CS 635 Advanced Object-Oriented Design & Programming
Fall Semester, 2018
Doc 13 Observer, Reactive, Template
Oct 25, 2018

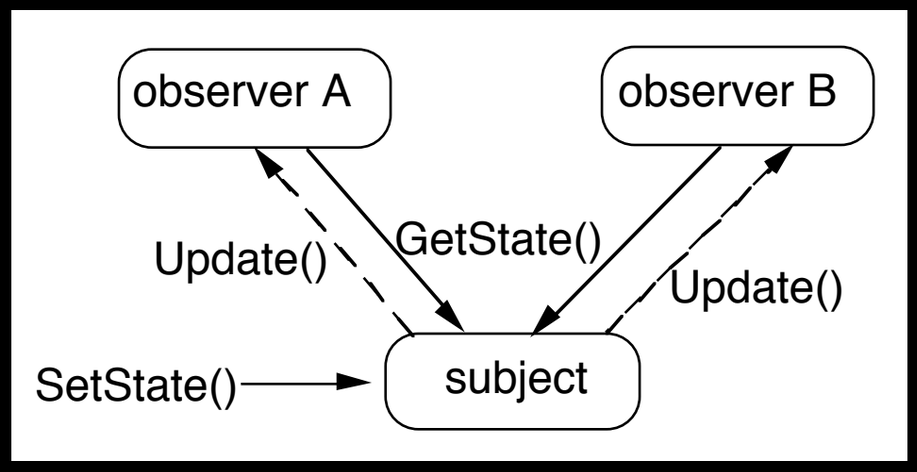
Observer

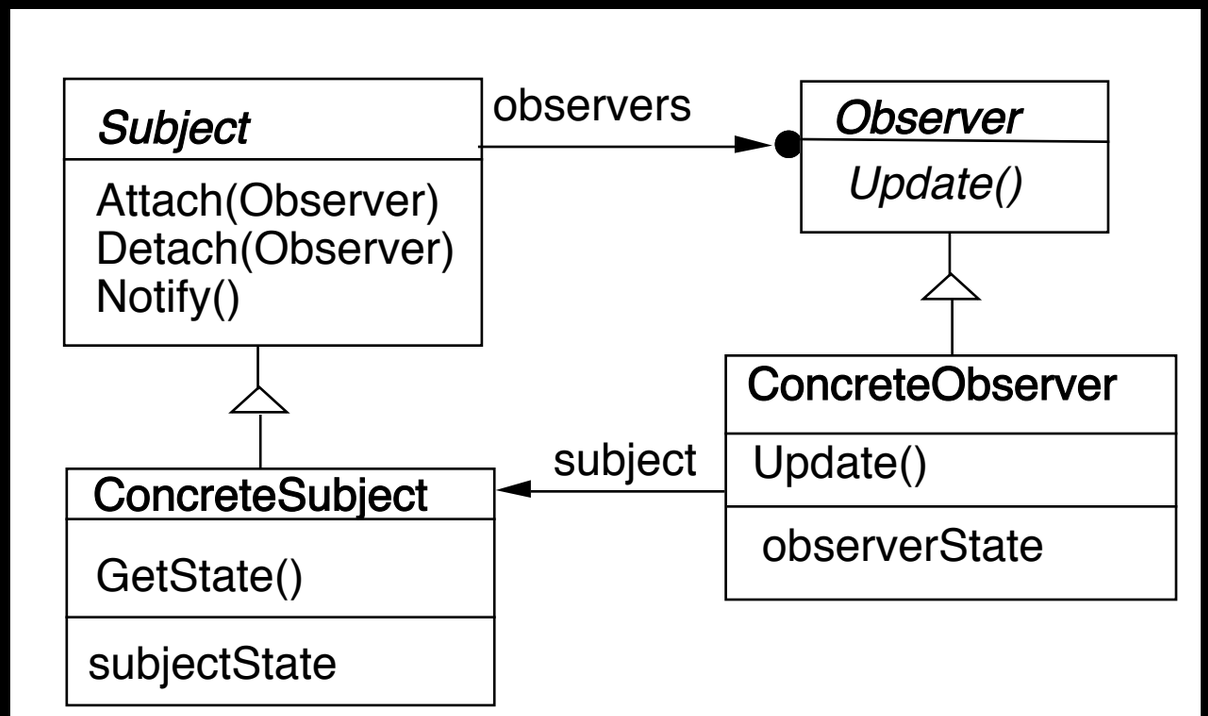
Observer

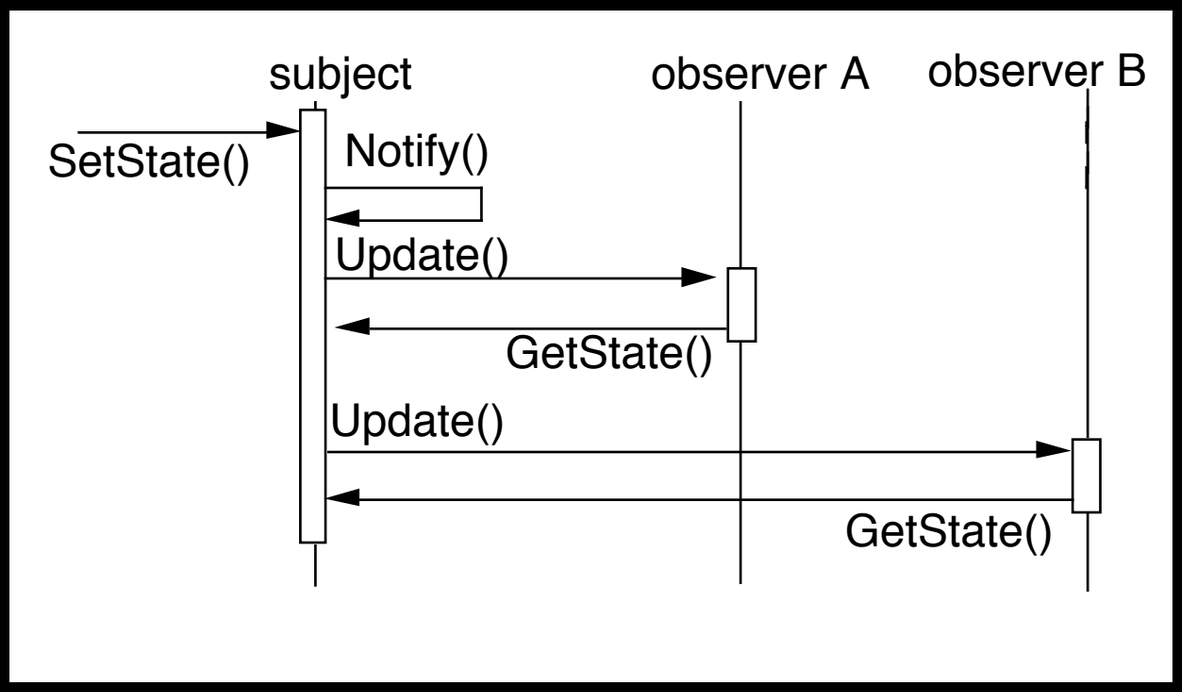
One-to-many dependency between objects

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

Structure


observer A
observer B
GetState()
Update()
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()

Deprecated in Java 9

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

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

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

2016 RxJava 2.0

ReactiveX 2.0 implementation in Java

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

Flutter (Google)

Fuchsia (Google)

Akka

Java Flow

ReactiveX

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

- RxAndroid (16,800 GitHub stars)
- RxCocoa

Reactive Programming - Elm

datatypes that represent a value 'over time'

```
main = lift asText Mouse.position
```

```
(144,49)
```

Compile | In Tab | Auto-compile:

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
```

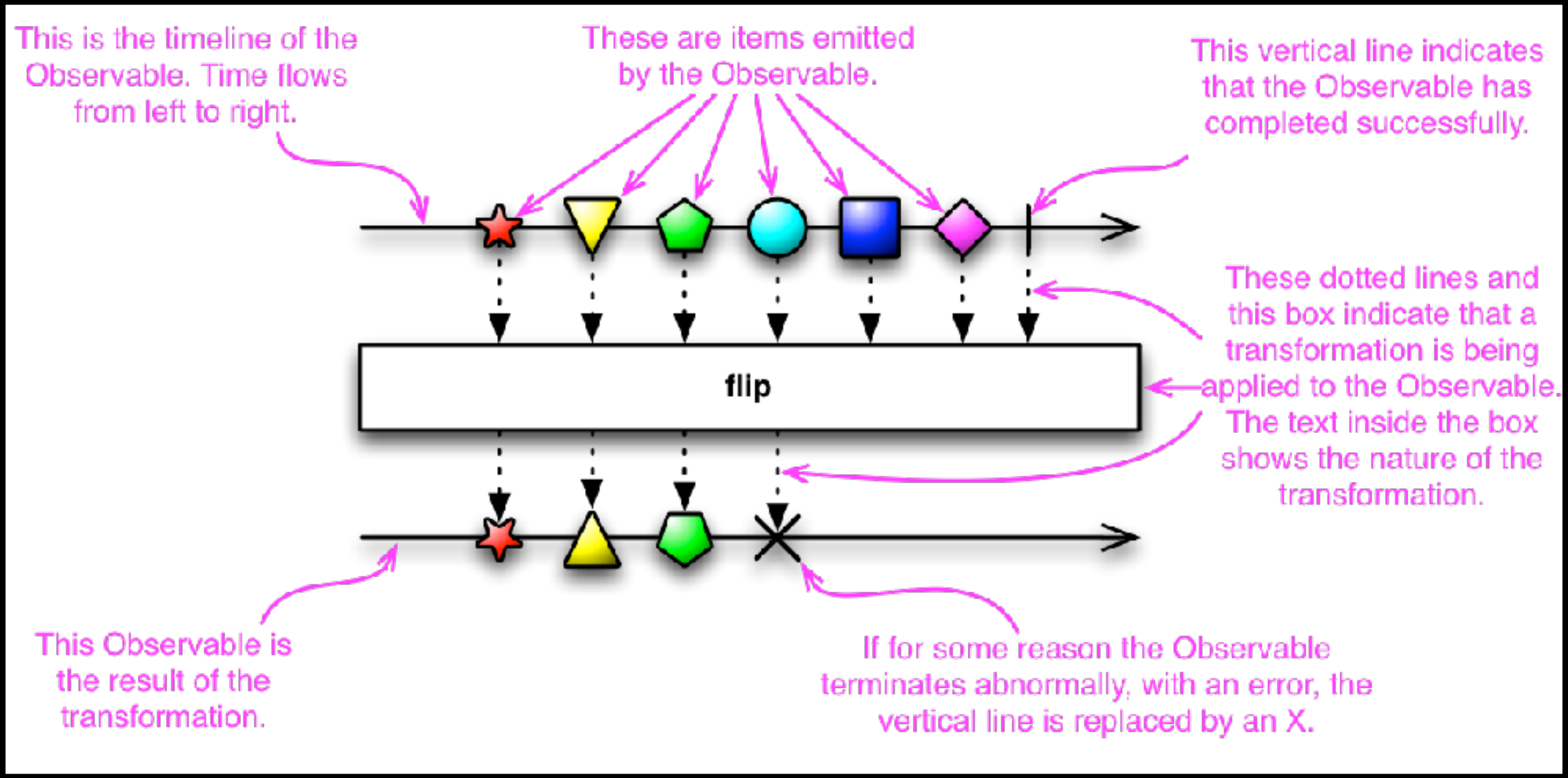
ReplaySubject Example

```
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();
    }
}
```

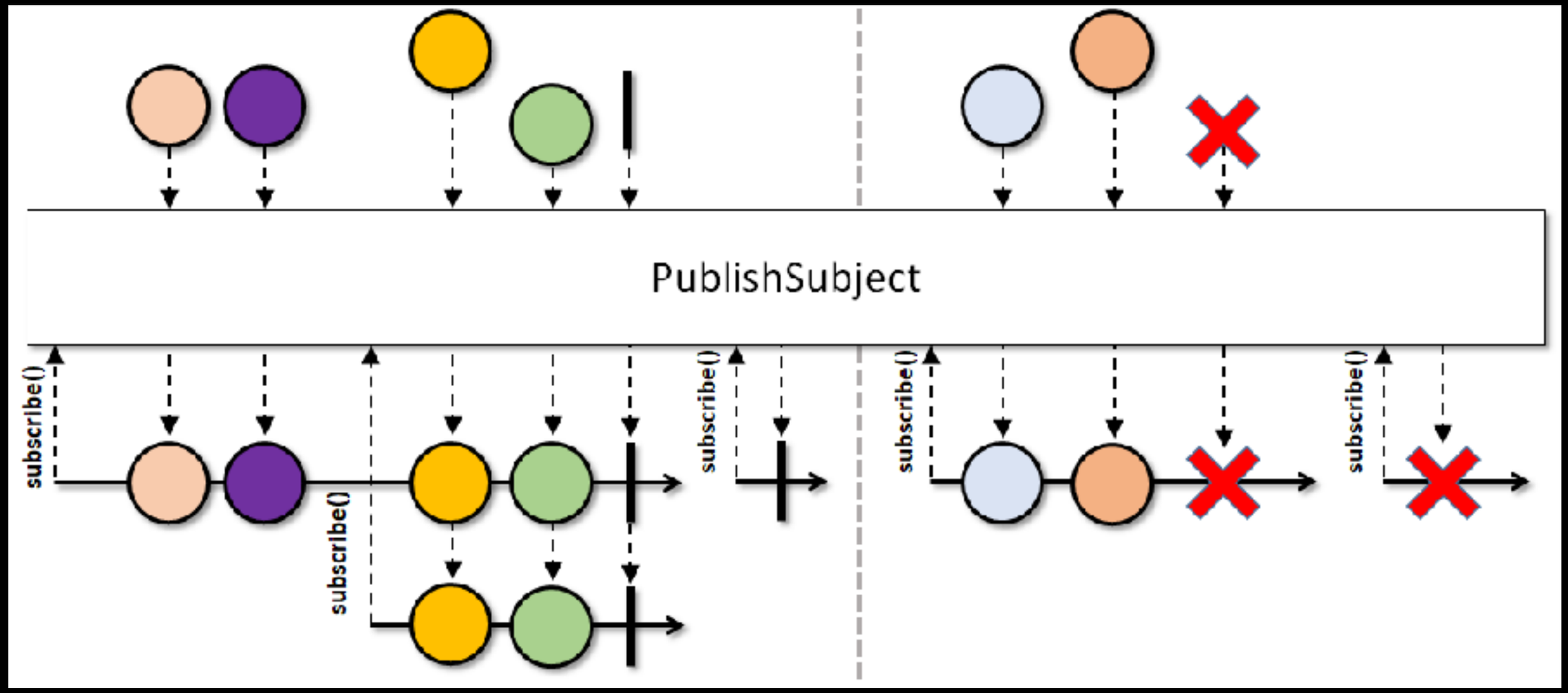
Output

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

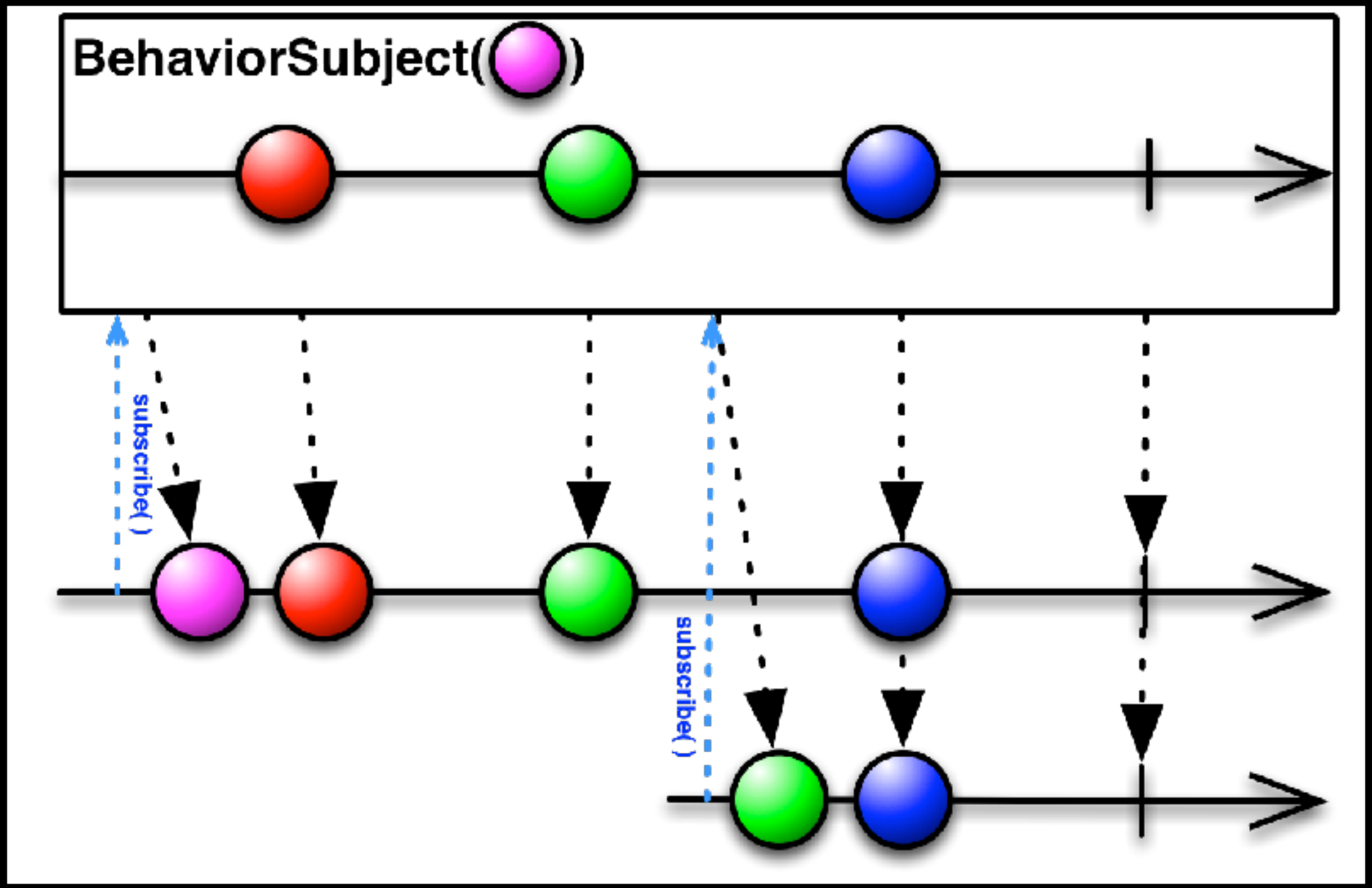
Diagrams


This is the timeline of the Observable. Time flows from left to right.
These are items emitted by the Observable.
This vertical line indicates that the Observable has completed successfully.
flip
These dotted lines and this box indicate that a transformation is being applied to the Observable.
The text inside the box shows the nature of the transformation.
This Observable is the result of the transformation.
If for some reason the Observable terminates abnormally, with an error, the vertical line is replaced by an X.

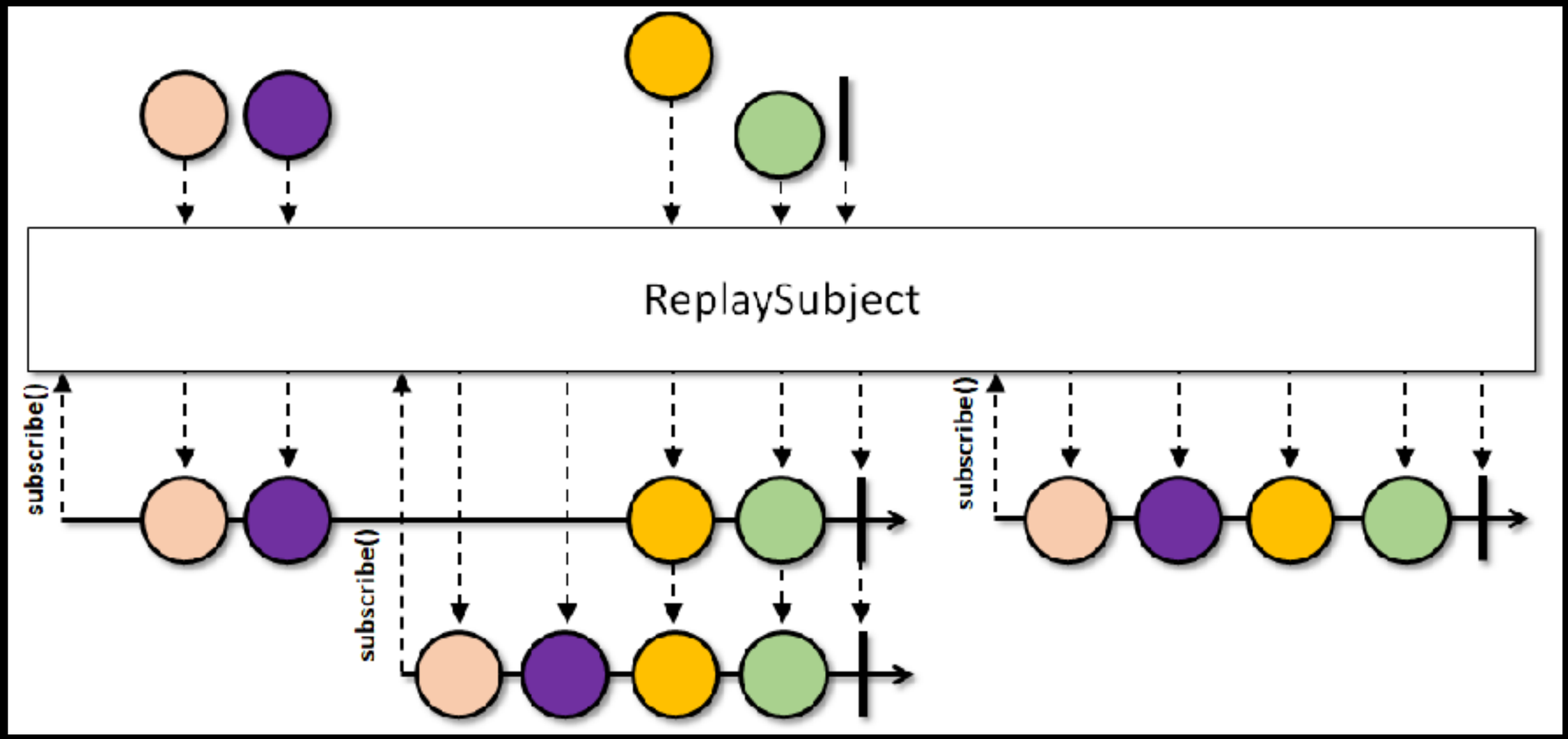
PublishSubject



BehaviorSubject



ReplaySubject



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

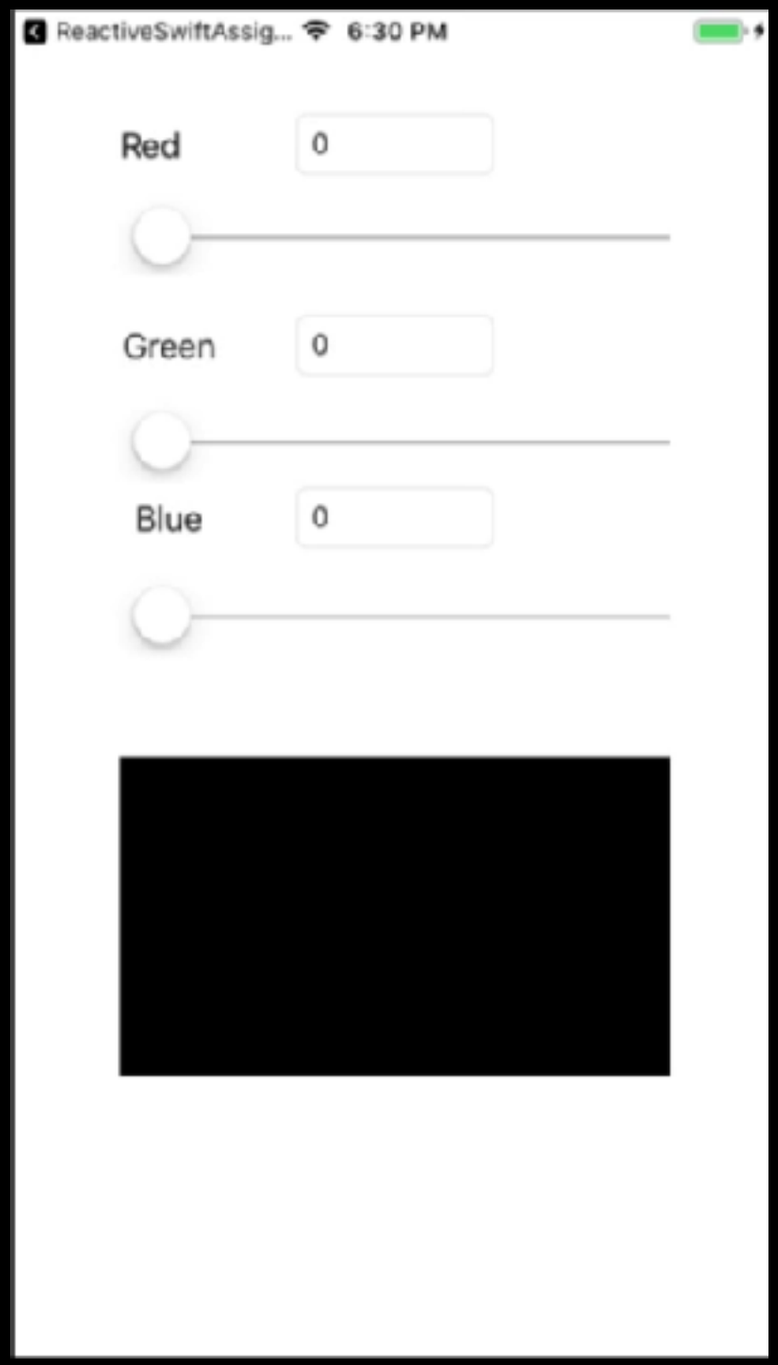
```
let subject = PublishSubject<Int>()
subject.subscribe(onNext: {print("Subject = \($0)")},
                  onCompleted: {print("Done")})

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")})
}
```

Sample App



Specs

Color values
- Integers
- 0 - 100

Change in slider
- Changes text field
- Changes color of box

Change in text field
- Changes slider
- Changes color of box

Standard Solution

Have reference to
- redSlider
- greenSlider
- blueSlider

- redText(field)
- greenText(field)
- blueText(field)

Have callback function called on change
- redSlider
- greenSlider
- blueSlider

- redText(field)
- greenText(field)
- blueText(field)

Color class
- Stores value of red, green, blue

Standard Solution

Slider call back function - each slider

- Called when slider changes
- Get value of slider
- Convert value to string
  - Set text field with string value of slider
- Change color of box
- Store the current color value

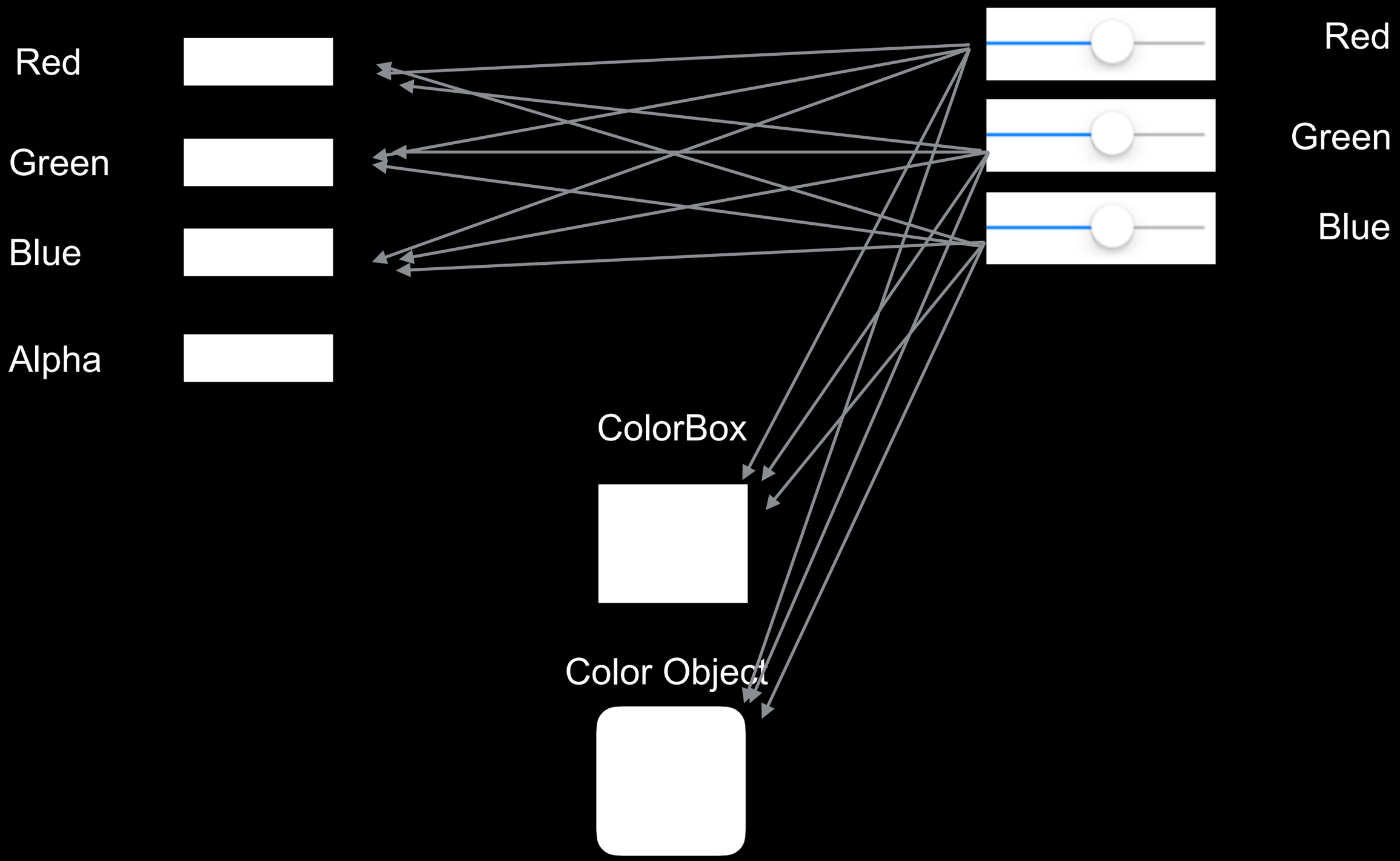
Textfield call back function

- Called when user types character or deletes a character
- Get value of textfield
- Convert string to float
  - Set value of slider to float value of textfield
- Change color of box
- Store the current color value

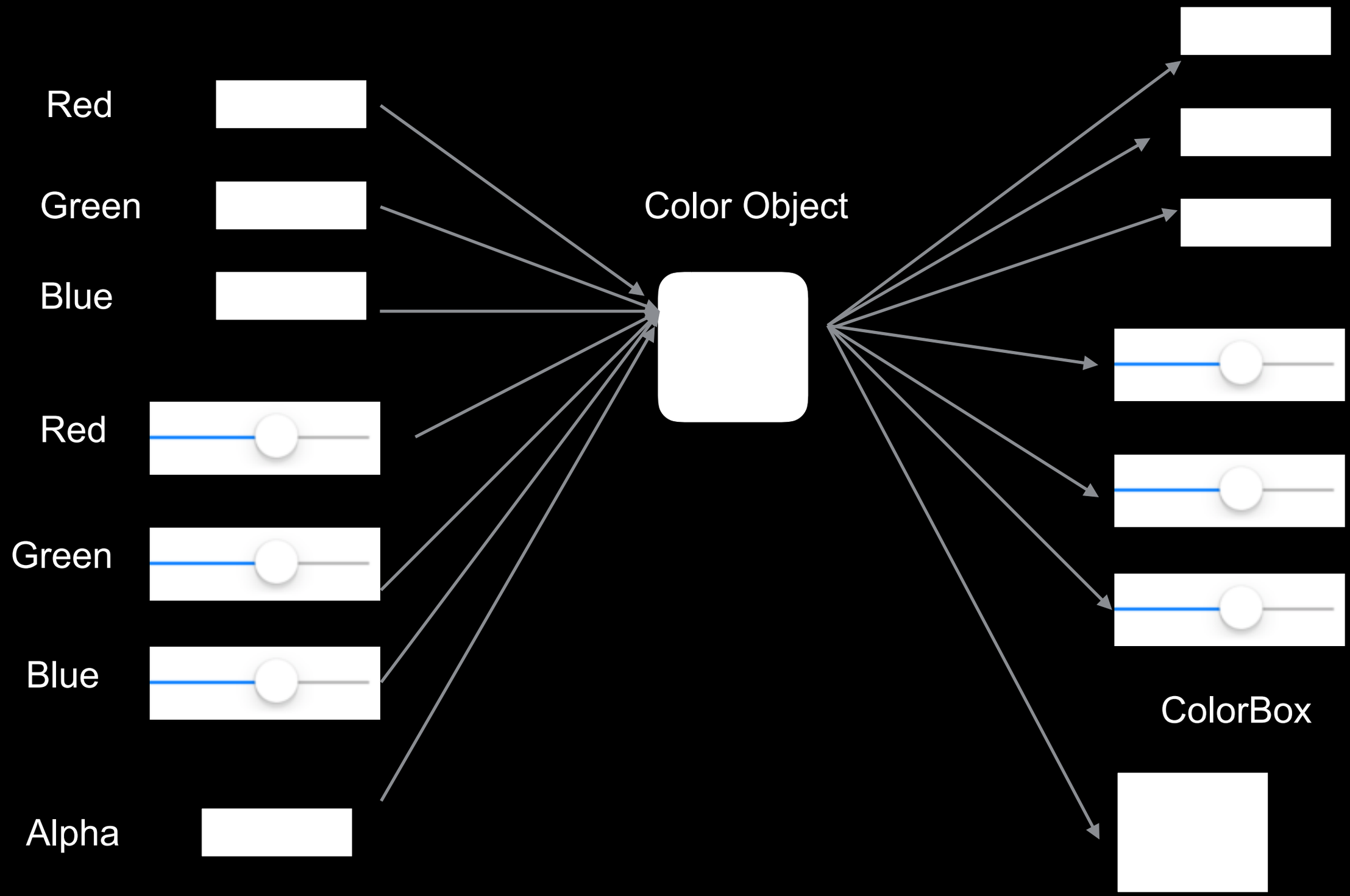
One Slider Callback

```
@IBAction func redSliderChanged(_ sender: Any) {
    redText.text = Int(redSlider.value).description
    guard   let redString = redText?.text,
            let red = Double(redString),
            let greenString = greenText?.text,
            let green = Double(greenString),
            let blueString = blueText?.text,
            let blue = Double(blueString) else {
        return
    }
    colorBox.backgroundColor = UIColor(red: CGFloat(red)/100,
                                       green: CGFloat(green)/100,
                                       blue: CGFloat(blue)/100, alpha: 1)
    color.red = red
}
```

Slider Callback Functions



Color as Subject/Observable



One Slider Callback

```
@IBAction func redSliderChanged(_ sender: Any) {
    color.red = Int(redSlider.value)
}
```

Color Updating UI

```
override func viewDidLoad() {
    super.viewDidLoad()
    color.observable.subscribe(onNext: {(type) in
        self.colorBox.backgroundColor = self.color.asUIColor()
        switch type {
            case .Red:
                self.redText.text = String(self.color.red)
                self.redSlider.value = Float(self.color.red)
        case .Green:
            self.greenText.text = String(self.color.green)
            self.greenSlider.value = Float(self.color.green)
        case .Blue:
            self.blueText.text = String(self.color.blue)
            self.blueSlider.value = Float(self.color.blue)
    }
})
```

Functional Reactive Programming

Mathematical Variables

x = y

x remains equal to y

redSlider.value = Float(self.color.red)

So why can't we mean redSlider.value is always the same value as:
Float(self.color.red)

ReactiveSwift

Reactive library for Swift

Same ideas as ReactiveX (RxSwift)
- Uses different terms for same ideas

Not tied to ReactiveX
- So syntax is more Swift-like
- Claims simpler than RxSwift

ReactiveSwift <~ operator

```
redSlider.reactive.value <~ color.red.map {Float($0)}
```

Whenever color.red changes then perform

```
redSlider.reactive.value = color.red.map {Float($0)}
```

```
color.redProperty.map {Float($0)}.signal.observeValues({self.redSlider.value = $0})
```

```
overload func viewDidLoad() {
        redSlider.reactive.value <~ color.red.map {Float($0)}
        redText.reactive.text <~ color.red.map { String($0)}
        greenSlider.reactive.value <~ color.green.map {Float($0)}
        greenText.reactive.text <~ color.green.map { String($0)}
        blueSlider.reactive.value <~ color.blue.map {Float($0)}
        blueText.reactive.text <~ color.blue.map { String($0)}

         //update data when sliders move
        color.red <~ redSlider.reactive.values.map {Int($0)}
        color.green <~ greenSlider.reactive.values.map {Int($0)}
        color.blue <~ blueSlider.reactive.values.map {Int($0)}

        //update data when text fields change
        color.redProperty <~ redText.reactive.continuousTextValues.map {
                                        self.stringToInt(value: $0)}
        color.greenProperty <~ greenText.reactive.continuousTextValues.map {
                                        self.stringToInt(value: $0)}
        color.blueProperty <~ blueText.reactive.continuousTextValues.map {
                                        self.stringToInt(value: $0)}
```

```
class Color {
    var red: MutableProperty<Int> = MutableProperty(0)
    var green: MutableProperty<Int> = MutableProperty(0)
    var blue: MutableProperty<Int> = MutableProperty(0)

    convenience init() {
        self.init(red: 30, green: 40, blue: 100)
    }
    init(red: Int, green: Int, blue: Int) {
        self.red.value = red
        self.green.value = green
        self.blue.value = blue
    }
}
```

Property generates a Signal(Channel)
Observers can listen for events
on the signal(channel)

What We Want Done vs How To Do it

```
@IBAction func redSliderChanged(_ sender: Any) {
    let redValue: Float = redSlider.value
    color.red = Int(redValue)
}
```

```
redSlider.reactive.value <~ color.red.map {Float($0)}
```

Reactive Programming

New terms

- Channels, Signals
- Events
- Producers
- etc

Needs to rethink how to write code

Aside

```
color.red.signal.observeValues
    {self.redSlider.value = Float($0)
      self.redText.text = String($0)}
color.green.signal.observeValues
    {self.greenSlider.value = Float($0)
      self.greenText.text = String($0)}
color.blue.signal.observeValues
    {self.blueSlider.value = Float($0)
      self.blueText.text = String($0)}

    verses

redSlider.reactive.value <~ color.red.map {Float($0)}
redText.reactive.text <~ color.red.map { String($0)}
greenSlider.reactive.value <~ color.green.map {Float($0)}
greenText.reactive.text <~ color.green.map { String($0)}
blueSlider.reactive.value <~ color.blue.map {Float($0)}
blueText.reactive.text <~ color.blue.map { String($0)}
```

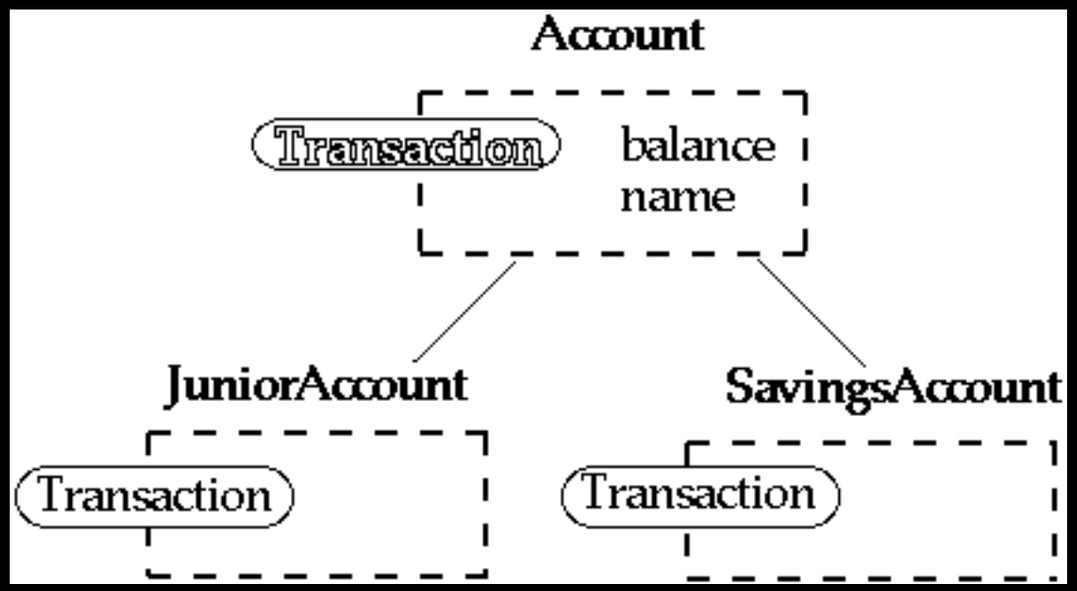
Template Method

Polymorphism

```
class Account {
    public:
        void virtual Transaction(float amount)
                { balance += amount;}
        Account(char* customerName, float InitialDeposit = 0);
    protected:
        char* name;
        float balance;
}

class JuniorAccount : public Account {
    public:   void Transaction(float amount) {//code here}
}

class SavingsAccount : public Account {
    public:   void Transaction(float amount) {//code here}
}

Account* createNewAccount(){
    // code to query customer and determine what type of
    // account to create
};
```

```
main() {
    Account*  customer;
    customer = createNewAccount();
    customer->Transaction(amount);
}
```

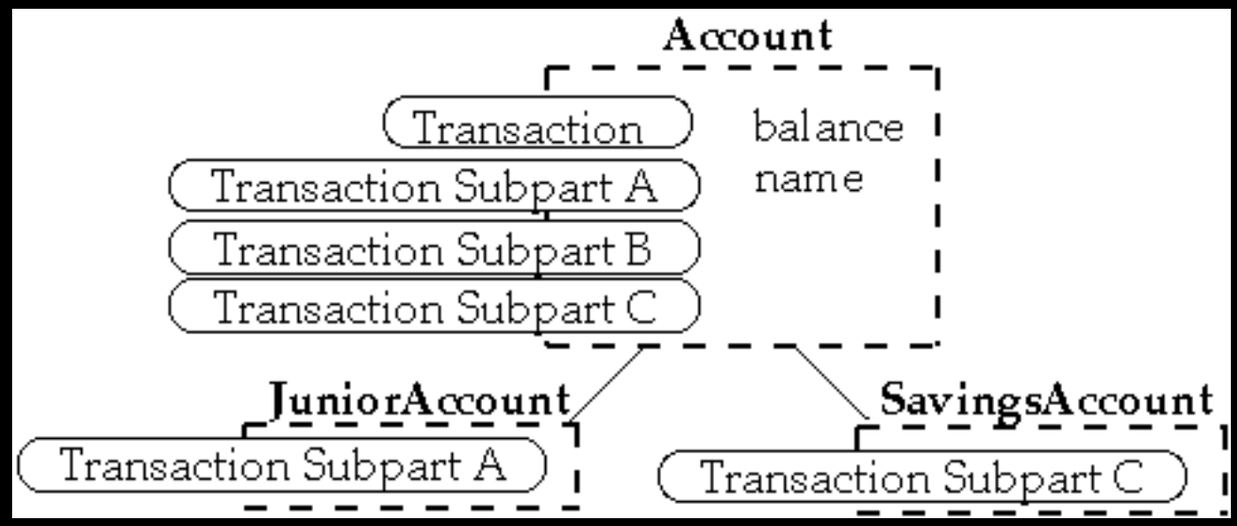
Deferred Methods




```
class Account {
   public:
      void virtual Transaction() = 0;
}

class JuniorAccount : public Account {
   public
      void Transaction() { put code here}
}
```

Template Method

```
class Account {
    public:
        void Transaction(float amount);
    protected:
        void virtual TransactionSubpartA();
        void virtual TransactionSubpartB();
        void virtual TransactionSubpartC();
}

void Account::Transaction(float amount)  {
    TransactionSubpartA();        TransactionSubpartB();
    TransactionSubpartC();        // EvenMoreCode;
}

class JuniorAccount : public Account {
    protected:            void virtual TransactionSubpartA(); }

class SavingsAccount : public Account {
    protected:            void virtual TransactionSubpartC(); }

Account*  customer;
customer = createNewAccount();
customer->Transaction(amount);
```



Intent

Define the skeleton of an algorithm in an operation, deferring some steps to subclasses

Template Method lets subclasses redefine certain steps of an algorithm without changing the algorithm’s structure

Java Example

```
import  java.awt.*;
class  HelloApplication  extends  Frame
  {
  public  void  paint(  Graphics  display  )
     {
     int startX  =  30;
     int startY  =  40;
     display.drawString(  "Hello World", startX, startY  );
     }
}
```

Ruby LinkedList Example

```
class LinkedList
  include Enumerable

  def [](index)
    Code not shown
  end

  def size
    Code not shown
  end

  def each
     Code not shown
  end

  def push(object)
   Code note shown
  end

end
```

```
def testSelect
  list = LinkedList.new
  list.push(3)
  list.push(2)
  list.push(1)

  a = list.select {|x| x.even?}
  assert(a == [2])
end
```

Where does list.select come from?

Methods defined in Enumerable

all?	any?	collect	detect
each_cons	each_slice	each_with_index	entries
enum_cons	enum_slice	enum_with_index	find
find_all	grep	include?	inject
map	max	member?	min
partition	reject	select	sort
sort_by	to_a	to_set	zip

All use "each"

Implement "each" and the above will work

java.util.AbstractCollection

Subclass AbstractCollection

Implement
- iterator
- size
- add

Get
- addAll
- clear
- contains
- containsAll
- isEmpty
- remove
- removeAll
- retainAll
- size
- toArray
- toString

Consequences

This is the most commonly used of the 23 GoF patterns

Important in class libraries

Inverted control structure

- Parent class calls subclass methods

Consequences

Inverted control structure

Java's paint method is a primitive operation called by a parent method

Beginning Java programs don't understand how the following works:

```
import  java.awt.*;
class  HelloApplication  extends  Frame
  {
  public  void  paint(  Graphics  display  )
     {
     int startX  =  30;
     int startY  =  40;
     display.drawString(  "Hello World", startX, startY  );
     }
  }
```

Consequences

Template methods tend to call:

- Concrete operations
- Primitive (abstract) operations
- Factory methods
- Hook operations

Provide default behavior that subclasses can extend

It is important to denote which methods

- Must overridden
- Can be overridden
- Can not be overridden

Refactoring to Template Method

Simple implementation
- Implement all of the code in one method
- The large method you get will become the template method

Break into steps
- Use comments to break the method into logical steps
- One comment per step

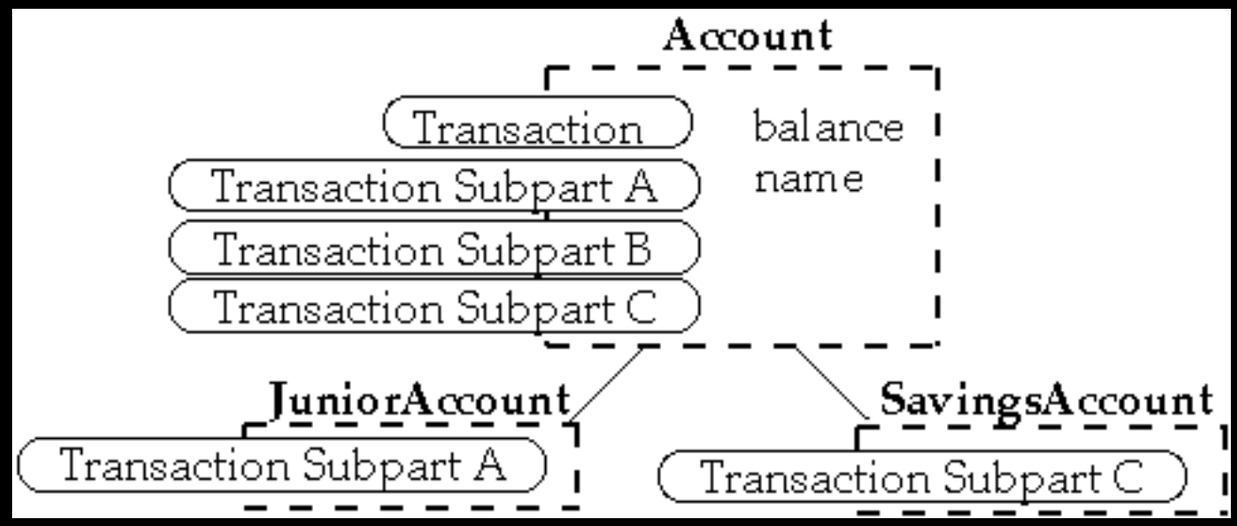
Make step methods
- Implement separate methods for each of the steps

Call the step methods
- Rewrite the template method to call the step methods

Repeat above steps
- Repeat the above steps on each of the step methods
- Continue until:
  - All steps in each method are at the same level of generality
  - All constants are factored into their own methods

Template Method & Functional Programming

```
class Account {
    public:
        void Transaction(float amount);
    protected:
        void virtual TransactionSubpartA();
        void virtual TransactionSubpartB();
        void virtual TransactionSubpartC();
}

void Account::Transaction(float amount)  {
    TransactionSubpartA();        TransactionSubpartB();
    TransactionSubpartC();        // EvenMoreCode;
}

class JuniorAccount : public Account {
    protected:            void virtual TransactionSubpartA(); }

class SavingsAccount : public Account {
    protected:            void virtual TransactionSubpartC(); }

Account*  customer;
customer = createNewAccount();
customer->Transaction(amount);
```



Template Method & Functional Programming

Pass in functions

```
def transaction(defaultPartA, defaultPartB, defaultPartC, amount, account) {
  defaultPartA();
  defaultPartB();
  defaultPartC();
  code code;
}
```

But this adds a lot of arguments

Requires knowing internal workings of transaction

Currying & Partial Evaluation

Pass in functions

```
def defaultTransaction = transaction(defaultPartA, defaultPartB, defaultPartC);
def juniorTransaction = transaction(juniorPartA, defaultPartB, defaultPartC);

defaultTransaction(amount, account);
juniorTransaction(amount, account);
```

But this requires knowing the account type

Multi-methods

```
defmulti transaction(amount, account) (getAccountType)

defmethod transaction(amount, account) (:default) {
  return defaultTransaction(amount, account);
}

defmethod transaction(amount, account) (:junior) {
  return juniorTransaction(amount, account);
}

transaction(amount, account);
```

Now have dynamic dispatch on the type like Java

Template Method vs Functional Solution

	Template Method	Functional
Method Variation	In multiple classes/files	In one place
Add new Variation	Add class/file + method	Add function
Type Logic	In class & parent class	