Filtering

Filter NumPy data for specific values.

Chapter Goals:

- Learn how to filter data in NumPy
- Write code for filtering NumPy arrays

A. Filtering data

Sometimes we have data that contains values we don't want to use. For example, when tracking the best hitters in baseball, we may want to only use the batting average data above .300. In this case, we should *filter* the overall data for only the values that we want.

The key to filtering data is through basic relation operations, e.g. `==`, `>`, etc. In NumPy, we can apply basic relation operations element-wise on arrays.

The code below shows relation operations on NumPy arrays. The `~` operation represents a boolean negation, i.e. it flips each truth value in the array.

```
arr = np.array([[0, 2, 3],
                [1, 3, -6],
                [-3, -2, 1]])
print(repr(arr == 3))
print(repr(arr > 0))
print(repr(arr != 1))
# Negated from the previous step
print(repr(~(arr != 1)))
```

Something to note is that `np.nan` can't be used with any relation operation. Instead, we use `np.isnan` to filter for the location of `np.nan`.

The code below uses `np.isnan` to determine which locations of the array contain `np.nan` values.

```
arr = np.array([[0, 2, np.nan],
                [1, np.nan, -6],
                [np.nan, -2, 1]])
print(repr(np.isnan(arr)))
```

Each boolean array in our examples represents the location of elements we want to filter for. The way we perform the filtering itself is through the `np.where` function.

B. Filtering in NumPy

The `np.where` function takes in a required first argument, which is a boolean array where `True` represents the locations of the elements we want to filter for. When the function is applied with only the first argument, it returns a tuple of 1-D arrays.

The tuple will have size equal to the number of dimensions in the data, and each array represents the `True` indices for the corresponding dimension. Note that the arrays in the tuple will all have the same length, equal to the number of `True` elements in the input argument.

The code below shows how to use `np.where` with a single argument.

```
print(repr(np.where([True, False, True])))

arr = np.array([0, 3, 5, 3, 1])
print(repr(np.where(arr == 3)))

arr = np.array([[0, 2, 3],
                [1, 0, 0],
                [-3, 0, 0]])
x_ind, y_ind = np.where(arr != 0)
print(repr(x_ind)) # x indices of non-zero elements
print(repr(y_ind)) # y indices of non-zero elements
print(repr(arr[x_ind, y_ind]))
```

The interesting thing about `np.where` is that it must be applied with exactly 1 or 3 arguments. When we use 3 arguments, the first argument is still the boolean array. However, the next two arguments represent the `True` replacement values and the `False` replacement values, respectively. The output of the function now becomes an array with the same shape as the first argument.

The code below shows how to use `np.where` with 3 arguments.

```
np_filter = np.array([[True, False], [False, True]])
positives = np.array([[1, 2], [3, 4]])
negatives = np.array([[-2, -5], [-1, -8]])
print(repr(np.where(np_filter, positives, negatives)))

np_filter = positives > 2
print(repr(np.where(np_filter, positives, negatives)))

np_filter = negatives > 0
print(repr(np.where(np_filter, positives, negatives)))
```

Note that our second and third arguments necessarily had the same shape as the first argument. However, if we wanted to use a constant replacement value, e.g. `-1`, we could incorporate broadcasting. Rather than using an entire array of the same value, we can just use the value itself as an argument.

The code below showcases broadcasting with `np.where`.

```
np_filter = np.array([[True, False], [False, True]])
positives = np.array([[1, 2], [3, 4]])
print(repr(np.where(np_filter, positives, -1)))
```

C. Axis-wise filtering

If we wanted to filter based on rows or columns of data, we could use the `np.any` and `np.all` functions. Both functions take in the same arguments, and return a single boolean or a boolean array. The required argument for both functions is a boolean array.

The code below shows usage of `np.any` and `np.all` with a single argument.

```
arr = np.array([[-2, -1, -3],
                [4, 5, -6],

                [3, 9, 1]])
print(repr(arr > 0))
print(np.any(arr > 0))
print(np.all(arr > 0))
```

The `np.any` function is equivalent to performing a logical OR (`||`), while the `np.all` function is equivalent to a logical AND (`&&`) on the first argument. np.any returns true if even one of the elements in the array meets the condition and np.all returns true only if all the elements meet the condition. When only a single argument is passed in, the function is applied across the entire input array, so the returned value is a single boolean.

However, if we use a multi-dimensional input and specify the `axis` keyword argument, the returned value will be an array. The `axis` argument has the same meaning as it did for `np.argmin` and `np.argmax` from the previous chapter. Using `axis=0` means the function finds the index of the minimum *row* element for each column. When we used `axis=1`, the function finds the index of the minimum *column* element for each row.

Setting `axis` to -1 just means we apply the function across the last dimension.

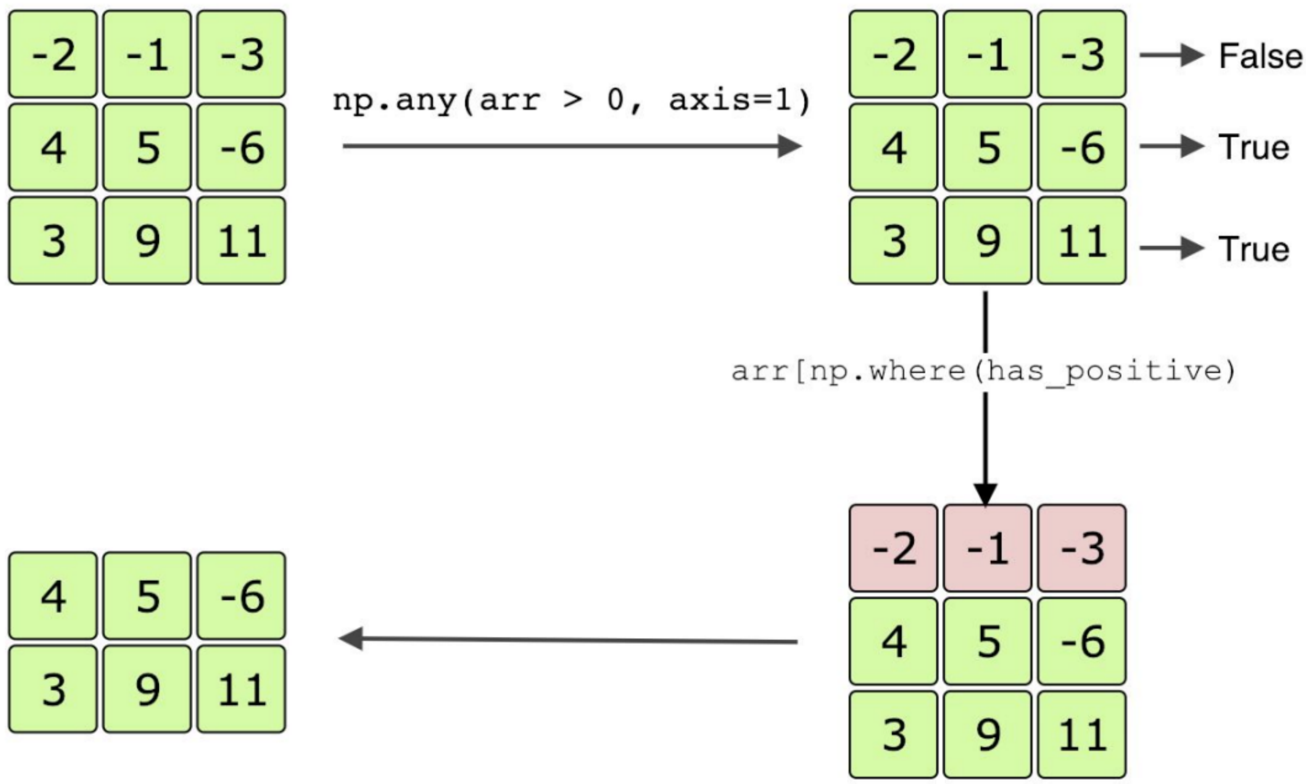
The code below shows examples of using `np.any` and `np.all` with the `axis` keyword argument.

```
arr = np.array([[-2, -1, -3],
                [4, 5, -6],
                [3, 9, 1]])
print(repr(arr > 0))
print(repr(np.any(arr > 0, axis=0)))
print(repr(np.any(arr > 0, axis=1)))
print(repr(np.all(arr > 0, axis=1)))
```

We can use `np.any` and `np.all` in tandem with `np.where` to filter for entire rows or columns of data.

In the code example below, we use `np.any` to obtain a boolean array representing the rows that have at least one positive number. We then use the

boolean array as the input to `np.where`, which gives us the actual indices of the rows with at least one positive number.




```
arr = np.array([[-2, -1, -3],
                [4, 5, -6],
                [3, 9, 1]])
has_positive = np.any(arr > 0, axis=1)
print(has_positive)
print(repr(arr[np.where(has_positive)]))
```

Time to Code!

Each coding exercise in this chapter will be to complete a small function that takes in a 2-D NumPy matrix (`data`) as input. The first function to complete is `get_positives`.

Set a tuple of `x_ind, y_ind` equal to the output of `np.where`, applied with the condition `data > 0`.

Then return `data[x_ind, y_ind]`.

```
def get_positives(data):
```

```
def get_positives(data):
  # CODE HERE
  pass
```

Next, we'll complete the function `replace_zeros`. The function replaces each of the non-positive elements in `data` with 0. We first create an array of all 0's, with the same shape as `data`.

Then we filter the `data` array and replace the non-positive elements with the corresponding element from `zeros` (which will be a 0).

Set `zeros` equal to `np.zeros_like` with `data` as the lone argument.

Set `zero_replace` equal to `np.where` with the condition of `data > 0`. The second argument will be `data` and the third argument will be `zeros`.

Return `zero_replace`.

```
def replace_zeros(data):
  # CODE HERE
  pass
```

The next function, `replace_neg_one`, will replace the non-positive elements of `data` with `-1`. Rather than creating a separate array, we'll use broadcasting.

Set `neg_one_replace` equal to `np.where` with the condition of `data > 0`. The second argument will be `data` and the third will be `-1`.

Return `neg_one_replace`.

```
def replace_neg_one(data):
  # CODE HERE
  pass
```

Our final function, `coin_flip_filter` will apply a filter using a boolean array as the condition. We'll first create a boolean coin flip array with the same as the condition. We'll first create a boolean coin flip array with the same shape as `data`.

Then we filter `data` using `bool_coin_flips` as the condition. For the `False` values in `bool_coin_flips`, we replace the corresponding index in `data` with a 1.

Set `coin_flips` equal to `np.random.randint` with `2` as the first argument and `data.shape` as the `size` keyword argument.

Set `bool_coin_flips` equal to `coin_flips`, cast as `np.bool` (using the `np.astype` function).

Set `one_replace` equal to `np.where` with `bool_coin_flips`, `data`, and `1` as the respective arguments.

Return `one_replace`.

```
def coin_flip_filter(data):
  # CODE HERE
  pass
```