SWE 4743:
Object-Oriented Design

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# UML Class Diagramming

# Agenda

- **Core Concepts and Layout**
  Understanding the three-zone structure of a UML class box (Name, Members, and Methods) and basic annotations like interfaces and enumerations.
- **Defining Relationships**
  Exploring inheritance (is-a), interface realization, and dependencies to represent how classes interact and utilize one another.
- **Structural Connections**
  Distinguishing between long-lived associations and the lifetime-specific differences of aggregation (shared) versus composition (owned).
- **Design Constraints and Multiplicity**
  Implementing access modifiers and multiplicity rules in code to enforce structural design decisions.
- **Practical Application**
  Best practices for using Mermaid to create versionable, AI-friendly diagrams that evolve alongside the codebase.

# Lecture Material

See **03-uml-class-diagramming.md** in the Presentations folder.

# UML Class Diagrams as a Design Tool

Class diagrams are valuable for thinking about design, communicating ideas, and defending decisions.

- Focus on understanding, not drawing mechanics or Mermaid syntax or choice of drawing tools.
- Use for discussion, design, and explanation – not creating giant diagrams no one uses.

# What a Class Diagram Represents

Class diagrams are static, *not behavioral*. They do **not** show execution flow. Instead, they show what exists in the system and how pieces relate structurally.

- Static structure of a system
  - Classes, interfaces, and relationships
  - A snapshot of design intent

# Why Diagrams Before Code

Diagrams help you decide who owns what, who depends on whom, and what abstractions exist *before code hardens*.

Code is harder to read later than it is to write now. Always be thinking about the next developer (which might be future-you wishing you had been more expressive the first time).

- Force explicit design decisions
  - Reveal responsibilities early
  - Cheaper to change in design than in code

# Communication Over Implementation

Code contains history, edge cases, and implementation details.

Diagrams strip that away so a group can focus on structure and intent.

- Shared visual language
  - Less noise than code
  - Ideal for teaching and review

# Structural Dependencies

**Structural dependencies represent long-lived relationships.**

These show what objects know about and rely on over time, not just during a single method call.

- Associations and ownership
  - Inheritance relationships
  - Interface realizations

# What Structural Dependencies Reveal

Dense or tangled structures are easier to spot in diagrams than in code.

This is often where students first notice over-coupling or god classes.

- Object lifetime relationships
  - Tight vs loose coupling
  - Potential design smells

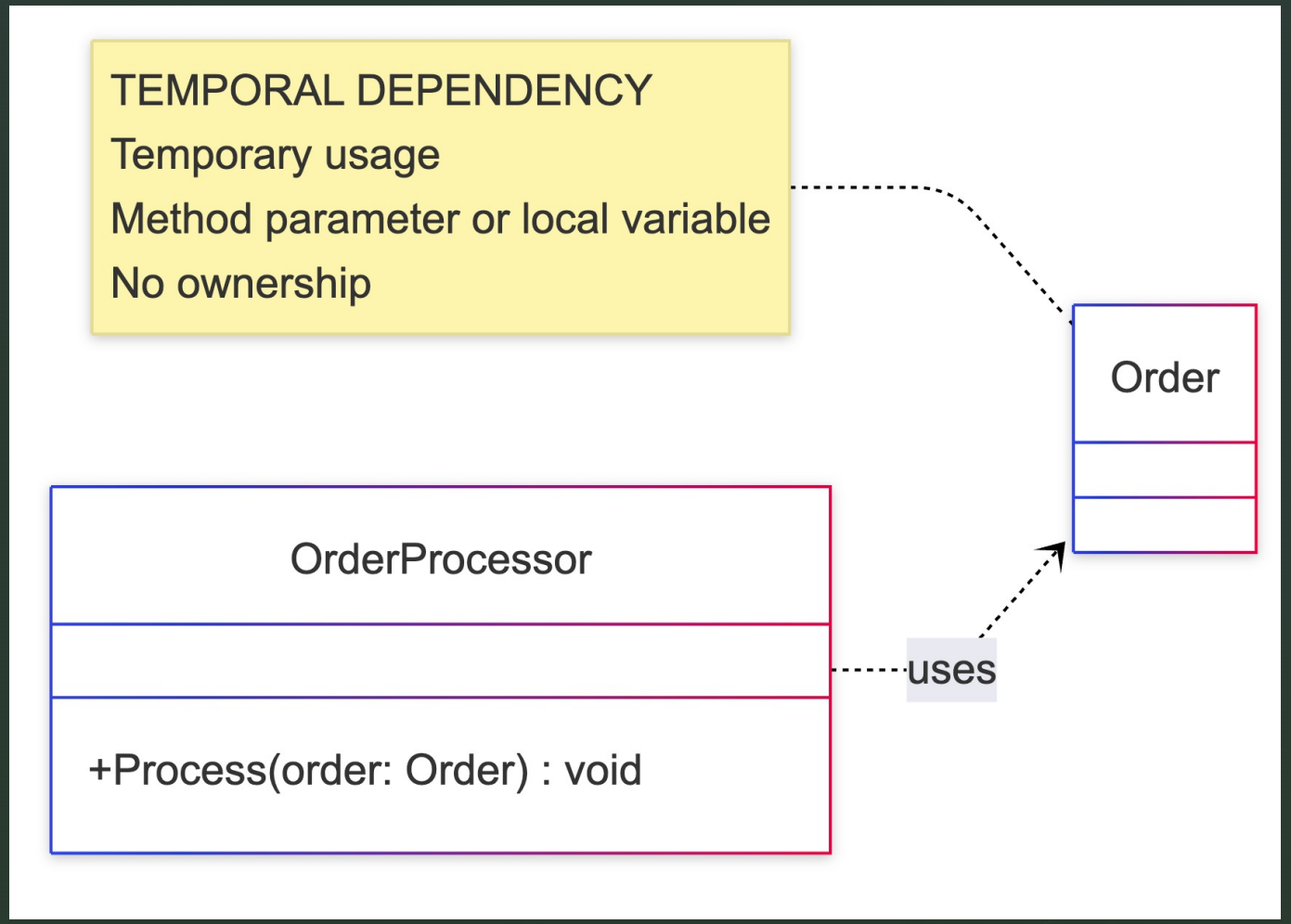
# Temporal / Usage Dependencies

Not all dependencies should be fields.

UML dependency arrows help distinguish temporary usage from structural ownership.

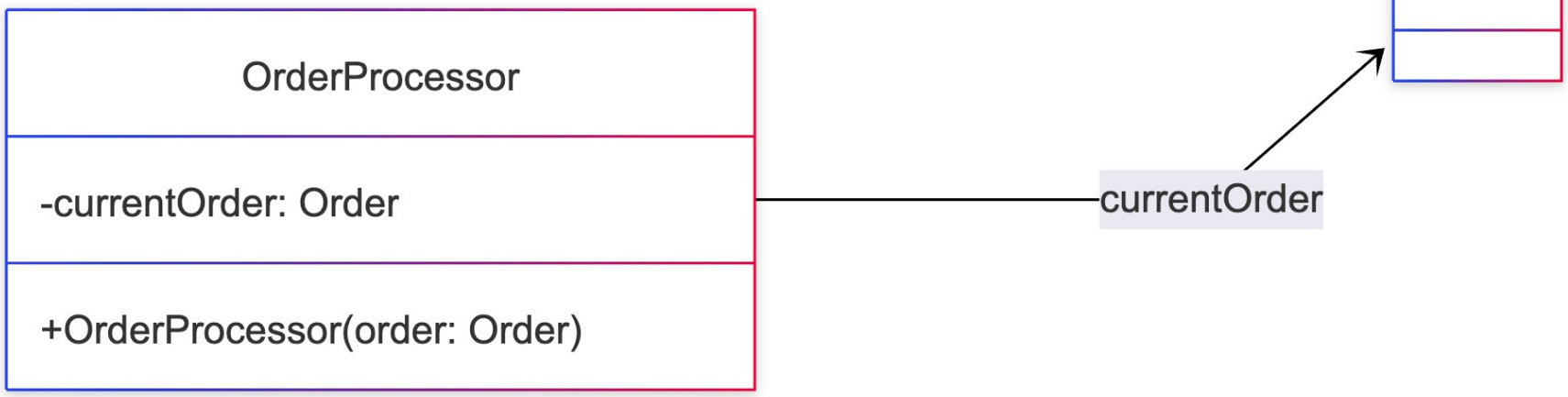
- Method parameters
  - Local variables
  - Short-lived interactions

# Dependency / Temporal

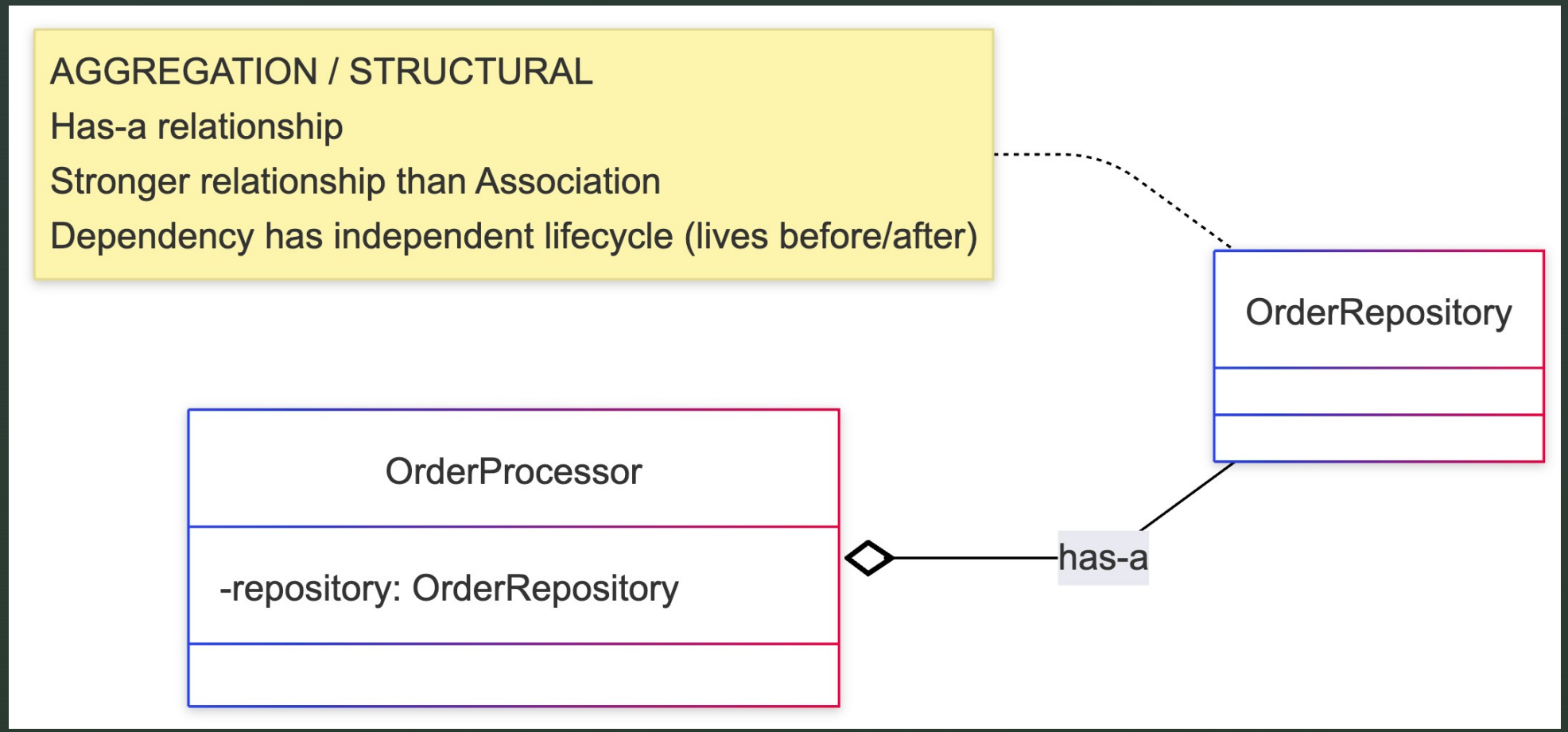


# Association / Structural

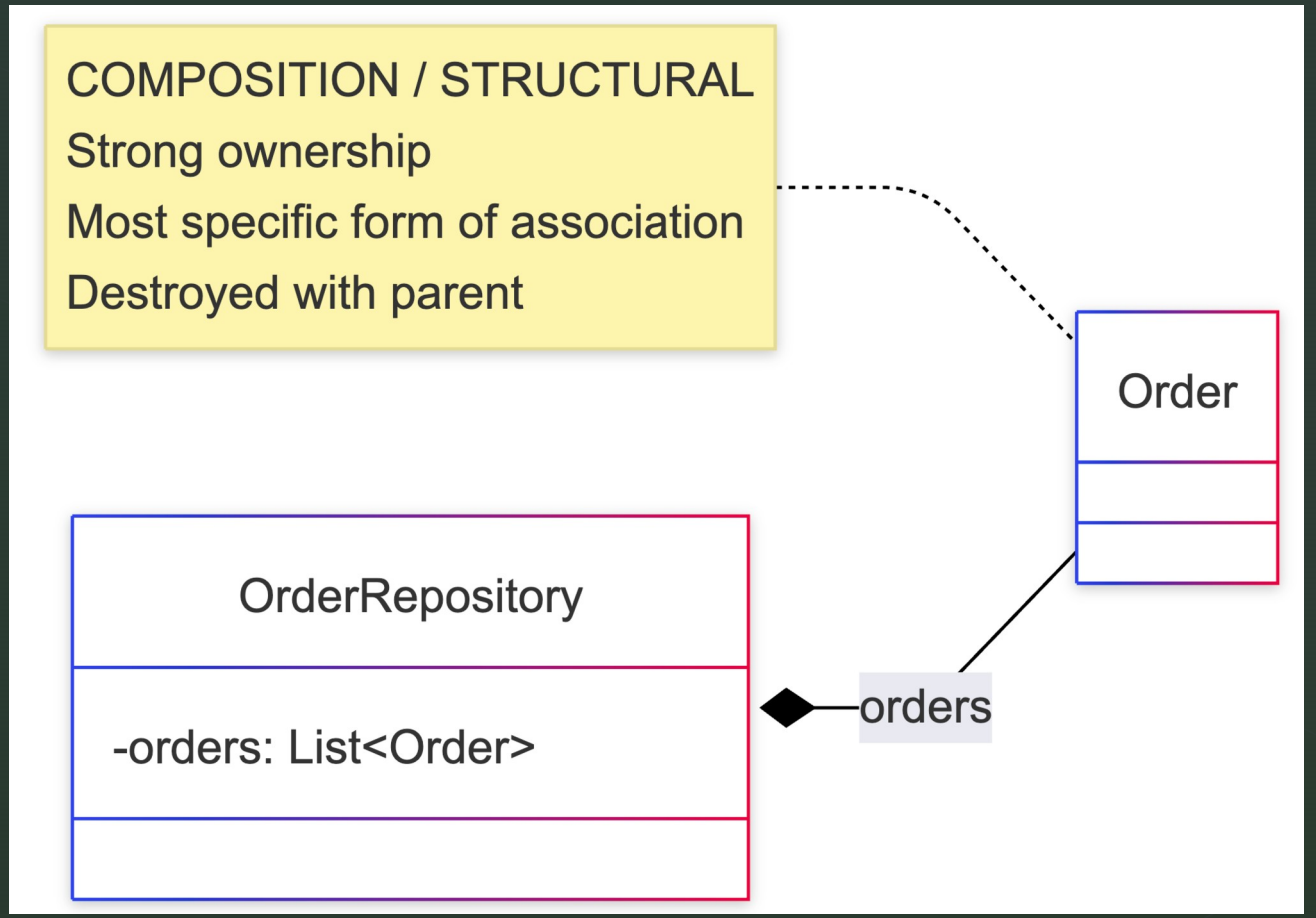
ASSOCATION / STRUCTURAL
Weakest structural relationship
Field populated numerous ways - constructor, method, setter, etc.
Preferred over Comp and Agg unless strict lifetime ownership is required



# Aggregation / Structural



# Composition / Structural



# Why Usage Dependencies Matter

- While performing your design, consider this: “Does this class really need to own this dependency, or does it only need it temporarily?”
- Reduce unnecessary coupling
  - Clarify required collaborators
  - Support cleaner APIs

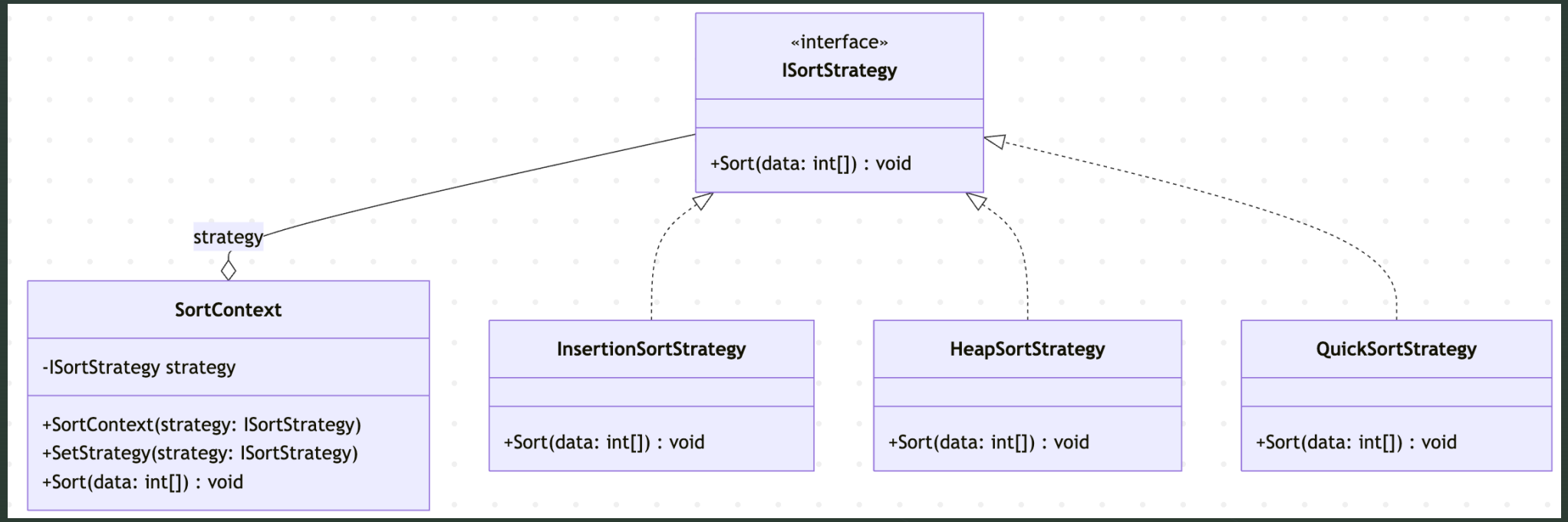
# Interfaces vs Concrete Dependencies

Interfaces describe capability *without commitment*.

Diagrams make this distinction obvious and visible.

- Interfaces express contracts
  - Concrete classes express decisions
  - Prefer depending on abstractions

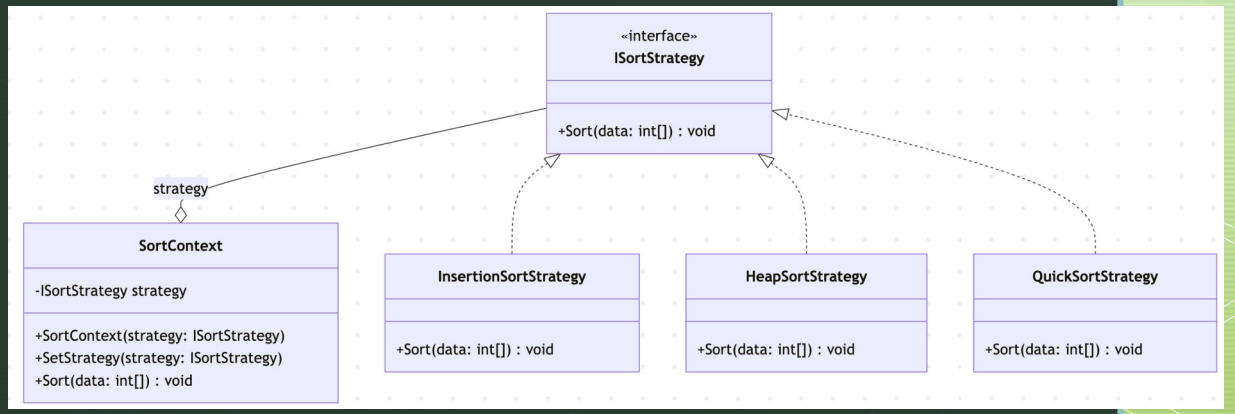
# Interfaces vs Concrete Dependencies



# Seeing Abstractions Visually

Patterns like Strategy and Observer become much clearer when interfaces are visible and not hidden behind concrete implementations.

- Interfaces as first-class elements
  - Multiple realizations
  - Pluggable behavior



# Focused Design Discussions

**Good diagrams are selective!** Diagram what matters for the decision you are considering, not everything that exists.

- Limit diagrams to key classes
  - Avoid giant system diagrams
  - Design is contextual

# Why Diagrams Beat Code for Discussion

**Reading code is serial and slow.**

Diagrams allow parallel understanding and quicker agreement or disagreement during reviews.

- Easier to reason about structure
  - Less cognitive load
  - Supports group conversation

# Pull Requests & Design Defense

Consider using diagrams in pull requests (PR: code you are submitting to your teammates, technical lead, open source project, etc.) for inclusion in a project or design reviews to explain *why* something is built a certain way instead of arguing line-by-line in code.

- Explain intent visually
  - Justify abstractions
  - Highlight dependency choices

# Responsibility Boundaries

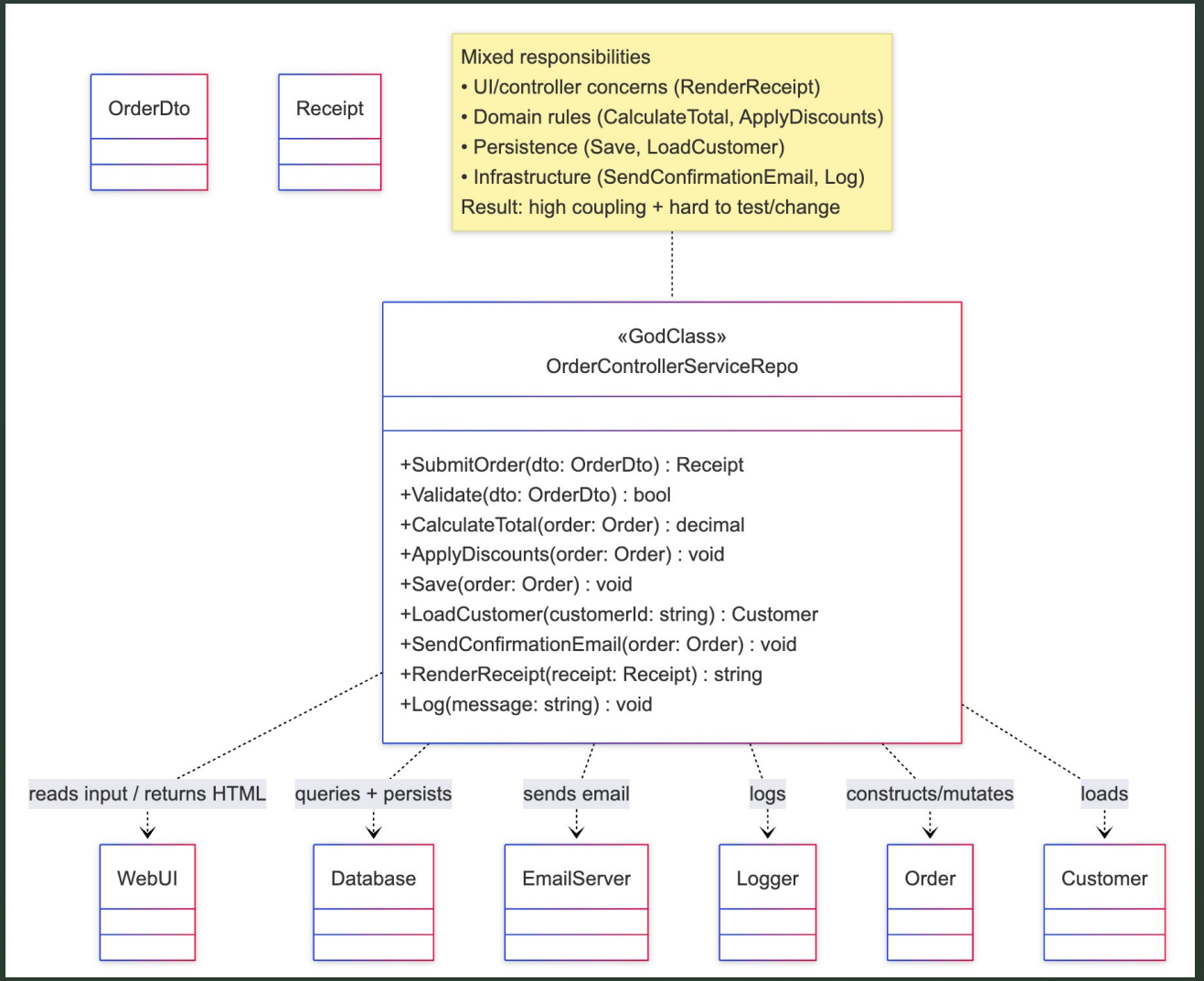
Each class box invites questions.

Too many relationships often indicate too many responsibilities.

Try to keep each class limited to a Single Responsibility. Diagrams help spot responsibility problems that might be less visible when reading code.

- Who does what?
  - Who knows about whom?
  - When to split classes

# Responsibility Boundaries



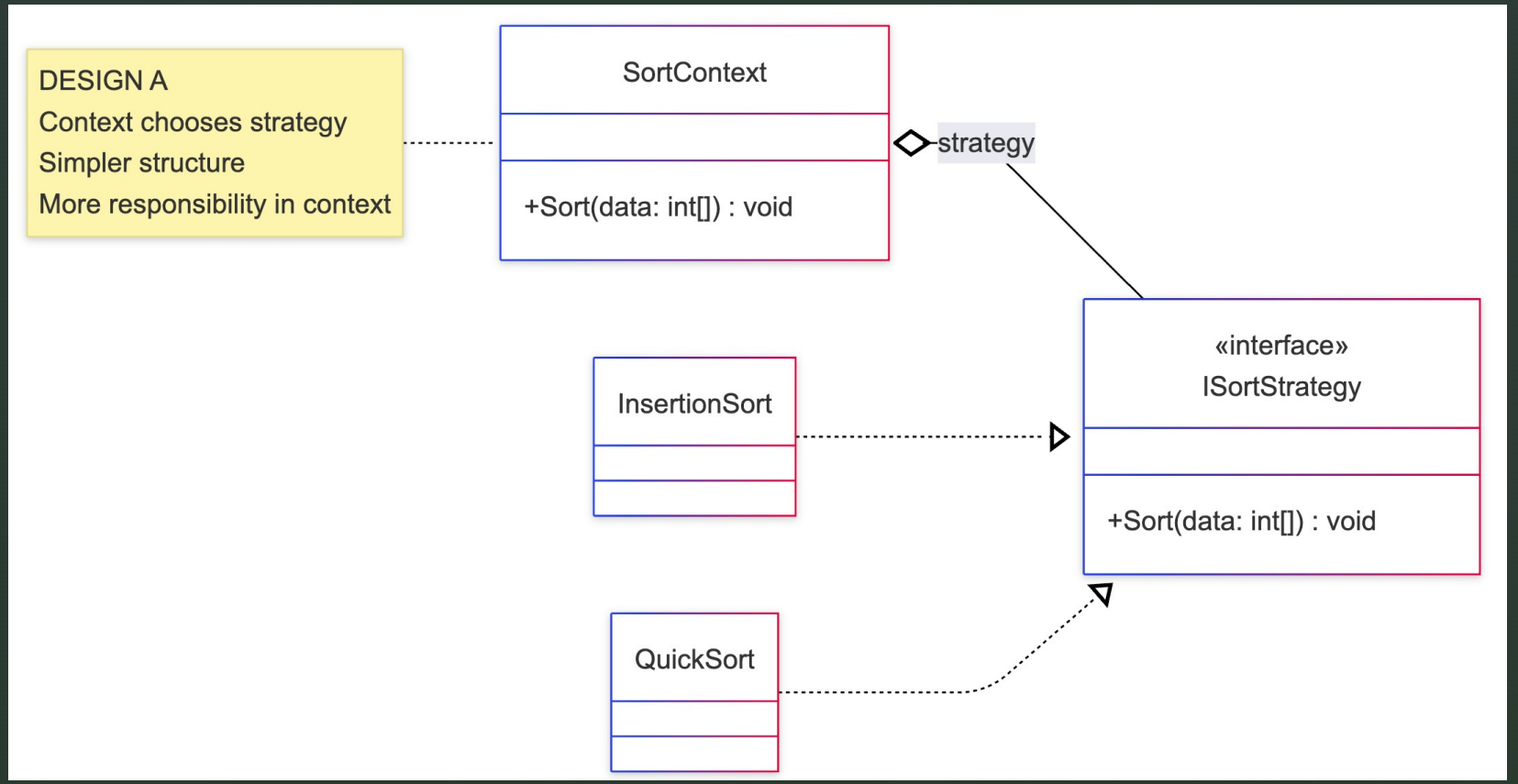
# Exploring Alternatives

Whiteboarding diagrams and diagram tool like Mermaid.js allow experimentation without refactoring code.

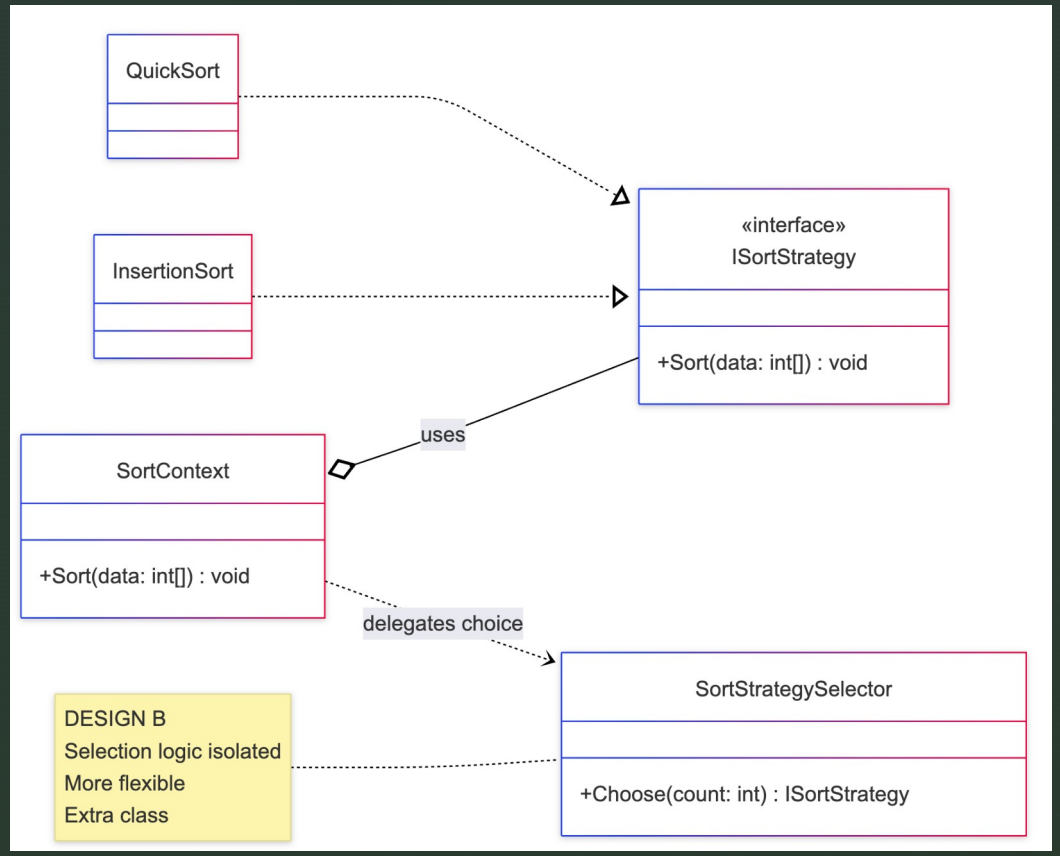
This encourages exploration instead of premature commitment.

- Try multiple designs quickly
  - Compare structures
  - Evaluate tradeoffs

# Exploring Alternatives: Example A



# Exploring Alternatives: Example B



# Diagrams as Living Documentation

Even if diagrams drift from code, they often preserve the original intent, which is incredibly valuable context later.

- Capture design intent
  - Aid future maintainers
  - Support architectural memory

# Why Code-Based Diagrams (Mermaid) Work Especially Well with AI

Even when diagrams drift from the code, they preserve **design intent**, which provides critical context for both humans and AI.

- **Improved AI reasoning**
  AI can reason over the structured text in code-based diagrams (such as Mermaid), enabling better code generation, refactoring suggestions, pattern recognition, and automated design critiques.
- **Shared context for humans and AI**
  Mermaid diagrams are versionable, diff-able, and colocated with code—making them a common language for developers *and* tools.

# Key Takeaways

Used lightly and intentionally, UML class diagramming is a powerful tool for designers and developers.

- Class diagrams support design thinking and critical decision making
  - They reveal dependencies and abstractions hidden by large code submissions
  - They focus and improve design conversations