

# Lecture 4: Relational, Logical, and Set Operators, Searching and Sorting

A8B17CAS

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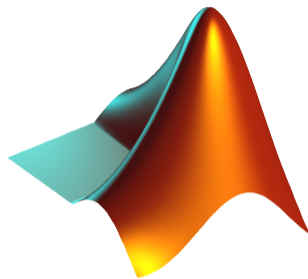
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1. Relational Operators
2. Logical Operators
3. Set Operators
4. Searching and Sorting



## Warm Up: Calendar Analysis



There is function `calendar()`. Let us play with it! Use MATLAB Editor...

Complete a snippet of code to get:

- ▶ A row vector of all Mondays in this month.
- ▶ How many they are?
- ▶ What day was January 1st, 1901?



# Relational Operators I.

- ▶ To find out, to compare, **whether “something” is greater than, less than, equal to, etc.**
- ▶ The result of the comparison is always either
  - ▶ positive (`true`), logical one “1”,
  - ▶ negative (`false`), logical zero “0”.
- ▶ All relation operators are vector-wise.
  - ▶ It is also possible to compare vector vs. vector, matrix vs. matrix, ...
- ▶ Often in combination with logical operators (*see later*)
  - ▶ Multiple relational operators can be applied to complex expressions.

<code>&gt;</code>	greater than
<code>&gt;=</code>	greater than or equal to
<code>&lt;</code>	less than
<code>&lt;=</code>	less than or equal to
<code>==</code>	equal to
<code>~=</code>	not equal to



## Relational Operators II.

- ▶ Having the vector  $\mathbf{G} = \left( \frac{\pi}{2} \quad \pi \quad \frac{3\pi}{2} \quad 2\pi \right)$ , find elements of  $\mathbf{G}$  that are
  - ▶ greater than  $\pi$ ,
  - ▶ less than or equal to  $\pi$ ,
  - ▶ not equal to  $\pi$ .
  - ▶ Try similar operations for  $\mathbf{H} = \mathbf{G}^T$ .
  
- ▶ Find out whether  $\mathbf{V} \geq \mathbf{U}$ :
  - ▶  $\mathbf{V} = \begin{pmatrix} -\pi & \pi & 1 & 0 \end{pmatrix}$ ,
  - ▶  $\mathbf{U} = \begin{pmatrix} 1 & 1 & 1 & 1 \end{pmatrix}$ .

# Relational Operators – Evaluation Goes From Left to Right!



- ▶ Find out the results of following relations.
  - ▶ Try to interpret the results.

```
2 < 1 ~= 1 % ???
```

```
r = 1/2;  
0 < r < 1 % ???
```

```
(1 > A) <= true
```



# Logical Operators I.

- ▶ To find out, **whether particular condition is fulfilled.**
- ▶ The result is always either
  - ▶ positive (`true`), logical one “1”,
  - ▶ negative (`false`), logical zero “0”.
- ▶ `all`, `any` is used to convert logical array into a scalar.
- ▶ MATLAB interprets any numerical value except 0 as `true`.
- ▶ All logical operators are vector-wise.
  - ▶ It is also possible to compare vector vs. vector, matrix vs. matrix, ...
- ▶ Function `is*` extends possibilities of logical expressions.

`&` and  
`|` or  
`~` not  
`xor`  
`all`  
`any`



## Logical Operators II.

Use vector  $\mathbf{A} = \left[ \frac{\pi}{2} \quad \pi \quad \frac{3\pi}{2} \quad 2\pi \right]$  to check the following conditions.

- ▶ Which elements are equal to  $\pi$  **or** are equal to  $2\pi$ .
- ▶ Which elements are greater than  $\frac{\pi}{2}$  **and at the same time** are not equal to  $2\pi$ .
- ▶ Group elements from the previous condition with vector  $\mathbf{A}$ .





# Logical Indexing I.

Assume a vector of 10 random numbers ranging from  $-10$  to  $10$ .

```
a = 20*rand(10, 1) - 10
```

- ▶ Return `true` for elements fulfilling the condition.
- ▶ Return values of those elements fulfilling the condition (logical indexing).
- ▶ Put value of  $-5$  to the position of elements fulfilling the condition.
- ▶ Zero all values in the range from  $-5$  to  $5$ .
- ▶ Thresholding (values below  $-5$  set equal to  $-5$ , values above  $5$  set equal to  $5$ ).

```
a < -5 % relation operator
```

```
a(a < -5)
```

```
a(a < -5) = -5
```

```
a(a > -5 & a < 5) = 0
```

```
a(a < -5 | a > 5) = ...
sign(a(a < -5 | a > 5))*5
```



## Logical Indexing II.

- ▶ Create a row vector **k** in the interval from 1 to 20 with step of 3.
- ▶ Create the vector **m** filled with elements from vector **k** that are:
  - ▶ greater than 10 **and at the same time** less than 16.
- ▶ Use logical operators.



# Logical Operators: Functions all And any

Create matrix **M** and answer following questions using functions `all` and `any`.

```
M = magic(3);
```

- ▶ In which of the columns are all elements greater than 2?

$$\text{any} \left( \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix} \right) = [ 1 \quad 1 \quad 1 ],$$

- ▶ In which of the rows is there at least one element greater than or equal to 8?

$$\text{all} \left( \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix} \right) = [ 0 \quad 1 \quad 0 ],$$

- ▶ Does the matrix **M** contain only positive numbers?

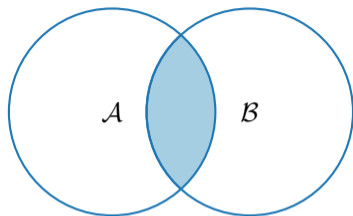
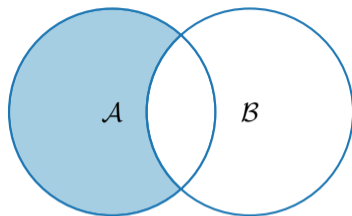
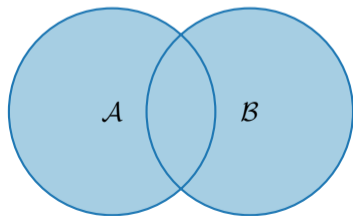
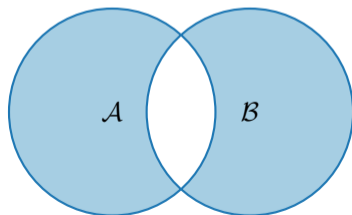
$$\text{any}(\text{all} \left( \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix} \right)) = \text{any}([ 0 \quad 1 \quad 0 ]) = 1$$



# Set Operations

- ▶ Set operations are applicable to vectors, matrices, arrays, cells, strings, tables,...
- ▶ Mutual sizes of these structures are usually not important.

Function	Description
<code>intersect</code>	intersection of two sets
<code>union</code>	union of two sets
<code>setdiff</code>	difference of two sets
<code>setxor</code>	exclusive OR of two sets
<code>unique</code>	unique values in a set
<code>sort</code>	sorting
<code>sortrows</code>	row sorting
<code>ismember</code>	is an element member of a set?
<code>issorted</code>	is a set sorted?

$A \cap B$  intersect () $A \setminus B = A \cap B^c$  setdiff () $A \cup B$  union () $A \oplus B = \overline{A \cap B}$  setxor ()



# Set Operations – Dirichlet's theorem

Consider three vectors **a**, **b**, **c** containing natural numbers  $x \in \mathbb{N}$  so that:

- ▶ vector **a** contains all primes up to (and including) 1000,
- ▶ vector **b** contains all even numbers up to (and including) 1000,
- ▶ vector **c** is complement of **b** in the same interval.

Find vector **v** so that  $\mathbf{v} = \mathbf{a} \cap (\mathbf{b} + \mathbf{c})$  and  $\mathbf{b} + \mathbf{c} \equiv [b_i + c_i], b_{i-1} < b_i < b_{i+1}, c_{i-1} < c_i < c_{i+1}$ .

- ▶ What elements does **v** contain?
- ▶ How many elements are there in **v**?

```

v =
Columns 1 through 18
   3   7  11  19  23  31  43  47  59  67  71  79  83 103 107 127 131 139
Columns 19 through 36
 151 163 167 179 191 199 211 223 227 239 251 263 271 283 307 311 331 347
Columns 37 through 54
 359 367 379 383 419 431 439 443 463 467 479 487 491 499 503 523 547 563
Columns 55 through 72
 571 587 599 607 619 631 643 647 659 683 691 719 727 739 743 751 787 811
Columns 73 through 87
 823 827 839 859 863 883 887 907 911 919 947 967 971 983 991
ans =
    87
  
```



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ans =
    87
```



# Array Sorting

Sort array elements:

- ▶ column-wise, in ascending order: `>> sort(A)`
- ▶ row-wise, in ascending order: `>> sort(A, 2)`
- ▶ in descending order: `>> sort(A, 'descend')`
- ▶ in descending order, row-wise: `>> sort(A, 2, 'descend')`

Function `sortrows` sorts rows of a matrix.

- ▶ Elements of the rows are not swapped – rows are sorted as blocks.

original matrix

$$\begin{bmatrix} 8 & 1 & 6 \\ 3 & 5 & 7 \\ 4 & 9 & 2 \end{bmatrix}$$

`sort()`

$$\begin{bmatrix} 3 & 1 & 2 \\ 4 & 5 & 6 \\ 8 & 9 & 7 \end{bmatrix}$$

`sortrows()`

$$\begin{bmatrix} 3 & 5 & 7 \\ 4 & 9 & 2 \\ 8 & 1 & 6 \end{bmatrix}$$

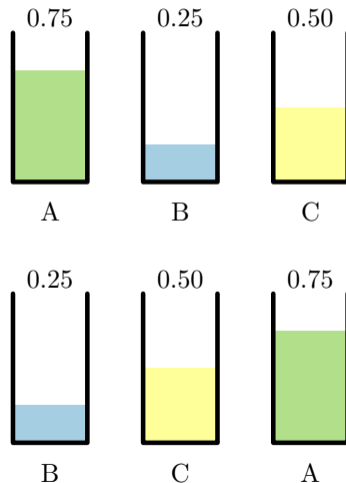




# Sort Multiple Data Sets

- ▶ When more data sets have to be sorted in the same order, get the ordering (ind below) and use it for array re-indexing:

```
bName = ["A", "B", "C"];  
bVolume = [0.75, 0.25, 0.50];  
  
[~, ind] = sort(bVolume);  
  
bNameSorted = bName(ind)  
bVolumeSorted = bVolume(ind)
```





# Searching in an Array

- ▶ Function `find` returns positions of non-zero (logical `true`) elements of a matrix.
- ▶ **Example:** Find the positions of those elements of vector  $\mathbf{A} = \left[ \frac{\pi}{2} \quad \pi \quad \frac{3}{2}\pi \quad 2\pi \right]$  fulfilling the condition  $\mathbf{A} > \pi$ :

```
>> A = pi/2*(1:4)
>> find(A > pi)
```

- ▶ Compare the above command with `>> A > pi`. What is the difference?
- ▶ To find the first/last  $k$  non-zero elements in  $\mathbf{X}$ :

```
>> ind = find(X, k, 'first')
>> ind = find(X, k, 'last')
```

- ▶ For more details see `>> doc find`.



# Array Searching

- ▶ Sort vector  $\mathbf{v} = [16 \ 2 \ 3 \ 13 \ 5 \ 11 \ 10 \ 8 \ 9 \ 7 \ 6 \ 12 \ 4 \ 14 \ 15 \ 1]$  in descending order and find the elements of the vector (and their respective positions within the vector) that are divisible by three and at the same time are greater than 10.

To get the vector quickly:

```
v = reshape(magic(4)', [1 numel(magic(4))])
```

```
v =
    16     2     3    13     5    11    10     8     9     7     6    12     4    14    15     1

v1 =
    1x16 logical array
    0     1     0     0     1     0     0     0     0     0     0     0     0     0     0     0

ans =
    15    12

ans =
     2     5
```

# Questions?

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