

Typeclasses

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Apple invented protocol-oriented programming:

Protocol Oriented Programming in Swift

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- “Protocols are central to Swift”
- “Protocols make it easy to extend classes, that’s why we made Swift the first protocol oriented programming language”

Audio

I watched a video today on Swift ... about ‘protocol oriented programming’ ... and they basically just introduced typeclasses and they were like ‘We invented this, it’s amazing’

Typeclasses in Haskell

Haskell from 1988

```
class Eq a where
  (==) :: a -> a -> Bool
  (/=) :: a -> a -> Bool
  x == y = not (x /= y)
  x /= y = not (x == y)
```

```
data Point = Point Float Float deriving (Show, Eq)

Prelude> Point 1 2
Point 1.0 2.0
Prelude> Point 1 2 == Point 1 2
True
Prelude> Point 2 1 /= Point 1 2
True
```

Typeclasses in 1988

Protocols in Swift

Swift in 2018

```
protocol IsEqual {
    static func == (lhs: Self, rhs: Self) -> Bool
    static func != (lhs: Self, rhs: Self) -> Bool
}

struct Point : Equatable {
    var x: Double
    var y: Double
}

print(Point(x: 1, y: 2) == Point(x: 1, y: 2)) // true
print(Point(x: 2, y: 1) != Point(x: 1, y: 2)) // true
```

If you're 30 years late, you must be the first to implement it
Apple has great marketing

What does this print out in go?

```
func main() {
    x := 1
    y := 2
    z := math.Min(x, y)
    fmt.Println(z)
}
```

FAIL: cannot use a (type int) as type float64 in argument to math.Min

Wat

Generics in C++

```
auto add(auto a, auto b) { return a + b; }
```

I've never said that these types were addable.

```
add("hello", 2);
```

Concepts in C++

```
template <NumericType T>  
auto add(T a, T b) -> T { return a + b; }
```

Numeric types in Swift

```
func add<T:Numeric>(a: T, b: T) -> T {  
    a + b  
}
```

Typeclasses in Rust

```
fn add<T: std::ops::Add>(a: T, b: T) -> T {  
    a + b  
}
```

Typeclasses in Haskell

```
class Num a where  
    add :: a -> a -> a
```

Shapes in Haskell

```
class Shape a where  
    name :: a -> String  
    area :: a -> Float  
    perimeter :: a -> Float  
  
data Circle = Circle {r :: Float}  
data Rectangle = Rectangle {w :: Float, h :: Float}
```

```

instance Shape Circle where
    name (Circle _) = "Circle"
    area (Circle r) = pi * r ^ 2
    perimeter (Circle r) = 2 * pi * r

instance Shape Rectangle where
    name (Rectangle _ _) = "Rectangle"
    area (Rectangle w h) = w * h
    perimeter (Rectangle w h) = 2 * w * 2 * h

printArea :: Shape a => a -> IO()
printArea s = putStrLn("My area is: " ++ show (area s) ++ "\n")

main = do
    printArea $ Circle 10
    printArea $ Rectangle 10 20

```

Shapes in Swift

```

protocol Shape {
    func name() -> String;
    func area() -> Float;
    func perimeter() -> Float;
}

struct Rectangle : Shape {
    let l: Float;
    let w: Float;
    init(l: Float, w: Float) { self.l = l; self.w = w; }
    func name() -> String { "Rectangle" }
    func area() -> Float { l * w }
    func perimeter() -> Float { 2 * (l * w) }
}

struct Circle : Shape {
    let r: Float;
    init(r: Float) { self.r = r; }
    func name() -> String { "Circle" }
    func area() -> Float { r * r * Float.pi }
    func perimeter() -> Float { 2 * Float.pi * r }
}

func print_area(s: Shape) { print(s.get_area()) }

```

```

func main() {
    print_area(s: Circle(r: 10))
    print_area(s: Rectangle(l: 10, w: 20))
}

```

Shapes in Rust

```

use std::fmt::Debug;

trait Shape {
    fn get_name(&self) -> String;
    fn get_area(&self) -> f32;
    fn get_perimeter(&self) -> f32;
}

#[derive(Debug)]
struct Circle {
    r: f32,
    name: String,
}

impl Circle {
    fn new(r: f32) -> Circle {
        Circle {
            r,
            name: "Circle".to_string(),
        }
    }
}

impl Shape for Circle {
    fn get_name(&self) -> String {
        self.name.clone()
    }

    fn get_area(&self) -> f32 {
        self.r * self.r * 3.14
    }

    fn get_perimeter(&self) -> f32 {
        self.r * 2.0 * 3.14
    }
}

```

```

#[derive(Debug)]
struct Rectangle {
    l: f32,
    w: f32,
    name: String,
}

impl Rectangle {
    fn new(l: f32, w: f32) -> Rectangle {
        Rectangle {
            l,
            w,
            name: "Rectangle".to_string(),
        }
    }
}

impl Shape for Rectangle {
    fn get_name(&self) -> String {
        self.name.clone()
    }

    fn get_area(&self) -> f32 {
        self.l * self.w
    }

    fn get_perimeter(&self) -> f32 {
        (self.l + self.w) * 2.0
    }
}

fn print_area<T>(t: T)
where
    T: Shape + Debug,
{
    println!("{:?}", t);
}

fn main() {
    let circle = Circle::new(10.0);
    println!("{}", circle.get_perimeter());
    let rectangle = Rectangle::new(10.0, 20.0);
    println!("{}", rectangle.get_perimeter());
    print_area(rectangle);
    print_area(circle);
}

```

```
}
```

Shapes in C++

```
#include <iostream>
#include <string>

class Shape {
public:
    virtual std::string getName() = 0;
    virtual double getPerimeter() = 0;
    virtual double getArea() = 0;

private:
    std::string name_ = "Shape";
};

class Rectangle : public Shape {
public:
    Rectangle(double l, double w) : l_(l), w_(w) {}
    std::string getName() { return name_; }
    double getPerimeter() { return 2 * (l_ + w_); }
    double getArea() { return l_ * w_; }

private:
    std::string name_ = "Rectangle";
    double l_;
    double w_;
};

class Circle : public Shape {
public:
    Circle(double r) : r_(r) {}
    std::string getName() { return name_; }
    double getPerimeter() { return 2 * r_ * 3.14; }
    double getArea() { return r_ * r_ * 3.14; }

private:
    std::string name_ = "Circle";
    double r_;
};

void printArea(Shape &shape) { std::cout << shape.getArea() << std::endl; }
```

```

int main() {
    Rectangle r = Rectangle(10, 20);
    Circle c = Circle(10.0);
    printArea(c);
    printArea(r);
}

```

Shapes in C

```

#include <stdio.h>

enum Shape_Type { CIRCLE, RECTANGLE };

struct Shape {
    enum Shape_Type shape_type;
    union {
        struct {
            double l;
            double w;
        };
        struct {
            double r;
        };
    };
    char *(*getName)(struct Shape);
    double (*getArea)(struct Shape);
    double (*getPerimeter)(struct Shape);
};

char *getName(struct Shape s) {
    if (s.shape_type == CIRCLE)
        return "Circle";
    else if (s.shape_type == RECTANGLE)
        return "Rectangle";
    else
        return "Shape";
}

double getArea(struct Shape s) {
    if (s.shape_type == CIRCLE)
        return s.r * s.r * 3.14;
    else if (s.shape_type == RECTANGLE)
        return (s.l + s.w) * 2;
    return 0;
}

```

```

}

double getPerimeter(struct Shape s) {
    if (s.shape_type == CIRCLE)
        return s.r * 2 * 3.14;
    else if (s.shape_type == RECTANGLE)
        return s.l * s.w;
    return 0;
}

struct Shape makeShape() {
    struct Shape s = {
        .getName = getName, .getArea = getArea, .getPerimeter = getPerimeter};
    return s;
}

struct Shape makeCircle(double r) {
    struct Shape c = makeShape();
    c.shape_type = CIRCLE;
    c.r = r;
    return c;
}

struct Shape makeRectangle(double l, double w) {
    struct Shape r = makeShape();
    r.shape_type = RECTANGLE;
    r.l = l;
    r.w = w;
    return r;
}

int main() {
    struct Shape c = makeCircle(10);
    printf("My perimeter is: %f\n", c.getPerimeter(c));
    printf("My area is: %f\n", c.getArea(c));
    printf("My name is: %s\n", c.getName(c));
    struct Shape r = makeRectangle(20, 40);
    printf("My perimeter is: %f\n", r.getPerimeter(r));
    printf("My area is: %f\n", r.getArea(r));
    printf("My name is: %s\n", r.getName(r));
}

```

Lessons Learned

OCaml at Cornell

Genealogically, OCaml comes from the line of programming languages whose grandfather is Lisp and includes modern languages such as Clojure, F#, Haskell, and Racket. Functional languages have a surprising tendency to predict the future of more mainstream languages. Java brought garbage collection into the mainstream in 1995; Lisp had it in 1958. Java didn't have generics until version 5 in 2004; the ML family had it in 1990.

First-class functions and type inference have been incorporated into mainstream languages like Java, C#, and C++ over the last 10 years, long after functional languages introduced them. By studying functional programming, you get a taste of what might be coming down the pipe next. Who knows what it might be? (My bet would be pattern matching.)



Figure 1: Apple Stock Price since 2015

Apple's Stock Price since 2015

Takeways

- Don't trust Apple's marketing
- Swift has a pretty nice protocol system
- People like to take ideas from functional programming and say they did it first.