Reactive Programming

Event-Based

BY RICCARDO TERRELL - @RIKACE

Objectives

- Stream processing motivation
- Real time stream analysis
- Simplify complex logic with reactive programming
- Composing events

Stream processing motivation

React to **high rate events** (near real time)

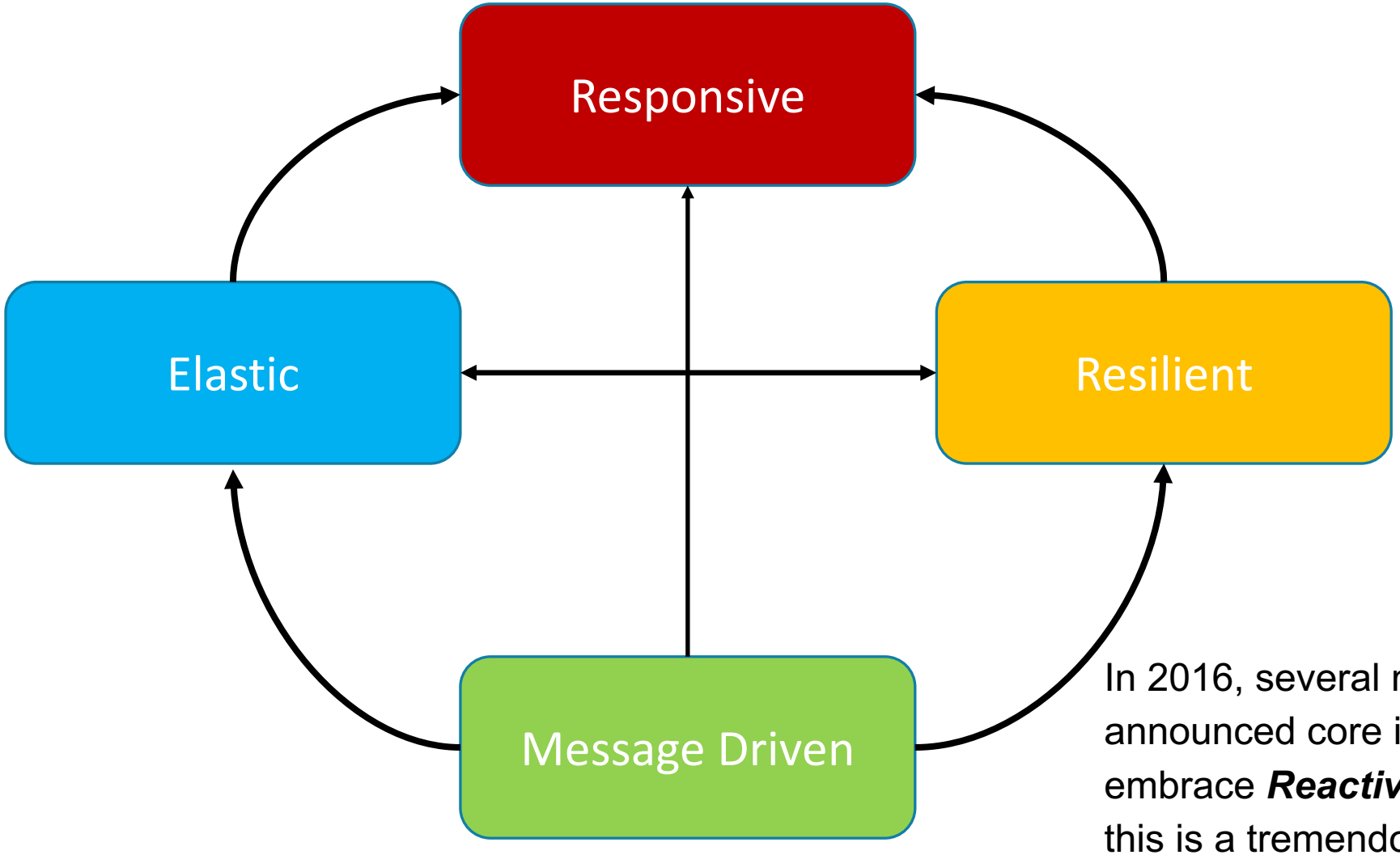
Compose events from **different sources**

Simplify complex logic

Lots of built in **combinators** (operators)

Pipeline for **combinators** over **event stream**.

Reactive Manifesto



In 2016, several major vendors have announced core initiatives to embrace ***Reactive Programming*** this is a tremendous validation of the problems faced by companies today.

http://www.reactivemanifesto.org

New Tools for a New Era

We to need to build systems that:

- *react* to events — **Event-Driven**
- *react* to load — **Scalable**
- *react* to failure — **Resilient**
- *react* to users — **Responsive**

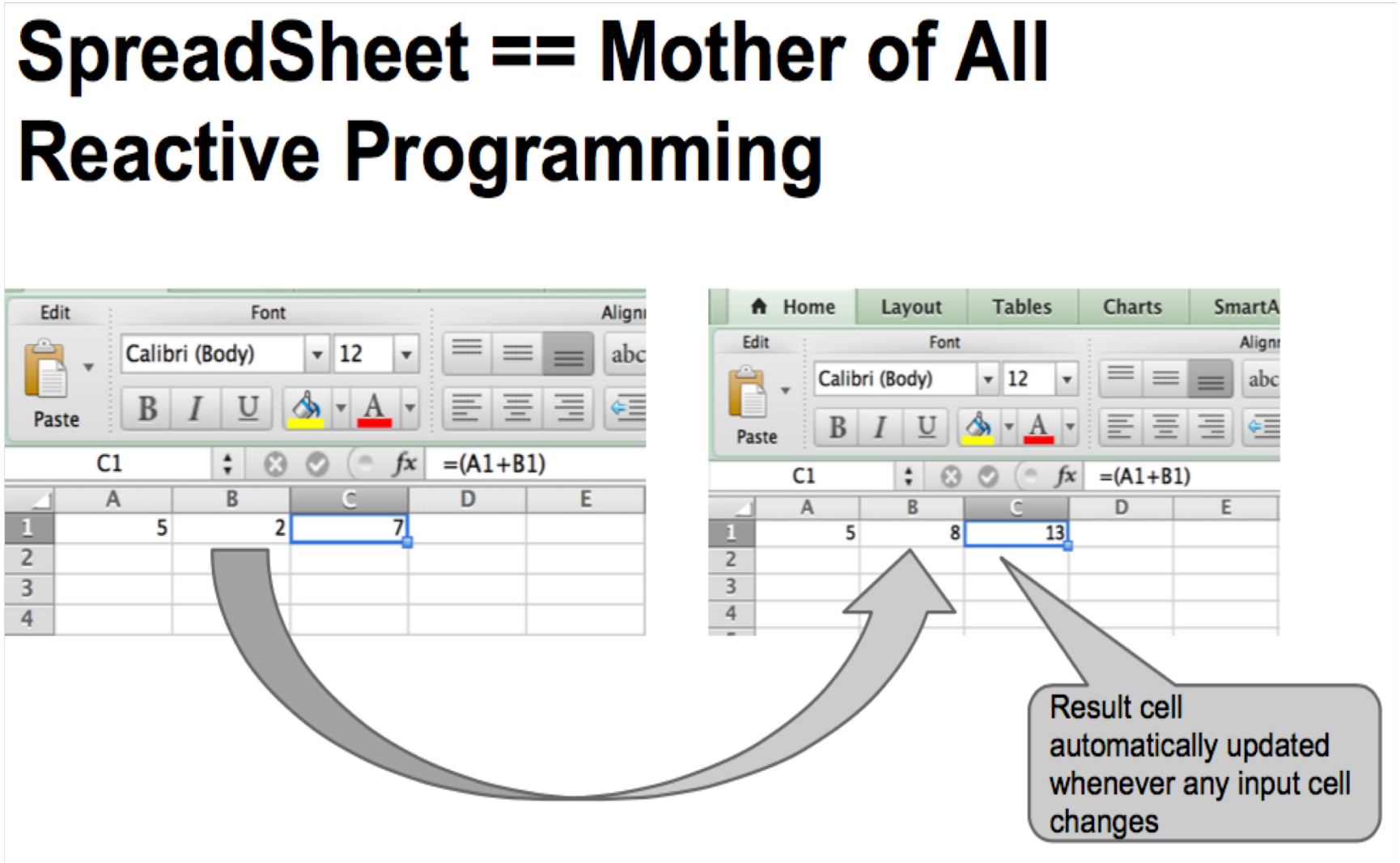
Functional Reactive Programming

Functional ~~Reactive~~ Programming

- declarative
- functions as values
- side-effects free
- referential transparency
- immutable
- composition

~~Functional~~ Reactive Programming

What is Reactive Programming?



Functional Reactive Programming

Push-Pull Functional Reactive Programming

Push-Pull Functional Reactive Programming

Conal Elliott

LambdaPix

conal@conal.net

Abstract

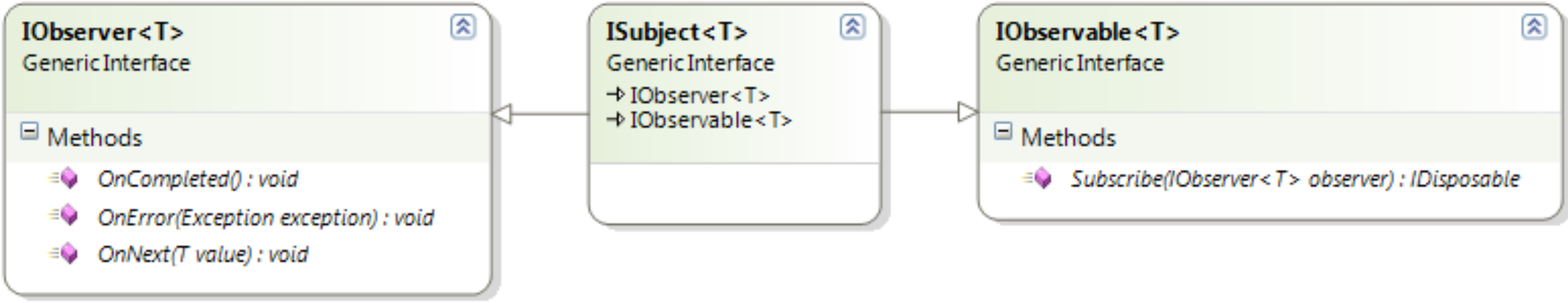
Functional reactive programming (FRP) has simple and powerful semantics, but has resisted efficient implementation. In particular, most past implementations have used demand-driven sampling, which accommodates FRP's continuous time semantics and fits well with the nature of functional programming. Consequently, values are wastefully recomputed even when inputs don't change. more composable than their finite counterparts, because they can be scaled arbitrarily in time or space, before being clipped to a finite time/space window.

While FRP has simple, pure, and composable semantics, its efficient implementation has not been so simple. In particular, past implementations have used demand-driven (pull) sampling of reactive behaviors, in contrast to the data-driven (push) evaluation typ-

Reactive Extensions

What are Reactive Extensions

Rx is a library for composing asynchronous and event-based programs using observable sequences and LINQ-style query operators



IObserver & IObservable

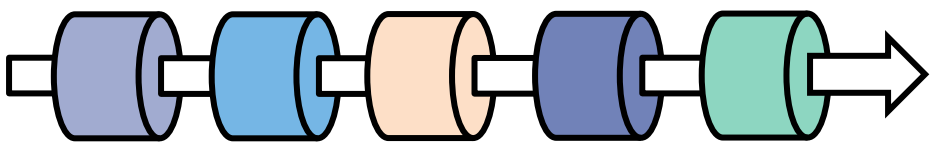
```
type IObserver<'a> = interface
    abstract OnCompleted : unit -> unit
    abstract OnError : exn -> unit
    abstract OnNext : 'a -> unit
end

type IObservable<'a> = interface
    abstract Subsrcribe : IObserver<'a> -> IDisposable
end
```

What is Rx?

Rx **compose pipeline** of operations over **single** or **multiple event's source**

Focus on what happens **between** the **Producer** and the **Consumer**

Rx is the **Pipeline**



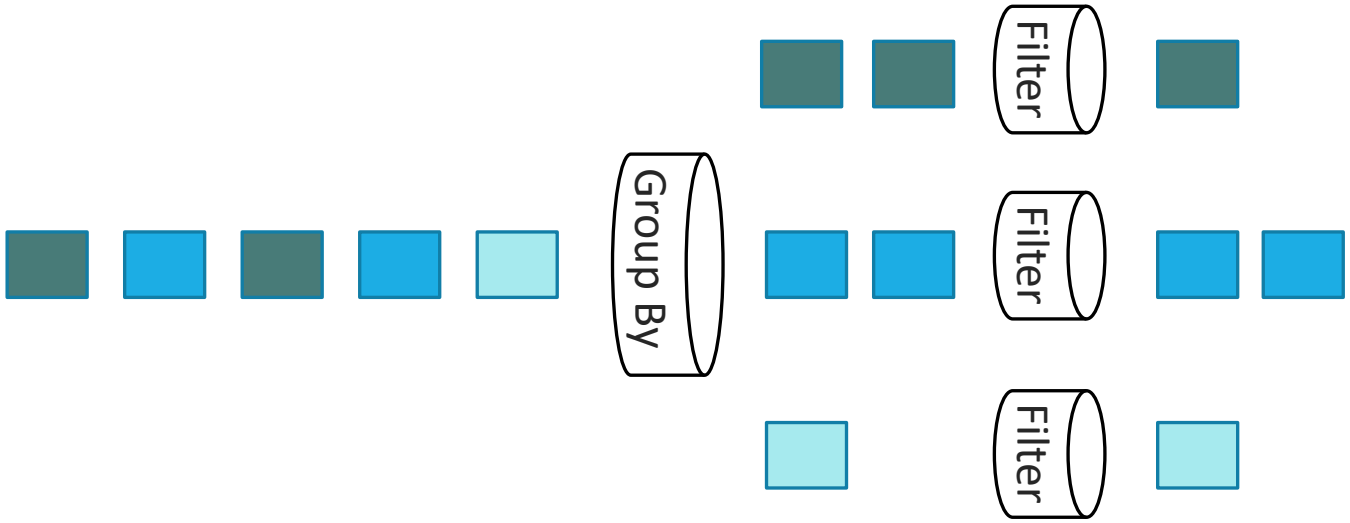
Rx = Async Data Stream Composition

Rx = LINQ to Async Data Stream

What is Rx?

Rx **compose pipeline** of operations over **single** or **multiple event's source**

Focus on what happens **between** the **Producer** and the **Consumer**



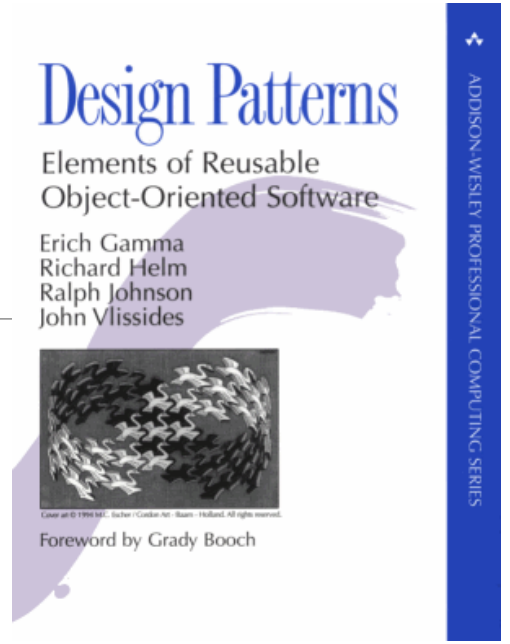
Rx = Async Data Stream Composition

Rx = LINQ to Async Data Stream

Fundamental Abstractions

Adapting the observer pattern

- Ensuring duality with the enumerator pattern
- More compositional approach



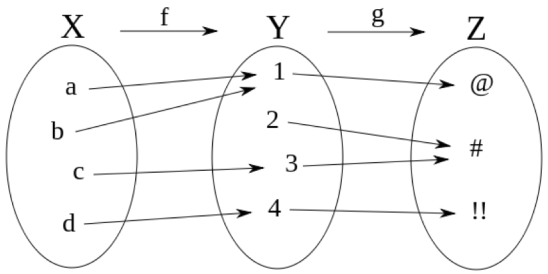
"Gang of four" book
Addison-Wesley

```
interface IObservable<out T>
{
    IDisposable Subscribe(IObserver<T> observer);
}

interface IObserver<in T>
{
    void OnNext(T value);
    void OnError(Exception error);
    void OnCompleted();
}
```

Notification grammar

```
OnNext* (OnError | OnCompleted)?
```

Highly Compositional



Function composition

LINQ-style query operators over IObservable<T>

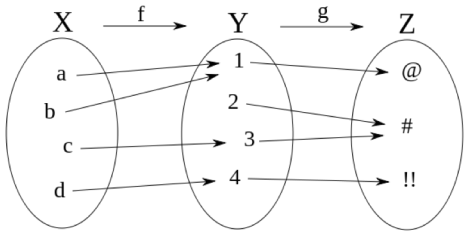
- Composition of 0-N input sequences

```
static class Observable
{
    static IObservable<T> Where<T>(this IObservable<T> source, Func<T, bool> f);
    static IObservable<R> Select<T, R>(this IObservable<T> source, Func<T, R> p);
    …
}
```

- Composition of disposable subscriptions and scheduler resources

```
interface IScheduler
{
    IDisposable Schedule(Action work);
    …
}
```

Highly Compositional



Function composition

Building a binary Merge operator

First-class: can build extension methods

Composition of resource management

```
public static class Observable
{
    public static IObservable<T> Merge<T>(this IObservable<T> xs, IObservable<T> ys)
    {
        return Create<T>(observer =>
        {
            var gate = new object();

            return new CompositeDisposable
            {
                xs.Subscribe(x => { lock (gate) { observer.OnNext(x); } }, …),
                ys.Subscribe(y => { lock (gate) { observer.OnNext(y); } }, …),
            };
        });
    }
}
```

The Role of Schedulers

Pure architectural layering of the system

- Logical query operators (~ relational engine)
- Physical schedulers (~ operating system)

```
public static IObservable<T> Return<T>(T value, IScheduler scheduler)
{
    return Create<T>(obs => scheduler.Schedule(() => { obs.OnNext(value);
                                                       obs.OnCompleted(); }));
}
```

Abstract over sources of asynchrony and time

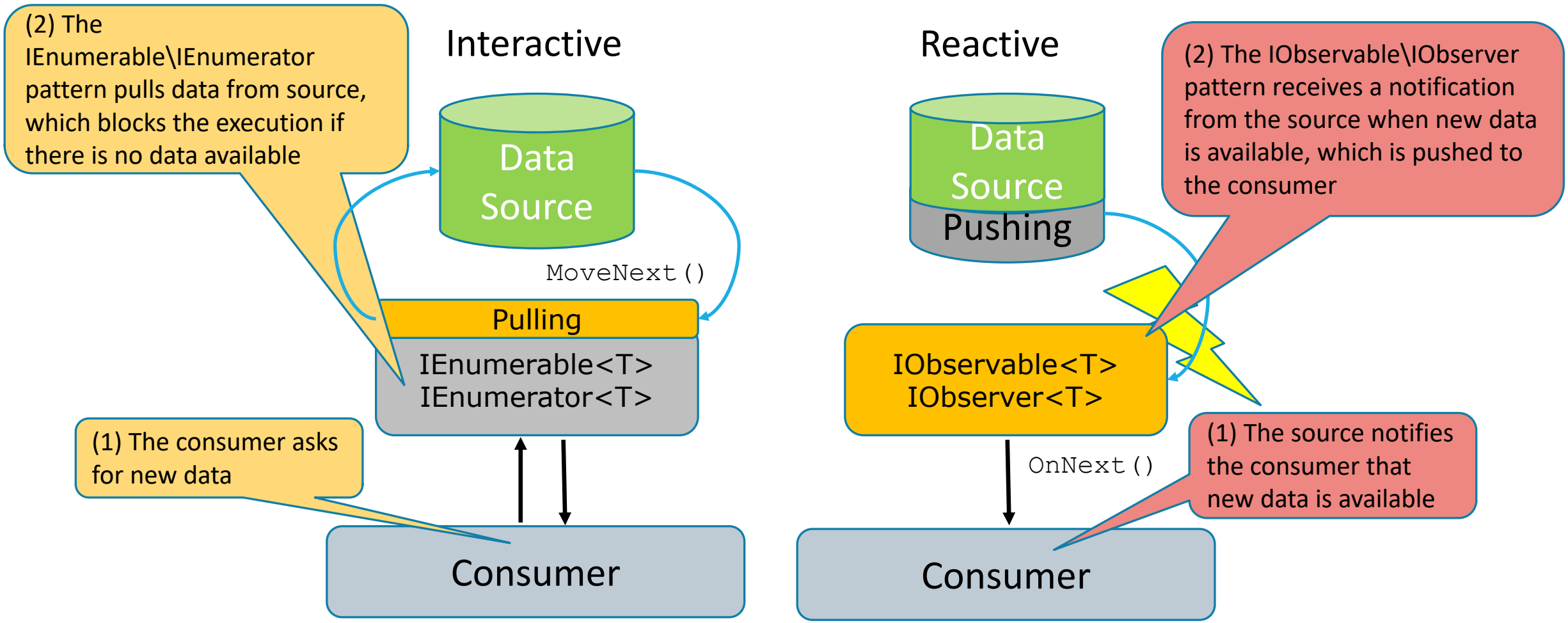
- Threads, thread pools, tasks, message loops
- DateTimeOffset.UtcNow, timers

One versus Many

When Task and Task<T> were born…

- Single-value specializations
- Await-ability of sequences (for aggregates)

	Synchronous	Asynchronous
One	`Func<T> f` `var x = wait f();`	`Task<T> t` `var x = await t;`
Many	`IEnumerable<T> xs` `foreach (var x in xs) { f(x); }`	`IObservable<T> xs` `xs.Subscribe(x => { f(x); });`


(2) The IEnumerable\IEnumerator pattern pulls data from source, which blocks the execution if there is no data available
Interactive
Data Source
MoveNext()
Pulling
IEnumerable<T>
IEnumerator<T>
(1) The consumer asks for new data
Consumer
Reactive
Data Source
Pushing
(2) The IObservable\IObserver pattern receives a notification from the source when new data is available, which is pushed to the consumer
IObservable<T>
IObserver<T>
OnNext()
(1) The source notifies the consumer that new data is available
Consumer

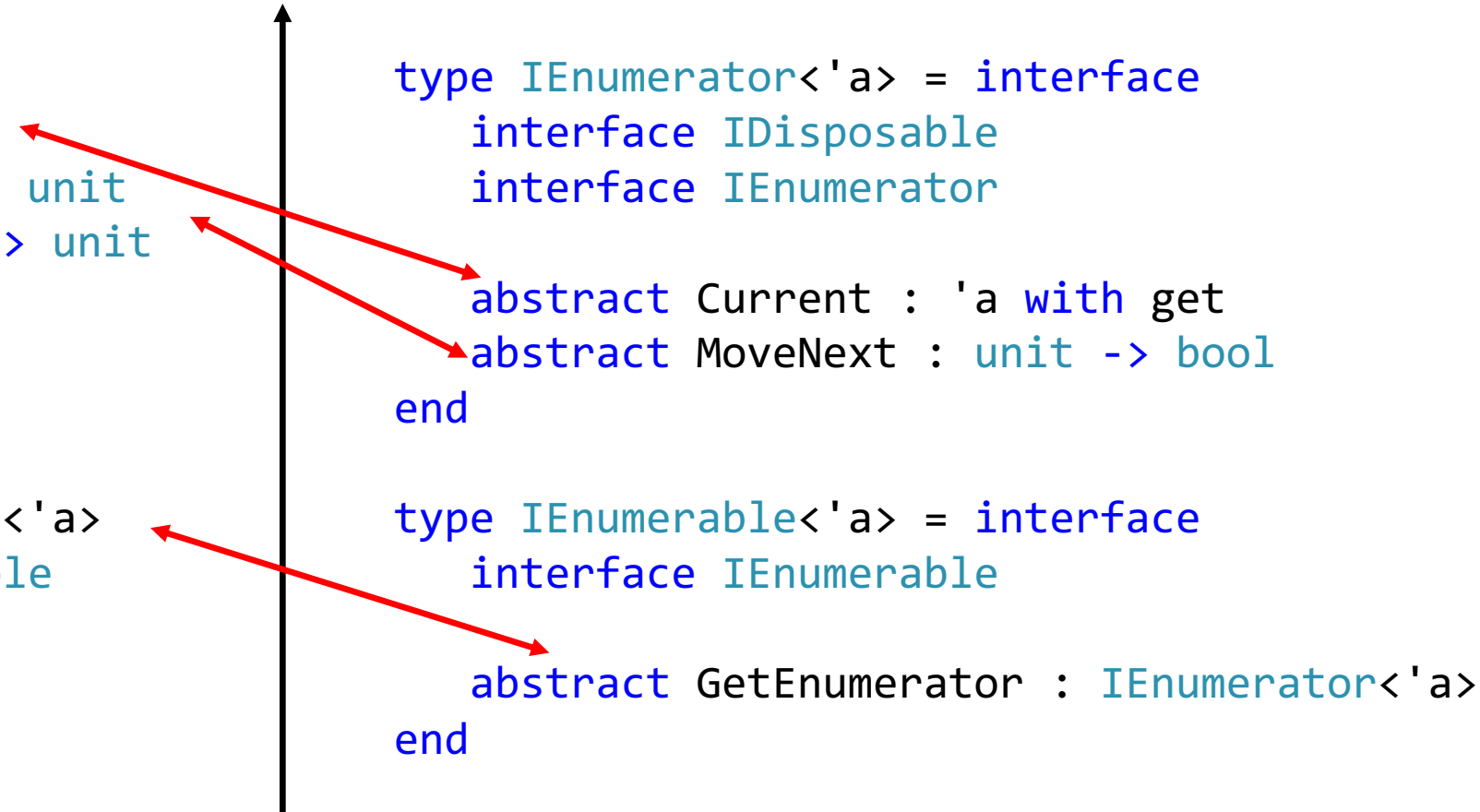
IObservable the dual of IEnumerable

Category theory to the rescue (Bierman, Meijer)

Observable/observer (push) is dual to enumerable/enumerator (pull)

Cross-influence of both domains

```
type IObserver<'a> = interface
  abstract OnNext : 'a with set
  abstract OnCompleted : unit -> unit
  abstract OnError : Exception -> unit
end


type IObservable<'a> = interface
  abstract Subscribe : IObserver<'a>
                    -> IDisposable
end
```



```
type IEnumerator<'a> = interface
   interface IDisposable
   interface IEnumerator

   abstract Current : 'a with get
   abstract MoveNext : unit -> bool
end

type IEnumerable<'a> = interface
   interface IEnumerable

   abstract GetEnumerator : IEnumerator<'a>
end
```

Stream processing basics - Event

Not first class in C#

Hard to compose

C#

```
button.Click += OnClick;

private void OnClick(object sender, RoutedEventArgs e)
{
    …
}
```

Stream processing basics – F# Event

First class in F#

Can have basic composition

F#

```
button1.Click
    |> Event.merge button2.Click
    |> Event.add (fun a -> MessageBox.Show "Hii"
                                |> ignore)
```

Stream processing basics – IObservable/IObserver

C#

```
var click1 = Observable
    .FromEventPattern(button1, nameof(button1.Click));

var click2 = Observable
    .FromEventPattern(button2, nameof(button2.Click));

Observable.Merge(click1, click2).Subscribe(OnClick);
```

Stream processing basics – IObservable/IObserver

F#

```
let button1 = Button()
let button2 = Button()

button1.Click
|> Observable.merge button2.Click
|> Observable.add (fun a -> MessageBox.Show "Hii“
                            |> ignore)
```

Stream processing basics – Combinators

F#

```
let observable = Observable
    .Interval(TimeSpan.FromSeconds(1.0))

observable.Subscribe (printfn "%d")
```

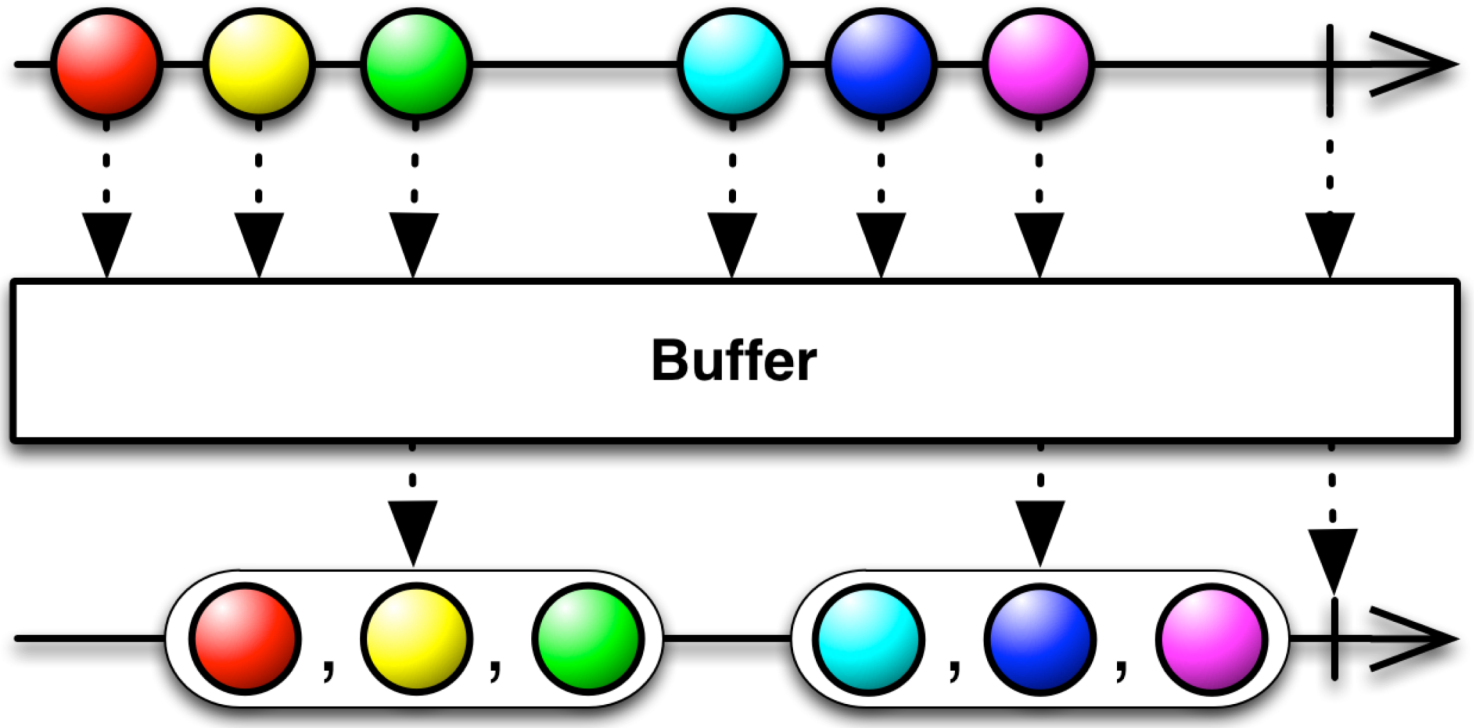
Stream processing basics – Combinators

F#

```
let observable = Observable
    .Interval(TimeSpan.FromSeconds(1.0))
    .GroupBy(fun x -> x % 3L)

let printKeyValue key value =
    printfn "%s %d" (String('*', key)) value
    ()

observable.Subscribe(fun obs ->
    obs.Subscribe (printKeyValue (int obs.Key)) |> ignore)
```

Stream processing basics – Combinators

Buffer — periodically gather items from an Observable into bundles and emit these bundles rather than emitting the items one at a time



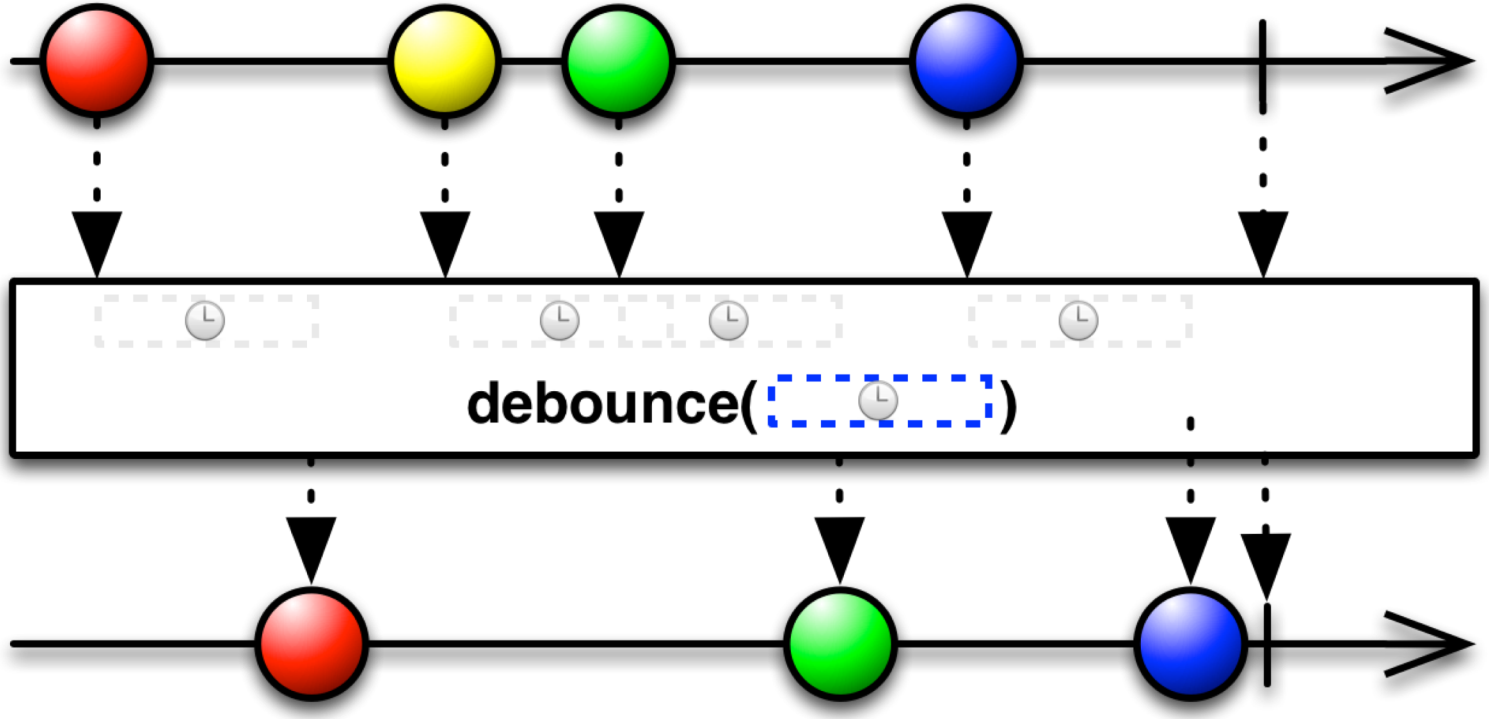
Stream processing basics – Combinators

F#

```
let observable = Observable
    .Interval(TimeSpan.FromSeconds(1.0))
    .Observable.Buffer(3)

observable.Subscribe (printfn "%A")
```

Stream processing basics – Combinators

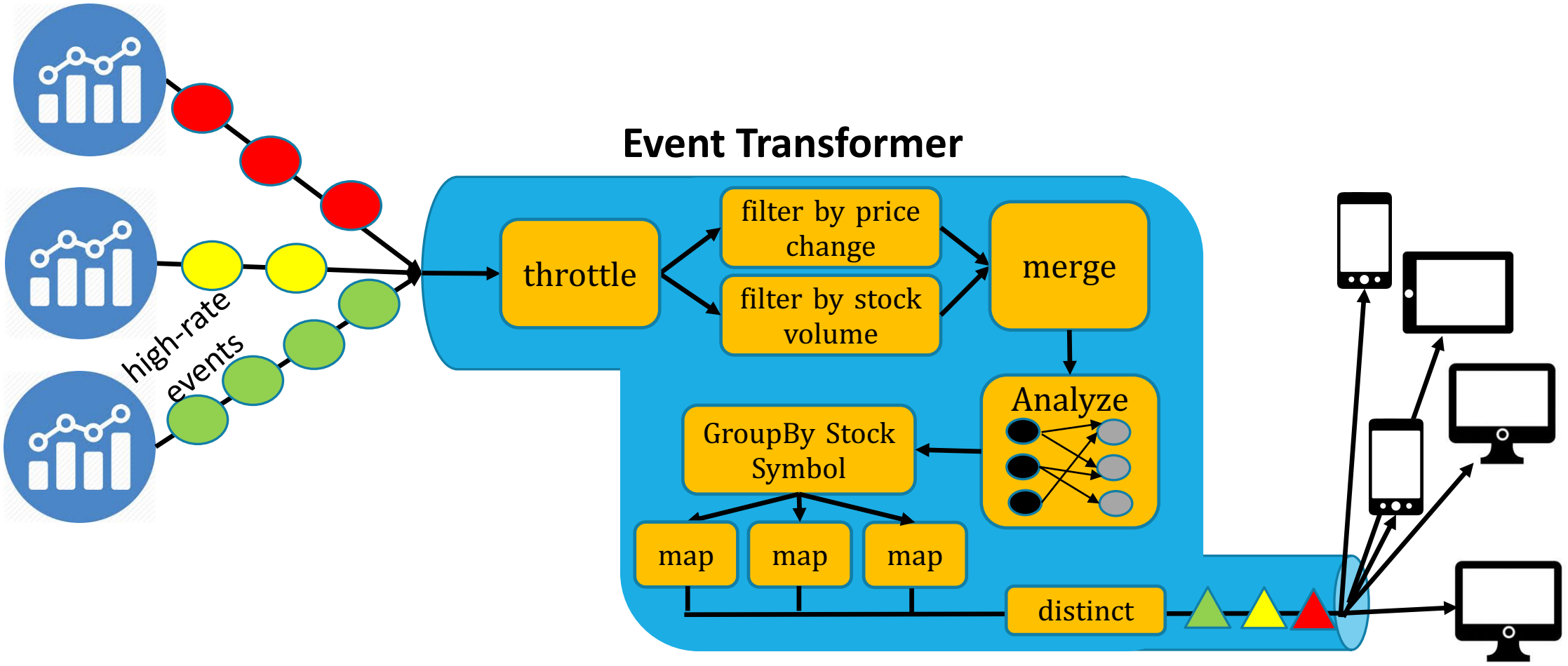
Throttle — only emit an item from an Observable if a particular timespan has passed without it emitting another item



Stream processing basics – Combinators

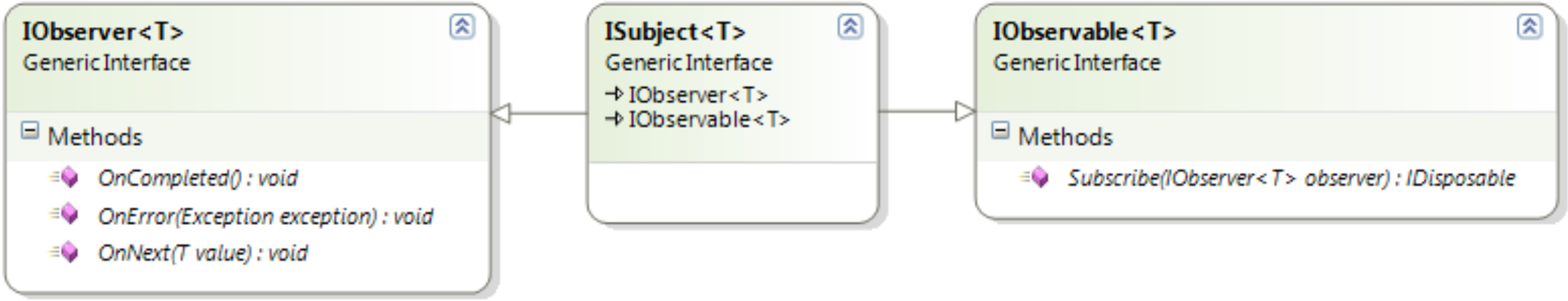
F#

```
let observable = Observable
    .FromEventPattern(txt, "TextChanged")
    .Throttle(TimeSpan.FromSeconds(1.0))

observable
    .ObserveOn(SynchronizationContext.Current)
    .Subscribe (fun text -> console.Text <- console.Text +
                            Environment.NewLine + txt.Text )
```

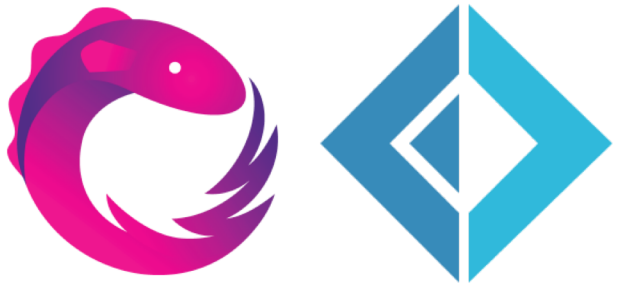

Event Transformer
high-rate events
throttle
filter by price change
filter by stock volume
merge
Analyze
GroupBy Stock Symbol
map
map
map
distinct

What are Reactive Extensions ?

Rx is a library for composing asynchronous and event-based programs using observable sequences and LINQ-style query operators



publisher *both* *subscriber*



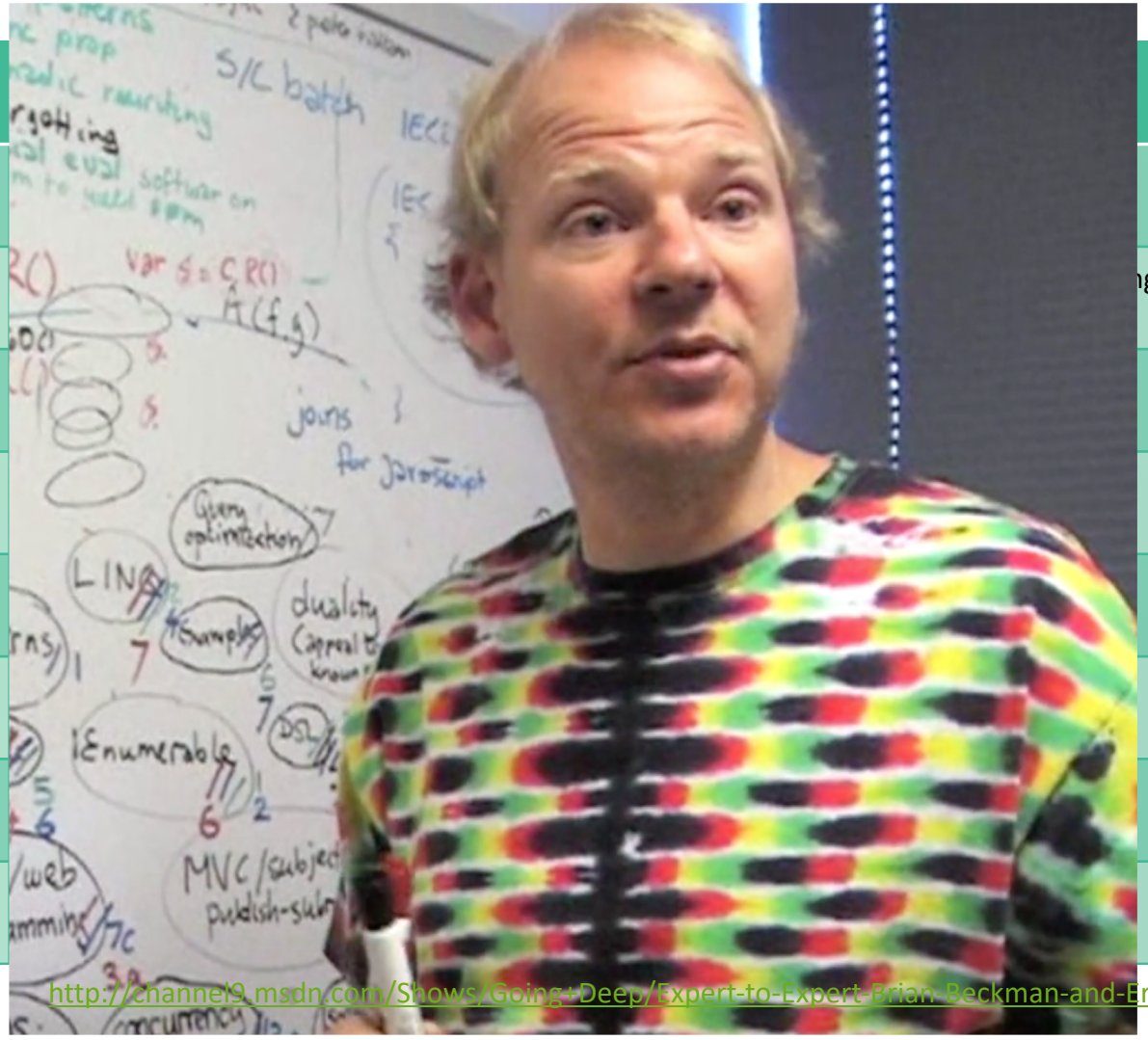
IObserver & IObservable

```
let observable = { new IObservable<string> with
                      member x.Subscribe(observer:IObserver<string>) = {
                         new IDisposable with
                            member x.Dispose() = ()
                    }
                  }

let observer = { new IObserver<string> with
                      member x.OnNext(value) = ()
                      member x.OnCompleted() = ()
                      member x.OnError(exn) = ()
                }
```

F# & .Net RX Api

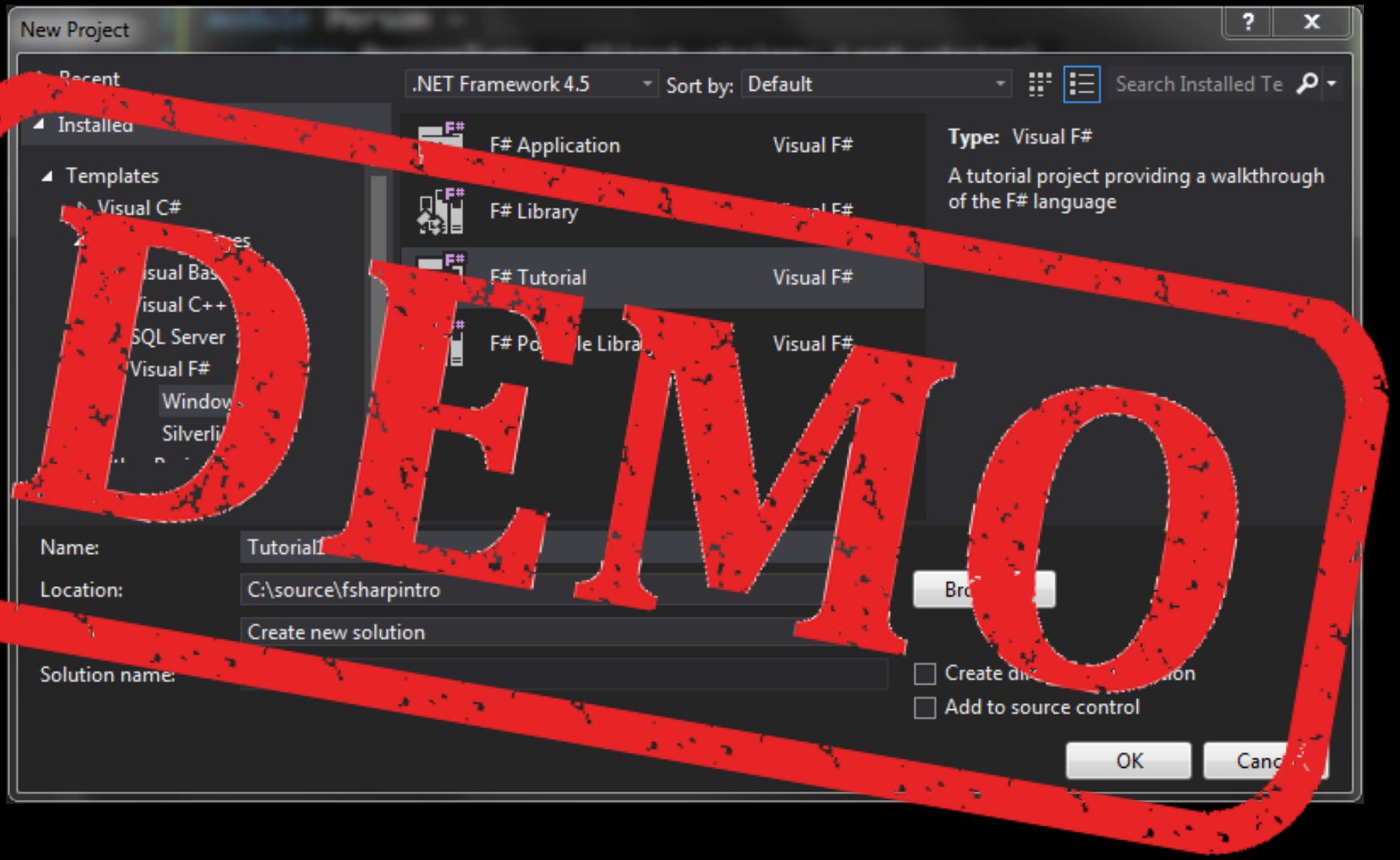
F# Observable
add
choose
filter
merge
pairwise
partition
scan
subscribe

.NET RX Api	
All	Amb
Combine	Count
Finally	First
Last	Latest
Multicast	Range
Switch	Select
Take	TakeLast
Window	When

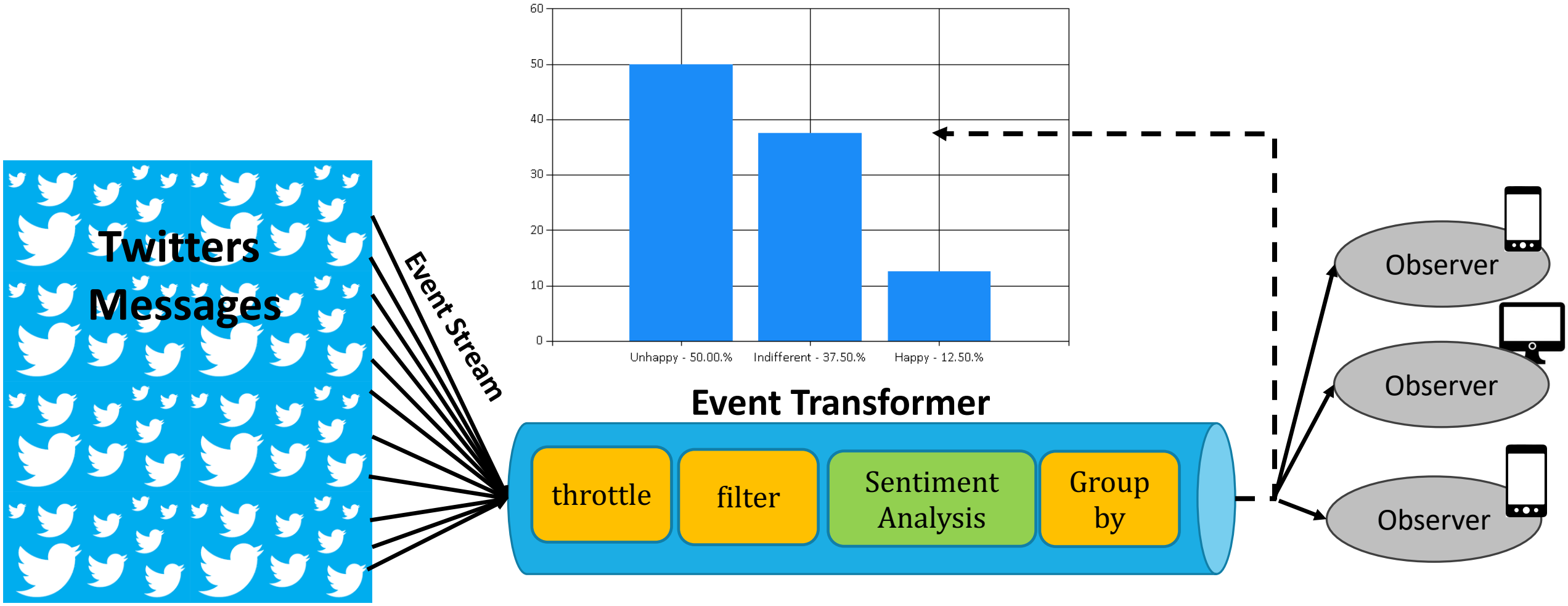


	Catch	Chunhify
nge	ElemntAt	ElementAtOrDefault
	If	IgnoreElement
	MinBy	MostRecent
	Never	Sum
	SkipUntill	Then
	While	When

http://channel9.msdn.com/Shows/Going-Deep/Expert-to-Expert-Brian-Beckman-and-Erik-Meijer-Inside-the-NET-Reactive-Framework-Rx

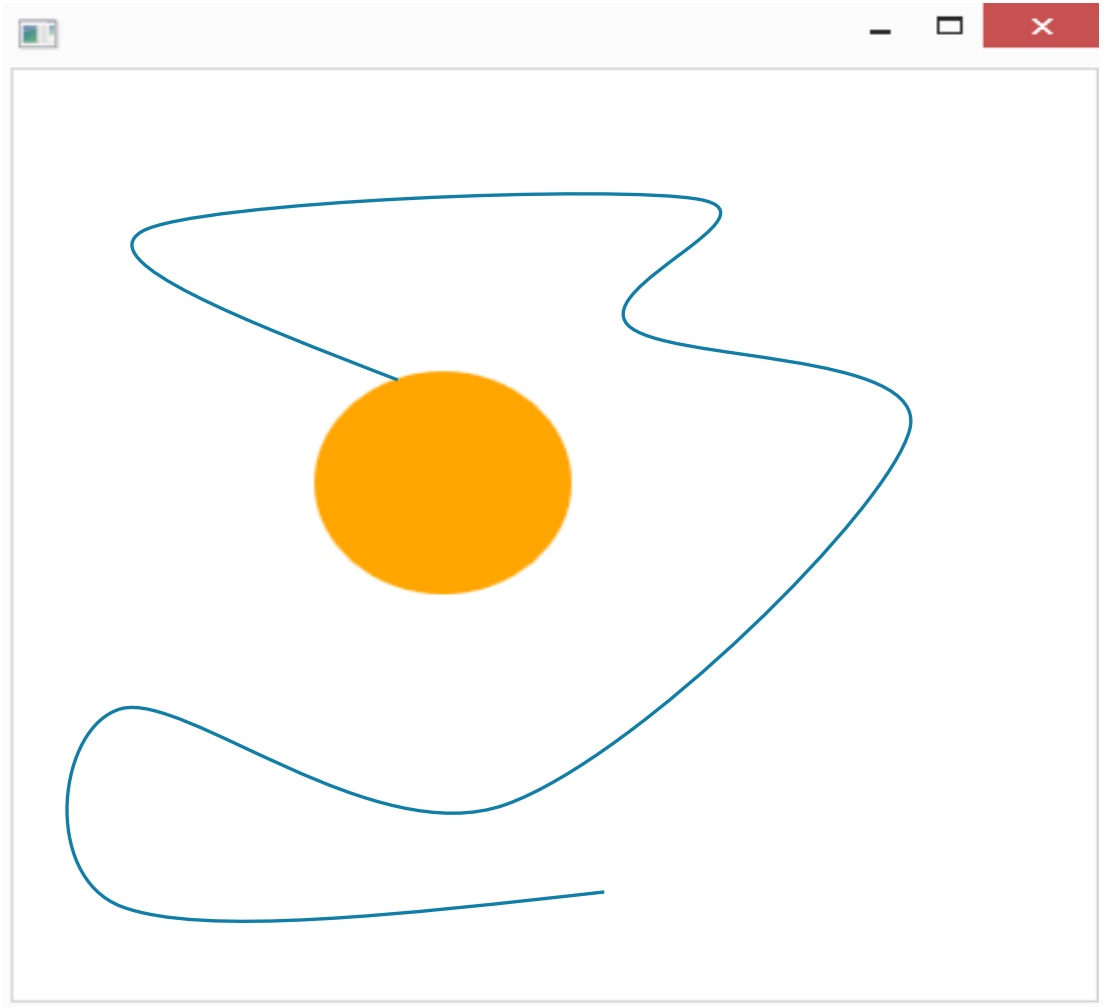

New Project
.NET Framework 4.5
Sort by:
Default
Search Installed Te
Installed
Templates
Visual C#
Visual C++
SQL Server
Visual F#
Silverli
F# Application
Visual F#
F# Library
F# Tutorial
Visual F#
Visual F#
Type: Visual F#
A tutorial project providing a walkthrough of the F# language
Name:
Tutorial1
Location:
C:\source\fsharpintro
Create new solution
Solution name:
Add to source control
OK
DEMO

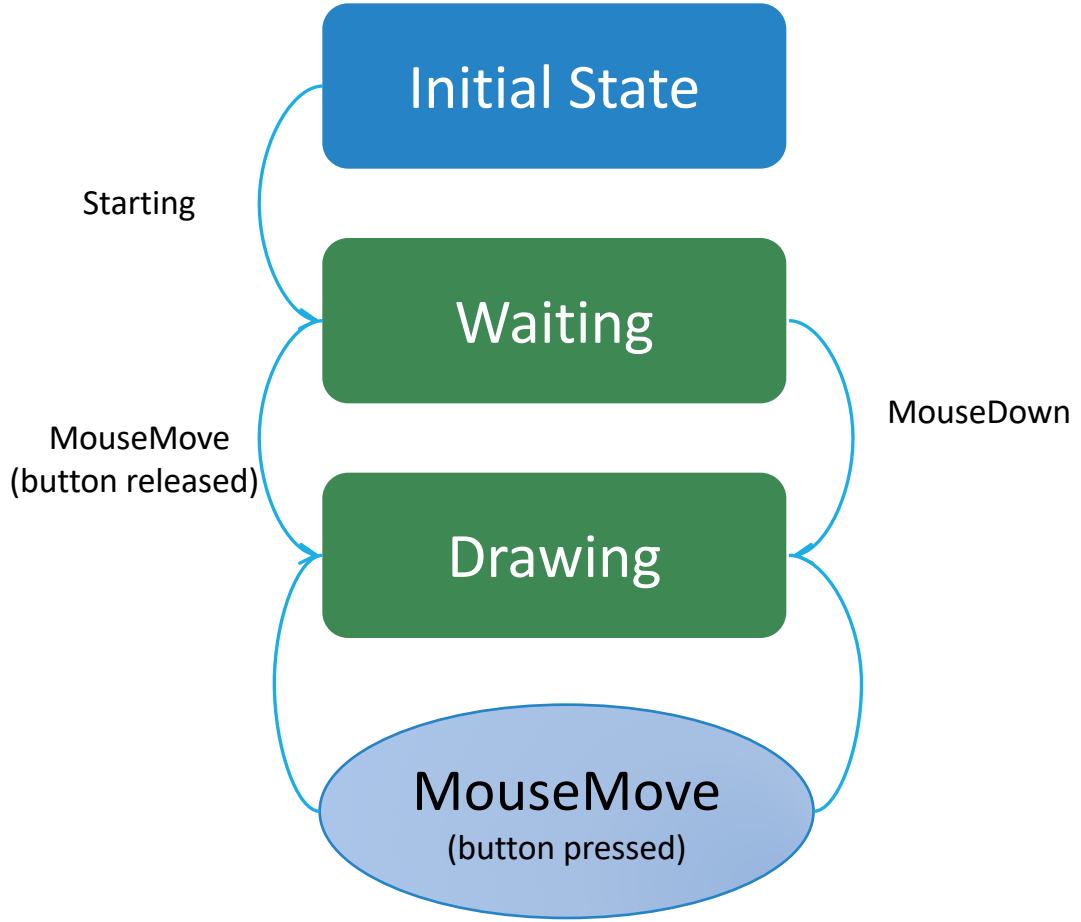
Lab :
Stock market
Twitter emotion

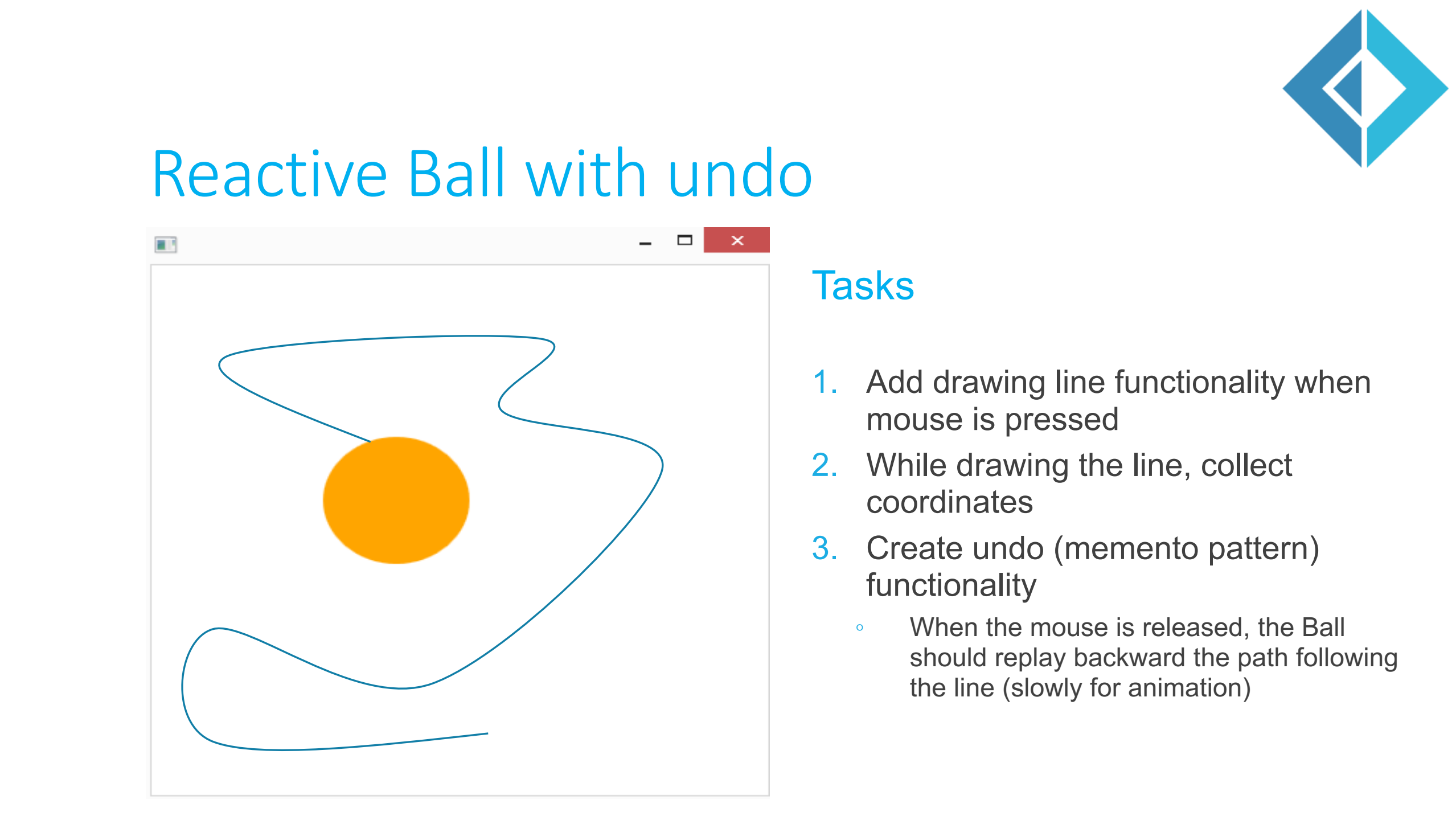

Twitters Messages
Event Stream
60
50
40
30
20
10
0
Unhappy - 50.00.%
Indifferent - 37.50.%
Happy - 12.50.%
Event Transformer
throttle
filter
Sentiment Analysis
Group by
Observer
Observer
Observer

Lab :
Reactive ball with undo

Reactive Ball with undo







Reactive Ball with undo

Tasks

1. Add drawing line functionality when mouse is pressed
2. While drawing the line, collect coordinates
3. Create undo (memento pattern) functionality
   - When the mouse is released, the Ball should replay backward the path following the line (slowly for animation)

The tools we use have a profound (and devious!) influence on our thinking habits, and, therefore, on our thinking abilities.

-- Edsger Dijkstra