CITS4401 Software Requirements and Design
Introduction to System Design

Unit Coordinator: Dr Mehwish Nasim
Based on notes by:
Arran Stewart and Prof. Rachel Cardell Oliver

System Design

The purpose of system design is to:

Bridge the gap between the system requirements and a system implementation in a manageable way

- We use “Divide and Conquer"
- We model the new system to be developed as a set of subsystems

Summary of this lecture

- Software Design focuses on the **solution** domain (the implementation). Requirements analysis focuses on the problem domain.

Class diagram

- In system design, objects identified during analysis are grouped into **subsystems**
- The degree of **cohesion within** and **coupling between** subsystems can be used to guide subsystem decomposition

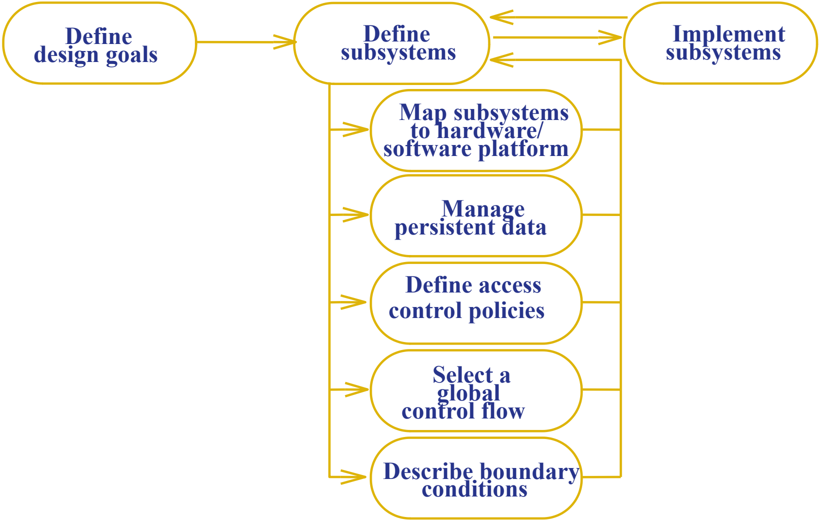
System Design is

- a creative process
  - no cook book solutions
- goal driven
  - we create a design for solving some problem
- constraint driven
  - by the function to be served and the constructions which are possible
- good designs can be recognised
  - simple, coherent, adequately meets requirements, adaptable

System Design Process

- . . . transforms the analysis model by
  - defining the design goals of the project
  - decomposing the system into smaller subsystems
  - selection of off-the-shelf and legacy components
  - mapping subsystems to hardware
  - selection of persistent data management infrastructure
  - selection of access control policy
  - selection of global control flow mechanism
  - handling of boundary conditions

System Design Activity Diagram

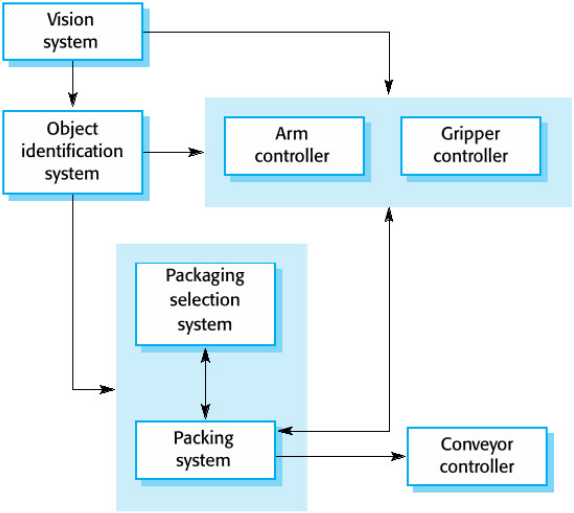


Modularity

- "modularity is the single attribute of software that allows a program to be intellectually manageable" [Mye78].
    - Monolithic software (i.e., a large program composed of a single module) cannot be easily grasped by a software engineer.
- The number of control paths, span of reference, number of variables, and overall complexity would make understanding close to impossible.
- In almost all instances, you should break the design into many modules, hoping to make understanding easier and as a consequence, reduce the cost required to build the software.

Example of system decomposition

A robotic system for packing in a factory:



Showing decomposition diagramatically

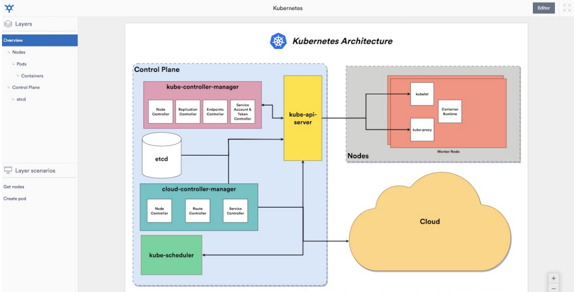
Useful for stakeholder communication

May be used as a focus of discussion by system stakeholders.

Showing decomposition diagramatically

How to do this?

Simple, informal block diagrams showing entities and relationships are the most frequently used method for documenting decomposition



Source: https://geekflare.com/create-application-architecture-diagram/

Showing decomposition diagramatically

Sometimes referred to as “box and line diagrams”

- Very abstract - they do not show the nature of component relationships nor the externally visible properties of the sub-systems.
- However, useful for communication with stakeholders and for project planning.

Information Hiding

- *Information hiding* is the idea that every module should *hide* aspects of its implementation - exposing only an undestandable *interface*
- Why do this?
  - reduces the likelihood of "side effects"
  - limits the global impact of local design decisions
  - emphasizes communication through controlled interfaces
  - discourages the use of global data
  - leads to encapsulation—an attribute of high quality design
  - results in higher quality software

Identifying Subsystems

Class diagrams in System Design

- A first step in system design is to break down the solution domain into simpler parts.
- A **subsystem** is a collection of classes, associations, operations, events and constraints that are inter-related
- Identifying subsystems usually involves backtracking, evaluation and revision of various solutions
- It is important to get the decomposition right
  - subsystems usually implemented by different teams
  - bad decomposition can lead to unworkable designs

Heuristics to Identify Subsystems

- Consider the objects and classes in your requirements analysis models.
- Try grouping objects into subsystems by
  - assigning objects in one use case into the same subsystem
  - create a dedicated subsystem for objects used for moving data among subsystems
  - minimizing the number of associations crossing subsystem boundaries
  - ensure all objects in the same subsystem are functionally related

Some further criteria

- Primary Question: what kind of service is provided by the subsystems?
- Secondary Question: Can the subsystems be hierarchically ordered (layers)?
- Criteria for selecting subsystems: most of the interaction should be within a subsystem and not across subsystem boundaries (we'll return to this idea)

Modular design

- A design is modular when
  - each activity of the system is performed by exactly one component
  - inputs and outputs of each component are well-defined, in that every input and output is necessary for the function of that component
  - the idea is to minimise the impact of later changes by abstracting from implementation details

Coupling and cohesion

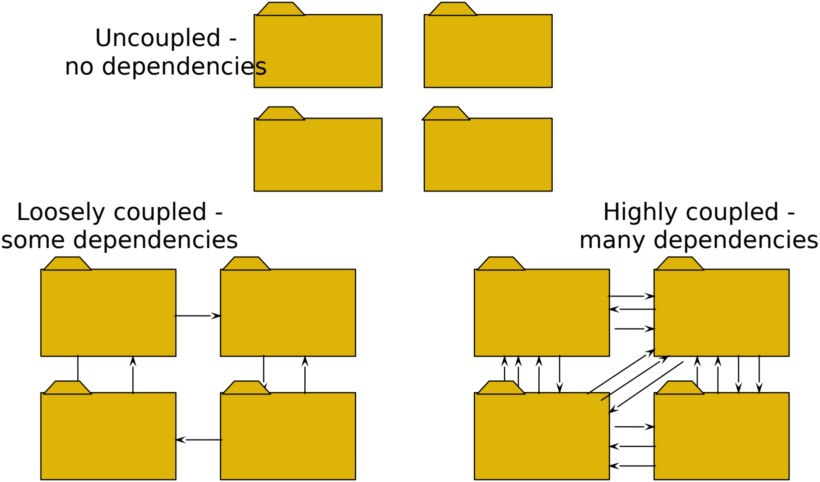
within subsystem

- Goal: Reduction of complexity while change occurs
- Cohesion measures the dependence among classes
  - High cohesion: The classes in the subsystem perform similar tasks and are related to each other (via associations)
  - Low cohesion: Lots of miscellaneous and auxiliary classes, no associations
- Coupling measures dependencies between subsystems
  - High coupling: Changes to one subsystem will have high impact on the other subsystem (change of model, massive recompilation, etc.)
  - Low coupling: A change in one subsystem does not affect any other subsystem
- Subsystems should have as maximum cohesion and minimum coupling as possible:
  - How can we achieve high cohesion?
  - How can we achieve loose coupling?

Coupling

- Coupling is the strength of dependencies BETWEEN two subsystems
- In general, the fewer dependencies between subsystems the better it is
- Why are fewer dependencies better ?
- Example:
  - 3 subsystems have high coupling with 3rd party database subsystem.
  - If database is changed then all 3 subsystems need to be modified
  - What if an extra subsystem is created to handle interface with database ?
- By reducing coupling, developers can introduce many unnecessary layers of abstraction that consume development time and processing time

Coupling levels



Coupling levels (2)

High coupling (bad)

LOOSE

Low coupling (good)

- Content coupling: when one module modifies or relies on the internal workings of another module
- Common coupling: when two modules share the same global data
- Control coupling: when one module controlling the logic of another, by passing its information on what to do
- Stamp coupling: when modules share a composite data structure and use only a part of it
- Data coupling: when modules share data through parameters
- Uncoupled: when nothing is shared

Coherence / Cohesion

- Coherence (or cohesion) is the strength of dependencies WITHIN a subsystem
- In general, the stronger the dependencies within a subsystem the better it is
- Strong coherence is best, middle level is better but low coherence must be avoided

Cohesion levels

High coherence (good)

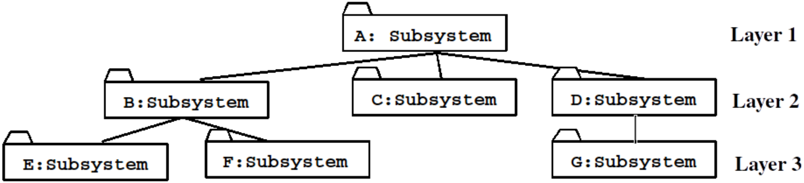
Low coherence (bad)

- Functional cohesion (best): when parts of a module all contribute to a single well-defined task of the module
- Sequential cohesion: when parts of a module are grouped because the output from one part is the input to another part
- Communicational cohesion: when parts of a module operate on the same data
- Procedural cohesion: when parts of a module always follow a certain sequence of execution
- Temporal cohesion: when parts of a module are grouped when they are processed
- Logical cohesion: when parts of a module are grouped because they logically do "the same thing" in some way
- Coincidental cohesion (worst) : when parts of a module are grouped arbitrarily (at random).

Partitions and layering

- Partitioning and layering are techniques to achieve low coupling.
- A large system is usually decomposed into subsystems using both, layers and partitions.
- **Partitions** divide a system into several independent (or weakly-coupled) subsystems that provide services on the **same level of abstraction** – i.e. they are on the same "layer"
- A **layer** is a subsystem that provides subsystem services to a higher layers (level of abstraction)
    - A layer can only depend on lower layers
    - A layer has no knowledge of higher layers

Partitions and layering



Partitions and layering

- Layer relationship
  - Layer A "Calls" Layer B (runtime)
  - Layer A "Depends on" Layer B ("make" dependency, compile time)
- Partition relationship
  - The subsystems have mutual but not deep knowledge about each other
  - Partition A "Calls" partition B and partition B "Calls" partition A

How does layering help?

- Supports *incremental development* of sub-systems in different layers.
- When a layer interface changes, (potentially) only the adjacent layer is affected.

Summary of this lecture

- Software Design focuses on the **solution** domain (the implementation). Requirements analysis focuses on the problem domain.
- In system design, objects identified during analysis are grouped into **subsystems**
- The degree of **cohesion within** and **coupling between** subsystems can be used to guide subsystem decomposition