Domain analysis

- Goal: build an object-oriented *model* of the real-world system (or imaginary world)
- Slicing the soup: OOA vs. OOD
  - OOA concerned with “what”, not “how”
  - OOA activities focus on the domain layer
- Common OOA activities: identify classes, assign (some) responsibilities to classes
  - Larman’s OOA: domain model (classes, associations, attributes), and system operations
    - Includes static and dynamic views of the domain
  - DA artifacts for CS 50 project: see assignment 3

Domain analysis activities

- Static view – model the domain
  - Identify domain concepts
  - Identify associations between the concepts
    - Now ready to start drawing domain model – a visual representation of these concepts and associations
  - Identify attributes of the concepts
    - Usually add to drawing (CS 50: add to class specifications)
- Dynamic view – model the system behavior
  - Make system sequence diagrams
  - Write system operation contracts

Identifying concepts

- Class = major abstraction (i.e.,not just an attribute)
- How to find candidate classes?
  - Think/brainstorm about the domain
    - Ask Who? What? When? Where?
    - But *save the How?* questions for OOD
  - Use a concept category list – e.g., pp. 140-141 in text
  - Identify the nouns & noun phrases in problem statement, use case descriptions, other …
- Consider all as candidates to start; refine later
  - i.e., a candidate class turns out to be just an attribute
    - But common error to decide too early

Suggest: start CRC cards now

Class (name)	
Responsibilities	**Collaborators**
…	…

- 1 card for each candidate class, showing:
  - Class name – do now
  - Responsibilities – knowledge now, operations in OOD
  - Collaborators – some now, more in OOD
- CRC cards are useful for both OOA and OOD:
  - OOA – help sort out classes; use to lay out diagrams
  - OOD – role-playing to find operations; more diagrams

Split cards into 3 piles

1. Critical classes – must include
2. Totally irrelevant classes – must reject
   - Set aside, but record as irrelevant in glossary
3. Classes you are still undecided about – ask yourself questions like the following:
   - Is it same as another class? Is it an instance?
   - Is it actually outside the system? (like a person)
   - Does it have unique knowledge/responsibilities?
   - Is it needed by other classes?

- Keep updating the piles as more is learned!

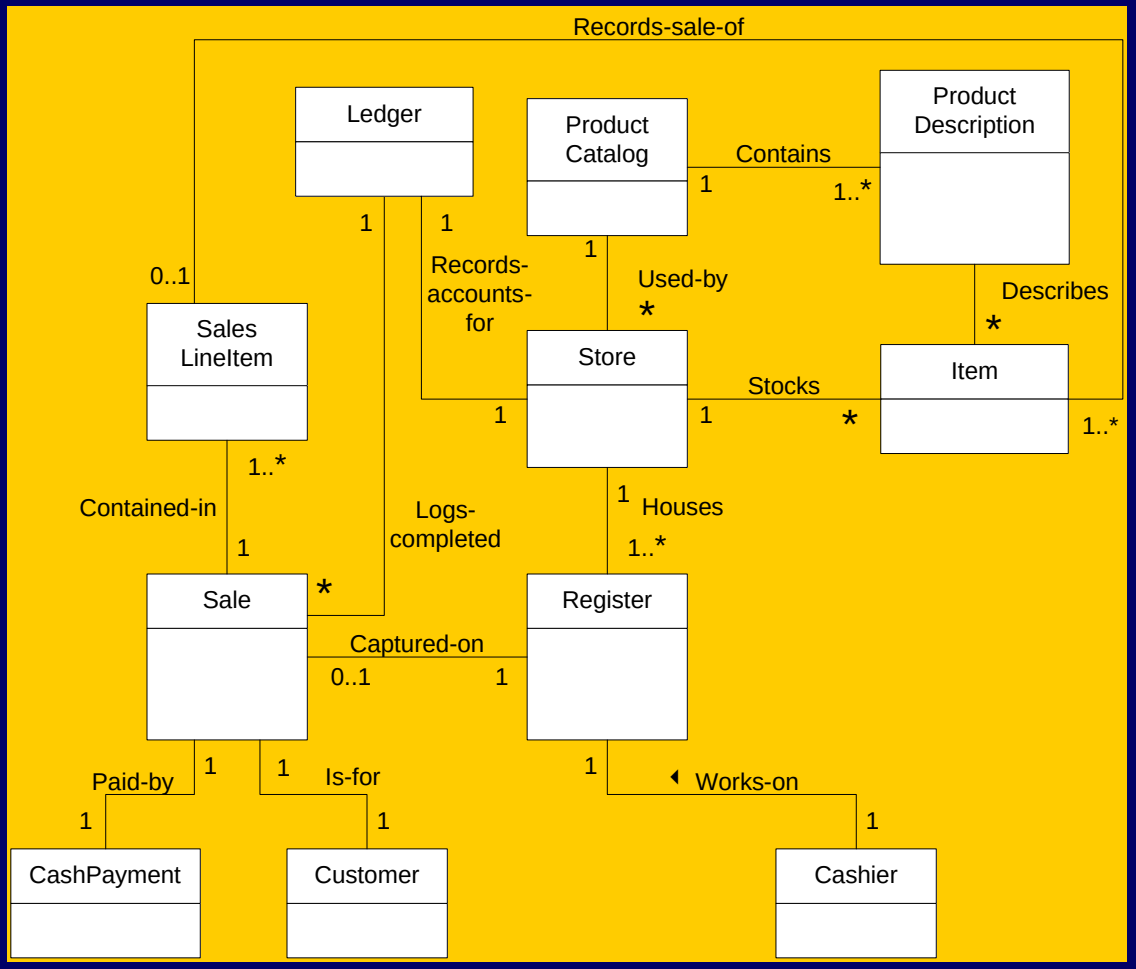
Choosing concept names

- Note: if you can't think of a *simple*, *clear name*, maybe you have a bad abstraction!
- A good test: Can a person with domain knowledge (not CS knowledge) describe the abstraction based on its name alone?
- Best to use existing names "in the territory"
  - See Larman's cartographer analogy (p. 145)
    - Also: "exclude irrelevant features" and "do not add things that are not there."
- But no sense to labor over good candidate names
  - e.g., "register" vs. "POST" – Larman choice is arbitrary

Specification types

- Larman tip: types that specify attributes for other types are often handy ("Description Classes")
  - e.g., a `ProductDescription` – includes UPC, price, and any other specs *common* to an `Item`
- Two main purposes:
  - Eliminate redundant storage – no need to store common specs with each `Item`
  - Prevents loss of info when objects depleted – i.e., when the last `Item` is sold
- In general, look for *unifying concepts*

Partial POS domain model



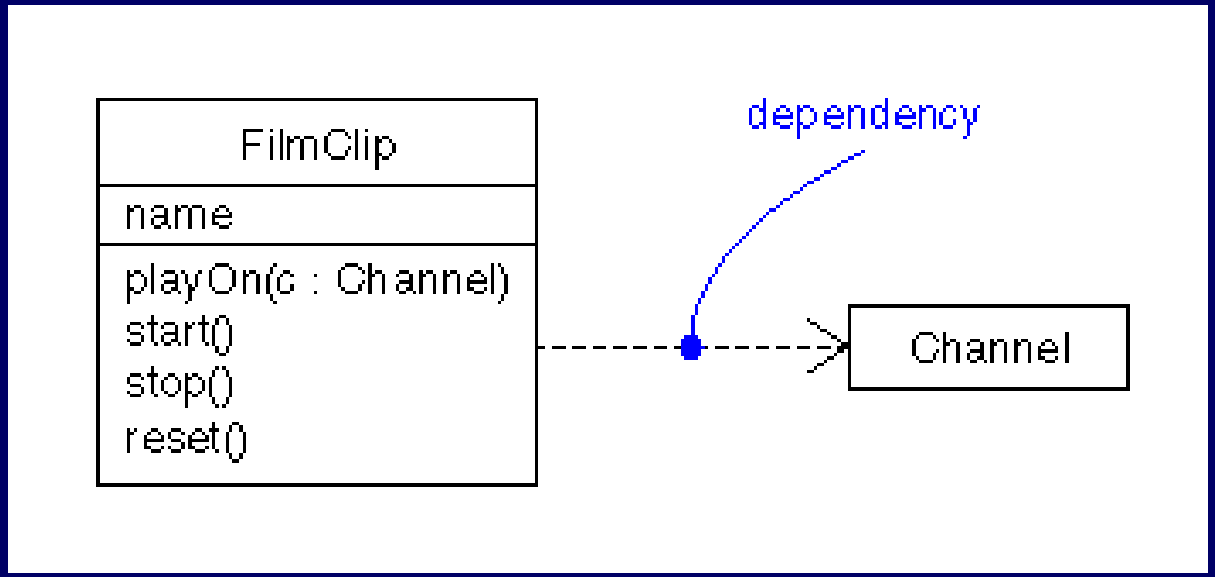
- a.k.a. static class diagram
- Concepts are boxes
- Associations are lines connecting boxes
- Other UML details to follow

Associations

- Def: relationships between concepts
- Common associations:
  - Dependency – a class “uses” another
  - Generalization – a class is derived from another
  - Aggregation – one class is a collection of others
  - But can be any kind of relationship
- Good association names are important too
  - And helpful to identify the direction of association
- Also helpful to use proper UML

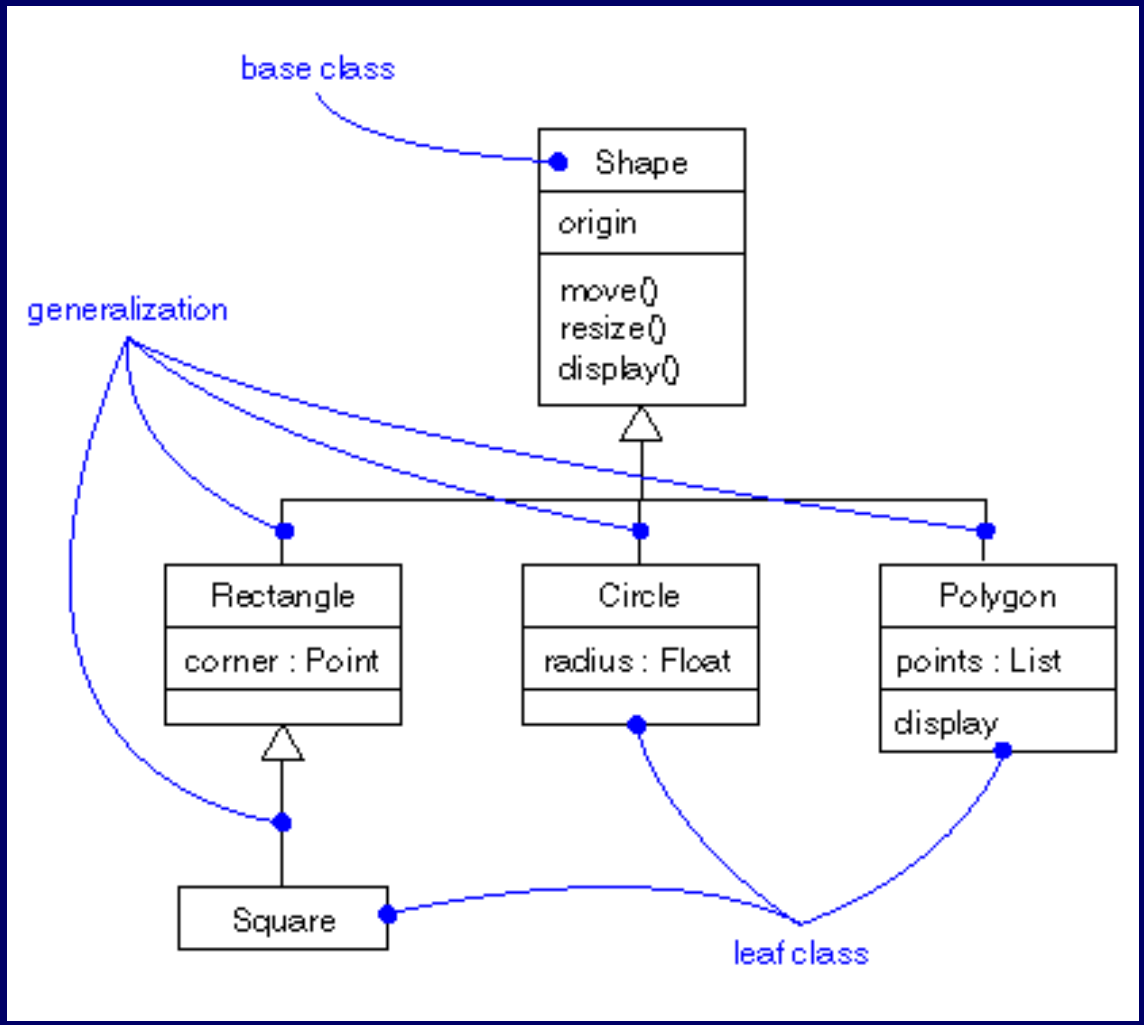
UML: dependency relationship

- When a class “uses” or otherwise depends on another class to fulfill a responsibility
  - Dashed line with arrow in UML

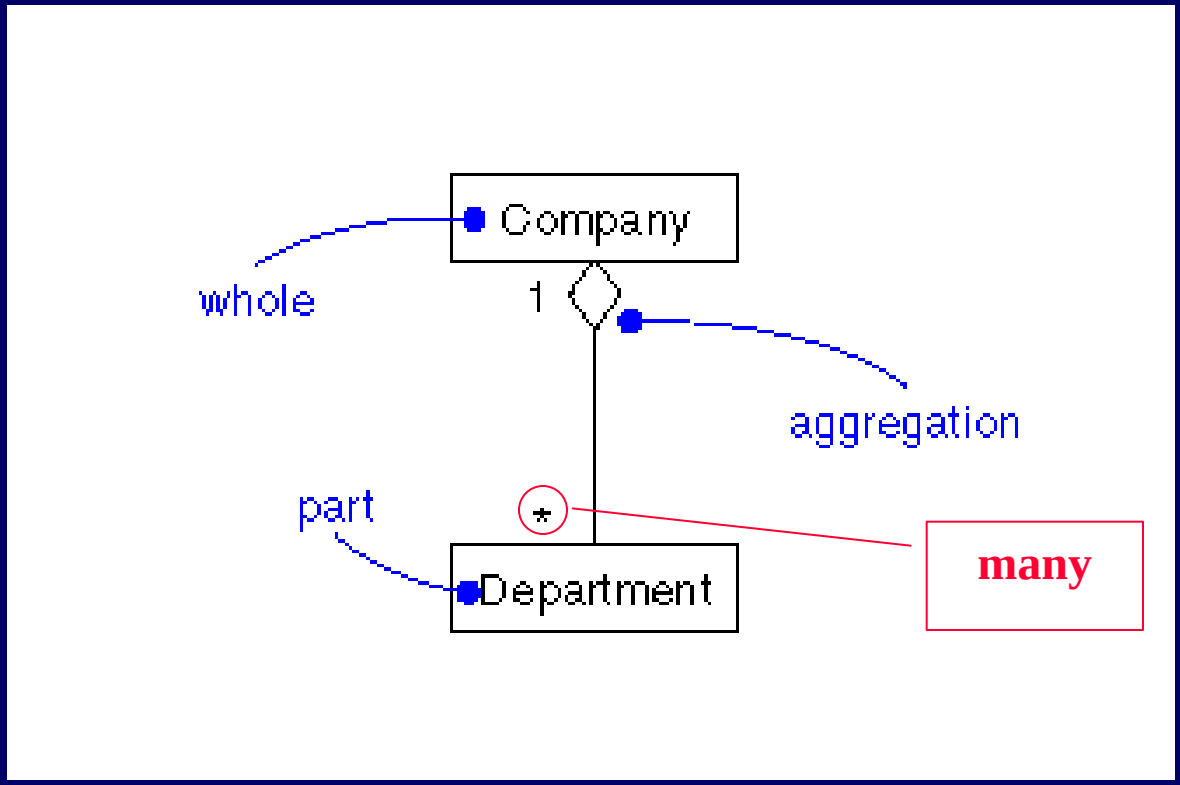


UML: showing generalization

- a.k.a., inheritance – one class is derived from another
  - In UML, triangle at end of line “points” at parent class



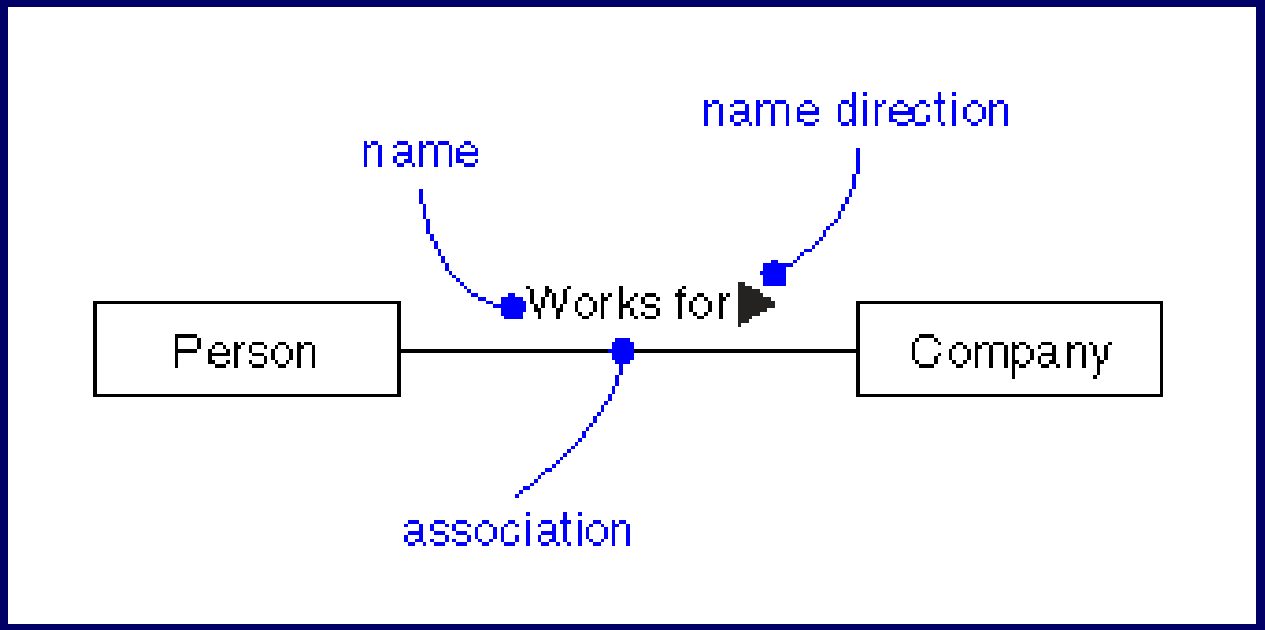
UML: aggregation & multiplicity



- "Whole" is identified by the diamond shape at that end of the line

Naming associations

- Recommended for any relation between concepts
  - Absolutely necessary if UML lacks notation (like dependency, aggregation, or generalization)
- Use verb or verb phrase: e.g., “records”, “paid by”



Identifying associations

- Handy tool: common associations list – pp. 155-6
- Don't overdo it
  - *Useful* associations only – otherwise clutter
  - Must be *domain-meaningful* at this stage
- Highest priority categories are "need-to-know" associations – knowledge of the relationship must be preserved for awhile
  - A is physically or logically part of B
  - A is physically or logically contained in B
  - A is recorded in B

Generalization

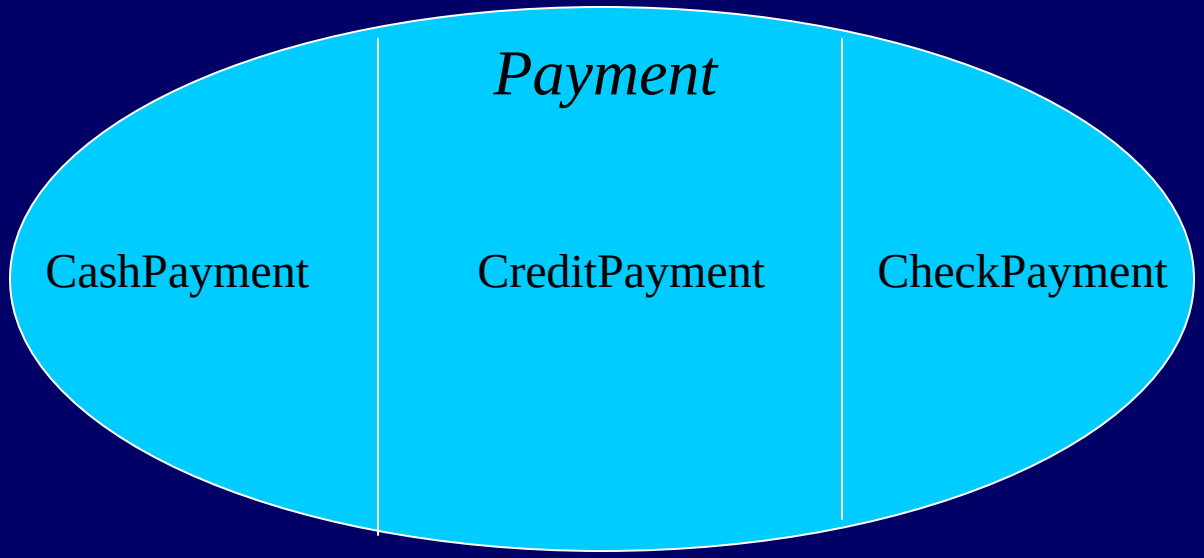
- A domain model term, concerning general-specific relationships
  - e.g., `Bird` – general – a.k.a. supertype
    `Penguin` – specific – a.k.a. subtype
    A Penguin *is a* Bird.
- Aids abstract thinking
- Facilitates handling
  - Express more economically in conceptual model
  - Lends itself to implementation using inheritance
    - Note: inheritance is a software term; not domain-related

When to use generalization

- Define a subtype of a concept when instances of the subtype differ from other instances, as in:
  - They have *additional* attributes, and/or associations
  - They are *handled differently*, in important ways
  - They represent things with *varying behaviors*
- Define a supertype to generalize concepts when:
  - All subtypes are *true* variations of a single concept,
  - Subtypes share the same attributes and associations,
  - And subtypes all conform to both:
    - 100% rule – all supertype attributes and associations apply
    - “is a” rule

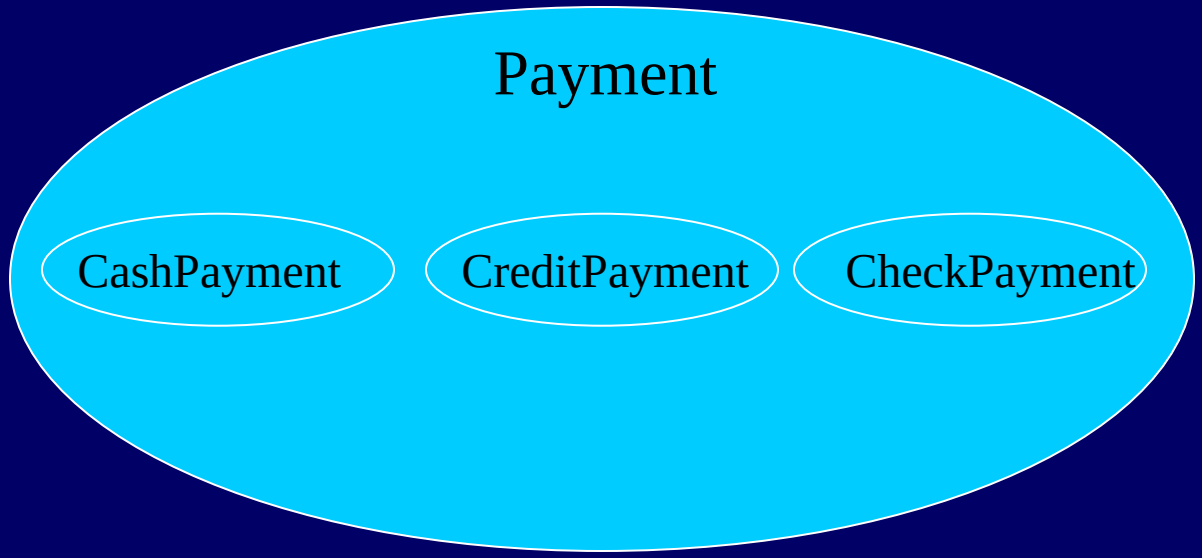
Abstract Classes

- Def.: If every instance of a class C must also be an instance of a subclass, then C is called an abstract conceptual class.



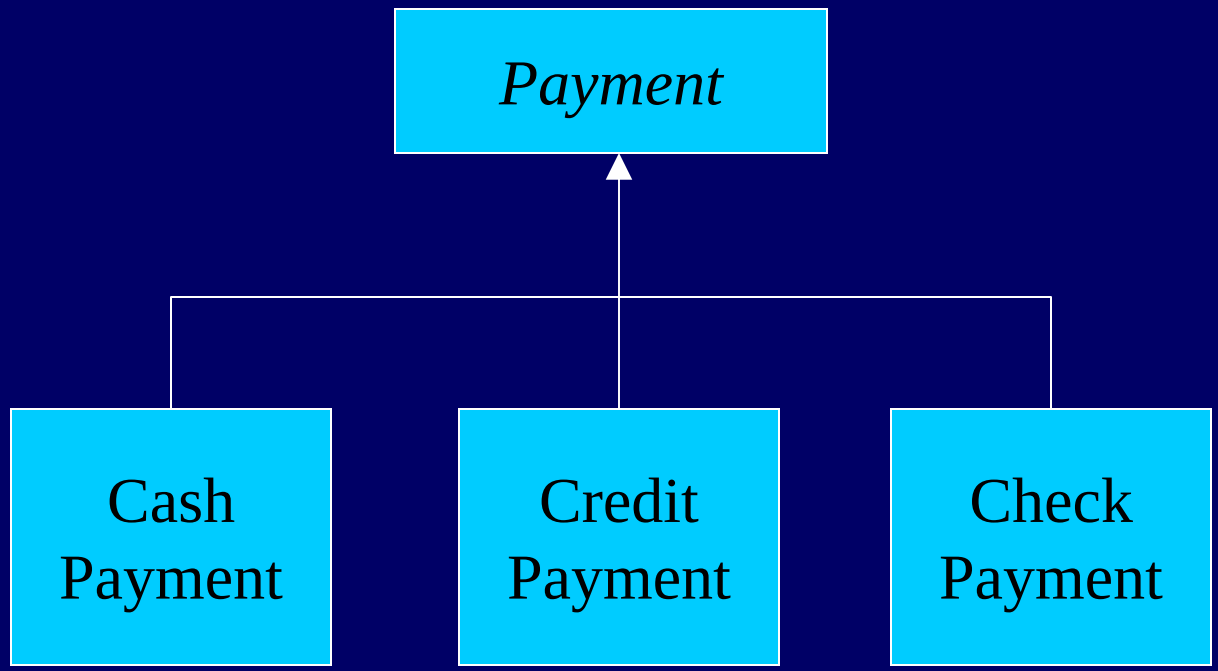
vs Concrete Classes

- If a Payment instance exists which is not a member of a subclass, then Payment is not abstract – it is concrete.



UML: Abstract Classes

- UML notation: *italicized* class name



Class attributes

- a.k.a., “properties” of classes
  - Describe an object’s state at a point in time
  - Attributes are “pure data values” – not complex things (which are concepts, not attributes)
- Purpose of attribution:
  - Insure that all *information* needed by the system’s objects is *remembered* somewhere
- Encapsulation principles help guide attribution
  - Info is most useful if stored where it’s needed most
  - Identity info of an object is best stored with that object

More attribution principles

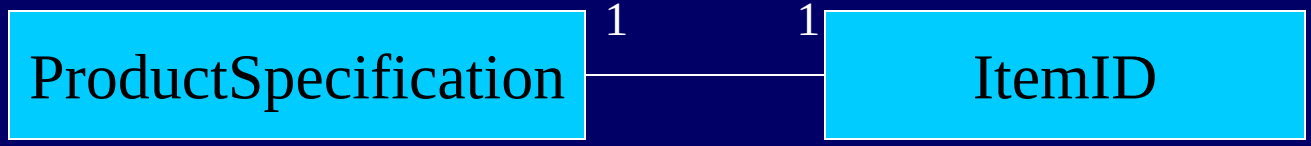
- What to store depends on the application
  - e.g. `Employee` – `Name`? `Address`? `Wage`? `Title`?
    - Key question: What does this application need?
  - i.e., need *pertinent abstractions* of concepts
- Representation depends on application too
  - i.e., how to represent in the conceptual model
    - e.g., `Title` just a String? – okay – else if complex meaning, maybe it is a concept of its own, or an association
- Should be simple – "data types"
  - e.g., 5, "white" – has no unique identity
  - Note: an attribute may become implemented as a class

Attribute or Class?

- Classes: objects with unique identity
  - e.g., 2 instances of Person
- Attributes: primitive types
  - e.g., number, string, time…
- What to do with non-primitive data types?
  - composed of separate sections (address)
  - quantities with units (payment amount)
  - has more attributes (promotional price: start/end)
  - has operations associated (SSN: validate)

UML: Attribute or Class?

- Non-primitive data types may be shown as attributes *or* classes!



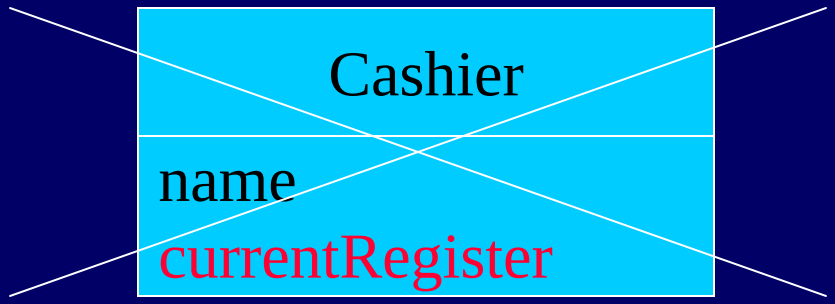
or

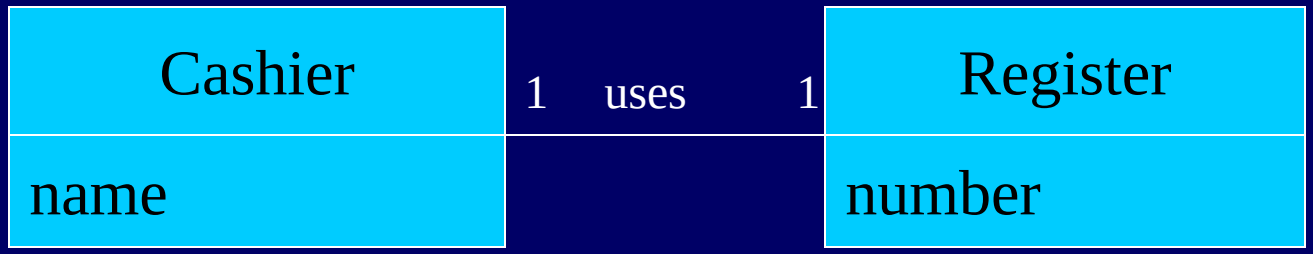
Attribution in practice

- Two complementary approaches:
  1. Choose a class – list its properties
  2. Choose a property – ask what it describes
  - Do it both ways for a complete set of attributes
- Probably will discover new concepts
  - Okay – augment the conceptual model
  - Note: sometimes an association should store attributes
    - Means the association is a concept of its own
    - e.g., `Gymnast`, `Team` – and *`Membership`* to associate them

Attribution Pitfall

- Relate conceptual classes with an association, not an attribute!





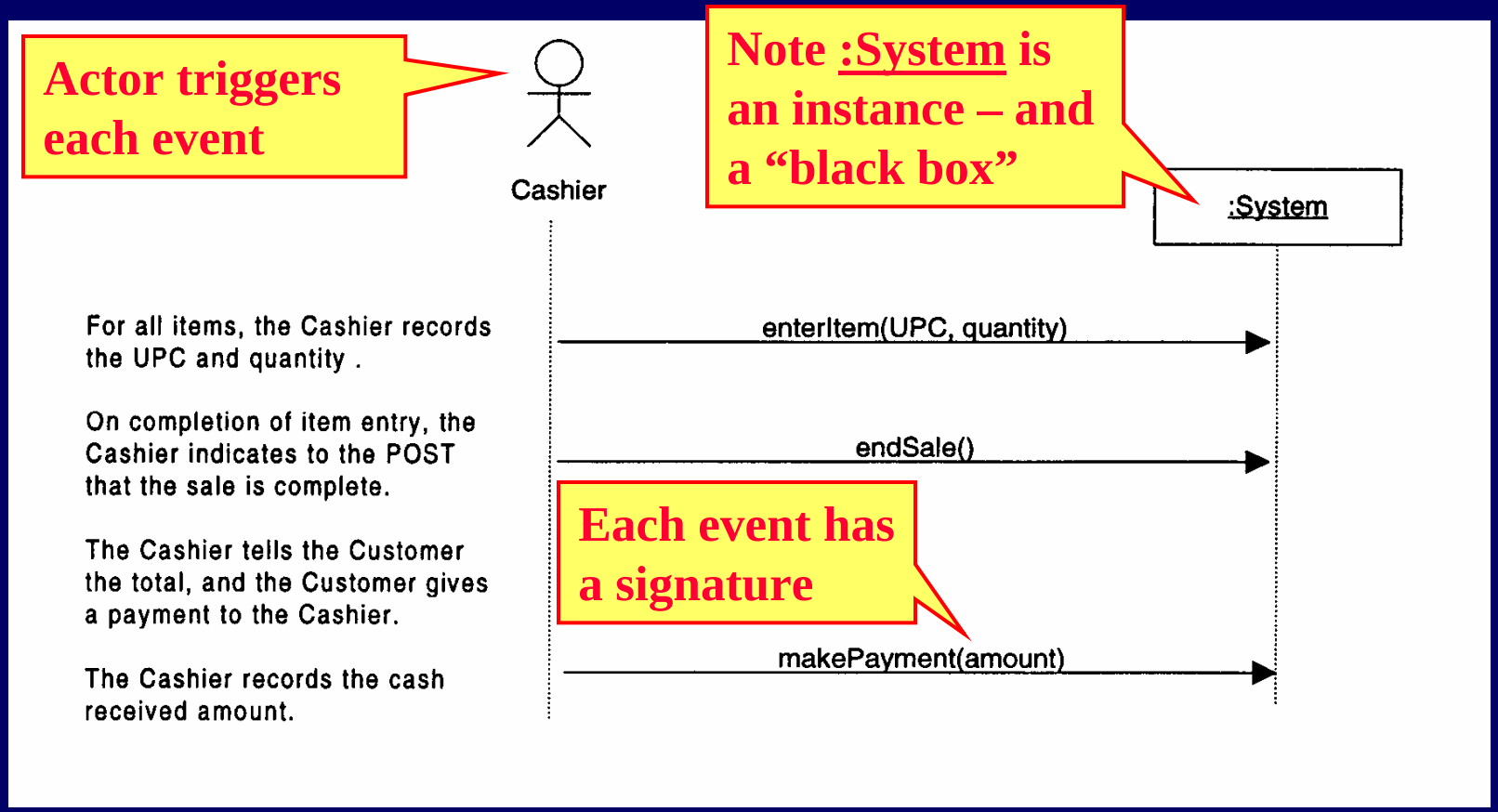
Glossary notes

- Record all attributes in the glossary
  - Sometimes called the “data dictionary”
- Also record all concepts, associations, operations, use cases, …
  - And any terms that require clarification
- Purpose: reduce risk of miscommunication
  - With clients, and other team members
  - And for yourself a few weeks down the road
  - And in CS 50 – so we can understand your artifacts
- But don’t overdo it – always minimize busywork

System behavior

- Focus is on dynamic view: states and sequences
- State of the system is like a snapshot – a point-in-time record of memory contents
  - What objects currently exist?
  - What associations are currently formed?
  - What are the current values of object attributes?
- System sequences involve changes in state
  - Objects are created and destroyed
  - Associations are formed and broken
  - Values of attributes are modified

System sequence diagrams



Partial SSD for Larman's `BuyItems` use case

Naming events

- Use “level of intent” (still OOA, not OOD)
  - i.e., not committed to a particular design
    - e.g., makePayment instead of submitCash – leaves flexibility for other payment types (in later cycle)
- Start with a verb – signifies something to happen
- Be sure to cover each event in each use case
  - i.e., playGame() is not an event! – it is at least a whole use case; probably many events
  - Best place to look: use cases’ typical courses of events
- Tip: if a simple name doesn’t work – maybe trying to name a complex process, not an event

System operations

- Focus in analysis stage is on *effect* of operations
  - i.e., *what* happens to system's state? – *not how*
- System operation contracts – describe the system's response to events
  - Operation – same as event name; include parameters
  - Cross References – at least the use case(s) involved
  - Pre-conditions – *assumptions* about system state before the operation begins
  - Post-conditions – *end changes* the operation makes to system state: instances, attributes, associations

Contract Example

Operation: makePayment(amount: Money)
Cross References: UseCases: ProcessSale
Preconditions: A sale is underway.
Postconditions:

- a payment instance p was created
- p.amountTendered became amount
- p was associated with current Sale
- current Sale was associated with Store

Contract Guidelines

- Identify system operations from SSDs
- For complex operations (may have subtle results, unclear in use case): write contract
- For postconditions, use categories:
  - instance creation/deletion
  - attribute modification
  - associations formed & broken
- As usual: Don’t overdo it!