Density and Contour Plots

Sometimes it is useful to display **three-dimensional data in two dimensions** using contours or color-coded regions.

There are three **Matplotlib functions** that can be helpful for this task:

`plt.contour` for **contour plots,**

`plt.contourf` for **filled contour plots,**

and `plt.imshow` for **showing images.**

This chapter looks at several examples of using these.

We'll start by setting up the notebook for plotting and importing the functions we will use:

In [ ]:
```
%matplotlib inline
import matplotlib.pyplot as plt
plt.style.use('seaborn-white')
import numpy as np
```

Visualizing a Three-Dimensional Function

Our first example demonstrates a contour plot using a function z = f(x, y),

using the following particular choice for f:

In [ ]:
```
def f(x, y):
    return np.sin(x) ** 10 + np.cos(10 + y * x) * np.cos(x)
```

A **contour plot** can be created with the `plt.contour` function.

It takes **three arguments:**

a grid of *x* values, a grid of *y* values, and a grid of *z* values.

The *x* and *y* values represent **positions** on the plot, and the *z* values will be represented by the **contour levels.**

Perhaps the most straightforward way to prepare such data is to use the `np.meshgrid` function,

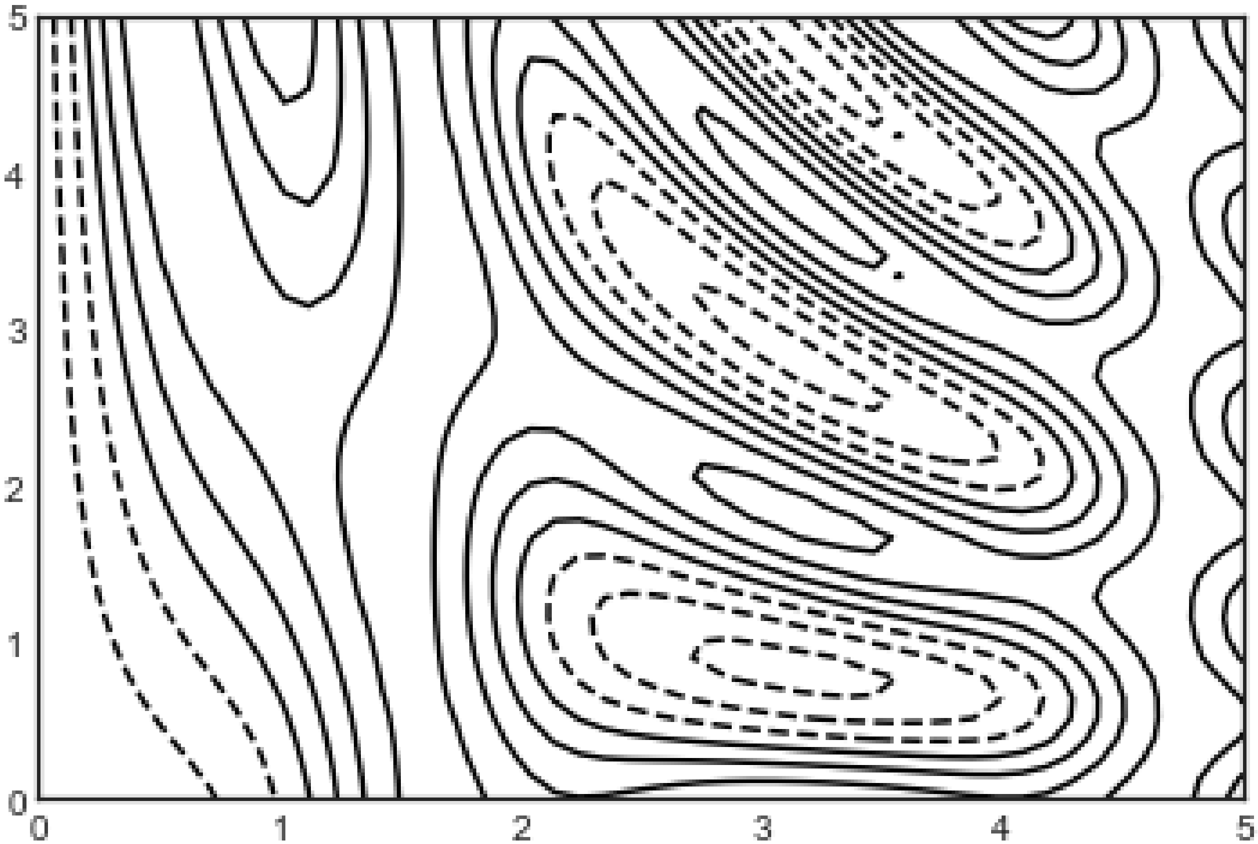
which builds **two-dimensional grids from one-dimensional arrays:**

In [ ]:
```
x = np.linspace(0, 5, 50)
y = np.linspace(0, 5, 40)

X, Y = np.meshgrid(x, y)
Z = f(X, Y)
```

Now let's look at this with a **standard line-only contour** plot (see the following figure):

In [ ]:
```
plt.contour(X, Y, Z, colors='black');
```

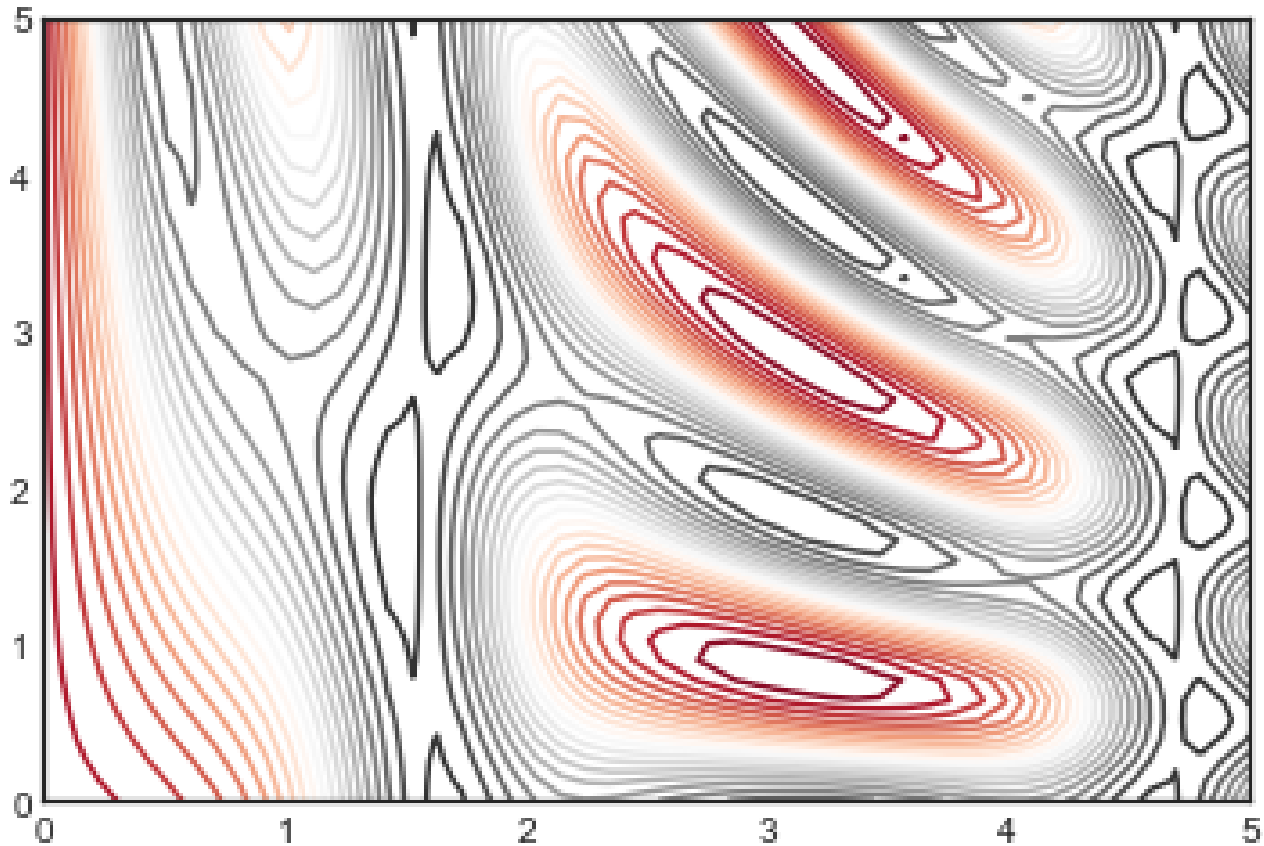


Notice that when a single color is used, **negative values** are represented by **dashed lines** and **positive values** by **solid lines.**

Alternatively, the **lines can be color-coded** by specifying a colormap with the `cmap` argument.

Here we'll also specify that we want **more lines** to be drawn, at 20 equally spaced intervals within the data range, as shown in the following figure:

In [ ]:
```
plt.contour(X, Y, Z, 20, cmap='RdGy');
```



Here we chose the `RdGy` (short for *Red–Gray*) **colormap**,

which is a good choice for **divergent data:** (i.e., data with positive and negative variation around zero).

Matplotlib has a **wide range of colormaps available,** which you can easily browse in IPython by doing a tab completion on the `plt.cm` module:

```
plt.cm.<TAB>
```

Our plot is looking nicer, but the **spaces between the lines** may be a bit **distracting.**

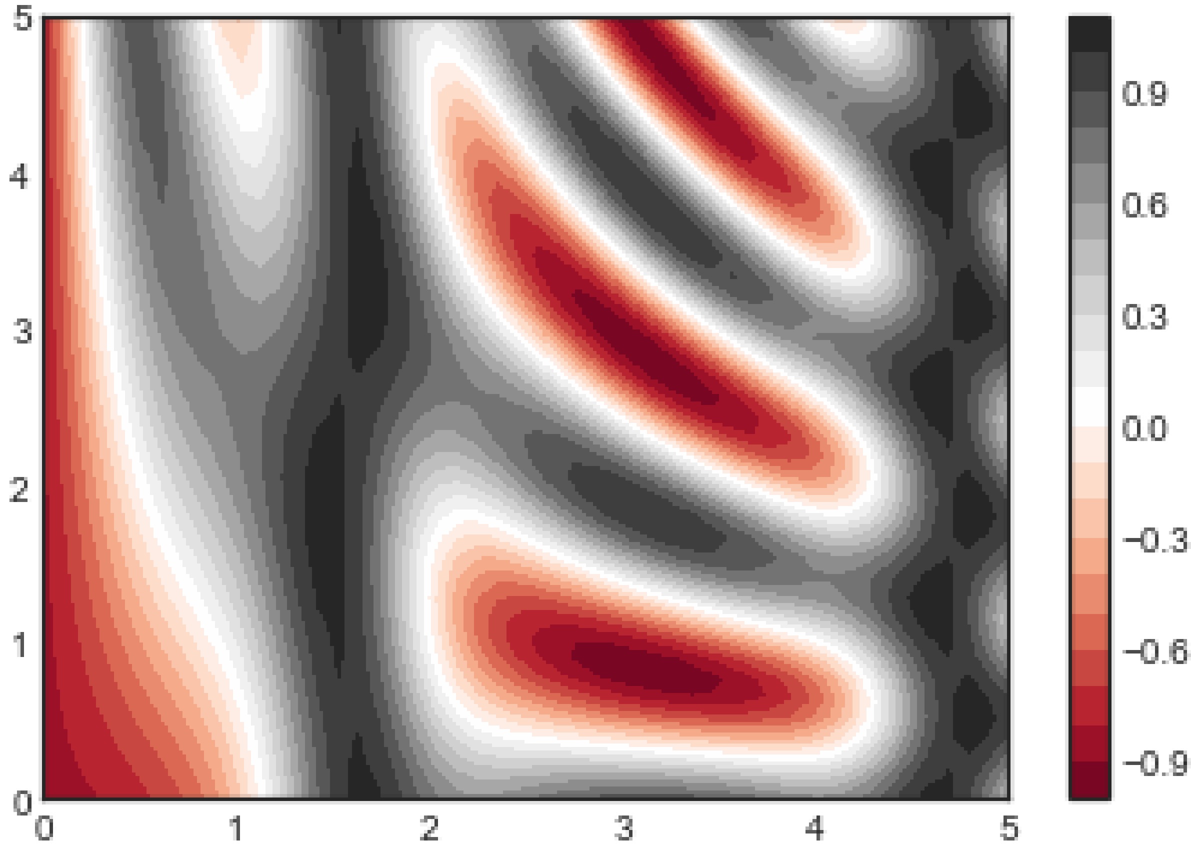
We can change this by switching to a **filled contour plot** using the `plt.contourf` function,

which uses largely the **same syntax** as `plt.contour`.

Additionally, we'll add a `plt.colorbar` command,

which creates an **additional axis** with **labeled color** information for the plot (see the following figure):

In [ ]:
```
plt.contourf(X, Y, Z, 20, cmap='RdGy')
plt.colorbar();
```



The colorbar makes it clear that the black regions are **"peaks,"** while the red regions are **"valleys."**

One potential issue with this plot is that it is a bit splotchy:

the **color steps** are **discrete** rather than continuous, which is not always what is desired.

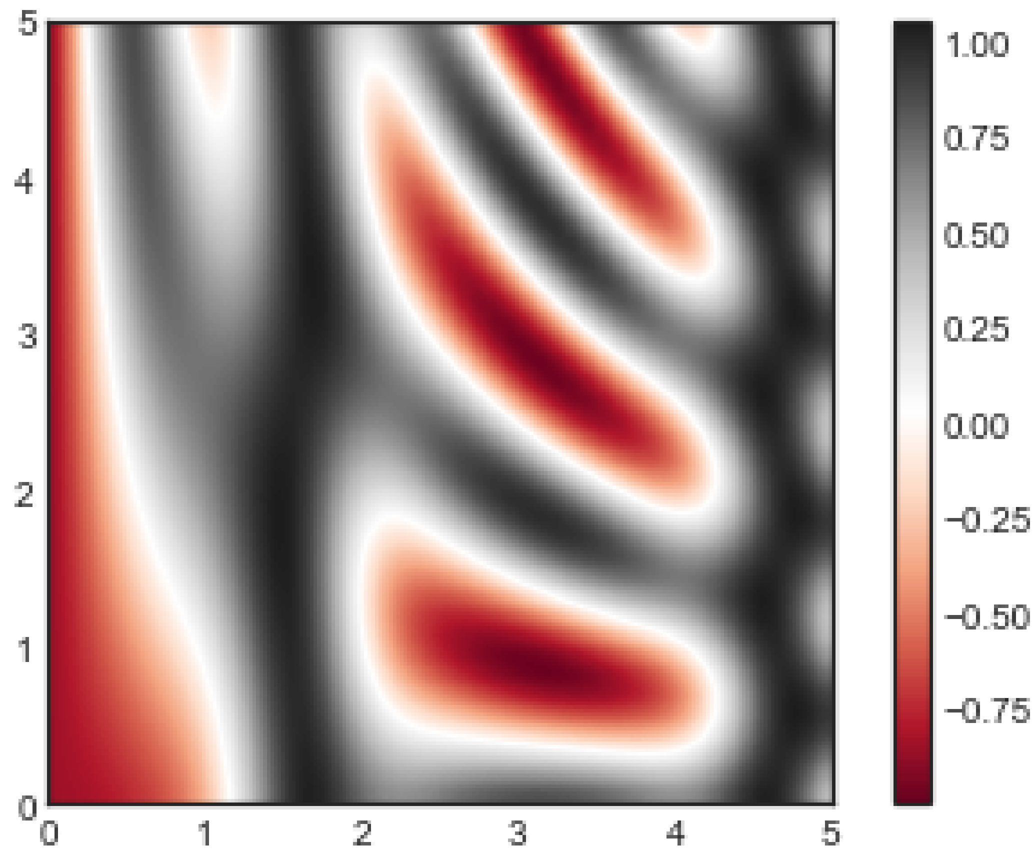
This could be remedied by setting the **number of contours** to a very **high number,** but this results in a rather inefficient plot:

Matplotlib must **render** a new polygon for **each step** in the level.

A **better way** to generate a **smooth representation** is to use the `plt.imshow` function,

which offers the `interpolation` argument to generate a smooth two-dimensional representation of the data (see the following figure):

In [ ]:
```
plt.imshow(Z, extent=[0, 5, 0, 5], origin='lower', cmap='RdGy
           interpolation='gaussian', aspect='equal')
plt.colorbar();
```



5
4
3
2
1
0
0
1
2
3
4
5
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75