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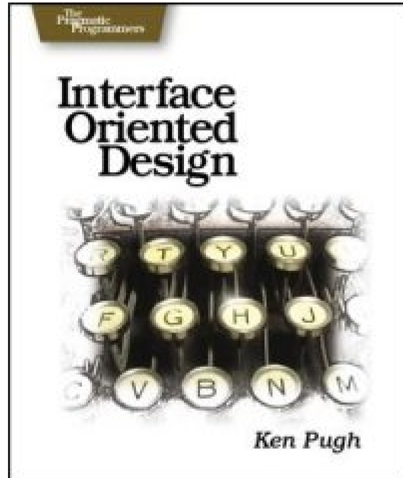

Interface Oriented Design

Chapter 5: Inheritance and Interfaces

by Ken Pugh

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Finding commonality among classes makes for effective object-oriented programming. Often, programmers express that commonality using an inheritance hierarchy, since that is one of the first concepts taught in object-oriented programming.

We're going to go to the other extreme in this chapter to explore the difference between using inheritance and using interfaces. An emphasis on interfaces guides you in determining what is the real essence of a class; once you have determined the essence, then you can look for commonalities between classes.

Creating an inheritance hierarchy prematurely can cause extra work when you then need to untangle it. If you start with interfaces and discover an appropriate hierarchy, you can easily refactor into that hierarchy. Refactoring into an inheritance hierarchy is far easier than refactoring out of an existing hierarchy.

We will look at examples of alternative designs that emphasize either inheritance or interfaces, so you can compare the two approaches. An interface-oriented alternative of a real-world Java inheritance hierarchy demonstrates the differences in code.

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5.1 Inheritance and Interfaces

You probably learned inheritance as one of the initial features of object oriented programming. With inheritance, a derived class receives the attributes and methods of a base class. The relationship between derived and base class is referred to as “is-a” or more specifically as “isa-kind-of.” For example, a mammal “is-a-kind-of” animal. Inheritance creates a class hierarchy.

You may hear the term inherits applied to interfaces. For example, a `PizzaShop` that implements the `PizzaOrdering` interface is often said to inherit the interface.[1] However, it is a stretch to say that a `PizzaShop` “is-a” `PizzaOrdering`. Instead, a more applicable relationship is that a `PizzaShop` “provides-a” `PizzaOrdering` interface.[2] Often modules that implement `PizzaOrdering` interfaces are not even object-oriented. So in this book, we use the term inherits only when a derived class inherits from a base class, as with the extends keyword in Java. A class “implements” an interface if it has an implementation of every method in the interface. Java uses the implements keyword precisely for this concept.[3]

Inheritance is an important facet of object-oriented programming, but it can be misused.[4] Concentrating on the interfaces that classes provide, rather than on their hierarchies, can help prevent inheritance misuse, as well as yield a more fluid solution to a design. Let’s look at some alternate ways to view example designs using both an inheritance-style approach and an interface-style approach. Both inheritance and interfaces provide polymorphism, a key feature of object-oriented design, so let’s start there.

5.2 Polymorphism

A common form of polymorphism consists of multiple classes that all implement the same set of methods. Polymorphism of this type can be organized in two ways. With inheritance, a base class contains a set of methods, and derived classes have the same set of methods.

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[1] Using a single term to represent two different concepts can be confusing. For example, how many different meanings are there for the keyword static in C++?

[2] You may see adjectives used for interface names, such as Printable;. With an adjective, you may see a reference such as a Document “is” Printable. The “is” in this case really means that a Document “provides-a” Printable interface.

[3] See the examples in Chapter 1 for how to code interfaces in C# and C++.

[4] See Designing Reusable Classes by Ralph E. Johnson and Brian Foote, http://www.laputan.org/drc/drc.html.

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The derived classes may inherit implementations of some methods and contain their own implementations of other methods. With interfaces, multiple classes each implement all the methods in the interface.

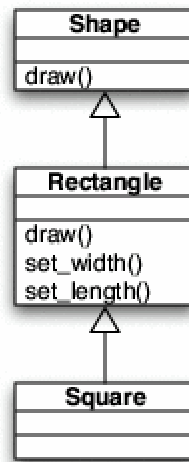

Figure 5.1: Shape hierarchy

With inheritance, the derived classes must obey the contract (of Design by Contract) of the base class. This makes an object of a derived class substitutable for an object of the base class. With interfaces, the implementation must also obey the contract, as stated in the First Law of Interfaces (see Chapter 2).

An example of an inheritance that violates a contract is the `Shape` hierarchy. The hierarchy looks like Figure 5.1 .

```
class Shape
    draw()
class Rectangle extends Shape
    set_sides(side_one, side_two)
    draw()
class Square extends Rectangle
    set_sides(side_one, side_two)
    draw()
```

A `Rectangle` is a `Shape`. A `Square` is a `Rectangle`. `Square` inherits the `set_sides()` method from `Rectangle`. For a `Rectangle`, any two positive values for `side_one` and `side_two` are acceptable. A `Square` can accept only two equal values. According to Design by Contract, a derived class can have less strict preconditions and stricter postconditions. This situation violates that rule, and thus the hierarchy is not ideal.

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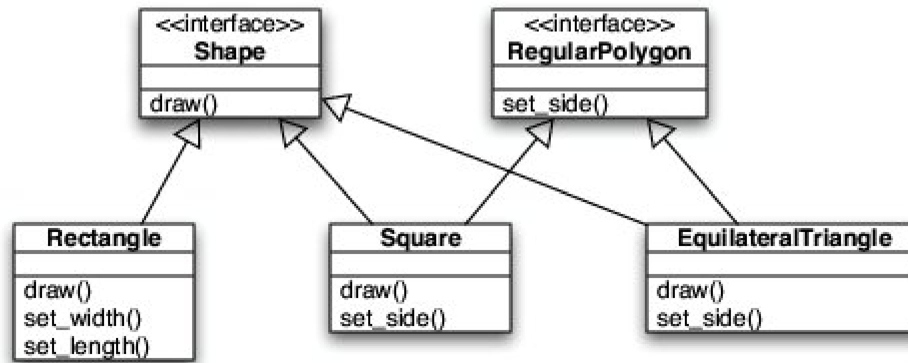

Figure 5.2: Diagram of interfaces

Although a `Square` is a `Rectangle` from a geometric point of view, it does not have the same behavior as a `Rectangle`. The error in this example comes from translating the common statement that "a square is a rectangle" into an inheritance hierarchy.

An alternative organization (Figure 5.2) using interfaces is as follows:

```
interface Shape
    draw()
Rectangle implements Shape
    set_sides(side_one, side_two)
    draw()
interface RegularPolygon
    set_side(measurement)
Square implements Shape, RegularPolygon
    set_side(measurement)
    draw()
EquilateralTriangle implements Shape, RegularPolygon
    set_side(measurement)
    draw()
```

With these interfaces, `Square` provides the `Shape` methods, but it also provides the methods in `RegularPolygon`. `Square` can obey the contract in both of these interfaces.

One difficulty with interfaces is that implementations may share common code for methods. You should not duplicate code; you have two ways to provide this common code. First, you can create a helper class and delegate operations to it. For example, if all `RegularPolygons` need to compute the perimeter and to compute the angles at the vertices, you could have this:

```
class RegularPolygonHelper
    set_side(measurement)
    compute_perimeter()
    compute_angle()
```


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Implementers of RegularPolygon would delegate operations to this class in order to eliminate duplicate code.

Second, you could create a class that implemented the interface and provided code for many, if not all, of the methods (such as the Java Swing adapter classes for event listeners shown in Chapter 3). You would then derive from that class instead of implementing the interface. For example:

```
interface RegularPolygon
    set_side(measurement)
    compute_perimeter()
    compute_angle()
class DefaultRegularPolygon implements RegularPolygon
    set_side(measurement)
    compute_perimeter()
    compute_angle()
class Square extends DefaultRegularPolygon, implements Shape
    set_side(measurement)
    compute_perimeter()
    compute_angle()
    draw()
```

In the case of single-inheritance languages, you need to decide which of the two potential base classes (Shape or RegularPolygon) is the more important one. If you decide on Shape, then you'll still need RegularPolygonHelper. Determining which one is important can be difficult until you have more experience with the classes. Starting with interfaces allows your to postpone that decision until you have that experience.

USING INTERFACES

Advantage—delay forming hierarchy until usage known

USING INHERITANCE

Advantage—less delegation of common operations

5.3 Hierarchies

The animal kingdom is a frequently used hierarchy example. The hierarchy starts with Animal on top. Animal breaks down into Mammals, Fishes, Birds, Reptiles, Amphibians, etc. The relationships parallel those of an object-oriented hierarchy: a cow "is-a" Mammal. The subclasses (derived classes) have attributes in common with the superclasses (base classes). This zoological classification is based on characteristics used to identify animals; Figure 5.3 shows a portion of the standard hierarchy.

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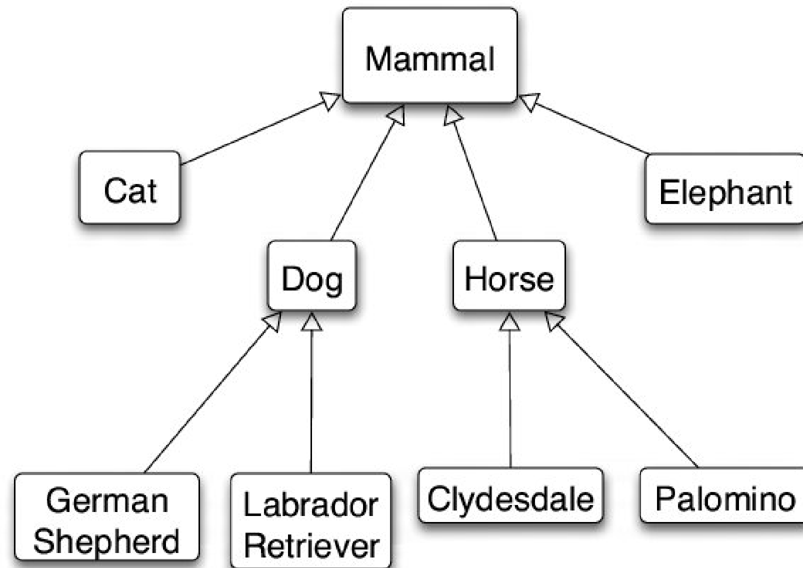

Figure 5.3: Mammalian hierarchy

The animal hierarchy is useful for identification, but it does not necessarily represent behavior. The hierarchy represents data similarities. Mammals all have hair (except perhaps whales and dolphins), are warm-blooded, and have mammary glands. The organization does not refer to services—things that animals do for us. Depending on your application that uses animals, a service-based description of animals may be more appropriate. The service-based description cuts across the normal hierarchy. Looking at what these animals do for us, we might have the following:

- Pull a Vehicle: Ox, Horse
- Give Milk: Cow
- Provide Companionship: Cat, Dog, Horse
- Race: Horse, Dog
- Carry Cargo: Horse, Elephant
- Entertain: Cat, Dog, Tiger, Lion, Elephant

We could organize these methods in the same way we did printers in Chapter 3; e.g., each animal could have a "can you do this for me" method, such as `can_you_carry_cargo()`. Alternatively, we could have a set of interfaces as shown in Figure 5.4. Animals would implement only the interfaces they could perform. The methods in the interfaces might be:

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```
interface Pullers
    hook_up
    pull_hard
    pull_fast
interface MilkGivers
    give_milk
    give_chocolate_milk
interface CompanionshipGivers
    sit_in_lap
    play_for_fun
```

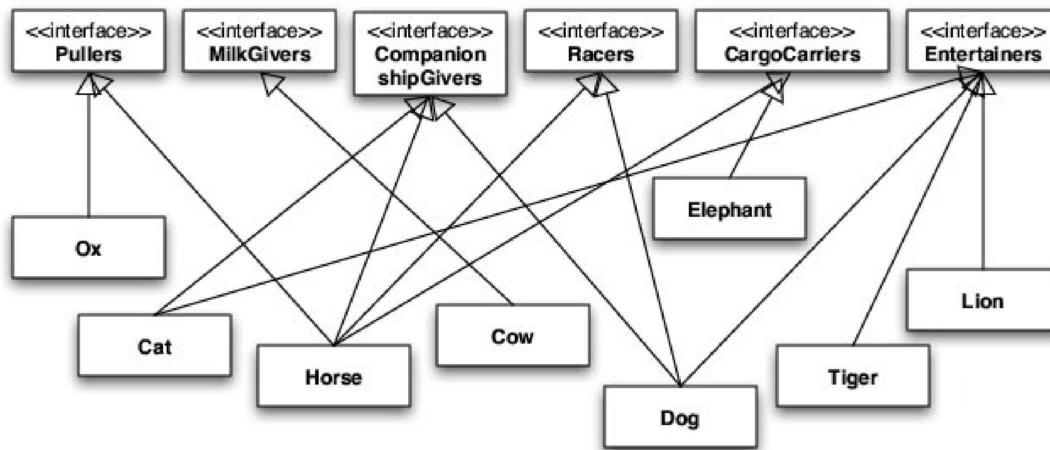

Figure 5.4: Animal interfaces

```
interface Racers
    run_fast
    run_long
interface CargoCarriers
    load_up
    get_capacity
interface Entertainers
    jump_through_hoop
    stand_on_two_legs
```

Depending on the application, you may employ both a hierarchy and service-based interfaces. For example, you might have a `Dog` hierarchy whose base class implemented the methods for `CompanionShipGivers`, `Racers`, and `Entertainers`. Particular breeds of dogs could inherit from `Dog` to obtain a default implementation.

You might also have a need for interfaces based on common characteristics that cross hierarchies, such as `LiveInWater`, `Vegetarian`, etc. These interfaces could each have a helper class that provided common implementations. Classes such as `Cow`, `Horse`, and `Ox` could delegate to a `VegetarianHelper` class.

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USING INTERFACES

Advantage—can cross hierarchies

USING INHERITANCE

Advantage—captures common attributes

Inheritance and Methods

Inheritance delineates a hierarchy of classes that all implement methods of the base class. The base class represents a general type, such as `Mammal`. The derived classes represent more specialized types, such as `Cow` and `Horse`. The derived classes may not necessarily offer additional methods.

On the other hand, derived classes can extend the base class and offer more methods. For example, for the `Printer` class in Chapter 4, a `ColorPrinter` represents more services than a `Printer`. When a derived class adds more methods to the base class, those additional methods can be considered an additional responsibility for the derived class. An interface could represent this additional responsibility.

For example, GUI components are usually organized as an inheritance hierarchy, like this:

```
class Component
    set_position()
    abstract draw()
class TextBox extends Component
    draw()
    set_text()
    get_text()
class CheckBox extends Component
    draw()
    set_state()
    get_state()
```

Here `TextBox` and `CheckBox` have additional methods that represent additional services for each derived class. Those additional methods could be denoted as interfaces, like this:

```
class Component
    set_position()
    abstract draw()
interface Textual
    set_text()
    get_text()
```


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```
class TextBox extends Component, implements Textual
    draw()
    set_text()
    get_text()
interface Checkable
    set_state()
    get_state()
class CheckBox extends Component, implements Checkable
    draw()
    set_state()
    get_state()
```

If each derived class has its own unique set of additional methods, there is no advantage to organizing the hierarchy with interfaces. However, if many of the derived classes do have a common set of services, you may make those commonalities more apparent by using interfaces.

For example, a drop-down box and a multiple selection list are usually on one branch of a GUI hierarchy. Radio buttons and check boxes are on another branch of the hierarchy. These two separate branches are based on their relative appearances. Another way to group commonality is to put radio buttons and drop-down lists together and multiple selections lists and check boxes together. Each of those groups has the same functionality. In the first group, the widgets provide selection of a single value. In the second group, the widgets provide the option of multiple values.[5] In this organization, they are grouped based on behavior, not on appearance. This grouping of behavior can be coded with interfaces:

```
interface SingleSelection
    get_selection()
    set_selection()
interface MultipleSelection
    get_selections()
    set_selections()
class RadioButtonGroup implements SingleSelection
class CheckBoxGroup implements MultipleSelection
class DropDownList implements SingleSelection
class MultipleSelectionList implements MultipleSelection
```

USING INTERFACES

Advantage—can capture common set of usage

USING INHERITANCE

Advantage—captures set of common behavior

[5] You might also put a list that allows only a single selection into this group.

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Football Team

The members of a football team can be depicted with either inheritance or interfaces. If you represented the positions with inheritance, you might have an organization that looks like this:[6]

```
FootballPlayer
    run()
DefensivePlayer extends Football Player
    tackle()
DefensiveBackfieldPlayer extends DefensivePlayer
    cover_pass()
Offensive Player extends Football Player
    block()
        Center extends OffensivePlayer
            snap()
        OffensiveReceiver extends OffensivePlayer
            catch()
            run_with_ball()
        OffensiveBackfieldPlayer extends OffensivePlayer
            catch()
            receive_handoff()
            run_with_ball()
        Quarterback extends OffensivePlayer
            handoff()
            pass()
```

An object of one of these classes represents a player. So, Payton Manning would be an object of `Quarterback`. Based on the methods in the hierarchy, Payton can run, block, hand off, and pass. This hierarchy looks pretty good. On the other hand, we can make our organization more fluid by using interfaces, like this:

```
interface FootballPlayer
    run()
interface Blocker
    block()
interface PassReceiver
    catch()
interface BallCarrier
    run_with_ball()
    receive_handoff()
interface Snapper
    snap()
interface Leader
    throw_pass()
    handoff()
    receive_snap()
```

[6] The services listed for each position are the required ones for each position. You could require that all FootballPlayers be able to catch and throw. The base class FootballPlayer would provide a basic implementation of these skills.

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```
interface PassDefender()
    cover_pass_receiver()
    break_up_pass()
    intercept_pass()
```

A role combines one or more interfaces. We might come up with the following roles for team members:

```
Center implements FootballPlayer, Blocker, Snapper
GuardTackle implement FootballPlayer, Blocker
EndTightOrSplit implements FootballPlayer, Blocker, PassReceiver
RunningBack implements FootballPlayer, BallCarrier, PassReceiver
Fullback implements Blocker, FootballPlayer, BallCarrier, PassReceiver
WideReceiver implements FootballPlayer, PassReceiver
Quarterback implements FootballPlayer, Leader, BallCarrier
```

Now along comes Deion Sanders, who plays both offense and defense. To fit Deion into the previous hierarchy, you need to create two objects: one an `OffensivePlayer` and the other a `DefensivePlayer`. Or you'd need to come up with some other workaround that does not fit cleanly into the hierarchy. With interfaces, Deion simply fulfills another role, like this:

```
SwitchPlayer implements FootballPlayer, PassReceiver, PassDefender
```

Roles can even be more fluid. For example, in one professional game, a backup quarterback lined up as a wide receiver.[7] Trying to fit such a role into a hierarchy can be daunting. With interfaces, he would have simply implemented `PassReceiver`, or he could take on a role like this:

```
ReceiverQuarterback implements FootballPlayer, PassReceiver, Quarterback
```

USING INTERFACES

Advantage—give more adaptability for roles that cross hierarchies

Disadvantage—may have duplicated code without helper classes to provide common functionality

###

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[7] This was Seneca Wallace in a Carolina Panthers/Seattle Seahawks game, for you trivia buffs.

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About the Author

Ken Pugh has worked on software and hardware projects for over thirty years, from requirements gathering through testing and maintenance. He has a wide variety of experience with numerous operating systems, languages, and development processes. He has developed software systems extending from long-baseline interferometry to real-time goat serum process control, and embedded systems for signal processing to networked file storage.

As a teacher and mentor, he has trained thousands of students in subjects ranging from object-oriented design to UNIX operating system internals. He has presented at numerous conferences seminars on software development processes, programming techniques, and system architecture. Ken has written four books on programming and operating systems.

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