NATIONAL ENGINEERING CENTER
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2.0 Data Types and Simple Operators

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Module 6 of the Business Intelligence and Analytics Certification of UP NEC and the UP Center for Business Intelligence

Outline for this Training

- Introduction to R and R Studio
- **Data Types and Operators**
  - **Case Study on R Scripting**
- Reading, Manipulating and Writing Data
  - Case Study on Dataset Analysis with ETL
- Basic R Programming
  - Case Study: Writing Functions
- Graphics and Plotting
- Deploying R and Dashboard Generation
  - Case Study: Deploying a Simple Dashboard
- Deploying R with C#
  - Case Study: A Simple Standalone GUI For R Apps

Outline for This Session

- One Dimensional Vector Arithmetic
- Multi Dimensional Vector Arithmetic
- Case Study

One Dimensional Vector Arithmetic

Definition 2.1: Variable

- A variable is a memory storage location paired with an associated symbolic name (an *identifier*),
- It contains some known or unknown quantity or information referred to as a value.

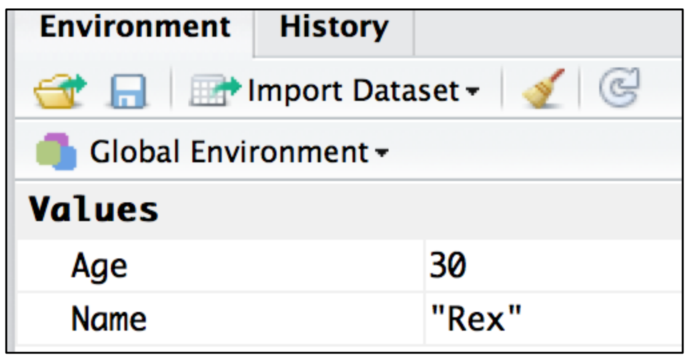
One Dimensional Vector Arithmetic

Example 2.1: Variables

- Example Type and Run the following Lines of Code

➢ `Name = "Rex"`

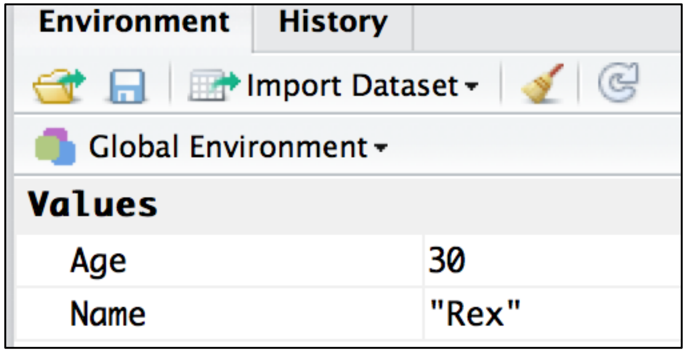
➢ `Age = 20`



One Dimensional Vector Arithmetic

Definition 2.2: The Environment

- The environment is where you can **view all** of your variables that you have declared
- Options for the Environment
  - Save Workspace Environment into an Rdata File
  - Open a Saved Workspace Environment
  - Clear Current Workspace



One Dimensional Vector Arithmetic

Definition 2.3: Vectors

- A vector is an entity consisting of an ordered collection of numbers.
- Generate vectors using the function c() which can take an arbitrary number of vector arguments and concatenates it into a single variable.
- An example of a vector:

$$x = \begin{bmatrix} 10.4 \\ 5.6 \\ 3.1 \\ 6.4 \\ 21.7 \end{bmatrix}$$

One Dimensional Vector Arithmetic

Example 2.2: Vectors

- Declare a new vector named x, consisting of five numbers, namely 10.4, 5.6, 3.1, 6.4 and 21.7 and print the result

➢ `#create a vector`

➢ `x <- c(10.4, 5.6, 3.1, 6.4, 21.7)`

➢ `#print the vector`

➢ `x`

```
> #create a vector
> x <- c(10.4, 5.6, 3.1, 6.4, 21.7)
> #print the vector
> x
[1] 10.4  5.6  3.1  6.4 21.7
>
```

One Dimensional Vector Arithmetic

- If an **expression** is used as a complete command, the value is printed and lost
  - ➢ `1/x`
  - – the reciprocals of the five values would be printed at the terminal (and the value of x, of course, unchanged).
- The **assignment**
  - ➢ `y <- c(x, 0, x)`
  - – would create a vector y with 11 entries consisting of two copies of x with a zero in the middle place.
- The `y` vector will be saved in the environment

One Dimensional Vector Arithmetic

Example 2.3: Assignments

- Print Assignments and Expressions

➢ #this vector is lost

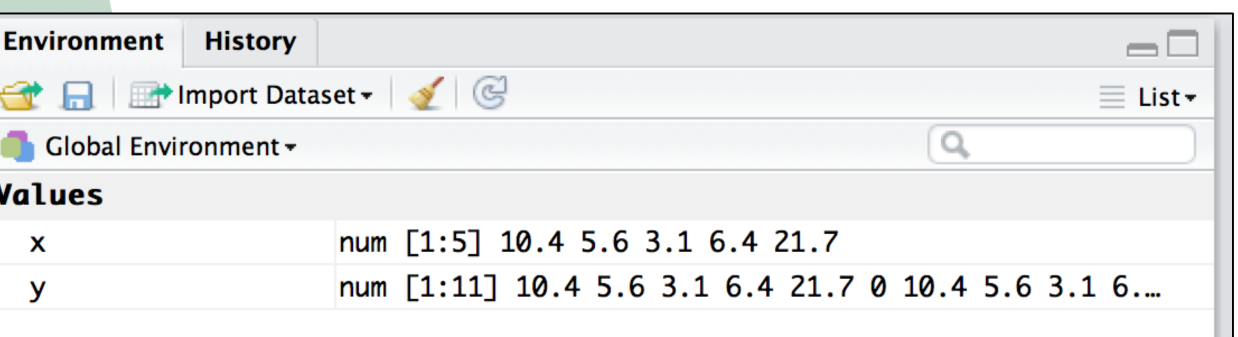
➢ 1/x

➢ #value is saved

➢ y <- c(x, 0, x)

➢ y

```
> #this vector is lost
> 1/x
[1] 0.09615385 0.17857143 0.32258065 0.15625000 0.04608295
> #value is saved
> y <- c(x, 0, x)
> y
 [1] 10.4  5.6  3.1  6.4 21.7  0.0 10.4  5.6  3.1  6.4 21.7
>
```



One Dimensional Vector Arithmetic

- Alternative Assignments
- `<-`
- `=`
- `->`
- Eg

➢ `c(10.4, 5.6, 3.1, 6.4, 21.7) -> x`

One Dimensional Vector Arithmetic

- Vectors can be used in arithmetic expressions, in which case the operations are performed element by element.
- Vectors occurring in the same expression need not all be of the same length. If they are not, the value of the expression is a vector with the same length as the longest vector
- Shorter vectors in the expression are recycled as often as need be until they match the length of the longest vector.
- A constant is simply repeated.
- Example

One Dimensional Vector Arithmetic

Example 2.4: Vector Arithmetic

- Calculate for $v = 2 * x + y + 1$

➢ #Different Lengths

➢ v <- 2*x + y + 1

➢ v

```
> #Different Lengths
> v <- 2*x + y + 1
Warning message:
In 2 * x + y :
  longer object length is not a multiple of shorter object length
> v
 [1] 32.2 17.8 10.3 20.2 66.1 21.8 22.6 12.8 16.9 50.8 43.5
> 
```

One Dimensional Vector Arithmetic

- Elementary arithmetic operators : +, -, *, / and ^ for raising to a power.
- Arithmetic functions are available. `log, exp, sin, cos, tan, sqrt, max, min.`
- `range` is a function whose value is a vector of length two, namely `c(min(x), max(x)).`
- `length(x)` is the number of elements in `x, sum(x)` gives the total of the elements in `x, and prod(x)` their product.

One Dimensional Vector Arithmetic

Example 2.4 (Cont.) : Vector Arithmetic

- Do some arithmetic operations on vector x

```
#Arithmetic Operations
z <- (2*x + 5)^2
z
# The Range of X
xrange = range(x)
xrange
# The Num of Elements in X
xlength = length(x)
xlength
```

One Dimensional Vector Arithmetic

```
> #Arithmetic Operations
> z <- (2*x + 5)^2
> z
[1]  665.64  262.44  125.44  316.84 2342.56
> # The Range of X
> xrange = range(x)
> xrange
[1]  3.1 21.7
> # The Num of Elements in X
> xlength = length(x)
> xlength
[1] 5
> 
```

One Dimensional Vector Arithmetic

- Elementary Statistical Operations
  - Calculating the average of a vector:
    - `mean(x)` which calculates the sample mean, which is the same as `sum(x)/length(x)`
  - Calculating the variance of a vector:
    - `var(x)` which is equal to `sum((x-mean(x))^2)/(length(x)-1)` or sample variance.
  - Calculating the standard deviation of a vector:
    - `sqrt(var(x))`
  - Calculating the median of a vector
    - `median(x)`

One Dimensional Vector Arithmetic

Example 2.5: Statistical Operations

- Do some arithmetic operations on vector x

➢ `#Mean of x`
➢ `mean(x)`
➢ `#Variance of x`
➢ `var(x)`
➢ `#Standard deviation of x`
➢ `sqrt(var(x))`
➢ `#Median of x`
➢ `median(x)`

```
> #Mean of x
> mean(x)
[1] 9.44
> #Variance of x
> var(x)
[1] 53.853
> #Standard deviation of x
> sqrt(var(x))
[1] 7.33846
> #Median of x
> median(x)
[1] 6.4
>
```

One Dimensional Vector Arithmetic

- Generating a sequential vector:
  - `1:30` is the vector `c(1, 2, ..., 29, 30)`
- The colon operator has a high priority within an expression,
- Example
  - `2*1:15` is the vector `c(2, 4, ..., 28, 30).`
- General format for generating sequences:
  - `seq(from, to, by=)`
  - `seq(length, from, to, by=)`
- Generate repeating valued vector
  - `rep(vector, times=)`

One Dimensional Vector Arithmetic

Example 2.6: Arithmetic Sequences

- `#Arithmetic Sequence from 1 to 30`
- `1:30`
- `#Priority of Operations`
- `2*1:15`
- `#Sequence Function`
- `seq(from=-5, to=5, by=.2)`
- `seq(length=51, from=-5, by=.2)`
- `#Repeat Function`
- `rep(1, times=5)`

One Dimensional Vector Arithmetic

```
> #Arithmetic Sequence from 1 to 30
> 1:30
 [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
[29] 29 30
> #Priority of Operations
> 2*1:15
 [1]  2  4  6  8 10 12 14 16 18 20 22 24 26 28 30
> #Sequence Function
> seq(from=-5, to=5, by=.2)
 [1] -5.0 -4.8 -4.6 -4.4 -4.2 -4.0 -3.8 -3.6 -3.4 -3.2 -3.0 -2.8 -2.6 -2.4 -2.2 -2.0 -1.8
[18] -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0  1.2  1.4  1.6
[35]  1.8  2.0  2.2  2.4  2.6  2.8  3.0  3.2  3.4  3.6  3.8  4.0  4.2  4.4  4.6  4.8  5.0
> seq(length=51, from=-5, by=.2)
 [1] -5.0 -4.8 -4.6 -4.4 -4.2 -4.0 -3.8 -3.6 -3.4 -3.2 -3.0 -2.8 -2.6 -2.4 -2.2 -2.0 -1.8
[18] -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0  1.2  1.4  1.6
[35]  1.8  2.0  2.2  2.4  2.6  2.8  3.0  3.2  3.4  3.6  3.8  4.0  4.2  4.4  4.6  4.8  5.0
> #Repeat Function
> rep(1, times=5)
[1] 1 1 1 1 1
> 
```

One Dimensional Vector Arithmetic

- The elements of a logical vector can have the values TRUE, FALSE, and NA (for “not available”).
- The logical operators are <, <=, >, >=, == for exact equality and != for inequality.
- Logical vectors are generated by conditions.

One Dimensional Vector Arithmetic

Example 2.7: Logical Vectors

- Create a variable temp to determine which elements in x are greater than 10

```
➢ #Logical Vectors
➢ x
➢ temp <- x > 10
➢ temp
```

```
> #Logical Vectors
> x
[1] 10.4  5.6  3.1  6.4 21.7
> temp <- x > 10
> temp
[1]  TRUE FALSE FALSE FALSE  TRUE
> 
```

One Dimensional Vector Arithmetic

- In some cases the components of a vector may not be completely known.
- When an element or value is "not available" or a "missing value" it will be assigned the special value NA.
- Any operation on an NA becomes an NA.
  - The motivation for this rule is simply that if the specification of an operation is incomplete, the result cannot be known and hence is not available.
- The function `is.na(x)` gives a logical vector of the same size as `x` with value TRUE if and only if the corresponding element in `x` is NA.

One Dimensional Vector Arithmetic

Example 2.8: Missing Values

- #Working with NA
- z <- c(1:3,NA)
- z
- ind <- is.na(z)
- ind

```
> #Working with NA
> z <- c(1:3,NA)
> z
[1]  1  2  3 NA
> ind <- is.na(z)
> ind
[1] FALSE FALSE FALSE  TRUE
>
```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One Dimensional Vector Arithmetic

- Character quantities and character vectors are used frequently in R, for example as plot labels.
- They are denoted by a sequence of characters delimited by the double quote character, e.g., "x-values", "New iteration results".
- Character strings are entered using either matching double (") or single (’) quotes, but are printed using double quotes
- The `paste()` function takes an arbitrary number of arguments and concatenates them one by one into character strings.

One Dimensional Vector Arithmetic

Example 2.9: Character Vectors

- #This is a character vector
- "x-values"
- #The use of paste
- paste("Eugene","-", "Rex")
- labs <- paste(c("X"), 1:10, sep="")
- labs

```
> #This is a character vector
> "x-values"
[1] "x-values"
> #The use of paste
> paste("Eugene","-", "Rex")
[1] "Eugene - Rex"
> labs <- paste(c("X"), 1:10, sep="")
> labs
 [1] "X1"  "X2"  "X3"  "X4"  "X5"  "X6"  "X7"  "X8"  "X9"  "X10"
>
```

One Dimensional Vector Arithmetic

- Dates are represented as the number of days since 1970-01-01, with negative values for earlier dates.
- use as.Date( ) to convert strings to dates
- Sys.Date( ) returns today's date.
- date() returns the current date and time.

One Dimensional Vector Arithmetic

Example 2.10: Date Vectors

- `mydates <- as.Date(c("2007-06-22", "2004-02-13"))`
- `# number of days between 6/22/07 and 2/13/04`
- `days <- mydates[1] - mydates[2]`
- `days`

```
> mydates <- as.Date(c("2007-06-22", "2004-02-13"))
> # number of days between 6/22/07 and 2/13/04
> days <- mydates[1] - mydates[2]
> days
Time difference of 1225 days
>
```

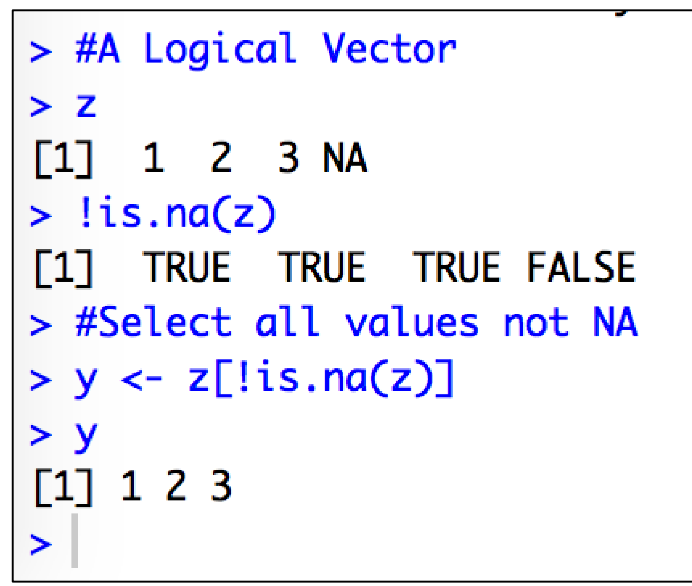
One Dimensional Vector Arithmetic

- Indexing
  - Subsets of the elements of a vector may be selected by appending to the name of the vector an index vector in square brackets.
  - Such index vectors can be any of four distinct types.
    - A Logical Vector: Selects all True Indices
    - A Sequence of Positive Integers: Selects all items from 1 to the end of the sequence
    - A Sequence of Negative Integers : Selects all except items from -1 to the end of the sequence
    - A Vector of Character Strings: Select only the ones in the character string

One Dimensional Vector Arithmetic

Example 2.11: Indexing

- #A Logical Vector
- z
- !is.na(z)
- #Select all values not NA
- y <- z[!is.na(z)]
- y



One Dimensional Vector Arithmetic

Example 2.11 (Cont.): Indexing

- `v`
- `#Include Using Positive Integers`
- `temp = v[1:10]`
- `temp`
- `#Exclude Using Negative Integers`
- `temp2 = v[-(1:5)]`
- `temp2`
- `#Include Using Any Number`
- `temp3 = v[c(1,4,6)]`
- `temp3`

One Dimensional Vector Arithmetic

Example 2.11 (Cont.): Indexing

```
> v
 [1] 32.2 17.8 10.3 20.2 66.1 21.8 22.6 12.8 16.9 50.8 43.5
> #Include Using Positive Integers
> temp = v[1:10]
> temp
 [1] 32.2 17.8 10.3 20.2 66.1 21.8 22.6 12.8 16.9 50.8
> #Exclude Using Negative Integers
> temp2 = v[-(1:5)]
> temp2
[1] 21.8 22.6 12.8 16.9 50.8 43.5
> #Include Using Any Number
> temp3 = v[c(1,4,6)]
> temp3
[1] 32.2 20.2 21.8
```

One Dimensional Vector Arithmetic

Example 2.11 (Cont.): Indexing

- `#A Vector of Character Strings`
- `fruit <- c(5, 10, 1, 20)`
- `names(fruit) <- c("orange", "banana", "apple", "peach")`
- `fruit`
- `lunch <- fruit[c("apple","orange")]`
- `lunch`

One Dimensional Vector Arithmetic

Example 2.11 (Cont.): Indexing

```
> #A Vector of Character Strings
> fruit <- c(5, 10, 1, 20)
> names(fruit) <- c("orange", "banana", "apple", "peach")
> fruit
orange banana  apple  peach
     5     10      1     20
> lunch <- fruit[c("apple","orange")]
> lunch
 apple orange
     1      5
> |
```

One Dimensional Vector Arithmetic

- An indexed expression can also appear on **the receiving end of an assignment**, in which case the assignment operation is performed only on those elements of the vector.
- The expression must be of the form `vector[index_vector]`

One Dimensional Vector Arithmetic

Example 2.12: Indexing and Assignment of Vectors

- #Assignment of operators
- z
- is.na(z)
- z[is.na(z)] <- 0
- z

```
> #Assignment of operators
> z
[1]  1  2  3 NA
> is.na(z)
[1] FALSE FALSE FALSE  TRUE
> z[is.na(z)] <- 0
> z
[1] 1 2 3 0
```

One Dimensional Vector Arithmetic

- R caters for changes of data types almost anywhere it could be considered sensible to do so, (and a few where it might not be).
- To know the **current type** of the object use: `mode(object)`
- To convert a **numeric vector to a string** use: `as.character(vector)`
- To convert a character vector (with numeric characters) to **an integer vector** use: `as.integer(vector)`

One Dimensional Vector Arithmetic

Example 2.13: Changing Data Types

- `#Changing Data Types`
- `digits <- as.character(z)`
- `mode(digits)`
- `digits <- as.integer(digits)`
- `mode(digits)`

```
> #Changing Data Types
> digits <- as.character(z)
> mode(digits)
[1] "character"
> digits <- as.integer(digits)
> mode(digits)
[1] "numeric"
>
```

One Dimensional Vector Arithmetic

Definition 2.4: Factors

- A factor is a vector object used to specify a discrete classification (grouping) of the components of other vectors of the same length.
- A factor is created using the `factor()` function

One Dimensional Vector Arithmetic

Example 2.14: Factors

- Suppose that we are looking at 5 individuals and their corresponding monthly income. We would like to treat their gender as a factor.

Gender	Monthly Income (000)
M	30
F	29
M	35
M	20
F	40

One Dimensional Vector Arithmetic

Example 2.14 (Cont.): Factors

```
#Working with Factors
gender <- c("M","F","M","M","F")
genderfactors <- factor(gender)
levels(genderfactors)
#Get average income per factor
income <- c(30,29,35,20,40)
incmeans <- tapply(income, genderfactors, mean)
incmeans
```

One Dimensional Vector Arithmetic

Example 2.14 (Cont.): Factors

```
> #Working with Factors
> gender <- c("M","F","M","M","F")
> genderfactors <- factor(gender)
> levels(genderfactors)
[1] "F" "M"
> #Get average income per factor
> income <- c(30,29,35,20,40)
> incmeans <- tapply(income, genderfactors, mean)
> incmeans
       F        M
34.50000 28.33333
```

Outline for This Session

- One Dimensional Vector Arithmetic
- **Multi Dimensional Vector Arithmetic**
- Case Study

Multi Dimensional Vector Arithmetic

Definition 2.5: Arrays

- An array can be considered as a multiple subscripted collection of data entries
- Converting a one-dimensional vector into a two dimensional matrix using a non-negative dimensional vector we use the `dim()` function

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Multi Dimensional Vector Arithmetic

Example 2.15: Dimensional Arrays

- #2-Dimensional Array
- z
- zmatrix <- z
- dim(zmatrix) = c(2,2)
- zmatrix

```
> #2-Dimensional Array
> z
[1] 1 2 3 0
> zmatrix <- z
> dim(zmatrix) = c(2,2)
> zmatrix
     [,1] [,2]
[1,]    1    3
[2,]    2    0
```

Multi Dimensional Vector Arithmetic

- Individual elements of an array may be **referenced** by giving the name of the array followed by the subscripts in square brackets, separated by commas.
- More generally, **subsections** of an array may be specified by giving a sequence of index vectors in place of subscripts

Multi Dimensional Vector Arithmetic

Example 2.16: Subsetting Arrays

- Consider the following matrix , select item [1,3], [2,2], [3,1] and replace them with zeros.

```
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
```

Multi Dimensional Vector Arithmetic

Example 2.16: Subsetting Arrays

```
# Generate a 4 by 5 array.
xindex <- array(1:20, dim=c(4,5))
xindex
#select item [1,3], [2,2], [3,1]
indextoselect <- array(c(1:3,3:1),
dim=c(3,2))
xindex[indextoselect]
#replace with zeroes
xindex[indextoselect]<-0
xindex
```

Multi Dimensional Vector Arithmetic

```
> # Generate a 4 by 5 array.
> xindex <- array(1:20, dim=c(4,5))
> xindex
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    9   13   17
[2,]    2    6   10   14   18
[3,]    3    7   11   15   19
[4,]    4    8   12   16   20
> #select item [1,3], [2,2], [3,1]
> indextoselect <- array(c(1:3,3:1), dim=c(3,2))
> xindex[indextoselect]
[1] 9 6 3
> #replace with zeroes
> xindex[indextoselect]<-0
> xindex
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    0   13   17
[2,]    2    0   10   14   18
[3,]    0    7   11   15   19
[4,]    4    8   12   16   20
> 
```

Multi Dimensional Vector Arithmetic

Definition 2.6: Matrix

- A matrix is just an array with two subscripts.
- R contains many operators and functions that are available only for matrices. For example `t(X)` is the matrix transpose function, as noted above.
- The functions `nrow(A)` and `ncol(A)` give the number of rows and columns in the matrix A respectively.

Multi Dimensional Vector Arithmetic

Example 2.17: Transpose of a Matrix

- `#To Transpose a Matrix`
- `xindex`
- `xtranspose = t(xindex)`
- `xtranspose`
- `nrow(xtranspose)`
- `ncol(xtranspose)`

Multi Dimensional Vector Arithmetic

```
> #To Transpose a Matrix
> xindex
     [,1] [,2] [,3] [,4] [,5]
[1,]    1    5    0   13   17
[2,]    2    0   10   14   18
[3,]    0    7   11   15   19
[4,]    4    8   12   16   20
> xtranspose = t(xindex)
> xtranspose
     [,1] [,2] [,3] [,4]
[1,]    1    2    0    4
[2,]    5    0    7    8
[3,]    0   10   11   12
[4,]   13   14   15   16
[5,]   17   18   19   20
> nrow(xtranspose)
[1] 5
> ncol(xtranspose)
[1] 4
>
```

Multi Dimensional Vector Arithmetic

- Review of Linear Algebra
  - Let $x = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ and $y = \begin{bmatrix} 4 & 3 \\ 2 & 1 \end{bmatrix}$
  - Element-wise product

$$x * y = \begin{bmatrix} 1*4 & 2*3 \\ 3*2 & 4*1 \end{bmatrix} = \begin{bmatrix} 4 & 6 \\ 6 & 4 \end{bmatrix}$$

  - Matrix Inner Product

$$x \circ y = \begin{bmatrix} 1*4+2*2 & 1*3+2*1 \\ 3*4+2*4 & 3*3+4*1 \end{bmatrix} = \begin{bmatrix} 8 & 5 \\ 20 & 13 \end{bmatrix}$$

  - Vector*Matrix Inner Product, $z = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$

$$z^T * x = \begin{bmatrix} 1*1+3*2 & 1*2+4*2 \end{bmatrix} = \begin{bmatrix} 7 & 10 \end{bmatrix}$$

Multi Dimensional Vector Arithmetic

- The * operator is the element-wise product multiplication
  - `A * B`
- While the following is a matrix inner product
  - `A %*% B`

Multi Dimensional Vector Arithmetic

Example 2.18: Matrix Multiplications

- `x<- array(c(1,3,2,4), dim=c(2,2))`
- `y<- array(c(4,2,3,1), dim=c(2,2))`
- `z<- array(c(1,2),dim=c(2,1))`
- `#Element Wise Multiplication`
- `x*y`
- `#Matrix Inner Product`
- `x%*%y`
- `#Vector Times Matrix Multiplication`
- `t(z)%*%x`

Multi Dimensional Vector Arithmetic

```
> #Matrix Multiplications
> x<- array(c(1,3,2,4), dim=c(2,2))
> y<- array(c(4,2,3,1), dim=c(2,2))
> z<- array(c(1,2),dim=c(2,1))
> #Element Wise Multiplication
> x*y
     [,1] [,2]
[1,]    4    6
[2,]    6    4
> #Matrix Inner Product
> x%*%y
     [,1] [,2]
[1,]    8    5
[2,]   20   13
> #Vector Times Matrix Multiplication
> t(z)%*%x
     [,1] [,2]
[1,]    7   10
>
```

Multi Dimensional Vector Arithmetic

- The function `cbind()` forms matrices by binding together matrices horizontally, or column-wise, and `rbind()` vertically, or row-wise.
  - `X <- cbind(arg_1, arg_2, arg_3, ...)`
- the arguments to `cbind()` must be either vectors of any length, or matrices with the same number of rows.
- The result is a matrix with the concatenated arguments `arg 1, arg 2, . . .` forming the columns.

Multi Dimensional Vector Arithmetic

- The function `rbind()` does the corresponding operation for rows. In this case any vector argument are of course taken as row vectors.
- Suppose `X1` and `X2` have the same number of rows. To combine these by columns into a matrix `X`, together with an initial column of 1s we can use
  - `X <- cbind(1, X1, X2)`
- The result of `rbind()` or `cbind()` is always a matrix. Hence `cbind(x)` and `rbind(x)` are possibly the simplest ways explicitly to allow the vector `x` to be treated as a column or row matrix respectively.

Multi Dimensional Vector Arithmetic

Example 2.19: CBIND and RBIND

- #cbind and rbind
- x
- y
- colbinded = cbind(x,y)
- colbinded
- rowbinded = rbind(x,y)
- rowbinded

```
> #cbind and rbind
> x
     [,1] [,2]
[1,]    1    2
[2,]    3    4
> y
     [,1] [,2]
[1,]    4    3
[2,]    2    1
> colbinded = cbind(x,y)
> colbinded
     [,1] [,2] [,3] [,4]
[1,]    1    2    4    3
[2,]    3    4    2    1
> rowbinded = rbind(x,y)
> rowbinded
     [,1] [,2]
[1,]    1    2
[2,]    3    4
[3,]    4    3
[4,]    2    1
>
```

Multi Dimensional Vector Arithmetic

- The function `table()` allows frequency tables to be calculated from equal length factors.
- If there are k factor arguments, the result is a k-way array of frequencies.

Multi Dimensional Vector Arithmetic

Example 2.20: Tables and Frequencies

- `#frequency`
- `table(genderfactors)`

```
> #frequency
> table(genderfactors)
genderfactors
F M
2 3
>
```

Outline for This Session

- One Dimensional Vector Arithmetic
- Multi Dimensional Vector Arithmetic
- **Case Study**

Case Study 1

- R Scripting Exercises

Outline for This Session

- One Dimensional Vector Arithmetic
- Multi Dimensional Vector Arithmetic
- Case Study

References

- http://www.r-tutor.com

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