Design Patterns

Martin Kellogg

Reading Quiz: Design Patterns

Reading Quiz: Design Patterns

Q1: Fowler argues that the names of design patterns should be:

A. adjectives
B. verbs
C. noun phrases
D. proper nouns (e.g., the person's name who invented them)

Q2: **TRUE** or **FALSE**: the article on microservices quotes the following "Law": "any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure"

Reading Quiz: Design Patterns

Q1: Fowler argues that the names of design patterns should be:

A. adjectives
B. verbs
C. noun phrases
D. proper nouns (e.g., the person's name who invented them)

Q2: **TRUE** or **FALSE**: the article on microservices quotes the following "Law": "any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure"

Reading Quiz: Design Patterns

Q1: Fowler argues that the names of design patterns should be:

A. adjectives
B. verbs
C. noun phrases
D. proper nouns (e.g., the person's name who invented them)

Q2: **TRUE** or **FALSE**: the article on microservices quotes the following "Law": "any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure"

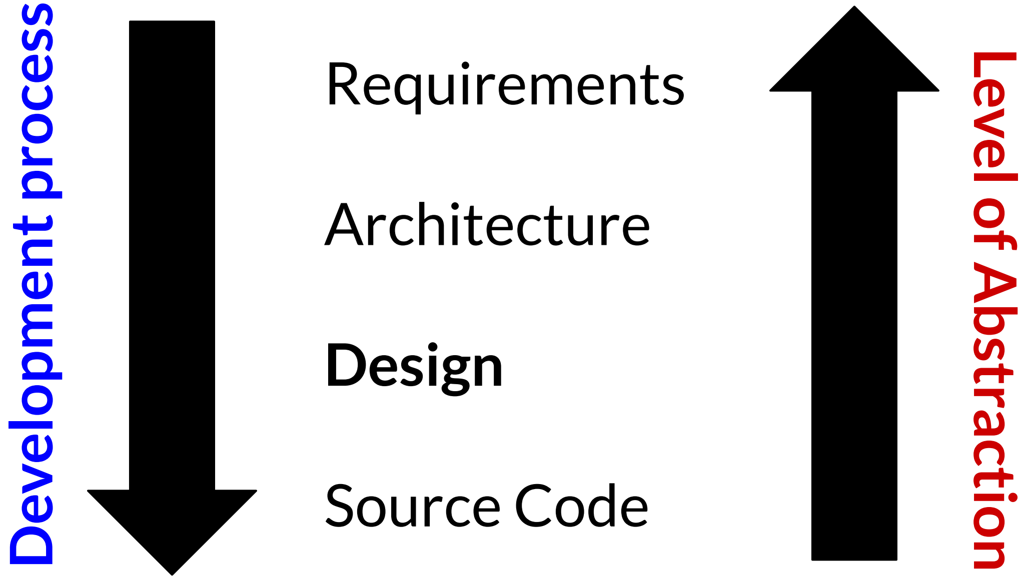
Design Patterns

Today's agenda:

- **Strategies for good design**
- Examples of design patterns
  - Structural patterns
  - Creational patterns
  - Behavioural patterns

Design

“Architecture” vs “Design”



Definition: ***software design*** is the structure or organization of a particular component of your system

Design

Key goal: design for **change** and **reuse**

Design

Key goal: design for **change** and **reuse**

- In class, many programs are written once, to a fixed specification, and then **thrown away**

Design

Key goal: design for **change** and **reuse**

- In class, many programs are written once, to a fixed specification, and then **thrown away**
- In industry, many programs are written once and then **modified** as requirements, customers, and developers change

Design

Key goal: design for **change** and **reuse**

- In class, many programs are written once, to a fixed specification, and then **thrown away**
- In industry, many programs are written once and then **modified** as requirements, customers, and developers change
- Many fundamental tenets of object-oriented design facilitate **subsequent change**
    - You may have seen these before, but now you are in a position to really appreciate the motivation!

Design: desiderata

Design: desiderata

- Classes are **open** to be modified/extended without invasive changes

Design: desiderata

- Classes are **open** to be modified/extended without invasive changes
- **Subtype polymorphism** enables changes behind interfaces

Design: desiderata

- Classes are **open** to be modified/extended without invasive changes
- **Subtype polymorphism** enables changes behind interfaces
- Classes **encapsulate** details likely to change behind (small) stable interfaces

Design: desiderata

- Classes are **open** to be modified/extended without invasive changes
- **Subtype polymorphism** enables changes behind interfaces
- Classes **encapsulate** details likely to change behind (small) stable interfaces
- Internal parts can be developed **independently**

Design: desiderata

- Classes are **open** to be modified/extended without invasive changes
- **Subtype polymorphism** enables changes behind interfaces
- Classes **encapsulate** details likely to change behind (small) stable interfaces
- Internal parts can be developed **independently**
- Internal details of other classes do not need to be understood, **contract** is sufficient

Design: desiderata

- Classes are **open** to be modified/extended without invasive changes
- **Subtype polymorphism** enables changes behind interfaces
- Classes **encapsulate** details likely to change behind (small) stable interfaces
- Internal parts can be developed **independently**
- Internal details of other classes do not need to be understood, **contract** is sufficient
- Class implementations and their contracts can be tested separately (**unit testing**)

Design for reuse

Design for reuse: delegation

Definition: ***Delegation*** is when one object relies on another object for some subset of its functionality

- e.g., in Java, Sort delegates functionality to some Comparator

Design for reuse: delegation

Definition: ***Delegation*** is when one object relies on another object for some subset of its functionality

- e.g., in Java, Sort delegates functionality to some Comparator

Judicious delegation enables **code reuse**:

Design for reuse: delegation

Definition: ***Delegation*** is when one object relies on another object for some subset of its functionality

- e.g., in Java, Sort delegates functionality to some Comparator

Judicious delegation enables **code reuse**:

- Sort can be reused with arbitrary sort orders

Design for reuse: delegation

Definition: ***Delegation*** is when one object relies on another object for some subset of its functionality

- e.g., in Java, Sort delegates functionality to some Comparator

Judicious delegation enables **code reuse**:

- Sort can be reused with arbitrary sort orders
- Comparators can be reused with arbitrary client code that needs to compare integers

Design for reuse: delegation

Definition: ***Delegation*** is when one object relies on another object for some subset of its functionality

- e.g., in Java, Sort delegates functionality to some Comparator

Judicious delegation enables **code reuse**:

- Sort can be reused with arbitrary sort orders
- Comparators can be reused with arbitrary client code that needs to compare integers
- Reduce “cut and paste” code and defects

Design for change: motivation

- Amazon.com processes millions of orders each year, selling in 75 countries, all 50 states, and thousands of cities worldwide.
  - These countries, states, and cities have hundreds of distinct sales tax policies
  - For any order and destination, Amazon.com must be able to compute the correct sales tax for the order and destination.

Design for change: motivation

- Amazon.com processes millions of orders each year, selling in 75 countries, all 50 states, and thousands of cities worldwide.
    - These countries, states, and cities have hundreds of distinct sales tax policies
    - For any order and destination, Amazon.com must be able to compute the correct sales tax for the order and destination.
- Over time:
    - Amazon moves into new markets
    - Laws and taxes in existing markets change

Design for change: motivati

Our key goal for today: learn about some of the **strategies** that companies like Amazon.com use to manage this complexity

- Amazon.com processes millions of o countries, all 50 states, and thousands of cities worldwide.
  - These countries, states, and cities have hundreds of distinct sales tax policies
  - For any order and destination, Amazon.com must be able to compute the correct sales tax for the order and destination.
- Over time:
  - Amazon moves into new markets
  - Laws and taxes in existing markets change

Design for Extensibility: Contracts + Subtyping

Design for Extensibility: Contracts + Subtyping

- **Design by contract** prescribes that software designers should define formal, precise and **verifiable** interface specifications for components, which extend the ordinary definition of abstract data types with **preconditions, postconditions** and invariants

Design for Extensibility: Contracts + Subtyping

- **Design by contract** prescribes that software designers should define formal, precise and **verifiable** interface specifications for components, which extend the ordinary definition of abstract data types with **preconditions, postconditions** and invariants
- A subclass can only have **weaker** preconditions
    - My super only works on positive numbers, but I work on all numbers

Design for Extensibility: Contracts + Subtyping

- **Design by contract** prescribes that software designers should define formal, precise and **verifiable** interface specifications for components, which extend the ordinary definition of abstract data types with **preconditions, postconditions** and invariants
- A subclass can only have **weaker** preconditions
  - My super only works on positive numbers, but I work on all numbers
- A subclass can only have **stronger** postconditions
  - My super returns any shape, but I return squares

Design for Extensibility: Contracts + Subtyping

- **Design by contract** prescribes that software designers should define formal, precise and **verifiable** interface specifications for components, which extend the ordinary definition of abstract data types with **preconditions, posto**
- A subclass can only have **weake**
  - My super only works on pos numbers
- A subclass can only have **stronger** postconditions
  - My super returns any shape, but I return squares

This is called the ***Liskov Substitution Principle***: “any subclass object should be safe to use in place of a superclass object at run time”

Design for Testability

Design for Testability

- If the majority cost of software engineering is maintenance

Design for Testability

- If the majority cost of software engineering is maintenance
    - and the majority cost of maintenance is QA

Design for Testability

- If the majority cost of software engineering is maintenance
  - and the majority cost of maintenance is QA
  - and the majority cost of QA is testing

Design for Testability

- If the majority cost of software engineering is maintenance
  - and the majority cost of maintenance is QA
  - and the majority cost of QA is testing
- Then we should design our software so that **testing** is effective:

Design for Testability

- If the majority cost of software engineering is maintenance
  - and the majority cost of maintenance is QA
  - and the majority cost of QA is testing
- Then we should design our software so that **testing** is effective:
  - Design to admit testing
  - Design to admit fault injection
  - Design to admit coverage
  - Recognize “free test” opportunities

Design to Admit Testing

Design to Admit Testing

- Consider a ***library-oriented architecture***, a variation of **modular programming** or **microservice architecture** with a focus on separation of concerns and **interface design**

Design to Admit Testing

- Consider a ***library-oriented architecture***, a variation of **modular programming** or **microservice architecture** with a focus on separation of concerns and **interface design**
    - “Package logical components of your application independently - literally as separate gems, eggs, RPMs, or whatever - and maintain them as internal open-source projects … This approach combats the tightly-coupled spaghetti so often lurking in big codebases by giving everything the Right Place in which to exist.”

Design to Admit Unit Testing

- Recall: it is hard to generate test inputs with high coverage for areas "**deep inside**" the code
    - Must solve the constraints for main(), then for foo(), then for bar(), etc., all at the same time!

Design to Admit Unit Testing

- Recall: it is hard to generate test inputs with high coverage for areas "**deep inside**" the code
  - Must solve the constraints for main(), then for foo(), then for bar(), etc., all at the same time!
- The farther code is from an entry point, the harder it is to test
  - This is one of the motivations behind **unit testing**

Design to Admit Unit Testing

- Recall: it is hard to generate test inputs with high coverage for areas "**deep inside**" the code
  - Must solve the constraints for main(), then for foo(), then for bar(), etc., all at the same time!
- The farther code is from an entry point, the harder it is to test
  - This is one of the motivations behind **unit testing**
- Solution: design with **more entry points** for self-contained functionality (cf. AVL tree, priority queue, etc.)

Example: MVC + Angry Birds

- Suppose you are designing Angry Birds
- It's a game, and also a simulation, so MVC is a reasonable choice

Example: MVC + Angry Birds

- Suppose you are designing Angry Birds
- It's a game, and also a simulation, so MVC is a reasonable choice
- Design so that it can be tested without someone actually playing the game!

Example: MVC + Angry Birds

- Suppose you are designing Angry Birds
- It's a game, and also a simulation, so MVC is a reasonable choice
- Design so that it can be tested without someone actually playing the game!
  - e.g., have an **interface** where abstract commands can be queued up: one way to get them is from the UI, but another is programmatic

Example: MVC + Angry Birds

- Suppose you are designing Angry Birds
- It's a game, and also a simulation, so MVC is a reasonable choice
- Design so that it can be tested without someone actually playing the game!
  - e.g., have an **interface** where abstract commands can be queued up: one way to get them is from the UI, but another is programmatic
  - "If I create a world with blocks X, Y and Z and then we launch bird A at angle B, does C occur within five timesteps?"

Example: fault injection

- Microsoft's Driver Verifier sat between a driver and the operating system and “pretended to fail (some of the time)” to expose poor driver code
- The CHESS project sat between a program and the scheduler and “forced strange schedules” to expose poor concurrency code

Example: fault injection

- Microsoft's Driver Verifier sat between a driver and the operating system and “pretended to fail (some of the time)” to expose poor driver code
- The CHESS project sat between a program and the scheduler and “forced strange schedules” to expose poor concurrency code
- Problem for both: Hardware, OS and Networking errors can occur **infrequently**, but you still want to test them

Example: fault injection

- Microsoft's Driver Verifier sat between a driver and the operating system and “pretended to fail (some of the time)” to expose poor driver code
- The CHESS project sat between a program and the scheduler and “forced strange schedules” to expose poor concurrency code
- Problem for both: Hardware, OS and Networking errors can occur **infrequently**, but you still want to test them
  - Must design for it! But how…?

Example: fault injection: add a level of indirection

- **Old adage**: the solution to everything in computer science is either to add a level of indirection or to add a cache

Example: fault injection: add a level of indirection

- **Old adage**: the solution to everything in computer science is either to add a level of indirection or to add a cache
- Don't have your code call fopen() or cout or whatever directly

Example: fault injection: add a level of indirection

- **Old adage**: the solution to everything in computer science is either to add a level of indirection or to add a cache
- Don't have your code call fopen() or cout or whatever directly
- Instead, add a very thin **level of indirection** where you call my_fopen which then calls fopen

Example: fault injection: add a level of indirection

- **Old adage**: the solution to everything in computer science is either to add a level of indirection or to add a cache
- Don't have your code call fopen() or cout or whatever directly
- Instead, add a very thin **level of indirection** where you call my_fopen which then calls fopen
- Later add “if coin_flip() then fail else ...” to that indirection layer to **inject faults** while testing
    - let the compiler optimize it away for your production code

Designing for coverage-based testing

- Remind me: what's **coverage** (in the context of testing)?

Designing for coverage-based testing

- Remind me: what's **coverage** (in the context of testing)?
- Code coverage has many flaws
  - At a high level, simple coverage metrics **do not align** with covering requirements (cf. traceability)

Designing for coverage-based testing

- Remind me: what's **coverage** (in the context of testing)?
- Code coverage has many flaws
  - At a high level, simple coverage metrics **do not align** with covering requirements (cf. traceability)
- Solutions:

Designing for coverage-based testing

- Remind me: what's **coverage** (in the context of testing)?
- Code coverage has many flaws
  - At a high level, simple coverage metrics **do not align** with covering requirements (cf. traceability)
- Solutions:
  - Better test suite adequacy metrics (mutation, etc.)

Designing for coverage-based testing

- Remind me: what's **coverage** (in the context of testing)?
- Code coverage has many flaws
  - At a high level, simple coverage metrics **do not align** with covering requirements (cf. traceability)
- Solutions:
  - Better test suite adequacy metrics (mutation, etc.)
  - Design and write the code so that high code coverage **correlates** with high requirements coverage!

Designing for coverage-based testing

- Line coverage is often inadequate because “visit line 5 when ptr==null” could be very different from “visit line 5 when ptr !=null”

Designing for coverage-based testing

- Line coverage is often inadequate because “visit line 5 when ptr==null” could be very different from “visit line 5 when ptr !=null”
    - Because “*ptr = 9” is really “if (ptr == null) abort(); else *ptr = 9;”

Designing for coverage-based testing

- Line coverage is often inadequate because “visit line 5 when ptr==null” could be very different from “visit line 5 when ptr !=null”
  - Because “*ptr = 9” is really “if (ptr == null) abort(); else *ptr = 9;”
- Consider **explicit conditionals** that check **requirements adherence**

Designing for coverage-based testing

- Line coverage is often inadequate because "visit line 5 when ptr==null" could be very different from "visit line 5 when ptr !=null"
  - Because "*ptr = 9" is really "if (ptr == null) abort(); else *ptr = 9;"
- Consider **explicit conditionals** that check **requirements adherence**
  - To get coverage points for reaching the true branch, the test will have to satisfy the requirement

Designing for coverage-based testing

- Line coverage is often inadequate because "visit line 5 when ptr==null" could be very different from "visit line 5 when ptr !=null"
  - Because "*ptr = 9" is really "if (ptr == null) abort(); else *ptr = 9;"
- Consider **explicit conditionals** that check **requirements adherence**
  - To get coverage points for reaching the true branch, the test will have to satisfy the requirement
- For example, consider a quality requirement: "finish X within Y time"

Designing for coverage-based testing

- Line coverage is often inadequate because “visit line 5 when ptr==null” could be very different from “visit line 5 when ptr !=null”
  - Because “*ptr = 9” is really “if (ptr == null) abort(); else *ptr = 9;”
- Consider **explicit conditionals** that check **requirements adherence**
  - To get coverage points for reaching the true branch, the test will have to satisfy the requirement
- For example, consider a quality requirement: “finish X within Y time”
  - Add in “get the time”, “do X”, “get the time”, “subtract”, “if t2 – t1 < Y then ...”

Designing for coverage-based testing

- Line coverage is often inadeq
  ptr==null” could be very diff ”
  - Because “*ptr = 9” is real ”
- Consider **explicit conditiona** **e**
  - To get coverage points fo ill
    have to satisfy the requir
- For example, consider a qual e”
  - Add in “get the time”, “do X 1 <
    Y then ...”

Explicit Conditional **Pros**:

Explicit Conditional **Cons**:

Designing for coverage-based testing

- Line coverage is often inadeq ...
  ptr==null" could be very diff ... l"
  - Because "*ptr = 9" is real ... "
- Consider **explicit conditiona** ... **e**
  - To get coverage points fo ... ill
    have to satisfy the requir ...
- For example, consider a qual ... e"
  - Add in "get the time", "do X ... 1 <
    Y then ..."

Explicit Conditional **Pros**:

- Testing tools can help you reason about partial progress

Explicit Conditional **Cons**:

Designing for coverage-based testing

- Line coverage is often inadeq ptr==null" could be very diff ... l"
    - Because "*ptr = 9" is real ... "
- Consider **explicit conditiona** ... **e**
    - To get coverage points fo ... ill have to satisfy the requir
- For example, consider a qual ... e"
    - Add in "get the time", "do X ... 1 < Y then ..."

Explicit Conditional **Pros**:

- Testing tools can help you reason about partial progress
- Testing tools can try to falsify claims

Explicit Conditional **Cons**:

Designing for coverage-based testing

- Line coverage is often inadeq[...] ptr==null” could be very diff[...]l”
  - Because “*ptr = 9” is real[...]”
- Consider **explicit conditiona**[...]**e**
  - To get coverage points fo[...]ill have to satisfy the requir[...]
- For example, consider a qual[...]e”
  - Add in “get the time”, “do X[...]1 < Y then ...”

Explicit Conditional **Pros**:

- Testing tools can help you reason about partial progress
- Testing tools can try to falsify claims

Explicit Conditional **Cons**:

- Muddies meaning of coverage (100% not desired)

Designing for testing: tests for free

Designing for testing: tests for free

- Many programs transform data from one format to another (cf. adapter pattern)

Designing for testing: tests for free

- Many programs transform data from one format to another (cf. adapter pattern)
- If the program is implementing a function with similar domain and range, you can often get high-coverage tests "for free" by **composing the program with itself**

Designing for testing: tests for free

- Many programs transform data from one format to another (cf. adapter pattern)
- If the program is implementing a function with similar domain and range, you can often get high-coverage tests “for free” by **composing the program with itself**
  - If possible, design your program so that this is possible

Designing for testing: tests for free

- Many programs transform data from one format to another (cf. adapter pattern)
- If the program is implementing a function with similar domain and range, you can often get high-coverage tests "for free" by **composing the program with itself**
  - If possible, design your program so that this is possible
- Examples:

Designing for testing: tests for free

- Many programs transform data from one format to another (cf. adapter pattern)
- If the program is implementing a function with similar domain and range, you can often get high-coverage tests “for free” by **composing the program with itself**
  - If possible, design your program so that this is possible
- Examples:
  - **Inversion**: forall X. unzip(zip(X)) = X

Designing for testing: tests for free

- Many programs transform data from one format to another (cf. adapter pattern)
- If the program is implementing a function with similar domain and range, you can often get high-coverage tests "for free" by **composing the program with itself**
  - If possible, design your program so that this is possible
- Examples:
  - **Inversion**: forall X. unzip(zip(X)) = X
  - **Convergence**: forall X. sort(sort(X)) = sort(X)

Design Patterns

Today's agenda:

- Strategies for good design
- **Examples of design patterns**
  - Structural patterns
  - Creational patterns
  - Behavioural patterns

Design patterns

Design patterns

Definition: A ***software design pattern*** is a general, reusable solution to a commonly occurring problem within a given context in software design.

Design patterns

Definition: A ***software design pattern*** is a general, reusable solution to a commonly occurring problem within a given context in software design.

- patterns reduce surprise for code readers

Design patterns

Definition: A ***software design pattern*** is a general, reusable solution to a commonly occurring problem within a given context in software design.

- patterns reduce surprise for code readers
- patterns separate the structure of a system from the implementation details

Design patterns

Definition: A ***software design pattern*** is a general, reusable solution to a commonly occurring problem within a given context in software design.

- patterns reduce surprise for code readers
- patterns separate the structure of a system from the implementation details
- patterns apply in almost all OO languages

Design patterns

Definition: A ***software design pattern*** is a general, reusable solution to a commonly occurring problem within a given context in software design.

- patterns reduce surprise for code readers
- patterns separate the structure of a system from the implementation details
- patterns apply in almost all OO languages
- all patterns have **tradeoffs**. In OO languages, design patterns often trade **verbosity or efficiency** for **extensibility**

Design patterns

Definition: A ***software design pattern*** is a general, reusable solution to a commonly occurring problem within a given context in software design.

- patterns reduce surprise for code readers
- patterns separate the structure of a system from the implementation details
- patterns apply in almost all OO languages
- all patterns have **tradeoffs**. In OO languages, design patterns often trade **verbosity or efficiency** for **extensibility**
- we'll consider **structural**, **creational** and **behavioral** design patterns

Design patterns: non-software

- Design patterns are **common in almost every field** (not just SE)

Design patterns: non-software

- Design patterns are **common in almost every field** (not just SE)
    - e.g., “multiple choice question” is a design pattern for exam making, “verse-chorus-verse-chorus-bridge-chorus” is a design pattern for songs

Design patterns: non-software

- Design patterns are **common in almost every field** (not just SE)
  - e.g., "multiple choice question" is a design pattern for exam making, "verse-chorus-verse-chorus-bridge-chorus" is a design pattern for songs
- *The Design of Everyday Things* (famous book): design serves as the **communication** between object and user

Design patterns: non-software

- Design patterns are **common in almost every field** (not just SE)
  - e.g., “multiple choice question” is a design pattern for exam making, “verse-chorus-verse-chorus-bridge-chorus” is a design pattern for songs
- *The Design of Everyday Things* (famous book): 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

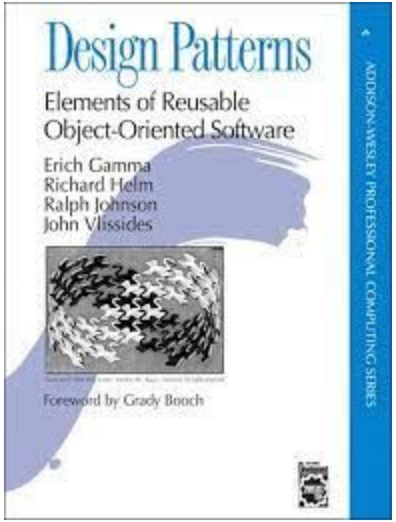
Design patterns: non-software

- Design patterns are **commo**
  - e.g., “multiple choice que
    making, “verse-chorus-v ... gn
    pattern for songs
- *The Design of Everyday Thing* ... 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

Same ideas apply to software:
- design GUIs that people **intuitively** know how to use
- design code that other developers **intuitively** know how to read

Design patterns: "gang of four"

- The book popularizing software design patterns is often called the "**Gang of Four**" book after its four authors
- I don't care if you remember this, but it'll be handy to know about (e.g., for interviews)



Design patterns: high-level advice

Design patterns: high-level advice

- Consider **code change as a certainty**
  - Redesign is expensive. Choosing the right pattern helps avoid it.

Design patterns: high-level 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.

Design patterns: high-level 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.

Design patterns: categories

- We're going to talk about three **categories** of design patterns:
  - Structural
  - Creational
  - Behavioural

Design patterns: categories

- We’re going to talk about three **categories** of design patterns:
  - Structural
  - Creational
  - Behavioural
- These are **rough** categories: some patterns don’t fit neatly into any of them, and some might fit into two or more
  - but, they’re a useful way to structure a lecture :)

Design patterns: categories

- We're going to talk about three categories of design patterns:
  - **Structural**
  - Creational
  - Behavioural
- These are **rough** categories: some patterns don't fit neatly into any of them, and some might fit into two or more
  - but, they're a useful way to structure a lecture :)

Design patterns: structural

- ***Structural design patterns*** ease design by identifying simple ways to realize **relationships** among **entities**.

Design patterns: structural

- ***Structural design patterns*** ease design by identifying simple ways to realize **relationships** among **entities**.
- In software, they usually:

Design patterns: structural

- ***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

Design patterns: structural

- ***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

Design patterns: structural

- ***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

Design patterns: structural: adapter

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

Design patterns: structural: adapter

- The ***adapter design pattern*** is a structural design pattern that converts the interface of a class into another interface clients expect.
  - analogy: dongles that convert HDMI to USB-C

Design patterns: structural: adapter

- The ***adapter design pattern*** is a structural design pattern that converts the interface of a class into another interface clients expect.
  - analogy: dongles that convert HDMI to USB-C
- Examples:

Design patterns: structural: adapter

- The ***adapter design pattern*** is a structural design pattern that converts the interface of a class into another interface clients expect.
    - analogy: dongles that convert HDMI to USB-C
- Examples:
    - Implementing a Stack interface using a LinkedList interface

Design patterns: structural: adapter

- The ***adapter design pattern*** is a structural design pattern that converts the interface of a class into another interface clients expect.
  - analogy: dongles that convert HDMI to USB-C
- Examples:
  - Implementing a Stack interface using a LinkedList interface
  - Early implementations of fstream in C++
    - … were simply adapters around the C FILE macro

Design patterns: other structural patterns

Design patterns: other structural patterns

- The **composite design pattern** allows clients to treat individual objects and groups of objects uniformly

Design patterns: other structural patterns

- The **composite design pattern** allows clients to treat individual objects and groups of objects uniformly
  - e.g., selecting and moving objects in PowerPoint

Design patterns: other structural patterns

- The **composite design pattern** allows clients to treat individual objects and 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

Design patterns: other structural patterns

- The **composite design pattern** allows clients to treat individual objects and 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
  - e.g., 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)

Design patterns: creational patterns

Design patterns: creational 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**.

Design patterns: creational 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:

Design patterns: creational 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
  - Specify different combinations of optional arguments

Design patterns: creational patterns

- ***Creational design patterns*** avoid complexity by controlling object creation so that objects ar… …e situation. They make a sys… **are created**.

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

- 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
  - Specify different combinations of optional arguments

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.

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;
};
```

Creational patterns: named constructor

- In the *Named Constructor Patter*
  constructors to be private or pr
  creation method.

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

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.

Creational patterns: factories

- Suppose we need to create and use polymorphic objects **without exposing their types** to the client

Creational patterns: factories

- 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.

Creational patterns: factories

- 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

Creational patterns: factories

- 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
    - this is a specific variant of the named constructor pattern

Creational patterns: factories

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

Creational patterns: factories

- The *factory method pattern* (or just *factory 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”);
```

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

```
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

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

Creational patterns: factories

- 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);
```

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

Creational patterns: example: anti-patterns

- An ***anti-pattern*** is a common response to a recurring problem that is usually ineffective and risks being counterproductive.

Creational patterns: example: anti-patterns

- An ***anti-pattern*** is a common response to a recurring problem that is usually ineffective and risks being counterproductive.
- A bad solution (i.e., 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();
```

Creational patterns: example: anti-patterns

- An ***anti-pattern*** is a common response to a recurring problem that is usually ineffective and risks being counterproductive.
- A bad solution (i.e., 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();
```

Why is this bad?

- code duplication
- consider how you'd add a new difficulty level

Creational patterns: example: anti-patterns

- An ***anti-pattern*** is a common response to a recurring problem that is usually ineffective and risks being counterproductive.
- A bad solution (i.e., 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();
```

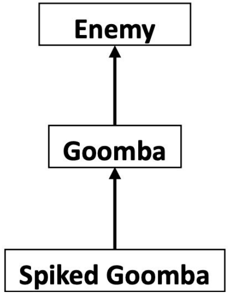
Why is this bad?

- code duplication
- consider how you'd add a new difficulty level...

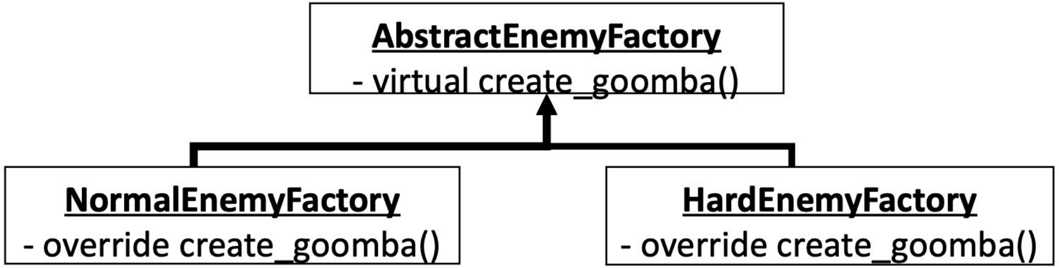
Creational patterns: abstract factories

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

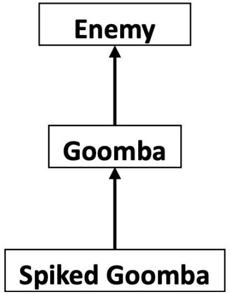
Creational patterns: abstract factories



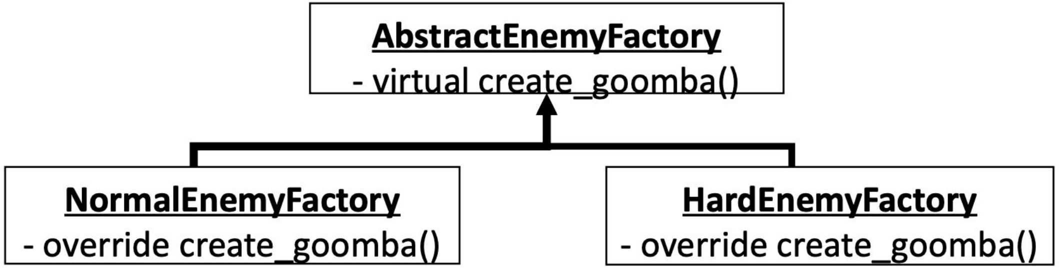
- The ***abstract factory pattern*** encapsulates a group of factories that have a common theme without specifying their concrete classes.



Creational patterns: abstract factories



- 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

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.

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 an **unprotected global variable** (e.g., a public static field).

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 an **unprotected global variable** (e.g., a public static field).
    - fails to control access or updates!

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 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.

Scenario: global application state

- Global variables are usually a **poor design choice**. However:

Scenario: global application state

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

Scenario: global application state

- Global variables are usually a **poor design choice**. However:
  - If you **must** 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.

Scenario: global application state

- Global variables are usually a **poor design choice**. However:
  - If you **must** 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)

Scenario: global application state

- Global variables are usually a **poor design choice**. However:
    - If you **must** 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 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

```
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

```
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; }
}
```

this constructor can't be called any other way

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; }
}
```

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()
- increment_billing_count() *// adds 1*

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

Singleton design pattern: example

What is the output of this code?

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

```
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);
 }
}
```

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?

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

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?

```
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 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?

```
Single s = Singleton.get_inst
System.out.println(s.get_bill
… // later
System.out.println(s.get_bill
```

- Is this a good idea or not?

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

- Making Game a Singleton is **tempting**
  - There is only one Game instance in our application

Singleton design pattern: another example

- 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.

Singleton design pattern: another example

- 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 design pattern: another example

- 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.

Behavioural Design Patterns

Behavioural Design Patterns

- ***Behavioral design patterns*** support common communication patterns among objects. They are concerned with algorithms and the assignment of responsibilities between objects.

Behavioural Design Patterns

- ***Behavioral design patterns*** support common communication patterns among objects. They are concerned with algorithms and the assignment of responsibilities between objects.
    - Commonly used to enable **limited sharing**

Behavioural Design Patterns

- ***Behavioral design patterns*** support common communication patterns among objects. They are concerned with algorithms and the assignment of responsibilities between objects.
  - Commonly used to enable **limited sharing**
    - e.g., same underlying algorithm, different interfaces or same interface, different underlying algorithms

Behavioural Design Patterns

- ***Behavioral design patterns*** support common communication patterns among objects. They are concerned with algorithms and the assignment of responsibilities between objects.
  - 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

- The ***iterator pattern*** is a common behavioral design pattern. It provides a uniform interface for traversing containers regardless of how they are implemented.

Iterator Pattern

- The ***iterator pattern*** is a common behavioral design pattern. It provides a uniform interface for traversing containers regardless of how they are implemented.
    - e.g., Java's List interface doesn't care whether it's backed by an array or a linked list

Iterator Pattern

- The ***iterator pattern*** is a common behavioral design pattern. It provides a uniform interface for traversing containers regardless of how they are implemented.
    - 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

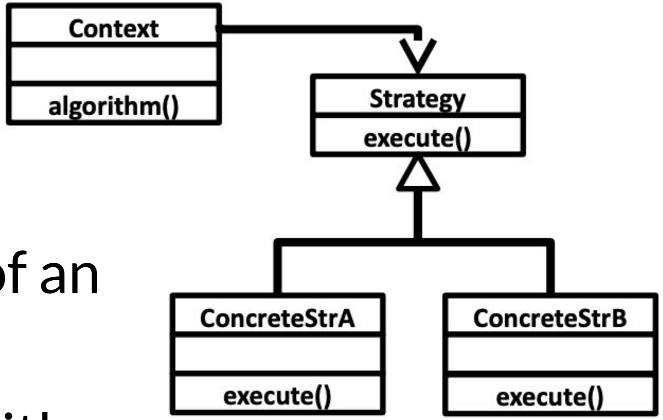
Strategy Design Pattern

- Problem: Clients need different **variants** of an algorithm

Strategy Design Pattern

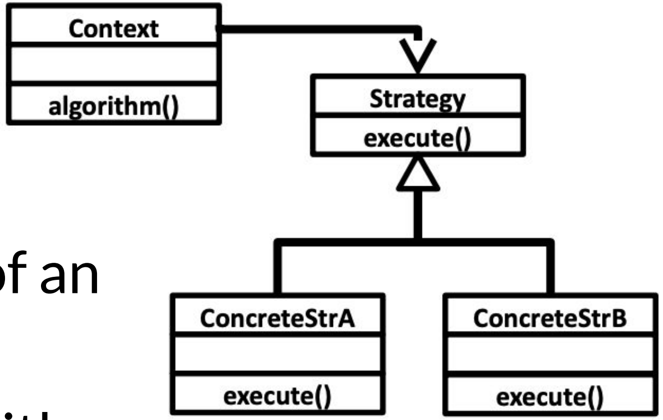
- Problem: Clients need different **variants** of an algorithm
- Solution: Create an **interface** for the algorithm, with an implementing class for each variant of the algorithm

Strategy Design Pattern



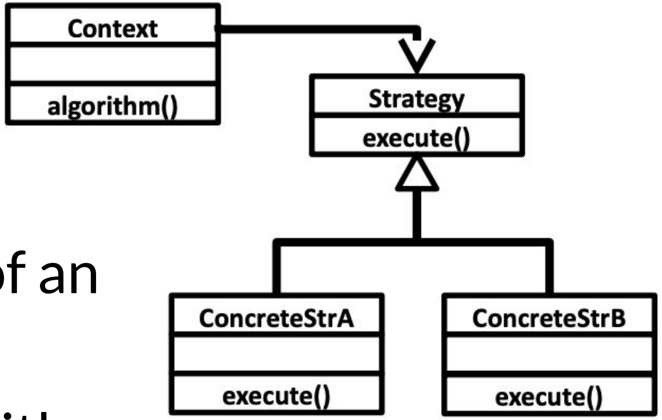
- Problem: Clients need different **variants** of an algorithm
- Solution: Create an **interface** for the algorithm, with an implementing class for each variant of the algorithm

Strategy Design Pattern



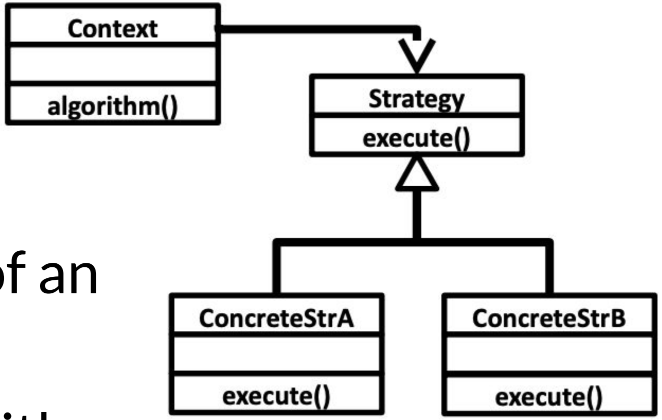
- Problem: Clients need different **variants** of an algorithm
- Solution: Create an **interface** for the algorithm, with an implementing class for each variant of the algorithm
- Consequences:

Strategy Design Pattern



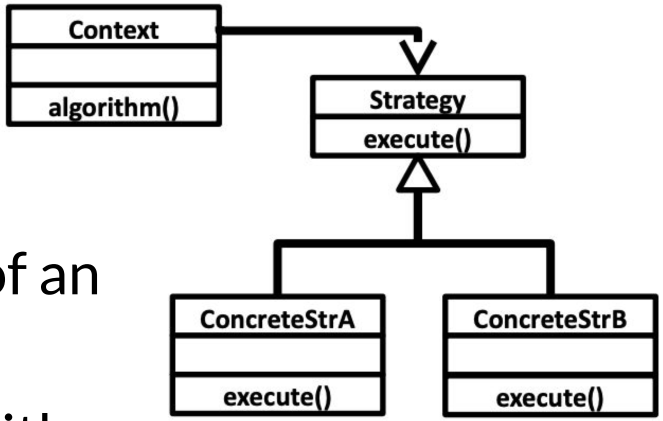
- Problem: Clients need different **variants** of an algorithm
- Solution: Create an **interface** for the algorithm, with an implementing class for each variant of the algorithm
- Consequences:
  - Easily extensible for new algorithm implementations

Strategy Design Pattern



- Problem: Clients need different **variants** of an algorithm
- Solution: Create an **interface** for the algorithm, with an implementing class for each variant of the algorithm
- Consequences:
  - Easily extensible for new algorithm implementations
  - Separates algorithm from client context

Strategy Design Pattern



- Problem: Clients need different **variants** of an algorithm
- Solution: Create an **interface** for the algorithm, with an implementing class for each variant of the algorithm
- 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

Template Method Design Pattern

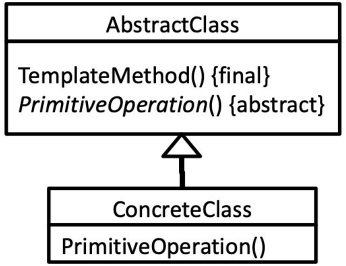
Template Method Design Pattern

- Problem: An algorithm has **customizable** and **invariant** parts

Template Method Design Pattern

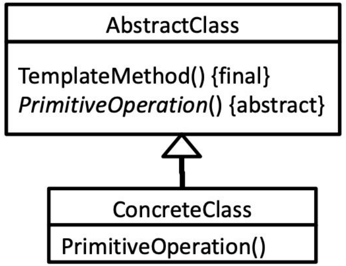
- Problem: An algorithm has **customizable** and **invariant** parts
- Solution: Implement the invariant parts of the algorithm in an **abstract** class, with abstract primitive operations representing the customizable parts of the algorithm. Subclasses customize the primitive operations.

Template Method Design Pattern



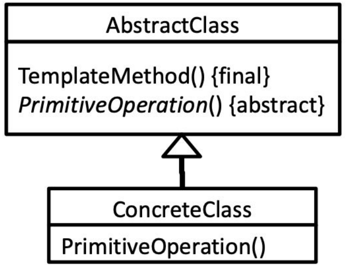
- Problem: An algorithm has **customizable** and **invariant** parts
- Solution: Implement the invariant parts of the algorithm in an **abstract** class, with abstract primitive operations representing the customizable parts of the algorithm. Subclasses customize the primitive operations.

Template Method Design Pattern



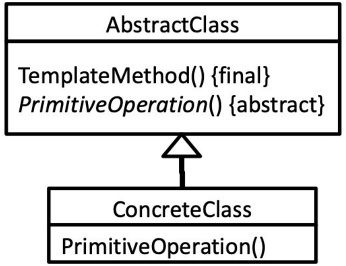
- Problem: An algorithm has **customizable** and **invariant** parts
- Solution: Implement the invariant parts of the algorithm in an **abstract** class, with abstract primitive operations representing the customizable parts of the algorithm. Subclasses customize the primitive operations.
- Consequences:

Template Method Design Pattern



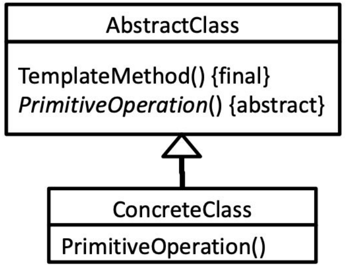
- Problem: An algorithm has **customizable** and **invariant** parts
- Solution: Implement the invariant parts of the algorithm in an **abstract** class, with abstract primitive operations representing the customizable parts of the algorithm. Subclasses customize the primitive operations.
- Consequences: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

Template Method Design Pattern



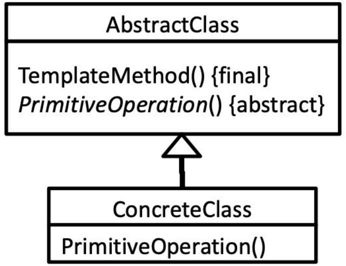
- Problem: An algorithm has **customizable** and **invariant** parts
- Solution: Implement the invariant parts of the algorithm in an **abstract** class, with abstract primitive operations representing the customizable parts of the algorithm. Subclasses customize the primitive operations.
- Consequences:
  - Code reuse for the invariant parts of algorithm
  - Customization is restricted to the primitive operations

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

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

Template vs. Strategy Design Pattern

- Both support variation in a larger context

Template vs. Strategy Design Pattern

- Both support variation in a larger context
- **Template method** uses inheritance + an overridable method

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

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

Scenario: binge-watching

- Idea: 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;
}
```

Scenario: binge-watching

- Idea: 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);
 }
}
```

Scenario: binge-watching

- Idea: 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?

Scenario: binge-watching: anti-patterns

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

Scenario: binge-watching: anti-patterns

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

Scenario: binge-watching: anti-patterns

- With this design, 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?

Scenario: binge-watching: anti-patterns

- With this design, 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

Scenario: binge-watching: anti-patterns

- With this design, User and Channel are **tightly coupled**
  - Changing one likely requires a change to the other
- The design does r
- What if we later w … nmendation 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

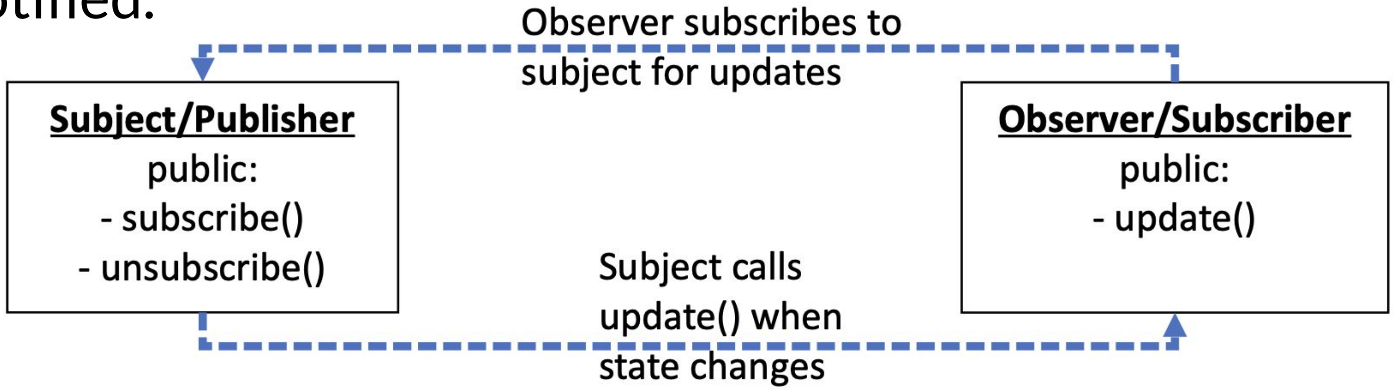
What can we do instead?

Observer Pattern

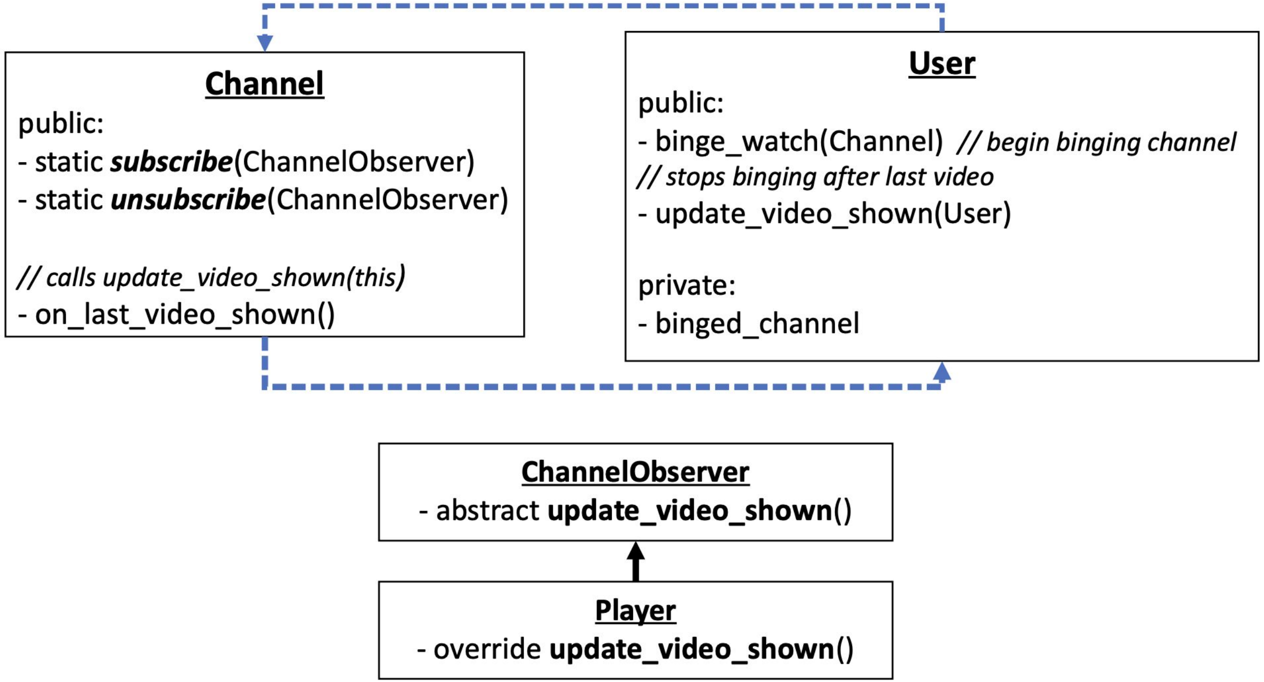
- The ***observer pattern*** (also called "***publish-subscribe***") allows dependent objects to be notified automatically when the state of a subject changes. It defines a one-to-many dependency between objects so that when one object changes state, all of it dependents are notified.

Observer Pattern

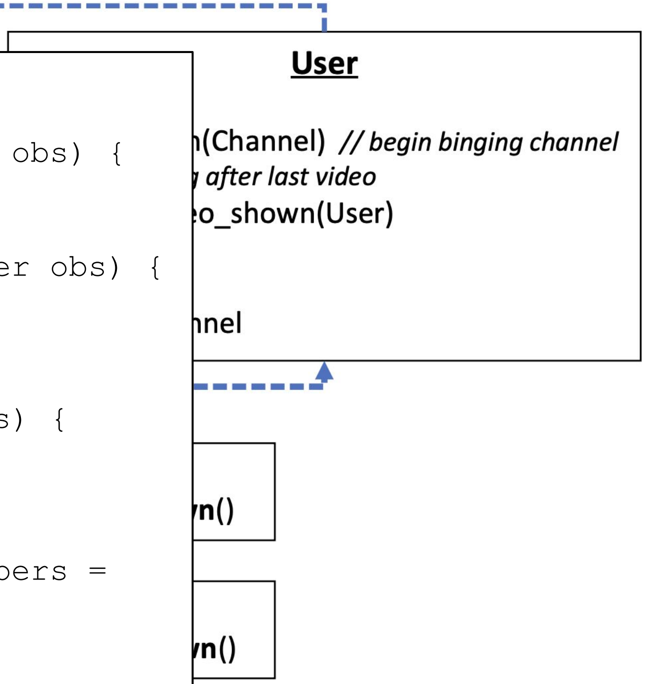
- The ***observer pattern*** (also called "***publish-subscribe***") allows dependent objects to be notified automatically when the state of a subject changes. It defines a one-to-many dependency between objects so that when one object changes state, all of it dependents are notified.



Observer Pattern: bing-watch scenario



Observer Pattern: bing-watch scenario

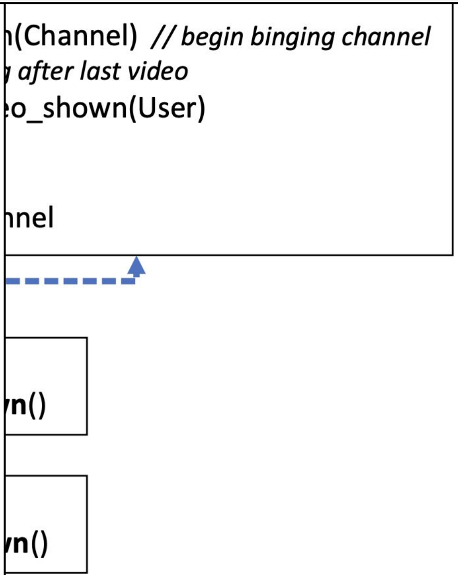



```
class Channel {
 public static void subscribe(ChannelObserver obs) {
   subscribers.Add(obs);
 }
 public static void unsubscribe(ChannelObserver obs) {
   subscribers.Remove(obs);
 }
 public void on_last_video_shown() {
   foreach (ChannelObserver obs in subscribers) {
     observer.update_video_shown(this);
   }
 }
 private static List<ChannelObserver> subscribers =
          new List<ChannelObserver>();
}
```

Observer Pattern: bing-watch scenario

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

```
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>();
}
```



Observer Pattern: bing-watch scenario

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

```
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>();
}
```

(Channel) *// begin binging channel*

after last video

o_shown(User)

nel

```
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 Pattern: update functions

- Having multiple “update_” functions, one for each type of state change, keeps messages **granular**

Observer Pattern: 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)

Observer Pattern: 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**)

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