Software properties and software engineering paradigms

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Software engineering paradigms

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Software engineering

Set of recommendations on how to develop software

- Software is a result of software engineering

A discipline with a considerable body of knowledge and considerable importance in both academia and industry

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Paradigms & anomalies

Paradigm |ˈperəˌdīm|

noun

1 *technical* a typical example or pattern of something; a model: *there is a new paradigm for public art in this country*.

2 *linguistics* a set of linguistic items that form mutually exclusive choices in particular syntactic roles.

3 *science* coherent tradition of scientific research (by Kuhn).

4 *engineering* coherent tradition of engineering research and practice (by Rajlich).

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Paradigms & anomalies

Anomaly |əˈnäməlē|

noun (plural **anomalies**)

1 something that deviates from what is standard, normal, or expected.

2 *astronomy* the angular distance of a planet or satellite from its last perihelion or perigee.

3 an important fact that directly contradicts an old paradigm (by Kuhn).

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The beginnings of software

Software separated from the hardware in 1950s

- emerged as a distinct technology
- became independent product

Original programmers recruited from the ranks of electrical engineers and mathematicians

- used ad-hoc techniques from their former fields

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The change of the 70s

The birth of software engineering

The response to complexity

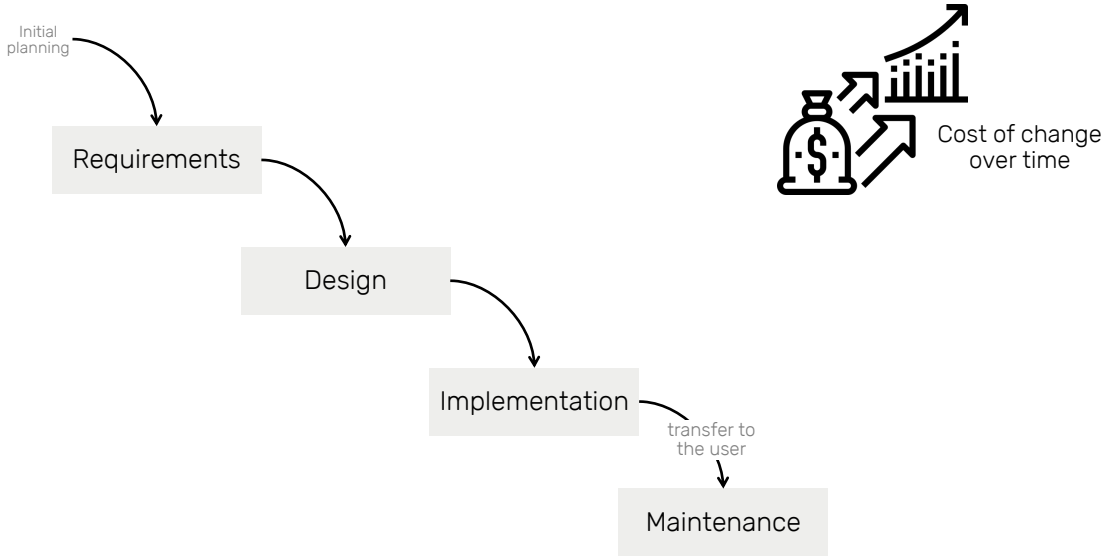
Anomaly

- Software complexity
- Previous (ad hoc) techniques did not scale up
- Brooks: "Mythical Man-Month"
  - Adding new people to a large software project that is already underway will slow it down instead of speed it up
  - Demands of the new operating system OS/360 taxed the limits of the programmers, project managers, and the resources of the IBM corporation

Paradigm change established discipline of software engineering (first ICSE)

- Software requires people with specialized skills
- Dealt with complexity of software
- Software design established as an important consideration
- Introduced the waterfall metaphor

The waterfall model



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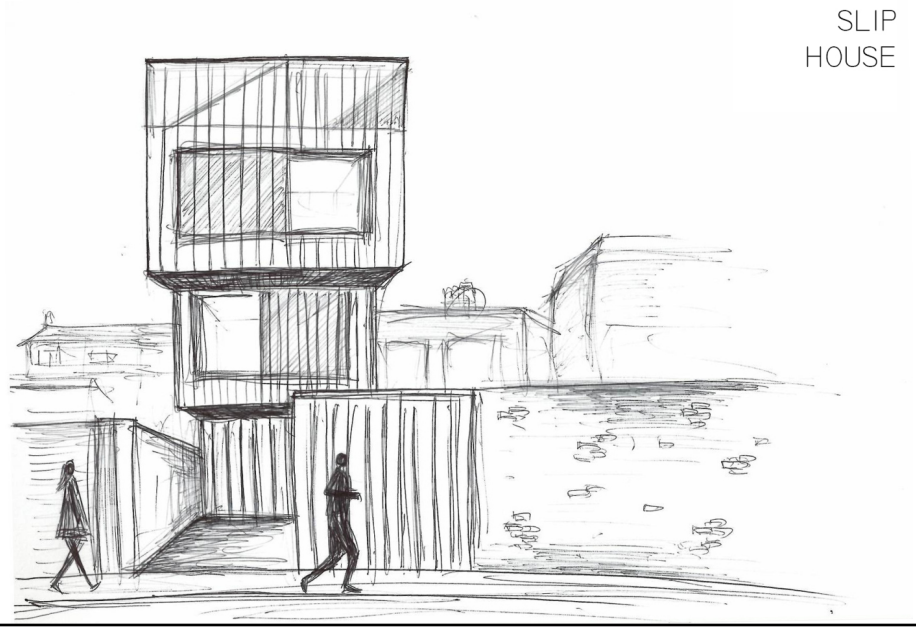
The waterfall model in construction



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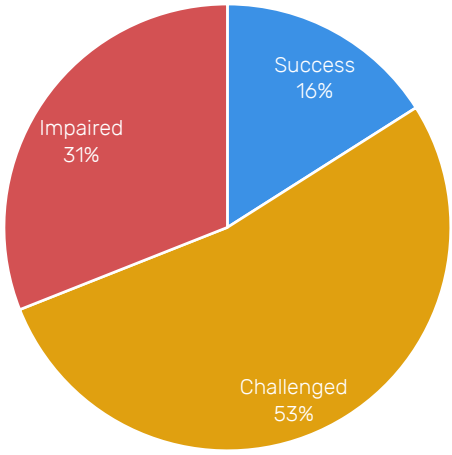
Waterfall is not enough in SE

The waterfall metaphor did not solve the problems of software development

It can't deal with volatility of requirements, technologies and knowledge

- Late software changes will happen

Different domains have different levels of volatility



Resolution of projects, The Standish Group report (1994)

The transition

Band-Aids

Band-Aid ::: Anticipation of changes

If changes can be anticipated at design time, they can be controlled by a parameterization, encapsulations, etc.

- Waterfall model still can be used

Experience confirms:

- Many changes are not anticipated by the original designers
- Inability to change software quickly and reliably means that business opportunities are lost

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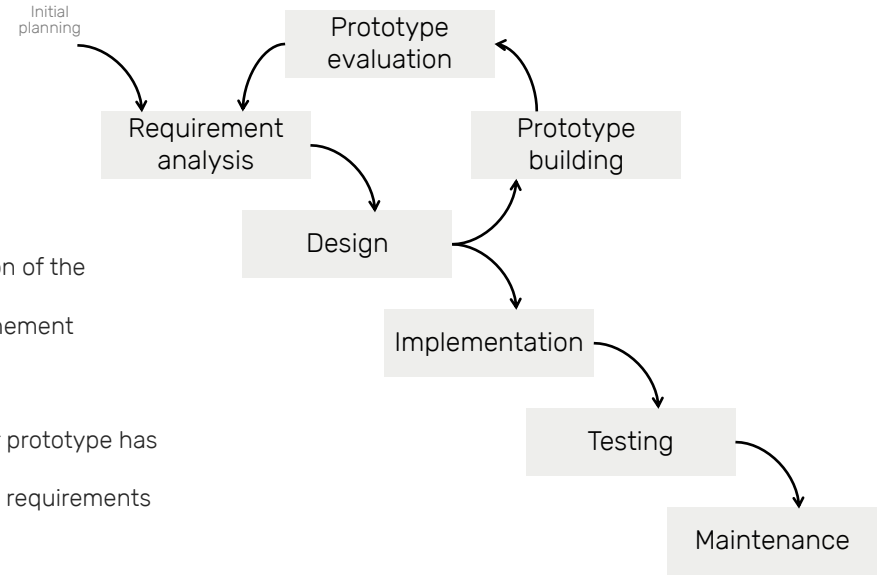
Band-Aid ::: Prototyping



Prototype

- A very preliminary version of the software
- Allows requirement refinement

Problem

- Volatility continues after prototype has been completed
- Only useful for the initial requirements elicitation

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The third paradigm

The iterative/evolutionary approach

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The response to volatility

Anomaly

- Volatility of requirements, technologies and knowledge
- The waterfall model can't accommodate volatility
- 30% or more requirements may change during development (Cusumano & Selby)
- Requirements for IT change at a rate of 2–3% per month (Caper-Jones)

Paradigm change shifted software engineers' priorities

- Focus on methods that allow to keep up with changes in requirements (technologies, knowledge)
- Plans are temporary
- Introduced the iterative and evolutionary approaches for software development

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The paradigm change of the 2000s

Iterative/evolutionary development
- Rational Unified Process
- …

New life-span models emphasize software evolution
- Staged model of software lifespan
- Based on data from long-lived systems

Agile development
- SCRUM
- Extreme programming
- …

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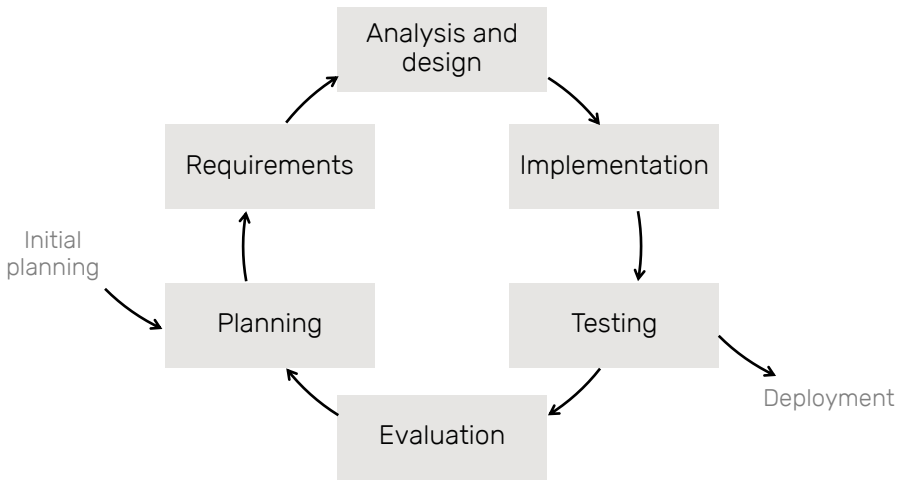
Iterative software development



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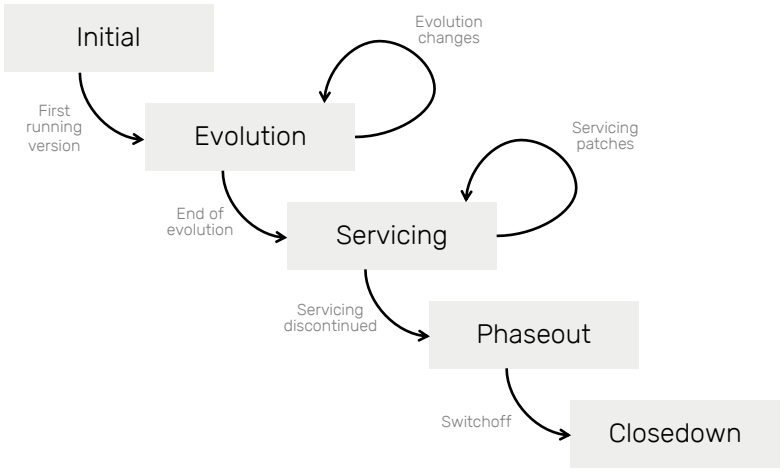
Staged model



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All paradigms currently coexist

The ad hoc paradigm is still used by some single programmers

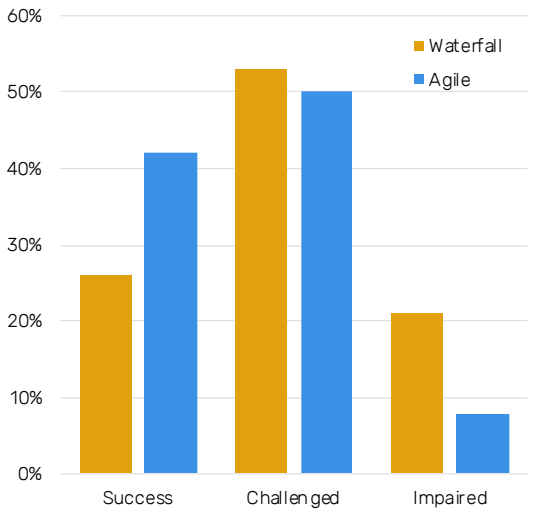
- Programming as an art rather than engineering
- Example: small games, some mobile apps

Waterfall works if there is no volatility

- Small or short-lived projects
- Unusually stable requirements and environments

The iterative/evolutionary/agile paradigms are the new mainstream

Evolution is the key process of the new paradigms



Resolution of projects,
The Standish Group report (2019)

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Software properties

Software properties types

Essential	Accidental
Intrinsic to software (determine its nature)	Related to its production
Ever-present	Ephemeral
Mental crafting of the conceptual construct	Implementation process

Essential properties ::: Complexity

Programs are among most complex systems ever created

Limited short-term memory capacity

- "The magical number seven, plus or minus two" by George Miller (1956)
- "The magical number 4 in short-term memory: A reconsideration of mental storage capacity" by Nelson Cowan (2001)

Cause of most of software problems

Several well-known strategies to deal with complexity

- Modeling
- Decomposition
- As-needed approach
- Abstraction

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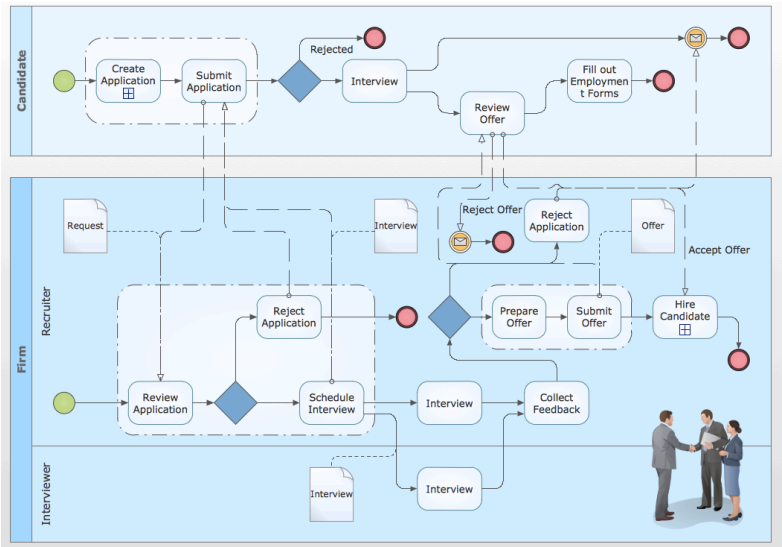
Modeling



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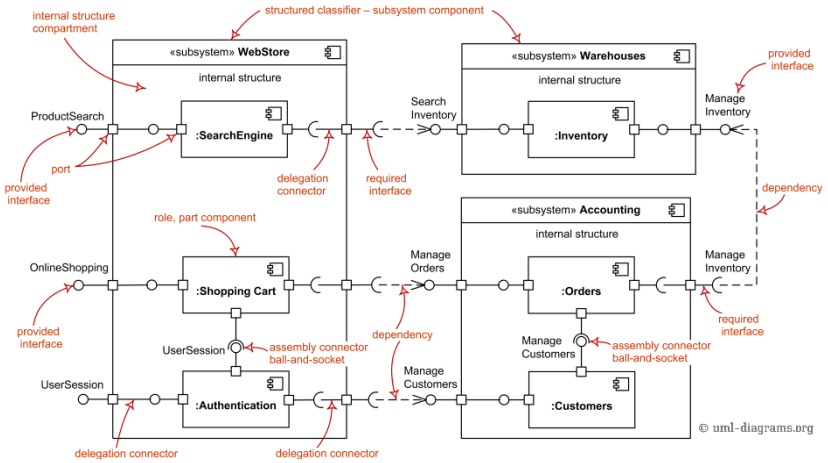
Decomposition



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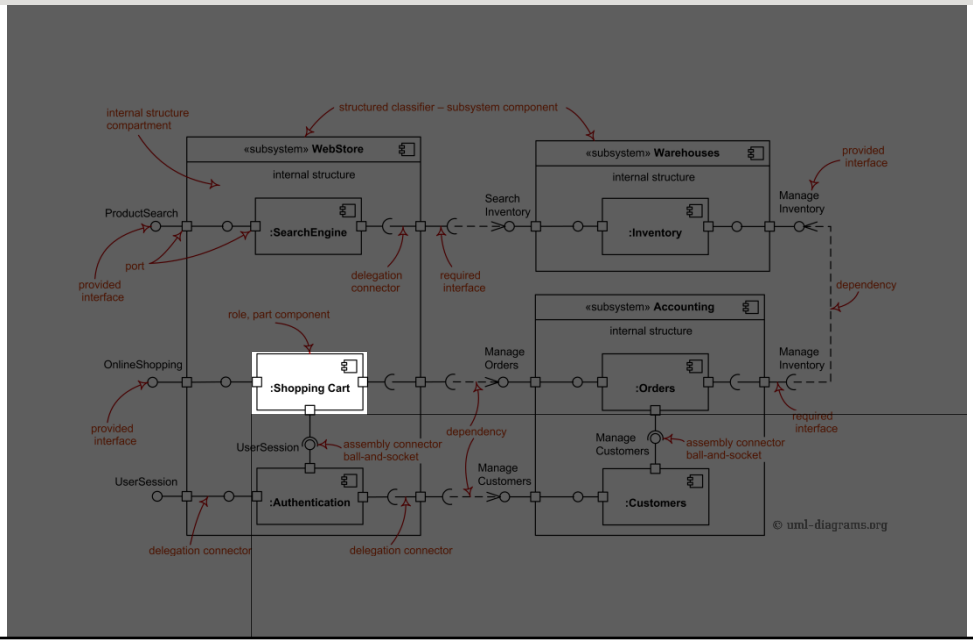
As-needed approach



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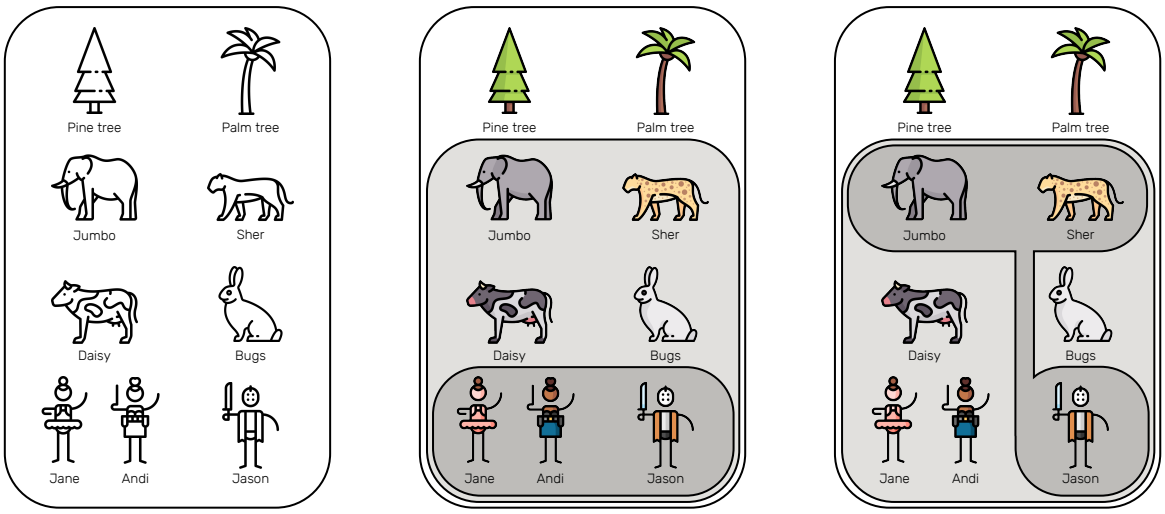
Abstraction



unclassified "things"

organisms, mammals, humans

organisms, mammals, dangerous mammals

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Essential properties ::: Conformity

Software is part of a larger system (domain) that consists of:

- Hardware
- Users
- Stakeholders
- Other systems

The software glues it all together, adding even more complexity

Changes in the domain force software change

Strategies: domain knowledge

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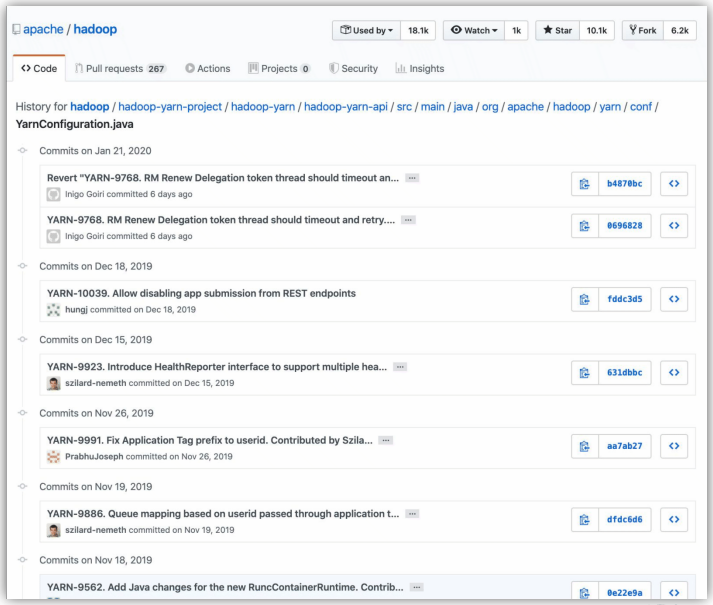
Essential properties ::: Changeability

Software is easy to change

- Ill-prepared or hasty changes are not uncommon

Yesterday's comprehension may be obsolete



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Essential properties ::: Invisibility

Software belongs to the category of abstract concepts

- Senses cannot be easily used in comprehension

Strategies to deal with invisibility (require lots of work)

- Visualization
- Sonification

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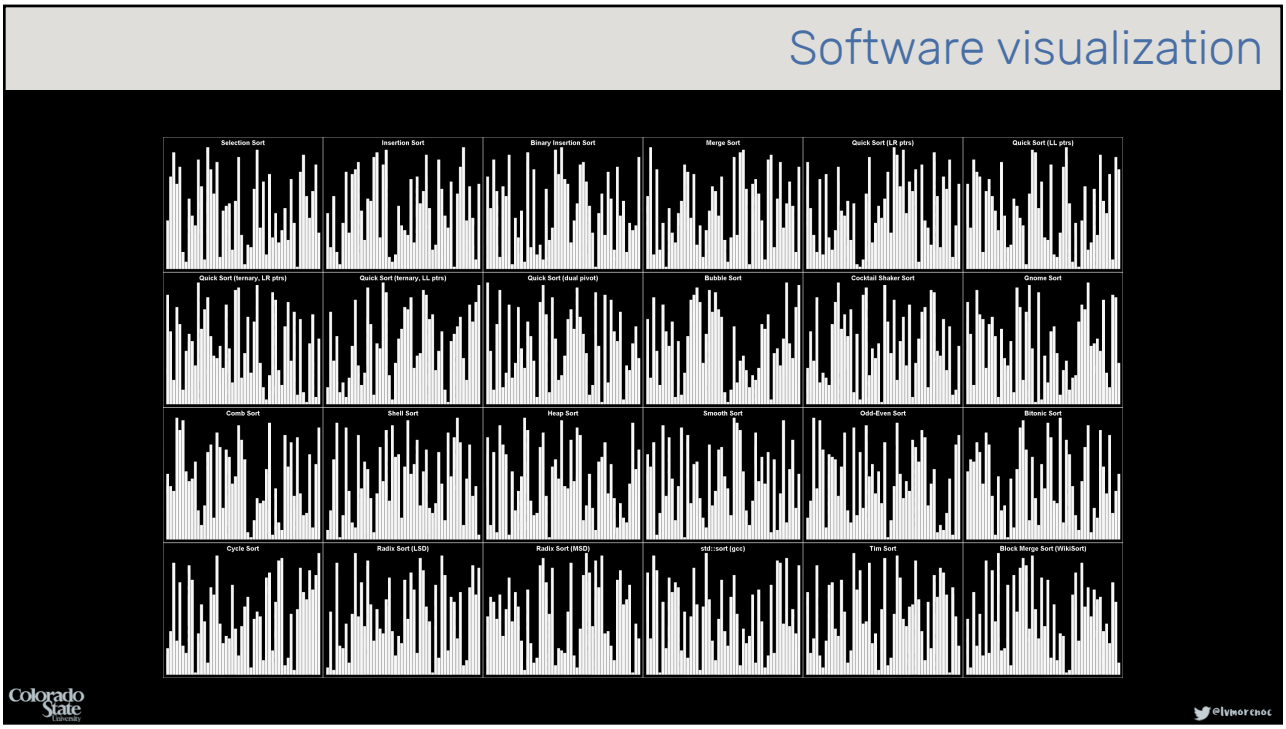
Software visualization



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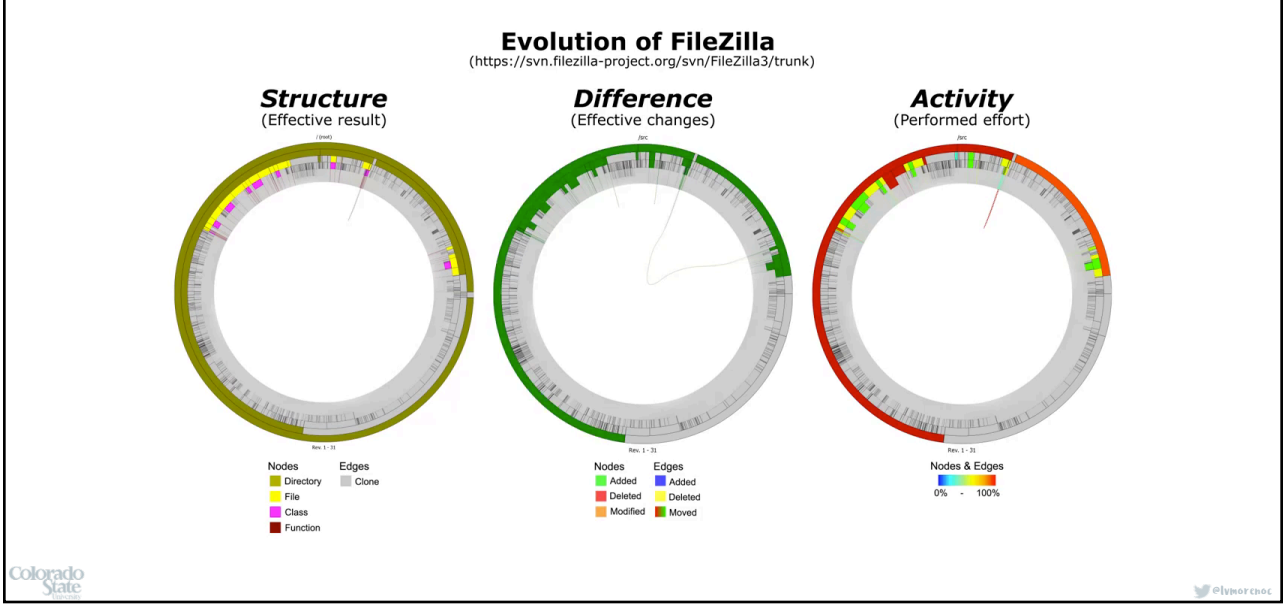
Software visualization



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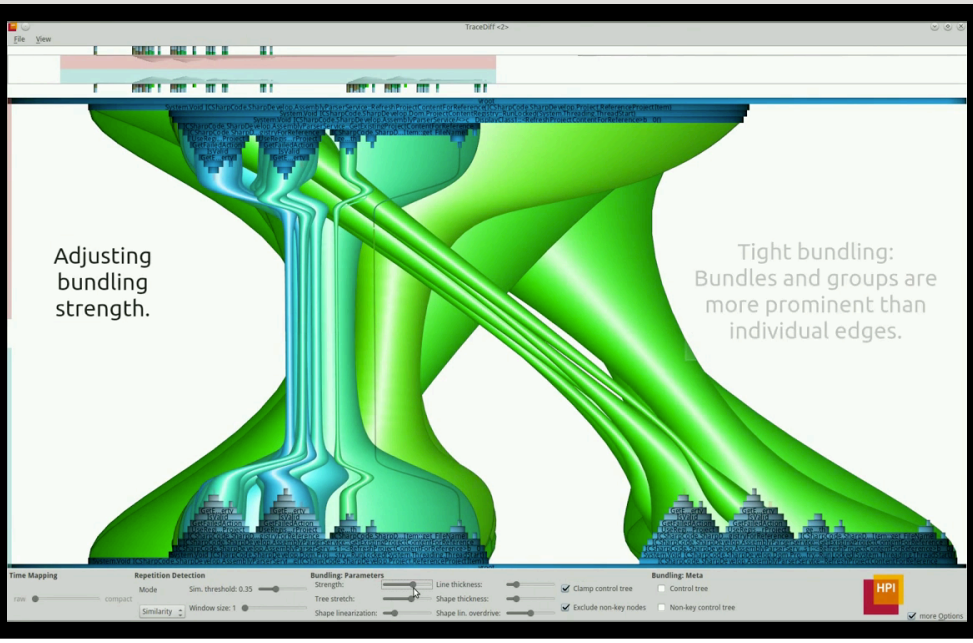
Software visualization



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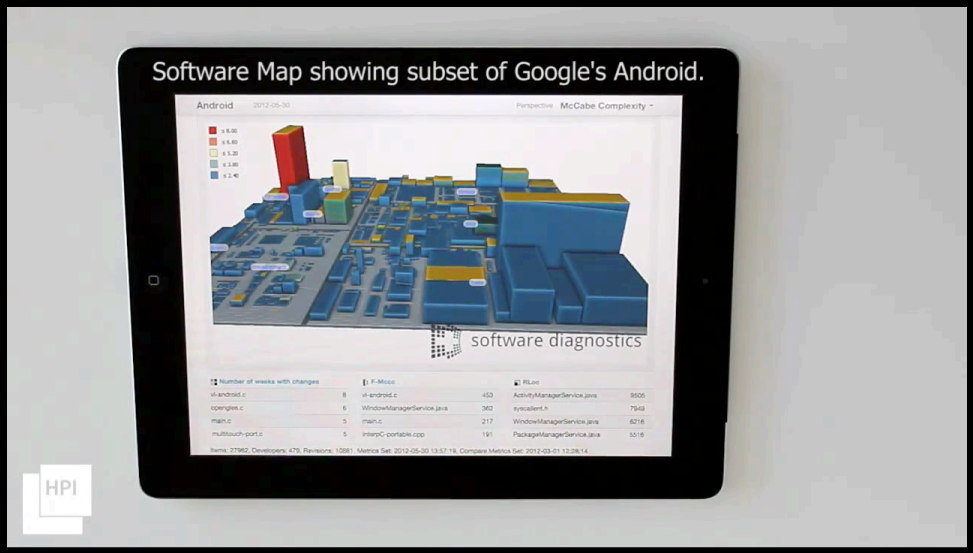
Software visualization



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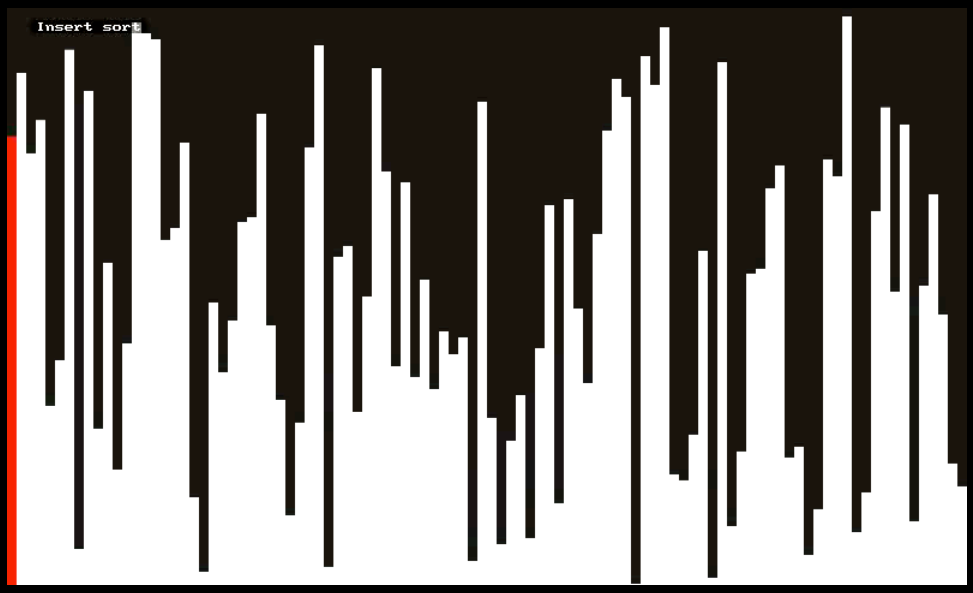
Software sonification



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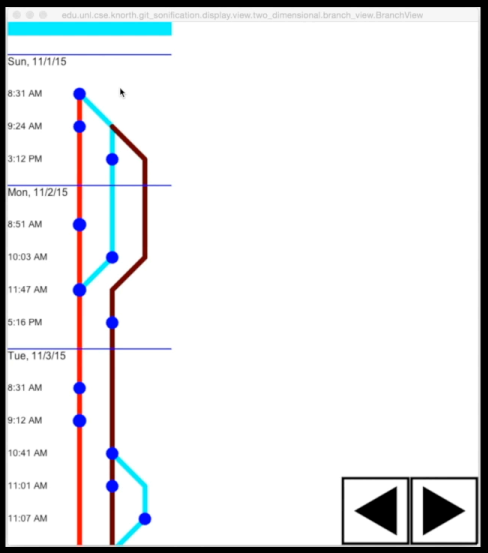
Software sonification



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Essential properties ::: Discontinuity

Understanding of continuous semi-linear systems comes easier, but software is discontinuous

In discontinuous systems, a small change in the input can result in a huge change in the output

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Some accidental difficulties

Past / current / future software technologies

Quirks of
- operating systems
- compilers
- programming languages
- processes

Hardware speed, memory size

Programming paradigm
- functional
- object oriented
- aspect oriented

Role of the software (critical, noncritical)

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Accidental difficulties and solutions

Accidental difficulty solved	Breakthrough	Impacts
Slow turnaround of batch programming Development interruptions	Time sharing	Productivity
Low-level constructs proper of concrete machine programming	High-level programming languages	Productivity, reliability, simplicity, comprehensibility
Use of individual tools	Unified programming environments	Productivity, maintainability

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Other solutions to accidental difficulties

- AI – expert systems
- Recommendation systems
- Automatic programming
- Graphical programming
- Formal methods – program verification
- …

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Reading

Brooks, Frederick P., "No Silver Bullet: Essence and Accidents of Software Engineering," Computer, Vol. 20, No. 4 (April 1987) pp. 10-19