Software Engineering

Lecture 1
Introduction, principles & architecture

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MPRI

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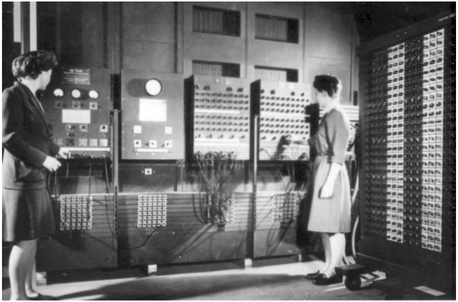
Introduction

Prehistory



Main control panel of ENIAC (1946)

First Turing-complete computers

- Huge and expensive (30 tons, 167m^2, 150kW, 6M$)
- One-off, built for specific purposes (military computations)
- Focus on making hardware reliable

Industrialization

IBM System/360 (1964)

Mainframe computers

- Wide range of applications, scientific to commercial
- Separation of architecture and implementation
- Software complexity rises

Birth of software engineering

1960' software crisis

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1968 NATO conference on Software Engineering

> *Need for software manufacturers to be based on the types of theoretical foundations and practical disciplines that are traditional in the established branches of engineering.*

More history

Hacker clubs, free software

Open-source software, Internet

Web services, cloud computing

Software Engineering

Approach : social sciences $\leftrightarrow$ computer science $\leftrightarrow$ hacking

- Principles behing good software products and processes.
- Methodologies that apply and promote those principles.
- Tools to implement and help follow methodologies.

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Activities	implem.
Products	code

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Activities	spec.	design	implem.	validation	evolution
Products	doc	doc	code	tests	history

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Correctness is meaningless without a spec!

- Always specify precisely what you need, and no more
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"There are two ways to write error-free programs; only the third works." (Alan J. Perlis)

- Be paranoid, seek to detect anomalies early on
- Design precise tests, run them after each change

Change

Anticipation of change

Code *will* evolve

- Bugs will have to be fixed
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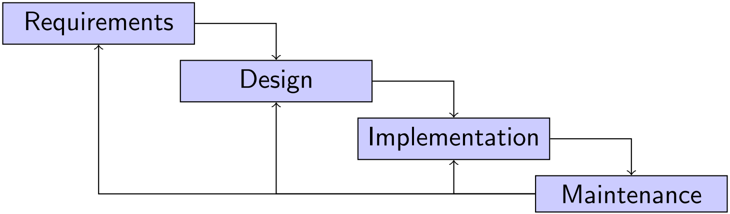
Brace yourself

- Actively work to identify potential changes
- Design code so that change and re-use is facilitated
- Use tools that help to keep track of change
- Organize work around upcoming changes

Software development processes

Waterfall model



Software development processes

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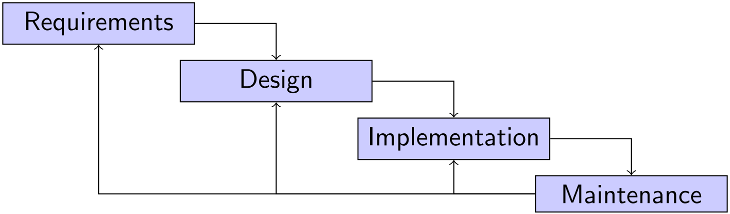

- Prevalent at least until 70'
- Probably inspired from other engineering fields
- DoD guidelines for military software: mandatory until 88
  remains reference after that (until recently?)

Incrementality

Proceed step by step to get early feedback and adjust.

- Start by implementing a subset of features.
- Start with functional correctness only.

Incremental development model

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Incremental development model

Pros/cons

- ⊕ Early feedback. Opportunity to fix requirements and design. May be necessary if requirements are not initially clear.
- ⊕ Good for the morale of developers and clients!
- ⊖ Requires refactoring to maintain good structure.
- ⊖ Hard to keep track of change in large projects.

The Linux kernel

The main invention in Linux is . . .

The Linux kernel

The main invention in Linux is its development model.

- Wide distribution and invitation to contribute,
  thanks to personal computers and the internet.
- Active integration of patches and frequent releases,
  initially by hand, then with dedicated tools.
- Pre-requisites in the code:
  - precise documentation
  - extensibility through modules for drivers, file system, etc.

E. S. Raymond, *The Cathedral and the Bazaar*, O'Reilly, 1999.

More development models

Collaborative software development

Incremental with collaboration and involvement of the public

Main model for open-source software:

- More testers $\rightarrow$ earlier bug reports
- Massive peer review (?)

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Agile software development

Incremental process + focus on collaboration & self-organization

`http://agilemanifesto.org/principles.html`

Various methodologies (XP, SCRUM...)

Modularity & Abstraction

Modularity

Segment project in modules with clearly defined interfaces.

Goals

- Develop, test independently, facilitate re-use.

Criteria

- High cohesion, low coupling
- Facilitate change.

David Parnas, *On the Criteria To Be Used in Decomposing Systems into Modules*, Communications of the ACM, 1972.

Abstraction

Design

- Do not specify implementation *details*.

Abstraction

Design

- Do not specify implementation *details*.
- Details are things that can easily change:
  max. waiting time, password length, graphics library, etc.

Code

- Code in a high-level language, far from the machine.
- Code for correctness first, then optimize if needed.
  "Premature optimization is the root of all evil." – Knuth
- Don't hardcode:
  no magic numbers, any constant should be justified.

Modularity + Abstraction

Segment project in modules with clearly defined interfaces.

Maximize information hiding in interfaces:

- Minimize coupling.
- Plan for evolution.

Language support

More or less constraining/helpful

- Modules and abstract types in ML-like languages
- Classes in object oriented programming
- Separate compilation units in other languages
- Procedures in *structured programming languages*!

Proof assistants

Concerns of computer-aided theorem proving

- Soundness: the whole point is to have trustworthy proofs!
- Usability: undo, notations, automation, efficiency, user extensions, etc.

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Edinburgh LCF (70's)

- Proof objects cannot be maintained for performance reasons
- Small trusted kernel provides sound manipulations of abstract datatype `theorem`
- Tactics and tacticals built on top of this sound kernel
- By-product: ML language and module system!

M. J. C. Gordon, *From LCF to HOL: a short history*, 2000.

Proof assistants

Concerns of computer-aided theorem proving

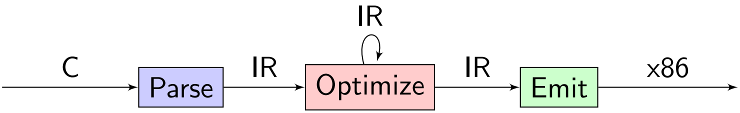
- Soundness: the whole point is to have trustworthy proofs!
- Usability: undo, notations, automation, efficiency, user extensions, etc.

Coq v7 (2000)

- Proof objects are maintained: relevant, non-local checks
- Isolated kernel: breaking dependency on undo-able objects
- (OCa)ML modules still used: abstraction ensures safety
- Kernel is purely functional, 1/3 of the code
- 2013, `v8.4pl2`: same design, impure kernel, 1/10 of the code

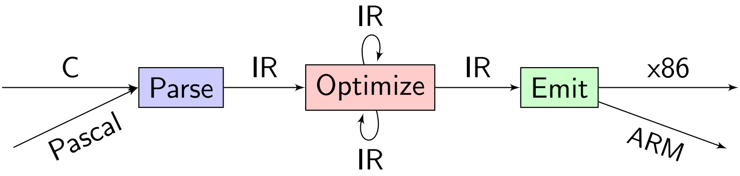
J-C. Filliâtre, *Design of a proof assistant: Coq version 7*, 2000.

Pipes and filters



- Parser generators are engineering pearls in themselves

Pipes and filters



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- Reason separately about individual “filters” (cf. CompCert)
- Easy extension with new front-ends, back-ends or optimizers?

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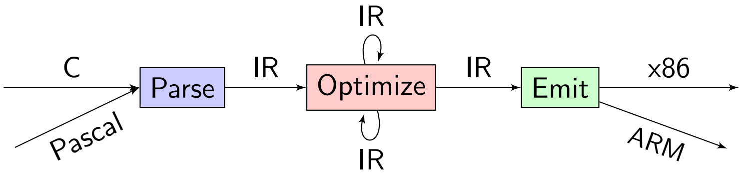

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- LLVM took this architecture seriously: truly decoupled phases, documented interfaces, ships as library, provides dynamic configuration tools
  ⇝ maximum re-use, huge community, lots of features

Chris Lattner, *The Architecture of Open Source Applications, volume I*, chapter 11: *LLVM*, 2012.

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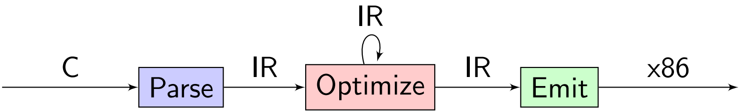

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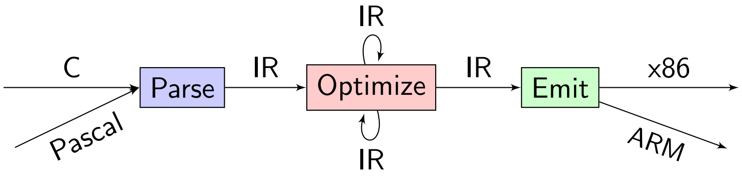

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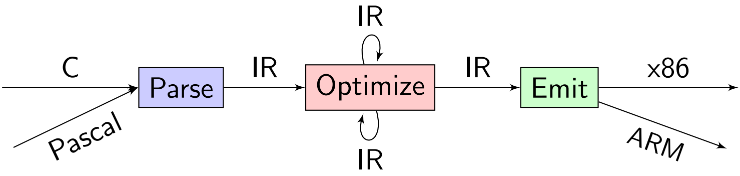

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That's all for now!

Today

We've seen the main principles, aka. the rules of the game:

- Rigor, Adaptability
- Modularity, Abstraction

Next

- Methods:
  - rigorous software development, notably through testing
  - software modelling to guide design
- Tools:
  - git, basic and advanced
  - during project, or on demand: documentation generators, debuggers, profilers...
- Experience through the project

References

- Frederick P. Brooks, *The Mythical Man-Month (20th anniversary edition)*, Addison-Wesley, Prentice Hall, 1995.
- Ian Sommerville, *Software Engineering (9th edition)*, Addison-Wesley, 2011.
- C. Ghezzi, M. Jazayeri, D. Mandrioli, *Fundamentals of Software Engineering*, Prentice Hall, 1991.
- A. Hunt, D. Thomas, *The Pragmatic Programmer*, Addison-Wesley, 2000.

. . . and many others cited in the slides.