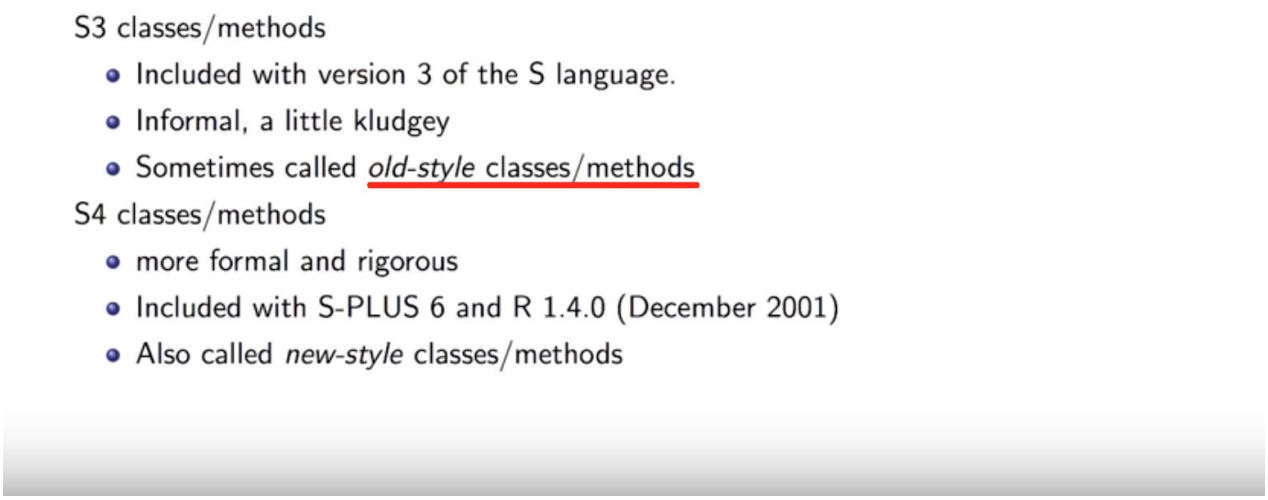
[Classes and Methods in R][https://www.youtube.com/watch?v=93N0HdoZW9g&list=PLI098pDmWQZqjayjwmeSJ2Zgt1M1Yi_RE&index=10&t=0s]

- Two styles of classes and methods



S3缺点就是新类别对象没有正式的定义

- Two worlds living side by side

- For now (and the forseeable future), S3 classes/methods and S4 classes/methods are separate systems (but they can be mixed to some degree).
- Each system can be used fairly independently of the other.
- Developers of new projects (you!) are encouraged to use the S4 style classes/methods.
  - Used extensively in the Bioconductor project
- But many developers still use S3 classes/methods because they are "quick and dirty" (and easier).
- In this lecture we will focus primarily on S4 classes/methods
- The code for implementing S4 classes/methods in R is in the **methods** package, which is usually loaded by default (but you can load it with `library(methods)` if for some reason it is not loaded)

- Object Oriented Programming in R

- A *class* is a description of an thing. A class can be defined using `setClass()` in the **methods** package.
- An *object* is an instance of a class. Objects can be created using `new()`.
- A *method* is a function that only operates on a certain class of objects.
- A generic function is an R function which dispatches methods. A generic function typically encapsulates a "generic" concept (e.g. `plot`, `mean`, `predict`, ...)
  - The generic function does not actually do any computation.
- A *method* is the implementation of a generic function for an object of a particular class.

generic funciton 典型地包含了'generic' 概念(plot,mean,predict,..是generic function而不是method)

generic funciton识别object的class，然后应用对应的method

- Things to look up

- The help files for the 'methods' package are extensive — do read them as they are the primary documentation
- You may want to start with `?Classes` and `?Methods`
- Check out `?setClass`, `?setMethod`, and `?setGeneric`
- Some of it gets technical, but try your best for now—it will make sense in the future as you keep using it.
- Most of the documentation in the **methods** package is oriented towards developers/programmers as these are the primary people using classes/methods

- Classes

All objects in R have a class which can be determined by the class function

```
> class(1)
[1] "numeric"
> class(TRUE)
[1] "logical"
> class(rnorm(100))
[1] "numeric"
> class(NA)
[1] "logical"
> class("foo")
[1] "character"
```

- Classes (cont'd)

Data classes go beyond the atomic classes

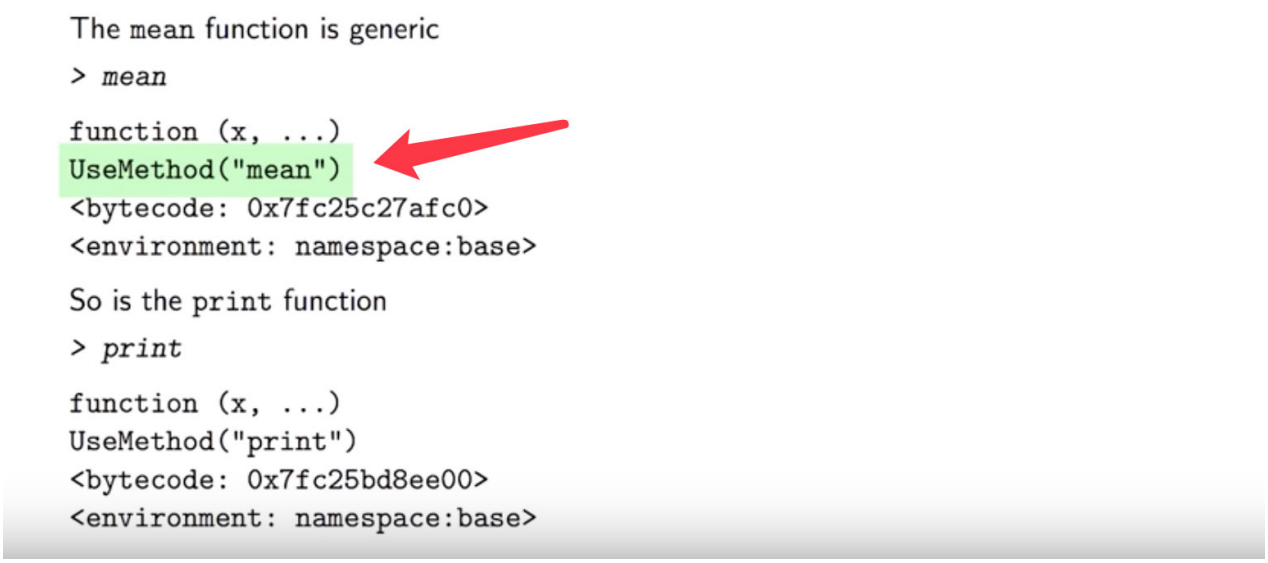
```
> x <- rnorm(100)
> y <- x + rnorm(100)
> fit <- lm(y ~ x)  ## linear regression model
> class(fit)
[1] "lm"
```

可以指定输出class，从而为输出配置对应的method

- Generics/Methods in R

- S4 and S3 style generic functions look different but conceptually, they are the same (they play the same role).
- When you program you can write new methods for an existing generic OR create your own generics and associated methods.
- Of course, if a data type does not exist in R that matches your needs, you can always define a new class along with generics/methods that go with it

- An S3 generic function(in the 'base' package)



根据x类型使用对应的'mean' method

- S3 methods

```
> methods("mean")
[1] mean.data.frame mean.Date
[3] mean.default    mean.difftime
[5] mean.POSIXct    mean.POSIXlt
```

使用method函数查看对应function的method信息，点后面指定class类型

- An S4 generic funciton(from the 'methods' pacakge)

The S4 equivalent of print is show

```
> show
standardGeneric for "show" defined from package "methods"

function (object)
standardGeneric("show")
<bytecode: 0x7fc25b5ced08>
<environment: 0x7fc25c51aea0>
Methods may be defined for arguments: object
Use  showMethods("show")  for currently available ones.
(This generic function excludes non-simple inheritance; see ?setIs)
```

The show function is usually not called directly (much like print) because objects are auto-printed

- S4 methods

There are many different methods for the show generic function

```
> showMethods("show")
Function: show (package methods)
object="ANY"
object="classGeneratorFunction"
object="classRepresentation"
object="envRefClass"
object="function"
    (inherited from: object="ANY")
object="genericFunction"
object="genericFunctionWithTrace"
object="MethodDefinition"
object="MethodDefinitionWithTrace"
object="MethodSelectionReport"
object="MethodWithNext"
```

- Generic/method mechanism(S3/4)

The first argument of a generic function is an object of a particular class (there may be other arguments)

1. The generic function checks the class of the object.
2. A search is done to see if there is an appropriate method for that class.
3. If there exists a method for that class, then that method is called on the object and we're done.
4. If a method for that class does not exist, a search is done to see if there is a default method for the generic. If a default exists, then the default method is called.
5. If a default method doesn't exist, then an error is thrown.

- Examining Code for Methods

Examining the code for an S3 or S4 method requires a call to a special function

- You cannot just print the code for a method like other functions because the code for the method is usually hidden.
- If you want to see the code for an S3 method, you can use the function `getS3method`.
- The call is `getS3method(<generic>, <class>)`
- For S4 methods you can use the function `getMethod`
- The call is `getMethod(<generic>, <signature>)` (more details later)

- S3 Class/Method: Example 1

What's happening here?

```
> set.seed(2)
> x <- rnorm(100)
> mean(x)
[1] -0.03069816
```

1. The class of x is "numeric"
2. But there is no mean method for "numeric" objects!
3. So we call the default function for `mean`.

- S3 Class/Method: Example1

```
> head(getS3method("mean", "default"))
1 function (x, trim = 0, na.rm = FALSE, ...)
2 {
3     if (!is.numeric(x) && !is.complex(x) && !is.logical(x)) {
4         warning("argument is not numeric or logical: returning NA")
5         return(NA_real_)
6     }
> tail(getS3method("mean", "default"))
19         lo <- floor(n * trim) + 1
20         hi <- n + 1 - lo
21         x <- sort.int(x, partial = unique(c(lo, hi)))[lo:hi]
22     }
23     .Internal(mean(x))
24 }
```

- S3 Class/Method: Example2

What happens here?

```
> set.seed(3)
> df <- data.frame(x = rnorm(100), y = 1:100)
> sapply(df, mean)
          x           y
0.01103557 50.50000000
```

1. The class of df is "data.frame"; in a data frame each column can be an object of a different class
2. We sapply over the columns and call the mean function
3. In each column, mean checks the class of the object and dispatches the appropriate method.
4. Here we have a numeric column and an integer column; in both cases mean calls the default method

数据框的每一列可以是不同的类型

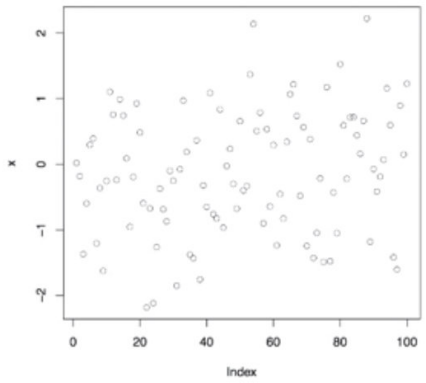
- Calling Methods

NOTE: Some methods are visible to the user (i.e. `mean.default`), but you should **never** call methods directly. Rather, use the generic function and let the method be dispatched automatically.

- S3 Class/Method: Example3

The `plot` function is generic and its behavior depends on the object being plotted.

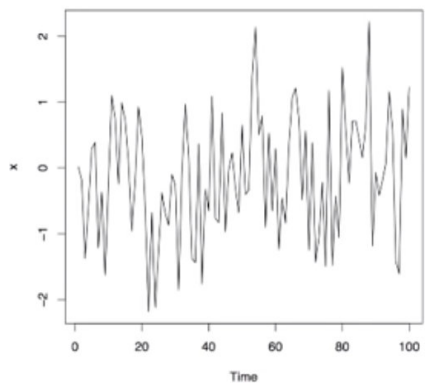
```
> set.seed(10)
> x <- rnorm(100)
> plot(x)
```



- S3 Class/Method: Example3

For time series objects, `plot` connects the dots

```
> set.seed(10)
> x <- rnorm(100)
> x <- as.ts(x)  ## Convert to a time series object
> plot(x)
```



- Write your own methods

If you write new methods for new classes, you'll probably end up writing methods for the following generics:

- print/show
- summary
- plot

There are two ways that you can extend the R system via classes/methods

- Write a method for a new class but for an existing generic function (i.e. like `print`)
- Write new generic functions and new methods for those generics

- S4 Classes

Why would you want to create a new class?

- To represent new types of data (e.g. gene expression, space-time, hierarchical, sparse matrices)
- New concepts/ideas that haven't been thought of yet (e.g. a fitted point process model, mixed-effects model, a sparse matrix)
- To abstract/hide implementation details from the user

I say things are "new" meaning that R does not know about them (not that they are new to the statistical community).

- S4 Class/Method: Creating a New Class

A new class can be defined using the `setClass` function

- At a minimum you need to specify the name of the class
- You can also specify data elements that are called *slots*
- You can then define methods for the class with the `setMethod` function
- Information about a class definition can be obtained with the `showClass` function

- S4 Class/Method: Polygon Class

Creating new classes/methods is usually not something done at the console; you likely want to save the code in a separate file

```
setClass("polygon",
         representation(x = "numeric",
                        y = "numeric"))
```

The slots for this class are x and y. The slots for an S4 object can be accessed with the @ operator.

- S4 Class/Method: Polygon Class

A plot method can be created with the setMethod function.

- For setMethod you need to specify a generic function (plot), and a *signature*.
- A signature is a character vector indicating the classes of objects that are accepted by the method. In this case, the plot method will take one type of object–a polygon object.

```
setMethod("plot", "polygon",
          function(x, y, ...) {
                  plot(x@x, x@y, type = "n", ...)
                  xp <- c(x@x, x@x[1])
                  yp <- c(x@y, x@y[1])
                  lines(xp, yp)
          })
```

Notice that the slots of the polygon (the x- and y-coordinates) are accessed with the @ operator.

function(x,y,...)必须含有x,y，因为'polygon'含有xy，可含有其他变量

- S4 Class/Method: Polygon Class

Create a new class

```
> setClass("polygon",
+          representation(x = "numeric",
+                         y = "numeric"))
```

Create a plot method for this class

```
> setMethod("plot", "polygon",
+           function(x, y, ...) {
+                   plot(x@x, x@y, type = "n", ...)
+                   xp <- c(x@x, x@x[1])
+                   yp <- c(x@y, x@y[1])
+                   lines(xp, yp)
+           })
[1] "plot"
```

If things go well, you will not get any messages or errors and nothing useful will be returned by either setClass or setMethod.

退出R, 重启需重新定义

- S4 Class/Method: Polygon Class

After calling setMethod the new plot method will be added to the list of methods for plot.

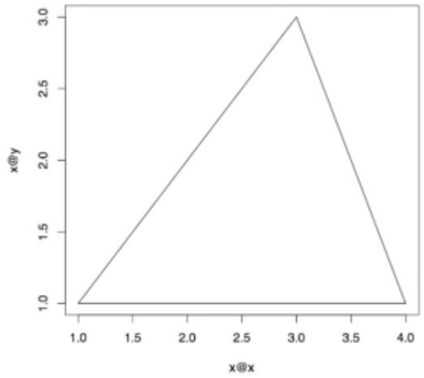
```
> showMethods("plot")
Function: plot (package graphics)
x="ANY"
x="polygon"
```

Notice that the signature for class polygon is listed. The method for ANY is the default method and it is what is called when now other signature matches

ANY, 表示defult method, polygon为自定义

- S4 Class/Method: Polygon class

```
> p <- new("polygon", x = c(1, 2, 3, 4), y = c(1, 2, 3, 1))
> plot(p)
```



- Where to Look, Places to Start

- The best way to learn this stuff is to look at examples (and try the exercises for the course)
- There are now quite a few examples on CRAN which use S4 classes/methods.
- Bioconductor (http://www.bioconductor.org) — a rich resource, even if you know nothing about bioinformatics
- Some packages on CRAN (as far as I know) — SparseM, gpclib, flexmix, its, lme4, orientlib, pixmap
- The `stats4` package (comes with R) has a bunch of classes/methods for doing maximum likelihood analysis.
