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SOFTWARE DESIGN AND CONSTRUCTION

10. DESIGN CONCEPTS

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Content

➔ 1. How do you design?

2. Coupling
3. Cohesion

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1.1. Design levels

Architectures/Framework
(Financial System, J2EE,...)

OOD Patterns

OOD Principles

Specific Data Structures
Algorithmic Approaches

General + OO Concepts

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Key design concepts

General	OO Specific
<ul style="list-style-type: none"> • Cohesion • Coupling • Information hiding <ul style="list-style-type: none"> • Encapsulation • Creation • Binding time 	<ul style="list-style-type: none"> • Behaviors follow data • Class vs. Interface Inheritance <ul style="list-style-type: none"> • Class = implementation • Interface = type • Inheritance / composition / delegation

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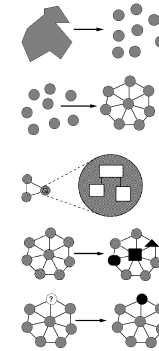
Modules

- A **module** is a relatively general term for a class or a type or any kind of design unit in software
- A **modular design** focuses on what modules are defined, what their specifications are, how they relate to each other, but not usually on the implementation of the modules themselves
- Overall, you've been given the modular design so far – and now you have to learn more about how to do the design

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Ideals of modular software

- Decomposable – can be broken down into modules to reduce complexity and allow teamwork
- Composable – “Having divided to conquer, we must reunite to rule [M. Jackson].”
- Understandable – one module can be examined, reasoned about, developed, etc. in isolation
- Continuity – a small change in the requirements should affect a small number of modules
- Isolation – an error in one module should be as contained as possible



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1.2. Good Design

- What's a design?
 - Express a idea to resolve a problem
 - Use for communications in the team members
- What's a good design?
 - Easy for Developing, Reading & Understanding
 - Easy for Communication
 - Easy for Extending (add new features)
 - Easy for Maintenance

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Two general design issues

- **Cohesion** – why are sub-modules (like methods) placed in the same module? Usually to collectively form an ADT
- **Coupling** – what is the dependence between modules? Reducing the dependences (which come in many forms) is desirable

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Cohesion

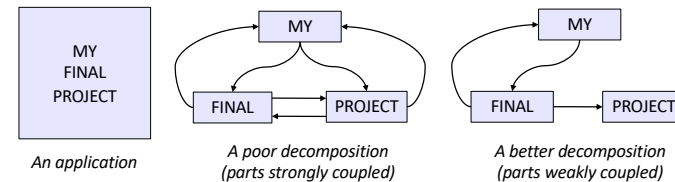
- The most common reason to put elements – data and behavior – together is to form an ADT
 - Sometimes may be other reasons, e.g. performance reasons: place together all code to be run upon initialization of a program
- The common design objective of separation of concerns suggests a module should address a single set of concerns
 - Should Item/DiscountItem know about added discount for purchasing 20+ items?
 - Should ShoppingCart know about bulk pricing?
 - Should BinarySearch know the type of the objects it is sorting?

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Coupling

Roughly, the more coupled k modules are, the more one needs to think of them as a single, larger module

- How are modules dependent on one another?
 - Statically (in the code)? Dynamically (at run-time)? And more
- Ideally, split design into parts that don't interact much



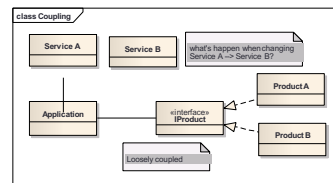
- An artist's rendition – to really assess coupling one needs to know what the arrows are, etc.

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Cohesion and Coupling

□ Coupling

Coupling or **Dependency** is the degree to which each program module relies on each one of the other modules.



□ Cohesion

Cohesion refers to the degree to which the elements of a module belong together. **Cohesion** is a measure of how strongly-related or focused the responsibilities of a single module are.

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Good design

- Easy for Developing, Reading & Understanding
- Easy for Communication
- Easy for Extending (add new features)
- Easy for Maintenance

➔ “Loose coupling and high cohesion”

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Content

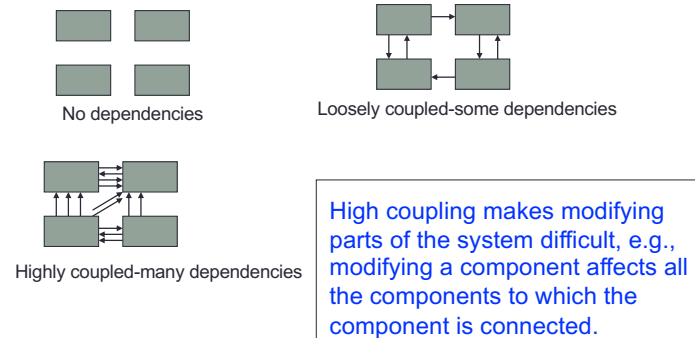
1. How do you design?

➡ 2. Coupling

3. Cohesion

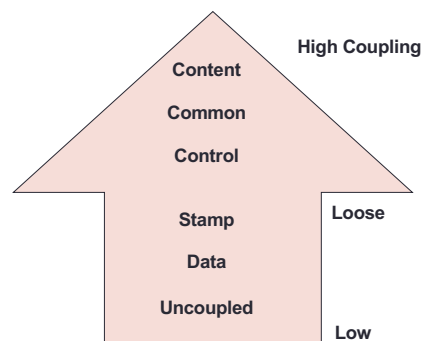
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Coupling: Degree of dependence among components



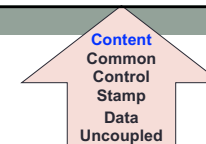
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Range of Coupling



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2.1. Content coupling



- Definition: One component references contents of another
- Example:
 - Component directly modifies another's data
 - Component refers to local data of another component in terms of numerical displacement
 - Component modifies another's code, e.g., jumps into the middle of a routine

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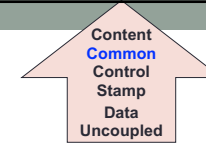
Exercise of Content Coupling

Part of program handles lookup for customer.
When customer not found, component adds customer by directly modifying the contents of the data structure containing customer data

=> How to improve?

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2.2. Common Coupling



- **Definition: Two components share data**
 - Global data structures
 - Common blocks
- Usually a poor design choice because
 - Lack of clear responsibility for the data
 - Reduces readability
 - Difficult to determine all the components that affect a data element (reduces maintainability)
 - Difficult to reuse components
 - Reduces ability to control data accesses

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Exercise of Common Coupling

- Process control component maintains current data about state of operation. Gets data from multiple sources. Supplies data to multiple sinks.
- Each source process writes directly to global data store. Each sink process reads directly from global data store.

=> How to improve?

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2.3. Control Coupling

- **Definition: Component passes control parameters to coupled components.**
- May be either good or bad, depending on situation.
 - Bad when component must be aware of internal structure and logic of another module
 - Good if parameters allow factoring and reuse of functionality

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Example 1

- **Acceptable**: Module p calls module q and q passes back flag that says it cannot complete the task, then q is passing data
- **Not Acceptable**: Module p calls module q and q passes back flag that says it cannot complete the task and, as a result, writes a specific message.

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Exercise 2 – Control Coupling

- In your video store, you might eventually create a method like this:
 - **updateCustomer(int whatKind, Customer customer)** where **whatKind** takes on the values **ADD**, **EDIT** or **DELETE**,
 - and **customer** is used for **EDIT**, but is not used at all for **ADD**, and only the **id** is used for **DELETE**.

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Exercise 3 – Control Coupling

- In your video store, you might eventually create a method like this:
 - **editCustomer(int whatKind, Customer customer)** where **whatKind** takes on the values **RETAIL**, or **AGENCY**

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2.4. Stamp Coupling

- **Definition**: Component passes a data structure to another component that does not have access to the entire structure.
- Requires second component to know how to manipulate the data structure (e.g., needs to know about implementation)
- May be necessary due to efficiency factors: this is a choice made by insightful designer, not lazy programmer.

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Example of Stamp Coupling

Customer billing system

The print routine of the customer billing accepts a customer data structure as an argument, parses it, and prints the name, address, and billing information.

=> How to improve?

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2.5. Data Coupling

- Definition: Two components are data coupled if there are homogeneous data items.
- Every argument is simple argument or data structure in which all elements are used
- Good, if it can be achieved.
- Easy to write contracts for this and modify component independently.

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Content

1. How do you design?

2. Coupling

➡ 3. Cohesion

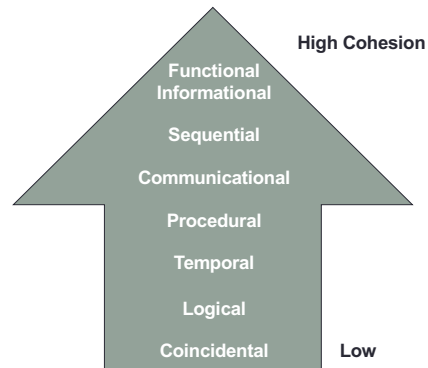
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3. Cohesion

- Definition: The degree to which all elements of a component are directed towards a single task and all elements directed towards that task are contained in a single component.
- Internal glue with which component is constructed
- All elements of component are directed toward and essential for performing the same task
- High is good

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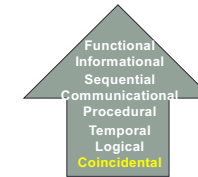
Range of Cohesion



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3.1. Coincidental Cohesion

- Definition: Parts of the component are only related by their location in source code
- Elements needed to achieve some functionality are scattered throughout the system.
- Accidental
- Worst form



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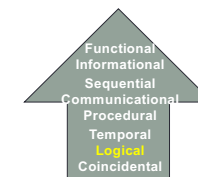
Example

- Print next line
- Reverse string of characters in second argument
- Add 7 to 5th argument
- Convert 4th argument to float

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3.2. Logical Cohesion

- Definition: Elements of component are related logically and not functionally.
- Several logically related elements are in the same component and one of the elements is selected by the client component.



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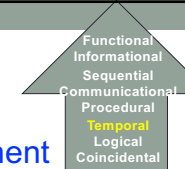
Example of Logical Cohesion

- A component reads inputs from tape, disk, and network. All the code for these functions are in the same component.
- Operations are related, but the functions are significantly different.
- => How to improve?

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3.3. Temporal Cohesion

- **Definition: Elements of a component are related by timing.**
- Difficult to change because you may have to look at numerous components when a change in a data structure is made.
- Increases chances of regression fault
- Component unlikely to be reusable.



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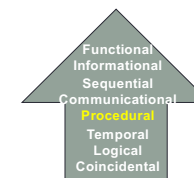
Example of Temporal Cohesion

- A system initialization routine: this routine contains all of the code for initializing all of the parts of the system. Lots of different activities occur, all at init time.
- => How to improve?

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3.4. Procedural Cohesion

- **Definition: Elements of a component are related only to ensure a particular order of execution.**
- Actions are still weakly connected and unlikely to be reusable



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Example

...

Read part number from database
update repair record on maintenance file.

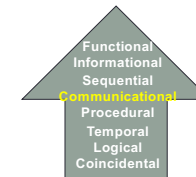
...

- May be useful to abstract the intent of this sequence. Make the data base and repair record components handle reading and updating. Make component that handles more abstract operation.

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3.5. Communicational Cohesion

- Definition: Module performs a series of actions related by a sequence of steps to be followed by the product and all actions are performed on the same data



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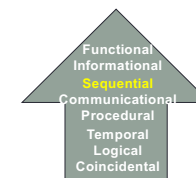
Example

- Update record in data base and send it to the printer.
- database.Update (record).
- record.Print().

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3.6. Sequential Cohesion

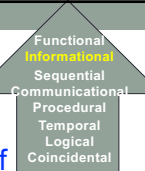
- The output of one component is the input to another.
- Occurs naturally in functional programming languages
- Good situation



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3.7. Informational Cohesion

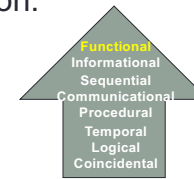
- Definition: Module performs a number of actions, each with its own entry point, with independent code for each action, all performed on the same data.
- Different from logical cohesion
 - Each piece of code has single entry and single exit
 - In logical cohesion, actions of module intertwined
- ADT and object-oriented paradigm promote



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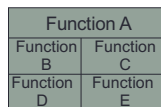
3.8. Functional Cohesion

- Definition: Every essential element to a single computation is contained in the component.
- Every element in the component is essential to the computation.
- Ideal situation.

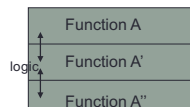


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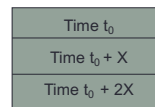
Examples of Cohesion



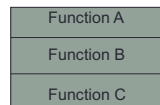
Coincidental
Parts unrelated



Logical
Similar functions



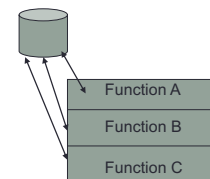
Temporal
Related by time



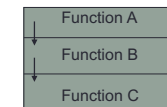
Procedural
Related by order of functions

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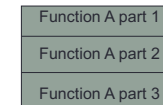
Examples of Cohesion-2



Communicational
Access same data



Sequential
Output of one is input to another



Functional
Sequential with complete, related functions

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Different kinds of dependences

- Aggregation – “is part of” is a field that is a sub-part
 - Ex: A car has an engine
- Composition – “is entirely made of” has the parts live and die with the whole
 - Ex: A book has pages (but perhaps the book cannot exist without the pages, and the pages cannot exist without the book)
- Subtyping – “is-a” is for substitutability
- Invokes – “executes” is for having a computation performed
- In other words, there are lots of different kinds of arrows (dependences) and clarifying them is crucial

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Law of Demeter

Karl Lieberherr [@](#) and colleagues

- Law of Demeter: An object should know as little as possible about the internal structure of other objects with which it interacts – a question of coupling
- Or... “only talk to your immediate friends”
- Closely related to representation exposure and (im)mutability
- Bad example – too-tight chain of coupling between classes


```
general.getColonel().getMajor(m).getCaptain(cap)
    .getSergeant(ser).getPrivate(name).digFoxHole();
```
- Better example


```
general.superviseFoxHole(m, cap, ser, name);
```

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An object should only send messages to ... (More Demeter)

- itself (**this**)
- its instance variables
- its method's parameters
- any object it creates
- any object returned by a call to one of **this**'s methods
- any objects in a collection of the above
- notably absent: objects returned by messages sent to other objects


Guidelines: not strict rules!
But thinking about them
will generally help you
produce better designs

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Coupling is the path to the dark side

- Coupling leads to complexity
- Complexity leads to confusion
- Confusion leads to suffering
- Once you start down the dark path, forever will it dominate your destiny, consume you it will



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God classes

- **God class**: a class that hoards too much of the data or functionality of a system
 - Poor cohesion – little thought about why all of the elements are placed together
 - Only reduces coupling by collapsing multiple modules into one (and thus reducing the dependences between the modules to dependences within a module)
- A god class is an example of an **anti-pattern** – it is a known bad way of doing things

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