Menti Q&A QR

Complexity and Challenges in Software

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Overview

We will explore:

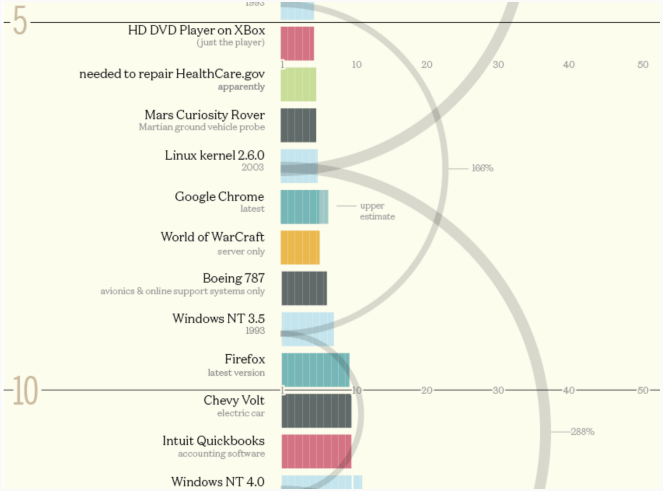
- Key challenges of developing software
- How abstraction helps us deal with complexity
- Difference between **code-owners** and **code-users**
- Key concepts of **coupling** and **cohesion**
  - Examples/classification of coupling/cohesion

Goal

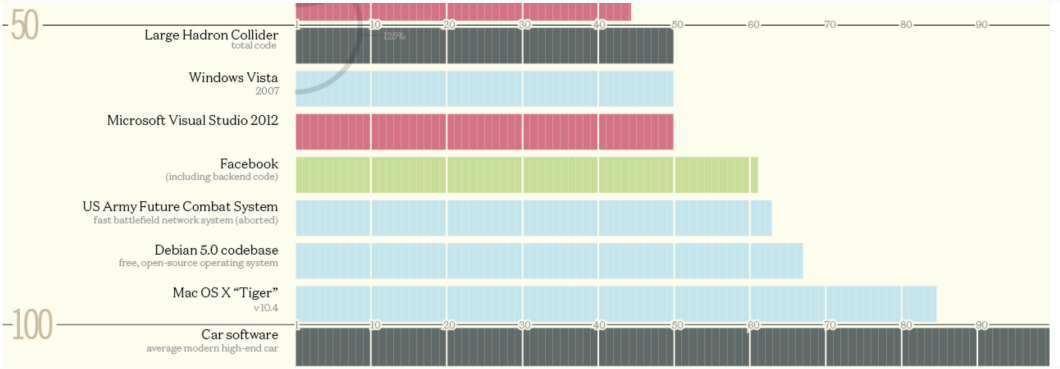
The **goal** of SE is to develop software solutions that **work** and **solve** some problem

- You might have the best design in the world
  - But if it doesn't work it is useless
    - In critical situtations can be worse than useless
  - But if it solves the wrong problem it is useless
    - Why the techniques of semester 1 are so important

Challenge 1: Scale



Challenge 1: Scale



From https://www.visualcapitalist.com/millions-lines-of-code/

Challenge 1: Scale

- No way any one person can fully understand all that code
  - Research suggests around 10,000 lines (of well designed code) **max**
- Necessitates:
  - **Techniques** to deal with complexity (this course!)
  - Working in teams (which add it's own complexities; Last semester)

Challenge 2: Change

- Unlike other disciplines software changes lots
  - To deal with hardware changes
  - Because the requirements weren't well scoped
  - Because everything needs emoji's now...

Image by Andrew Bell (Wikimedia)

Challenge 2: Change

- The **agile** techniques (semester 1) are **all about change**
  - How do we handle requirements changing? don't *rely* on gathering ahead of time
  - How do we detect issues that need change? constant communication (standups)
  - How do we track *changes* to functionality? user stories/sprint boards

Good Software Design must also allow for **change**

Challenges Recap

- Key challenges for SE are:
  - Scale
  - Change

We must **Design** for both

Abstraction as a Fundamental Technique to Handle Scale

- We need ways to reason about a system, without reasoning about every detail
  - Too many details otherwise
- Key technique is **Abstraction**
  - Replace *specific* code/chunks/modules/components/ideas with a *generalised* version
  - Reason on abstract version unless you need more information
- *Divide and Conquer* is a related technique
  - Divide general components into sub-components

Abstraction is Not Just Useful For Software

- Electronic Engineers *abstract* charge movement and call it *current*
- Electronic Engineers *abstract* transistors into *integrated circuits*
- Mathematicians *abstract* objects with (specific) binary operators into *groups*
- Car users care about speed-up/slow-down not how disk-brakes work internally
- ...

Working at Levels of Abstraction

- Engineers work at different levels of abstractions
- Don't need to understand all code, but still need to understand:
  - How to use components
  - How components fit together into a larger design
    - Sometimes a specialised position: *software architect*
- Components provide a well specified[1] application programming interface (API)
  - Details expected inputs/outputs/types/state changes etc

[1] Hopefully!

Developer Roles

Code-Owner

The person (or team) developing a particular component

Owners know all the details!

Code-User

The person (or team) using a particular component

Don't need to know everything, an abstract model of what happens is enough

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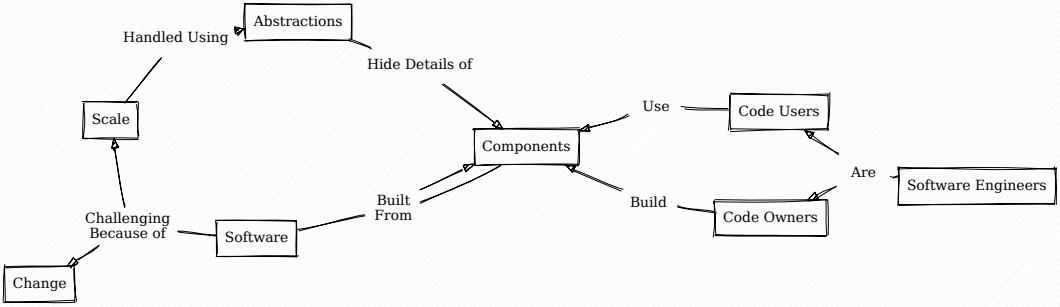
- In practice you are often both
  - Owner during initial development
  - User when developing other parts of the program
  - Owner when fixing bugs/improving documentation etc

Ownership

- Important to be aware of ownership
  - Company policy might stop you editing other code[2]
  - Might be owned by a third party, e.g. open source
  - Might not have editing rights, e.g. interfacing with commercial libraries
- A big reason companies minimise external dependencies
  - It's great there's a python library for everything; but who actually owns it?

[2] No matter how much you wish that int was a float please don't just change it!

Concept Map


Abstractions
Handled Using
Hide Details of
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Components
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Code Users
Are
Software Engineers
Built From
Build
Code Owners
Challenging Because of
Software
Change

Coupling and Cohesion

- Q: How do we best split up a program into components?
  - What makes a good component?

Cohesion

"the situation when the members of a ~~group or society~~ **[component]** are united (Cambridge Dictionary)"

How components are built **internally**

Coupling and Cohesion

Cohesion

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How components are built **internally**

Coupling

"a device that joins two things together" (Cambridge Dictionary)

How components are **connected**

Coupling and Cohesion

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How components are built **internally**

Coupling

"a device that joins two things together" (Cambridge Dictionary)

How components are **connected**

Both are about **relationships** between components/elements

Key Take-away

We want high cohesion and low coupling

These are (roughly) opposites: Low coupling usually means High Cohesion

High Cohesion

- Internals of Components should be related
  - Helps future developers (probably future-you!) find things
  - Example: you don't expect the database connector to be inside the HTML rendering function
- Components should do one thing well
  - The push towards *microservices* based around this

Cohesion From The Creator of eXtreme Programming

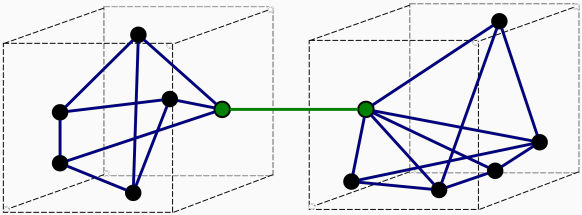
Change as a central theme again!

Lecture Q&A: menti.com/alo6c2asngoh

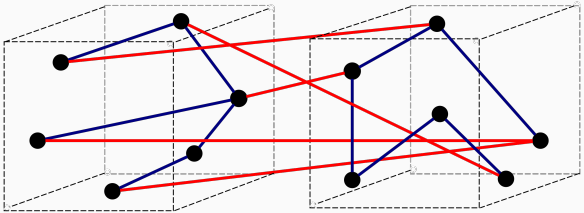
Low Coupling

- Internal details should not leak between components
  - If they do **change** becomes very difficult

Coupling and Cohesion Diagrammatically



a) Good (loose coupling, high cohesion)



b) Bad (high coupling, low cohesion)

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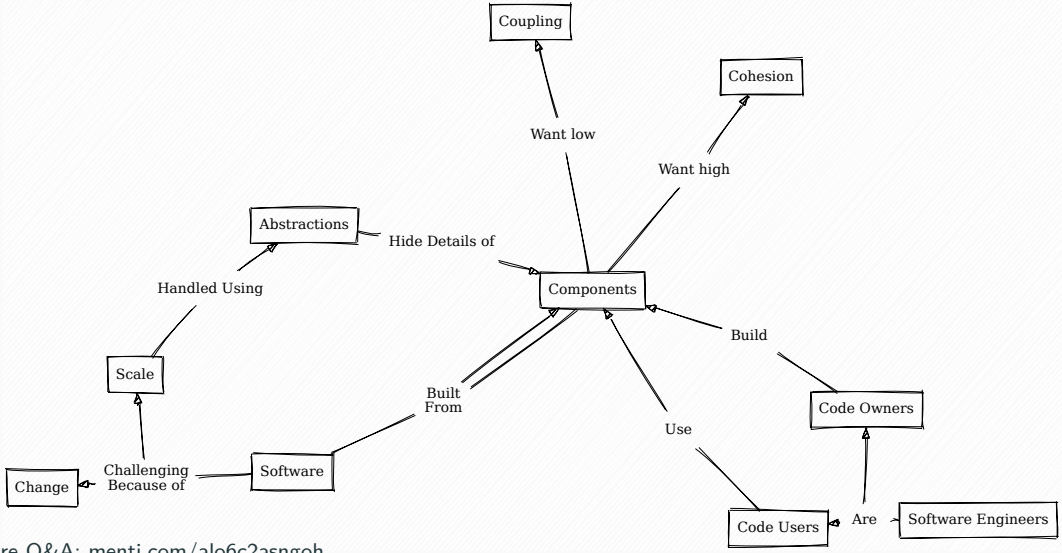
Public Domain Image (Wikimedia)

Recap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Software Cohesion

- Cohesion can be split into different *types*
  - Some are better than others
- What follows is a longish list of types
  - You might need to go over this a few times
  - Don't worry if you don't remember it all first time

Software Cohesion

- Cohesion can be split into different *types*
  - Some are better than others
- What follows is a longish list of types
  - You might need to go over this a few times
  - Don't worry if you don't remember it all first time
- Important bit is to **think about relationships between components**

Coincidental/Utility Cohesion (Usually Bad)

- Grouping of components without meaningful relationships
- Often a *misc* or *utils* module 杂项和工具块儿

```
List<Integer> list_of_int_pair(Integer x, Integer y) { ... }

List<Pair<Integer, Integer>>
cartesian_prod(List<Integer> x, List<Integer> y) { ... }

String prettyPrintList(List<Showable> s) { ... }
```

Logical Cohesion (Usually Bad)

- Grouping components that do similar logic
- Commonality can be quite superficial
- Examples:
  - All writes/reads to a database from a single place
  - All formatting functions for different datatypes

```
List<User> readUserDB() { ... }
List<Websites> readWebsiteContent() { ... }
```

Sequential/Procedural/Temporal Cohesion

- Groupings components that are used in-order/at the same time
- Related via *time*

```
void initialise() { ... }

int start_processing() { ... }
float compute_something(int) { ... }

void tear_down() { ... }
```

- *Might* have ordering/data movement constraints
  - Procedural: f(); g(); h()
  - Sequential: x = f(); y = g(x); z = h(x, y); ...

Communication/Informational Cohesion

- Components that operate on the *same data* are kept together
  - Should sound familiar from from object orientated programming!
  - The data should make coherent sense too: `int numUsers` and `bool ctrlKeyDown` don't seem very related!

```
class Point {
  private int x;
  private int y;

  ...
  void move(int offsetx, int offsety) { ... }
  bool isOrigin() { ... }
  String toString() { ... };
}
```

Functional Cohesion (Best)

- Grouping to solves a (well-defined) single problem
  - Binary search of a list: Takes a list and an element and says yes/no
  - Greatest common divisor
- Good for "solved" problems; much harder in the messy "real-world"
- Good when thinking at a higher-level of abstraction
  - The function of a web server is to serve web-pages and that (should be!) all

Recap

- Types of Cohesion
  - Coincidental/Utility Cohesion (Usually Bad)
  - Logical Cohesion (Usually Bad)
  - Sequential/Procedural/Temporal Cohesion
  - Communication/Informational Cohesion
  - Functional Cohesion (Best)

Reminder: We want **High Cohesion** when possible

Software Coupling

- Like Cohesion, can be split into different types
- Important bit is to **think about components interact**

Content Coupling (Usually bad)

- Component relies on the *internal* details of another
  - Assumes a specific algorithm, e.g. that some variable will exist after the algorithm runs
  - Assumes a data format
- Issue: if the internal details change, another component stops working!
- In general, internal details should be *hidden*
  - Remember: What the "encapsulation"/"abstraction"/"polymorphism" pillars of OOP are all about!

Common Data Coupling (Usually bad; read-only data can be okay)

- Dependency on shared data: **Global Variables**
- Issue: What if someone else changes/removes the global data you were depending on?
  - Very tricky to track changes and to debug
  - For modern systems makes *parallelism* very difficult
- We will see later in the course a better way (Singletons) to handle this

Control Coupling (Not always bad)

- Functionality of a module is changed from another
  - An additional parameter determines what a function should do
  - `void printValue(bool alsoPrintNewLine) { ... }`
- One component now needs to know control parameters for another
  - Okay if this is a small set, and all callers agree
  - Can make it harder to change a component since it needs to respect the "old" control interface

Stamp Coupling

- More information/features is passed between components than is needed
  - Gives too much power to the other component
  - For languages that copy parameters, can hurt performance

```
// Usually you don't want public here; just for the example!
class UserAccount { public String name; public int accBalance }

class View {
  public void displayName(UserAccount u) {
     // Why is the displayName function allowed to do this!
     // Does it need to know about balances?
     u.accBalance += 100000;
     System.out.println(u.name);
  }
}
```

Stamp Coupling

Better approach is to only give parameters that are needed

```
class UserAccount { public String name; public int accBalance }

class View {
  public void displayName(String name) {
     // Now we can't do this; It's an error!
     // u.accBalance += 100000;
     System.out.println(name);
  }
}
```

Data Coupling

- Two components interact through sharing data
- The more data you pass, the tighter the coupling is:
  - Passing lots of parameters to a method
  - Extra objects can reduce this, e.g. now you only couple to a single interface
    - But be careful of stamp coupling
- Not *common data coupling* as the data movement is local, e.g. via parameters

Routine/Temporal Coupling

- Methods/Components need to be called together to do something
  - `setup()`, `act()`, `teardown()`
- A *temporal* relationship exists between these
- Calling code must get the order right

Interface Coupling (Best Form)

- Interactions through a well defined API
  - Implementation details are hidden
  - Overall goal needs to be explicit: `CalculateTotal()` not `f()`

Recap

- Types of Coupling:
  - Content Coupling
  - Common Data Coupling
  - Control Coupling
  - Stamp Coupling
  - Data Coupling
  - Routine/Temporal Coupling
  - Interface

Reminder: We want **Low Coupling** when possible

Worked Example

```
1  void cleanup(boolean memfull, boolean user_req) {
2    if (user_req && IGNORE_USER_REQ) return;
3    log.write(LOG_LEVEL);
4    log.write("start cleanup");
5    collector.cleanup(memfull, mem.size, mem.start, mem.end, mem.id);
6    log.write(LOG_LEVEL);
7    log.write("end cleanup");
8  }
```

Worked Example

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```

- *Routine*: log writes are ordered
- *Common Data*: Who is setting `IGNORE_USER_REQ`, where is `mem`
- *Control*: `user_req` parameter controls behaviour
- *Content*: `mem.size` relies on `mem` having a (public) size attribute
- *Data*: Many elements of `mem` passed to collector

Improved Solution

```
1  void cleanup(boolean memfull, boolean user_req) {
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```

- Let's start by replacing data and content coupling by passing `mem` directly
  - Shouldn't directly access members of objects (they should be private)
  - The collector can decide what attributes of mem it needs
    - No reason this method needs to know about them
- This requires a non-local change: collector needs a new interface

Improved Solution

```
1  void cleanup(boolean memfull, boolean user_req) {
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3    log.write(LOG_LEVEL, "start cleanup");
4    collector.cleanup(memfull, mem);
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```

- Remove routine/temporal coupling by adding a new log method
  - Takes the log_level and message together
  - User now **can't** forget to set this

Improved Solution

```
1  void cleanup(boolean memfull, boolean user_req) {
2    if (user_req && globals.should_ignore_user_req()) return;
3    log.write(LOG_LEVEL, "start cleanup");
4    collector.cleanup(memfull, mem);
5    log.write(LOG_LEVEL, "end cleanup");
6  }
```

- Global object allows control over variable access
  - Better than global, publicly accessible variable
  - Singleton pattern (later in the course) allows for this
- Control coupling still present
  - Probably not a big issue in this case
    - Very simple control change
    - Not clear how you would use polymorphism etc

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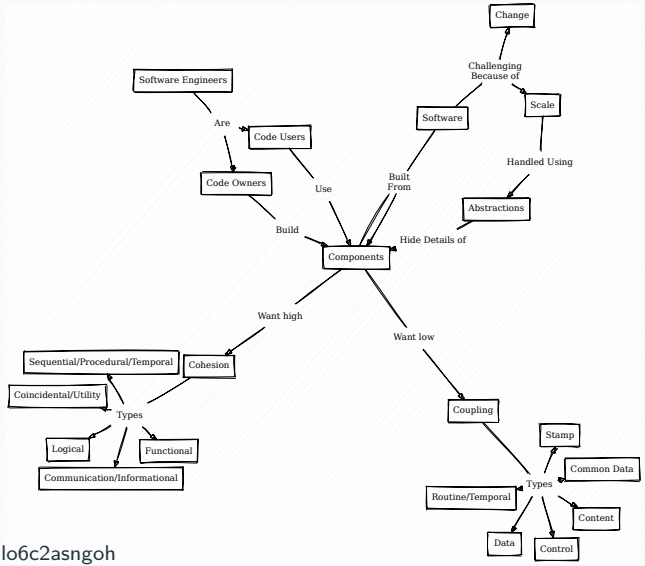
Summary



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Labs Next Week (25/1/23)

- Will be looking at programs with poor coupling/cohesion
  - Determine ways to fix it
- Please try to attend
  - Being about to read code, understand it, criticise the design, and suggest improvements would make a great exam question...

Links and Further Reading

- https://thevaluable.dev/cohesion-coupling-guide-examples/
- https://www.educative.io/answers/what-are-the-different-types-of-coupling
- https://en.wikipedia.org/wiki/Cohesion_(computer_science)
- https://en.wikipedia.org/wiki/Coupling_(computer_programming)