Architectural Principles

Truong Ho-Quang
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Schedule

Week		Date	Time	Lecture	Note
3	L1	Wed, 20 Jan	10:15 – 12:00	Introduction & Organization	Truong Ho
3	L2	Thu, 21 Jan	13:15 – 15:00	Architecting Process & Views	Truong Ho
4		Tue, 26 Jan	10:15 – 12:00	**Skip**	
4	S1	Wed, 27 Jan	10:15 – 12:00	<< Supervision: Launch Assi	
4	L3	Thu, 28 Jan	13:15 - 15:00	Roles/Responsibilities & Functional Dec	Ho
5	L4	Mon, 1 Feb	13:15 – 15:00	Architectural Styles P1	Ho
5	S2	Wed, 3 Jan	10:15 – 12:00	<< Supervision/A	
5	L5	Thu, 4 Jan	13:15 – 15:00	Architectural Styles P2	bara
6	L6	Mon, 8 Feb	13:15 – 15:00	Architectural Styles P3	Truong Ho
6	S3	Wed, 10 Feb	10:15 – 12:00	<< Supervision/Assignment>>	TAs
6	L7	Thu, 11 Feb	13:15 – 15:00	Design Principles (Maintainability, Modifiability)	Truong Ho
7	L8	Mon, 15 Feb	13:15 – 15:00	Architectural Tactics & Analysis	Truong Ho
7	S4	Wed, 17 Feb	10:15 – 12:00	<< Supervision/Assignment>>	TAs
7	L9	Thu, 18 Feb	13:15 – 15:00	Architecture Evaluation	Truong Ho
8	L10	Mon, 22 Feb	13:15 – 15:00	Reverse Engineering & Correspondence	Truong Ho
8	S5	Wed, 24 Feb	10:15 – 12:00	<< Supervision/Assignment>>	TAs
8	L11	Thu, 25 Feb	13:15 – 15:00	Guest Lecture 1	TBD
9	L12	Mon, 1 Mar	13:15 – 15:00	Guest Lecture 2: Architectural Changes in Volvo AB	Anders M.
9	S6	Wed, 3 Mar	10:15 – 12:00	<< Supervision/Assignment>>	TAs
9	L13	Thu, 4 Mar	13:15 – 15:00	To be determined (exam practice?)	Truong Ho
9		Fri, 5 Mar	Whole day	Group presentation of Assignment (TBD)	Teachers
11	Exam				

We are HERE!

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4	S1	Wed, 27 Jan	10:15 – 12:00	<< Supervision: Launch Assignment 1>>	TAs
4	L3	Thu, 28 Jan	13:15 - 15:00	Roles/Responsibilities & Functional Decomposition	Truong Ho
5	L4	Mon, 1 Feb	13:15 – 15:00	Architectural Styles P1	Truong Ho
5	S2	Wed, 3 Jan	10:15 – 12:00	<< Supervision/Assignment>>	TAs
5	L5	Thu, 4 Jan	13:15 – 15:00	Architectural Styles P2	Sam Jobara
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11	Exam				

Assignment schedule

Week		Date	Lecture	Assignment 1 – Task 1 (A1T1)	Assignment 1 – Task 2 (A1T2)	Assignment 2 (A2)
3	L1	Wed, 20 Jan	10:15 – 12:00			
3	L2	Thu, 21 Jan	13:15 – 15:00			
4		Tue, 26 Jan	10:15 – 12:00			
4	S1	Wed, 27 Jan	10:15 – 12:00	Launch A1T1		
4	L3	Thu, 28 Jan	13:15 - 15:00			
5	L4	Mon, 1 Feb	13:15 – 15:00			
5	S2	Wed, 3 Jan	10:15 – 12:00	Work A1T1		
5	L5	Thu, 4 Jan	13:15 – 15:00			
6	L6	Mon, 8 Feb	13:15 – 15:00			
6	S3	Wed, 10 Feb	10:15 – 12:00	Work A1T1		
6	L7	Thu, 11 Feb	13:15 – 15:00	Hand-in A1T1 Peer Rev A1T1	A1T2 released	
7	L8	Mon, 15 Feb	13:15 – 15:00			
7	S4	Wed, 17 Feb	10:15 – 12:00	Hand-in PR A1T1	MQTT intro	A2 released
7	L9	Thu, 18 Feb	13:15 – 15:00			
8	L10	Mon, 22 Feb	13:15 – 15:00			
8	S5	Wed, 24 Feb	10:15 – 12:00		Work A1T2	
8	L11	Thu, 25 Feb	13:15 – 15:00			
9	L12	Mon, 1 Mar	13:15 – 15:00			
9	S6	Wed, 3 Mar	10:15 – 12:00		Work A1T2	Hand-in A2
9	L13	Thu, 4 Mar	13:15 – 15:00			
9		Fri, 5 Mar	Whole day		Present A1T2	
11	Exam					

Hand-in deadline today

Outline

- Recap
  - Architectural Styles
- Design Principles
- Tactics

Learning Objectives

- Know/explain design principles
- Apply design principles
- Recognize violations of design principles

- *Hint*: try if you can think up a counter-example for each design principle

Advice on Design of Software

- Generic Design Principles
- Principles for Architectural Design
- Principles for Design of Components
- Principles for collaboration amongst Components

Design = trade-offs = gray area

➔ Principles are heuristics

Not today: User Interface design, protocol design

General Software - Design Principles 1

Information Hiding:

All information about a module should be private to the module unless required externally

Minimize Coupling

Every module should depend on as few others as possible

Coherence:

Keep things together that belong together

Keep behaviour together with related data

Keep information about one thing in one place

General Software Design Principles 2

<u>Divide and Conquer</u>

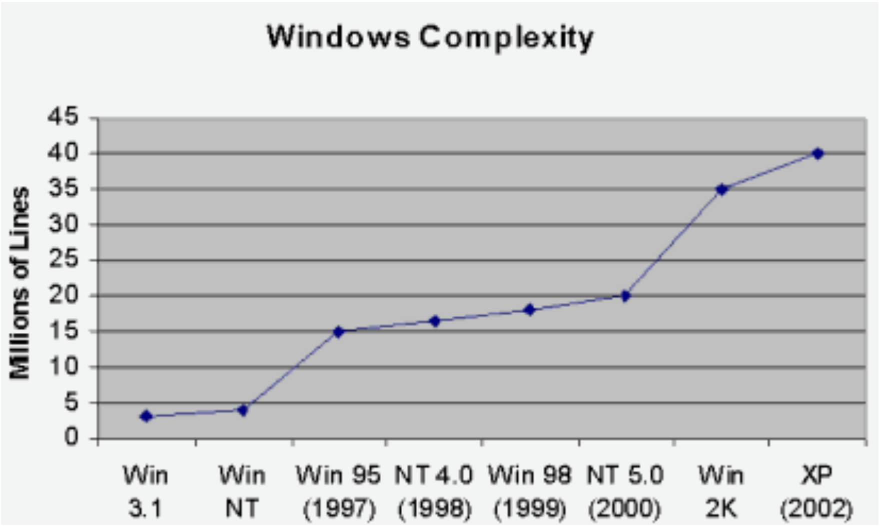
Break a big problem into smaller ones

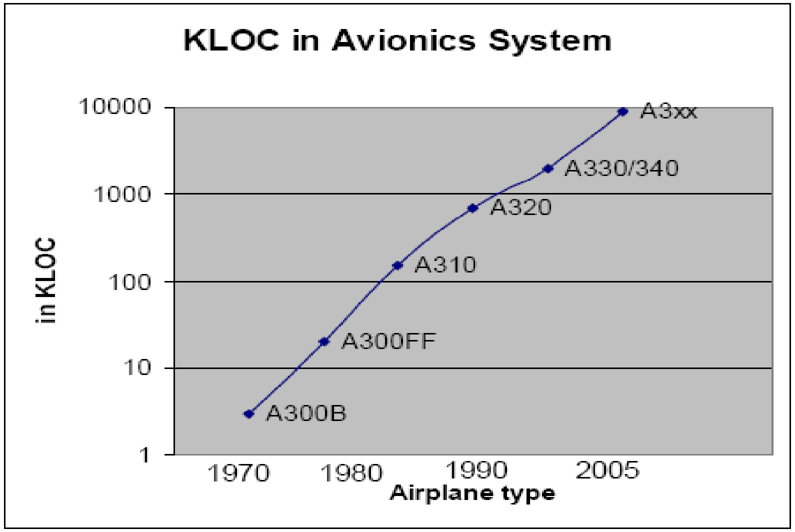
<u>Separation of Concerns</u>

Divide into different parts logic
that addresses different issues

<u>Keep it Simple</u>

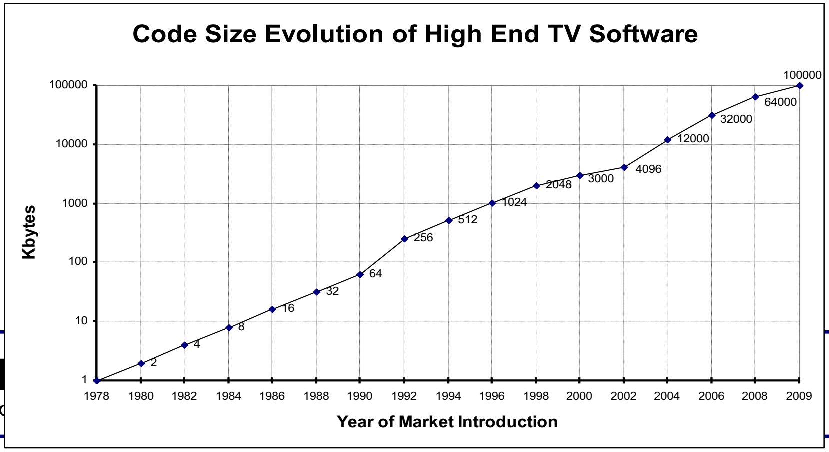
Motivation:
Increasing amount of software in systems



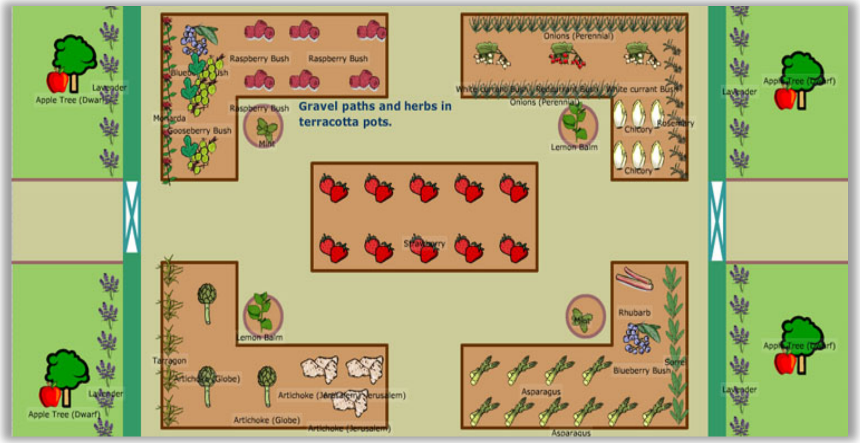


Nb: logarithmic scale

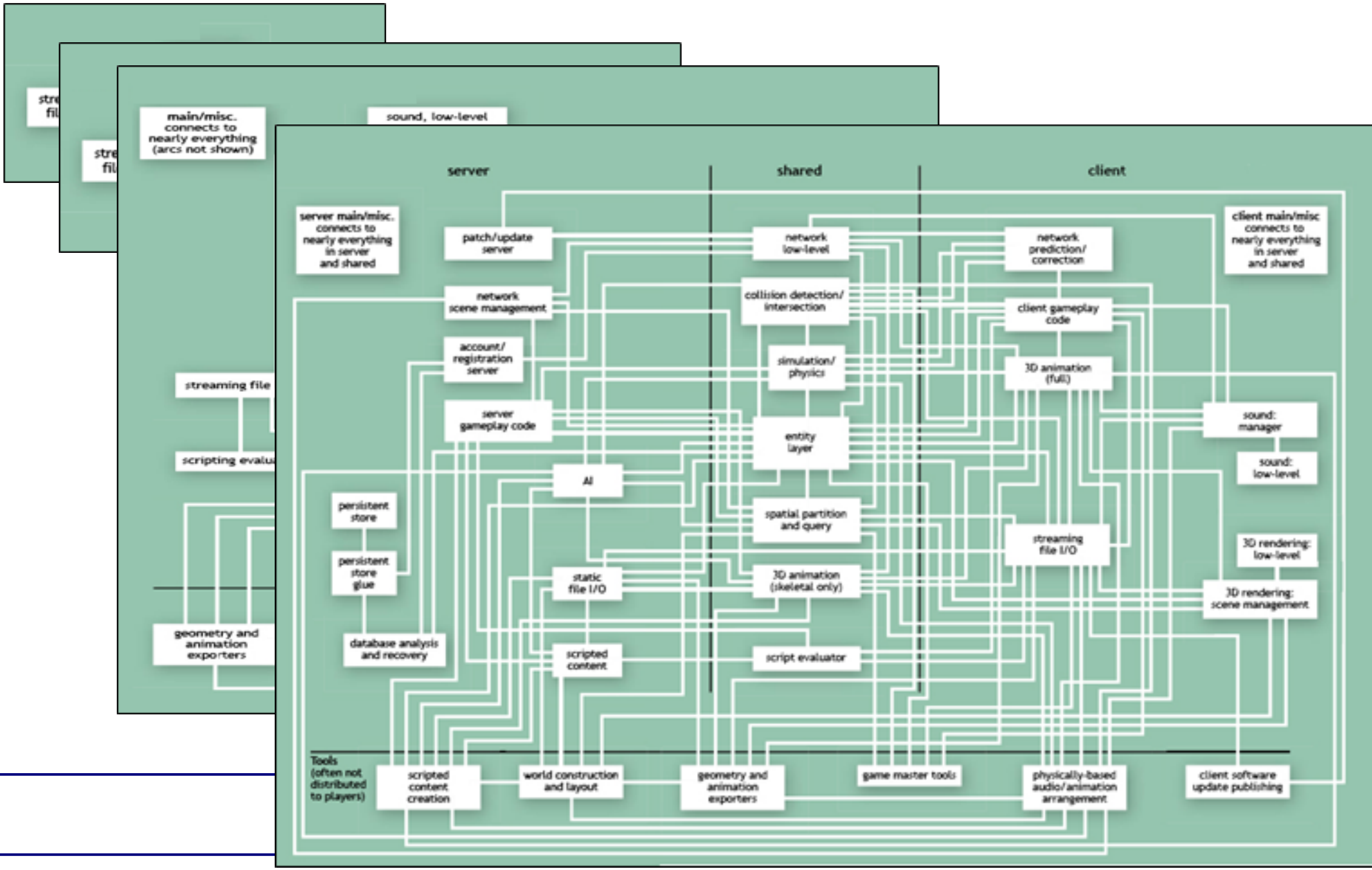
The amount of software increases 10 fold every 10 years



Software Evolves ‘Organically’



Increasing Complexity of Software



Blow, J. "Game Development: Harder Than You Think." *ACM Queue*

Complexity of Software

Slide by prof. Jurgen Vinju

If Kafka would write a book today…

This kind of software exists everywhere:

- 10K to 25M lines of code
- 2 to 10 programming languages and dialects
- 20 to 200 dependencies on library components and frameworks
- 10 to 1000 programmers
- 1 to 1M users
- 10 to 40 years lifetime
- “IT happens”

Franz Kafka

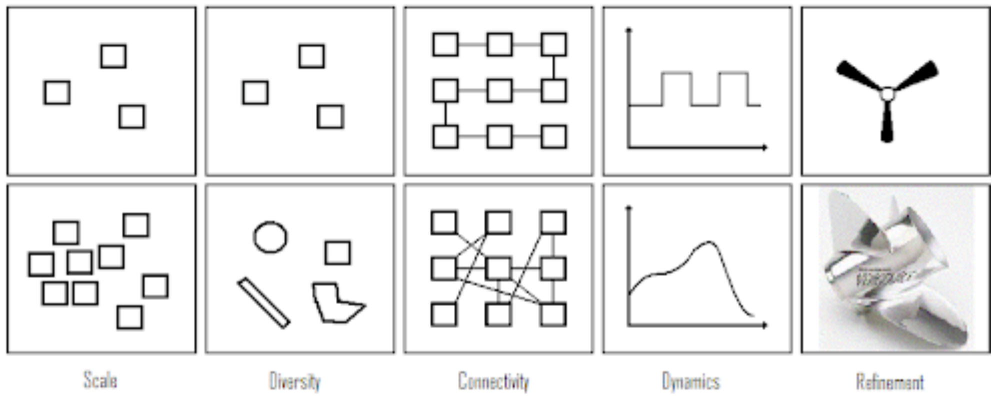
Writer

Franz Kafka was a German-language writer of novels and short stories, regarded by critics as one of the most influential authors of the 20th century. Wikipedia

Born: July 3, 1883, Prague, Czech Republic

having a nightmarishly complex, bizarre, or illogical quality

The 5 Complexity Dimensions of Software



Complexity in this regard means complex for humans to understand and contribute to.

1. **Scale**. The larger the system, the more complex.
2. **Diversity**. The more frameworks, languages, integration techniques, tools, platforms, and design patterns used, the more complex.
3. **Connectivity**. The more connections, the more complex. This relates to coupling.
4. **Dynamics**. The more number of states or the larger state space, the more complex.
5. **Refinement**. Over time every living piece of software is refined, optimized, and polished. Corner cases are found and handled, and regression test suites grow. Refinement drives complexity.

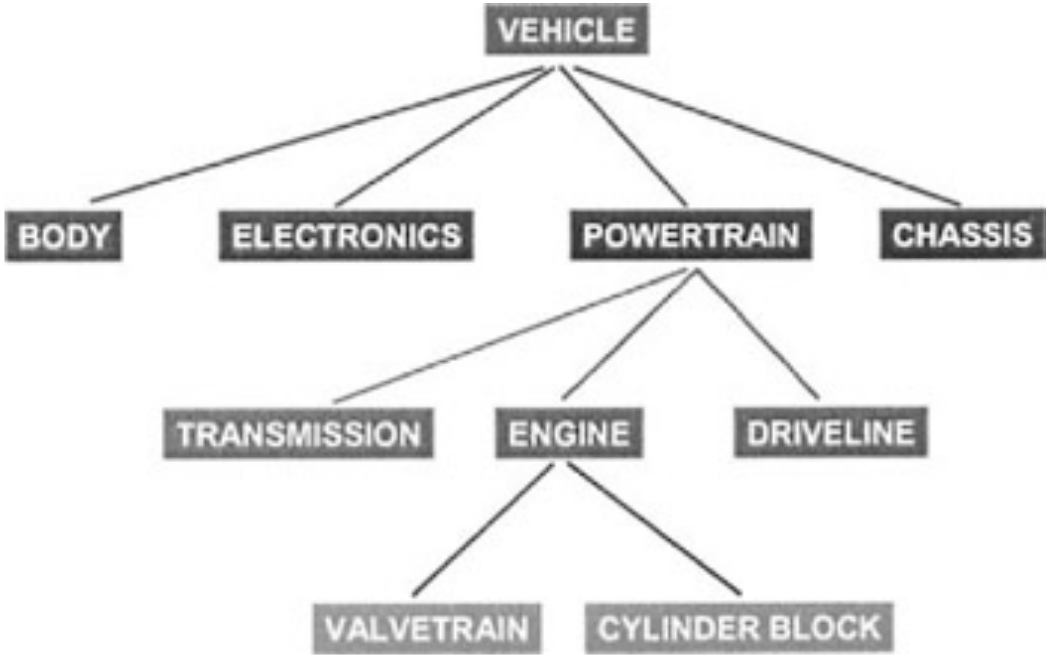
From : John Wilander http://appsandsecurity.blogspot.com/2011/03/5-complexity-dimensions-of-software.html

Generic Design Principles

- Decomposition

  Break problem into independent smaller parts

  Independent?



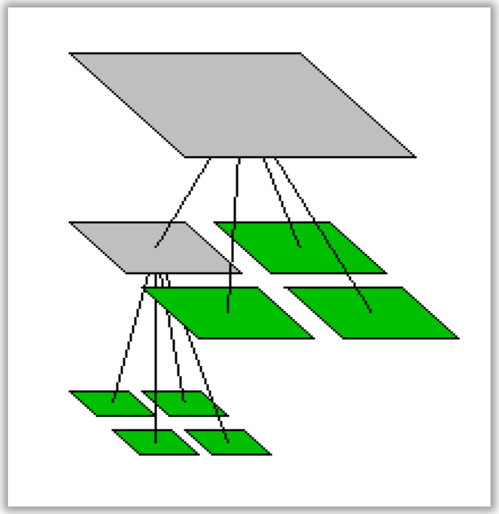
Single Responsibility

- What is a responsibility?
  - Rebecca Wirfs-Brock role-stereotypes
  - Depends on level of design
  - Relates to Parnas' principle of Information Hiding:
    - The responsibility relates to the secret
      - E.g. sorting
      - Viewer: way of displaying information
      - Model: storing & querying information

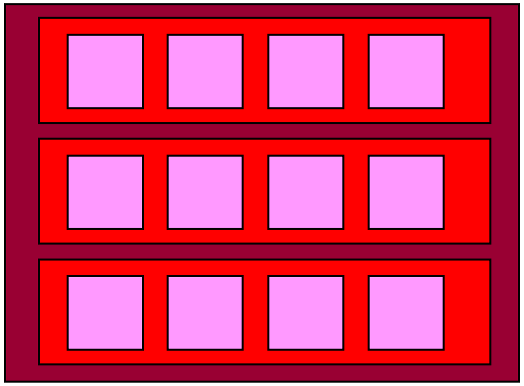
  - Alternative formulation ('Uncle Bob'):
    - A class should have only one reason to change

Design Principle : Divide and conquer

- Trying to deal with something big all at once is harder than dealing with a set of smaller things
  - Each individual component is smaller, and therefore easier to understand
  - Parts can be replaced or changed without having to replace or extensively change other parts.
  - Separate people can work on separate parts
  - An individual software engineer can specialize



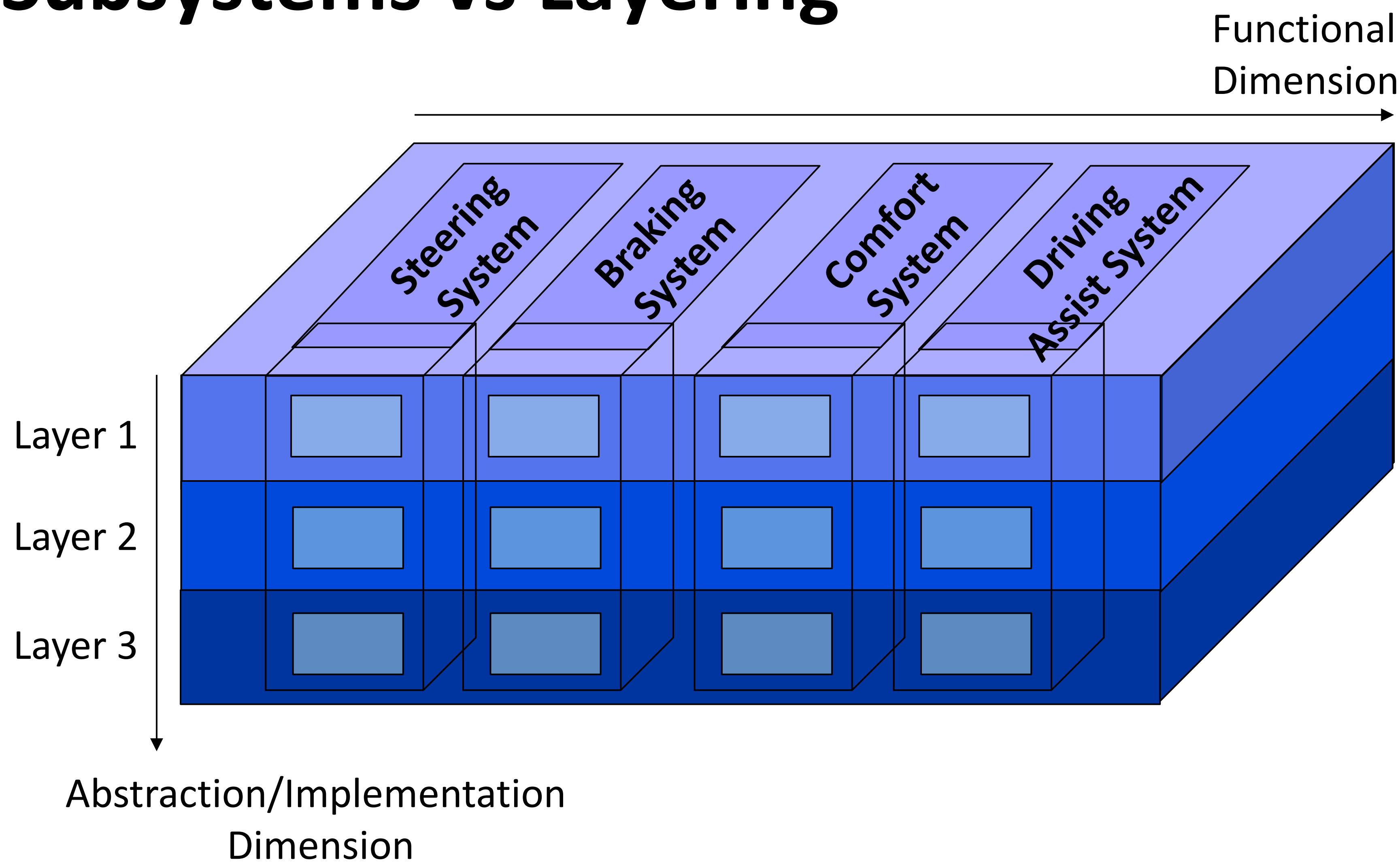
Ways of dividing a software system



A system can be divided up into

- Layers & subsystems
- A *subsystem* can be divided up into one or more *packages*
- A *package* is divided up into *classes*
- A *class* is divided up into *methods*

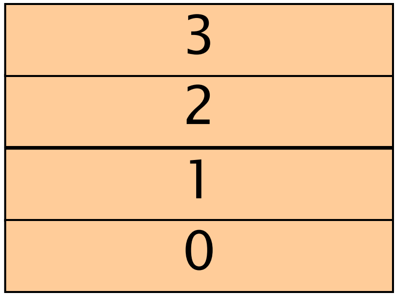
Subsystems vs Layering

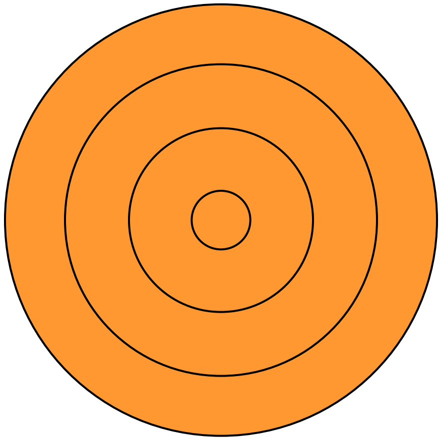


Layering

Goals: Separation of Concerns, Abstraction, Modularity, Portability

Partitioning in non-overlapping units that
- provide a cohesive set of services at an abstraction level
  (while abstracting from their implementation)
- layer *n* is allowed to use services of layer *n-1*
  (and not vice versa)
  alternative:
    bridging layers: layer *n* may use layers <*n*
    enhances efficiency but hampers portability





A Component-based Reference Architecture for Computer Games

(E. Folmer, 2007)

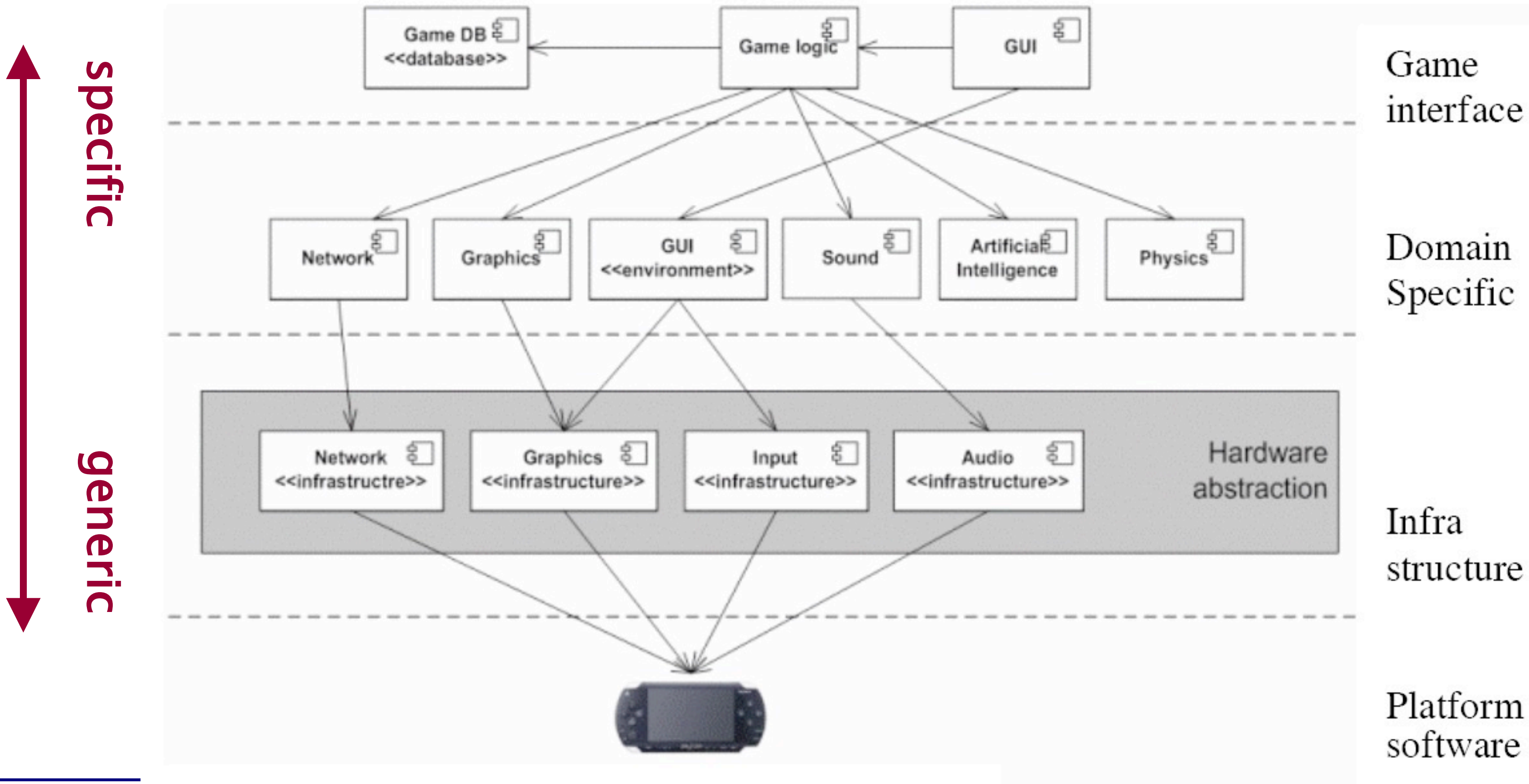
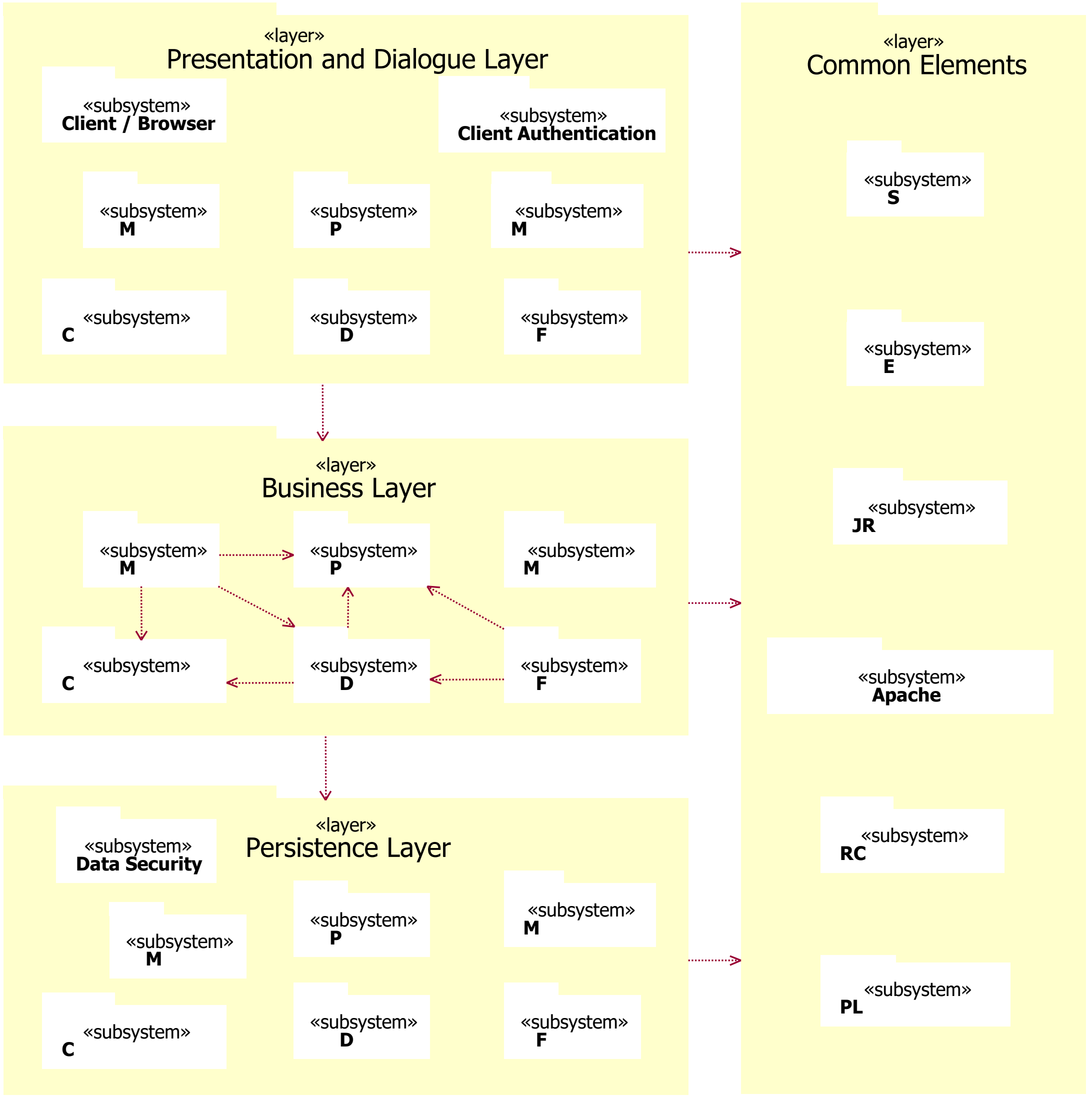


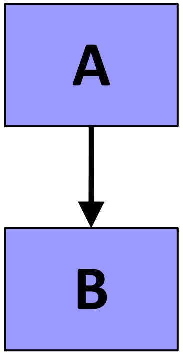
Fig. 1. A reference architecture for the games domain

Example



«layer»
Presentation and Dialogue Layer
«subsystem»
Client / Browser
«subsystem»
Client Authentication
«subsystem»
M
«subsystem»
P
«subsystem»
M
«subsystem»
C
«subsystem»
D
«subsystem»
F
«layer»
Business Layer
«subsystem»
M
«subsystem»
P
«subsystem»
M
«subsystem»
C
«subsystem»
D
«subsystem»
F
«layer»
Persistence Layer
«subsystem»
Data Security
«subsystem»
P
«subsystem»
M
«subsystem»
M
«subsystem»
C
«subsystem»
D
«subsystem»
F
«layer»
Common Elements
«subsystem»
S
«subsystem»
E
«subsystem»
JR
«subsystem»
Apache
«subsystem»
RC
«subsystem»
PL

What is a dependency?



A depends on B

- Component A requires B for it to *work*
  - Functional coupling

Run-time

- A change in module B requires a change in module A
  - Implementation coupling
  - Typically requires: re-testing A & B

Development-time

Dependency/Coupling

There is coupling between two classes ***A*** and ***B*** if:

- ***A*** calls a service of an object ***B***
- ***A*** has a method which references ***B***

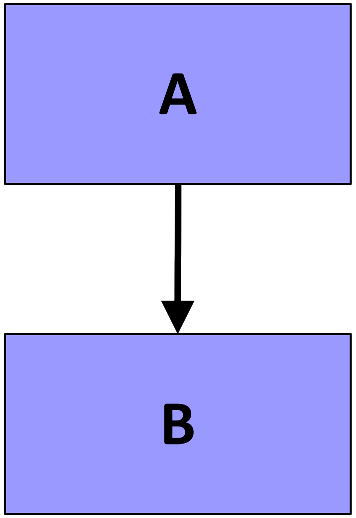
  (via return type or parameter)
- ***A*** has an attribute that refers to ***B***
- ***A*** is of type (inherits from) ***B***
  - ***A*** is a subclass of (or implements) class ***B***

This is not an exhaustive definition

A may depend on some assumption on another component B

Architecture Design Principles

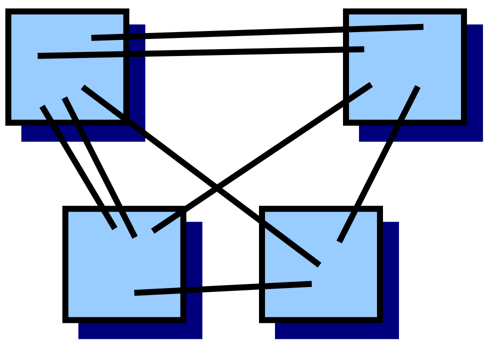
- Dependencies direct in the direction of **stability**



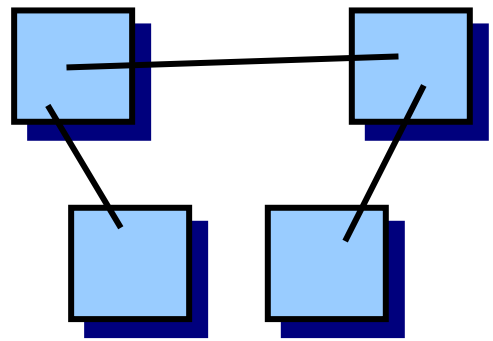
B should be
less likely to change
than A

Dependency: Coupling

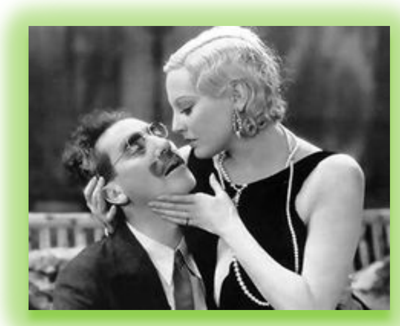
Coupling is the degree of interdependence between modules



high coupling

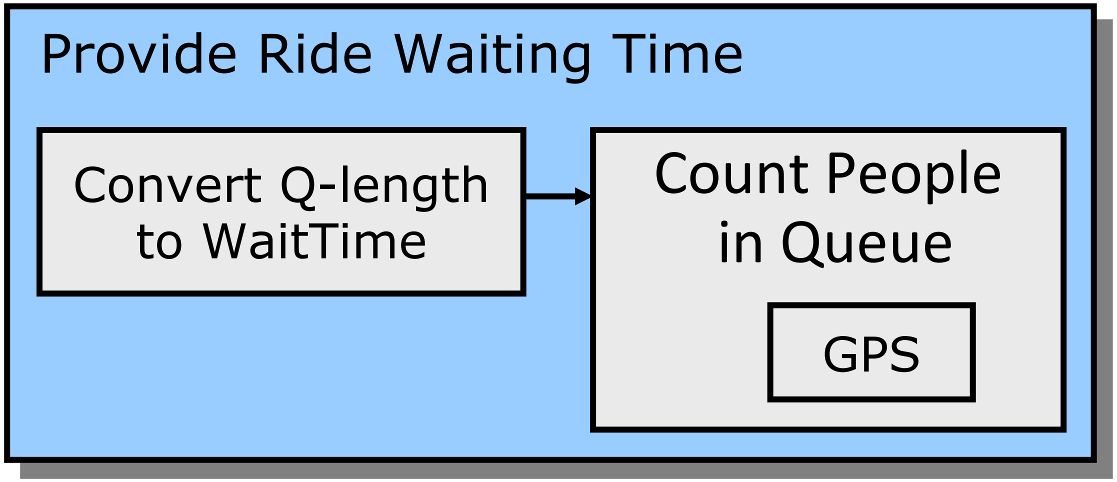


low coupling



Cohesion

Cohesion is concerned with the *relatedness **within** a module*

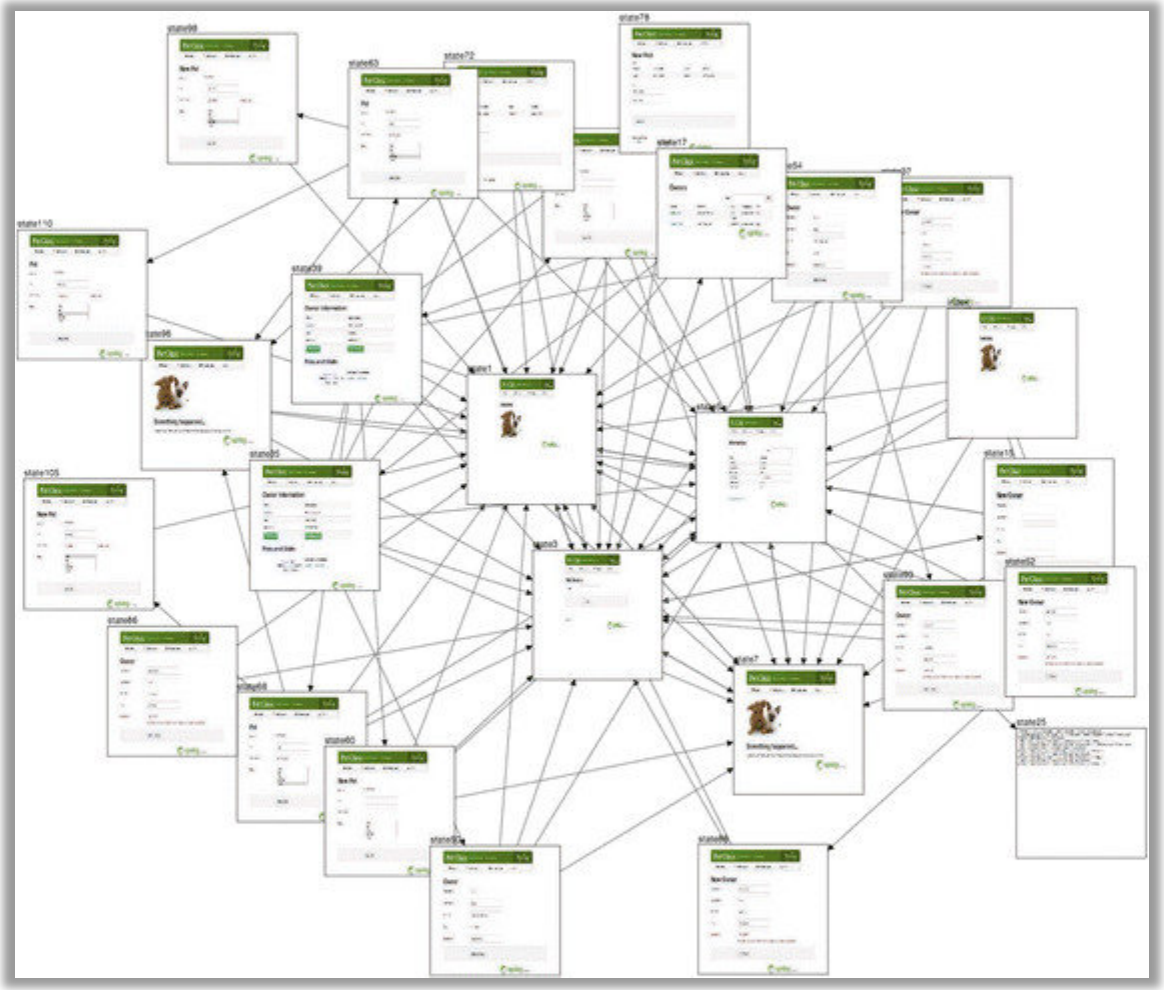


Benefits of Low Coupling/Dependencies

1. Modules are easier to replace
2. fewer interconnections between modules reduce time needed for **understanding** the modules and interactions
3. fewer interconnections between modules reduce the chance that **changes** in one module cause **problems** in other modules, which enhances *reusability*
4. fewer interconnections between modules reduce the chance that a fault in one module will cause a **failure** in other modules, which enhances *robustness*

Page-Jones, M. 1980. *The Practical Guide to Structured Systems Design*. New York, Yourdon Press, 1980.

What to avoid: many dependencies



Only 25 classes!

Reducing Coupling: Information Hiding

- Information Hiding:
  - Try to localize future change
  - Hide system details likely to change independently
  - Separate parts that are likely to have a different rate of change
  - In interfaces expose only assumptions unlikely to change
- Why is information hiding a good idea?
  - which types of coupling are prevented/reduced?

Information Hiding

Information Hiding is a means of avoiding dependencies.

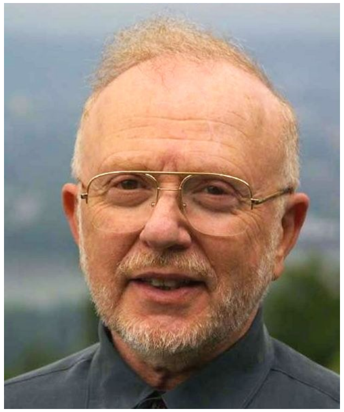
- Minimize the information interfaces disclose about the inner-workings of components
  - Balance with genericity
- Information hiding aims at avoiding dependencies on implementation details
- Corollary:
  - Components typically encapsulate volatile technologies

David Parnas

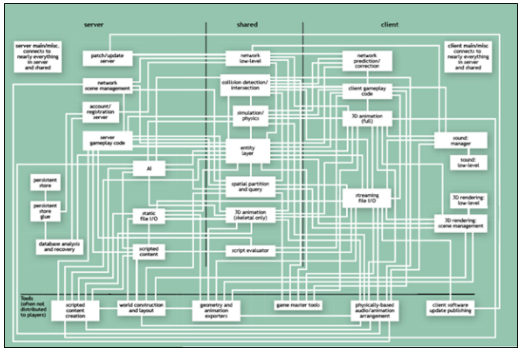
- *We propose that one begins with a list of:*
  - *difficult design decisions, or*
  - *design decisions which are likely to change*

*Each module is then designed to **hide** such a decision from the other modules.*

- *Goal: **ISOLATE CHANGE***
- *Means: Information hiding, minimizing dependencies*



David Parnas
1941-…



I advise students to pay more attention to the fundamental ideas rather than the latest technology.

The technology will be out-of-date before they graduate. Fundamental ideas never get out of date.

Design Principle: Information Hiding

- what is inside, must stay inside.

WHAT versus HOW

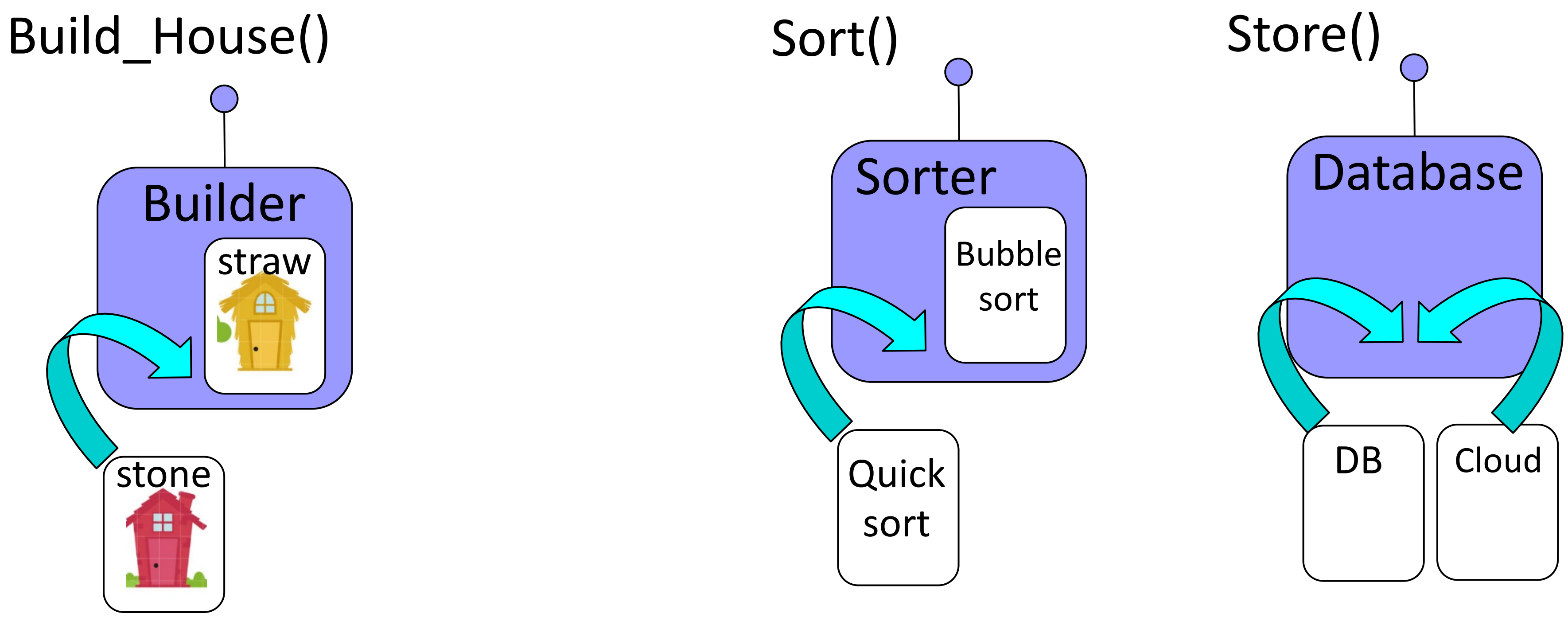
- ‘WHAT’: think Responsibility, Declarative
- Mechanisms are about ‘HOW’

WHAT: Build a house

HOW: stone, sticks, straw

Example: Change implementation

Public Interface



Supports evolution and platform-independence

Example 1

- IPrimeEncrypt(m,p)
- ICeasarEncrypt(m,s)
- IEncrypt(m)

Information hiding guides the design of the interface

The interface should aim to be:

- generic
  - We can do this by stating ‘what’, but not ‘how’
  - We can do this by avoiding unnecessary parameters in the calling of the component

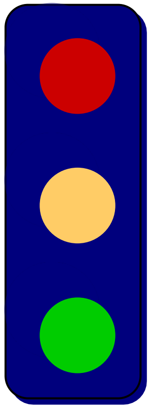
Example 2

- Steer a vehicle

- Interface
  - Option 1: Isteer = { TurnLeft, TurnRight }
  - Option 2: Isteer = { PressLeft, PressRight }
  - Option 3: Isteer = { Left, Right }

Alternative Interfaces

- Traffic Light



What should the interface of the traffic light look like?

Which secrets to hide? 

which abstraction to expose via the interface?

Take 3 minutes to design your own interface

Traffic Light - Alternative Interfaces

Traffic Light1

- Reset()
  - Postcondition: RED
- Run()
  - Red→Green→ Orange→ Red
- SetIntervalDuration(t)

‘Secrets’

- Actual colours
- Initial state
- Order of lights (easy to change)
- ‘On’ is Mutual exclusive

Synchronization/Timing?

Traffic Light2

- SetRed(On/Off):Exc
- SetOrange(On/Off):Exc
- SetGreen(On/Off):Exc
- Blink/Disco()
- GetState(…)

‘Secrets’

- Initial state
- Order of states

More Generic

(lights not exclusive)

Traffic Light3

- Halt()
- Warn()
- Drive()

‘Secrets’

- Actual colours
- Initial state
- Order of states

Higher Level of abstraction

Chest of drawers by *Droog* Design

Build from ‘modules’

But no stable architecture

Many dependencies from all drawers on all other drawers

Simplicity

Simplicity is a great virtue but it requires hard work to achieve it and education to appreciate it.

And to make matters worse:

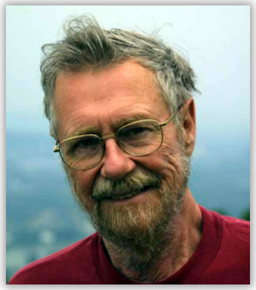
Complexity sells better.

Turing Award (1972)

Source: Edsger W. Dijkstra

EWD896 - On the nature of Computing Science

Edsger Wybe Dijkstra



A

RIJKSUNIVERSITEIT TE LEIDEN

STUDIEJAAR 1951—1952

No. 1209

De RECTOR MAGNIFICUS verklaart, dat

~~mej.~~ de heer E. W. Dijkstra

als STUDENT is ingeschreven en mitsdien gedurende bovenvermeld studiejaar toegang heeft tot alle lessen der Rijksuniversiteiten, alsmede tot de daarbij behorende inrichtingen en verzamelingen.

LEIDEN, 15 OCT 1951

[Handtekening van de ingeschrevene (ne varietur)]:

10454 - 51

De ingeschrevene is verplicht deze kaart bij zich te hebben wanneer hij(zij) een college, inrichting of verzameling bezoekt en hem op verzoek van een controlerend ambtenaar te tonen.

- 1930-2002
- Ph.D. in Physics
  Leiden University, Netherlands
- Contributions to:

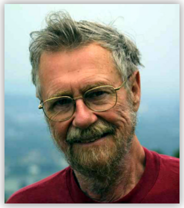
  Algorithms, Concurrency, Distributed Systems,
  Program Correctness, Discipline of Design:

  Structured Programming (Go To considered Harmful)

  Separation of Concerns
- Turing Award (1972)

O.-J. Dahl, E. W. Dijkstra, C. A. R. Hoare, *Structured Programming*, Academic Press, London, 1972

Generic Design Principle: Separation of Concerns



Edsger W. Dijkstra

- Decomposition / Divide and Conquer

- Issues that are not related should be handled in separate parts

- Single responsibility:
  - Assign a single responsibility to a single component/class

    Typical responsibilities: to know something, to do something

    E.g. to know an algorithm (worker)

    to coordinate workers (coordination)

    to manage student-records (information holder)

Example Separation of Concern Principle

Telecom Domain:

Telecom protocol:

- **decode1 ; handle1 ; decode2 ; handle2 ; decode3**

handle & encode/ decode

Separate the encoding/decoding of a message from the handling of a message:

decode1 ; decode2 ; decode3 ; handle1 ; handle2

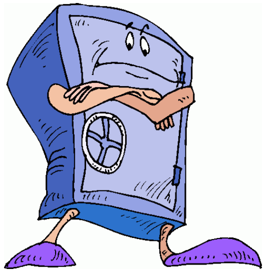
handle

encode/ decode

Separation of Concerns in Interface Design

- Separate ***What*** from ***How***

- The interface of a component exposes **what** it do, but not **how** it does this.
- The 'how' is the *information-hiding* 'secret'
  - Details of the data representation
  - Details of the algorithm



Design Principles

- Keep things that belong together at a single place

  e.g. in OO: data and
  the operations on that data

- Don't replicate

  functionality, storage of data

Summary

- Design Principles

  Know them, Apply them

  Recognize violations

Information Hiding

Minimize Coupling

Divide and Conquer

Separation of Concerns

Keep it Simple

- Design Structure Matrix
  - can you read it? make it?

Questions?

- Explain how layering relates to separation of concerns?

Summary of key architecting practices

- Understand the **drivers** for the project
- Get stakeholder involvement early and often
- Understand the requirements incl. quality properties
  - SMART & prioritized
- Develop iteratively and incrementally
- Describe architecture using multiple views
  - abstract, but precise, design decisions & rationale
- Design for change (modularity, low coupling, inform. hiding)
- Analyze in an early stage (use maths! and scenarios)
- **Simplify, simplify, simplify**
- Regularly update planning and risk analysis
- Monitor that architecture is implemented
- Get **good people**, make them happy set them loose