Lecture Set #13: Algorithms and Design

1. Algorithmic Design
2. Algorithmic Analysis
3. System Design

What is an algorithm?

- The method used to solve a particular problem is called an **algorithm**.
- **Example**: Make a peanut butter and jelly sandwich:
  - Get a loaf of bread
  - Remove two slices
  - Get a jar of peanut butter
  - Get a knife
  - Open the jar
  - Using the knife, get some peanut butter and spread it on one slice
  - ...blah, blah, blah
- There is essentially **one sequential process** being described.
Low-Level Design: Pseudo-Code and Algorithms

- We have already talked about pseudo-code as a design technique
  - NOT English
  - NOT a program
  - Something in-between
    - Captures the logic, flow of desired code
    - Note that pseudo-code could be translated into any programming language (not just Java)
- Pseudo-code is used to represent algorithms = step-by-step solutions to problems
- Algorithms are often coded as single methods

Concerns at the Algorithmic Level of Design

- Correctness
  - Does my algorithm correctly solve the problem?
- Efficiency
  - Is my algorithm fast enough for the job?
- Clarity
  - Is my algorithm understandable? and is it implementable?
Putting all your eggs in one basket

- Problem: I have 16 baskets full of 12 eggs each; I want to “put all of my eggs in one basket”. 😊
- Algorithm #1 ??
  - Combine #1 and #2
  - Combine result with #3
  - Combine result with #4; etc.
- Algorithm #2 ??
  - Combine #1, #2; combine #3, #4; combine #5, #6…
  - Combine <1,2> with <3,4>; Combine <5,6> with <7,8>…
  - Combine <1,2,3,4> with <5,6,7,8>
  - Combine last two …

Algorithmic Efficiency Analysis

- Measuring which is better for time.
- What if the time required for the merging machine is constant?
  - both have 15 calls to the merging machine when there are 16 baskets to merge
  - what if the number of baskets is another value?
- What if the time required for the merging machine is dependent on the number of eggs being merged?
  - for example 1 second per egg (i.e. merging two baskets of 12 each takes 24 seconds)
  - this takes more math when you want to generalized on the number of baskets
Big-O Notation

- Categories of formulas
- What takes over as $n$ approaches infinity
  - $O(\log n)$
  - $O(n)$
  - $O(n \cdot \log n)$
  - $O(n^2)$
  - $O(n^2 \cdot \log n)$

Coding vs. Software Design

- **Coding**: writing of (Java) code to implement classes, methods, etc.
  - Projects so far have been primarily coding
  - We have told you what to code
- **Design**: determination of what to code
  - What classes are needed?
  - How should classes interact?
  - What methods belong in each class?
  - How should method functionality be implemented?
Interfaces and Design

- Next level up the design hierarchy: what methods should go in classes?
- This information can be captured using interfaces
- These interfaces can also be used to identify opportunities for polymorphism (reusable code)
- Rules of Thumb
  - Keep interfaces small
  - Think carefully about operations needed “between classes”
  - Use interfaces to support polymorphism (and keep code size down)

Upper Levels of Software Design

- Where do ideas for classes, interactions between classes come from?
  - Software development part of larger system design process
  - System design requires identifying what system users expect system to do
  - These user requirements often suggest system components and how they fit together
- First part of software design: understand system design
System Design: What Is It?

- **System design** is concerned with:
  - coordinating a collection of entities…
  - … to achieve a complex process
- Each entity has its own responsibilities to the others to achieve an overall objective
- E.g. Running a restaurant involves a coordinated interaction of many entities within one system:
  - Entities: Chef, owners, waiters, etc.
  - System: Restaurant

Other Examples of Systems

**Classroom environment**: Lecturers, TAs, students, …

**Library**: Circulation (checkout and return), indexing services (online catalogue), library users, book buyers, shlefers, …

**Pharmacy**: Patients (and medical records), pharmacists, doctors, drug retailers, the pharmacy (products in stock), …

**Video game**: Race cars, motorcycles, warriors, space ships, death squads, monsters, aliens, mutants, guns, swords, weapons of mass destruction, cute Japanese cartoon animals with huge eyes, …

Pikachu visits Doom3
Essential Questions

- **Challenges**: System design is very hard. Once the number of entities and interactions becomes large, it is very hard to foresee all the possible consequences of these interactions.

- **Essential Questions**:
  - What is the **desired behavior** of the program (as a whole)?
  - system design - overview
  - What are the **entities** that produce this behavior?
  - classes or objects
  - How do these entities **interact**?
  - API for each class
  - How does each one **work**?
  - algorithm for each task

Behavior

- **Specifying Desired Behavior**: A **use case** is a description of the interaction of a user and the system. It includes:
  - Prerequisites (**pre-conditions**): What must hold for this use case to arise?
  - Possible actions and interactions: What happens?
  - Effects (**post-conditions**): What conditions hold, what changes have taken place, as a result of these actions.

- **Example**: Customer in a restaurant.
  - **Pre-conditions**:
    - **Customer**: hungry and has money
    - **Restaurant**: has food
  - **Actions**: get menu, order food, be served, eat, pay, leave
  - **Post-conditions**:
    - **Customer**: less hungry and less money
    - **Restaurant**: more money and less food.
Principal Design Elements

- **Components:**
  - What are the entities that make up our system?
  - What are the roles they play?
  - How do we separate the system into distinct units?
- **State:** What is the current status/state of the units that define our system?
- **Contract:** What are the responsibilities and services associated with each component? What guarantees does it make?
- **Communication:** How do components request interactions with each other?
- **Example: Pharmacy Store System**
  - **Components:** Pharmacist, customers, doctors, prescription, store stock.
  - **State:** For a patient: Current prescriptions, number of times refilled, date of last refill, health insurance information.
  - **Fill-prescription Contract:** A valid prescription is presented by the customer. Check patient records and inform of possible side-effects. Dispense the prescription. Update patient records. Deliver medication to patient.

Relationship to Java

- **System:** A Java program
- **Components** (or community members): Java class objects
- **State:** Each object stores information about its current status. These are stored in class instance variables.
- **Contract** (or specification): This is called an API (Application Programmer Interface), or simply an interface. This is the external (class user) view of an object. It provides an abstraction of what the object does, without indicating how it is implemented. The interface provides the signatures, that is, details on how invoke, each action.

  The contract is implemented by the object’s class methods.