

Software Engineering

Lecture 1

Introduction, principles & architecture

David Baelde

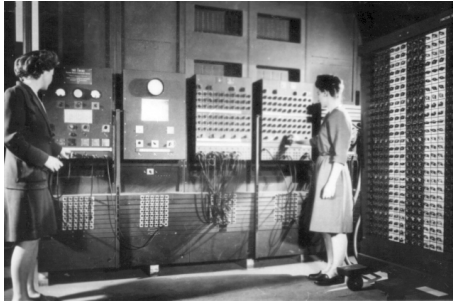
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MPRI

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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

- ▶ Spectacular failures: bugs, cost, overtime, cancellation

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The flaws in design and execution pervade especially the control program. [...] The product was late, it took more memory than planned, the costs were several times the estimate, and it did not perform very well until several releases after the first.

Birth of software engineering

1960' software crisis

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- ▶ Frederick P. Brooks about OS/360:

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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.*

Software Engineering

Problems

Complexity

Change

Goal

Correctness

Evolvability

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Approach

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

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Scope

Activities
Products

implem.
code

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Scope

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

Software Engineering

A lot of parameters:

- ▶ **Product**: is it critical? clearly defined? meant to evolve?
- ▶ **Economical aspects**: cost of machines and workers, competition and time pressure.

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Relies on common sense, computer science but also social sciences: psycho, ethno, experiments, etc.

No best approach, hence the need for critical thinking.

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There *will* be bugs!

- ▶ 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
- ▶ Requirements and the environment may change
- ▶ Components could be re-used in a (slightly different) context

Anticipation of change

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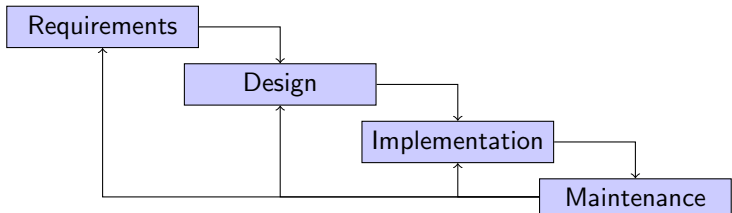
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Be ready

- ▶ 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

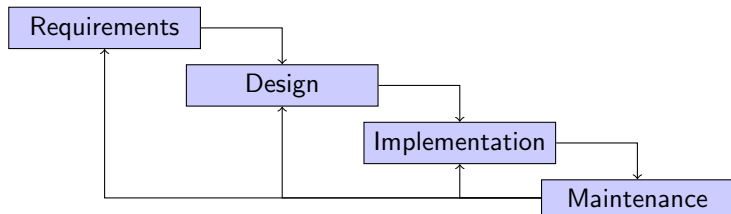
Software development processes

Waterfall model



Software development processes

Waterfall model



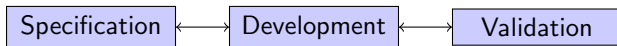
- ▶ Prevalent at least until 70'
- ▶ Probably inspired from other engineering fields
- ▶ DoD guidelines for military software: mandatory until 88
remains reference after that (until recently?)

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 → earlier bug reports
- ▶ Massive peer review (?)

More development models

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Agile software development

Incremental process + focus on collaboration & self-organization

<http://agilemanifesto.org/principles.html>

Various methodologies (XP, SCRUM...)

Modularity

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Segment project in **modules** with clearly defined **interfaces**.

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A slogan: High Cohesion, Low Coupling

- ▶ Maximize modularity:
parallelizability of the software process, chances of re-use
- ▶ Minimize interactions:
separately test, modify... understand, then integrate

Example (types of cohesion)

- ▶ Coincidental: no (good) reason
- ▶ Temporal: executed around the same time, e.g., init
- ▶ Functional: realize a task, e.g., convert file
- ▶ ...

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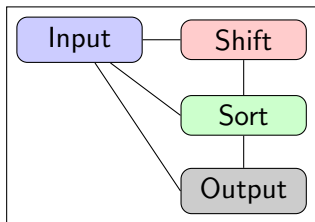
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What is a **good** modularization?

Modularity



Modules export arrays

No text in shifted/sorted arrays

A possible modularization for a *KWIC index generator*:

Input: lines of text

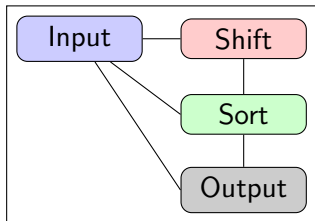
Output:

all permutations of those lines,
sorted alphabetically



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

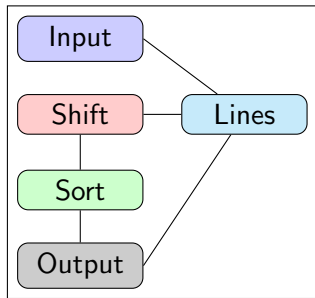
Modularity



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vs.

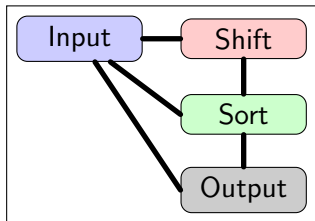


Modules export `get/set()`



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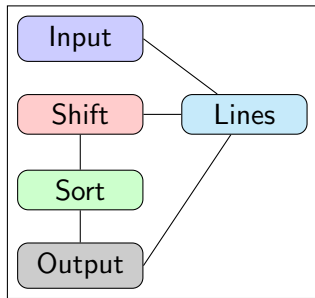
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- ▶ Functional: realize a task, e.g., convert file
- ▶ **Informational**: independent operations on same data, e.g., list

Modularization goes hand in hand with **information hiding**, aka ...

Abstraction

Ignoring details

Design

- ▶ Do not specify implementation details.
- ▶ Details are things that can easily change:
maximum waiting time, password length, 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!
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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, **v8.4p12**: same design, impure kernel, 1/10 of the code



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

Exercises

Intermediaries

Discuss the following Java function:

```
public void  
showDeadline(User u, Conference c) {  
    TimeZone tz = u.getLocation().getTimeZone();  
    Date d = c.getPaperDeadline();  
    ... // something involving only tz and d  
}
```

Pairs

(Based on 2013 MPRI project “Geriatric Terrorist Anarchy”)

Two C++ classes use pairs:

- ▶ The UI performs drawing using SFML's `Vector2f` class.
- ▶ The simulator moves characters around the world, also using 2D floating point coordinates.

Alternatives to discuss:

- ▶ Use `Vector2f` for the simulator code.
- ▶ Create a new class for pairs of floats.
- ▶ (Use `std::pair`.)

strtok

```
char *strtok(char *str, const char *delim);
```

The `strtok()` function parses a string into a sequence of tokens. On the first call to `strtok()` the string to be parsed should be specified in `str`. In each subsequent call that should parse the same string, `str` should be `NULL`.

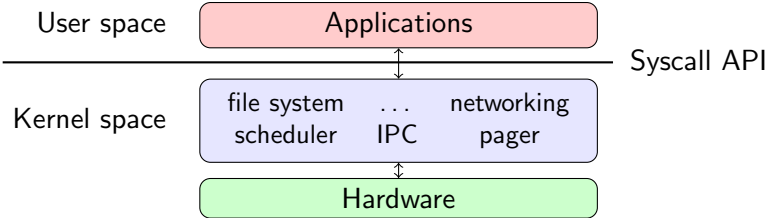
Discuss

- ▶ What's wrong with this spec?
- ▶ Give examples of when the function is unusable.
- ▶ Propose other designs, not necessarily in C.

Software architecture examples

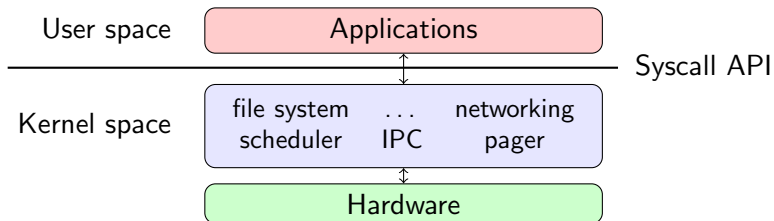
Layers

Monolithic kernel architecture



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Unix

Powerful **abstractions** such as processes and file descriptors.

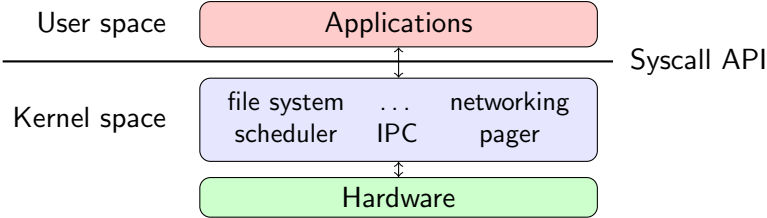
The success of Unix lies not so much in new inventions but rather in the full exploitation of a carefully selected set of fertile ideas.



N. Gordon, *Ghosts of the UNIX past: a historical search for design patterns*, LWN, 2010.

Layers

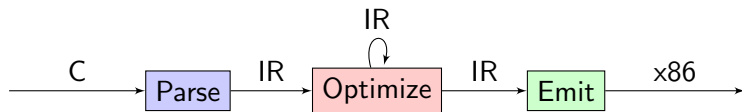
Monolithic kernel architecture



Exercise

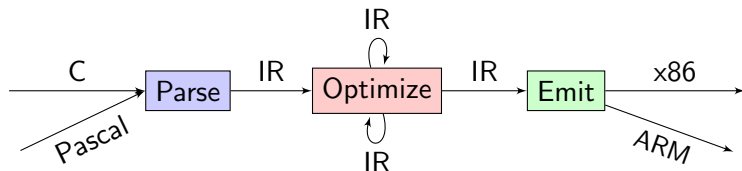
Does Unix follow a strict layered architecture?

Pipes and filters



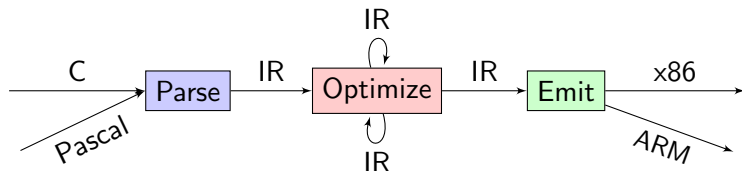
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Pipes and filters



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

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.