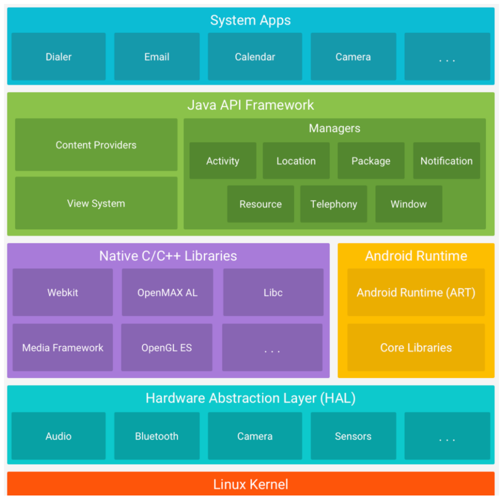
软件系统的规模的扩张速度





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三个基本观测（假设）

1. 摩尔定律是有极限的，而算力需求没有极限
2. 软件系统的复杂度是超线性增长的

“已经没有任何公司或主权可以独立维护所有的软件栈”

“软件吞噬世界，开源软件吞噬软件”

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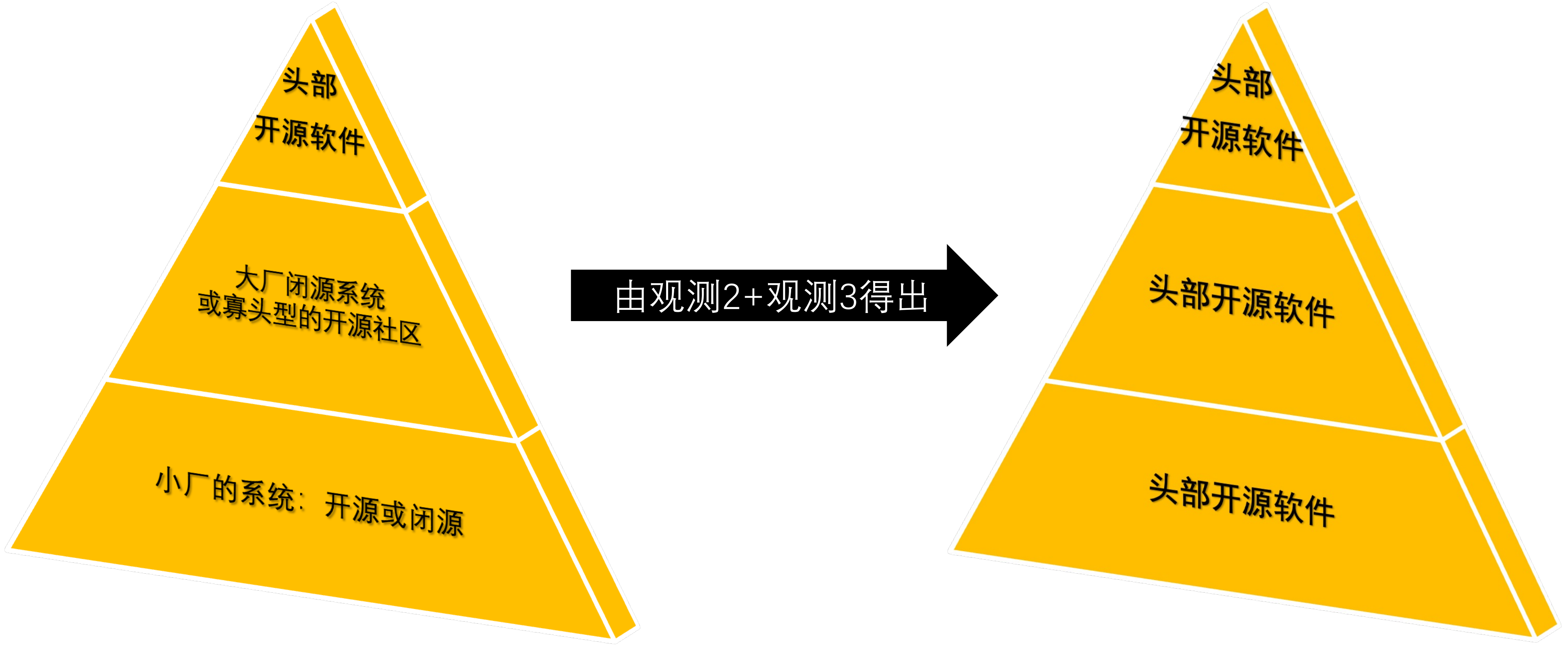
一个细分领域只有头部一两个开源社区最终活跃，而

不被上游维护的代码就像是活在ICU里：费用昂贵、死亡率高

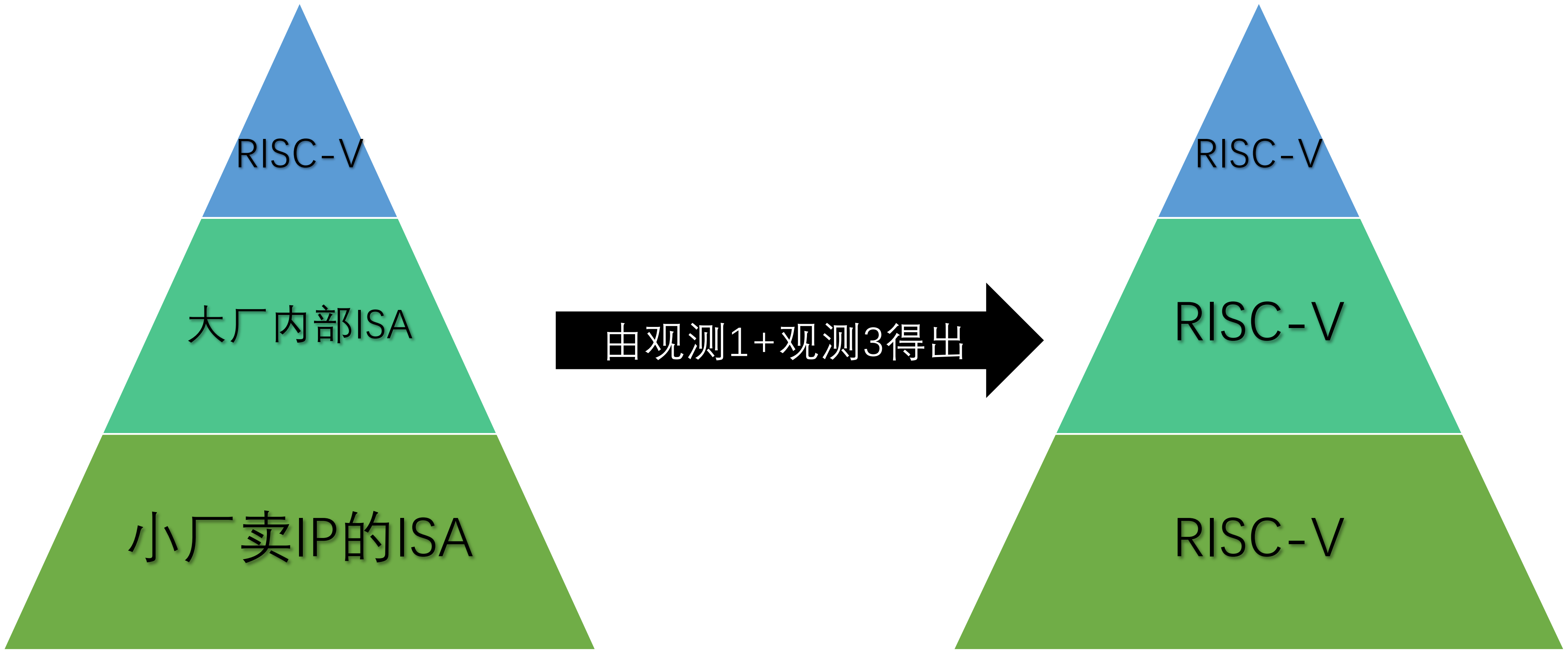
推论1: 开源软件吞噬一切

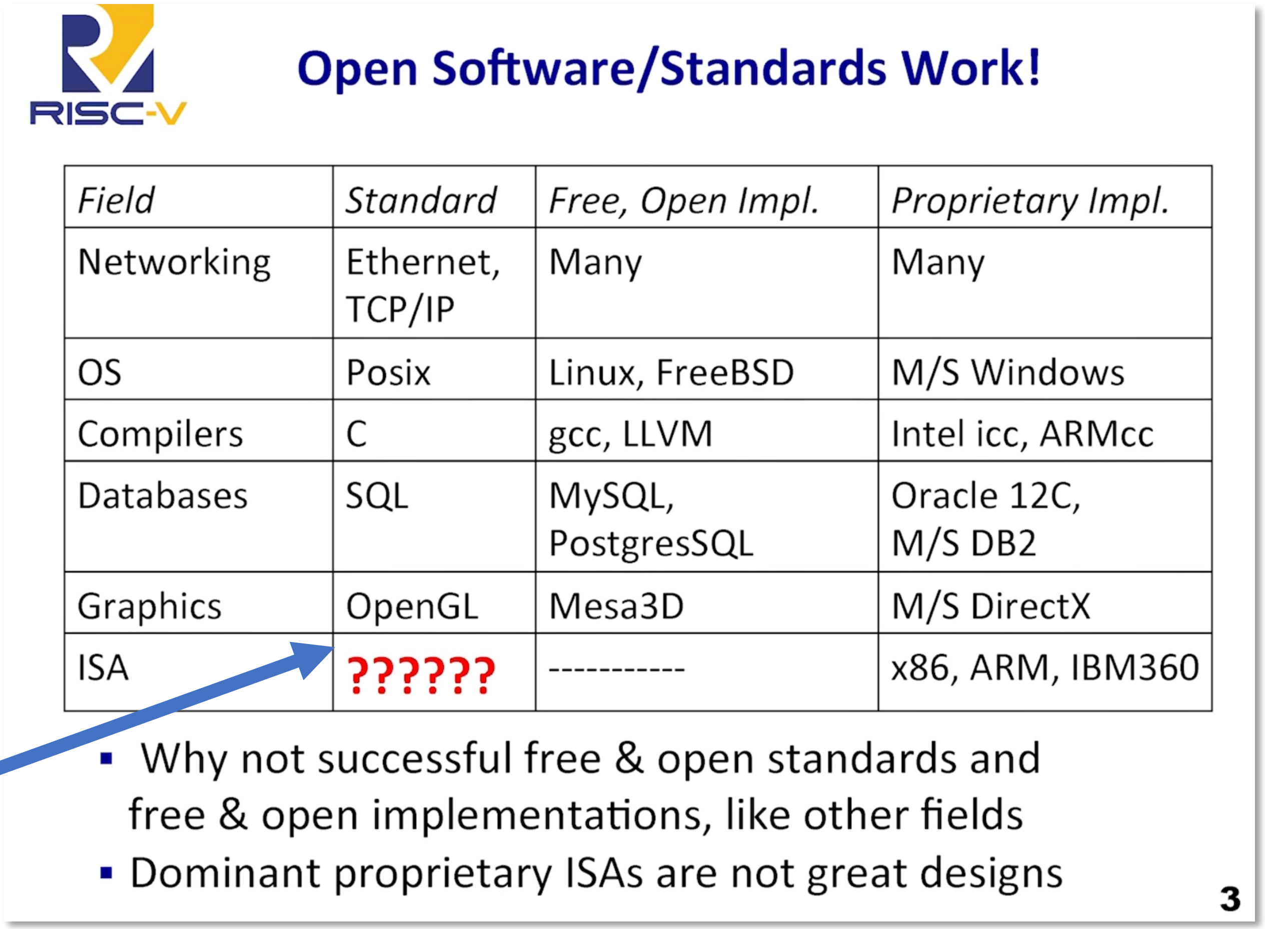
在开源生态基础上构筑商业软件已是常态



推论2: 必然会出现自由开放的指令集

还在做自研指令集的同行们，是时候重新考虑下职业规划了！





Open Software/Standards Work!

Field	*Standard*	*Free, Open Impl.*	*Proprietary Impl.*
Networking	Ethernet, TCP/IP	Many	Many
OS	Posix	Linux, FreeBSD	M/S Windows
Compilers	C	gcc, LLVM	Intel icc, ARMcc
Databases	SQL	MySQL, PostgresSQL	Oracle 12C, M/S DB2
Graphics	OpenGL	Mesa3D	M/S DirectX
ISA	??????	-----------	x86, ARM, IBM360

- Why not successful free & open standards and free & open implementations, like other fields
- Dominant proprietary ISAs are not great designs

3

RISC-V

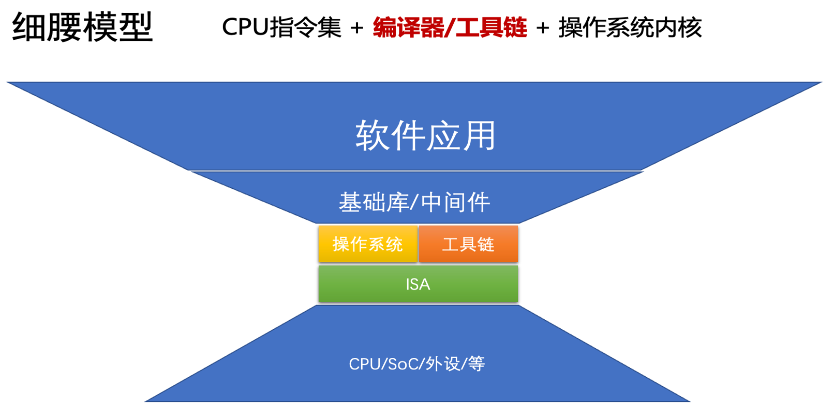
"Instruction Sets Want to be Free" Krste Asanovic, Professor of UCB

推论2.1：自由开放的指令集可能只有1个会存活下来

- 领域专属架构（DSA）将无处不在
    - 不可避免地会有许多（免费和开放的）指令集。
- 开源软件吞噬一切
    - 每个细分领域只有1-2开源社区能够长期生存。
    - 只有极少数指令集会被开源社区长期高质量地维护，

      尤其是需要JIT支持的软件/系统。

预测未来：



- 硬件：开放指令集、DSA
- 软件：开源操作系统、开源工具链
- 需要更多的开发者参与到开源社区

为此我们做了些什么

新人入门和人才培养：PLCT在做，超用心

已经初步建立起覆盖编译原理、GCC、LLVM、操作系统、链接器、虚拟机、调试器、模拟器等所有基础工具软件的教学课程，为国内的学生和技术人员自学讨论出一份力。

- 循序渐进，学习开发一个RISC-V上的操作系统 https://www.bilibili.com/video/BV1Q5411w7z5/
- 徒手写一个RISC-V编译器 https://www.bilibili.com/video/BV1gY4y1E7Ue/
- 从零开始实现链接器 https://www.bilibili.com/video/BV1D8411j7fo/
- 从零开始的RISC-V模拟器开发 https://www.bilibili.com/video/BV12Z4y1c74c/
- 零基础入门 RISC-V GCC 编译器开发 https://www.bilibili.com/video/BV1kU4y137Ba/
- 淦！移植个V8不可能这么难！ https://www.bilibili.com/video/BV1hp4y1t7Mx/
- 每周技术分享： https://space.bilibili.com/296494084

2024年PLCT实验室的斐波那契式路线图即将开启

https://github.com/plctlab/PLCT-Weekly/blob/master/PLCT-Roadmap-2023.md

- 2023年未完成的及新增的FLAGS自动滚入2023年许愿池
- 欢迎加入自己感兴趣的开源社区一起贡献！

PLCT实验室在RISC-V领域的贡献及合作机会

- **基础软件领域的「国家队」**，为国内企业和RISC-V社区提供「**开源软件公共品**」
  - 编译器领域：Clang/LLVM、GNU工具链、MLIR、gollvm、方舟编译器、
  - 虚拟机领域：V8、Spidermonkey、NodeJS、OpenJDK/RV32G、LuaJIT、DynamoRIO
  - 模拟器领域：QEMU、Spike、gem5、Sparta
  - 应用领域：OpenCV、HPC Software Stack、LibreOffice、Firefox、Chromium

2024，更“大”的期待：世界超算500强

“We predict that by the end of 2025, there will be more than one RISC-V architecture machine in the world’s top 500 supercomputers.”

-- Wei Wu, Director of PLCT Lab, ISCAS

谢谢各位

RISC-V是一个遍地机会的新世界，欢迎加入 ☺

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qjivy
中国大陆

扫一扫上面的二维码图案，加我为朋友。