Lecture 9

Lecture 5: Selection Statements

Relational operators

>	greater than
<	less than
>=	greater than or equals
<=	less than or equals
==	equality
~=	inequility

Logical operators

<table>
<tr><td>||</td><td>or</td></tr>
<tr><td>&&</td><td>and</td></tr>
<tr><td>~</td><td>not</td></tr>
</table>

- Form of the relational expression

  Expression1 (**relational operator**) expression 2

  Example:
  ```
  >> X > Y
  ```

  Possible value is either logically true or logically false.

- Form of the logical operation

  Expression1 (**logical operator**) expression2.

  ```
  >>  X || Y
  >>  X && Y
  >>  ~X
  ```

These two expressions are generally logical type

Lecture 5: Selection Statements

- Expression1 (**relational operators**) expression 2

  3 + 1 > 5 + 6

  3 + 1 == 2 + 2

  3 + 1 ~= 2 + 2

  x = 3 + 1 ~= 2 + 2

- Expression1 (**logical operators**) expression2

  3 + 1 > 5 || 3 + 1 == 2 + 2

  3 + 1 > 5 && 3 + 1 == 2 + 2

  2.4 || 0

  x = 3 + 1 > 5 && 3 + 1 == 2 + 2

- **Operator Precedence Rules**

Operators	**Precedence**
Parentheses ()	highest
Transpose and power ‘, ^	
Unary negation (-), not (~)	
Multiplication, division *, /, \	
Addition, subtraction +, -	
Colon operator :	
Relational <, <=, > >=, ==, ~=	
And &&	
Or ||	
Assignment =	lowest

So far, the relational operators and logical operators are used for scalars.

Logical Vectors

- **Logical Vectors**
  - The relational operators can also be used with vectors and matrices. For example, there is a vector, and we want to compare every element in the vector to 5 to determine whether it is greater than 5 or not. The result would be a vector with the same length as the original

```
>> vec = [5  9  3  4  6  11];
>> isg = vec > 5
isg =
    0  1  0  0  1  1
```

What if vec is a matrix?

Can we compare two vectors with the same dimensions?

Although this is a vector of ones and zeros, the numerical operations can be done on the vector isg

```
>> doubres = isg + 5
doubres =
    5   6   5   5   6   6
```

How to determine how many elements are greater than 5?

Logical Vectors

- **Logical Vectors**

  To determine how many of the elements in the vector ‘vec’ are greater than 5, the sum function could be used on the resulting vector isg.

```
>> sum(isg)
ans =
     3
```

```
>> help sum
S = sum(X) is the sum of the elements of the
vector X. If X is a matrix, S is a row vector with
the sum over each column.
```

Using this way, we can determine the number of elements in a vector meeting any criteria.

Questions: How to determine the number of elements in a MATRIX meeting any criteria?

Logical Vectors

- **Logical Vectors**

  The **logical vector** isg can also be used to index into the vector. For example, if only the elements from the vector that are greater than 5 are desired.

```
>> vec = [5  9  3  4  6  11];
>> isg = vec > 5
isg =
   1 x 6 logical array
     0  1  0  0  1  1
>> vec(isg)
ans =
       9   6   11
```

This statement is equivalent to vec([2 5 6])

Question:
Can we use: >> vec([0 1 0 0 1 1]) ?

Logical Vectors

- **Logical Built-in Functions**
  - any: returns logical true if any element in a vector is logically true, and false if not.
  - all: returns logical true only if all elements in a vector are logically true.

```
>> vec1 = [1  1  0  1];
>> any(vec1)
ans =
      1
>> vec2 = [2  0  3  5];
>> any(vec2)
ans = 1

>> all(vec1)
ans =
      0
```

The vector does not have to be logical type

What if vec is a column vector?

What if vec is a matrix?

Logical Vectors

- **Logical Built-in Functions**
  - any: for matrices, function any is evaluated column by column, and returns logical true if any element in a column is logically true, and false if not. For a m x n matrix, it returns a 1 x n matrix.
  - all: returns logical true only if all elements in a column of a matrix are logically true.

```
>> mat = [2  0  3; 0  1  4]
>> mat =
          2   0   3
          0   1   4

>> any(mat)
ans =
  1×3 logical array
   1   1   1

>> all(mat)
ans =
  1×3 logical array
   0   0   1
```

Questions:

1. How to determine if there are any element in a matrix that are logical true?
2. How to determine if there are any element in a matrix that are logical false?
3. How to determine if all elements in a matrix are logical true?
4. How to determine if all elements in a matrix are logical false?

Logical Vectors

Questions:

1. How to determine whether there are some elements in a matrix that are logical true?

This question is equivalent to: If there are some elements in a matrix that are logical true, the result is logical true. If all elements are logical false, the result is logical false. We first use any(mat) to examine the columns. If any element in a particular column is logical true, then the value for that column is logical true. any(mat) will return a row vector with logical values. Then we use any(any(mat)) to examine the elements in the row vector of any(mat). If some elements in the row vector are logical true, i.e. there are logical true values in the corresponding columns, any(any(mat)) will return a logical true value. If all elements in mat are logical false, then all elements in the row vector any(mat) will be logical false, and then any(any(mat)) will be logical false.

2. How to determine whether there are some element in a matrix that are logical false? (all(all(mat)))

This question is equivalent to: If there are some elements that are logical false, then the results is logical true. If all elements are logical true, the result is logical false. We first use all(mat) to examine the columns. If any element in a particular column is logical false, then the value for that column is logical false. all(mat) will return a row vector with logical values. Then we use all(all(mat)) to examine the elements in the row vector of all(mat). If some elements in the row vector are logical false, i.e. there are logical false values in the corresponding columns, all(all(mat)) will return a logical false value. Then we use ~all(all(mat)) to get the logical true value. If all elements in mat are logical true, then the elements in the row vector all(mat) is logical true, then all(all(mat)) is logical true, and ~all(all(mat)) is logical false.

3. How to determine whether all elements in a matrix are logical true?

This question is equivalent to: If all elements are logical true, then the result is logical true, otherwise, logical false. This question is similar to question 2. We can use all(all(mat))

4. How to determine whether all elements in a matrix are logical false?

This question is equivalent to: If all elements are logical false, then the result is logical true, otherwise, logical false. We first use any(mat) to examine the columns. If all elements in a column are logical false, then the corresponding value in any(mat) is logical false. Then we use any(any(mat)) to examine the elements in any(mat), if all elements in any(mat) are false, then any(any(mat)) is false, ~any(any(mat)) is true. Otherwise ~any(any(mat)) is false.

Logical Vectors

- **Logical Built-in Functions**
  - find: returns the indices of a vector that meet some criteria.

```
>> vec = [5  3  6  7  2  8]
vec =
    5    3    6    7    2    8

>> find(vec > 5)
ans =
      3    4    6
```

equivalent to find([0   0   1   1   0   1])

How to get those values?

```
>> vec = [5;  3;  6;  7;  2;  8]
vec =
    5
    3
    6
    7
    2
    8
>> find(vec > 5)
ans =
    3
    4
    6
```

What if vec is a matrix?

Logical Vectors

- **Logical Built-in Functions**
  - find: for matrices, find returns the indices of a matrix that meet some criteria.

```
>> mat = [5  3  6;  7  2  8];
mat =
    5     3     6
    7     2     8
>> find(mat > 5)
ans =
    2
    5
    6
```

MATLAB unwinds matrix column wise, so the elements in a matrix can be accessed with a single index

Question: How to find those elements? mat(ans) returns the values of the elements

Logical Vectors

- **Logical Built-in Functions**
  - isequal: is used to compare vectors.

```
>> vec1 = [1  3  -4  2  99];
>> vec2 = [1  2  -4  3  99];
```

Method 1:

```
>> isequal(vec1,vec2)
ans =
     0
```

Method 2:

```
>> vec1 == vec2
ans =
    1  0  1  0  1
```

Create a logical type vector

```
>> all(vec1 == vec2)
ans =
    0
```

all: returns logical true only if all elements in a vector are logically true.

Logical Vectors

- **Logical Built-in Functions**
  - MATLAB also has **or** and **and** operators that work elementwise for vectors and matrices:

    | : elementwise 'or' for vectors and matrices

    & : elementwise 'and' for vectors and matrices

    These operators will compare any two vectors or matrices, as long as they are the same size, element-by-element, and return a vector or matrix of the same size of logical 1's and 0's.

    (|| and && are used only with scalars, not matrices)

    Examples:

```
>> v1 = [3  0  5  1];
>> v2 = [0  0  2  0];
>> v1 & v2
ans =
      0  0  1  0
>> v1 | v2
ans =
      1  0  1  1
```

The vectors don't have to be logical type. Zeros are treated as logical false, non-zero values are treated as logical true.

Logical Vectors

- **Logical Built-in Functions**
  - MATLAB also has the **not** operator that work elementwise for vectors and matrices:

    Examples:

```
>> v1 = [3  0  5  1];
>> ~v1
ans =
  1×4 logical array
   0   1   0   0
```

The vectors don't have to be logical type. Zeros are treated as logical false, non-zero values are treated as logical true.

Logical Vectors

- **Summary**

- **Homework on Canvas**