Technical debt, refactoring, and maintenance (1/2)

Martin Kellogg

Reading quiz: technical debt

Q1: **TRUE** or **FALSE**: just like financial debts, all technical debts need to eventually be paid back.

Q2: Which of the following was used as an example of a system that deferred too much maintenance and suffered for it in the article?

A. Washington DC’s Metro’s signal system
B. UC Berkeley’s CalMail
C. NASA’s Mars polar orbiter
D. AWS’ us-east-1

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Announcements

- Signups for preliminary demo slots (with me) are open
    - This is mandatory, but only 5/16 teams have signed up so far
        - Free reading quiz credit for all team members if you sign up for a slot before Monday morning
    - See Discord for the link
- Snafu with Wizard-of-Oz demo recordings
    - Some of you have feedback from me, some have feedback from your TA
- If you still haven’t picked up your midterm, but you want to, come to office hours

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Today’s agenda:

- **Finish design pattern slides**
- Technical debt: the costs of bad design
- How to pay off technical debt: refactoring

Review: design patterns

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- ***Structural design patterns*** ease design by identifying simple ways to realize relationships among entities.
    - e.g., the adapter pattern transforms one format to another
- ***Creational design patterns*** control object creation so that objects are created in a manner suitable for the situation.

Creational patterns: named constructor

- In the ***Named Constructor Pattern***, you declare the class's normal constructors to be private or protected and make a public static creation method.

```
class Llama {
public:
 static Llama* create_llama(string name) {
 return new Llama(name);
 }
private: // Making ctor private
 Llama(string name_in): name(name_in) {}
 string name;
};
```

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Why might you do this?

- might want to change to Llama subclass later
- want to validate arguments from clients, but make construction fast internally
- etc.

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    - this is a specific variant of the named constructor pattern

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Payment * payment_factory(string name, string type) {
 if (type == “credit_card”)
   return new CreditCardPayment(name);
 else if (type == “bitcoin”)
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 … }

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 payment_factory(customer_name, “credit_card”);
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Creational patterns: factories

- The *factory method pattern* (or
  design pattern that uses facto
  without having the return type

Note how the implementation details are hidden from the client, and they can only treat the result as a generic payment

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Creational patterns: example

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- e.g., normal difficulty = regular Goomba

- hard difficulty = spiked Goomba

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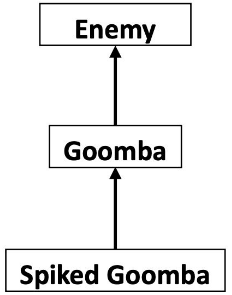

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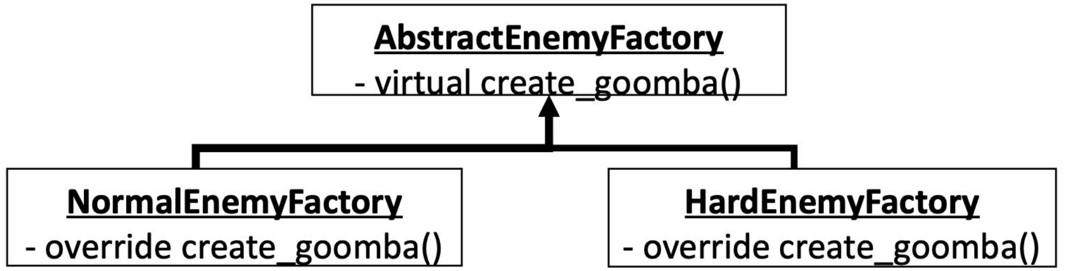
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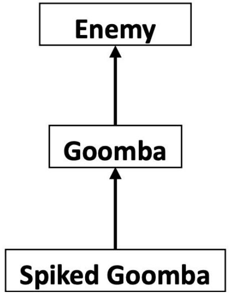

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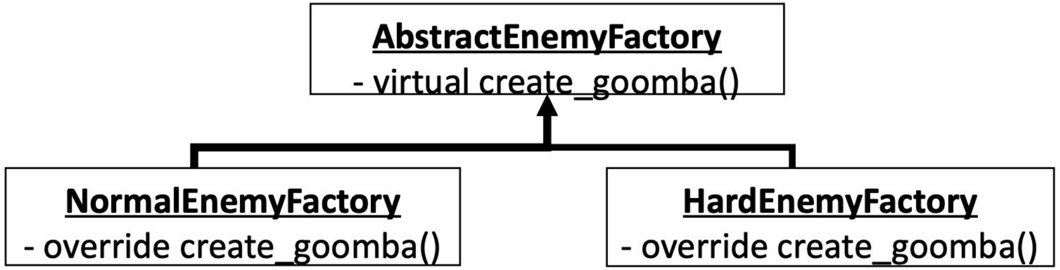
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```
// Only have to do this once!
AbstractEnemyFactory* factory = nullptr;
if (difficulty == “normal”)
  factory = new NormalEnemyFactory();
else if (difficulty == “hard”)
  factory = new HardEnemyFactory();
Enemy* goomba = factory->create_goomba();
```

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- Suppose we have some application **state that needs to be globally accessible**. However, we need to control how that data is accessed and updated.
- The anti-pattern (**bad**) solution is to have an **unprotected global variable** (e.g., a public static field).
  - fails to control access or updates!
- A "less bad" solution is to put all of the state in one class and have a **global instance** of that class.

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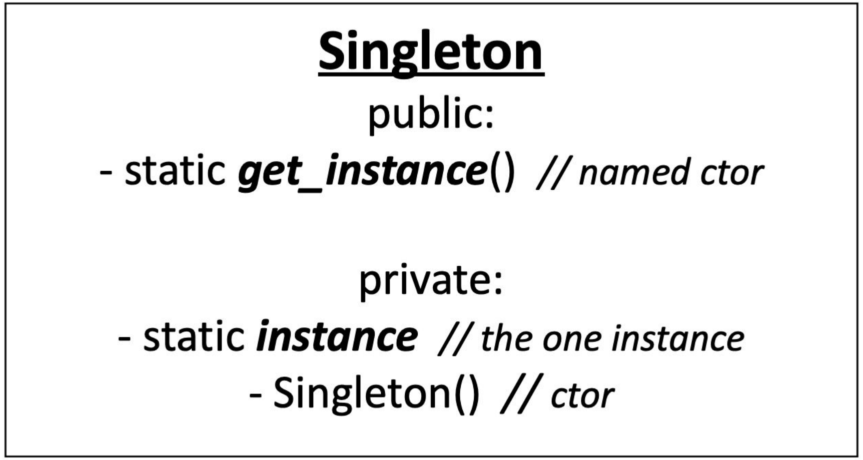
        - This is not an argument for using global variables to avoid passing a few parameters.
    - Or if you need to access state stored outside your program (e.g., database, web API)
    - Then global variables **may** be acceptable

Singleton design pattern

- The ***singleton pattern*** restricts the instantiation of a class to **exactly one** logical instance. It ensures that a class has only one logical instance at runtime and provides a global point of access to it.



Singleton

public:

- static ***get_instance***() *// named ctor*

private:

- static ***instance*** *// the one instance*
- Singleton() *// ctor*

Singleton design pattern: example

```
class Singleton {
 // public way to get “the one logical instance”
 public static Singleton get_instance() {
   if (Singleton.instance == null) Singleton.instance = new Singleton();
   return Singleton.instance;
 }
 private static Singleton instance = null;
 private Singleton() { // only runs once
   billing_database = 0;
   System.out.println("Singleton DB created");
 }
 // Our global state
 private int billing_database;
 public int get_billing_count() { return billing_database; }
 public void increment_billing_count() { billing_database += 1; }
}
```

Singleton design pattern: example

lazy initializaton of single object

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```

this constructor can’t be called any other way

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```

all clients share this global state

Singleton design pattern: example

Singleton

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- static ***get_instance***() *// named ctor*
- get_billing_count()
- increment_billing_count() *// adds 1*

private:

- static ***instance*** *// the one instance*
- Singleton() *// ctor, prints message*
- billing_database

What is the output of this code?

```
class Main {
 public static void main(String[] args) {
   int bills = Singleton.get_instance().get_billing_count();
   System.out.println(bills);

   Singleton.get_instance().increment_billing_count();
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Output:

```
Singleton DB created
0
1
```

Singleton design pattern: get_instance()

- Could we avoid typing Single.get_instance() so many times by doing this at all of the points in our program that use the singleton?

```
Singleton s = Singleton.get_instance();
System.out.println(s.get_billing_count());
… // later
System.out.println(s.get_billing_count());
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This is a **bad idea**. There is **no guarantee** that get_instance() will return the same pointer (same object) every time it is called. (It may return different **concrete copies** of the **same logical item**.)

Singleton design pattern: another example

- Suppose we are implementing a computer version of the card game Euchre. In addition to a few abstract datatypes, we have a Game class that stores the state needed for a game of Euchre. When started, our application prototype plays one game of Euchre and then exits.

- Design question: **should we make Game a singleton**?

Singleton design pattern: another example

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- We should only use the Singleton pattern when current or future **requirements** dictate that only one instance should exist.
  - Singleton is **not** a license to make everything global.

Behavioural Design Patterns

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    - Commonly used to enable **limited sharing**
        - e.g., same underlying algorithm, different interfaces or same interface, different underlying algorithms
    - Examples: strategy pattern, template method pattern, iterator pattern, observer pattern, etc.

Iterator Pattern

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  - e.g., Java’s List interface doesn’t care whether it’s backed by an array or a linked list
- Similar patterns exist for other kinds of data structures
  - e.g., ***visitor pattern*** for tree-like structures

Strategy Design Pattern

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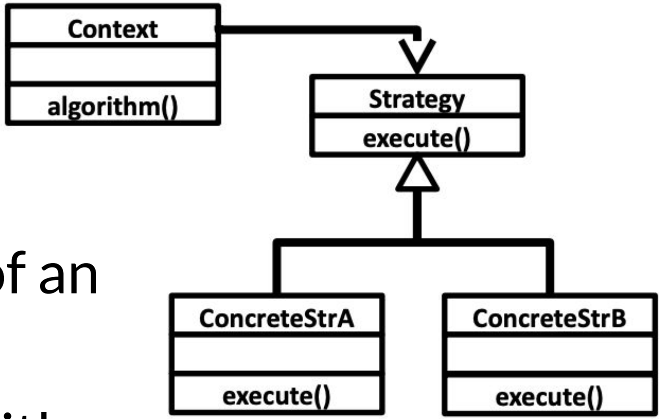

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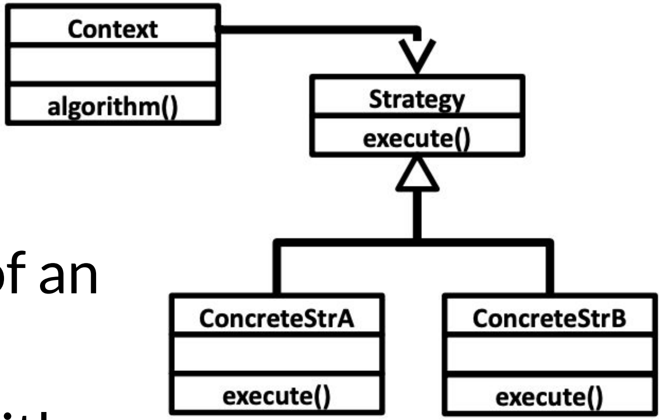

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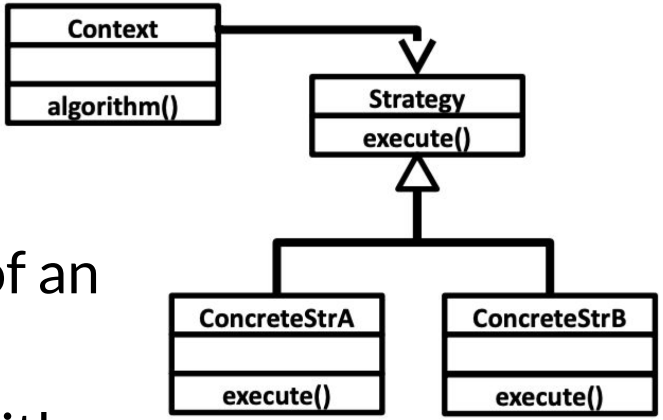

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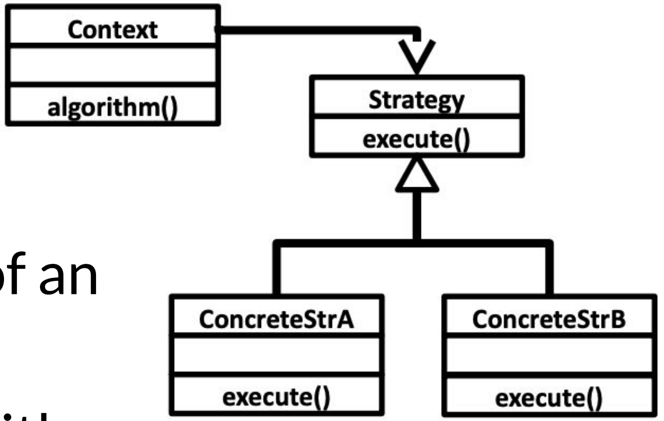

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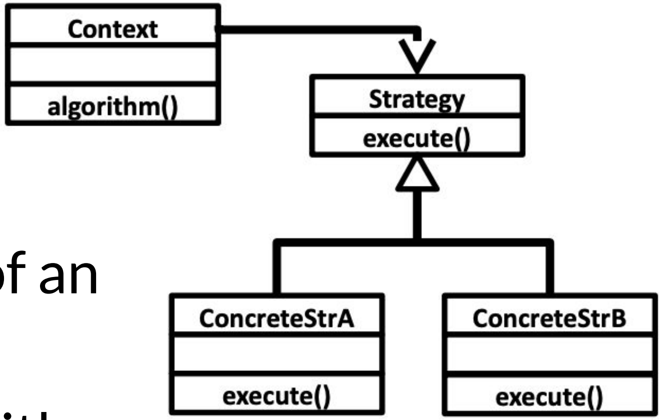

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- Consequences:
  - Easily extensible for new algorithm implementations
  - Separates algorithm from client context
  - Introduces extra interfaces and classes: code can be harder to understand; adds overhead if the strategies are simple

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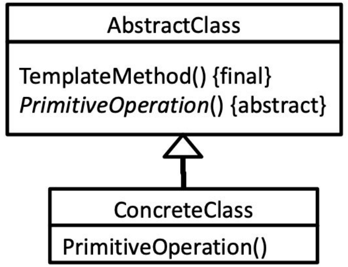

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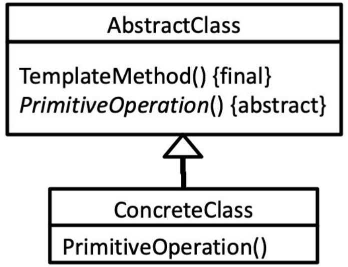

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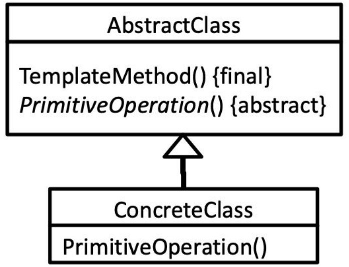

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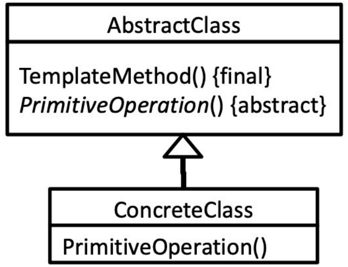
- Consequences:
  - Code reuse for the invariant parts of algorithm

Template Method Design Pattern



- Problem: An algorithm has **customizable** and **invariant** parts
- Solution: Implement the invariant parts of the algorithm in an **abstract** class, with abstract primitive operations representing the customizable parts of the algorithm. Subclasses customize the primitive operations.
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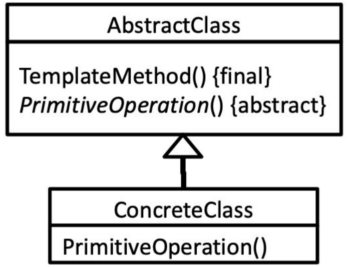

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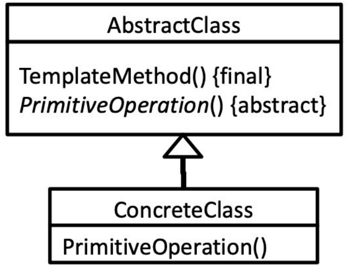

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    - Invariant parts of the algorithm are not changed by subclasses

Template vs. Strategy Design Pattern

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- Both support variation in a larger context

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Template vs. Strategy Design Pattern

- Both support variation in a larger context
- **Template method** uses inheritance + an overridable method
- **Strategy** uses an interface and polymorphism (via composition)
    - Strategy objects are reusable across multiple classes
    - Multiple strategy objects are possible per class

Scenario: binge-watching

- Suppose we're implementing a video streaming website in which users can “binge-watch” (or “lock on”) to one channel. The user will then see that channel's videos in sequence. When the last such video is watched, the user should stop binge-watching that channel.

Scenario: binge-watching

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```
class Channel {
 // Called when the last video is shown
 public void on_last_video_shown() {
   // Global accessor for the user
   get_user().release_binge_watch(this);
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- What are some problems with this approach?

Scenario: binge-watching: anti-patterns

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What can we do instead?

Observer Pattern

- The ***observer pattern*** (also called "***publish-subscribe***") allows dependent objects to be notified automatically when the state of a subject changes. It defines a one-to-many dependency between objects so that when one object changes state, all of it dependents are notified.

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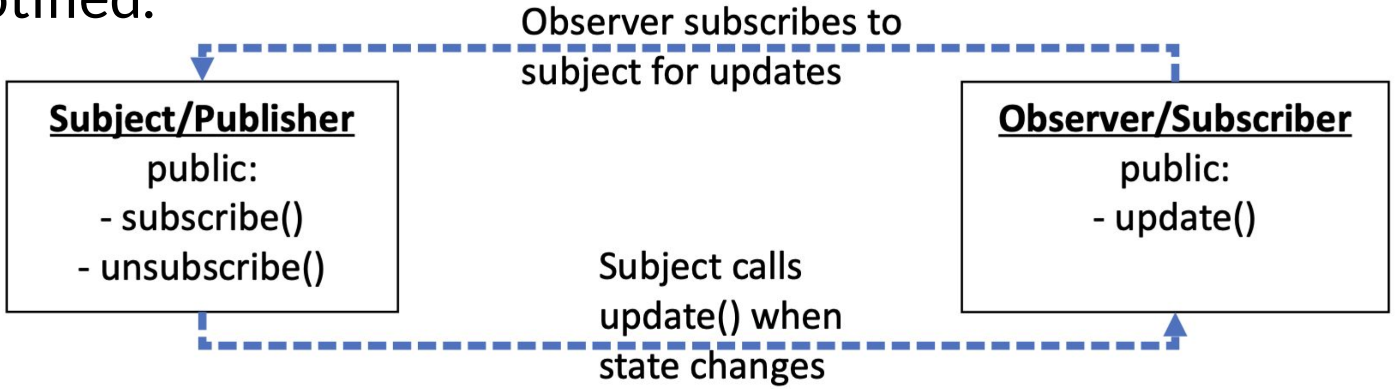
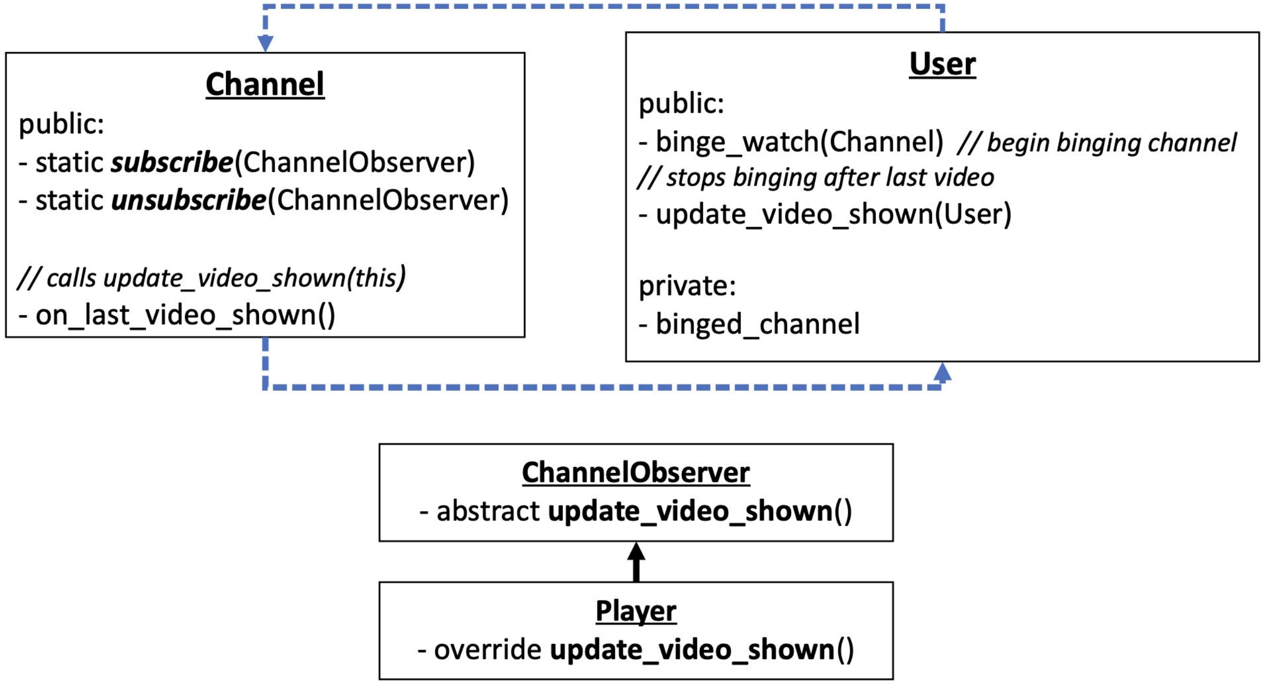
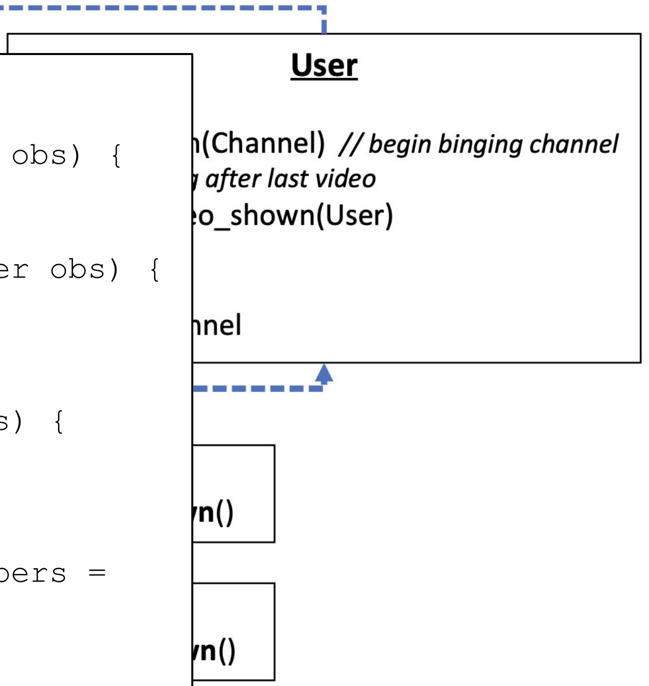


Observer Pattern: bing-watch scenario



Channel
public:
- static ***subscribe***(ChannelObserver)
- static ***unsubscribe***(ChannelObserver)
// calls update_video_shown(this)
- on_last_video_shown()
User
public:
- binge_watch(Channel) *// begin binging channel*
// stops binging after last video
- update_video_shown(User)
private:
- binged_channel
ChannelObserver
- abstract **update_video_shown**()
Player
- override **update_video_shown**()

Observer Pattern: bing-watch scenario



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class Channel {
 public static void subscribe(ChannelObserver obs) {
   subscribers.Add(obs);
 }
 public static void unsubscribe(ChannelObserver obs) {
   subscribers.Remove(obs);
 }
 public void on_last_video_shown() {
   foreach (ChannelObserver obs in subscribers) {
     observer.update_video_shown(this);
   }
 }
 private static List<ChannelObserver> subscribers =
          new List<ChannelObserver>();
}
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Observer Pattern: bing-watch scenario

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interface ChannelObserver {
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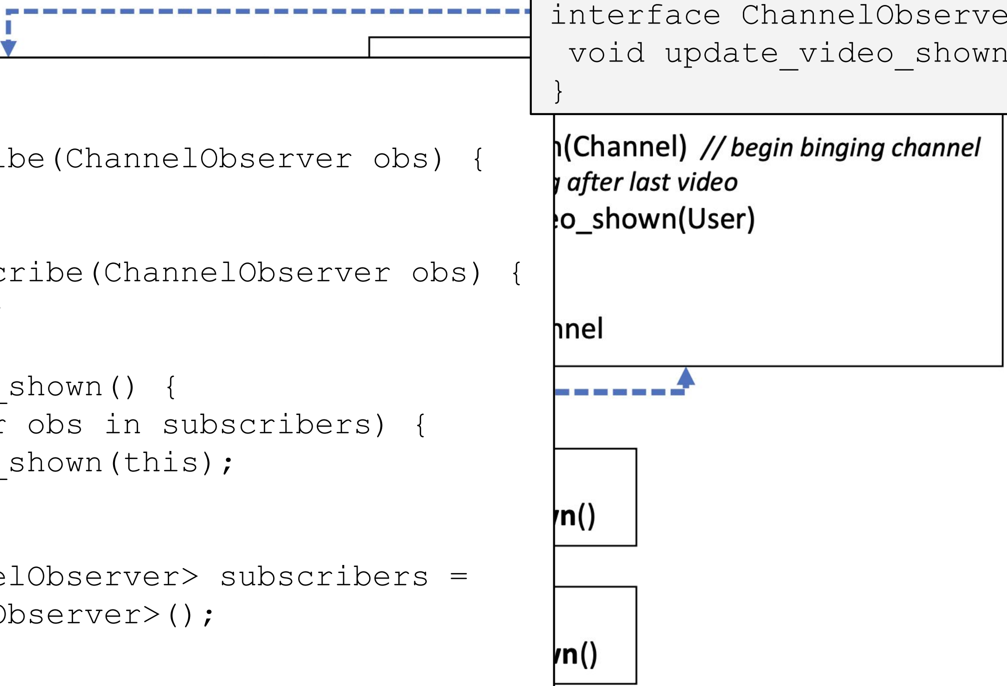

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- Having multiple “update_” functions, one for each type of state change, keeps messages **granular**
    - Observers that do not care about a particular type of update can ignore it (via an empty implementation of the update function)
- Generally it is better to pass the newly-updated data as a parameter to the update function (**push**) as opposed to making observers fetch it each time (**pull**)

Design patterns: takeaways

- Thinking about design before you start coding is usually worthwhile for large projects
  - Design around the most expensive parts of the software engineering process (usually maintenance!)
- Design patterns are reusable solutions to common problems
- Be familiar with them enough to recognize when they're being used
  - and to know when to use them yourself
  - you can look up details of a pattern if you remember its name!
- Be mindful of and avoid common anti-patterns

Tech debt, refactoring, and maintenance (1/2)

Today’s agenda:

- Finish design pattern slides
- **Technical debt: the costs of bad design**
- How to pay off technical debt: refactoring

Technical debt

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- analogy to **financial debts**:
  - you gain some immediate benefit
    - in a financial debt, you gain a large sum of money
    - in a technical debt, you gain implementation speed, etc.
  - you pay for it over time
    - in a financial debt, you pay interest
    - in a technical debt, your maintenance costs increase

Technical debt: benefits

- Why might you **intentionally** make a sub-optimal design decision?

Technical debt: benefits

- Why might you **intentionally** make a sub-optimal design decision?
  - Cost
    - either in dev time or because the code isn’t done yet
  - Need to meet a deadline
  - Avoid premature optimization
  - Code reuse
  - Principle of least surprise
  - Organizational requirements/politics
  - etc.

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  - make the system easy to extend, modify, etc.

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- Recall our goals in good design:
  - design for **change and reuse**
  - make the system easy to extend, modify, etc.
- **Implication**: a system with technical debt is **harder** to change and reuse

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- code smells

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Technical debt: benefits and costs

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● code smells	● “smelly” code is less flexible
● missing tests	● tests don’t catch breaking change, causing outages
● missing documentation	● need to spend time to figure out how to system works
● dependency on old versions of third-party systems	● may need to take over maintenance of old system

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Whether to take on technical debt is often one of the ***most consequential*** choices you get to make as an engineer. **Take it seriously!**

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    - risk should preclude you from taking on certain kind of debts
        - e.g., never use laughably-bad security or break laws, even if you don't plan to deploy this prototype
- Best practice (especially for relatively risky debts): **write everything down**!
    - that way, you know what you need to fix before releasing

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- This is an example of technical debt:
    - **immediate benefit**: saves hard disk space (expensive in 1980)
    - **long-term cost**: if the program is still being used in 2000, need to fix it!
        - "I just never imagined anyone would be using these systems 10 years later, let alone 20."

[Philippe Kruchten, Robert Nord, Ipek Ozkaya: "Managing Technical Debt: Reducing Friction in Software Development"]

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    - the amount of technical debt you have is higher than if your bus factor was very high
- Other examples include having **high staff turnover** (which systematically lowers bus factor) or few senior engineers

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  - If the code's structure does not also evolve, it will "rot"

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    - but, if you end up needing to write performance-critical or safety-critical code in them, you're going to have a bad time!
  - on the other hand, investing in writing in a safe and performant language (e.g., Rust, Kotlin) has a **higher upfront cost**

Technical debt example: languages

- **Language choice** is a common example of a place where it might make sense to take on technical debt:
  - relatively-unsafe and/or non-performant languages (e.g., Python, Ruby, JavaScript) are **easier to write** code in
    - but, if you end up needing to write performance-critical or safety-critical code in them, you're going to have a bad time!
  - on the other hand, investing in writing in a safe and performant language (e.g., Rust, Kotlin) has a **higher upfront cost**
    - but you might save a big headache later

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Other similar choices include:

- middleware frameworks
- deployment pipeline
- major dependencies

Technical debt example: Facebook + PHP

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  - Hack added **new safety features** (including gradual typing and type inference)
  - “Hack enables us to dynamically convert our code one file at a time” - Facebook Technical Lead, HipHop VM (HHVM)

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  - but if you don't pay down the debt quickly…

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- However, early signs are **not promising**:
  - LLMs seem to be easily confused by atypical code patterns, quirks of leaky abstractions, etc. (all hallmarks of tech debt)
  - LLMs can **introduce technical debt** themselves
    - e.g., recent studies have shown that with an LLM assistant, devs are more likely to write insecure code [1]

[1] *Do Users Write More Insecure Code with AI Assistants?* Neil Perry, Megha Srivastava, Deepak Kumar, and Dan Boneh. CCS 2023.

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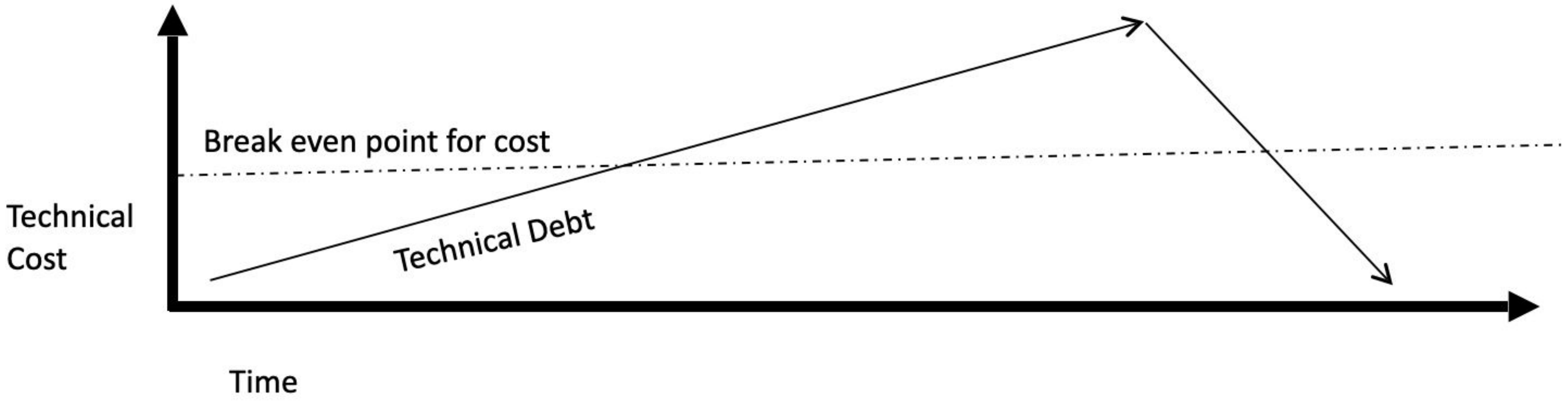
  - one option: **rewriting** the whole system (but think about today's Spolsky reading!)
  - more common: **refactoring** the code
- ***refactoring*** is the process of applying behaviour-preserving transformations (called ***refactorings***) to a program, with the goal of improving its non-functional properties (e.g., design, performance)

Paying down technical debt



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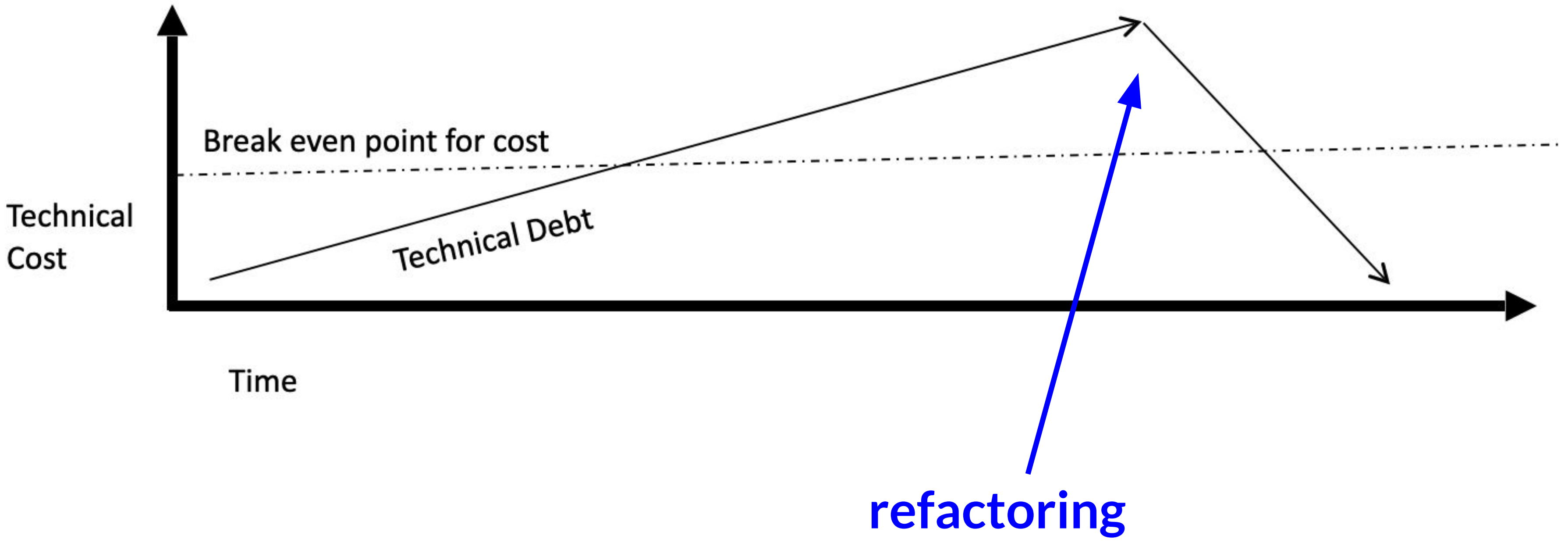

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- Have a plan: **don’t put off dealing with technical debt indefinitely**
  - When a crisis hits, it’s too late
  - Hasty fixes to unmaintainable code likely to multiply problems!
  - Eventually, mounting technical debt can bury a team

Tech debt, refactoring, and maintenance

Agenda:

- Finish design pattern slides
- Technical debt: the costs of bad design
- **How to pay off technical debt: refactoring**

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What refactoring is **not**:

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What refactoring is **not**:

- rewriting code
- adding features
- debugging code

Refactoring: motivation

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- If the code does not do one or more of these, it ***is*** broken.
- Refactoring should improve the software's design:
  - more extensible, flexible, understandable, performant, …
  - every design improvement has costs (and risks)

Refactoring: when to refactor

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- many code smells -> good idea to refactor
- a good refactoring often fixes more than one code smell
  - sometimes many more than one

Refactoring: when to refactor

Examples of **common code smells**:

Refactoring: when to refactor

Examples of **common code smells**:

- Duplicated code
- Poor abstraction (change one place → must change others)
- Large loop, method, class, parameter list; deeply nested loop
- Module has too little cohesion
- Modules have too much coupling
- Module has poor encapsulation
- Dead code
- Design is unnecessarily general
- Design is too specific

Refactoring: “low-level” refactoring

- “***low-level***” refactorings are small changes to the code that mitigate or remove one or more code smells. Examples:

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- “***low-level***” refactorings are small changes to the code that mitigate or remove one or more code smells. Examples:
    - Renaming (methods, variables)
    - Naming (extracting) “magic” constants
    - Extracting common functionality (including duplicate code) into a module/method/etc.
    - Changing method signatures
    - Splitting one method into two or more to improve cohesion and readability (by reducing its size)

also see https://refactoring.com/catalog/

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        - e.g., Eclipse, VSCode, IntelliJ, etc.
- they automate:
    - renaming of variables, methods, classes
    - extraction of methods and constants
    - extraction of repetitive code snippets
    - changing method signatures
    - warnings about inconsistent code
    - …

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My advice/opinion: don’t rely on your IDE too much. It’s useful for auto-complete, simple refactoring, red squiggles, etc. But, if you let it control the build process you’ll have a bad time.

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- Compared to low-level refactoring, high-level is:
  - Not as well-supported by tools
  - But much **more important**!

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These are a good set of criteria for deciding to refactor code

- especially "needs new features", because if you don't refactor you'll be **paying interest** on the tech debt!

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  - Add any **new features**.
  - As always, keep changes small, do code reviews, etc.

Takeaways: tech debt and refactoring

- Technical debt accrues when you take a shortcut for some immediate benefit that makes a system harder to maintain
  - tech debt is inevitable in large systems
  - but you should be thoughtful about when/how you take it on!
- When and how you take on technical debt is one of the biggest judgment calls that you will make as a low-level engineer
- Refactoring is the process of improving a codebase's non-functional properties while maintaining its behavior
  - refactoring is a useful way to reduce tech debt
  - you often want to pair refactoring with adding new features