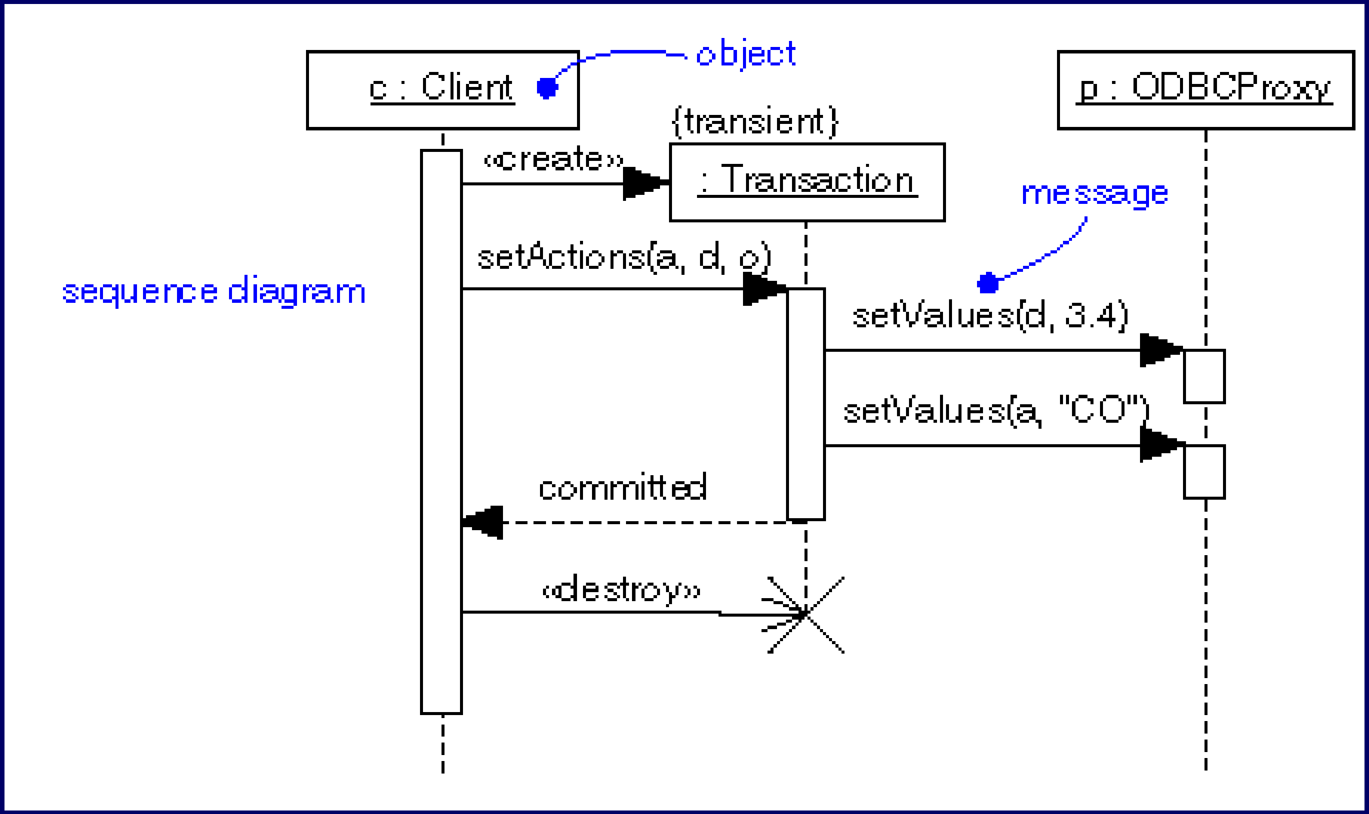
About domain “controllers”

- 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
    - e.g., `setEnabled(false)` in Swing – means not ready yet

Interaction diagrams

- Dynamic views of *interacting objects*
  - Starts by system event (*external message*)
  - Receiving object either handles alone, or passes message along (*internal messages*)
    - Links in diagrams indicate visibility between classes
- Why bother diagramming?
  - Easier to change drawing than code
  - Get big picture – better design, code, system
- Do together with class diagrams/specifications
- 2 basic types: sequence and communication

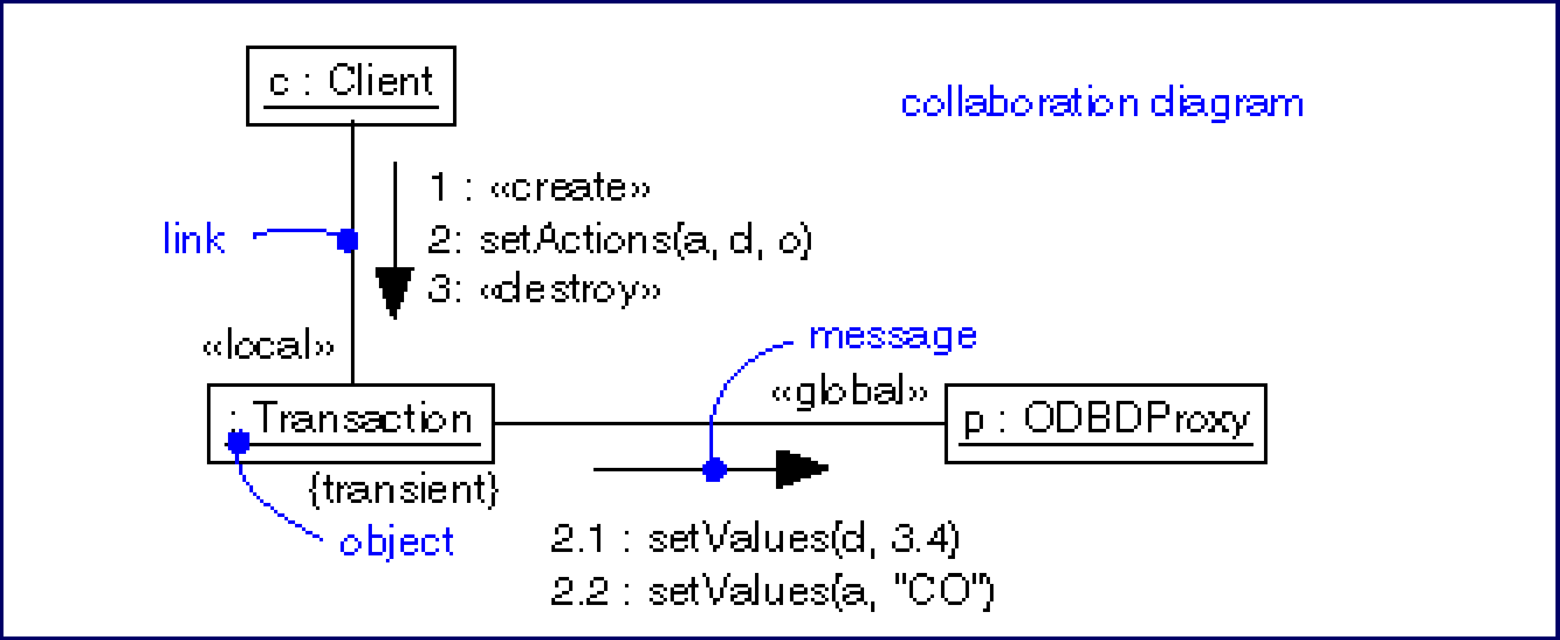
Sequence diagrams



- 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



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.,
    ```
    1:[new sale]create() →
    :POST------------------------:Sale
    ```
  - See fig. 15.30 (p. 244) for mutually exclusive conditions
- 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

Design principles

- Not exactly "rules" – 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
    - Larman: assigning responsibilities = "desert island skill"
    - Also notes: "one person's pattern is another's primitive building block"
  - "Design patterns" usually are more specific

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

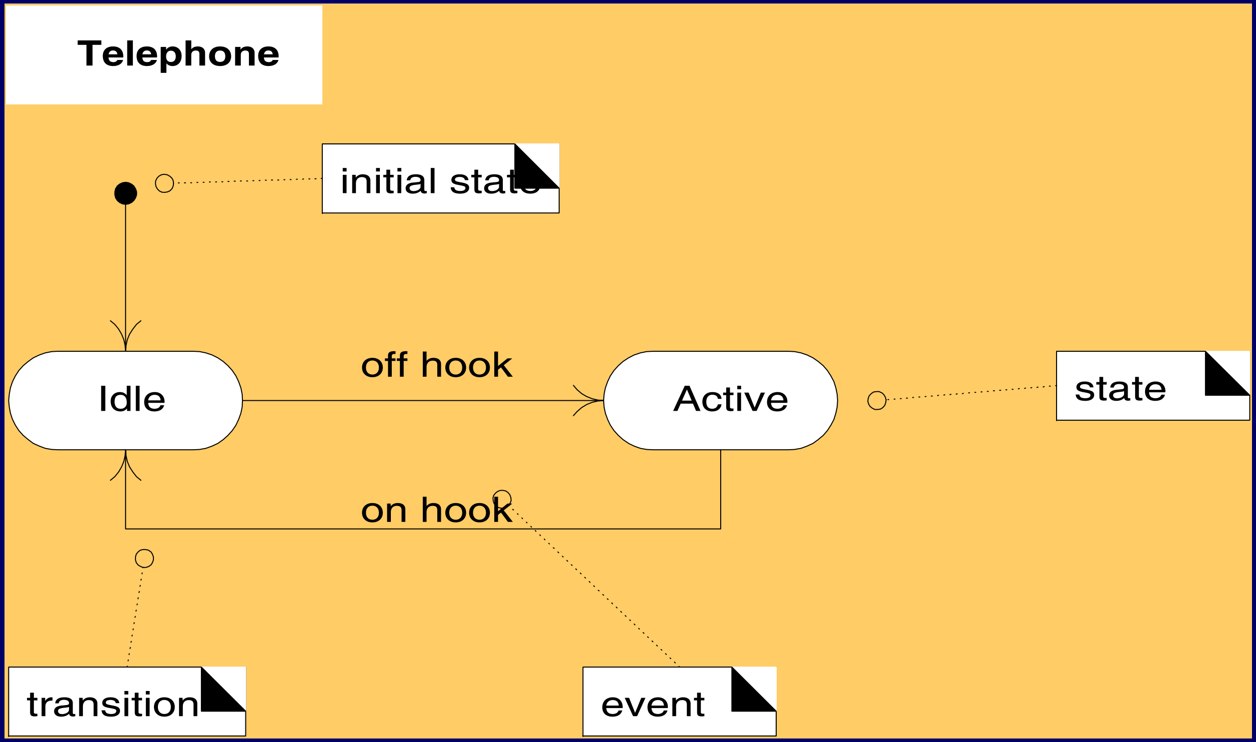
- Refers to *functional* cohesion
  - Means no class does too much work – especially not a bunch of unrelated things
  - Basically should avoid “bloated” classes
    - Hard to understand, maintain, reuse, …
    - Usually means other classes should take some responsibilities
      - Like an overworked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

Statechart diagrams

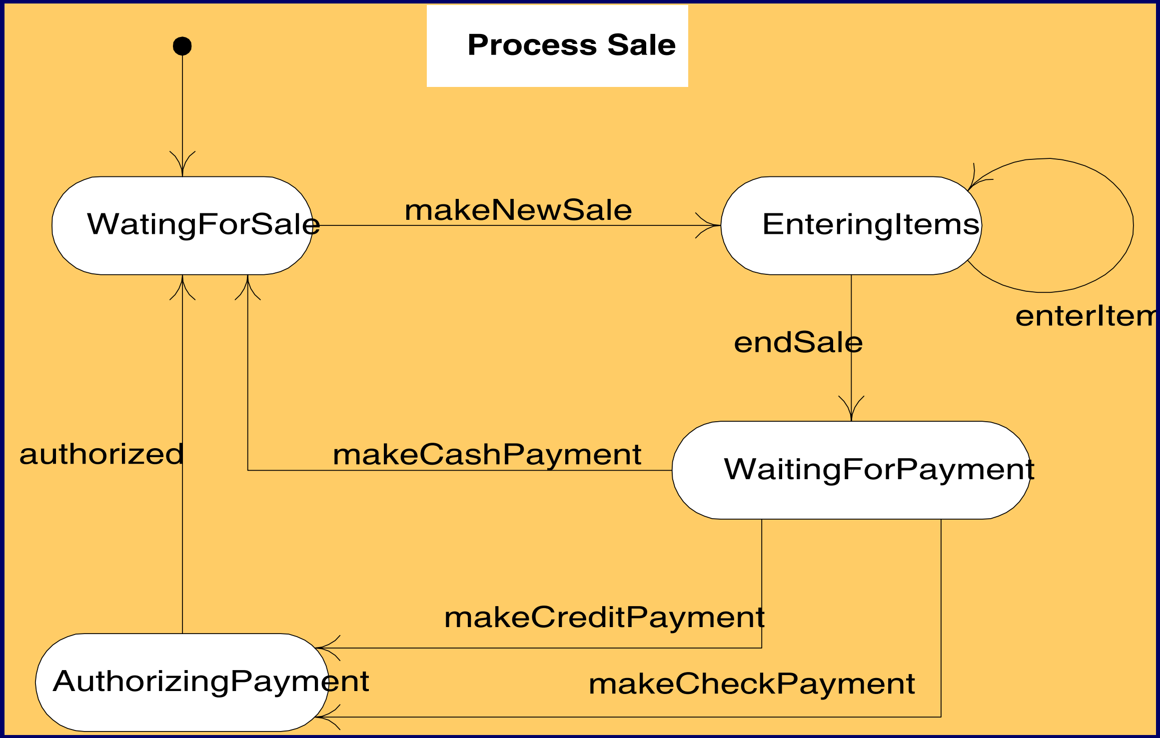
- Purpose: to model the changing states of complex objects



Utility of statechart diagrams

- Normally not useful for internal events
  - Internal event – caused by an object inside the system boundary
  - Because interaction diagrams already cover it
- Useful for system as a whole
  - Especially to model changing system states during the course of a use case
    - Larman calls it a use case statechart diagram
- Note: many prior CS 50 students discovered this usefulness on their own
  - This quarter, we ask all of you to consider them

A use case statechart diagram



- Helps designer insure things are done in the correct order
- Other notation: transition actions, guards, nested states – see text figures 29.2 and 29.3 (pp. 489-90)

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
  - – Assign cohesive set of responsibilities to a fabrication
- 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()`
    - e.g., `trajectory.map()` – normally mapped by outside observer if at all
- Assume 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 extends Canvas` – okay, but limited, because Easel cannot inherit from any other class now
  - Alternative is composition
    - More flexible to let Easel have a Canvas to draw on

Diagramming generalization

- See figure 31.9 (p. 512)
- Note: can overdo diagramming hierarchies
  - Show lower levels only if it helps *communication*
  - Adding hierarchical levels increases complexity
    - Harder to understand/explain
    - Opens door to team misinterpretation
  - e.g., see figure 31.10 (p. 513)
  - Another note: application of Bridge pattern (to be discussed) could simplify the design of fig. 32.9
    - Question: what to do if new payment type like Debit card?
    - Solution involves abstract types

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

Inheritance with Java

- `class B extends A`
  - B is an A – so can always refer to a B as an A
    - But cannot refer to an A as a B (without an explicit cast)
  - B cannot also be a C, unless C is an A too
- `abstract class A`
  - Has some abstract methods
    - Concrete subclasses *must* implement them
    - Cannot say “new A” – even if A has a constructor
- `interface A`
  - Completely abstract – just defines services
  - So okay to inherit multiple interfaces

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
  - See Figure 31.13 (p. 515)
- 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/cs50/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
- Are 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

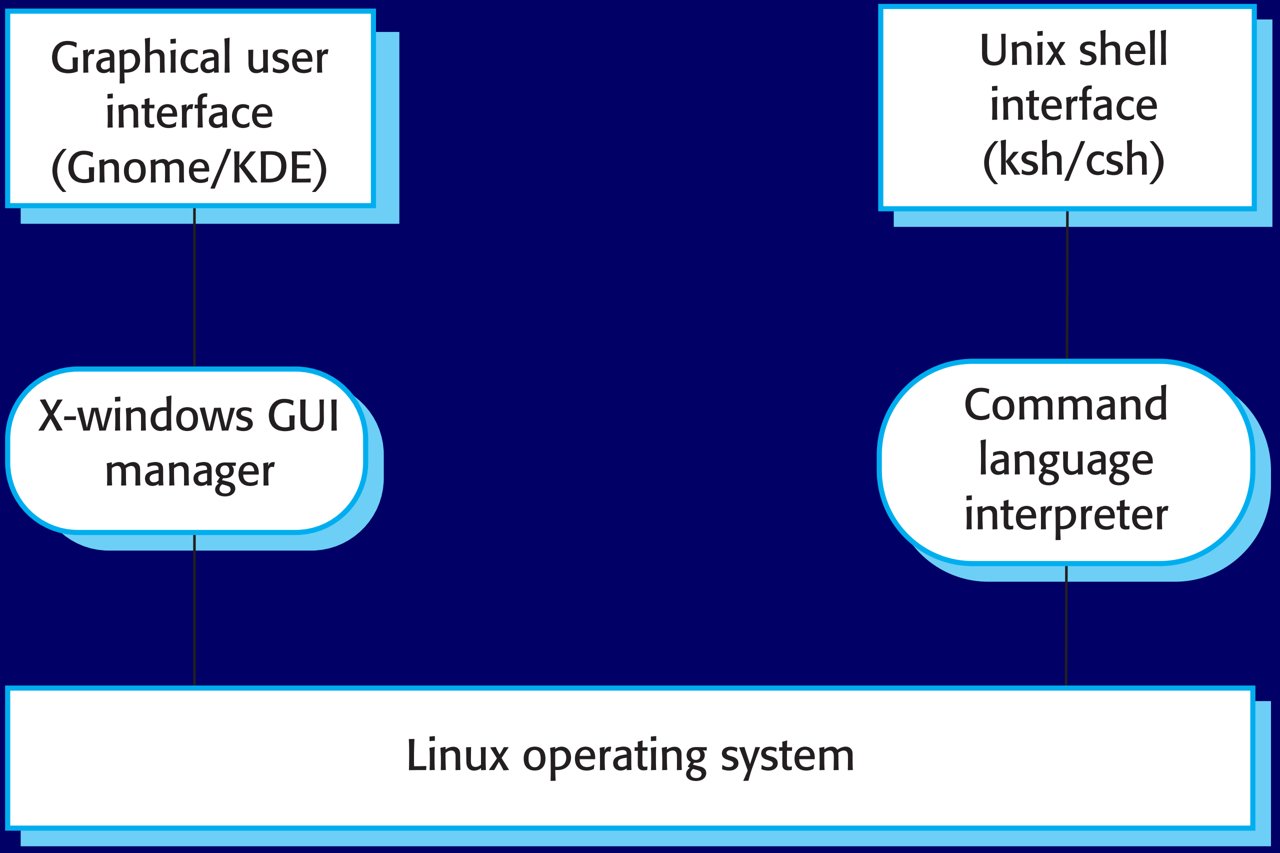


Figure from Ian Sommerville, *Software Engineering 8th edition*, Chapter 16

UI design process

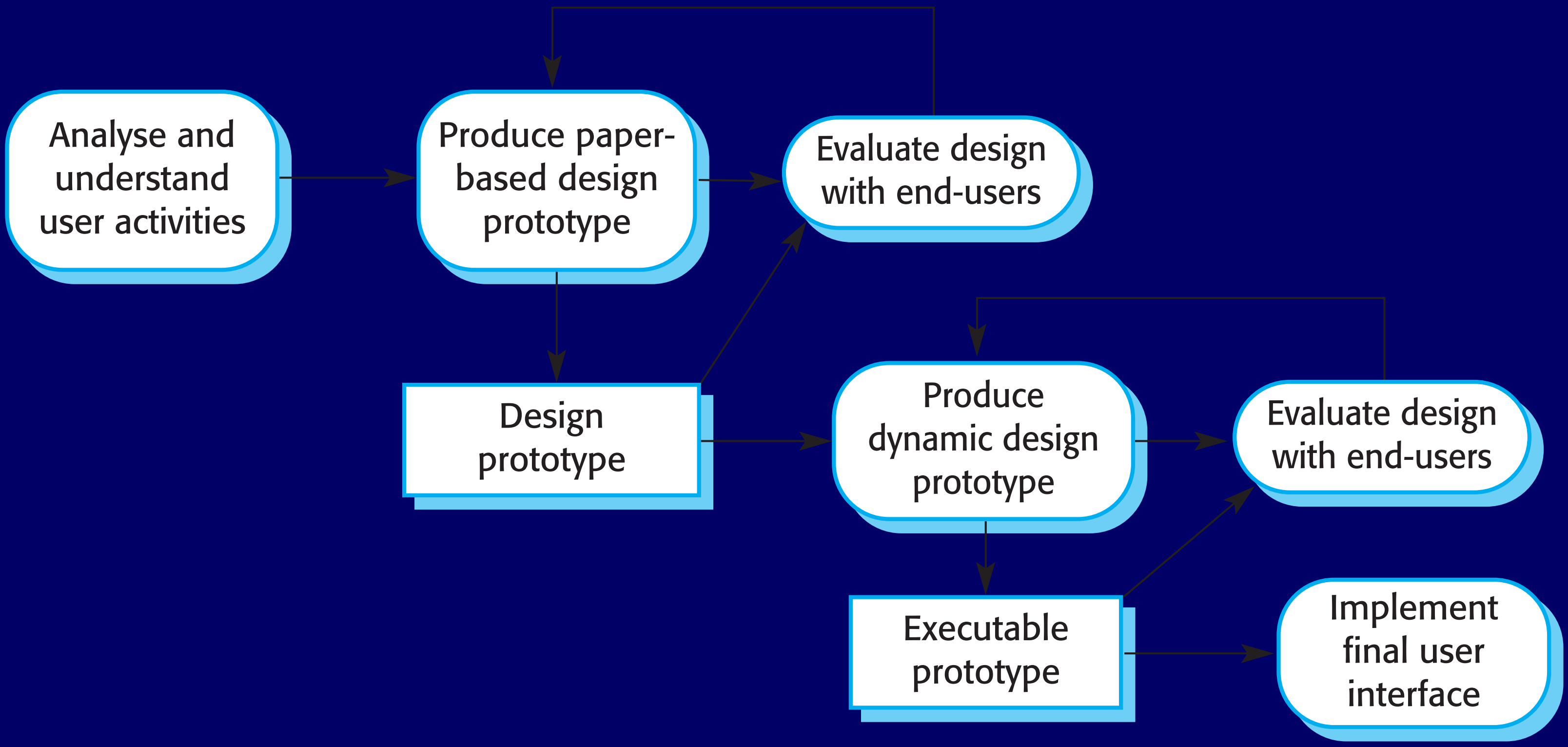


Figure from Ian Sommerville, *Software Engineering 8th edition*, Chapter 16