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ITSS SOFTWARE DEVELOPMENT

# 10. DESIGN CONCEPTS

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## Content

1. How do you design?
2. Coupling
3. Cohesion

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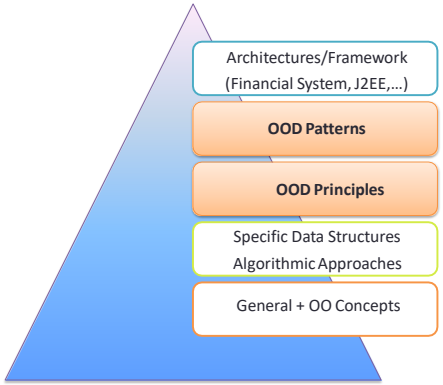
## 1.1. Design levels

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## Key design concepts

| General | OO Specific |
|---|---|
| • Cohesion<br>• Coupling<br>• Information hiding<br>  • Encapsulation<br>  • Creation<br>• Binding time | • Behaviors follow data<br>• Class vs. Interface Inheritance<br>  • Class = implementation<br>  • Interface = type<br>• 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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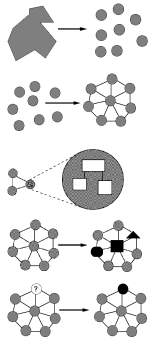
## Ideals of modular software

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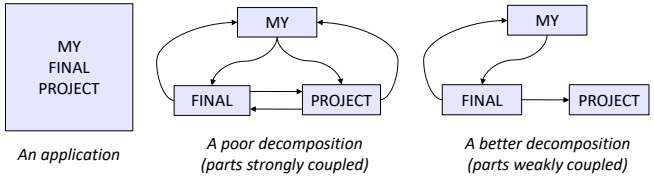
Roughly, the more coupled k modules are, the more one needs to think of them as a single, larger module

## Coupling

- 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 application* | *A poor decomposition (parts strongly coupled)* | *A better decomposition (parts weakly coupled)*

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

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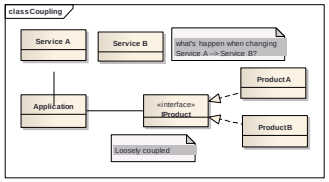
## Cohesion and Coupling

- 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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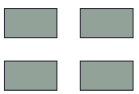
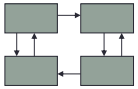
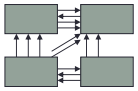
## Coupling: Degree of dependence among components



No dependencies



Loosely coupled-some dependencies



Highly coupled-many dependencies

High coupling makes modifying parts of the system difficult, e.g., modifying a component affects all the components to which the component is connected.

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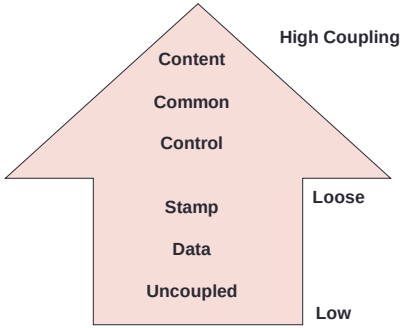
## Range of Coupling

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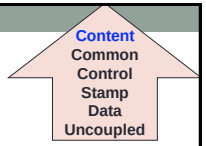
## 2.1. Content coupling




- 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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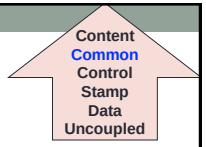
## 2.2. Common Coupling




- 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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## 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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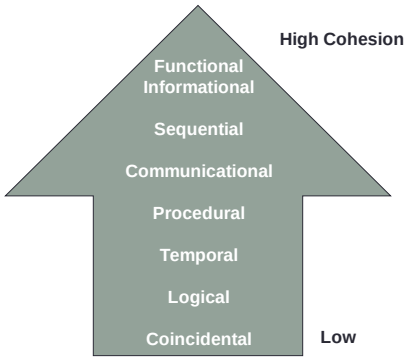
## Range of Cohesion

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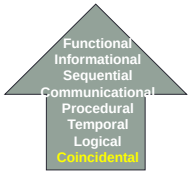
## 3.1. Coincidental Cohesion

- 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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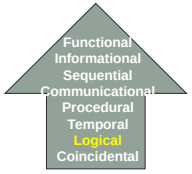
## 3.2. Logical Cohesion

- 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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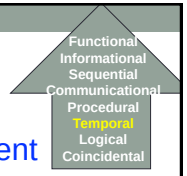
## 3.3. Temporal Cohesion




- 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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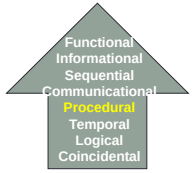
## 3.4. Procedural Cohesion

- 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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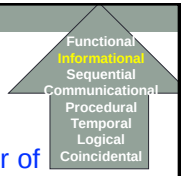
## 3.7. Informational Cohesion




- 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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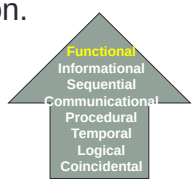
## 3.8. Functional Cohesion

- 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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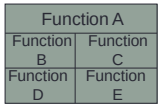
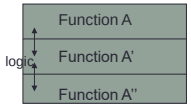
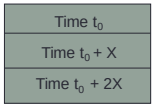
## Examples of Cohesion



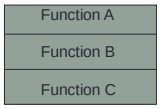

Coincidental
Parts unrelated




Logical
Similar functions




Temporal
Related by time




Procedural
Related by order of functions

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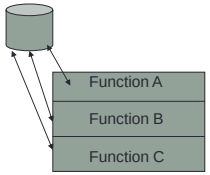
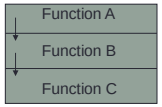
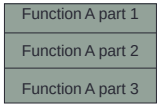
## Examples of Cohesion-2




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

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

- notably absent: objects returned by messages sent to other objects

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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