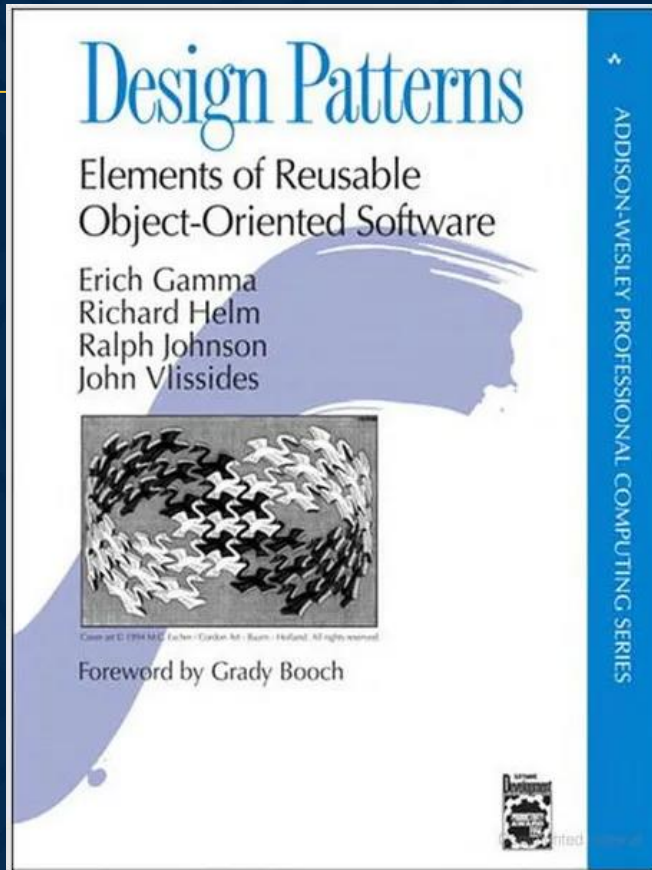


Patterns and Anti-Patterns

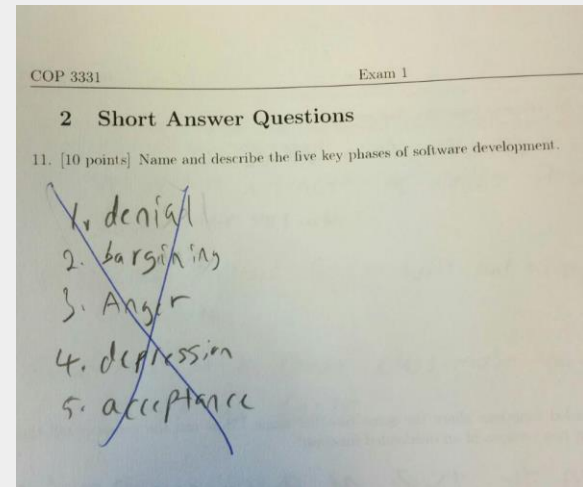
Prof. Kochunas
EECS 481 (W23)



Special thanks for James Perretta!

The Story so far...

- We want to deliver and support a quality software product
 - We understand the stakeholder requirements
 - We understand process and design
 - We understand quality assurance
- How should we make process and design decisions **designs** the first time?

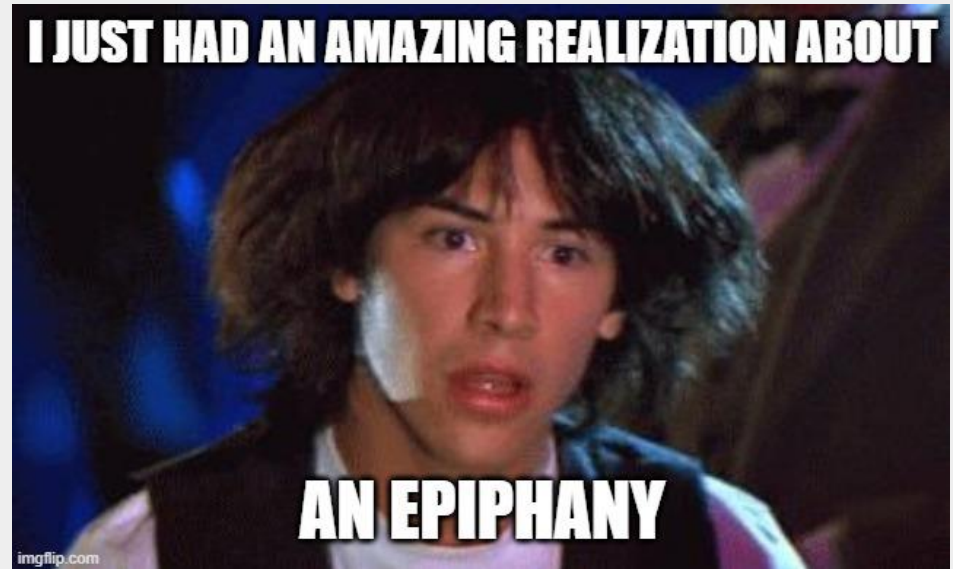


One-Slide Summary

- Software **design patterns** are general, reusable solutions to commonly-occurring problems. They separate the **structure** of a system from its **implementation**. They apply in almost all OO languages.
- Every design has **tradeoffs**. Object-oriented design patterns often trade verbosity or efficiency for **extensibility**.
- We'll consider **structural**, **creational**, and **behavioral** design patterns.

Outline (the emotional journey)

- 10,000 Foot View
- Structural Patterns
- Creational Patterns
- Behavioral Patterns



Learning Objectives: by the end of today's lecture you should be able to...

1. (*knowledge*) explain at a high level what types of software problems *structural*, *creational*, and *behavioral* patterns deal with
2. (*knowledge*) explain what an anti-pattern is
3. (*skill*) think critically about the implications of design choices
4. (*knowledge*) explain some of the patterns discussed in this lecture

10,000 ft view



Patterns in Non-Software Design

Multiple choice question

1. Rick Astley's never gonna:

← Question Stem

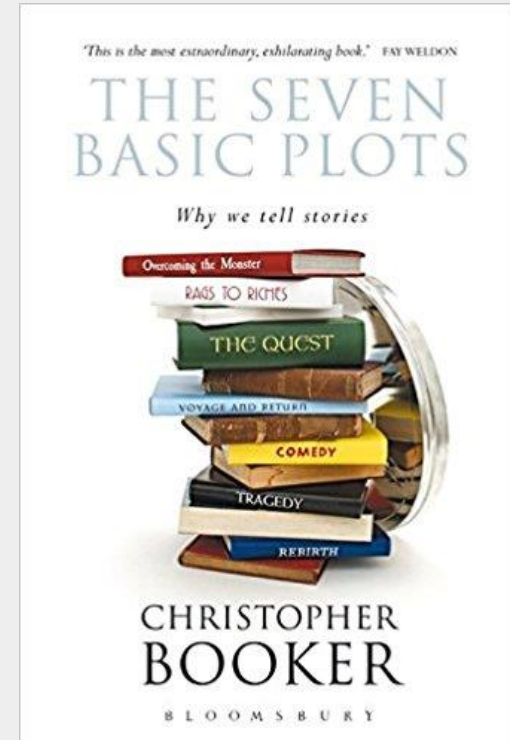
Options

- Give you up
- Let you down
- Run around and
- Desert you
- All of the above

← Distractors

← Correct

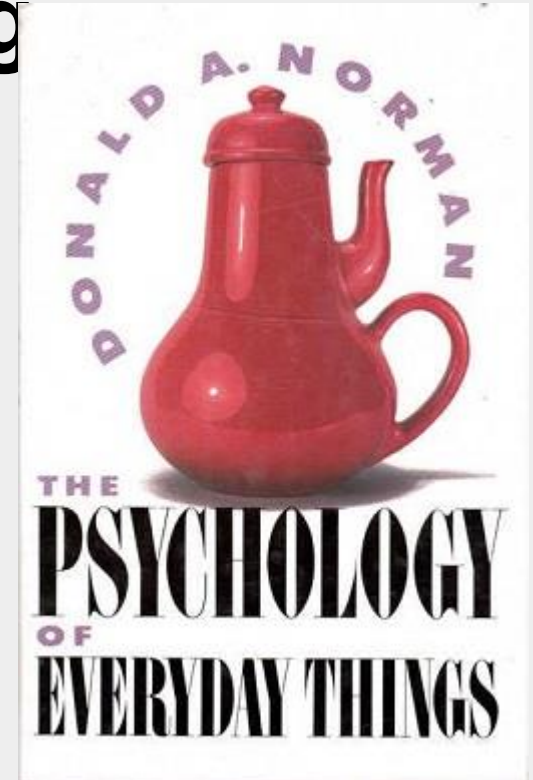
VERSE	CHORUS	VERSE	CHORUS	BRIDGE	CHORUS
A	B	A	B	C	B



Further Real-World Reading

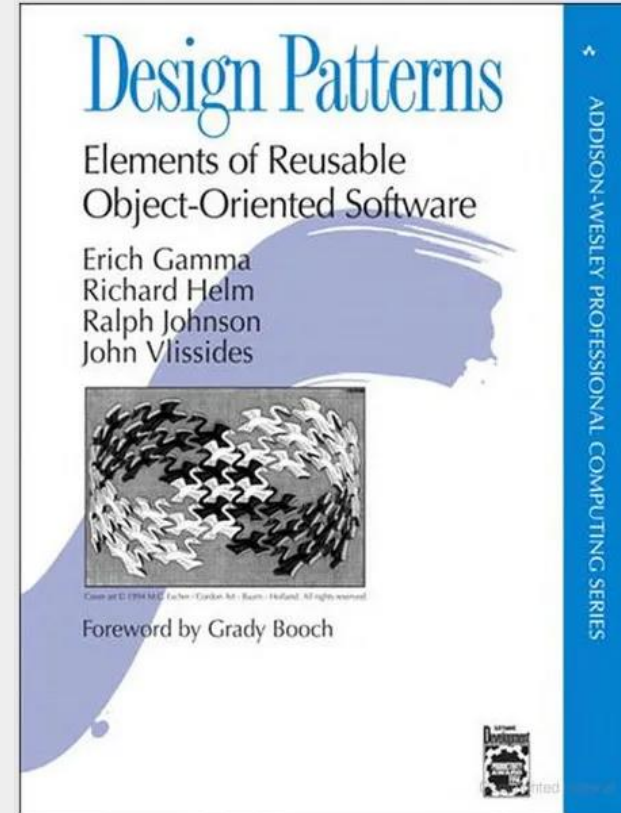
- **The Design of Everyday Things**

- design serves as the communication between object and user
- although people often blame themselves when objects appear to malfunction, it is not the fault of the user but rather the lack of intuitive guidance that should be present in the design
- behavioral psych + ergonomics



Jargon

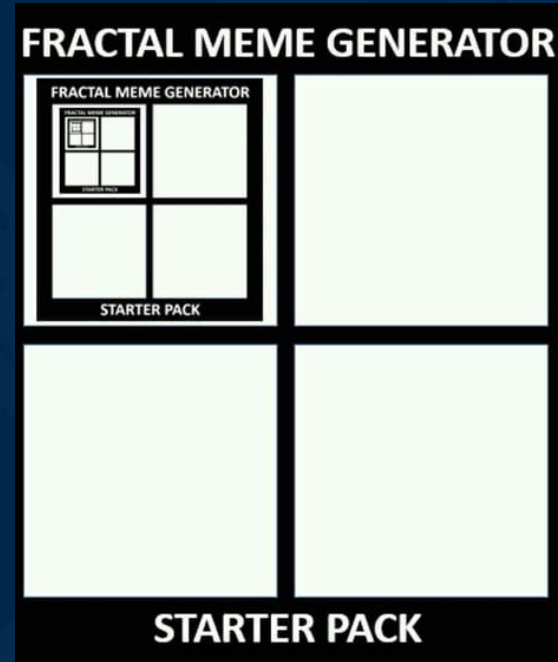
- The book popularizing software design patterns is often called the **Gang of Four** book after its four authors
- (Sometimes handy for talking to interviewers or practitioners.)



High-Level Design Pattern Advice

- **Consider code change** as a certainty
 - Redesign is expensive. Choosing the right pattern helps avoid it.
- **Consider your requirements** and their changes
 - Use patterns that fit your current or anticipated needs.
- **Consider multiple designs**
 - Diagram your designs before writing code.

Structural Patterns



Structural Patterns

- **Structural design patterns** ease design by identifying simple ways to **realize relationships among entities**.
- In software, they usually
 - Build new classes or interfaces from existing ones
 - Hide implementation details
 - Provide cleaner or more specialized interfaces



Adapter Design Pattern

- The **adapter design pattern** is a structural design pattern that converts the interface of a class into another interface clients expect.



Adapter Examples (1/2)

- Implementing a Stack interface using a LinkedList interface



Stack

- push ()
- top ()
- pop ()

LinkedList

- push_front ()
- front ()
- pop_front ()
- push_back ()
- back ()
- pop_back ()
- insert ()

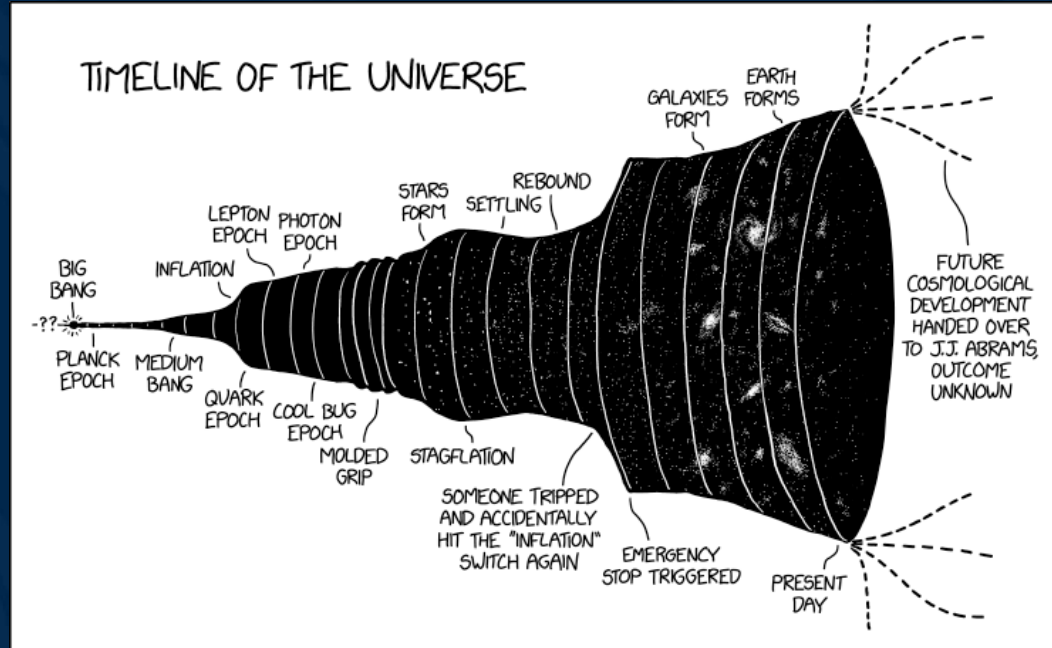
Adapter Examples (2/2)

- Early implementations of `fstream` in C++
 - ... were simply adapters around the C `FILE` macro
- The autograder used for this course securely runs student code
- It does this via an adapter around a containerization library (e.g., `docker`)
 - Handles quirks of the library
 - Makes sure that certain options are always used

Other Structural Patterns

- The **composite design pattern** allows clients to treat individual objects as groups of objects uniformly
 - e.g., selecting and moving objects in PowerPoint
- The **proxy design pattern** provides a surrogate or placeholder for another object to control access to it
 - `std::vector` exposes `std::vector::reference` as a method of accessing individual bits. In particular, objects of this class are returned by `operator[]` by value.
https://en.cppreference.com/w/cpp/container/vector_bool

Creational Patterns



Creational Design Patterns

- **Creational design patterns** avoid complexity by controlling object creation so that objects are created in a manner suitable for the situation. They make a system **independent of how its objects are created**.
- A plain constructor may not allow you to
 - Control how and when an object is used
 - Overcome language limitations (e.g., no default arguments)
 - Hide polymorphic types

The Named Constructor Idiom

- In the **Named Constructor Idiom** 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;  
};
```

A Common Problem

- Suppose we need to create and use polymorphic objects **without exposing their types** to the client
 - Recall: design for maintainability and extensibility. We don't want the client to depend on (and thus “lock in”) the actual subtypes.
- The typical solution is to write a function that creates objects of the type we want but returns that object so that it appears to be (“cast to”) a member of the base class

The Factory Pattern

- The **factory method pattern** is a creational design pattern that uses factory methods to create objects without having the return type reveal the exact subclass created.

```
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");
```

Factory Pattern Variant

- You may also encounter implementations in which special methods create the right type:

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

```
Payment * webapp_session_payment =  
PaymentFactory::make_credit_payment(customer_name);
```

Scenario: Difficulty-Based Enemies

- 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.

- Normal Difficulty → Goomba



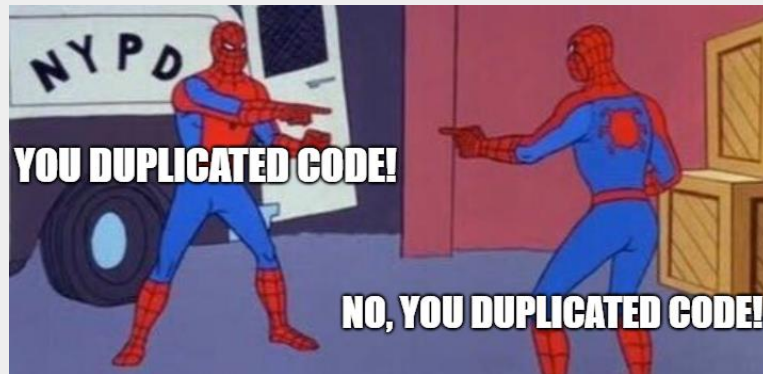
- Hard Difficulty → Spiked Goomba



Anti-Patterns

- An anti-pattern is a common response to a recurring problem that is usually ineffective and risks being counterproductive.
- A *bad* solution (anti-pattern) would be to check the difficulty at each of the many places in the code related to spawning enemies:

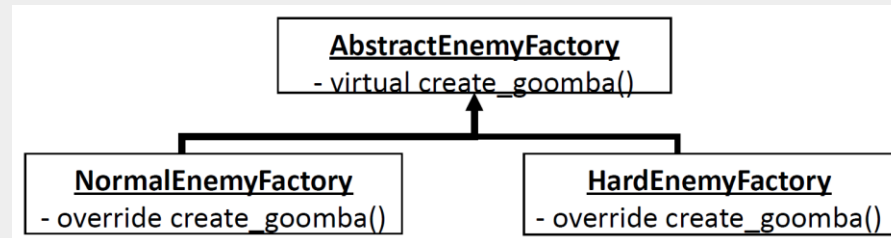
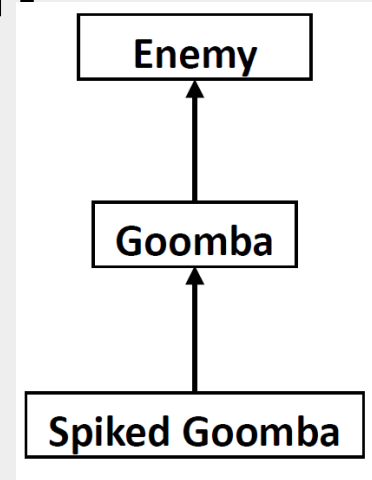
```
Enemy* goomba = nullptr;  
if (difficulty == "normal")  
    goomba = new Goomba();  
else if (difficulty == "hard")  
    goomba = new SpikedGoomba();
```



Abstract Factory Design Pattern

- The abstract factory pattern encapsulates a group of factories that have a common theme without specifying their concrete classes.

```
// 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();
```



Scenario: Global Application State

- 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 a naked global variable.
 - 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.



Acceptability of Global Variables

- Global variables are usually a **poor design choice**. However:
- If you need to access some state everywhere, passing it as a parameter to every function clutters the code (readability vs. ...)
 - 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 Example

What the professor covered



What's on the exam



What you remember



```
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;  
    }  
}
```

Single Use Example

- 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();  
        bills = Singleton.get_instance().get_billing_count();  
        System.out.println(bills);  
    }  
}
```

Singleton

public:

- 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

Single Use Example

- What is the output of this code?

Output:
Singleton DB created

cl

0

1

```
args) {  
instance().get_billing_count();
```

```
Singleton.get_instance().increment_billing_count();  
bills = Singleton.get_instance().get_billing_count();  
System.out.println(bills);  
}  
}
```

Singleton

public:

- 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

Singleton.get_instance()

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

```
Single s = Singleton.get_instance();  
System.out.println(s.get_billing_count());  
... // later  
System.out.println(s.get_billing_count());
```

- Is this a good idea or not?

Singleton.get_instance()

```
Single s =  
System.out  
... // later  
System.out
```



```
nce ();  
ng_count ());  
ng_count ());
```

- This is a bad idea. There is **no guarantee** that `Singleton.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 Scenario

- 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.
- Should we make **Game** a singleton?

Scenario Considerations

- Making Game a Singleton is tempting
 - There is only one Game instance in our application
- However, there only happens to be one instance of Game. There's no *requirement* that we only have one instance.
- 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.

Trivia Break



Trivia: Mexican History

- This priest and professor was a leader in the Mexican War of Independence (1810-1820). After giving the famous “Cry of Dolores” speech he gathered an army of 90,000 farmers and fought the Spanish. His troops fled and he was betrayed and executed. Although he did not live to see independence in 1821, the day of his speech (16 September 1810) is officially recognized as the day of Mexican independence.



Trivia: Geography

- This national capital is the most populous city in Western Asia. Almost all inhabitants speak Persian (تهران). It is home to the Azadi Tower memorial, hosted a WWII conference between Roosevelt, Stalin and Churchill, and despite air pollution issues, it is a popular migration destination.



Trivia: US Toys

- This Mattel fashion doll franchise (and associated web series) was created in 2010. It features fictional “ghouls” and “mansters”, such as vegan vampire Draculaura and clumsy Frankie Stein, attending the eponymous school. It was so successful that rival lines such as Bratzillaz and Equestria Girls are viewed as direction reactions attempting to cash in on the same trend.





Psychology: Reaction and Information

- How long does it take you to choose from among multiple stimuli, even when you know the right answer?
- An early experiment presented subjects with a few lamps. Each lamp was labeled (e.g., A, B, C, etc.). Every five seconds, one of the lamps would light up. The subject was asked to press the key, as quickly and as accurately as possible, corresponding to the lamp that lit up.
- While only one lamp was ever lit, the experimenter varied the total number of other lamps (e.g., from 2 to 10).
- How does your reaction time vary as a function of the number of choices?

Psychology: Hick's Law

- Given n equally probable choices, the average reaction time T required for a human to choose among them is: $T = b \cdot \log_2(n + 1)$
 - b is an empirically-learned constant
- **Increasing the number of choices increases decision time logarithmically.** The amount of time taken to process a certain amount of bits is known as the rate of gain of information.

[Hick, W. E. (1 March 1952). "On the rate of gain of information". Quarterly Journal of Experimental Psychology. 4 (1): 11–26]
[Hyman, R (March 1953). "Stimulus information as a determinant of reaction time". Journal of Experimental Psychology. 45 (3): 188–96.]

Psychology: Hick's Law

- Implications for SE:
- Hick's Law is often used to justify menu design decisions in human interfaces – from restaurant menus to UI design in computing. Users given many choices have to take time to interpret and decide, work they typically don't want (cf. analysis paralysis, Mac vs. Windows design philosophy, etc.). Why don't we like voluminous bug-finding tool output again?



Behavioral Patterns



Behavioral

- **Behavioral design patterns** that support common communication patterns among objects. They are concerned with algorithms and the assignment of responsibilities between objects.
- The **iterator pattern** is a common behavioral design pattern. It provides a uniform interface for traversing containers regardless of how they are implemented.

Scenario: Binge-Watching on Video Website

- 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.



Binge-Watch Anti-Pattern

- When the last video is watched, call `release_binge_watch()` on the user.

```
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);  
    }  
}
```

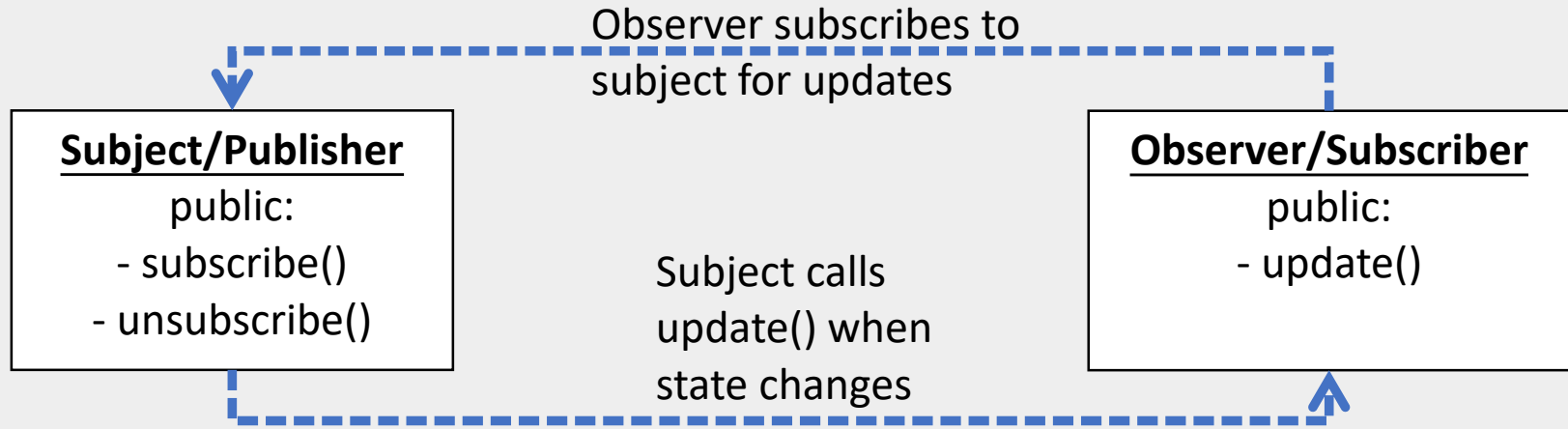
- What are some problems with this approach?

Anti-Pattern Discussion

- User and Channel are tightly coupled
 - Changing one likely requires a change to the other
- The design does not support multiple users
- 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**

Observer Design 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 its dependents are notified.



Note: subscribe and unsubscribe can be static or non-static, depending on implementation.

Observer Pattern Exercise

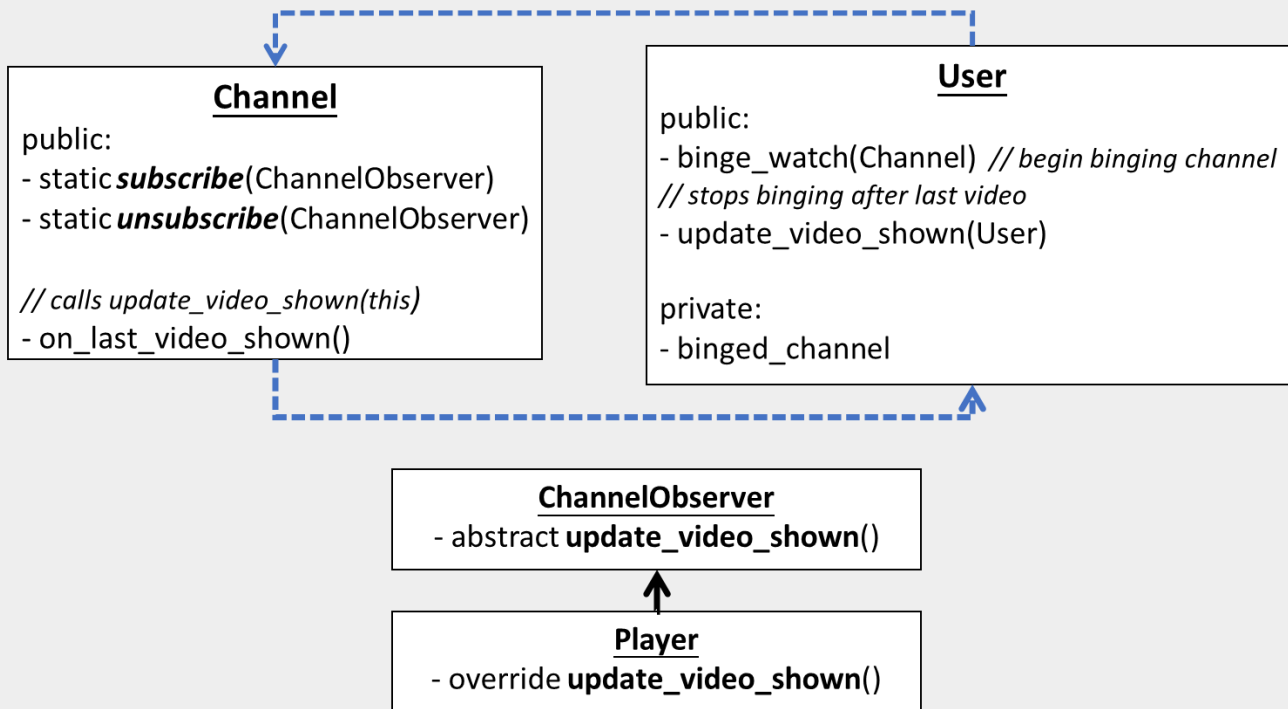
- How many times is “Received update” printed?

```
class Subject {  
    public static void subscribe(Observer obs) {  
        subscribers.Add(obs);  
    }  
    public static void unsubscribe(Observer obs) {  
        subscribers.Remove(obs);  
    }  
    public static void change_state() {  
        foreach (Observer obs in subscribers) {  
            obs.update();  
        }  
    }  
    private static List<Observer> subscribers  
        = new List<Observer>();  
}
```

```
class Observer {  
    public void update() {  
        Console.WriteLine("Received update");  
    }  
}
```

```
class MainClass {  
    public static void Main(string[] args) {  
        Observer observer1 = new Observer();  
        Observer observer2 = new Observer();  
  
        Subject.subscribe(observer1);  
        Subject.change_state();  
  
        Subject.subscribe(observer2);  
        Subject.change_state();  
  
        Subject.unsubscribe(observer2);  
        Subject.change_state();  
    }  
}
```

Observer Pattern for Binge-Watch Scenario



*Abstract means “derived classes must override this method”

Observer for Binge-Watch Implementation

```
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>();
}
```

```
interface ChannelObserver {
    void update_video_shown(Channel channel);
}
```

```
class User: ChannelObserver {
    public void update_video_shown(Channel c) {
        if (c == binged_channel)
            binged_channel = null;
    }

    public void binge_watch(Channel c) {
        binged_channel = c;
    }

    private Channel binged_channel;
}
```

Observer “update_” Functions

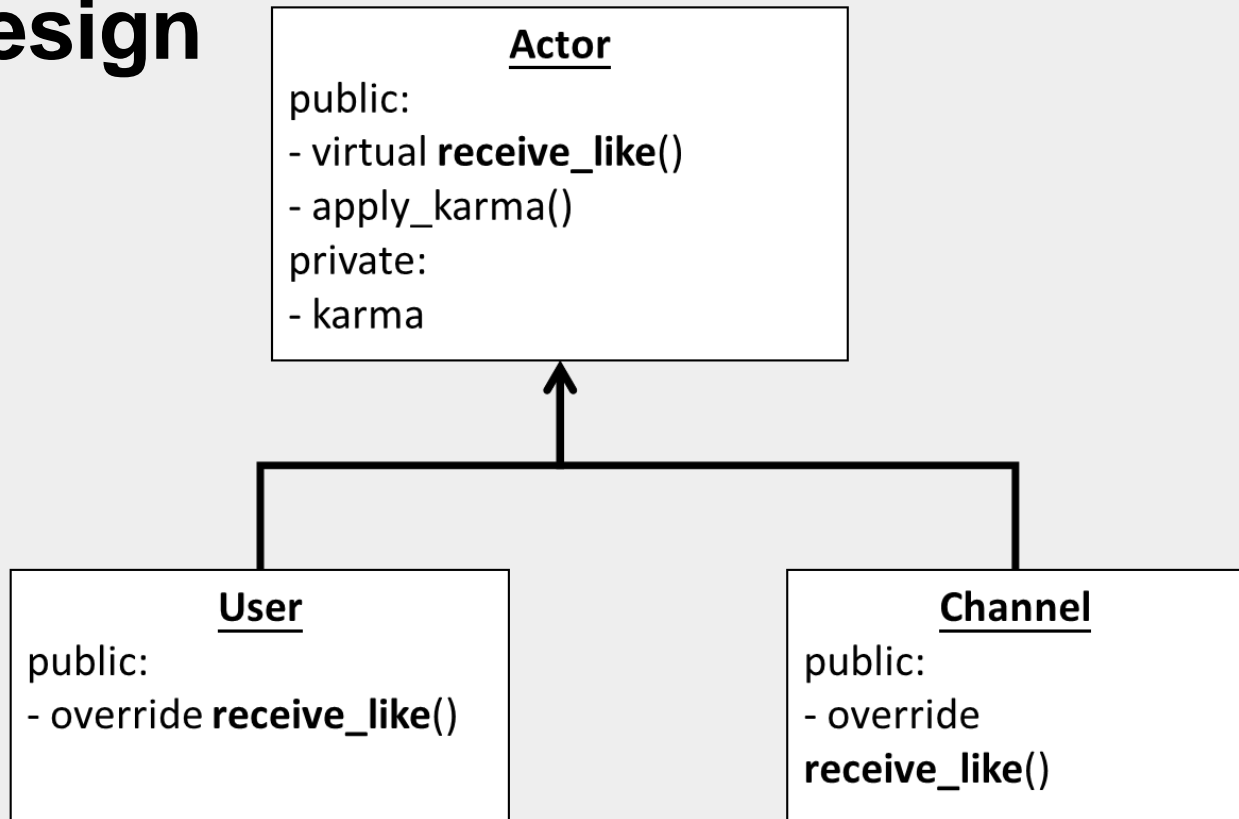
- Having multiple “update_” functions, one for each type of state change, keeps messages **granular**
 - Observers that do not care about a particular type of update can ignore it (via an empty implementation of the update function)
- Generally it is better to pass the newly-updated data as a parameter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

Scenario: “Likes” In Social Streaming Website

- Suppose we're building a social video streaming website where both users and channels can receive likes (for good comments or good videos). When a user or channel receives a like, it gets karma. At 50,000 karma, a channel gets a trophy. At 50,000 karma, a user gets ad-free access.

Likes: First Design

Note: `receive_like` is called on an Actor when someone likes its comment or video, etc.



Likes: Anti-Pattern Observations

```
class Actor {  
    public virtual void receive_like() {  
        karma += 1;  
    }  
    public float get_karma() { return karma; }  
    private float karma = 42;  
    public void note_karma() {  
        Console.WriteLine("Some karma  
received!");  
    }  
}
```

```
class User: Actor {  
    public override void receive_like() {  
        base.receive_like();  
        if (get_karma() >= 50000)  
            Console.WriteLine("Ad-free access!");  
        else  
            note_karma();  
    }  
}
```

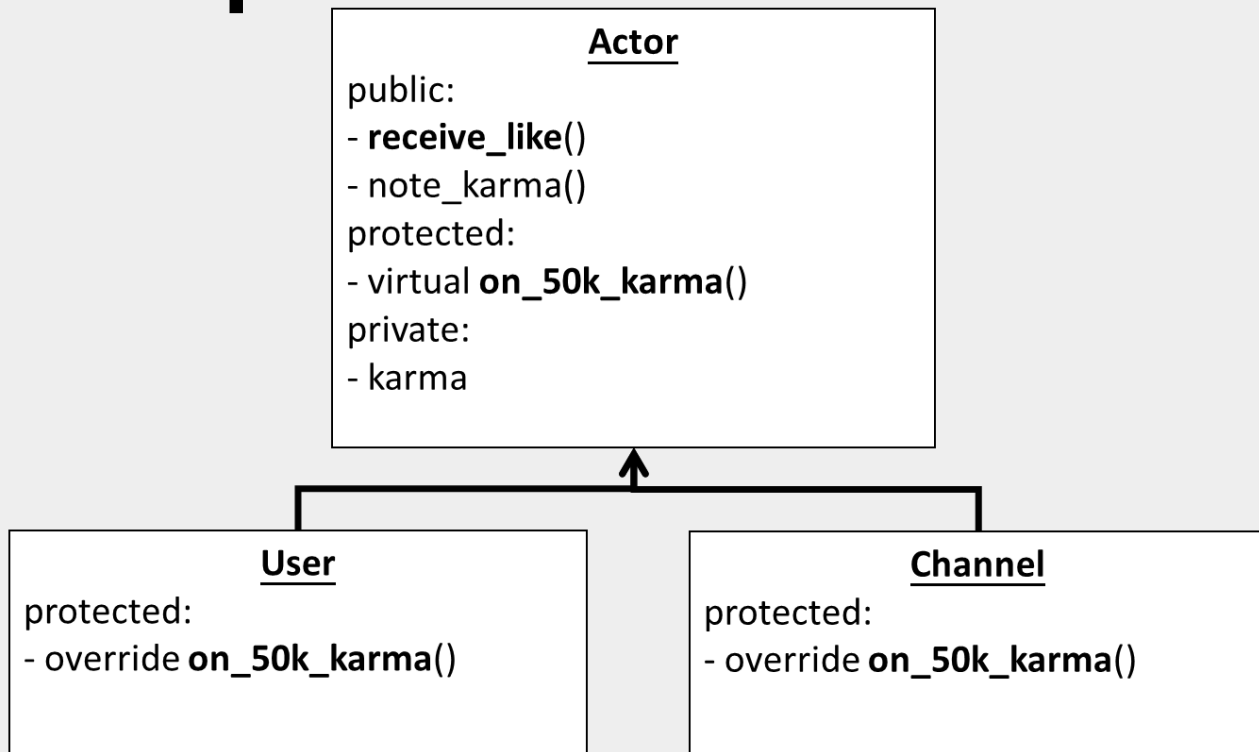
```
class Channel: Actor {  
    public override void receive_like() {  
        base.receive_like();  
        if (get_karma() >= 50000)  
            Console.WriteLine("Channel trophy!");  
        else  
            note_karma();  
    }  
}
```



Template Method Design Pattern

- The **template method** behavioral design pattern involves a method in a superclass that operates in terms of high-level steps that are implemented by abstract helper methods provided by concrete implementations.
- Define the skeleton of an algorithm in an operation, deferring some steps to subclasses. Template method design lets subclasses redefine certain steps of that algorithm without changing the algorithm's structure.

Likes: Template Method



Likes: Template Method Implementation

```
class Actor {  
    public void receive_like() {  
        karma += 1;  
        if (get_karma() >= 50000)  
            on_50k_karma();  
        else  
            note_karma();  
    }  
    protected virtual void on_50k_karma() {}  
  
    // Other members same as before  
}
```

```
class Channel: Actor {  
    protected override void on_50k_karma() {  
        Console.WriteLine("Channel trophy!");  
    }  
}
```

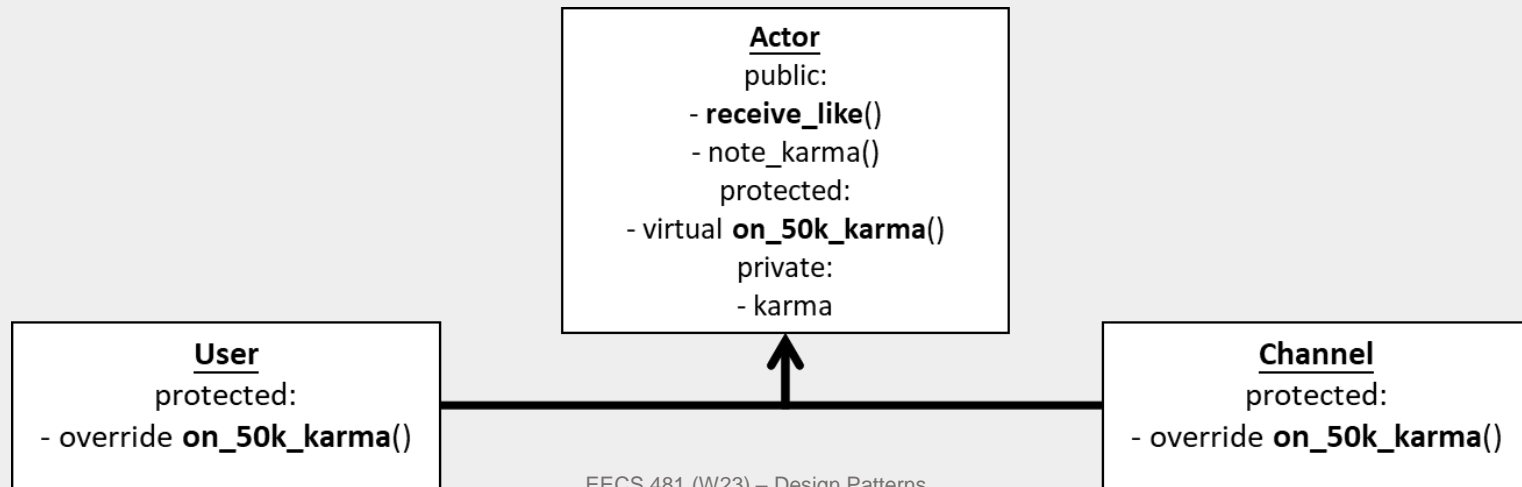
```
class User: Actor {  
    protected override void on_50k_karma() {  
        Console.WriteLine("Ad-free access!");  
    }  
}
```

Template Method: The “Hollywood Principle”

- In the first (anti-pattern) implementation, the **derived class called the base class** version of `receive_like()`
- In the template method implementation, the non-virtual **base class** `receive_like()` called derived **class methods**
- “Don't call us, we'll call you!”

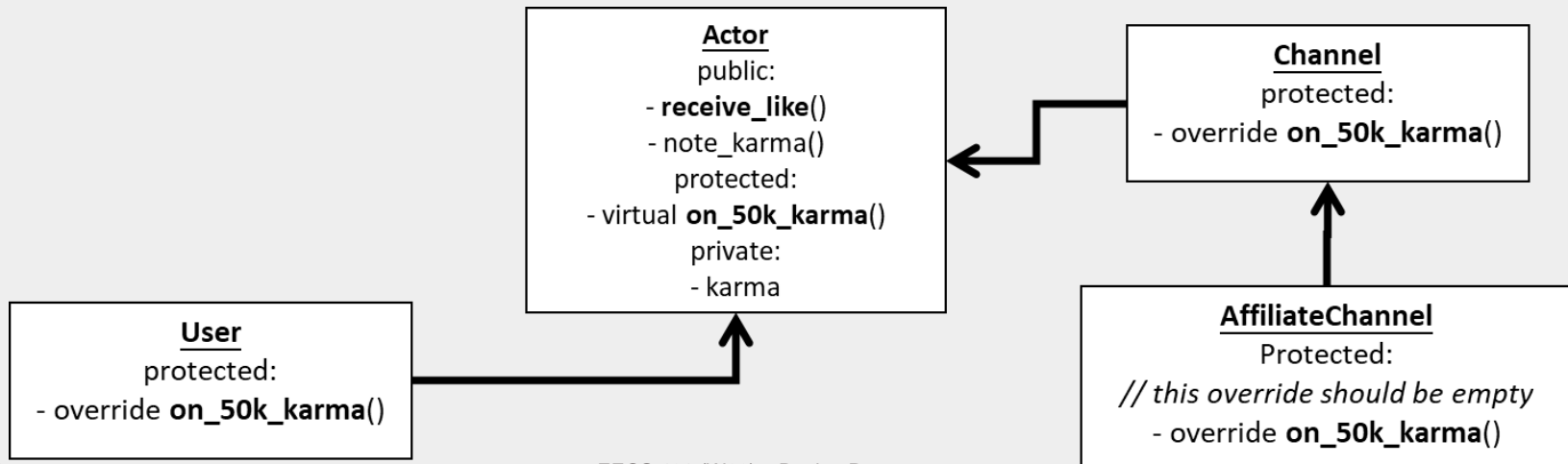
Exercise

- Suppose we want to add an AffiliateChannel to our setup. An AffiliateChannel does not receive a trophy on 50,000 karma, but instead received nothing.
- Modify our design to include this new type.



Exercise

- Suppose we want to add an AffiliateChannel to our setup. An AffiliateChannel does not receive a trophy on 50,000 karma, but instead received nothing.
- Modify our design to include this new type.



Questions?

- Further reading from EECS 381
<http://www.umich.edu/~eecs381/lecture/notes.html>
- See “Idioms and Design Patterns” PDFs
- Gang of Four
<https://search.lib.umich.edu/catalog/record/99187292508206381>