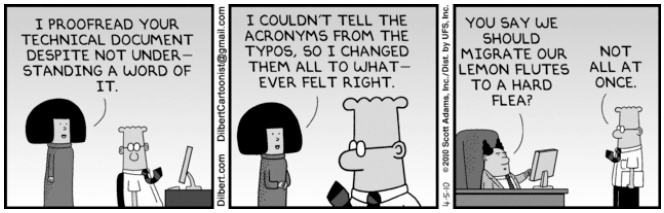
Architectural Design

Designing the Module Structure
Design Principles
Design Documentation



Architecture Design Process

Building architecture to address business goals:

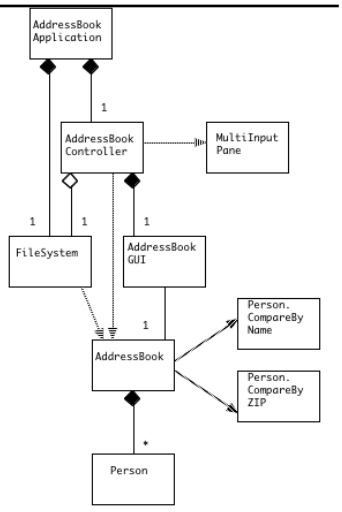
1. Understand the goals for the system
2. Define the quality requirements
3. *Design the architecture*
    1. Views: which architectural structures should we use? (goals<->architectural structures<->representation)
    2. Documentation: how do we communicate design decisions?
    3. Design: how do we decompose the system?
4. Evaluate the architecture (is it a good design?)

Decomposition Strategies

- How do we develop this structure so that the leaf modules make independent work assignments?
  - Dependencies are few
  - Decisions that might change are encapsulated
  - Interfaces are simple and well defined
- Design goals: modifiability, work assignments, maintainability, reusability, understandability, etc.
- Observed strategies did not result in independent modules
  - Use-case driven OOD, heuristics
  - MVC Pattern
- What should be done differently?
  - Why did these approaches fail?

Use Case Driven OO Process

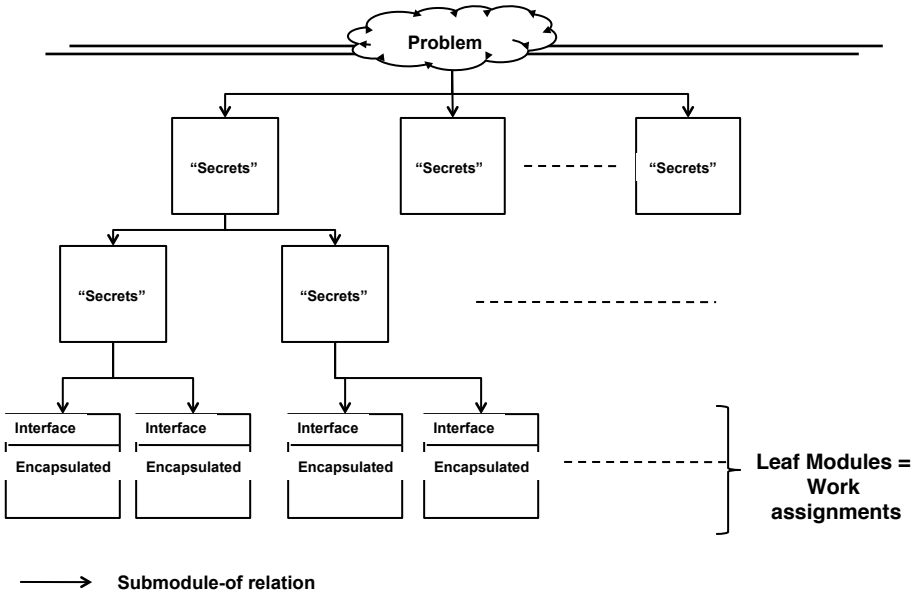
- Address book design: in-class exercise
- Requirements
- Problem Analysis
  - Identify use cases from requirements
  - Identify domain classes operationalizing use cases (apply heuristics)
- OO Design (refinement)
  - Allocate responsibilities among classes
  - Identify object interactions supporting use cases
  - Identify supporting classes (& associations)
- Detailed Design
  - Design class interfaces (class attributes and services)



Modular Structure

- Architecture = components, relations, and interfaces
- Components
  - Called modules
  - Leaf modules are work assignments
  - Non-leaf modules are the union of their submodules
- Relations (connectors)
  - submodule-of => implements-secrets-of
    - Module is an aggregate of its submodules
  - Constrained to be acyclic tree (hierarchy)
- Interfaces (externally visible component behavior)
  - Defined in terms of access procedures (services or method)
  - Services provide only access to module internals

Module Hierarchy



Design Principles

- Principle (n): a comprehensive and fundamental rule, doctrine, or assumption
- Design Principles – rules that guide developers in making design decisions consistent with overall design goals and constraints
  - Guide the decision making process of design by helping choose between alternatives
  - Embodied in methods and techniques (e.g., for decompositions)

Three Key Design Principles

- Most solid first
- Information hiding
- Abstraction

Principle: Most Solid First

- View design as a sequence of decisions
  - Later decisions depend on earlier
  - Early decisions harder to change
- Most solid first: in a sequence of decisions, those that are least likely to change should be made first
- Goal: reduce rework by limiting the impact of changes
- Application: used to order a sequence of design decisions
  - Generally applicable to design decisions
  - Module decomposition – ease of change

Information Hiding

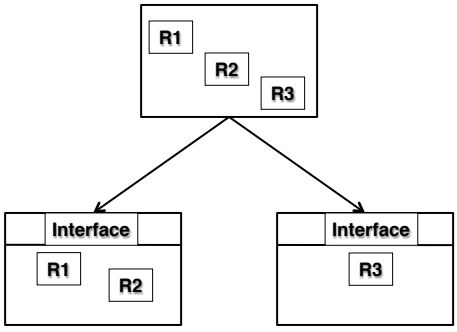
- Design principle of limiting dependencies between components by hiding information other components should not depend on
- An information hiding decomposition is one following the design principles that (Parnas):
  - System details that are likely to change independently are put in different modules
  - The interface of a module reveals only those aspects considered unlikely to change
  - Details other modules should not depend on are encapsulated

Decomposition Strategy

- Decompose recursively
  - If a module holds decisions that are likely to change independently, then decompose it into submodules
  - Decisions that are likely to change together are allocated to the same submodule
  - Decisions that change independently should be allocated to different submodules
- Stopping criteria
  - Each module contains only things likely to change together
  - Each module is simple enough to be understood fully, small enough that it makes sense to throw it away rather than re-do
- Define the Interfaces
  - Anything that other modules should not depend on become secrets of the module (e.g., implementation details)
  - If the module has an interface, only things not likely to change can be part of the interface

Effects of Changes

- Consider what happens to communication among module developers
- Suppose we have groups of requirements R1 – R3:
  - R1 and R3 are related and likely to change together
  - R2 is likely to change independently
- Suppose we put R1 and R2 in the same module and assign to different teams
  - What happens when R1 changes?
  - R2?
- Suppose R1 and R3 are put in the same module?



Abstraction

- General: disassociating from specific instances to represent what the instances have in common
  - Abstraction defines a *one-to-many relationship*
    E.g., one type, many possible implementations
- Modular decomposition: Interface design principle of providing only essential information and suppressing unnecessary detail

Abstraction

- Two primary uses
- Reduce Complexity
  - Goal: manage complexity by reducing the amount of information that must be considered at one time
  - Approach: Separate information important to the problem at hand from that which is not
    - Abstraction suppresses or hides “irrelevant detail”
    - Examples: stacks, queues, abstract device
- Model the problem domain
  - Goal: leverage domain knowledge to simplify understanding, creating, checking designs
  - Approach: Provide components that make it easier to model a class of problems
    - May be quite general (e.g., type real, type float)
    - May be very problem specific (e.g., class automobile, book object)

Exercise: Address Book Data Module

- Design the “model” module
  - What should be hidden?
  - What services should it provide?
  - What else does the user need to know to use the module correctly?

Lessons on Patterns

- Patterns are often misused
- Using a pattern correctly requires understanding it
  - “Correctly” – such that the pattern’s design goals are realized in your design
  - “Understanding” – you understand what the pattern is supposed to accomplish, how it works, and how to apply it in your context

Lessons on Patterns (2)

- A pattern is a three part rule that expresses a relation between [Schmidt]:
  1. A particular problem context
  2. A set of competing forces (goals and constraints) in that context
  3. A software *configuration* that *resolves* the set of forces
     - *Configuration ==* objects, interfaces, relations
     - *Resolves ==* concurrently addresses the goals and constraints

Summary

- Heuristics and patterns are guidelines
  - Do not guarantee qualities
  - Must understand how and why they work to apply effectively
- Principles are more direct – achieve qualities *by construction*
- Good design requires careful thinking
  - Which goals are we trying to achieve
  - How design decisions address those goals

Documenting a Module Structure

Communicating Architectural Decisions

Architecture Development Process

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Purpose and Audience

- To understand what to communicate, consider who will use it and for what purpose
  - Coders/maintainers: defines the build-to spec.
    - Where to put/find specific parts of the system (e.g., where functionality is implemented)
    - Embodies system qualities as design decisions
    - Constrains detailed design and implementation
  - Quality stakeholders
    - How the system satisfies design goals
    - Why specific design decisions were made
  - Testers: which parts should be tested to establish specific qualities

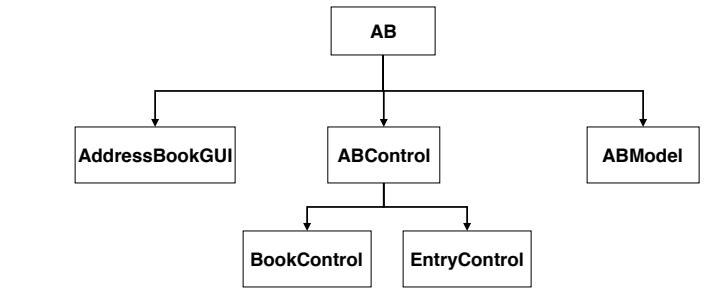
Communicating Architecture

- Provide a set of views addressing key qualities
- For each architectural view deployed
  - Which architectural structures are used (components, relations, and interfaces)
  - Which quality requirements are being addressed in the structure (why)
- Within a given structure
  - How to use/navigate the structure to find specific information
  - What design decisions are made
  - Rationale for important decisions

Example: Module Structure Documentation

- **Module Guide**
  - Documents the module structure:
    - The set of modules and the responsibility of each module in terms of the module's secret
    - The "submodule-of relationship"
  - Document purpose(s)
    - Guide for finding the module responsible for each aspect of the system behavior
    - Provides a record of design decisions (rationale)
- **Module Interface Specifications**
  - Documents all assumptions user's can make about the module's externally visible behavior (of leaf modules)
    - Access programs, events, types, undesired events
    - Design issues, assumptions
  - Document purpose(s)
    - Provide all the information needed to write a module's programs or use the programs on a module's interface

Address Book Modular Structure



Submodule-of

Module

Excerpts From The FWS Module Guide (1)

1. AddressBookModel

The ABModel provides the services needed to store and retrieve information about address books and the information contained in an address book.

Services

Provides the services needed to

Secret

How to use services provided by other modules to start and maintain the proper operation of a FWS.

Excerpts From Module Guide (2)

2. AddressBookControl Modules

The ABControl modules consist of those programs that need to be changed if the operations on address books or address book entries are changed. The secrets of the AB modules include how the model is used to store or retrieve data requested by the GUI and any algorithms used to manipulate that data. It provides the services necessary to fulfill user requests.

2.1. Wind Sensor Device Driver

Service

Provide access to the wind speed sensors. There may be a submodule for each sensor type.

Secret

How to communicate with, e.g., read values from, the sensor hardware.

Note

This module hides the boundary between the FWS domain and the sensors domain. The boundary is formed by an abstract interface that is a standard for all wind speed sensors. Programs in this module use the abstract interface to read the values from the sensors.

A Method for Specifying Interfaces

- Define services provided and services needed (assumptions)
- Decide on syntax and semantics for accessing services
- In parallel
  - Define access method effects
  - Define terms and local data types
  - Define visible states of the module
  - Record design decisions
- Define test cases and use them to verify access methods
  - Cover testing effects, parameters, exceptions
  - Test both positive and error use cases
- Can use Javadoc or similar

Benefits Good Module Specs

- Enables development of complex projects:
  - Support partitioning system into separable modules
  - Complements incremental development approaches
- Improves quality of software deliverables:
  - Clearly defines what will be implemented
  - Errors are found earlier
  - Error Detection is easier
  - Improves testability
- Defines clear acceptance criteria
- Defines expected behavior of module
- Clarifies what will be easy to change, what will be hard to change
- Clearly identifies work assignments

For Your Projects

- Develop at least one architectural view
- Include rationale for the overall design
- Include any significant design decisions
- Outcome: should be able to trace from requirements to code objects

Questions?

```
/** The Data Banker provides synchronized storage for sensor readings.
 ** <ul>
 ** Services Provided
 ** <ol>
 ** <li>    Initialize the set of stored sensor readings.
 ** <li>    Store a new sensor reading, maintaining only the necessary
 ** history, and retrieve the current sensor reading history, keeping
 ** reads and writes synchronized.
 ** </ol>
 ** <p>
 ** Synchronization: Supports concurrent access to read/write methods.
 ** Read or write operations on a vector of sensor readings act as atomic
 ** operations.
 ** <p>
 ** Exceptions: N/A
 ** <p>
 ** Uses: SensorReading
 **/
public class DataBanker
{
    /** HistoryLength is the number of wind speed readings that are retained
     **/
    public static final int HistoryLength = 4;

    /** Initialize the DataBanker for a type of sensor reading.
     ** <p>
     ** Initializes a vector of elements of type sensorType of length
     ** HistoryLength for each sensor of sensorType with initial values of null.
     **
     ** @param sensorType    The String name of the sensor type
     ** @param numSensors    Number of sensors.
     **/
    public static void initialize(String sensorType, int numSensors)
    {
        Vector<SensorReading> v = new Vector<SensorReading>();
        for (int j = 0; j < HistoryLength * numSensors; j++)
            v.addElement(null);
        map.put(sensorType, v);
    }
```

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