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

Martin Kellogg

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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

Software Architecture (Part 2 of 2)

Agenda:

- Strategies for good design
- Design patterns
  - Structural patterns
  - **Creational patterns**
  - Behavioural patterns

Design patterns: creational patterns

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    - Control how and when an object is used
    - Overcome language limitations (e.g., no default arguments)
    - Hide polymorphic types
    - Specify different combinations of optional arguments

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> Different creational patterns allow you to overcome these limitations of simple constructors

Creational patterns: named constructor

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```
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")
   return new BitcoinPayment(name);
 … }

Payment * webapp_session_payment =
 payment_factory(customer_name, "credit_card");
```

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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```
class PaymentFactory {
public:
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 }
 static Payment* make_bc_payment(string name){
   return new BitcoinPayment(name);
 }};
Payment * webapp_session_payment =
PaymentFactory::make_credit_payment(customer_name);
```

Creational patterns: example

- Suppose we're implementing a computer game with a **polymorphic Enemy class hierarchy**, and we want to spawn **different versions** of enemies based on the difficulty level.
- e.g., normal difficulty = regular Goomba

- hard difficulty = spiked Goomba

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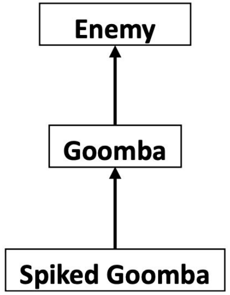

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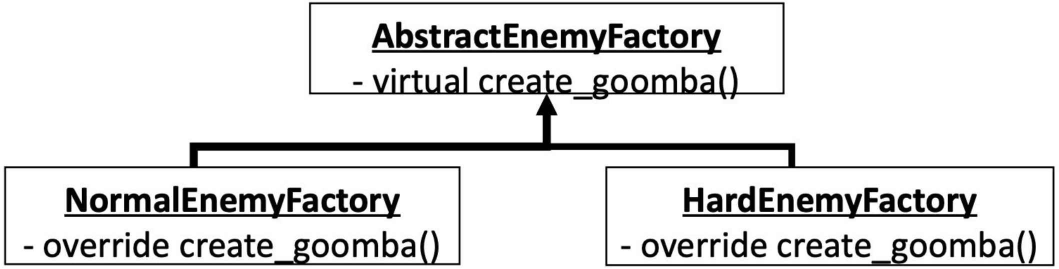

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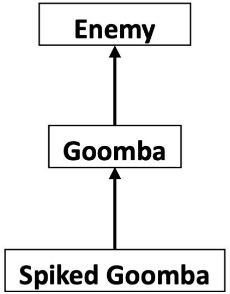

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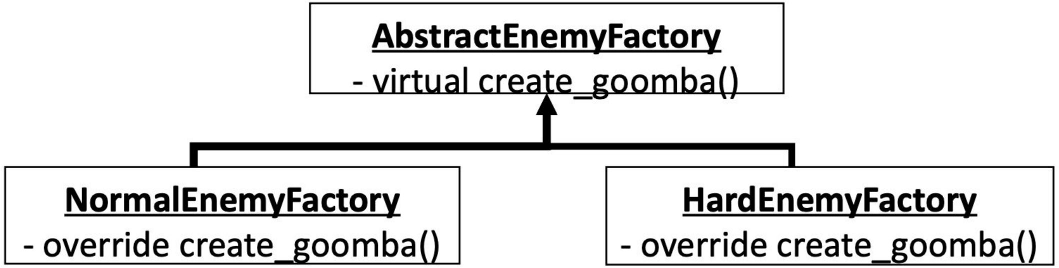


```
// Only have to do this once!
AbstractEnemyFactory* factory = nullptr;
if (difficulty == “normal”)
  factory = new NormalEnemyFactory();
else if (difficulty == “hard”)
  factory = new HardEnemyFactory();
Enemy* goomba = factory->create_goomba();
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-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

What is the output of this code?

<u>Singleton</u>
public:
- static ***get_instance***() *// named ctor*
- get_billing_count()
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private:
- static ***instance*** *// the one instance*
- Singleton() *// ctor, prints message*
- billing_database

```
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: 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**?

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  - Singleton is **not** a license to make everything global.

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  - Examples: strategy pattern, template method pattern, iterator pattern, observer pattern, etc.

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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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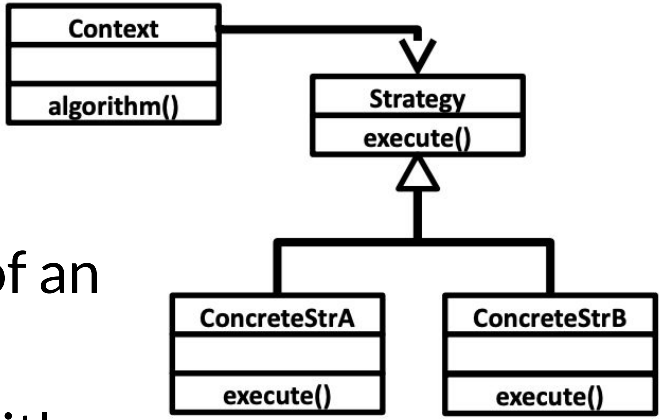

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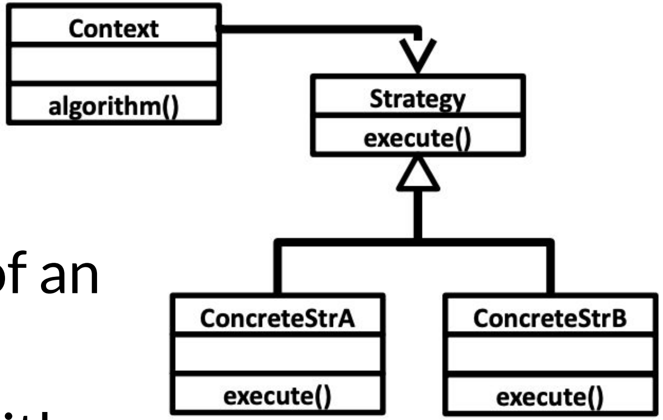

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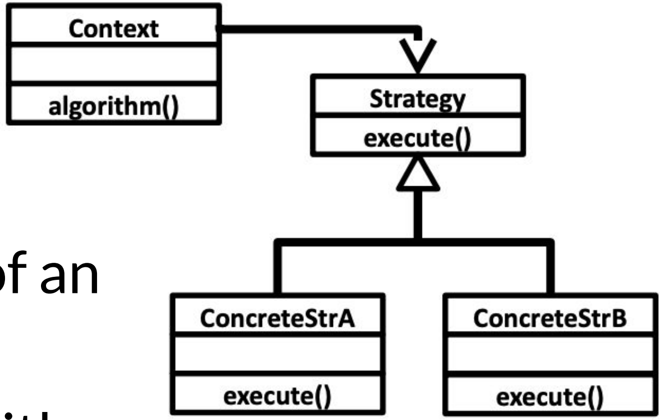

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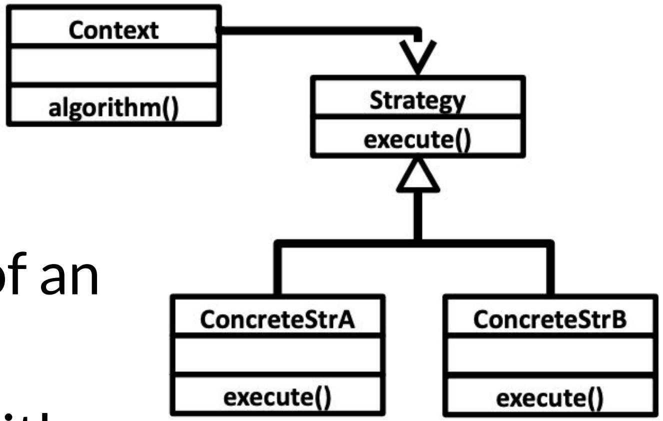

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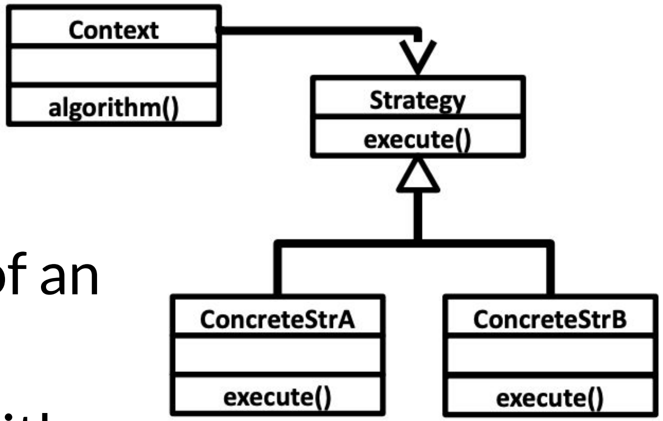

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- Consequences:
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  - Separates algorithm from client context
  - Introduces extra interfaces and classes: code can be harder to understand; adds overhead if the strategies are simple

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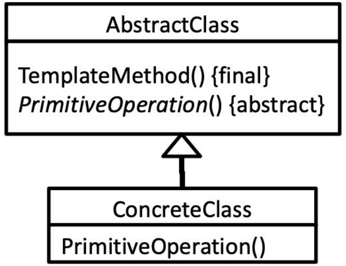

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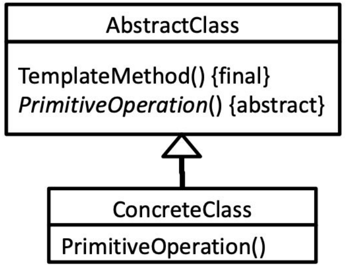

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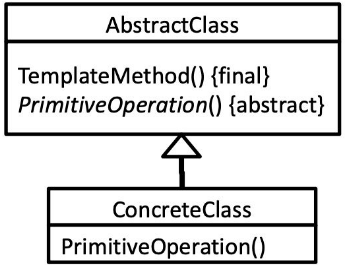

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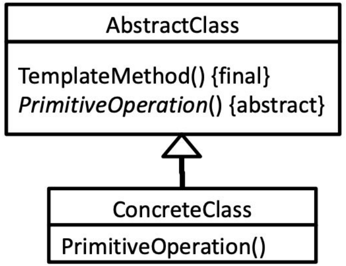

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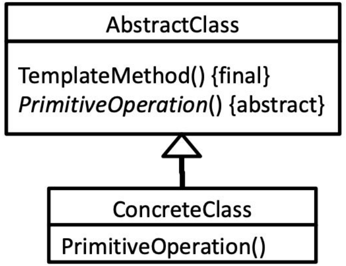

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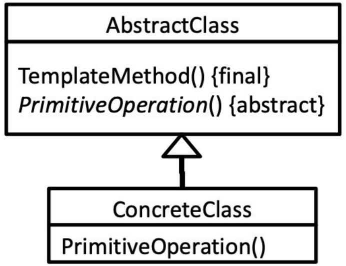

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    - Customization is restricted to the primitive operations
    - Inverted ("Hollywood-style") control for customization: "don't call us, we'll call you" (cf. comparison function in sorting)
    - Invariant parts of the algorithm are not changed by subclasses

Template vs. Strategy Design Pattern

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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.

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```
class User {
 public void release_binge_watch(Channel c) {
   if (c == binge_channel) {
     binge_channel = null;
   }
 }
 private Channel binge_channel;
}
```

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class User {
 public void release_binge_watch(Channel c) {
   if (c == binge_channel) {
     binge_channel = null;
   }
 }
 private Channel binge_channel;
}
```

```
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);
 }
}
```

Scenario: binge-watching

- Idea: when the last video is watched, call release_binge_watch() on the user.

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- What are some problems with this approach?

Scenario: binge-watching: anti-patterns

- With this design, User and Channel are **tightly coupled**
    - Changing one likely requires a change to the other

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- What if we later want to update a user's “recommendation queue” when they finish binge-watching a channel?
- Whenever requirements change and we want to do something else when a video finishes (e.g., update advertising) we **must update the Channel class** and couple it to the new feature

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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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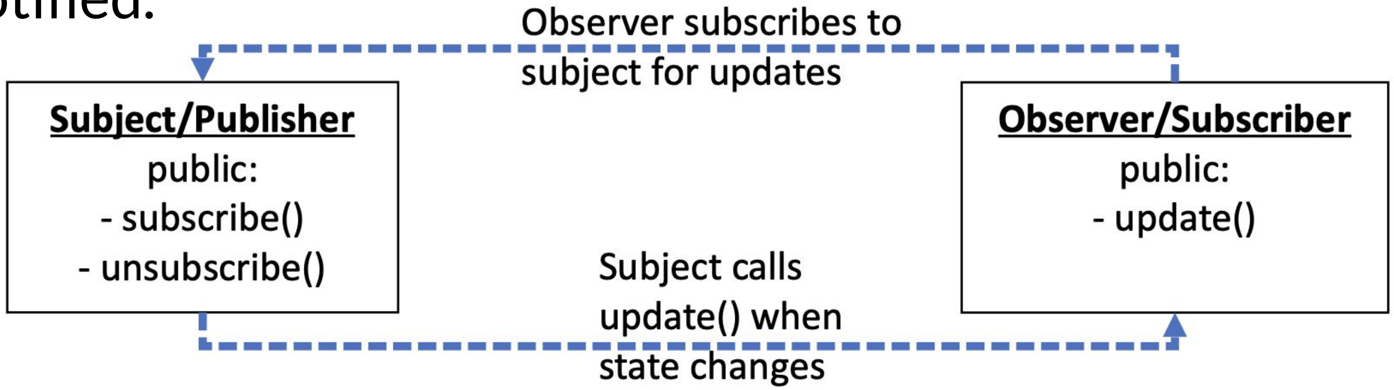
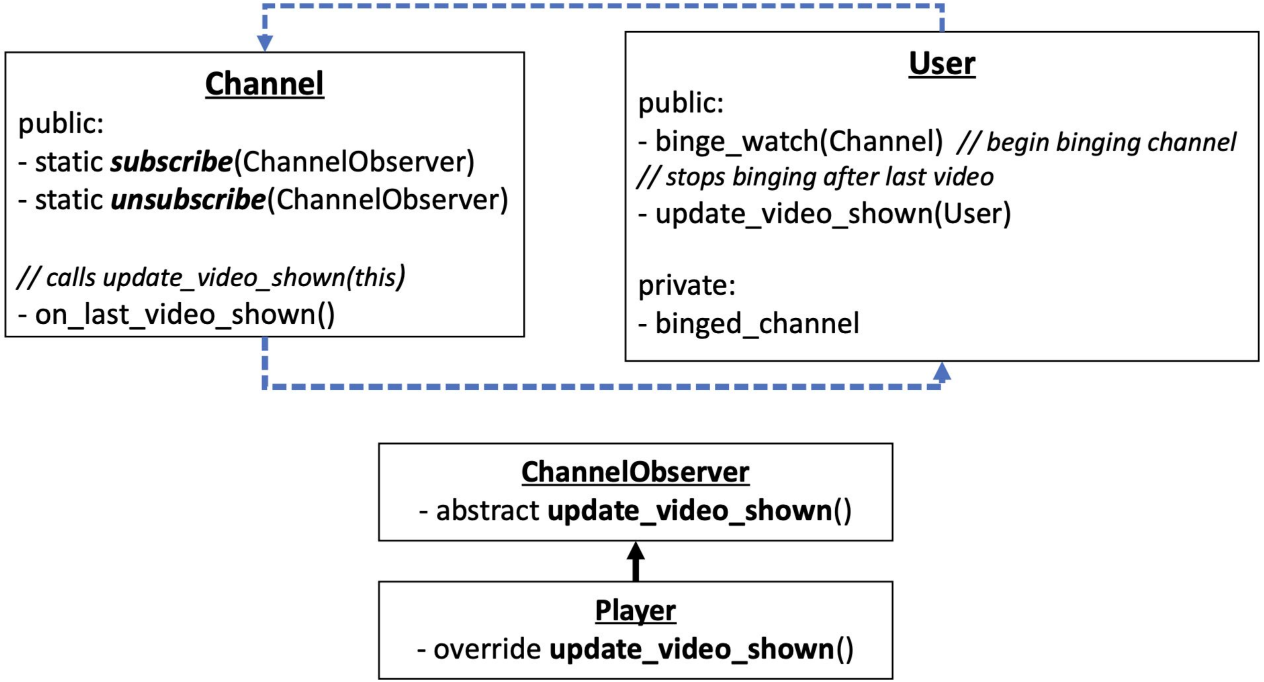


Observer Pattern: bing-watch scenario



Observer Pattern: bing-watch scenario

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class Channel {
 public static void subscribe(ChannelObserver obs) {
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 }
 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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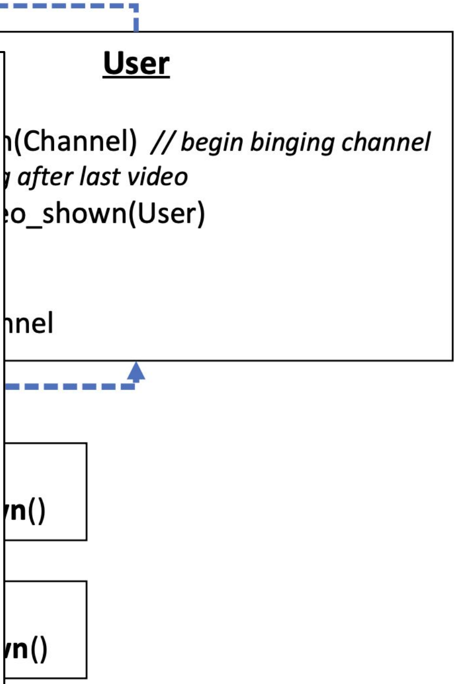

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Observer Pattern: update functions

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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 maintainence!)
- Design patterns are re-usable 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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- may need to take over maintenance of old system
- lose potential customers

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

Martin Kellogg

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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

Technical debt: Y2k example

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    - assumption: current year = "19" + those two digits
- 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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- Why does bitrot happen?
  - Systems evolve to meet new needs and add new features
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  - If the code's structure does not also evolve, it will "rot"

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Other similar choices include:

- middleware frameworks
- deployment pipeline
- major dependencies

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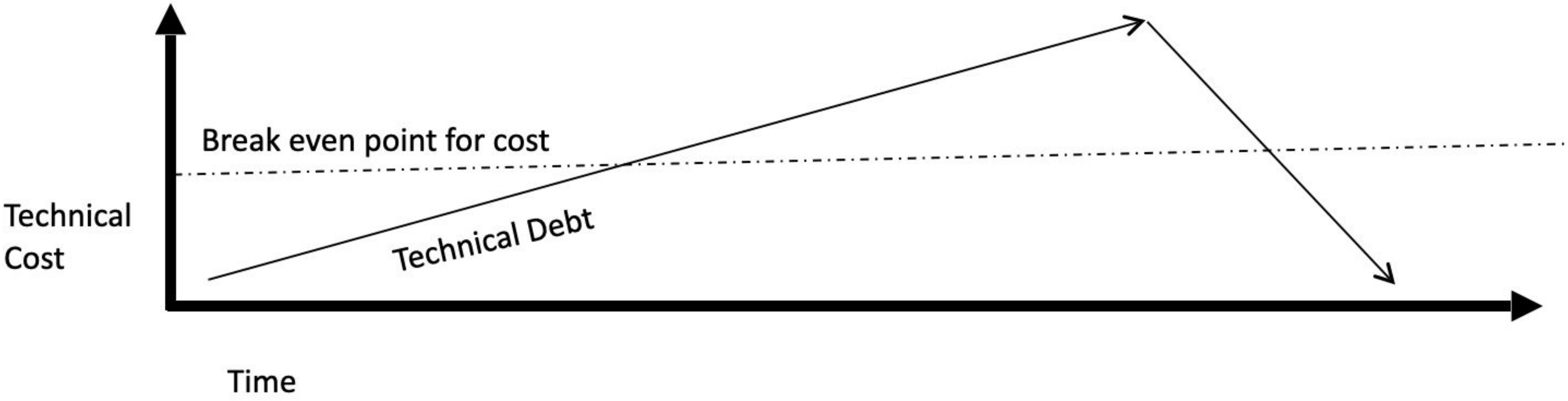
    - one option: **rewriting** the whole system (but think about next class' reading!)
    - more common: **refactoring** the code
- ***refactoring*** is the process of applying behaviour-preserving transformations (called ***refactorings***) to a program, with the goal of improving its non-functional properties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

Paying down technical debt



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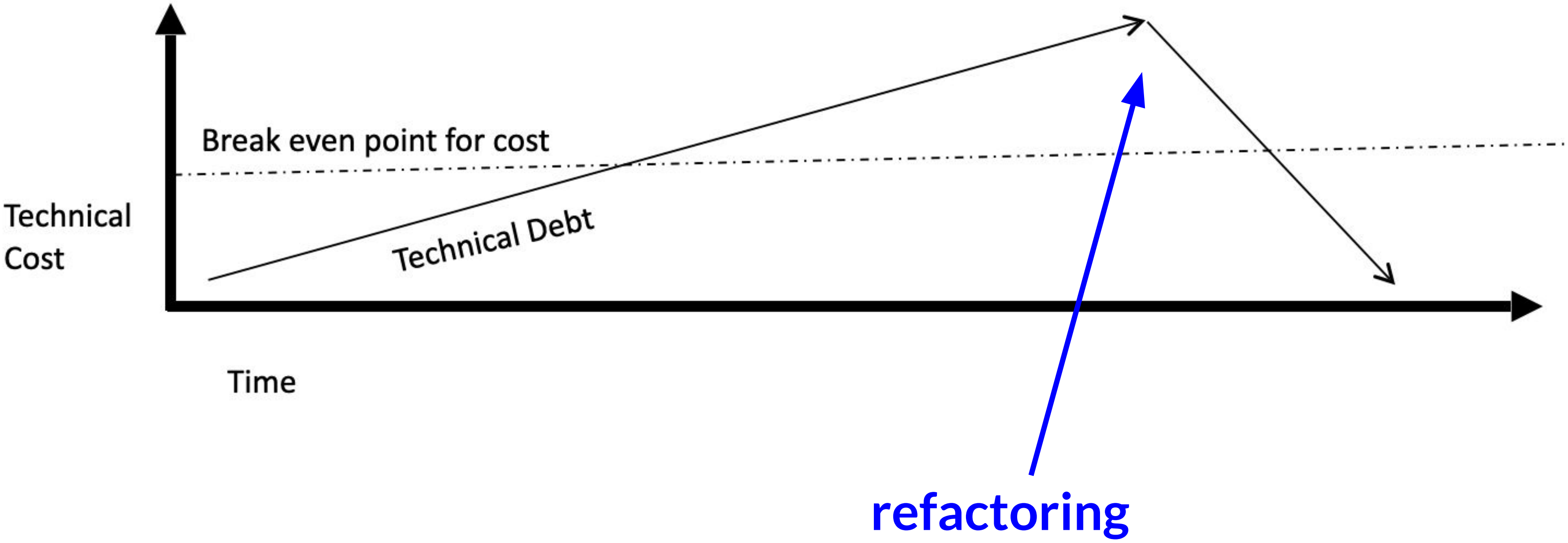

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  - i.e., refactoring at the start of a project to make the rest of the new code easier to write
- Have a plan: **don’t put off dealing with technical debt indefinitely**
  - When a crisis hits, it’s too late
  - Hasty fixes to unmaintainable code likely to multiply problems!
  - Eventually, mounting technical debt can bury a team

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

Today’s agenda:

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

Refactoring

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What refactoring is **not**:

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What refactoring is **not**:

- rewriting code
- adding features
- debugging code

Aside: rewriting code

- “refactoring code” != “rewriting 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

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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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Refactoring: “low-level” refactoring

- modern IDEs have good support for low-level refactoring
    - ***IDE*** = “***integrated development environment***”
        - 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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  - Performance optimization
  - Clarifying a statement that has evolved over time or is unclear
- 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.

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A. Firefox at Mozilla
B. the Mars Polar Orbiter at NASA
C. CalMail at Berkeley

Q2: **TRUE** or **FALSE**: the author argues that there are “some forms of technical debt are so expensive that they should be avoided entirely whenever possible”

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A. it's harder to read code than to write it
B. testing can show the presence of bugs, but not their absence
C. always double your estimates (even those you already doubled)

Q2: The main complaint of the author of "software disenchantment" is:

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Critical discussion of “software disenchantment”

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We had a brief discussion of the second reading for today. Highlights:

- the author is mostly complaining, and doesn’t actually offer solutions. This is very common (but not very productive!)
- this sort of article is popular with a certain segment of engineers (e.g., HackerNews). You will hear these kind of hot takes again
  - be ready to recognize this when you run into it
- I (Prof Martin) don’t agree with all of these complaints
- One explanation for “why is software so big” is that it handles many special cases well (i.e., many bugs have already been fixed)
  - rewriting would destroy this collective knowledge!