ENGG1811: Computing For Engineers

2025 Term 2

(even more on!) NumPy

Week 9: Friday 1st August, 2025

Friday 16:00 - 18:00 | OboeME304

Today

Housekeeping

(even more on) Numpy

Lab Tips

Housekeeping

General Feedback on Assignment 1

- I am Very happy with everyone's work.
- If you would like more feedback, contact me via email or ask in the lab.
- Please follow the style guide as closely as possible for Assignment 2 — in particular, many people lost marks for not including function comments (see the style guide here). These should briefly provide black-box information about what inputs the function takes and what it outputs.

General Feedback on Assignment 1 (Cont.)

- The other big style issue was not importing functions from another file! Don't copy your code—reuse the logic by calling functions.
- Methods were good, but some were a bit too technical. Methods should aim to give a high-level overview and explanation.
- When marks are released (if they aren't already), see the Collect Submission page on the assignment for specific style feedback and to view any failed tests.

Week 10 Lab Important Info

- The Week 10 lab is conducted differently from the other labs:
  1. For the first hour, you'll do a mock exam.
  2. I will then go over the solutions to the exam for ≈15–30 minutes.
  3. I will then give tips for the final for ≈15–30 minutes.
  4. Outstanding marking from Week 9 (with a valid reason) will be done in the remaining time.
- There is no MCQ for Week 10, and you are marked *strictly* on attendance.
- Remember that both Assignment 2 and the second self-directed lab are due next Friday at 5 PM. Please start working on them!

MyExperience

- You should all have (or will soon) see the window asking you to complete the "MyExperience" survey when you log into Moodle.
- Please complete the survey for this course as well as your other courses—it really does help us improve in future terms.
- Your feedback may also affect your future courses, so it can be beneficial for you too!

(even more on) Numpy

NumPy: Shape & Size

1	2	3	4
5	6	7	8
9	10	11	12

All examples are using the top-right array

- `np.shape(array)`
  - Gives the shape — the number of rows and columns — of the given array
  - `np.shape(array) = (3, 4)`
- `np.size(array)`
  - Gives the area (number of elements) of the given array
  - `np.size(array) = 12`

NumPy: Ravel

1	2	3	4
5	6	7	8
9	10	11	12

- `np.ravel(array)`
  Using the array at the top-right
  - Unravels the data into a single horizontal array (list) — converts an n dimensional array into a 1 dimensional array
  - `np.ravel(array) = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]`
- **Question:** Can we achieve the same result using the reshape function? Why or why not?

NumPy: Slicing

1	2	3	4
5	6	7	8
9	10	11	12

We can slice out a subarray using the format:

```
array[row_start:row_end:row_step,
      column_start:column_end:column_step]
```

Here are some examples:

- `array[1:, :2] = array([[ 5,  6],`
  `[ 9, 10]])`
- `array[::-1, :] = array([[ 9, 10, 11, 12],`
  `[ 5,  6,  7,  8],`
  `[ 1,  2,  3,  4]])`
- `array[::3, :2:] = array([[1, 2]])`

NumPy: ix_

1	2	3	4
5	6	7	8
9	10	11	12

- **Recall:** When we wish to use boolean indexing, we must create an array of the same shape as the array we wish to index, and then fill each entry with either a `True` or `False` value
- For the array at the top right, we might have to make (from scratch) the following array to index it:

```
mask = np.array([[False, False, False, False],
                 [False, True,  True,  True],
                 [False, True,  True,  True]])
```

- **Question:** What is the output of `array[mask]`?

NumPy: ix_ (Cont I)

1	2	3	4
5	6	7	8
9	10	11	12

- This is a slightly burdensome procedure — can we be a bit lazier?
  - Imagine having to create your own boolean array every time you want to do some simple indexing
- Fortunately, we can!
  - We have two options: we can select all the rows, and then boolean index on the columns **OR** we can select all the columns, and boolean index on the rows
  - **Question I**: What is the output of `array[[False, True, True], :]` ?
  - **Question II**: What is the output of `array[:, [False, True, True, True]]`?

NumPy: ix_ (Cont II)

1	2	3	4
5	6	7	8
9	10	11	12

Limitation

What if we want to boolean index both the rows and columns at the same time?

- What's actually stopping us? Let's try

```
array[[False, True, True],
      [False, True, True, True]]
```

Question: What should this *intuitively* give us?

NumPy: ix_ (Cont III)

False	False	False	False
True	True	True	True
True	True	True	True

&

False	True	True	True
False	True	True	True
False	True	True	True

=

False	False	False	False
False	True	True	True
False	True	True	True

Figure: Intuitive results

- Annoyingly, we get this back instead:

Error Message From Above

```
IndexError: shape mismatch: indexing arrays could
not be broadcast together with shapes (2,) (3,)
```

NumPy: ix_ (Cont IV)

1	2	3	4
5	6	7	8
9	10	11	12

- `np.ix_(rows_boolean_array, columns_boolean_array)`
  - `rows_boolean_array` is the boolean array which selects which rows you want to keep
  - `columns_boolean_array` is the boolean array which selects which columns you want to keep
  - creates a boolean array with desired rows and columns
- Use case:

```
mask = np.ix_([False, True, True],
              [False, True, True, True])
array[mask] = np.array([[6, 7, 8],
                        [10, 11, 12]])
```

This solves our problem, and we can now be slightly lasier when it comes to boolean indexing (so long as we remember the `ix_` function!)

NumPy: Diff

- `numpy.diff(array)`
  - If we have an array $[x_0, x_1, \ldots, x_{n-1}]$ then this will return us back the list

$$[x_1 - x_0, x_2 - x_1, \ldots, x_{i+1} - x_i, \ldots, x_{n-1} - x_{n-2}].$$

  - In plain English, it is calculating for us the (forward) difference between consecutive elements of a given `array`
- Example:

```
array = np.array([3, 7, 4, 9, 4, -1])
np.diff(array) = array([ 4, -3, 5, -5, -5])
```

NumPy: Broadcasting

- One of the many neat features of NumPy is that it allows arrays of different sizes to work together
- Intuitively, what should be the answer of adding these two arrays together?
  - Example 1:

1	2	3	4
5	6	7	8
9	10	11	12

$+$

1
2
3

$= \; ?$

  - Example 2:

1	2	3	4
5	6	7	8
9	10	11	12

$+$

1	2	3	4

$= \; ?$

NumPy: Broadcasting (Cont I)

Here is what NumPy is *really* doing for the above examples

- Example 1:

1	2	3	4
5	6	7	8
9	10	11	12

$+$

1
2
3

$=$

1	2	3	4
5	6	7	8
9	10	11	12

$+$

1	1	1	1
2	2	2	2
3	3	3	3

- Example 2:

1	2	3	4
5	6	7	8
9	10	11	12

$+$

1	2	3	4

$=$

1	2	3	4
5	6	7	8
9	10	11	12

$+$

1	2	3	4
1	2	3	4
1	2	3	4

NumPy: Broadcasting (Cont II)

Let's do a few more examples:

- Example 3:

$$\begin{array}{|c|c|c|c|} \hline 1 & 2 & 3 & 4 \\ \hline 5 & 6 & 7 & 8 \\ \hline 9 & 10 & 11 & 12 \\ \hline \end{array} \quad - \quad \boxed{1} \quad = \quad ?$$

- Example 4 (perhaps this one won't be intuitive):

$$\begin{array}{|c|c|c|} \hline 1 & 2 & 3 \\ \hline \end{array} \quad \times \quad \begin{array}{|c|} \hline 1 \\ \hline 2 \\ \hline 3 \\ \hline \end{array} \quad = \quad ?$$

NumPy: Broadcasting (Cont III)

- Example 3:

1	2	3	4
5	6	7	8
9	10	11	12

$-$

1	1	1	1
1	1	1	1
1	1	1	1

$=$

0	1	2	3
4	5	6	7
8	9	10	11

- Example 4:

1
2
3

(3,1)

$\times$

1	2	3

(1,3)

$=$

1	1	1
2	2	2
3	3	3

(3,3)

$\times$

1	2	3
1	2	3
1	2	3

(3,3)

$=$

1	2	3
2	4	6
3	6	9

(3,3)

NumPy: Broadcasting (Cont IV)

- Hopefully from these examples, we can see that broadcasting is only going to work if the arrays are **compatible** :
  1. The two arrays share a dimension of the same size and *,
  2. One of the dimensions — for at least one of the arrays — is one
- **Examples**:
  - 2×3 and 1×3 are compatible — they satisfy both conditions
  - 5×89 and 5×1 are compatible — they satisfy both conditions
  - 2×3 and 3×4 are *not* compatible — why?
  - 5×6 and 5×2 are *not compatible* — why?
- **Question:** Why did I put an asterisk over the 'and'? What's the exception?

NumPy: The &, | and ~ Operators

- It is a quirk of Python for `and` and `or` to behave badly with boolean conditions in NumPy — once again, we have a workaround
- Equivalent operations for NumPy Boolean Arrays:

English	Python	NumPy
AND	`and`	`&`
OR	`or`	`|`
NOT	`not`	`~`

NumPy: The &, | and ~ Operators (cont)

1	2	3
4	5	6
7	8	9

- When using the array in the top right corner:
  - `(array <= 5) & (array >= 3) \`
    `== array([[False, False, True],`
    `[True, True, False],`
    `[False, False, False]])`
  - `(array >= 5) | (array <= 3) \`
    `== array([[True, True, True],`
    `[False, True, True],`
    `[True, True, True]])`
  - `~(array <= 5) \`
    `== array([[True, True, True],`
    `[True, False, False],`
    `[False, False, False]])`

NumPy: Unique

1	1	3	2
2	2	1	3
4	3	4	3

- `np.unique(array, return_counts = False)`
  - Returns an array of all the unique values of a given `array`
  - `return_counts = False` is an *optional* argument — if it is set to `True`, it will also return a list which gives back the amount of times each unique element occurs
- Example:

```
unique_vals, counts = np.unique(array,
                                return_counts = True)
unique_vals = np.array([1, 2, 3, 4])
counts      = np.array([3, 3, 4, 2])
```

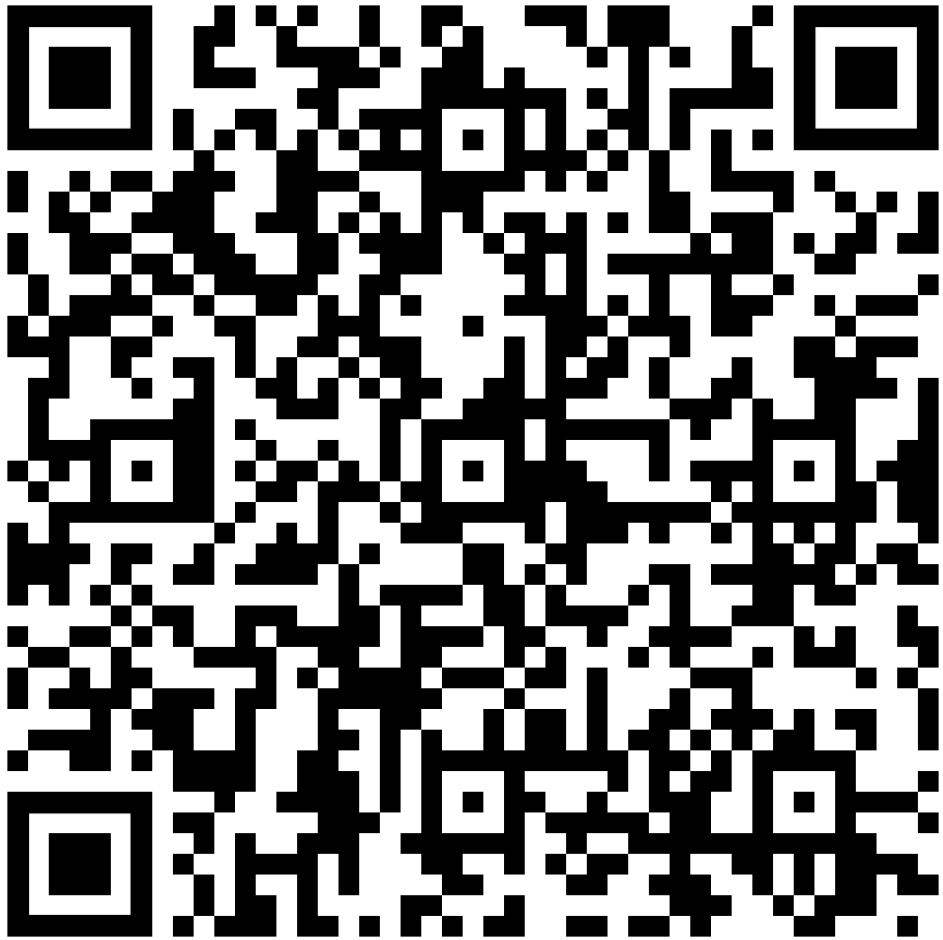
Lab Tips

Lab Tips

- You can check some of your answers on the course website (or in the starter code for Part A). Please do so before getting marked off!
- You aren't allowed to use any loops in Part A or Part B.
- Part A:
  - Think about how we discussed performing arithmetic operations efficiently in NumPy.
  - You can use NumPy functions to operate elementwise. You may want to use the square root function from some library (which one?) to do this.
- Part B:
  - Keep an eye on which methods the questions specifically ask you to use — if they do, then you have to use that method!
  - If, for Question 4 the week/Question 8 from part (b) in Week 7, you used slicing (as is wanted in this lab), then instead use the reshape approach from Week 7 (so that you've done one of each approach).

Feedback

Feel free to provide anonymous feedback about the lab!



Feedback Form