# Reactive Python for Data

# Part IV - The Observable

## 4.1A - Creating an Observable

An Observable pushes items. It can push a finite or infinite series of items over time. To create an Observable that pushes 5 text strings, you can declare it like this:

from rx import Observable  
  
letters = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])

We create an Observable using the from\_() function, and pass it a list of five strings. It will take the list and **emit** (or push) each item from it. The Observable.from\_() will work with any iterable.

However, running this does nothing more than save an Observable to a variable called letters. For the items to actually get pushed, we need a Subscriber.

## 4.1B - Subscribing to an Observable

To receive emissions from an Observable, we need to create a Subscriber by implementing an Observer. An Observer implements three functions on\_next() which receives an emission, on\_completed() which is called when there are no more items, and on\_error() which receives an error in the event one occurs.

Then we can pass an implementation of this Observer to the Observable's subscribe() function. It will then fire the emissions to our Subscriber.

from rx import Observable, Observer  
  
letters = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
  
  
class MySubscriber(Observer):  
 def on\_next(self, value):  
 print(value)  
  
 def on\_completed(self):  
 print("Completed!")  
  
 def on\_error(self, error):  
 print("Error occured: {0}".format(error))  
  
  
letters.subscribe(MySubscriber())

**OUTPUT:**

Received: Alpha  
Received: Beta  
Received: Gamma  
Received: Delta  
Received: Epsilon  
Completed!

## Example 4.1C - Subscribing Shorthand with Lambdas

Implementing a Subscriber is a bit verbose, so we also have the option of passing more concise lambda arguemnts to the subscribe() function. Then it will use those lambas to create the Subscriber for us.

from rx import Observable  
  
letters = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
  
letters.subscribe(on\_next = lambda value: print(value),  
 on\_completed = lambda: print("Completed!"),  
 on\_error = lambda error: print("Error occurred: {0}".format(error)))

You do not even have to supply all the lambda arguments. You can leave out the on\_completed and on\_error, but for production code you should try to have an on\_error so errors are not quietly swallowed.

letters.subscribe(on\_next = lambda value: print(value))  
  
# or  
  
letters.subscribe(lambda value: print("Received: {0}".format(value)))

We will be using lambdas constantly as we do reactive programming.

## 4.2A - Some Basic Operators

RxPy has approximately 130 operators to powerfully express business logic, transformations, and concurrency behaviors. For now we will start with two basic ones: map() and filter() and cover more in the next section.

For instance, we can map() each String to its lenth, and then filter only to lengths that are at least 5.

from rx import Observable  
  
letters = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
  
mapped = letters.map(lambda s: len(s))  
  
filtered = mapped.filter(lambda i: i >= 5)  
  
filtered.subscribe(lambda value: print(value))

**OUTPUT:**

Received: 5  
Received: 5  
Received: 5  
Received: 7

Each operator yields a new Observable emitting that transformation. We can save each one to a variable if we want and then subscribe() to the one we want, but oftentimes you will likely want to call them all in a single chain.

from rx import Observable  
  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .map(lambda s: len(s)) \  
 .filter(lambda i: i >= 5) \  
 .subscribe(lambda value: print(value))

If you are using an IDE like PyCharm, operators like filter() and map() will unfortunately not be available for auto-complete. The reason is RxPy will add these operators to the Observable at runtime. For PyCharm, you may want to disable *Unresolved References* under *Settings -> Editor -> Inspection -> Python* so you do not get any warnings.

## 4.2B Using Observable.range() and Observable.just()

There are other ways to create an Observable. For instance, you can emit a range of numbers:

from rx import Observable  
  
letters = Observable.range(1,10)  
  
letters.subscribe(lambda value: print(value))

**OUTPUT:**

Received: 1  
Received: 2  
Received: 3  
Received: 4  
Received: 5  
Received: 6  
Received: 7  
Received: 8  
Received: 9  
Received: 10

You can also use Observable.just() to emit a single item.

from rx import Observable  
  
greeting = Observable.just("Hello World!")  
  
greeting.subscribe(lambda value: print(value))

**OUTPUT:**

Received: Hello World!

# 4.2C - Using Observable.empty()

You can also create an Observable that emits nothing and call on\_completed() immediately via Observable.empty(). While this may not seem useful, an empty Observable is the reactive equivalent to None, null, or an empty collection.

from rx import Observable  
  
Observable.empty() \  
 .subscribe(on\_next= lambda s: print(s),  
 on\_completed= lambda: print("Done!")  
 )

**OUTPUT:**

Done!

# 4.3A - Creating an Observable from Scratch

You can also create an Observable source from scratch. Using Observable.create(). you can pass a function with an observer argument, and call it's on\_next(), on\_completed(), and on\_error() to pass items or events to the Observer or the next operator in the chain.

from rx import Observable  
  
def push\_numbers(observer):  
 observer.on\_next(100)  
 observer.on\_next(300)  
 observer.on\_next(500)  
 observer.on\_completed()  
  
Observable.create(push\_numbers).subscribe(on\_next = lambda i: print(i))

**OUTPUT:**

100  
300  
500

## 4.3B - An Interval Observable

Observables do not have to strictly emit data. They can also emit events. Remember our definition that states *events are data, and data are events*? Events and data are treated the same way in ReactiveX. They both can be pushed through an Observable.

For instance, we can use Observable.interval() to emit a consecutive integer every 1 second.

from rx import Observable  
  
Observable.interval(1000) \  
 .map(lambda i: "{0} Mississippi".format(i)) \  
 .subscribe(lambda s: print(s))  
  
# Keep application alive until user presses a key  
input("Press any key to quit\r\n")

**OUTPUT:**

0 Mississippi  
1 Mississippi  
2 Mississippi  
3 Mississippi  
4 Mississippi  
5 Mississippi  
6 Mississippi  
7 Mississippi  
8 Mississippi

Notice how the Observable in fact has a notion of time? It is emitting an integer every second, and each emission is both data and an event. Observables can be created to emit button clicks for a UI, server requests, new Tweets, and any other event while repsresenting that event as data.

Note also we had to use input() to make the main thread pause until the user presses a key. If we did not do this, the Observable.interval() would not have a chance to fire because the application will exit. The reason for this is the Observable.interval() has to operate on a separate thread and create a separate workstream driven by a timer. The Python code will finish and terminate before it has a chance to fire.

# 4.3C - Using Observable.defer() (EXTRA)

A behavior to be aware of with Observable.from\_() and other functions that create Observables is they may not reflect changes that happen to their sources.

For instance, if have an Observable.range() built off two variables x and y, and one of the variables changes later, this change will not be captured by the source.

1  
2  
3  
4  
5  
  
Setting y = 10  
  
1  
2  
3  
4  
5

**OUTPUT:**

Alpha  
Beta  
Gamma  
  
Adding Delta!  
  
Alpha  
Beta  
Gamma  
Delta

Using Observable.defer() allows you to create a new Observable from scratch each time it is subscribed, and therefore capturing anything that might have changed about its source. Just supply how to create the Observable through a lambda.

from rx import Observable  
  
x = 1  
y = 5  
  
integers = Observable.defer(lambda: Observable.range(x, y))  
integers.subscribe(lambda i: print(i))  
  
print("\nSetting y = 10\n")  
y = 10  
  
integers.subscribe(lambda i: print(i))

**OUTPUT:**

1  
2  
3  
4  
5  
  
Setting y = 10  
  
1  
2  
3  
4  
5  
6  
7  
8  
9  
10

The lambda argument ensures the Observable source declaration is rebuilt each time it is subscribed to.

# 4.3D - Unsubscribing from an Observable

When you subscribe() to an Observable it returns a Disposable so you can disconnect the Subscriber from the Observable at any time.

from rx import Observable  
import time  
  
disposable = Observable.interval(1000) \  
 .map(lambda i: "{0} Mississippi".format(i)) \  
 .subscribe(lambda s: print(s))  
  
# sleep 5 seconds so Observable can fire  
time.sleep(5)  
  
# disconnect the Subscriber  
print("Unsubscribing!")  
disposable.dispose()  
  
# sleep a bit longer to prove no more emissions are coming  
time.sleep(5)

**OUTPUT:**

0 Mississippi  
1 Mississippi  
2 Mississippi  
3 Mississippi  
Unsubscribing!

Unsubscribing/disposing is usually not necessary for Observables that are finite and quick (they will unsubscribe themselves), but it can be necessary for long-running or infinite Observables.

# 4.4 - An Observable emitting Tweets

Later we will learn how to create Observables that emit Tweets for a given topic, but here is a preview of what's to come. Using Tweepy and Observable.create(), we can create a function that yields an Observable emitting Tweets for specified topics. For instance, here is how to get a live stream of text bodies from Tweets for "Britain" and "France".

## 4.4A - A Twitter Observable

from tweepy.streaming import StreamListener  
from tweepy import OAuthHandler  
from tweepy import Stream  
import json  
from rx import Observable  
  
# Variables that contains the user credentials to access Twitter API  
access\_token = "CONFIDENTIAL"  
access\_token\_secret = "CONFIDENTIAL"  
consumer\_key = "CONFIDENTIAL"  
consumer\_secret = "CONFIDENTIAL"  
  
  
def tweets\_for(topics):  
  
 def observe\_tweets(observer):  
 class TweetListener(StreamListener):  
 def on\_data(self, data):  
 observer.on\_next(data)  
 return True  
  
 def on\_error(self, status):  
 observer.on\_error(status)  
  
 # This handles Twitter authetification and the connection to Twitter Streaming API  
 l = TweetListener()  
 auth = OAuthHandler(consumer\_key, consumer\_secret)  
 auth.set\_access\_token(access\_token, access\_token\_secret)  
 stream = Stream(auth, l)  
 stream.filter(track=topics)  
  
 return Observable.create(observe\_tweets).share()  
  
  
topics = ['Britain','France']  
  
tweets\_for(topics).map(lambda d: json.loads(d)) \  
 .filter(lambda map: "text" in map) \  
 .map(lambda map: map["text"].strip()) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

RT @YourAnonCentral: The ﬁve biggest international arms exports suppliers in 2008–12 were the #US,#Russia, #Germany, #France and #China. ht…  
RT @parismarx: Marine Le Pen believes France "will provide the third stage of a global political uprising" following Brexit &amp; Trump https:/…  
Attentats du 13-Novembre: des rescapés racontent leur vie un an après https://t.co/VMM5rlsoQu via @RFI  
RT @AOLNews: 1 year after the Paris attacks, France's state of emergency remains: https://t.co/PD0U6mXHcN https://t.co/QUHWRSCLxt  
おむつは不要、手ぶらで登園。少子化を克服したフランスの保育園事情とは https://t.co/4ImUajYSq2 @HuffPostJapanさんから  
RT @CPIF\_: #France Interdit cette année, les islamistes tentent de convertir les femmes en faisant l'expérience du voile à…  
RT @StewartWood: This week our Government should remember &amp; make clear that Britain's alliances must be based on our values, not our values…  
RT @MaxAbrahms: "Britain will spend the next two months trying to convince Mr Trump's team of the need to remove President Assad." https://…  
RT @Bassounov: #Trump est devenu présidentiable grâce à 10 ans de #téléPoubelle. En 2022 en France, la présidence se jouera entre #Hanouna…  
# Panoramix #Radio #Station  
...

## 4.4B Cold vs Hot Observables

Observables that emit data typically are **cold Observables**, meaning they will replay emissions to each individual Subscriber. For instance, this Observable below will emit all five strings to both Subscribers individually.

from rx import Observable  
  
source = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
  
source.subscribe(lambda s: print("Subscriber 1: {0}".format(s)))  
source.subscribe(lambda s: print("Subscriber 2: {0}".format(s)))

**OUTPUT:**

Subscriber 1: Alpha  
Subscriber 1: Beta  
Subscriber 1: Gamma  
Subscriber 1: Delta  
Subscriber 1: Epsilon  
Subscriber 2: Alpha  
Subscriber 2: Beta  
Subscriber 2: Gamma  
Subscriber 2: Delta  
Subscriber 2: Epsilon

However, **hot Observables** will not replay emissions for tardy subscribers that come later. Our Twitter Observable is an example of a hot Observable. If a second Subscriber subscribes to a Tweet feed 5 seconds after the first Subscriber, it will miss all Tweets that occurred in that window. We will explore this later.

# Part V - Operators

In this section, we will learn some of the 130 operators available in RxPy. Learning these operators can be overwhelming, so the best approach is to seek the right operators out of need. The key to being productive with RxPy and unleashing its potential is to find the key operators that help you with the tasks you encounter. With practice, you will become fluent in composing them together.

The best way to see what operators are available in RxPy is to look through them on GitHub https://github.com/ReactiveX/RxPY/tree/master/rx/linq/observable

You can also view the ReactiveX operators page which has helpful marble diagrams showing each operator's behavior http://reactivex.io/documentation/operators.html

You can also explore various operators using the interactive RxMarbles website http://rxmarbles.com/

## 5.1 Suppressing Emissions

Here are some operators that can be helpful for supressing emissions that fail to meet a criteria in some form.

### 5.1A filter()

You have already seen the filter(). It supresses emissions that fail to meet a condition specified by you. For instance, only allowing emissions forward that are at least length 5.

from rx import Observable  
  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .filter(lambda s: len(s) >= 5) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

Alpha  
Gamma  
Delta  
Epsilon

## 5.1B take()

You can also use take() to cut off at a certain number of emissions and call on\_completed(). For instance, calling take(2) like below will only allow the first two emissions coming out of the filter() to come through.

from rx import Observable  
  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .filter(lambda s: len(s) >= 5) \  
 .take(2) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

Alpha  
Gamma

take() will not throw an error if it fails to get the number of items it wants. It will just emit what it does capture. For instance, when take(10) only recieves 4 emissions (and not 10), it will just emit those 4 emissions.

from rx import Observable  
  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .filter(lambda s: len(s) >= 5) \  
 .take(10) \  
 .subscribe(on\_next = lambda s: print(s), on\_error = lambda e: print(e))

**OUTPUT:**

Alpha  
Beta  
Gamma  
Delta  
Epsilon

## 5.1C take\_while()

take\_while() will keep passing emissions based on a condition. For instance if we have an Observable emitting some integers, we can keep taking integers while they are less than 100. We can achieve this using a take\_while().

from rx import Observable  
  
Observable.from\_([2,5,21,5,2,1,5,63,127,12]) \  
 .take\_while(lambda i: i < 100) \  
 .subscribe(on\_next = lambda i: print(i), on\_completed = lambda: print("Done!"))

When the 127 is encountered, the take\_while() specified as above with the condition i < 100 will trigger on\_completed() to be called to the Subscriber, and unsubscription will prevent any more emissions from occurring.

# 5.2 Distinct Operators

## 5.2A distinct()

You can use distinct() to suppress redundant emissions. If an item has been emitted before (based on its equality logic via its \_\_eq\_\_ implementation), it will not be emitted.

This will emit the distinct lengths

from rx import Observable  
  
Observable.from\_(["Alpha", "Beta", "Gamma", "Delta", "Epsilon"]) \  
 .map(lambda s: len(s)) \  
 .distinct() \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

5  
4  
7

## 5.2B distinct() with mapping

You can also pass a lambda specifying what you want to distinct on. If we want to emit the String rather than its length, but use distinct logic on its length, you can leverage a lambda argument.

from rx import Observable  
  
Observable.from\_(["Alpha", "Beta", "Gamma", "Delta", "Epsilon"]) \  
 .distinct(lambda s: len(s)) \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

Alpha  
Beta  
Epsilon

## 5.2C distinct\_until\_changed()

The distinct\_until\_changed() will prevent *consecutive* duplicates from emitting.

from rx import Observable  
  
Observable.from\_(["Alpha", "Theta", "Kappa", "Beta", "Gamma", "Delta", "Epsilon"]) \  
 .map(lambda s: len(s)) \  
 .distinct\_until\_changed() \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

5  
4  
5  
7

Just like distinct(), you can also provide a lambda to distinct on an attribute.

from rx import Observable  
  
Observable.from\_(["Alpha", "Theta", "Kappa", "Beta", "Gamma", "Delta", "Epsilon"]) \  
 .distinct\_until\_changed(lambda s: len(s)) \  
 .subscribe(lambda i: print(i))

Alpha  
Beta  
Gamma  
Epsilon

# 5.3 Aggregating Operators

When working with data, there will be many instances where we want to consolidate emissions into a single emission to reflect some form of an aggregated result.

With the exception of scan(), one thing to be careful about when aggregating emissions is they rely on on\_completed() to be called. Infinite Observables will cause an aggregation operator to work forever aggregating an infinite series of emissions.

## 5.3A - count()

The simplest aggregation to an Observable is to simply count() the number of emisssions, and then push that count forward as a single emission once on\_completed() is called. If we want to count the number of text strings that are not 5 characters, we can achieve it like this:

from rx import Observable  
  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .filter(lambda s: len(s) != 5) \  
 .count() \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

2

## 5.3B reduce()

The reduce() allows you to define a custom aggregation operation to "fold" each value into a rolling value. For instance, you can find the sum of numeric emissions (less than 100) using reduce() in this manner.

from rx import Observable  
  
Observable.from\_([4,76,22,66,881,13,35]) \  
 .filter(lambda i: i < 100) \  
 .reduce(lambda total, value: total + value) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

216

You can use this to consolidate emissions in your own custom way for most cases. Keep in mind that there are already built in mathematical aggregators like sum() (which could replace this reduce()) as well as min(), max(), and average(). These only work on numeric emissions, however.

## 5.3C scan()

The scan() is almost identical to reduce(), but it will emit each rolling total for each emission that is received. Therefore, it can work with infinite Observables such as Twitter streams and other events.

from rx import Observable  
  
Observable.from\_([4,76,22,66,881,13,35]) \  
 .scan(lambda total, value: total + value) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

4  
80  
102  
168  
1049  
1062  
1097

Each accumulation is emitted every time an emission is added to our running total. We start with 4, then 4 + 76 which is 80, then 80 + 22 which is 102, etc...

# 5.4 Collecting Operators

You can consolidate emissions by collecting them into a List or Dict, and then pushing that collection forward as a single emission.

## 5.4A - to\_list()

to\_list() will collect the emissions into a single List until on\_completed() is called, then it will push that List forward as a single emission.

from rx import Observable  
  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .to\_list() \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

['Alpha', 'Beta', 'Gamma', 'Delta', 'Epsilon']

Typically you want avoid excessively collecting things into Lists unless business logic requires it. Prefer to keep emissions flowing forward one-at-a-time in a reactive manner when possible, rather than stopping the flow and collecting emissions into Lists.

## 5.4B - to\_dict()

The to\_dict() will collect emissions into a Dict and you specify a lambda that derives the key. For instance, if you wanted to key each String off its first letter and collect them into a Dict, do the following:

from rx import Observable  
  
Observable.from\_(["Alpha", "Beta", "Gamma", "Delta", "Epsilon"]) \  
 .to\_dict(lambda s: s[0]) \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

{'B': 'Beta', 'E': 'Epsilon', 'A': 'Alpha', 'G': 'Gamma', 'D': 'Delta'}

You can optionally provide a second lambda argument to specify a value other than the emission itself. If we wanted to map the first letter to the length of the String instead, we can do this:

from rx import Observable  
  
Observable.from\_(["Alpha", "Beta", "Gamma", "Delta", "Epsilon"]) \  
 .to\_dict(lambda s: s[0], lambda s: len(s)) \  
 .subscribe(lambda i: print(i))

## 6.1A - Observable.merge()

from rx import Observable  
  
source1 = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
source2 = Observable.from\_(["Zeta","Eta","Theta","Iota"])  
  
Observable.merge(source1,source2) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

Alpha  
Zeta  
Beta  
Eta  
Gamma  
Theta  
Delta  
Iota  
Epsilon

Notice that although emissions from both Observable are now a single stream, the emissions are interleaved and jumbled. This is because Observable.merge() will fire emissions from all the Observables at once rather than sequentially one-at-a-time.

## 6.1B - Observable.merge() (Continued)

If you want this sequential ordered guarantee, you will want to use Observable.concat() which is discussed later. But the Observable.merge() can be helpful for merging multiple event streams.

from rx import Observable  
  
source1 = Observable.interval(1000).map(lambda i: "Source 1: {0}".format(i))  
source2 = Observable.interval(500).map(lambda i: "Source 2: {0}".format(i))  
source3 = Observable.interval(300).map(lambda i: "Source 3: {0}".format(i))  
  
Observable.merge(source1, source2, source3) \  
 .subscribe(lambda s: print(s))  
  
# keep application alive until user presses a key  
input("Press any key to quit\n")

**OUTPUT:**

Source 3: 0  
Source 2: 0  
Source 3: 1  
Source 3: 2  
Source 1: 0  
Source 2: 1  
Source 3: 3  
Source 2: 2  
Source 3: 4  
Source 3: 5  
Source 2: 3  
Source 1: 1  
etc...

Three infinite Observables above are emitting a consecutive integer at different intervals (1000 milliseconds, 500 milliseconds, and 300 milliseconds), and putting each integer into a String labeling the source. But we merged these three infinite Observables into one using Observable.merge().

## 6.1C - merge\_all()

Another way to accomplish this is to make a List containing all three Observables, and then passing it to Observable.from\_(). This will make an Observable emitting Observables, then you can call merge\_all() to turn each one into its emissions.

from rx import Observable  
  
source1 = Observable.interval(1000).map(lambda i: "Source 1: {0}".format(i))  
source2 = Observable.interval(500).map(lambda i: "Source 2: {0}".format(i))  
source3 = Observable.interval(300).map(lambda i: "Source 3: {0}".format(i))  
  
Observable.from\_([source1,source2,source3]) \  
 .merge\_all() \  
 .subscribe(lambda s: print(s))  
  
# keep application alive until user presses a key  
input("Press any key to quit\n")

## 6.1D - merge\_all() (Continued)

If you are creating an Observable off each emission on-the-fly, merge\_all() can be helpful here as well. Say you have a list of Strings containing numbers separated by /. You can map each String to be split() and then pass those separated values to an Observable.from\_(). Then you can call merge\_all() afterwards.

from rx import Observable  
  
items = ["134/34/235/132/77", "64/22/98/112/86/11", "66/08/34/778/22/12"]  
  
Observable.from\_(items) \  
 .map(lambda s: Observable.from\_(s.split("/"))) \  
 .merge\_all() \  
 .map(lambda s: int(s)) \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

134  
34  
64  
235  
22  
66  
132  
98  
8  
77  
112  
34  
86  
778  
11  
22  
12

## 6.1E - flat\_map()

An alternative way of expressing the previous example (5.1D) is using flat\_map(). It will consolidate mapping to an Observable and calling merge\_all() into a single operator.

from rx import Observable  
  
items = ["134/34/235/132/77", "64/22/98/112/86/11", "66/08/34/778/22/12"]  
  
Observable.from\_(items) \  
 .flat\_map(lambda s: Observable.from\_(s.split("/"))) \  
 .map(lambda s: int(s)) \  
 .subscribe(lambda i: print(i))

We will try to prefer the flat\_map() over the map()/merge\_all() from now on since it is much more succinct.

# 6.2 Concat and Zip

Observable.concat() and the concat\_all() operator are simliar to Observable.merge() and the merge\_all() operator. The only difference is they will emit items from each Observable *sequentially*. It will fire off each Observable in order and one-at-a-time. Therefore, this not something you want to use with infinite Observables, because the first infinite Observable will occupy its place in the queue forever and stop the Observables behind it from firing. They are helpful for finite data sets though.

## 6.2A - concat()

Our previous merge() example can now emit items in order:

from rx import Observable  
  
source1 = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
source2 = Observable.from\_(["Zeta","Eta","Theta","Iota"])  
  
Observable.concat(source1,source2) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

Alpha  
Beta  
Gamma  
Delta  
Epsilon  
Zeta  
Eta  
Theta  
Iota

## 6.2B - concat\_all()

We can make our earlier example splitting Strings ordered using concat\_all() instead of merge\_all().

from rx import Observable  
  
items = ["134/34/235/132/77", "64/22/98/112/86/11", "66/08/34/778/22/12"]  
  
Observable.from\_(items) \  
 .map(lambda s: Observable.from\_(s.split("/"))) \  
 .concat\_all() \  
 .map(lambda s: int(s)) \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

134  
34  
235  
132  
77  
64  
22  
98  
112  
86  
11  
66  
08  
34  
778  
22  
12

If you do not care about ordering, it is recommend to use merge\_all() or flat\_map(). concat\_all() can behave unpredictably with certain operators like group\_by(), which we will cover later.

## 6.2C - Zip

Zipping pairs emissions from two or more sources and turns them into a single Observable.

from rx import Observable  
  
letters = Observable.from\_(["A","B","C","D","E","F"])  
numbers = Observable.range(1,5)  
  
Observable.zip(letters,numbers, lambda l,n: "{0}-{1}".format(l,n)) \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

A-1  
B-2  
C-3  
D-4  
E-5

You can alternatively express this as an operator.

letters.zip(numbers, lambda l,n: "{0}-{1}".format(l,n)) \  
 .subscribe(lambda i: print(i))

## 6.3D - Using Zip to Space Emissions

Zip can also be helpful to space out emissions by zipping an Observable with an Observable.interva(). For instnance, we can space out five emissions by one second intervals.

from rx import Observable  
  
letters = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
intervals = Observable.interval(1000)  
  
Observable.zip(letters,intervals, lambda s,i: s) \  
 .subscribe(lambda s: print(s))  
  
input("Press any key to quit\n")

Note that zip() can get overwhelmed with infinite hot Observables where one produces emissions faster than another. You might want to consider using combine\_latest() or with\_latest\_from() instead of zip(), which will pair with the latest emission from each source. For the sake of brevity, we will not cover this in this course. But you can read more about it in the ReactiveX documentation.

# 6.4 - Group By

For the purposes of data science, one of the most powerful operators in ReactiveX is group\_by(). It will yield an Observable emitting GroupedObservables, where each GroupedObservable pushes items with a given key. It behaves just like any other Observable, but it has a key property which we will leverage in a moment.

But first, let's group some String emissions by keying on their lengths. Then let's collect emissions for each grouping into a List. Then we can call flat\_map() to yield all the Lists.

## 6.4A - Group into Lists

from rx import Observable  
  
items = ["Alpha", "Beta", "Gamma", "Delta", "Epsilon"]  
  
Observable.from\_(items) \  
 .group\_by(lambda s: len(s)) \  
 .flat\_map(lambda grp: grp.to\_list()) \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

['Alpha', 'Gamma', 'Delta']  
['Beta']  
['Epsilon']

group\_by() is efficient because it is still 100% reactive and pushing items one-at-a-time through the different GroupedObservables. You can also leverage the key property and tuple it up with an aggregated value. This is helpful if you want to create Dict that holds aggregations by key values.

For instance, if you want to find the count of each word length occurrence, you can create a Dict like this:

## 6.4B - Getting Length Counts

from rx import Observable  
  
items = ["Alpha", "Beta", "Gamma", "Delta", "Epsilon"]  
  
Observable.from\_(items) \  
 .group\_by(lambda s: len(s)) \  
 .flat\_map(lambda grp:  
 grp.count().map(lambda ct: (grp.key, ct))  
 ) \  
 .to\_dict(lambda key\_value: key\_value[0], lambda key\_value: key\_value[1]) \  
 .subscribe(lambda i: print(i))

**OUTPUT:**

{4: 1, 5: 3, 7: 1}

You can interpret the returned Dict above as "for length 4 there are one occurrences, for length 5 there are 3 occurrences, etc".

group\_by() is somewhat abstract but it is a powerful and efficient way to perform aggregations on a given key. It also works with infinite Observables assuming you use infinite-friendly operators on each GroupedObservable. We will use group\_by() a few more times in this course.

# Section VII - Reading and Analyzing data

In this chapter we will look over basic ways to reactively read data and analyze data from text files, URL's, and SQL. We will also integrate concepts we previously learned to create a reactive word counter that runs on a schedule and detects changes to a file.

One catch with using Observable.from\_() with a data source iterable is it only iterates once, causing multiple Subscribers to not receieve data after the first Subscriber. To get around this we will use functions to create a new Observable each time we need to subscribe to a data source. A slightly more advanced way to solve this issue is to use Observable.defer() which we will not cover here, but you can read about it in the Appendix.

It is good to leverage functions that return Observables anyway. You can accept arguments to build the Observable chain that is returned and increase reusability.

## 7.1A - Reading a Text File

As stated earlier, anything that is iterable can be turned into an Observable using Observable.from\_(). We can emit the lines from a text file in this manner. If I have a raw text file called bbc\_news\_article.txt in my Python project, I can emit the lines like this:

from rx import Observable  
  
  
def read\_lines(file\_name):  
 file = open(file\_name)  
  
 return Observable.from\_(file) \  
 .map(lambda l: l.strip()) \  
 .filter(lambda l: l != "")  
  
  
read\_lines("bbc\_news\_article.txt").subscribe(lambda s: print(s))

**OUTPUT:**

Giant waves damage S Asia economy  
Governments, aid agencies, insurers and travel firms are among those counting the cost of the massive earthquake and waves that hammered southern Asia.  
The worst-hit areas are Sri Lanka, India, Indonesia and Thailand, with at least 23,000 people killed. Early estimates from the World Bank put the amount of aid needed at about $5bn (£2.6bn), similar to the cash offered Central America after Hurricane Mitch. Mitch killed about 10,000 people and caused damage of about $10bn in 1998. World Bank spokesman Damien  
...

I use the map() and filter() operators to strip any leading and trailing whitespace for each line, as well as rid lines that are empty.

We will use this example for a project at the end of this section.

## 7.1B - Reading a URL

You can also read content from the web in a similar manner. This can be a powerful way to do web scraping and data wrangling, especially if you reactively push multiple URL's or URL arguments and scrape the content off each page. Just be kind and don't tax somebody's system!

I saved a simple raw text page of the 50 U.S. states on a Gist page. You can view it with this URL: https://goo.gl/rIaDyM.

If you want to read the lines off the response, you can do it like this:

from rx import Observable  
from urllib.request import urlopen  
  
  
def read\_request(link):  
 f = urlopen(link)  
  
 return Observable.from\_(f) \  
 .map(lambda s: s.decode("utf-8").strip()) \  
  
read\_request("https://goo.gl/rIaDyM") \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

Alabama  
Alaska  
Arizona  
Arkansas  
California  
Colorado  
Connecticut  
Delaware  
...

In the map we have to decode the bytes and convert them to UTF-8 Strings. Then we also clean leading and trailing whitespace with strip(). then finally we print each line.

## 7.1C Recursively Iterating Files in Directories (EXTRA)

You can use Rx to do powerful recursion patterns to iterate files. You can download and unzip a BBC article datset for this example here, with thousands of articles in text file format: http://mlg.ucd.ie/datasets/bbc.html

from rx import Observable  
import os  
  
  
def recursive\_files\_in\_directory(folder):  
  
 def emit\_files\_recursively(observer):  
 for root, directories, filenames in os.walk(folder):  
 for directory in directories:  
 observer.on\_next(os.path.join(root, directory))  
 for filename in filenames:  
 observer.on\_next(os.path.join(root, filename))  
  
 observer.on\_completed()  
  
 return Observable.create(emit\_files\_recursively)  
  
  
recursive\_files\_in\_directory('/home/thomas/Desktop/bbc\_data\_sets') \  
 .filter(lambda f: f.endswith('.txt')) \  
 .subscribe(on\_next=lambda l: print(l), on\_error=lambda e: print(e))

You can iterate files through a directory and any nested directories, filter only for files you are interested in (such as .txt files), and then emit the lines from all the files.

from rx import Observable  
import os  
  
  
def recursive\_files\_in\_directory(folder):  
  
 def emit\_files\_recursively(observer):  
 for root, directories, filenames in os.walk(folder):  
 for directory in directories:  
 observer.on\_next(os.path.join(root, directory))  
 for filename in filenames:  
 observer.on\_next(os.path.join(root, filename))  
  
 observer.on\_completed()  
  
 return Observable.create(emit\_files\_recursively)  
  
  
recursive\_files\_in\_directory('/home/thomas/Desktop/bbc') \  
 .filter(lambda f: f.endswith('.txt')) \  
 .flat\_map(lambda f: Observable.from\_(open(f, encoding="ISO-8859-1"))) \  
 .map(lambda l: l.strip()) \  
 .filter(lambda l: l != "") \  
 .subscribe(on\_next=lambda l: print(l), on\_error=lambda e: print(e))

## 7.2 - Reading a SQL Query

SQLAlchemy is the go-to Python library for SQL querying, and since it is iterable it can easily support Rx. In this example, I am using a SQLite database file which you can download at https://goo.gl/9DYXPS. You can also download it on my [*Getting Started with SQL* GitHub page](https://github.com/thomasnield/oreilly_getting_started_with_sql).

### 7.2A - Emitting a query

When you set up your engine, statement, and connection, you can reactively emit each result (which will be a tuple) from a query using Observable.from\_(). Since a SQL query result set can only be iterated once, it is easiest to use a function to create a new one and return it in an Observable each time. That way multiple subscribers can be accommodated easily.

from sqlalchemy import create\_engine, text  
from rx import Observable  
  
engine = create\_engine('sqlite:///rexon\_metals.db')  
conn = engine.connect()  
  
  
def get\_all\_customers():  
 stmt = text("SELECT \* FROM CUSTOMER")  
 return Observable.from\_(conn.execute(stmt))  
  
  
get\_all\_customers().subscribe(lambda r: print(r))

**OUTPUT:**

(1, 'LITE Industrial', 'Southwest', '729 Ravine Way', 'Irving', 'TX', 75014)  
(2, 'Rex Tooling Inc', 'Southwest', '6129 Collie Blvd', 'Dallas', 'TX', 75201)  
(3, 'Re-Barre Construction', 'Southwest', '9043 Windy Dr', 'Irving', 'TX', 75032)  
(4, 'Prairie Construction', 'Southwest', '264 Long Rd', 'Moore', 'OK', 62104)  
(5, 'Marsh Lane Metal Works', 'Southeast', '9143 Marsh Ln', 'Avondale', 'LA', 79782)

### 7.2B - Merging multiple queries

You can create some powerful reactive patterns when working with databases. For instance, say you wanted to query for customers with ID's 1, 3, and 5. Of course you can do this in raw SQL like so:

SELECT \* FROM CUSTOMER WHERE CUSTOMER\_ID in (1,3,5)

However, let's leverage Rx to keep our API simple and minimize the number of query functions it needs.

You can create a single customer\_for\_id() function that returns an Observable emitting a customer for a given customer\_id. You can compose it into a reactive chain by using merge\_all() or flat\_map(). Do this by emitting the desired ID's, mapping them to the customer\_for\_id(), and then calling merge\_all() to consolidate the results from all three queries.

from sqlalchemy import create\_engine, text  
from rx import Observable  
  
engine = create\_engine('sqlite:///rexon\_metals.db')  
conn = engine.connect()  
  
def get\_all\_customers():  
 stmt = text("SELECT \* FROM CUSTOMER")  
 return Observable.from\_(conn.execute(stmt))  
  
def customer\_for\_id(customer\_id):  
 stmt = text("SELECT \* FROM CUSTOMER WHERE CUSTOMER\_ID = :id")  
 return Observable.from\_(conn.execute(stmt, id=customer\_id))  
  
# Query customers with IDs 1, 3, and 5  
Observable.from\_([1, 3, 5]) \  
 .flat\_map(lambda id: customer\_for\_id(id)) \  
 .subscribe(lambda r: print(r))

**OUTPUT:**

(1, 'LITE Industrial', 'Southwest', '729 Ravine Way', 'Irving', 'TX', 75014)  
(3, 'Re-Barre Construction', 'Southwest', '9043 Windy Dr', 'Irving', 'TX', 75032)  
(5, 'Marsh Lane Metal Works', 'Southeast', '9143 Marsh Ln', 'Avondale', 'LA', 79782)

## 7.2D - Writing Data (EXTRA)

You can also use Rx to write data to a database. One way to do this is to put the writing operations in the Subscriber, but you can get a bit more creative and flexible with Rx. For instance, we can create a function called insert\_new\_customer() that accepts the parameters needed to create a new CUSTOMER record. But, we can return an Observable that emits the automatically assigned PRIMARY KEY value for that record. This allows us to compose writing operations with other operations, such as querying for the record we just created.

from sqlalchemy import create\_engine, text  
from rx import Observable  
  
  
engine = create\_engine('sqlite:///rexon\_metals.db')  
conn = engine.connect()  
  
  
def get\_all\_customers():  
 stmt = text("SELECT \* FROM CUSTOMER")  
 return Observable.from\_(conn.execute(stmt))  
  
  
def customer\_for\_id(customer\_id):  
 stmt = text("SELECT \* FROM CUSTOMER WHERE CUSTOMER\_ID = :id")  
 return Observable.from\_(conn.execute(stmt, id=customer\_id))  
  
  
def insert\_new\_customer(customer\_name, region, street\_address, city, state, zip\_code):  
 stmt = text("INSERT INTO CUSTOMER (NAME, REGION, STREET\_ADDRESS, CITY, STATE, ZIP) VALUES ("  
 ":customer\_name, :region, :street\_address, :city, :state, :zip\_code)")  
  
 result = conn.execute(stmt, customer\_name=customer\_name, region=region, street\_address=street\_address, city=city, state=state, zip\_code=zip\_code)  
 return Observable.just(result.lastrowid)  
  
# Create new customer, emit primary key ID, and query that customer  
insert\_new\_customer('RMS Materials','Northeast', '5764 Carrier Ln', 'Boston', 'Massachusetts', '02201') \  
 .flat\_map(lambda i: customer\_for\_id(i)) \  
 .subscribe(lambda s: print(s))

**OUTPUT:**

(6, 'RMS Materials', 'Northeast', '5764 Carrier Ln', 'Boston', 'Massachusetts', 2201)

## 7.3 - A Scheduled Reactive Word Counter

Let's apply everything we have learned so far to create a reactive word counter process.

### 7.3A - Emitting words from a text file

Let's start by creating a function that returns an Observable emitting and cleaning the words in a text file, ridding punctuation, empty lines, and making all words lower case.

from rx import Observable  
import re  
  
  
def words\_from\_file(file\_name):  
 file = open(file\_name)  
  
 # parse, clean, and push words in text file  
 return Observable.from\_(file) \  
 .flat\_map(lambda s: Observable.from\_(s.split())) \  
 .map(lambda w: re.sub(r'[^\w]', '', w)) \  
 .filter(lambda w: w != "") \  
 .map(lambda w: w.lower())  
  
article\_file = "bbc\_news\_article.txt"  
words\_from\_file(article\_file).subscribe(lambda w: print(w))

**OUTPUT:**

giant  
waves  
damage  
governments  
s  
aid  
asia  
agencies  
the  
economy  
...

### 7.3B - Counting Word Occurrences

Let's create another function called word\_counter(). It will leverage the existing words\_from\_file() then use group\_by() to count the word occurrances, then tuple the word with the count.

from rx import Observable  
import re  
  
  
def words\_from\_file(file\_name):  
 file = open(file\_name)  
  
 # parse, clean, and push words in text file  
 return Observable.from\_(file) \  
 .flat\_map(lambda s: Observable.from\_(s.split())) \  
 .map(lambda w: re.sub(r'[^\w\s]', '', w)) \  
 .filter(lambda w: w != "") \  
 .map(lambda w: w.lower()) \  
  
  
  
def word\_counter(file\_name):  
  
 # count words using `group\_by()`  
 # tuple the word with the count  
 return words\_from\_file(file\_name) \  
 .group\_by(lambda word: word) \  
 .flat\_map(lambda grp: grp.count().map(lambda ct: (grp.key, ct)))  
  
article\_file = "bbc\_news\_article.txt"  
word\_counter(article\_file).subscribe(lambda w: print(w))

**OUTPUT:**

('giant', 1)  
('waves', 3)  
('damage', 6)  
('governments', 3)  
('s', 1)  
('aid', 10)  
('asia', 6)  
('agencies', 3)  
('the', 78)  
('economy', 1)  
...

## 7.3C - Scheduling the Word Count And Notifying of Changes

Finally, let's schedule this word count to occur every 3 seconds and collect them into a Dict. We can use distinct\_until\_changed() to only emit Dict items that have changed due to the text file being edited.

# Schedules a reactive process that counts the words in a text file every three seconds,  
# but only prints it as a dict if it has changed  
  
from rx import Observable  
import re  
  
  
def words\_from\_file(file\_name):  
 file = open(file\_name)  
  
 # parse, clean, and push words in text file  
 return Observable.from\_(file) \  
 .flat\_map(lambda s: Observable.from\_(s.split())) \  
 .map(lambda w: re.sub(r'[^\w\s]', '', w)) \  
 .filter(lambda w: w != "") \  
 .map(lambda w: w.lower()) \  
  
  
  
def word\_counter(file\_name):  
  
 # count words using `group\_by()`  
 # tuple the word with the count  
 return words\_from\_file(file\_name) \  
 .group\_by(lambda word: word) \  
 .flat\_map(lambda grp: grp.count().map(lambda ct: (grp.key, ct)))  
  
  
# composes the above word\_counter() into a dict  
def word\_counter\_as\_dict(file\_name):  
 return word\_counter(file\_name).to\_dict(lambda t: t[0], lambda t: t[1])  
  
  
# Schedule to create a word count dict every three seconds an article  
# But only re-print if text is edited and word counts change  
  
article\_file = "bbc\_news\_article.txt"  
  
# create a dict every three seconds, but only push if it changed  
Observable.interval(3000) \  
 .flat\_map(lambda i: word\_counter\_as\_dict(article\_file)) \  
 .distinct\_until\_changed() \  
 .subscribe(lambda word\_ct\_dict: print(word\_ct\_dict))  
  
# Keep alive until user presses any key  
input("Starting, press any key to quit\n")

**OUTPUT:**

Starting, press any key to quit  
{'a': 7, 'governments': 3, 'first': 1, 'getting': 1, 'offered': 1, ...

Every time the file is edited and words are added, modified, or removed, it should push a new Dict reflecting these changes. This can be helpful to run a report on a schedule, and you can only emit a new report to an output if the data has changed.

Ideally, it is better to hook onto the change event itself rather than running a potentially expensive process every 3 seconds. We will learn how to do this with Twitter in the next section.

If you want to see an intensive reactive data analysis example, see my [social media example on Gist](https://goo.gl/NO0Q4P)

# Section VIII - Hot Observables

In this section we will learn how to create an Observable emitting Tweets for a set of topics. We will wrap an Observable.create() around the Tweepy API. But first, let's cover multicasting.

## 8.1A - Creating a ConnectableObservable

Remember how cold Observables will replay data to each Subscriber like a music CD?

from rx import Observable  
  
source = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"])  
  
source.subscribe(lambda s: print("Subscriber 1: {0}".format(s)))  
source.subscribe(lambda s: print("Subscriber 2: {0}".format(s)))

**OUTPUT:**

Subscriber 1: Alpha  
Subscriber 1: Beta  
Subscriber 1: Gamma  
Subscriber 1: Delta  
Subscriber 1: Epsilon  
Subscriber 2: Alpha  
Subscriber 2: Beta  
Subscriber 2: Gamma  
Subscriber 2: Delta  
Subscriber 2: Epsilon

This is often what we want so no data is missed for each Subscriber. But there are times we will want to force cold Observables to become hot Observables. We can do this by calling publish() which will return a ConnectableObservable. Then we can subscribe our Subscribers to it, then call connect() to fire emissions to all Subscribers at once.

from rx import Observable  
  
source = Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]).publish()  
  
source.subscribe(lambda s: print("Subscriber 1: {0}".format(s)))  
source.subscribe(lambda s: print("Subscriber 2: {0}".format(s)))  
  
source.connect()

**OUTPUT:**

Subscriber 1: Alpha  
Subscriber 2: Alpha  
Subscriber 1: Beta  
Subscriber 2: Beta  
Subscriber 1: Gamma  
Subscriber 2: Gamma  
Subscriber 1: Delta  
Subscriber 2: Delta  
Subscriber 1: Epsilon  
Subscriber 2: Epsilon

This is known as multicasting. Notice how the emissions are now interleaved? This is because each emission is going to both subscribers. This is helpful if "replaying" the data is expensive or we just simply want all Subscribers to get the emissions simultaneously.

## 8.1B - Sharing an Interval Observable (EXTRA)

Observable.interval() is actually a cold Observable too. If one Subscriber subscribes to it, and 5 seconds later another Subscriber comes in, that second subscriber will receive its own emissions that "start over".

from rx import Observable  
import time  
  
source = Observable.interval(1000)  
  
source.subscribe(lambda s: print("Subscriber 1: {0}".format(s)))  
  
# sleep 5 seconds, then add another subscriber  
time.sleep(5)  
source.subscribe(lambda s: print("Subscriber 2: {0}".format(s)))  
  
input("Press any key to exit\n")

**OUTPUT:**

Subscriber 1: 0  
Subscriber 1: 1  
Subscriber 1: 2  
Subscriber 1: 3  
Press any key to exit  
Subscriber 1: 4  
Subscriber 2: 0  
Subscriber 1: 5  
Subscriber 2: 1  
Subscriber 1: 6  
Subscriber 2: 2  
Subscriber 1: 7  
Subscriber 2: 3

Subscriber 2 starts at 0 while Subscriber 2 is already at 4. If we want both to be on the same timer, we can use publish() to create a ConnectableObservable.

from rx import Observable  
import time  
  
source = Observable.interval(1000).publish()  
  
source.subscribe(lambda s: print("Subscriber 1: {0}".format(s)))  
source.connect()  
  
# sleep 5 seconds, then add another subscriber  
time.sleep(5)  
source.subscribe(lambda s: print("Subscriber 2: {0}".format(s)))  
  
input("Press any key to exit\n")

**OUTPUT:**

Subscriber 1: 0  
Subscriber 1: 1  
Subscriber 1: 2  
Subscriber 1: 3  
Press any key to exit  
Subscriber 1: 4  
Subscriber 2: 4  
Subscriber 1: 5  
Subscriber 2: 5

## 8.1C - Autoconnecting (EXTRA)

We can have our ConnectableObservable automatically connect() itself when it gets a Subscriber by calling ref\_count() on it.

from rx import Observable  
import time  
  
source = Observable.interval(1000).publish().ref\_count()  
  
source.subscribe(lambda s: print("Subscriber 1: {0}".format(s)))  
  
# sleep 5 seconds, then add another subscriber  
time.sleep(5)  
source.subscribe(lambda s: print("Subscriber 2: {0}".format(s)))  
  
input("Press any key to exit\n")

You can also call an alias for publish().ref\_count() by calling share() instead.

source = Observable.interval(1000).share()

Again, multicasting is helpful when you want all Subscribers to receive the same emissions simultaneously and prevent redundant, expensive work for each Subscriber.

## 8.2D - Multicasting Specific Points (EXTRA)

The placement of the mutlicasting matters. For instance, if you map three emissions to three random integers, but multicast *before* the map() operation, two subscribers will both receive separate random integers.

from rx import Observable  
from random import randint  
  
  
three\_emissions = Observable.range(1, 3).publish()  
  
three\_random\_ints = three\_emissions.map(lambda i: randint(1, 100000))  
  
three\_random\_ints.subscribe(lambda i: print("Subscriber 1 Received: {0}".format(i)))  
three\_random\_ints.subscribe(lambda i: print("Subscriber 2 Received: {0}".format(i)))  
  
three\_emissions.connect()

**OUTPUT:**

Subscriber 1 Received: 56976  
Subscriber 1 Received: 882  
Subscriber 1 Received: 59873  
Subscriber 2 Received: 12911  
Subscriber 2 Received: 47631  
Subscriber 2 Received: 84640

However, putting the publish() *after* the map() operation, both subscribers will receive the same emissions.

from rx import Observable  
from random import randint  
  
  
three\_emissions = Observable.range(1, 3)  
  
three\_random\_ints = three\_emissions.map(lambda i: randint(1, 100000)).publish()  
  
three\_random\_ints.subscribe(lambda i: print("Subscriber 1 Received: {0}".format(i)))  
three\_random\_ints.subscribe(lambda i: print("Subscriber 2 Received: {0}".format(i)))  
  
three\_random\_ints.connect()

**OUTPUT:**

Subscriber 1 Received: 17500  
Subscriber 2 Received: 17500  
Subscriber 1 Received: 71398  
Subscriber 2 Received: 71398  
Subscriber 1 Received: 90457  
Subscriber 2 Received: 90457

Therefore, note that most operators will create a separate stream for each subscriber, even if upstream there is a mutlicasting operation. Typically, you multicast up to the point where operations are common to both subscribers. For instance, if one subscriber simply printed each random number while the second subscriber performed a sum on them, the multcasting will happen before the summing operation since that is where digressive operations occur.

from rx import Observable  
from random import randint  
  
  
three\_emissions = Observable.range(1, 3)  
  
three\_random\_ints = three\_emissions.map(lambda i: randint(1, 100000)).publish()  
  
three\_random\_ints.subscribe(lambda i: print("Subscriber 1 Received: {0}".format(i)))\  
  
three\_random\_ints.reduce(lambda total, item: total + item) \  
 .subscribe(lambda i: print("Subscriber 2 Received: {0}".format(i)))  
  
three\_random\_ints.connect()

**OUTPUT:**\*

Subscriber 1 Received: 17618  
Subscriber 1 Received: 66227  
Subscriber 1 Received: 36159  
Subscriber 2 Received: 120004

## 8.2E - Subjects (EXTRA)

Another way to create a kmutlicasted Observable is by declaring a Subject. A Subject is both an Observable and Observer, and you can call its Observer functions to push items through it and up to any Subscribers at any time. It will push these items to all subscribers.

from rx.subjects import Subject  
  
subject = Subject()  
  
subject.filter(lambda i: i < 100) \  
 .map(lambda i: i \* 1000) \  
 .subscribe(lambda i: print(i))  
  
subject.on\_next(10)  
subject.on\_next(50)  
subject.on\_next(105)  
subject.on\_next(87)  
  
subject.on\_completed()

**OUTPUT:**

10000  
50000  
87000

While they seem convenient, Subjects are often discouraged from being used. They can easily encourage antipatterns and are prone to abuse. They also are difficult to compose against and do not respect subscribe\_on(). It is better to create Observables that strictly come from one defined source, rather than be openly mutable and have anything push items to it at anytime. Use Subjects with discretion.

## 8.2 - Querying Live Twitter Feeds

You can use Observable.create() to wrangle and analyze a live Twitter feed.

You will need to create your own application and access keys/tokens at https://apps.twitter.com.

If we want to query a live stream of Tweets pertaining to the topics of "Britain" or "France", we can do it like this:

from tweepy.streaming import StreamListener  
from tweepy import OAuthHandler  
from tweepy import Stream  
import json  
from rx import Observable  
  
# Variables that contains the user credentials to access Twitter API  
access\_token = "PUT YOURS HERE"  
access\_token\_secret = "PUT YOURS HERE"  
consumer\_key = "PUT YOURS HERE"  
consumer\_secret = "PUT YOURS HERE"  
  
  
def tweets\_for(topics):  
 def observe\_tweets(observer):  
 class TweetListener(StreamListener):  
 def on\_data(self, data):  
 observer.on\_next(data)  
 return True  
  
 def on\_error(self, status):  
 observer.on\_error(status)  
  
 # This handles Twitter authetification and the connection to Twitter Streaming API  
 l = TweetListener()  
 auth = OAuthHandler(consumer\_key, consumer\_secret)  
 auth.set\_access\_token(access\_token, access\_token\_secret)  
 stream = Stream(auth, l)  
 stream.filter(track=topics)  
  
 return Observable.create(observe\_tweets).share()  
  
  
topics = ['Britain', 'France']  
  
tweets\_for(topics) \  
 .map(lambda d: json.loads(d)) \  
 .subscribe(on\_next=lambda s: print(s), on\_error=lambda e: print(e))

# IX - Concurrency

(Refer to slides to cover concurrency concepts).

## 9.1 - Using subscribe\_on()

## 9.1A - Two Long-Running Processes

We will not dive too deep into concurrency topics, but we will learn enough to make it useful and speed up slow processes. Note also the [GIL issue in Python](https://stackoverflow.com/questions/1294382/what-is-a-global-interpreter-lock-gil#1294402) can undermine concurrency performance in Python applications, but hopefully you will still get some marginal benefit. Be sure to test your concurrency strategies and measure what brings the best performance.

Keep in mind your output may be different than mine, because concurrency tends to shuffle emissions of multiple sources. Output is almost never deterministic when multiple threads are doing work simultaneously and being merged.

Below, we create two Observables we will call "Task 1" and "Task 2". The first Observable is emitting five strings and the other emits numbers in a range. These Observables will fire quickly when subscribed to, but concurrency is more useful and apparent with long-running tasks. To emulate long-running expensive processes, we will need to exaggerate and slow down emissions. We can use a intense\_calculation() function that sleeps for a short random duration (between 0.5 to 2.0 seconds) before returning the value it was given. Then we can use this in a map() operator for each Observable.

We will use current\_thread().name to identify the thread that is calling each on\_next() in the Subscriber. Python will label each thread it creates consecutively as "Thread-1", "Thread-2", "Thread-3", etc.

Before "Task 2" can start, it must wait for "Task 1" to call on\_completed() because by default both are on the ImmediateScheduler. This scheduler uses the same MainThread that runs our Python program.

from rx import Observable  
from threading import current\_thread  
import multiprocessing, time, random  
  
def intense\_calculation(value):  
 # sleep for a random short duration between 0.5 to 2.0 seconds to simulate a long-running calculation  
 time.sleep(random.randint(5,20) \* .1)  
 return value  
  
# Create TASK 1  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe(on\_next=lambda s: print("TASK 1: {0} {1}".format(current\_thread().name, s)),  
 on\_error=lambda e: print(e),  
 on\_completed=lambda: print("TASK 1 done!"))  
  
# Create TASK 2  
Observable.range(1,10) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe(on\_next=lambda i: print("TASK 2: {0} {1}".format(current\_thread().name, i)),  
 on\_error=lambda e: print(e),  
 on\_completed=lambda: print("TASK 2 done!"))  
  
input("Press any key to exit\n")

**OUTPUT (May not match yours):**

TASK 1: MainThread Alpha  
TASK 1: MainThread Beta  
TASK 1: MainThread Gamma  
TASK 1: MainThread Delta  
TASK 1: MainThread Epsilon  
TASK 1 done!  
TASK 2: MainThread 1  
TASK 2: MainThread 2  
TASK 2: MainThread 3  
TASK 2: MainThread 4  
TASK 2: MainThread 5  
TASK 2: MainThread 6  
TASK 2: MainThread 7  
TASK 2: MainThread 8  
TASK 2: MainThread 9  
TASK 2: MainThread 10  
TASK 2 done!

## 9.1B - Kicking off both processes simultaneously

This would go much faster if we kick off both "Task 1" and "Task 2" simultaneously. We can kick off the Subscription in "Task 1" and then immediately move on to kicking off "Task 2". We will kick off both of their subscriptions simultaneously.

In advance, we can create a ThreadPoolScheduler that holds a number of threads equaling the *number of CPU's on your computer* + 1. If your computer has 4 cores, the ThreadPoolScheduler will have 5 threads. The reason for the extra thread is to utilize any idle time of the other threads. To make the Observables work on this ThreadPoolScheduler, we can pass it to a subscribe\_on() operator anywhere in the chain. The subscribe\_on(), no matter where it is in the chain, will instruct the source Observable what thread to push items on.

You are welcome to experiment and specify your own arbitrary number of threads. Just keep in mind there will be a point of diminishing return.

The code below will execute all the above:

from rx import Observable  
from rx.concurrency import ThreadPoolScheduler  
from threading import current\_thread  
import multiprocessing, time, random  
  
  
def intense\_calculation(value):  
 # sleep for a random short duration between 0.5 to 2.0 seconds to simulate a long-running calculation  
 time.sleep(random.randint(5,20) \* .1)  
 return value  
  
# calculate number of CPU's and add 1, then create a ThreadPoolScheduler with that number of threads  
optimal\_thread\_count = multiprocessing.cpu\_count() + 1  
pool\_scheduler = ThreadPoolScheduler(optimal\_thread\_count)  
  
print("We are using {0} threads".format(optimal\_thread\_count))  
  
# Create Task 1  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe\_on(pool\_scheduler) \  
 .subscribe(on\_next=lambda s: print("TASK 1: {0} {1}".format(current\_thread().name, s)),  
 on\_error=lambda e: print(e),  
 on\_completed=lambda: print("TASK 1 done!"))  
  
# Create Task 2  
Observable.range(1,10) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe\_on(pool\_scheduler) \  
 .subscribe(on\_next=lambda i: print("TASK 2: {0} {1}".format(current\_thread().name, i)),  
 on\_error=lambda e: print(e),  
 on\_completed=lambda: print("TASK 2 done!"))  
  
input("Press any key to exit\n")

**OUTPUT (May not match yours):**

TASK 1: Thread-1 Alpha  
TASK 2: Thread-2 1  
TASK 1: Thread-1 Beta  
TASK 1: Thread-1 Gamma  
TASK 2: Thread-2 2  
TASK 2: Thread-2 3  
TASK 1: Thread-1 Delta  
TASK 2: Thread-2 4  
TASK 1: Thread-1 Epsilon  
TASK 1 done!  
TASK 2: Thread-2 5  
TASK 2: Thread-2 6  
TASK 2: Thread-2 7  
TASK 2: Thread-2 8  
TASK 2: Thread-2 9  
TASK 2: Thread-2 10  
TASK 2 done!

We use the input() function to hold the MainThread and keep the application alive until a key is pressed, allowing the Observables to fire. Notice how the emissions between Task 1 and Task 2 are interleaved, indicating they are both working at the same time. If we did not have the subscribe\_on() calls, "Task 1" would have to finish before "Task 2" can start, because they both would use the default ImmediateScheduler as shown earlier.

Notice also that "Task 1" requested a thread from our ThreadPoolScheduler and got Thread-1, and "Task 2" got Thread 2. They both will continue to use these threads until on\_completed() is called on their Subscribers. Then the threads will be given back to the ThreadPoolScheduler so they can be used again later.

## 9.2 - Using observe\_on() to redirect in the middle of the chain

Not all source Observables will respect a subscribe\_on() you specify. This is especially true for time-driven sources like Observable.interval() which will use the TimeoutScheduler and effectively ignore any subscribe\_on() you try to call. However, although you cannot instruct the source to emit on a different scheduler, you can specify a different scheduler to be used *at a certain point* in the Observable chain by using observe\_on().

Let's create a third process called "Task 3". The source will be an Observable.interval() which will emit on the TimeoutScheduler. After each emitted number is multiplied by 100, the emission is then moved to the ThreadPoolScheduler via the observe\_on() operator. This means for the remaining operators, the emissions will be passed on the ThreadPoolScheduler. Unlike subscribe\_on(), the placement of observe\_on() does matter as it will redirect to a different executor *at that point* in the chain.

from rx import Observable  
from rx.concurrency import ThreadPoolScheduler  
from threading import current\_thread  
import multiprocessing, time, random  
  
def intense\_calculation(value):  
 # sleep for a random short duration between 0.5 to 2.0 seconds to simulate a long-running calculation  
 time.sleep(random.randint(5,20) \* .1)  
 return value  
  
# calculate number of CPU's and add 1, then create a ThreadPoolScheduler with that number of threads  
optimal\_thread\_count = multiprocessing.cpu\_count() + 1  
pool\_scheduler = ThreadPoolScheduler(optimal\_thread\_count)  
  
# Create Task 1  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon"]) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe\_on(pool\_scheduler) \  
 .subscribe(on\_next=lambda s: print("TASK 1: {0} {1}".format(current\_thread().name, s)),  
 on\_error=lambda e: print(e),  
 on\_completed=lambda: print("TASK 1 done!"))  
  
# Create Task 2  
Observable.range(1,10) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe\_on(pool\_scheduler) \  
 .subscribe(on\_next=lambda i: print("TASK 2: {0} {1}".format(current\_thread().name, i)), on\_error=lambda e: print(e), on\_completed=lambda: print("TASK 2 done!"))  
  
# Create Task 3, which is infinite  
Observable.interval(1000) \  
 .map(lambda i: i \* 100) \  
 .observe\_on(pool\_scheduler) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe(on\_next=lambda i: print("TASK 3: {0} {1}".format(current\_thread().name, i)), on\_error=lambda e: print(e))  
  
input("Press any key to exit\n")

**OUTPUT (May not match yours):**

TASK 2: Thread-2 1  
TASK 1: Thread-1 Alpha  
TASK 1: Thread-1 Beta  
TASK 3: Thread-4 0  
TASK 2: Thread-2 2  
TASK 1: Thread-1 Gamma  
TASK 3: Thread-4 100  
TASK 1: Thread-1 Delta  
TASK 2: Thread-2 3  
TASK 3: Thread-6 200  
TASK 1: Thread-1 Epsilon  
TASK 1 done!  
TASK 3: Thread-13 300  
TASK 2: Thread-2 4  
TASK 3: Thread-15 400  
TASK 2: Thread-2 5  
TASK 3: Thread-4 500  
TASK 2: Thread-2 6  
TASK 3: Thread-4 600  
TASK 2: Thread-2 7  
TASK 3: Thread-4 700  
TASK 2: Thread-2 8  
TASK 3: Thread-4 800  
TASK 2: Thread-2 9  
TASK 3: Thread-4 900  
TASK 3: Thread-4 1000  
TASK 2: Thread-2 10  
TASK 2 done!  
TASK 3: Thread-4 1100  
TASK 3: Thread-4 1200  
TASK 3: Thread-4 1300  
TASK 3: Thread-4 1400  
...

Unlike subscribe\_on(), the observe\_on() may use a different thread for each emission rather than reserving one thread for all emissions. You can use as many observe\_on() calls as you like in an Observable chain to redirect emissions to different thread pools at different points in the chain. But you can only have one subscribe\_on().

You can use the do\_action() to essentially put Subscribers in the middle of the Observable chain, often for debugging purposes. This can be helpful to print the current thread at different points in the Observable chain. Refer to the Appendix to learn more.

# 9.3 - Parallelization

An Observable will only process one item at a time. However, we can use a subscribe\_on() or an observe\_on() in a flat\_map() and do multiple operations in parallel *within* that flat\_map().

For instance, say I have 10 Strings I need to process. Because our intense\_calculation() will take 0.5 to 2.0 seconds to process each emission, this could take up to 20 seconds.

from rx import Observable  
from rx.concurrency import ThreadPoolScheduler  
from threading import current\_thread  
import multiprocessing, time, random  
  
def intense\_calculation(value):  
 # sleep for a random short duration between 0.5 to 2.0 seconds to simulate a long-running calculation  
 time.sleep(random.randint(5,20) \* .1)  
 return value  
  
# Create Parallel Process  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon","Zeta","Eta","Theta","Iota","Kappa"]) \  
 .map(lambda s: intense\_calculation(s)) \  
 .subscribe(on\_next=lambda s: print("{0} {1}".format(current\_thread().name, s)),  
 on\_error=lambda e: print(e),  
 on\_completed=lambda: print("TASK 1 done!"))  
  
  
input("Press any key to exit\n")

This would go much faster if we processed multiple emissions at a time rather than one at a time. Let's set

My computer has 8 cores, but let's use Python to count the number of cores dynamically. Let's set a ThreadPoolScheduler to have that many threads (plus one) according to our rough optimal formula. Rather than process 1 item at a time, I can now process 9 at a time which will yield a much faster completion. I just need to make sure the expensive operators happen within a flat\_map(), starting with that single emission wrapped in an Observable.just() and scheduled using subscribe\_on().

from rx import Observable  
from rx.concurrency import ThreadPoolScheduler  
from threading import current\_thread  
import multiprocessing, time, random  
  
def intense\_calculation(value):  
 # sleep for a random short duration between 0.5 to 2.0 seconds to simulate a long-running calculation  
 time.sleep(random.randint(5,20) \* .1)  
 return value  
  
# calculate number of CPU's and add 1, then create a ThreadPoolScheduler with that number of threads  
optimal\_thread\_count = multiprocessing.cpu\_count() + 1  
pool\_scheduler = ThreadPoolScheduler(optimal\_thread\_count)  
  
# Create Parallel Process  
Observable.from\_(["Alpha","Beta","Gamma","Delta","Epsilon","Zeta","Eta","Theta","Iota","Kappa"]) \  
 .flat\_map(lambda s:  
 Observable.just(s).subscribe\_on(pool\_scheduler).map(lambda s: intense\_calculation(s))  
 ) \  
 .subscribe(on\_next=lambda i: print("{0} {1}".format(current\_thread().name, i)),  
 on\_error=lambda e: print(e),  
 on\_completed=lambda: print("TASK 1 done!"))  
  
  
input("Press any key to exit\n")

**OUTPUT:**

Press any key to exit  
Thread-4 Delta  
Thread-6 Zeta  
Thread-1 Alpha  
Thread-2 Beta  
Thread-9 Iota  
Thread-3 Gamma  
Thread-8 Theta  
Thread-4 Kappa  
Thread-7 Eta  
Thread-5 Epsilon  
PROCESS done!

Now this takes less than 3 seconds! Of course the 10 items are now racing each other and complete in a random order. Only 9 threads are available, thus a 10th item must wait for one of the first 9 to complete. It looks like this item was Kappa which received Thread-4 from Delta after it was done.

Parallelization using flat\_map() (or merge\_all()) can greatly increase performance if each emission must go through an expensive operation. Just wrap that emission into an Observable.just(), schedule it with subscribe\_on() or observe\_on() (preferably subscribe\_on() if possible), and then make all the expensive operations happen inside the flat\_map().

The reason each emission must be broken into its own Observable is because an Observable is sequential and cannot be parallelized. But you can take multiple Observables and merge them into a single Observable, even if they are working on a different threads. The merged Observable will only push out items on one thread, but the items inside flat\_map() can process in parallel.

# 9.4 - Redirecting Work with switch\_map()

Imagine you have an Observable and you use flat\_map() to yield a emissions from another Observable. However, say you wanted to *only* puruse the Observable for the latest emission, and kill any previous Observables to stop their emissions coming out of flat\_map().

You can achieve this with switch\_map(). It operates much like a flat\_map(), but will only fire items for the latest emission. All previous Observables derived from previous emissions will be unsubscribed.

This example is slightly contrived, but let's say we have a finite Observable emitting Strings. We want an Observable.interval() to emit every 6 seconds, and have each emission flat map to our Observable of strings which are artificially slowed by intense\_calculation(). But instead of using flat\_map(), we can use switch\_map() to only chase after the latest Observable created off each interval emission and unsubscribe previous ones.

We also need to parallelize using subscribe\_on() so each Observable within the switch\_map() happens on a different thread.

from rx import Observable  
from rx.concurrency import ThreadPoolScheduler  
from threading import current\_thread  
import multiprocessing, time, random  
  
  
def intense\_calculation(value):  
 # sleep for a random short duration between 0.5 to 2.0 seconds to simulate a long-running calculation  
 time.sleep(random.randint(5, 20) \* .1)  
 return value  
  
# calculate number of CPU's and add 1, then create a ThreadPoolScheduler with that number of threads  
optimal\_thread\_count = multiprocessing.cpu\_count() + 1  
pool\_scheduler = ThreadPoolScheduler(optimal\_thread\_count)  
  
strings = Observable.from\_(["Alpha", "Beta", "Gamma", "Delta", "Epsilon", "Zeta", "Eta", "Theta", "Iota", "Kappa"])  
  
Observable.interval(6000) \  
 .switch\_map(lambda i: strings.map(lambda s: intense\_calculation(s)).subscribe\_on(pool\_scheduler)) \  
 .subscribe(on\_next = lambda s: print("Received {0} on {1}".format(s, current\_thread().name)),  
 on\_error = lambda e: print(e))  
  
  
input("Press any key to exit\n")

**OUTPUT (May Vary):**

Press any key to exit  
Received Alpha on Thread-2  
Received Beta on Thread-2  
Received Gamma on Thread-2  
Received Delta on Thread-2  
Received Alpha on Thread-4  
Received Beta on Thread-4  
Received Gamma on Thread-4  
Received Alpha on Thread-6  
Received Beta on Thread-6  
Received Gamma on Thread-6  
Received Delta on Thread-6  
Received Epsilon on Thread-6  
Received Alpha on Thread-2  
...

Using switch\_map() is a convenient way to cancel current work when new work comes in, rather than queuing up work. This is desirable if you are only concerned with the latest data or want to cancel obsolete processing. If you are scraping web data on a schedule using Observable.interval(), but a scrape instance takes too long and a new scrape requests comes in, you can cancel that scrape and start the next one.

# Appendix

## 1 - Deferred Observables

A behavior to be aware of with Observable.from\_() and other functions that create Observables is they may not reflect changes that happen to their sources.

For instance, if have an Observable.range() built off two variables x and y, and one of the variables changes later, this change will not be captured by the source.

1  
2  
3  
4  
5  
  
Setting y = 10  
  
1  
2  
3  
4  
5

**OUTPUT:**

Alpha  
Beta  
Gamma  
  
Adding Delta!  
  
Alpha  
Beta  
Gamma  
Delta

Using Observable.defer() allows you to create a new Observable from scratch each time it is subscribed, and therefore capturing anything that might have changed about its source. Just supply how to create the Observable through a lambda.

from rx import Observable  
  
x = 1  
y = 5  
  
integers = Observable.defer(lambda: Observable.range(x, y))  
integers.subscribe(lambda i: print(i))  
  
print("\nSetting y = 10\n")  
y = 10  
  
integers.subscribe(lambda i: print(i))

**OUTPUT:**

1  
2  
3  
4  
5  
  
Setting y = 10  
  
1  
2  
3  
4  
5  
6  
7  
8  
9  
10

The lambda argument ensures the Observable source declaration is rebuilt each time it is subscribed to. This is especially helpful to use with data sources that can only be iterated once, as opposed to calling a helper function for each Subscriber (this was covered in Section VII):

def get\_all\_customers():  
 stmt = text("SELECT \* FROM CUSTOMER")  
 return Observable.from\_(conn.execute(stmt))

We can actually create an Obserable that is truly reusable for multiple Subscribers.

stmt = text("SELECT \* FROM CUSTOMER")  
  
# Will suppport multiple subscribers and coldly replay to each one  
all\_customers = Observable.defer(lambda: Observable.from\_(conn.execute(stmt)))

## 2 - Debugging with do\_action()

A helpful operator that provides insight into any point in the Observable chain is the do\_action(). This essentially allows us to insert a Subscriber after any operator we want, and pass one or more of on\_next(), on\_completed(), and on\_error() actions.

from rx import Observable  
  
Observable.from\_(["Alpha", "Beta", "Gamma", "Delta", "Epsilon"]) \  
 .map(lambda s: len(s)) \  
 .do\_action(on\_next=lambda i: print("Receiving {0} from map()".format(i)),  
 on\_completed=lambda: print("map() is done!")) \  
 .to\_list() \  
 .subscribe(on\_next=lambda l: print("Subscriber received {0}".format(l)),  
 on\_completed=lambda: print("Subscriber done!"))

**OUTPUT:**

Receiving 5 from map()  
Receiving 4 from map()  
Receiving 5 from map()  
Receiving 5 from map()  
Receiving 7 from map()  
map() is done!  
Subscriber received [5, 4, 5, 5, 7]  
Subscriber done!

Above, we declare a do\_action right after the map() operation emitting the lengths. We print each length emission before it goes to the to\_list(). Finally, on\_completed is called and prints a notification that map() is not giving any more items. Then it pushes the completion event to the to\_list() which then pushes the List to the Subscriber. Then to\_list() calls on\_completed() up to the Subscriber *after* the List is emitted.

Use do\_action() when you need to "peek" inside any point in the Observable chain, either for debugging or quickly call actions at that point.

## 3 - Subjects

Another way to create an Observable is by declaring a Subject. A Subject is both an Observable and Observer, and you can call its Observer functions to push items through it and up to any Subscribers at any time.

from rx.subjects import Subject  
  
subject = Subject()  
  
subject.filter(lambda i: i < 100) \  
 .map(lambda i: i \* 1000) \  
 .subscribe(lambda i: print(i))  
  
subject.on\_next(10)  
subject.on\_next(50)  
subject.on\_next(105)  
subject.on\_next(87)  
  
subject.on\_completed()

**OUTPUT:**

10000  
50000  
87000

While they seem convenient, Subjects are often discouraged from being used. They can easily encourage antipatterns and are prone to abuse. They also are difficult to compose against and do not respect subscribe\_on(). It is better to create Observables that strictly come from one defined source, rather than be openly mutable and have anything push items to it at anytime. Use Subjects with discretion.

## 4. Error Recovery

There are a number of error recovery operators, but we will cover two helpful ones. Say you have an Observable operation that will ultimately attempt to divide by zero and therefore throw an error.

from rx import Observable  
  
Observable.from\_([5, 6, 2, 0, 1, 35]) \  
 .map(lambda i: 5 / i) \  
 .subscribe(on\_next=lambda i: print(i), on\_error=lambda e: print(e))

**OUTPUT:**

1.0  
0.8333333333333334  
2.5  
division by zero

There are multiple ways to handle this. Of course, the best way is to be proactive and use filter() to hold back any 0 value emissions. But for the sake of example, let's say we did not expect this error and we want a way to handle any errors we have not considered.

One way is to use on\_error\_resume\_next() which will switch to an alternate Observable source in the event there is an error. This is somewhat contrived, but if we encounter an error we can switch to emitting an Observable.range().

from rx import Observable  
  
Observable.from\_([5, 6, 2, 0, 1, 35]) \  
 .map(lambda i: 5 / i) \  
 .on\_error\_resume\_next(Observable.range(1,10)) \  
 .subscribe(on\_next=lambda i: print(i), on\_error=lambda e: print(e))

**OUTPUT:**

1.0  
0.8333333333333334  
2.5  
1  
2  
3  
4  
5  
6  
7  
8  
9  
10

It probably would be more realistic to pass an Observable.empty() instead to simply stop emissions once an error happens.

from rx import Observable  
  
Observable.from\_([5, 6, 2, 0, 1, 35]) \  
 .map(lambda i: 5 / i) \  
 .on\_error\_resume\_next(Observable.empty()) \  
 .subscribe(on\_next=lambda i: print(i), on\_error=lambda e: print(e))

**OUTPUT:**

1.0  
0.8333333333333334  
2.5

Although this is not a good example to use it, you can also use retry() to re-attempt subscribing to the Observable and hope the next set of emissions are successful without error. You typically should pass an integer argument to specify the number of retry attempts before it gives up and lets the error go to the Subscriber. If you do not, it will retry an infinite number of times.

from rx import Observable  
  
Observable.from\_([5, 6, 2, 0, 1, 35]) \  
 .map(lambda i: 5 / i) \  
 .retry(3) \  
 .subscribe(on\_next=lambda i: print(i), on\_error=lambda e: print(e))

**OUTPUT:**

1.0  
0.8333333333333334  
2.5  
1.0  
0.8333333333333334  
2.5  
1.0  
0.8333333333333334  
2.5  
division by zero

You can also use this in combination with the delay() operator to hold off subscribing for a fixed time period, which can be helpful for intermittent connectivity problems.

## 5. combine\_latest()

There is one operation for merging multiple Observables together we did not cover: combine\_latest(). It behaves much like zip() but will only combine the *latest* emissions for each source in the event one of them emits something. This is helpful for hot event sources especially, such as user inputs in a UI, where do you not care what the previous emissions are.

Below, we have two interval sources put in combine\_latest(): source1 emitting every 3 seconds and source2 every 1 second. Notice that source2 is going to emit a lot faster, but rather than get queued up like in zip() waiting for an emission from source1, it is going to pair with only the latest emission from source1. It is not going to wait for any emission to be zipped with. Conversely, when source1 does emit something it is going to pair with the latest emission from source2, not wait for an emission.

from rx import Observable  
  
source1 = Observable.interval(3000).map(lambda i: "SOURCE 1: {0}".format(i))  
source2 = Observable.interval(1000).map(lambda i: "SOURCE 2: {0}".format(i))  
  
Observable.combine\_latest(source1, source2, lambda s1,s2: "{0}, {1}".format(s1,s2)) \  
 .subscribe(lambda s: print(s))  
  
input("Press any key to quit\n")

**OUTPUT:**

Press any key to quit  
SOURCE 1: 0, SOURCE 2: 1  
SOURCE 1: 0, SOURCE 2: 2  
SOURCE 1: 0, SOURCE 2: 3  
SOURCE 1: 0, SOURCE 2: 4  
SOURCE 1: 1, SOURCE 2: 4  
SOURCE 1: 1, SOURCE 2: 5  
SOURCE 1: 1, SOURCE 2: 6  
SOURCE 1: 1, SOURCE 2: 7  
SOURCE 1: 2, SOURCE 2: 7  
SOURCE 1: 2, SOURCE 2: 8  
SOURCE 1: 2, SOURCE 2: 9  
SOURCE 1: 2, SOURCE 2: 10  
SOURCE 1: 3, SOURCE 2: 10  
SOURCE 1: 3, SOURCE 2: 11  
SOURCE 1: 3, SOURCE 2: 12  
SOURCE 1: 3, SOURCE 2: 13

Again, this is a helpful alternative for zip() if you want to emit the *latest combinations* from two or more Observables.