Vectors and indexing

Tools of the trade

CS112 Scientific Computation
Department of Computer Science
Wellesley College

Sunspots

- Discovered independently by Christoph Scheiner (1610) and Galileo (1613)
- Indicate disturbances in the sun’s magnetic field
- The number of sunspots varies over time in a cyclical way
- Sunspot Cycle* discovered by Samuel Schwabe (1843)

* There is some connection between sunspots and extreme weather
The length of the sunspot cycle: ~ 12 years

Indexing

Each location of a vector stores a value and has an index that specifies its position within the vector

numbers = [3 7 2 6 5]

The first location has index 1, and indices increment by 1 for successive locations
Reading, Riting, & Rithmetic

We can read or change the contents of a location by referring to its index.

```plaintext
num = numbers(2)
numbers(5) = 4
sumNum = numbers(2) + numbers(5)
```

![Numbers Array]

The end game

The keyword `end`, when provided as an index of a vector, refers to the last index of the vector.

```plaintext
sumNum = numbers(2) + numbers(5)
sumNum = numbers(2) + numbers(end)
```

![Numbers Array]

**Exercise:** Write a sequence of assignment statements that exchange the contents of the first and last locations of `numbers`, assuming you don’t know the length of `numbers`.
Out of bounds

An attempt to read the contents of a location whose index is outside the range of indices is not good

```matlab
>> numbers = [3 7 2 6 5];
>> num = numbers(8)
??? Index exceeds matrix dimensions.
>> num = numbers(end + 1)
??? Index exceeds matrix dimensions.
```

MATLAB is more forgiving than the emperor 😊

However, MATLAB allows you to add a new value at a location beyond the range of indices

```matlab
>> numbers = [3 7 2 6 5];
>> numbers(6) = 9;
>> numbers(9) = 4;
```

```matlab
numbers     3  7  2  6  5  9
  1  2  3  4  5  6
```

```matlab
numbers     3  7  2  6  5  9  0  0  4
  1  2  3  4  5  6  7  8  9
```
Starting from scratch

We can create an initial vector of 0’s from scratch

```matlab
>> numbers = zeros(1,6);
```

```
numbers =
   0   0   0   0   0   0
```

```matlab
>> numbers(1) = input('first number');
>> numbers(2) = input('second number');
```

Referring to multiple locations

We can refer to multiple locations all at once using a vector of indices

```matlab
>> newNumbers = numbers([2 4])
```

```
newNumbers =
   7   6
```

* What is the value of `newNumbers` after executing:
  ```matlab
  newNumbers = numbers([9 4 7 2])
  ```
Change contents of multiple locations

We can also change the values stored in multiple locations using a vector of indices

\[
\text{numbers} = \begin{bmatrix}
3 & 7 & 2 & 6 & 5 & 9 & 0 & 0 & 4 \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9
\end{bmatrix}
\]

\[\text{numbers}( [1 \ 3 \ 5 \ 7] ) = 2\]

\[
\text{numbers} = \begin{bmatrix}
2 & 7 & 2 & 6 & 9 & 2 & 0 & 4 \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9
\end{bmatrix}
\]


Different locations get different values

Change multiple locations all at once, given equal length indices on the left & values on the right

\[
\text{numbers} = \begin{bmatrix}
3 & 7 & 2 & 6 & 5 & 9 & 0 & 0 & 4 \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9
\end{bmatrix}
\]

\[\text{numbers}( [2 \ 4 \ 6] ) = [9 \ 5 \ 1]\]

\[
\text{numbers} = \begin{bmatrix}
3 & 9 & 2 & 5 & 5 & 1 & 0 & 0 & 4 \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9
\end{bmatrix}
\]
Time-out exercise

Given the `numbers` vector,

<table>
<thead>
<tr>
<th>numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 9 2 5 5 1 0 0 4</td>
</tr>
</tbody>
</table>

what will be the new contents of `numbers` after executing the following statements?

```matlab
>> numbers([4 5]) = numbers(8)
>> numbers([1 2 3]) = numbers([7 end 6])
```

Analyzing health data

What is the average cholesterol level for women in their twenties who exercise at least 30 minutes a day?

<table>
<thead>
<tr>
<th>cholesterol</th>
<th>189</th>
<th>239</th>
<th>178</th>
<th>185</th>
<th>251</th>
<th>165</th>
<th>…</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>25</td>
<td>35</td>
<td>28</td>
<td>40</td>
<td>28</td>
<td>22</td>
<td>…</td>
</tr>
<tr>
<td>sex</td>
<td>'m'</td>
<td>'m'</td>
<td>'f'</td>
<td>'m'</td>
<td>'m'</td>
<td>'f'</td>
<td>…</td>
</tr>
<tr>
<td>exercise</td>
<td>30</td>
<td>15</td>
<td>40</td>
<td>25</td>
<td>15</td>
<td>60</td>
<td>…</td>
</tr>
</tbody>
</table>
Selecting vector contents with logical vectors

Suppose we want to refer to vector locations whose contents *satisfy a logical condition*.

For example:

1. Change all negative numbers to 0
2. Store the even and odd numbers in separate vectors
3. Calculate the average of all numbers larger than 10

Selection using logical vectors

A logical vector, when supplied as an index of a vector, *selects locations where logical value is 1 (true)*.

**Case 1:** Logical vector is given as the index of a vector *in an expression*

\[
\text{nums} = \begin{bmatrix} 6 & -7 & -2 & 6 & -5 & 3 & 8 \end{bmatrix}
\]

\[
\text{negNums} = \text{nums}(\text{nums} < 0)
\]

\[
\text{negNums} = \begin{bmatrix} -7 & -2 & -5 \end{bmatrix}
\]
Selection using logical vectors (again)  

**Case 2:** Logical vector is given as the index of a vector on the *left side of an assignment*

```
nums = [6, -7, -2, 6, -5, 3, 8]
```

```
nums[nums < 0] = 0
```

```
nums = [6, 0, 0, 6, 0, 3, 8]
```

* This was task (1) *Change all negative numbers to 0*

---

Selection using logical vectors (again)

**Store even and odd numbers in separate vectors**

```
nums = [8, 14, 7, 17, 22, 5, 10]
```

```
evenNums = 
odeodNums =
```

* Hint: rem(a, b) returns the remainder of dividing a by b*
Selection using logical vectors (again)³

Calculate the average of all numbers larger than 10*

<table>
<thead>
<tr>
<th>nums</th>
<th>8</th>
<th>14</th>
<th>7</th>
<th>17</th>
<th>22</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

avgVal =

*Hint: The mean() function is your friend

Now for the pièce de résistance

What is the average cholesterol level for women in their twenties who exercise at least 30 minutes a day?

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