CS 635 Advanced Object-Oriented Design & Programming
Fall Semester, 2022

Doc 7 Observer Pattern
Sep 15, 2022

Why Software Projects Go Wrong (2)

More software projects have gone awry from management's taking action based on incorrect system models than for all other causes combined.

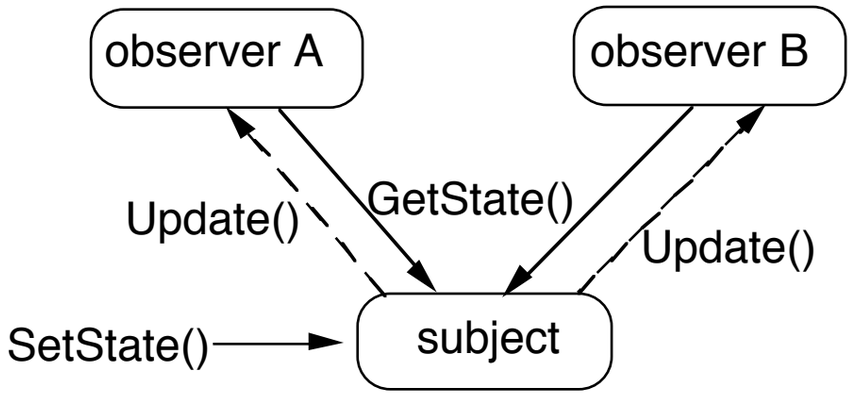
Gerald M. Weinberg

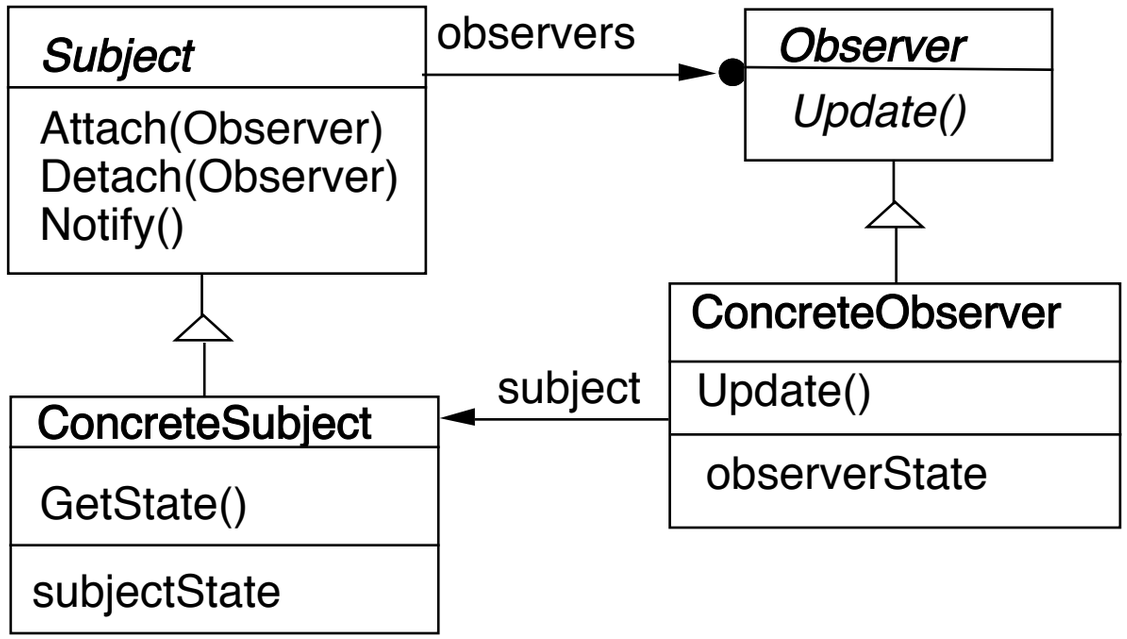
Observer

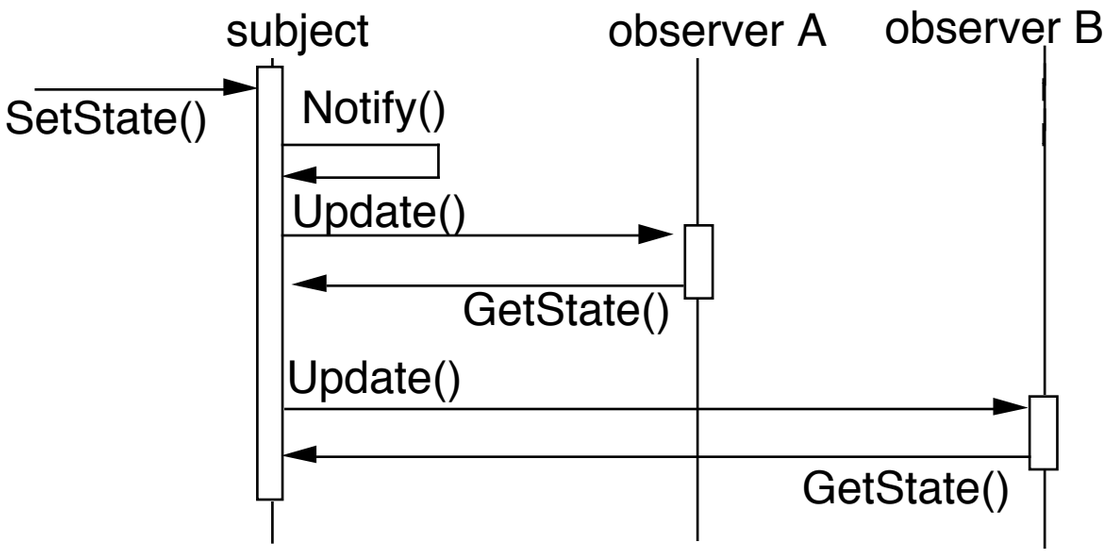
One-to-many dependency between objects

When one object changes state,
all its dependents are notified and updated automatically

Structure


observer A
observer B
Update()
GetState()
Update()
SetState()
subject


Subject
Attach(Observer)
Detach(Observer)
Notify()
observers
Observer
Update()
ConcreteObserver
Update()
observerState
subject
ConcreteSubject
GetState()
subjectState


subject
observer A
observer B
SetState()
Notify()
Update()
GetState()
Update()
GetState()

Common Java Example - Listeners

Java Interface

View.OnClickListener

abstract void onClick(View v)

Called when a view has been clicked.

Java Example

```
public class CreateUIInCodeActivity extends Activity implements View.OnClickListener{
    Button test;

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.main);
        test = (Button) this.findViewById(R.id.test);
        test.setOnClickListener(this);
    }

    public void onClick(View source) {
      Toast.makeText(this, "Hello World", Toast.LENGTH_SHORT).show();
    }
}
```

Pseudo Java Example

```
public class Subject {
   Window display;
   public void someMethod() {
      this.modifyMyStateSomeHow();
      display.addText( this.text() );
   }
}
```

Abstract coupling - Subject & Observer

Broadcast communication

Updates can take too long

```
public class Subject {
   ArrayList observers = new ArrayList();

   public void someMethod() {
      this.modifyMyStateSomeHow();
      changed();
   }

   private void changed() {
      Iterator needsUpdate = observers.iterator();
      while (needsUpdate.hasNext() )
         needsUpdate.next().update( this );
   }
}

public class SampleWindow {
   public void update(Object subject) {
      text = ((Subject) subject).getText();
      Thread.sleep(10000).
   }
}
```

Some Language Support

Smalltalk	Java	Ruby	Clojure	Observer Pattern
Object	~~Observer~~		function	Abstract Observer class
Object & Model	~~Observable~~	Observable	watches on data	Subject class

Smalltalk Implementation

Object implements methods for both Observer and Subject.

Actual Subjects should subclass Model

Java's Observer

Class java.util.Observable

void addObserver(Observer o)
void clearChanged()
int countObservers()
void deleteObserver(Observer o)
void deleteObservers()
boolean hasChanged()
void notifyObservers()
void notifyObservers(Object arg)
void setChanged()

Observable object may have any number of Observers

Whenever the Observable instance changes,
it notifies all of its observers

Notification is done by calling the update() method on all observers.

Interface java.util.Observer

Allows all classes to be observable by instances of class Observer

Java	Observer Pattern
Interface Observer	Abstract Observer class
Observable class	Subject class

Deprecated in Java 9

Flow

Java Observer & Observable are replaced by
- java beans
- Reactive Streams (Flow)

Flow

- Publisher (Subject)
- Subscriber (Observer)
- Processor (Subject & Observer)
- Subscription
  - Link between publisher & subscriber

Coupling & Observer Pattern

Subject coupled to Observer interface

Does not know the concrete type of the observers

There can be 0+ observers

Implementation Issues

Mapping subjects(Observables) to observers

Use list in subject

Use hash table

```
public class Observable {
    private boolean changed = false;
    private Vector obs;

public Observable() {
    obs = new Vector();
}

public synchronized void addObserver(Observer o) {
    if (!obs.contains(o)) {
        obs.addElement(o);
    }
}
```

Observing more than one subject

If an observer has more than one subject how does it know which one changed?

Pass information in the update method

Deleting Subjects

In C++ the subject may no longer exist

Java/Smalltalk observer may prevent subject from garbage collection

Who Triggers the update?

Have methods that change the state trigger update

```
class Counter extends Observable  {          // some code removed
   public void increase()  {
       count++;
       setChanged();
       notifyObservers( INCREASE );
   }
}
```

Have clients call Notify at the right time

```
class Counter extends Observable  {       // some code removed
       public void increase()  {   count++;  }
}

Counter pageHits = new Counter();
pageHits.increase();
pageHits.increase();
pageHits.increase();
pageHits.notifyObservers();
```

Subject is self-consistent before Notification

```
class ComplexObservable extends Observable {
    Widget frontPart = new Widget();
    Gadget internalPart = new Gadget();

    public void trickyChange() {
        frontPart.widgetChange();
        internalpart.anotherChange();
        setChanged();
        notifyObservers( );
    }
}

class MySubclass extends ComplexObservable {
    Gear backEnd = new Gear();

    public void trickyChange() {
        super.trickyChange();
        backEnd.yetAnotherChange();
        setChanged();
        notifyObservers( );
    }
}
```

Adding information about the change

push models - add parameters in the update method

```
class IncreaseDetector extends Counter implements Observer { // stuff not shown

  public void update( Observable whatChanged, Object message) {
      if ( message.equals( INCREASE) )
          increase();
  }
}
```

```
class Counter extends Observable {          // some code removed
  public void increase()  {
      count++;
      setChanged();
      notifyObservers( INCREASE );
  }
}
```

Adding information about the change

pull model - observer asks Subject what happened

```
class IncreaseDetector extends Counter implements Observer {
 public void update( Observable whatChanged ) {
     if ( whatChanged.didYouIncrease() )
         increase();
 }
}
```

```
class Counter extends Observable {          // some code removed
 public void increase() {
     count++;
     setChanged();
     notifyObservers( );
 }
}
```

Rate of Updates

In single threaded operation

All observers must finish before subject can continue operation

What to do when subject changes faster than observers can handle

Scaling the Pattern

Java Event Model

AWT/Swing components broadcast events to Listeners

JDK1.0 AWT components broadcast an event to all its listeners

A listener normally not interested all events

Broadcasting to all listeners was too slow with many listeners

Java 1.1+ Event Model

Each component supports different types of events:

Component supports

ComponentEvent	FocusEvent
KeyEvent	MouseEvent

Each event type supports one or more listener types:

MouseEvent

MouseListener	MouseMotionListener

Each listener interface replaces update with multiple methods

MouseListener

mouseClicked()	mouseEntered()
mousePressed()	mouseReleased()

Listeners

- Only register for events of interest
- Don't need case statements to determine what happened

Small Models

Often an object has a number of fields(aspects) of interest to observers

Rather than make the object a subject make the individual fields subjects

- Simplifies the main object
- Observers can register for only the data they are interested in

VisualWorks ValueHolder

Subject for one value

ValueHolder allows you to:

- Set/get the value
  - Setting the value notifies the observers of the change
- Add/Remove dependents

Reactive Programming

Reactive Manifesto

https://www.reactivemanifesto.org

Organizations working in disparate domains are independently discovering patterns for building software that look the same.

These systems are more robust, more resilient, more flexible and better positioned to meet modern demands.

Reactive Systems are

- Responsive
- Resilient
  - React to failure
- Elastic
  - React to load
- Message Driven

Motivation

- Need millisecond response
- 100% uptime
- Data is measured in Petabytes
- Applications run on
  - Mobile
  - Clusters of 1000s of multicore processors

History

1997 - Elliott & Hudak

Fran - reactive animations Reactive Functional Programing

2009 Akka

Actor model + reactive streams

2009 Reactive Extension for .NET early version

2011 Reactive Extension for .NET Official release

2012 Elm - RFP for the web

2013 React

Facebook's system for Web UI components

2014 RxJava 1.0 - Port of Reactive Extensions (ReactiveX) to Java

2015 Flutter beta

2016 RxJava 2.0

2018 Flutter 1.0

2019 Swift UI, Android Compose

ReactiveX

http://reactivex.io

Their claim

> The Observer pattern done right
>
> ReactiveX is a combination of the best ideas from
>
> - Observer pattern,
> - Iterator pattern,
> - Functional programming

Ported to multiple languages

- Basic ideas same
- Syntax differs

Reactive Programming

datatypes that represent a value 'over time'

Spreadsheets

3	1	2
5	3	4
8		

Reactive Programming

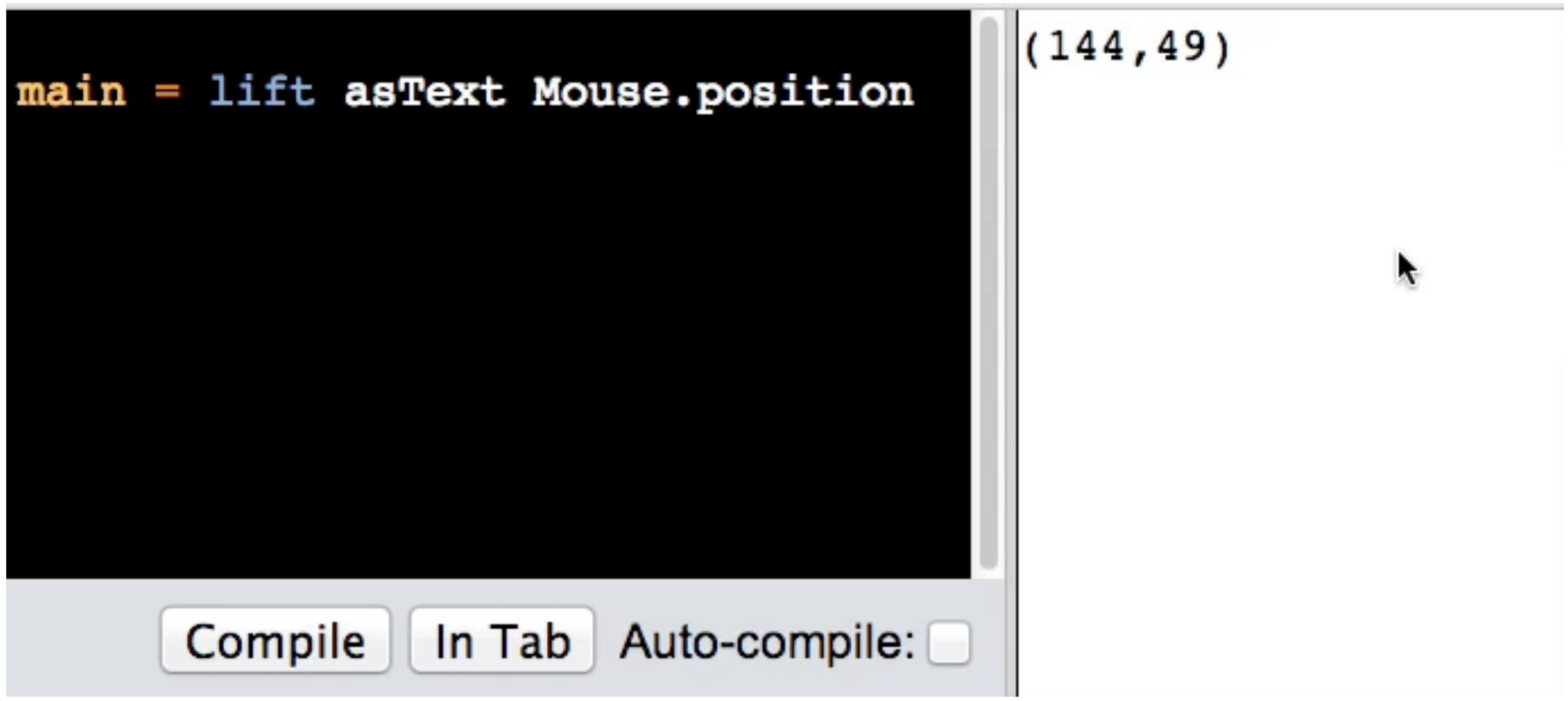
Spreadsheets
Elm
React (Facebook)
Reagent (Clojure)
Android Architecture Components
SwiftUI
Swift Combine
Flutter (Google)
Fuchsia (Google)
Akka
Java Flow

ReactiveX
- RxJava (35,500 GitHub stars)
- RxJS
- Rx.NET
- RxPY
- RxSwift
- RxKotlin

Android Compose

Reactive Programming - Elm

datatypes that represent a value 'over time'

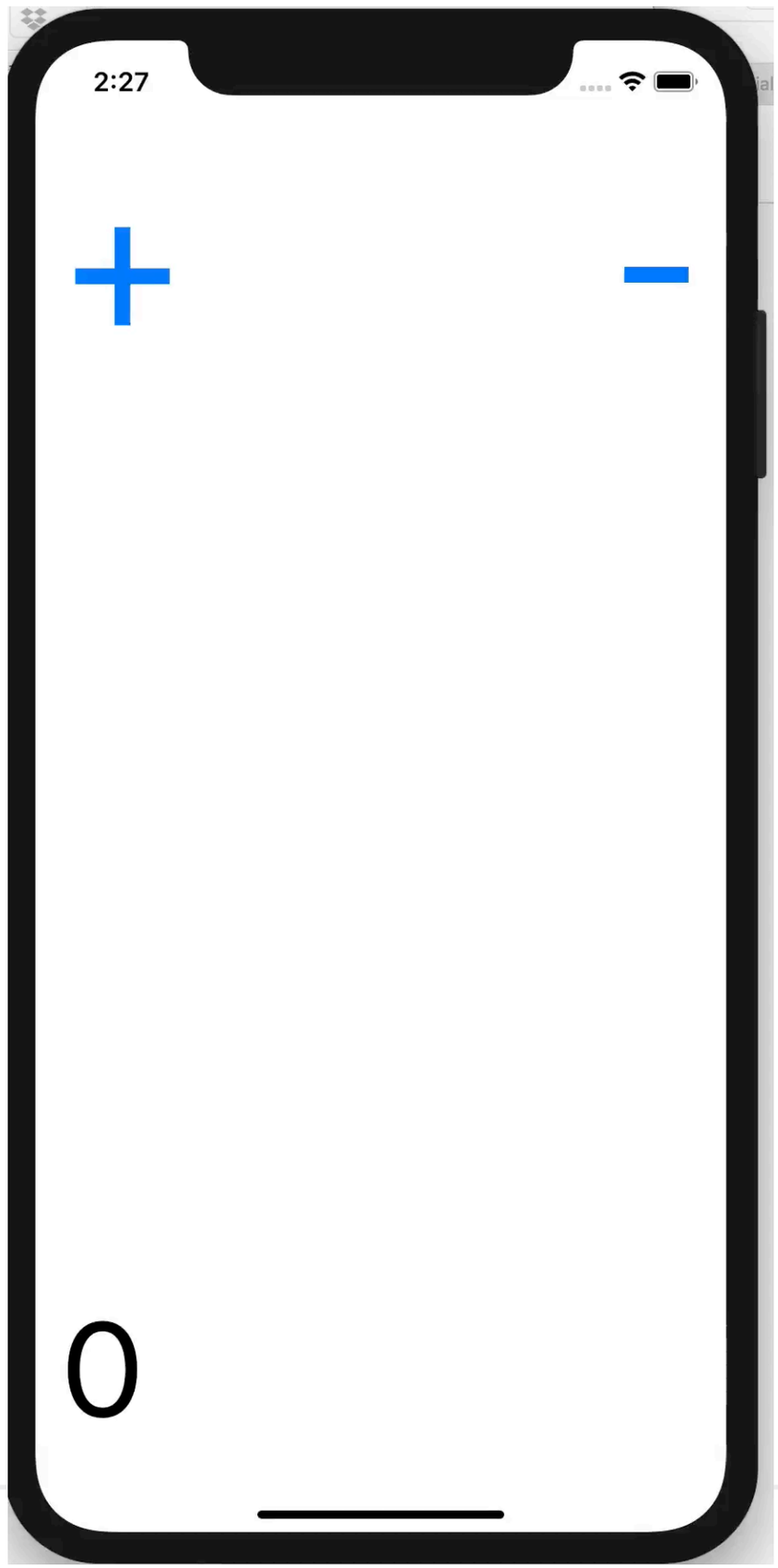


SwiftUI Example

```
import SwiftUI

struct ContentView : View {
    @State private var count : Int = 0

    var body: some View {
        VStack(alignment: .leading) {
            HStack {
                Button(action: {self.count = self.count + 1}){
                    Text("+").font(.system(size: 120))
                }
                Spacer()
                Button(action: {self.count = self.count - 1}){
                    Text("-").font(.system(size: 120))
                }
            }
            Spacer()
            Text("\(count)").font(.system(size: 80))
        }.padding()
    }
}
```



Reactive Programming Concepts

Unify data types into stream of events/data

- Events
- Collections
- Value changing
- Asynchronous callbacks

One-way data flows

- React & Flux

Unify Data Types

```
Iterator<String> list = strings.iterator();
while (list.hasNext()){
    String element = list.next();
    processEachElement(element);
    }
}
```

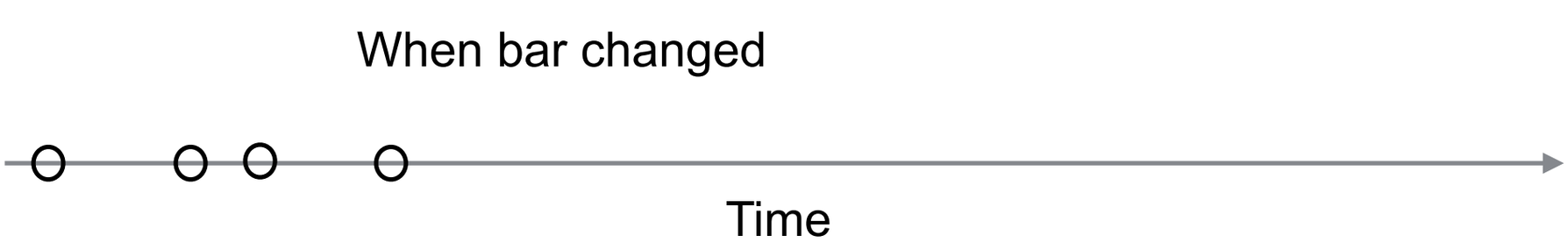
When Elements are processes

But some elements take longer to process

Unify Data Types

```
class Foo {
   int bar;
```

bar changes value over time



The Basics

Subjects (Observables) generate a stream or flow of events/data

Streams

- Support map, filter and other functions

- Send three types of messages/events
  - onNext - the next data in the stream
  - onCompleted - The stream is at the end
  - onError - An error occurred

Observers subscribe to streams

- Some subjects give all the events/data to new subscribers
- Some give only current value and future changes
- Some subjects allow observers to tell subjects to slow down

RxJava - Basic Classes

io.reactivex.Flowable:

0..N flows, supporting Reactive-Streams and backpressure

io.reactivex.Observable:

0..N flows, no backpressure

io.reactivex.Single:

a flow of exactly 1 item or an error

io.reactivex.Completable:

a flow without items but only a completion or error signal

io.reactivex.Maybe:

a flow with no items, exactly one item or an error.

RxJava HelloWorld

```
import io.reactivex.*;

public class Example {
    public static void main(String[] args) {
        Flowable.just("Hello world")
                    .subscribe(System.out::println);
    }
}
```

RxJava Subscribe methods

subscribe(Consumer<? super T> onNext)

subscribe(Consumer<? super T> onNext,
Consumer<? super Throwable> onError)

subscribe(Consumer<? super T> onNext,
Consumer<? super Throwable> onError,
Action onComplete)

Java Consumer

Lambda or function that has one argument and no return value

Consumer<String> print = text -> System.out.println(text);
print.accept("hello World");

```
import io.reactivex.*;

public class Example {
    public static void main(String[] args) {
        Flowable<Integer> flow = Flowable.range(1, 5)
                .map(v -> v * v)
                .filter(v -> v % 2 == 0);
        System.out.println("Start");
        flow.subscribe(System.out::println);
        System.out.println("Second");
        flow.subscribe(value -> System.out.println("Second " + value));
    }
}
```

Output

```
Start
4
16
Second
Second 4
Second 16
```

Observables with Varying Number of Events

Flowable<Integer> flow = Flowable.range(1, 5)

flow has fixed number of data points

So more like iterator over a collection

How to create observable with varying number of data points/events

Emitters

Subjects

Emitter Interface

onComplete()
onError(Throwable error)
onNext(T value)

Example

```
import io.reactivex.*;

public class Example {
    public static void main(String[] args) {
        Observable<String> observable = Observable.create(emitter -> {
                emitter.onNext("A");
                emitter.onNext("B");
                emitter.onNext("B");
                emitter.onComplete();
                });
        System.out.println("Start");
        observable.subscribe(System.out::println,Throwable::printStackTrace,
                                                        () -> System.out.println("Done"));
    }
}
```

Longer Running Example

```
import io.reactivex.*;

public class Example {
    public static void main(String[] args) {
        Observable<Long> observable = Observable.create(emitter -> {
            while (!emitter.isDisposed()) {
                long time = System.currentTimeMillis();
                emitter.onNext(time);
                if (time % 2 != 0) {
                    emitter.onError(new IllegalStateException("Odd millisecond!"));
                    break;
                }
            }
        });
        System.out.println("Start");
        observable.subscribe(System.out::println,Throwable::printStackTrace);
    }
}
```

Important Notes

Data generation all done in lambda

- But could have called a method on an object

Observable just knows to pass emitter to observer

Subjects

Subjects are
- Observable
- Observers

Multiple Types
- BehaviorSubject
  - Sends current value and future values to observers
- PublishSubject
  - Sends future values to observers
- ReplaySubject
  - Sends past, current and future values to observers

PublishSubject Example

```
import io.reactivex.subjects.PublishSubject;
import io.reactivex.subjects.Subject;

public class Example {
    public static void main(String[] args) {
        Subject<String> subject = PublishSubject.create();
        subject.subscribe(System.out::println,
                                Throwable::printStackTrace,
                                () ->System.out.println("Done"));
        subject.onNext("Start");
        subject.onNext("A");

        subject.subscribe(text -> System.out.println("Later " + text));
        subject.onNext("B");
        subject.onNext("C");
        subject.onComplete();
    }
}
```

Output

```
Start
A
B
Later B
C
Later C
Done
```

BehaviorSubject Example

```
import io.reactivex.subjects.BehaviorSubject;
import io.reactivex.subjects.Subject;

public class Example {
    public static void main(String[] args) {
        Subject<String> subject = BehaviorSubject.create();
        subject.subscribe(System.out::println,
                                Throwable::printStackTrace,
                                () ->System.out.println("Done"));

        subject.onNext("Start");
        subject.onNext("A");

        subject.subscribe(text -> System.out.println("Later " + text));
        subject.onNext("B");
        subject.onNext("C");
        subject.onComplete();
    }
}
```

Output

```
Start
A
Later A
B
Later B
C
Later C
Done
```

ReplaySubject Example

```
import io.reactivex.subjects.ReplaySubject;
import io.reactivex.subjects.Subject;

public class Example {
    public static void main(String[] args) {
        Subject<String> subject = ReplaySubject.create();
        subject.subscribe(System.out::println,
                          Throwable::printStackTrace,
                          () ->System.out.println("Done"));

        subject.onNext("Start");
        subject.onNext("A");

        subject.subscribe(text -> System.out.println("Later " + text));
        subject.onNext("B");
        subject.onNext("C");
        subject.onComplete();
    }
}
```

Output

```
Start
A
Later Start
Later A
B
Later B
C
Later C
Done
```

RxPy

```
from rx import Observable

source = Observable.of("Alpha", "Beta", "Gamma", "Delta", "Epsilon")

source.subscribe(on_next=lambda value: print("Received {0}".format(value)),
                 on_completed=lambda: print("Done!"),
                 on_error=lambda error: print("Error Occurred: {0}".format(error))
                 )

source.subscribe(on_completed=lambda: print("Done!"),
                 on_next=lambda value: print("Received {0}".format(value))
                 )

source.subscribe(lambda value: print("Received {0}".format(value)))


source.subscribe(print)
```

RxPy

```
from rx import Observable

xs = Observable.from_(range(10))
d = xs.filter(lambda x: x % 2)
        .map(lambda x: x * 2)
        .subscribe(print)
```

```
2
6
10
14
18
```

```
xs = Observable.range(1, 5)
ys = Observable.from_("abcde")
zs = xs.merge(ys).subscribe(print)
```

```
a
1
b
2
c
3
d
4
e
5
```

PublishSubject

```
from rx.subjects import Subject

stream = Subject()
stream.subscribe(on_next=lambda value: print("Received {0}".format(value)),
                 on_completed=lambda: print("Done!"),
                 on_error=lambda error: print("Error Occurred: {0}".format(error))
                 )
stream.on_next("Start")
stream.on_next("A")
d = stream.subscribe(lambda x: print("Got: %s" % x))

stream.on_next("B")

d.dispose()
stream.on_next("C")
stream.on_next(10)

stream.on_completed()
```

```
Received Start
Received A
Received B
Got: B
Received C
Received 10
Done!
```

ReplaySubject

```
from rx.subjects import ReplaySubject

stream = ReplaySubject()
stream.subscribe(on_next=lambda value: print("Received {0}".format(value)),
                 on_completed=lambda: print("Done!"),
                 on_error=lambda error: print("Error Occurred: {0}".format(error))
                 )
stream.on_next("Start")
stream.on_next("A")
d = stream.subscribe(lambda x: print("Got: %s" % x))

stream.on_next("B")

d.dispose()
stream.on_next("C")
stream.on_next(10)

stream.on_completed()
```

```
Received Start
Received A
Got: Start
Got: A
Received B
Got: B
Received C
Received 10
Done!
```

RxSwift

```
import RxSwift

let dataSequence = Observable.from([1, 2, 3])
dataSequence.subscribe(onNext: {print($0)})
```

```
1
2
3
```

```
dataSequence.subscribe(
                        onNext: {print($0)},
                        onCompleted: {print("Done")})
```

```
1
2
3
Done
```

```
dataSequence
    .map {$0 + 1}
    .scan(0) {$0 + $1}
    .subscribe(onNext: {print($0)},onCompleted: {print("Done")})
```

```
2
5
9
Done
```

PublishSubject

```
let subject = PublishSubject<Int>()
subject.subscribe(onNext: {print("Subject = \($0)")},
                  onCompleted: {print("Done")})

subject.map {$0 + 10}
       .subscribe(onNext: {print("Plus 10 = \($0) ")})

print("Start")
subject.onNext(2)
print("After 2")
subject.onNext(4)
print("No more")
```

```
Start
Subject = 2
Plus 10 = 12
After 2
Subject = 4
Plus 10 = 14
No more
```

Network Calls

```
if let url = URL(string: "https://bismarck.sdsu.edu/registration/subjectlist") {
    let request = URLRequest(url: url)

    let responseJSON = URLSession.shared.rx.json(request: request)

    let cancelRequest = responseJSON.subscribe(
                                onNext: { json in print(json) },
                                onCompleted: {print("Done")})
}
```

Reactive Programming

New terms

- Channels, Signals
- Events
- Producers
- etc

Needs to rethink how to write code