Transition: analysis to design

Now know "what"
Time to focus on "how"

Decided what to do
Might as well do it right
System design

- **Goal, in general: solve the problem**
  - Goal of OOD: convert OOA results into something that can be implemented
    - e.g, as software (and/or hardware, services, …)

- **Key considerations (a.k.a. tradeoffs):**
  - Cost-effectiveness of solution vs. design/coding effort
    - Can reduce effort by applying patterns, idioms, 3rd party, …
  - Reusability – maybe worth investing effort in
    - Could save lots of effort later
    - But can overly complicate a simple problem if overdone
Design in practice

- No "cookbook" method – no "right" way
  - But have some basic principles for guidance
  - And have a growing knowledge base on patterns
- Is an exercise in problem solving, so attack using the usual strategies
  - Divide/conquer – solve sub-problems to solve whole
  - Top-down approach, with stepwise refinements
- Unlike analysis – leave room for creativity
  - Concentration → incubation → inspiration
Design activities

- Consider "real" use cases
  - Sharpen focus to actual technology, specific user interfaces, particular other systems, ...
- Package coherent subsystems together
  - And organize the packages into overall system architecture
- Model the interactions between objects
  - Including interactions between packages
- See Draft Project: System Design
System architecture

- High-level descriptions of the system
  - Broad focus on significant structural elements
    - Subsystems, packages, interfaces to other systems
  - Level of detail all developers & stakeholders can follow
    - Use case views, deployment views, design views, …

- Many basic architecture types – vary by purpose
  - Pipes & Filters – for flexibility without user interaction
  - Repository – favor big data storage-retrieval systems
  - Layers – considered the "object-oriented architecture"
    - Much more to come …
Diagramming packages

- Groups of classes – good for architectural modeling
  - Abstraction benefit: lots of concepts modeled as one
    - A handy way to "divide and conquer" the problem

- Idea is to separate functional subsystems
  - Many associations among classes in same package
  - Few associations between packages

- Side benefit: team members can split work by packages
  - Works best with "clean" interfaces
Application logic layer partitions

- Partition by logical units (organize as packages)
  - Refer to collaborations on CRC cards – look for:
    - Minimal coupling between packages (few collaborations)
    - Highly cohesive within packages (many collaborations)
- CS 48: Agree on package interfaces as a team
  - Then split up the work accordingly
- At least split domain from service classes
  - e.g., report generators, database interfaces, offscreen graphics builders, …
Basic 3-tier architecture

- Can have many layers, but 3 are basic:
  1. **Presentation** layer – windows, reports, GUIs
  2. **Application logic** layer – domain, object services
  3. **Storage** layer – persistent data, basic services
About layered architectures

- Concept – each layer is a base for implementing layers above it
  - Ideally, knowledge and contact is one-way: down ↓
  - Lower layers don’t even know upper layers exist
- What are some good reasons to use layers?
  - Reduce complexity – separate the domain from the implementation as much as possible
  - Increase modifiability, and reuse potential
  - Easy to plug in off-the-shelf and 3rd party stuff
Layers can free up our thinking: e.g., wxWidgets architecture

<table>
<thead>
<tr>
<th>wxWidgets API</th>
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<td>wxWidgets Port</td>
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Data services sub-layers

- Goal: insulate domain classes from storage details
- How? – interface classes
- Note: often start design by choosing services (inc. software and hardware choices)
Storage and network layer(s)

• The lowest and *least coupled* layers
• 3 main ways to store and/or transmit data
  – 1. Object databases, and remote object interaction
    • Most abstract, so easiest to adapt (high level access)
  – 2. Relational databases, and query-response sessions
    • Mid-level access (records ↔ objects) – need an interface
  – 3. Do-it-yourself schemes – lowest level access
• Best to decide early
  – And whether to buy or build new, adapt old, …
Separating models and views

- Basic principle: domain (model) never directly contacts the presentation (view)
  - But is ready to answer requests from the view
  - Or can contact indirectly by "broadcasting"

- Related idea: view should not control the domain
  - Okay if GUI signals an event (then model takes over)
  - Often use a mediator, an "application coordinator"
Model-view separation benefits

- Reuse model with different views
- Maybe reuse view with different models
- Have multiple views of the same model
  - Even simultaneously!
  - e.g., view model from many angles
- Side benefit – complexity management
  - Benefit here – don't have to worry about display while working on the model
- Reflects a recurring OOP themes – encapsulation and information hiding
About domain "controllers"

- Not usually a domain concept
  - Added to the model during design
- They tie the system to external events
  - e.g., classes a GUI will know about
- Common types:
  - Façade controller – represents whole system, overall business, "world" – e.g., an application coordinator
  - Role controller – mimics a real-world role
  - Use case controller – handles sequences of events, monitors use case progress
Interaction diagrams

- **Dynamic views** of interacting objects
  - Usually starts by system event (i.e., external message)
  - Receiving object either handles alone, or passes message along (internal messages)

- **Why bother diagramming interactions?**
  - Get big picture view – better design, code, system
  - Easier to change drawing than code

- Do together with class diagrams/specifications
  - Links in diagrams indicate visibility between classes

- 2 basic types: sequence and communication
Sequence diagrams

- Use for simpler interactions – sequence easily shown as top-to-bottom interactions
Communication diagrams

- Handy for more complicated interactions – show sequences by numbering the interactions

![Collaboration diagram](image)
Notation for interactions

- **Class vs. instance** –
  - `Sale` – class name for static methods only
  - `mySale:Sale` – object name:type for other

- **Messages** – shown along link line
  - Must number in communication diagram
  - Show parameters too (with optional types)
    - e.g., `2: cost:=price(amount:double)`
  - And return values if not void
    - e.g., `1.1: items:=count():int`

- **Iteration** – use * and optional [iteration clause]
  - e.g., `3*: [i:=1...10]li:=item(i):LineItem`
More notation for interactions

- **Conditions** – [condition:boolean]
  - e.g., \[new sale\].create() \[\rightarrow \]

  \[\textbf{POST}------------------------:Sale\]

- **Use "stack" icon for multi-objects (collections)**
  - Note: message may be to the collection object itself (e.g., a list), or to the individual elements if *

- **Show algorithms as notes (dog-ear symbol)**
  - But only need if tricky or otherwise relevant
  - Or if using a CASE tool that translates note to code
Design principles

- Not exactly "rules" – instead things to consider
  - Should lead to high quality designs
    - Easier to maintain, understand, reuse, and extend
    - e.g., expert, low coupling, high cohesion, do-it-myself
- Note: Larman labels some as "patterns"
  - General Responsibility Assignment Software Patterns
  - Says assigning responsibilities = "desert island skill"
    - Also notes: "one person's pattern is another's primitive building block" to acknowledge not exactly design patterns
The expert principle

- Assign responsibility to class that has the necessary information
  - i.e., the "information expert"
- Avoids passing info between objects
- Still have collaboration as objects help others
  - e.g., Sale knows about all LineItems, and LineItems know quantity (and get price from Specs)
    - So let LineItem calculate subtotal()
    - Sale accumulates total from subtotals
- Main benefit: encapsulation maintained
  - Easier to program, maintain, extend independently
Low coupling

- Minimize dependencies between classes
  - Note how expert principle does this too
  - e.g., Sale does not contact ProductSpecification directly – LineItem does that instead; otherwise, Sale needs parallel collection of ProductSpecifications

- So fundamental it influences all design decisions
  - Is an "evaluative" pattern – used to rate design quality

- Supports independent classes
  - More reusable, less subject to changes elsewhere, easier to program, …
High cohesion

- Refers to functional cohesion
  - Means no class does too much work – especially not a bunch of unrelated things
  - Basically should avoid "bloated" classes
    - Hard to understand, maintain, reuse, …
    - Usually means other classes should take some responsibilities
      - Like an overworked manager – should delegate more

- Rule of thumb: insure all parts of a class are somehow related – all attributes and operations
  - Working together to provide "well-bounded behavior"

- Benefits – the usual list, plus greater simplicity
Events, states, and transitions

- **Event** – a significant occurrence
  - e.g., telephone receiver taken “off hook”
- **State** – condition of an object at a moment in time (the time between events)
  - e.g., telephone “idle” between being placed on hook and taken off hook
- **Transition** – relationship between two states as an event occurs
  - e.g., when “off hook” event occurs, transition from “idle” to “active” state
State diagrams

- Purpose: to model the changing states of complex objects
Utility of state diagrams

- Normally not useful for internal events
  - An internal event is one that is triggered by an object inside the system boundary
  - Interaction diagrams already cover internal events
- Useful for monitoring (whole) system sequences
  - Idea is to model the changing system states during the course of a use case
- Previous students in the CS project class said they are *very* useful tools for making sure all important states and sequences are managed properly
  - So don’t just take the instructor’s word for it!
Helps designer insure things are done in the correct order

Other notation: transition actions, guards, nested states – see Reading #11
More GRASP principles

- **Polymorphism** – if behavior varies *by type*
  - Assign responsibility for the variation to the types
    - Do not test for type or use other conditional logic!

- **Indirection** – to reduce coupling
  - Assign responsibility to *intermediate* class or interface

- **Pure fabrication** – artificial, non-domain class
  - e.g., encapsulate a cohesive set of responsibilities

- **Protected variations** – for variable/unstable parts
  - Assign responsibilities to *stable* interfaces
Software realities

- **Do-it-myself** principle (a.k.a., animation pattern)
  - Objects must do for themselves what normally is done to the real world objects they represent
  - e.g., in real world, somebody draws the figure – in software, figure draws itself: `figure.draw()`
  - Another e.g., `trajectory.map()` – normally would be mapped by outside observer if at all

- Assume/insure **basic services** are always available
  - i.e., get/set for attributes, add/remove/… for lists, …
  - So no need to include in class diagrams or specs
Inheritance – a software idea

- An object-oriented software construct for implementing generalization relations
  - Can reuse code by inheriting it with new code
- Allows consistent handling of different subtypes
  - As long as they have a common supertype
- But can be overdone!
  - Common error: forcing an “is a” relationship
    - e.g., `class Easel : public Canvas` – okay, but limited, because Easel cannot inherit from any other class now
  - Alternative is composition
    - e.g., more flexible to let Easel have a Canvas to draw on
Abstract types

- Always supertypes, by definition
  - Have no concrete existence in model
  - Definition – class A is an abstract type if every instance of A must be a subtype of A
  - e.g., Thing – an abstract type
    - How to draw a Thing? Describe a Thing? …
    - Must have a concrete Thing to draw, describe, …
  - Certain operations must be implemented by subtypes

- Abstract types are central to many design patterns
  - pure abstractions are more flexible than concrete types
  - actually just define interfaces for “families” of types
A note about subtypes & states

- Avoid using subtypes of a concept to represent changing states of that concept
  - Usually better to consider a State concept
    - State is an abstract type – with concrete subtypes
    - The original concept “is in” one State or another

- Exception is when it really makes sense to do
  - e.g., a Caterpillar becomes a Butterfly
  - i.e., a complete metamorphosis – change in state results in different attributes and associations
Design patterns introduction

- “Tricks of the trade” for OO designers
  - Tried and true solutions to recurrent problems
    - Generally apply to various situations – e.g., Façade Pattern
    - Usually reflect basic design principles
- “Gang of Four” (GoF) patterns – seminal catalog
  - Four essential elements:
    1. A meaningful name – elevates thought to higher abstraction
    2. A problem description – where the pattern can apply
    3. The solution – like a template to apply the pattern
    4. Consequences – results and trade-offs
- Recurring theme: “encapsulate what varies most”
Types of GoF design patterns

- 7 are *structural* patterns – composition of classes/objects
  - e.g., Adapter
    - Problem: tool has interface X, client prefers interface Y
    - Solution: Adapter satisfies X, but looks like Y
    - Consequences: don’t reprogram X, and don’t distort Y to satisfy X
  - Bridge, Composite, Decorator, Façade, Flyweight and Proxy
- 5 are *creational* patterns – for creating objects
  - Abstract Factory, Builder, Factory Method, Prototype, Singleton
- 11 are *behavioral* patterns – ways classes/objects interact
  - e.g., Chain of Responsibility, Command, and … 9 more
- See cs.ucsb.edu/~mikec/cs48/misc/Design_Class_Diagrams.htm
User interface design

- Major goal: match the skills, experience and expectations of its anticipated users
- Consider “human factors”
  - People have limited short-term memory, they make mistakes, and they are not all the same
- Some basic principles of UI design
  - User-oriented, not computer-oriented
  - Consistency – and especially minimal surprise
  - Recoverability, and guidance
User Interface issues

- Two fundamental problems to solve
  - How should information from the user be provided to the computer system?
  - How should information from the computer system be presented to the user?
- Many interaction styles – each has a place
  - Direct manipulation
  - Menu selection
  - Form fill-in
  - Commands – and (ideally) natural language
Sometimes multiple interfaces

Figure from Ian Sommerville, *Software Engineering 8th edition*, Chapter 16
UI design process

Figure from Ian Sommerville, *Software Engineering 8th edition*, Chapter 16