

# Exploratory data analysis

Fraida Fund

## In this notebook

In this notebook:

- We practice using `pandas` to read in and manipulate a data set. (We won't have a separate tutorial on `pandas` - we will learn basic `pandas` techniques as we need them.)
- We learn a basic "recipe" for exploratory data analysis and apply it to an example

## Introduction

The first step in applying machine learning to a real problem is *finding* or *creating* an appropriate data set with which to train your model.

### What makes data "good"?

What makes a good data set?

- **Size:** the more *samples* are in the data set, the more examples your machine learning model will be able to learn from, and the better it will do. Often, a simple machine learning model trained on a large data set will outperform a "fancy" model on a small data set.
- **Quality:** Are there *predictive* features in the data? Are no values (or very few values) missing, noisy, or incorrect? Is the scenario in which the data collected similar to the scenario in which your model will be used? These are examples of questions that we might ask to evaluate the quality of a data set.

One of the most important principles in machine learning is: **garbage in, garbage out**. If the data you use to train a machine learning model is problematic, or not well suited for the purpose, then even the best model will produce useless predictions.

### Purpose of exploratory data analysis

Once we have identified one or more candidate data sets for a particular problem, we perform some *exploratory data analysis*. This process helps us

- detect and possibly correct mistakes in the data
- check our assumptions about the data
- identify potential relationships between features
- assess the direction and rough size of relationships between features and the target variable

Exploratory data analysis is important for understanding whether this data set is appropriate for the machine learning task at hand, and if any extra cleaning or processing steps are required before we use the data.

### "Recipe" for exploratory data analysis

We will practice using a basic "recipe" for exploratory data analysis.

1. Set down *expectations* about the data
2. Load data and check that it is loaded correctly
3. Inspect the data to make sure it is consistent with your expectations ("sanity checks"), and clear or filter the data if needed
4. Explore relationships in the data to identify good candidate features and target variables

Every exploratory data analysis is different, as specific characteristics of the data may lead you to explore different things in depth. However, this “recipe” can be a helpful starting point.

### Example: Brooklyn Bridge pedestrian data set

The Brooklyn Bridge is a bridge that connects Brooklyn and Manhattan. It supports vehicles, pedestrians, and bikers.



Support you are developing a machine learning model to predict the volume of pedestrian traffic on the Brooklyn Bridge. There is a dataset available that you think may be useful as training data: [Brooklyn Bridge Automated Pedestrian Counts dataset](#), from the NYC Department of Transportation.

We will practice applying the “recipe” for exploratory data analysis to this data.

We will use the `pandas` library in Python, which includes many powerful utilities for managing data. You can refer to the [pandas reference](#) for more details on the `pandas` functions used in this notebook.

### Set down expectations about the data

The first step is to codify your expectations about the data *before* you look at it:

- Read about *methodology* and *data codebook*
- How many rows and columns are in the data?
- What does each variable mean? What units are data recorded in? What is the expected range or typical value for each column?
- What variables do you think could be used as target variable? What variables could be used as features from which to learn?
- How was data collected? Identify sampling issues, timeliness issues, fairness issues, etc.

For the Brooklyn Bridge dataset, you can review the associated documentation on the NYC Data website:

- [NYC Data Website](#)
- [Data dictionary](#)

## Load data and check that it is loaded correctly

The next step is to load the data in preparation for our exploratory data analysis. Then, we'll check that it is loaded correctly.

Some examples of the things we'll look for include:

- Does the `DataFrame` have the correct number of rows and columns (consistent with our expectations from the first step)?
- Is the first row of "data" in the `DataFrame` real data, or is it column labels that were misinterpreted as data? (Similarly, are the column labels actually labels, or are they the first row of data?)
- Are the data types of every column consistent with our expectations?

At this stage, we might also do some very basic manipulation of the data

- for example, compute some fields that are derived directly from other fields. (For example, suppose you have a "distance" field in miles and you wanted to convert it to meters - you could do that here!)

First, we will import some useful libraries:

- In Python - libraries add powerful functionality
- You can import an entire library (`import foo`) or part (`from foo import bar`)
- You can define a nickname, which you will use to call functions of these libraries (many libraries have "conventional" nicknames)

`pandas` is a popular Python library for working with data. It is conventionally imported with the `pd` nickname.

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

# set up notebook to show all outputs, not only last one
from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = "all"
```

Now we are ready to read in our data!

The main type of data structure in `pandas` is a `DataFrame`, which organizes data into a 2D table, like a spreadsheet. Unlike a `numpy` array, however, different column in a `DataFrame` can have different data types - for example, you can have a string column, an integer column, and a float column all in the same `DataFrame`.

(The other major type of data in `pandas` is a `Series`, which is like a 1D array- any individual row or column from a `DataFrame` will be a `Series`.)

You *can* create a `DataFrame` or a `Series` "by hand" - for example, try

```
pd.Series([1,2,3,99])
```

or

```
pd.DataFrame({'fruit': ['apple', 'banana', 'kiwi'], 'cost': [0.55, 0.99, 1.24]})
```

But usually, we'll read in data from a file.

Our data for this Brooklyn Bridge example is in CSV format, so will use the `read_csv` function in pandas to read in our data. This function accepts a URL or a path to a file, and will return our data as a DataFrame.

Function documentation: [pandas reference](#)

```
pandas.read_csv(filepath_or_buffer,
                 sep=',', header='infer',
                 names=None,
                 ...)
```

`read_csv` is for “flat” text files, where each data point is on another row, and the fields in a row are separated by some delimiter (e.g. comma). Other pandas functions exist for loading other kinds of data (read from database, Excel file, etc.)

```
url = 'https://data.cityofnewyork.us/api/views/6fi9-q3ta/rows.csv?accessType=DOWNLOAD'
df = pd.read_csv(url)
```

We will want to verify that the data was loaded correctly. For *tabular* data, we can start by looking at the first few rows of data or the last few rows of data with the `head` and `tail` functions, respectively. (For data that is not tabular, such as image, text, or audio data, we would similarly start by looking at some samples.)

```
df.head()
```

	hour_beginning	location	Pedestrians	Towards Manhattan	\
0	04/30/2019 12:00:00 AM	Brooklyn Bridge	3		3
1	12/31/2019 10:00:00 PM	Brooklyn Bridge	10		9
2	12/31/2019 11:00:00 PM	Brooklyn Bridge	2		0
3	12/31/2019 09:00:00 PM	Brooklyn Bridge	12		0
4	04/01/2019 03:00:00 AM	Brooklyn Bridge	1		0

	Towards Brooklyn	weather_summary	temperature	precipitation	lat	\
0	0	NaN	NaN	NaN	40.708164	
1	1	cloudy	42.0	0.0005	40.708164	
2	2	cloudy	42.0	0.0004	40.708164	
3	12	cloudy	42.0	0.0036	40.708164	
4	1	clear-night	36.0	0.0000	40.708164	

	long	events	Location1
0	-73.999509	NaN	(40.7081639691088, -73.9995087014816)
1	-73.999509	NaN	(40.7081639691088, -73.9995087014816)
2	-73.999509	NaN	(40.7081639691088, -73.9995087014816)
3	-73.999509	NaN	(40.7081639691088, -73.9995087014816)
4	-73.999509	NaN	(40.7081639691088, -73.9995087014816)

```
df.tail()
```

	hour_beginning	location	Pedestrians	\
16052	06/22/2018 04:00:00 AM	Brooklyn Bridge	7	
16053	07/19/2018 06:00:00 AM	Brooklyn Bridge	192	
16054	06/16/2018 04:00:00 PM	Brooklyn Bridge	2623	
16055	07/24/2018 06:00:00 PM	Brooklyn Bridge	2016	
16056	07/23/2018 12:00:00 AM	Brooklyn Bridge	57	

	Towards Manhattan	Towards Brooklyn	weather_summary	temperature	\
16052	4	3	partly-cloudy-night	67.0	
16053	89	103	clear-day	65.0	
16054	1161	1462	clear-day	82.0	
16055	1069	947	partly-cloudy-day	80.0	
16056	20	37	cloudy	75.0	
	precipitation	lat	long	events	\
16052	0.0000	40.708164	-73.999509	NaN	
16053	0.0000	40.708164	-73.999509	NaN	
16054	0.0000	40.708164	-73.999509	NaN	
16055	0.0000	40.708164	-73.999509	NaN	
16056	0.0103	40.708164	-73.999509	NaN	
	Location1				
16052	(40.7081639691088, -73.9995087014816)				
16053	(40.7081639691088, -73.9995087014816)				
16054	(40.7081639691088, -73.9995087014816)				
16055	(40.7081639691088, -73.9995087014816)				
16056	(40.7081639691088, -73.9995087014816)				

We can also get a few random rows:

```
df.sample(5)
```

	hour_beginning	location	Pedestrians	\	
2318	04/01/2019 04:00:00 AM	Brooklyn Bridge	0		
2762	04/20/2019 12:00:00 PM	Brooklyn Bridge	1824		
9114	12/19/2017 08:00:00 AM	Brooklyn Bridge	276		
1693	10/26/2019 11:00:00 PM	Brooklyn Bridge	86		
14044	03/20/2018 07:00:00 AM	Brooklyn Bridge	139		
	Towards Manhattan	Towards Brooklyn	weather_summary	temperature	\
2318	0	0	clear-night	35.0	
2762	1062	762	cloudy	61.0	
9114	110	166	partly-cloudy-day	45.0	
1693	82	4	cloudy	57.0	
14044	57	82	clear-night	31.0	
	precipitation	lat	long	events	\
2318	0.0000	40.708164	-73.999509	NaN	
2762	0.0093	40.708164	-73.999509	NaN	
9114	0.0000	40.708164	-73.999509	NaN	
1693	0.0000	40.708164	-73.999509	NaN	
14044	0.0000	40.708164	-73.999509	NaN	
	Location1				
2318	(40.7081639691088, -73.9995087014816)				
2762	(40.7081639691088, -73.9995087014816)				
9114	(40.7081639691088, -73.9995087014816)				
1693	(40.7081639691088, -73.9995087014816)				
14044	(40.7081639691088, -73.9995087014816)				

Looking at some rows can help us spot obvious problems with data loading. For example, suppose we had tried to read in the data using a tab delimiter to separate fields on the same row, instead of a comma.

```
df_bad = pd.read_csv(url, sep='\t')
df_bad.head()
```

```
hour_beginning,location,Pedestrians,Towards Manhattan,Towards
    Brooklyn,weather_summary,temperature,precipitation,lat,long,events,Location1
0  04/30/2019 12:00:00 AM,Brooklyn Bridge,3,3,0,...
1  12/31/2019 10:00:00 PM,Brooklyn Bridge,10,9,1,...
2  12/31/2019 11:00:00 PM,Brooklyn Bridge,2,0,2,c...
3  12/31/2019 09:00:00 PM,Brooklyn Bridge,12,0,12...
4  04/01/2019 03:00:00 AM,Brooklyn Bridge,1,0,1,c...
```

This “bad” version of the DataFrame has only a single column (because it believes tabs are used to separate fields in the same row, when actually commas are used). The variable names are combined together into one long column name. By looking at the first few rows of data, we can spot this obvious error.

Here is another example of a “bad” DataFrame. Suppose we tell `read_csv` that the data file itself does not have a header row at the top, with column names in it; instead, we supply column names ourselves.

```
col_names = ["hour_beginning", "location", "Pedestrians", "Towards Manhattan",
             "Towards Brooklyn", "weather_summary", "temperature", "precipitation",
             "lat", "long", "events", "Location1"]
df_bad = pd.read_csv(url, header=None, names=col_names)
df_bad.head()
```

	hour_beginning	location	Pedestrians	Towards Manhattan	\
0	hour_beginning	location	Pedestrians	Towards Manhattan	
1	04/30/2019 12:00:00 AM	Brooklyn Bridge	3	3	
2	12/31/2019 10:00:00 PM	Brooklyn Bridge	10	9	
3	12/31/2019 11:00:00 PM	Brooklyn Bridge	2	0	
4	12/31/2019 09:00:00 PM	Brooklyn Bridge	12	0	

	Towards Brooklyn	weather_summary	temperature	precipitation	\
0	Towards Brooklyn	weather_summary	temperature	precipitation	
1	0	NaN	NaN	NaN	
2	1	cloudy	42	0.0005	
3	2	cloudy	42	0.0004	
4	12	cloudy	42	0.0036	

	lat	long	events	\
0	lat	long	events	
1	40.7081639691088	-73.9995087014816	NaN	
2	40.7081639691088	-73.9995087014816	NaN	
3	40.7081639691088	-73.9995087014816	NaN	
4	40.7081639691088	-73.9995087014816	NaN	

	Location1
0	Location1
1	(40.7081639691088, -73.9995087014816)
2	(40.7081639691088, -73.9995087014816)
3	(40.7081639691088, -73.9995087014816)
4	(40.7081639691088, -73.9995087014816)

In this example, the first row in the file is actually a column header, and we mistakenly read it in as data. (A similar problem can occur in reverse - if we told `read_csv` that the first row is a header when it is not, then our “column labels” would actually be the first row of data.)

We should always check the shape of the data frame - the number of rows and columns. This, too, should be checked against our assumptions about the data (in this case, what we know from the NYC Data website.)

```
df.shape
```

```
(16057, 12)
```

Check the names of the columns and their data types:

```
df.columns
df.dtypes
```

```
Index(['hour_beginning', 'location', 'Pedestrians', 'Towards Manhattan',
       'Towards Brooklyn', 'weather_summary', 'temperature', 'precipitation',
       'lat', 'long', 'events', 'Location1'],
      dtype='object')
```

```
hour_beginning    object
location          object
Pedestrians       int64
Towards Manhattan int64
Towards Brooklyn  int64
weather_summary   object
temperature       float64
precipitation     float64
lat               float64
long              float64
events            object
Location1         object
dtype: object
```

The main data types we’ll see most often are `int64` (integer), `float64` (numeric), `bool` (True or False), or `object` (which includes string).

We can also get a quick summary with `info()`;

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 16057 entries, 0 to 16056
Data columns (total 12 columns):
hour_beginning    16057 non-null object
location          16057 non-null object
Pedestrians       16057 non-null int64
Towards Manhattan 16057 non-null int64
Towards Brooklyn  16057 non-null int64
weather_summary   16041 non-null object
temperature       16041 non-null float64
precipitation     16041 non-null float64
```

```
lat          16057 non-null float64
long         16057 non-null float64
events       1124 non-null object
Location1    16057 non-null object
dtypes: float64(4), int64(3), object(5)
memory usage: 1.5+ MB
```

pandas infers the data type of each column automatically from the contents of the data.

If the data type of a column is not what you expect it to be, this can often be a signal that the data needs cleaning. For example, if you expect a column to be numeric and it is read in as non-numeric, this indicates that there are probably some samples that include a non-numeric value in that column. (The [NYC Data website](#) indicates what type of data *should* be in each column, so you should reference that when checking this output. )

We have a date/time column (`hour_beginning`) that was read in as a string. Let's take a closer look at that. We can get one column of data either using a notation like a dictionary, as in

```
df['hour_beginning']
```

or using class attribute-like notation, as in

```
df.hour_beginning
```

(either one returns exactly the same thing!) (Note that if the column name includes spaces, you can only use the notation with the brackets, since it encloses the column name in quotes.)

pandas includes a `to_datetime` function to convert this string to a “native” date/time format, so we can use that now:

```
df['hour_beginning'] = pd.to_datetime(df['hour_beginning'])
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 16057 entries, 0 to 16056
Data columns (total 12 columns):
hour_beginning    16057 non-null datetime64[ns]
location          16057 non-null object
Pedestrians       16057 non-null int64
Towards Manhattan 16057 non-null int64
Towards Brooklyn  16057 non-null int64
weather_summary   16041 non-null object
temperature       16041 non-null float64
precipitation     16041 non-null float64
lat              16057 non-null float64
long             16057 non-null float64
events           1124 non-null object
Location1         16057 non-null object
dtypes: datetime64[ns](1), float64(4), int64(3), object(4)
memory usage: 1.5+ MB
```

You may notice that the `hour_beginning` variable includes the full date and time in one field. For our analysis, it would be more useful to have separate fields for the date, month, day of the week, and hour.

We can create these additional fields by assigning the desired value to them directly - then, observe the effect:



```
df['hour'] = df['hour_beginning'].dt.hour
df['month'] = df['hour_beginning'].dt.month
df['date'] = df['hour_beginning'].dt.date
df['day_name'] = df['hour_beginning'].dt.day_name()

df.head()
```

	hour_beginning	location	Pedestrians	Towards Manhattan	\
0	2019-04-30 00:00:00	Brooklyn Bridge	3	3	
1	2019-12-31 22:00:00	Brooklyn Bridge	10	9	
2	2019-12-31 23:00:00	Brooklyn Bridge	2	0	
3	2019-12-31 21:00:00	Brooklyn Bridge	12	0	
4	2019-04-01 03:00:00	Brooklyn Bridge	1	0	

	Towards Brooklyn	weather_summary	temperature	precipitation	lat	\
0	0	NaN	NaN	NaN	40.708164	
1	1	cloudy	42.0	0.0005	40.708164	
2	2	cloudy	42.0	0.0004	40.708164	
3	12	cloudy	42.0	0.0036	40.708164	
4	1	clear-night	36.0	0.0000	40.708164	

	long	events	Location1	hour	month	\
0	-73.999509	NaN	(40.7081639691088, -73.9995087014816)	0	4	
1	-73.999509	NaN	(40.7081639691088, -73.9995087014816)	22	12	
2	-73.999509	NaN	(40.7081639691088, -73.9995087014816)	23	12	
3	-73.999509	NaN	(40.7081639691088, -73.9995087014816)	21	12	
4	-73.999509	NaN	(40.7081639691088, -73.9995087014816)	3	4	

	date	day_name
0	2019-04-30	Tuesday
1	2019-12-31	Tuesday
2	2019-12-31	Tuesday
3	2019-12-31	Tuesday
4	2019-04-01	Monday

## Inspect (and possibly clean/filter) the data

Now we are ready to inspect the data.

Some examples of the things we'll look for include:

- Are there missing values? There may be rows *in* the data where some or all fields are missing (which can be denoted as None, NaN, or even 0 or -1 - which can be misleading when 0 or -1 are also valid values for that field.) There may also be rows *not in* the data, that we expect *should be* in the data.
- For numeric fields: Is the min and max of each field consistent with our expectation? Is the median consistent with our expectation?
- For non-numeric fields: Are the number of unique values in each field consistent with our expectations? Are the values of the factor levels (where these can reasonably be assessed) described consistently throughout the data?
- Are the relationships *between* variables consistent with our expectations? (We can evaluate this visually, and also by looking at summary statistics.)
- If the data is a time series, is the trend of each variable over time consistent with our expectations?

For many of these “sanity checks”, we will need some *domain knowledge*. It’s hard to have reasonable expectations about the values in the data if you do not understand the topic that the data relates to.

Let us start by checking whether the data is complete. First, we’ll check whether there are any rows in the data where some or all fields are missing.

We can see the number of missing values in each column by summing up all the instances where the `isnull` function returns a True value:

```
df.isnull().sum()
```

```
hour_beginning      0
location            0
Pedestrians         0
Towards Manhattan   0
Towards Brooklyn    0
weather_summary     16
temperature         16
precipitation       16
lat                0
long               0
events             14933
Location1           0
hour               0
month             0
date              0
day_name          0
dtype: int64
```

(Note that this only tells us about missing values that are explicitly denoted as such - for example, explicit NaN values. If a missing value is coded as something else - like a 0 or -1 - we wouldn’t know unless we noticed an unusually high frequency of 0 or -1 values.)

We notice that the majority of rows are missing a value in the `events` field, which is used to mark dates that are holidays or other special events. This is reasonable, since most dates do not have any remarkable events.

Let’s look at the rows that *do* have a value in the `events` field. To filter a dataframe, we’ll use the `.loc[]` operator. This accepts either an index (for example, we can do `df.loc[0]` to see the first record in the dataframe), an array of indices (for example, `df.loc[[0,1,2]]`), or an array of boolean values the length of the entire dataframe. That’s what we’ll use here.

```
df.loc[df['events'].notnull()]
```

	hour_beginning	location	Pedestrians	Towards Manhattan	\
5	2019-12-25 14:00:00	Brooklyn Bridge	3171	1685	
65	2019-10-31 00:00:00	Brooklyn Bridge	13	11	
76	2019-03-17 23:00:00	Brooklyn Bridge	1	0	
78	2019-02-18 16:00:00	Brooklyn Bridge	1439	622	
89	2019-09-02 01:00:00	Brooklyn Bridge	0	0	
...	...	...	...	...	
15962	2018-07-04 16:00:00	Brooklyn Bridge	2726	2726	
15990	2018-07-04 12:00:00	Brooklyn Bridge	2010	1073	
15997	2018-06-17 23:00:00	Brooklyn Bridge	353	168	
16017	2018-06-17 03:00:00	Brooklyn Bridge	16	11	
16024	2018-06-17 14:00:00	Brooklyn Bridge	2038	897	

	Towards Brooklyn	weather_summary	temperature	precipitation \
5	1486	clear-day	44.0	0.0000
65	2	cloudy	61.0	0.0000
76	1	clear-night	37.0	0.0000
78	817	partly-cloudy-day	40.0	0.0002
89	0	partly-cloudy-night	69.0	0.0000
...	...	...	...	...
15962	0	partly-cloudy-day	82.0	0.0133
15990	937	partly-cloudy-day	84.0	0.0000
15997	185	clear-night	74.0	0.0000
16017	5	clear-night	66.0	0.0000
16024	1141	clear-day	86.0	0.0000

	lat	long	events \
5	40.708164	-73.999509	Christmas Day
65	40.708164	-73.999509	Halloween
76	40.708164	-73.999509	St. Patrick's Day
78	40.708164	-73.999509	Presidents' Day (regional holiday)
89	40.708164	-73.999509	Labor Day
...	...	...	...
15962	40.708164	-73.999509	Independence Day
15990	40.708164	-73.999509	Independence Day
15997	40.708164	-73.999509	Father's Day
16017	40.708164	-73.999509	Father's Day
16024	40.708164	-73.999509	Father's Day

	Location1	hour	month	date \
5	(40.7081639691088, -73.9995087014816)	14	12	2019-12-25
65	(40.7081639691088, -73.9995087014816)	0	10	2019-10-31
76	(40.7081639691088, -73.9995087014816)	23	3	2019-03-17
78	(40.7081639691088, -73.9995087014816)	16	2	2019-02-18
89	(40.7081639691088, -73.9995087014816)	1	9	2019-09-02
...	...	...	...	...
15962	(40.7081639691088, -73.9995087014816)	16	7	2018-07-04
15990	(40.7081639691088, -73.9995087014816)	12	7	2018-07-04
15997	(40.7081639691088, -73.9995087014816)	23	6	2018-06-17
16017	(40.7081639691088, -73.9995087014816)	3	6	2018-06-17
16024	(40.7081639691088, -73.9995087014816)	14	6	2018-06-17

	day_name
5	Wednesday
65	Thursday
76	Sunday
78	Monday
89	Monday
...	...
15962	Wednesday
15990	Wednesday
15997	Sunday
16017	Sunday
16024	Sunday

[1124 rows x 16 columns]

We also notice a small number of rows missing weather information. It's not clear why these are missing. Let's take a closer look at some of those rows, by *filtering* the dataframe to only rows that meet a specific condition - in this case, that the temperature field is missing.

```
df.loc[df.temperature.isnull()]
```

	hour_beginning	location	Pedestrians	Towards Manhattan	\
0	2019-04-30 00:00:00	Brooklyn Bridge	3	3	
482	2019-01-06 00:00:00	Brooklyn Bridge	3	3	
701	2019-11-03 01:00:00	Brooklyn Bridge	0	0	
2140	2019-01-14 00:00:00	Brooklyn Bridge	0	0	
2604	2019-01-09 00:00:00	Brooklyn Bridge	3	3	
2944	2019-03-10 02:00:00	Brooklyn Bridge	0	0	
3951	2019-01-16 00:00:00	Brooklyn Bridge	7	2	
4198	2019-05-02 00:00:00	Brooklyn Bridge	3	2	
5206	2019-09-17 00:00:00	Brooklyn Bridge	2	2	
5277	2019-06-17 01:00:00	Brooklyn Bridge	0	0	
5562	2019-02-02 00:00:00	Brooklyn Bridge	0	0	
5934	2019-09-06 00:00:00	Brooklyn Bridge	2	1	
5962	2019-05-08 00:00:00	Brooklyn Bridge	3	2	
7696	2019-03-05 00:00:00	Brooklyn Bridge	2	0	
12271	2018-03-11 02:00:00	Brooklyn Bridge	0	0	
12796	2018-05-13 00:00:00	Brooklyn Bridge	98	69	

	Towards Brooklyn	weather_summary	temperature	precipitation	\
0	0	NaN	NaN	NaN	
482	0	NaN	NaN	NaN	
701	0	NaN	NaN	NaN	
2140	0	NaN	NaN	NaN	
2604	0	NaN	NaN	NaN	
2944	0	NaN	NaN	NaN	
3951	5	NaN	NaN	NaN	
4198	1	NaN	NaN	NaN	
5206	0	NaN	NaN	NaN	
5277	0	NaN	NaN	NaN	
5562	0	NaN	NaN	NaN	
5934	1	NaN	NaN	NaN	
5962	1	NaN	NaN	NaN	
7696	2	NaN	NaN	NaN	
12271	0	NaN	NaN	NaN	
12796	29	NaN	NaN	NaN	

	lat	long	events	\
0	40.708164	-73.999509	NaN	
482	40.708164	-73.999509	NaN	
701	40.708164	-73.999509	Daylight Saving Time ends	
2140	40.708164	-73.999509	NaN	
2604	40.708164	-73.999509	NaN	
2944	40.708164	-73.999509	Daylight Saving Time starts	
3951	40.708164	-73.999509	NaN	
4198	40.708164	-73.999509	NaN	
5206	40.708164	-73.999509	NaN	

5277	40.708164	-73.999509		NaN
5562	40.708164	-73.999509		NaN
5934	40.708164	-73.999509		NaN
5962	40.708164	-73.999509		NaN
7696	40.708164	-73.999509		NaN
12271	40.708164	-73.999509	Daylight Saving Time starts	
12796	40.708164	-73.999509	Mother's Day	

	Location1	hour	month	date \
0	(40.7081639691088, -73.9995087014816)	0	4	2019-04-30
482	(40.7081639691088, -73.9995087014816)	0	1	2019-01-06
701	(40.7081639691088, -73.9995087014816)	1	11	2019-11-03
2140	(40.7081639691088, -73.9995087014816)	0	1	2019-01-14
2604	(40.7081639691088, -73.9995087014816)	0	1	2019-01-09
2944	(40.7081639691088, -73.9995087014816)	2	3	2019-03-10
3951	(40.7081639691088, -73.9995087014816)	0	1	2019-01-16
4198	(40.7081639691088, -73.9995087014816)	0	5	2019-05-02
5206	(40.7081639691088, -73.9995087014816)	0	9	2019-09-17
5277	(40.7081639691088, -73.9995087014816)	1	6	2019-06-17
5562	(40.7081639691088, -73.9995087014816)	0	2	2019-02-02
5934	(40.7081639691088, -73.9995087014816)	0	9	2019-09-06
5962	(40.7081639691088, -73.9995087014816)	0	5	2019-05-08
7696	(40.7081639691088, -73.9995087014816)	0	3	2019-03-05
12271	(40.7081639691088, -73.9995087014816)	2	3	2018-03-11
12796	(40.7081639691088, -73.9995087014816)	0	5	2018-05-13

	day_name
0	Tuesday
482	Sunday
701	Sunday
2140	Monday
2604	Wednesday
2944	Sunday
3951	Wednesday
4198	Thursday
5206	Tuesday
5277	Monday
5562	Saturday
5934	Friday
5962	Wednesday
7696	Tuesday
12271	Sunday
12796	Sunday

We can see that for these particular instances, all of the weather information. There's no obvious reason or pattern. We'll deal with these soon, when we try to clean/filter the data.

Before we do that, though, let's check for the *other* kind of missing data: rows that are missing completely, that we expect *should* be present.

In this example, the data is a time series, and we expect that there is exactly one row of data for every single hour over the time period in which this data was collected.

Let's see if the data is complete, or if there are gaps in time.

First, we will use `pd.date_range` to get the list of hour intervals that we expect to find in the dataset.

Then, we will find the difference between this list and the actual list of hour intervals in the dataset - these are missing intervals.

```
# get beginning and end of date range
min_dt = df.hour_beginning.min()
max_dt = df.hour_beginning.max()
print(min_dt)
print(max_dt)
```

```
2017-10-01 00:00:00
2019-12-31 23:00:00
```

```
expected_range = pd.date_range(start = min_dt, end = max_dt, freq='H' )
expected_range
```

```
DatetimeIndex(['2017-10-01 00:00:00', '2017-10-01 01:00:00',
               '2017-10-01 02:00:00', '2017-10-01 03:00:00',
               '2017-10-01 04:00:00', '2017-10-01 05:00:00',
               '2017-10-01 06:00:00', '2017-10-01 07:00:00',
               '2017-10-01 08:00:00', '2017-10-01 09:00:00',
               ...,
               '2019-12-31 14:00:00', '2019-12-31 15:00:00',
               '2019-12-31 16:00:00', '2019-12-31 17:00:00',
               '2019-12-31 18:00:00', '2019-12-31 19:00:00',
               '2019-12-31 20:00:00', '2019-12-31 21:00:00',
               '2019-12-31 22:00:00', '2019-12-31 23:00:00'],
              dtype='datetime64[ns]', length=19728, freq='H')
```

```
# then identify the missing hours
missing_hours = expected_range.difference(df['hour_beginning'])
print(missing_hours)
```

```
DatetimeIndex(['2018-08-01 00:00:00', '2018-08-01 01:00:00',
               '2018-08-01 02:00:00', '2018-08-01 03:00:00',
               '2018-08-01 04:00:00', '2018-08-01 05:00:00',
               '2018-08-01 06:00:00', '2018-08-01 07:00:00',
               '2018-08-01 08:00:00', '2018-08-01 09:00:00',
               ...,
               '2018-12-31 14:00:00', '2018-12-31 15:00:00',
               '2018-12-31 16:00:00', '2018-12-31 17:00:00',
               '2018-12-31 18:00:00', '2018-12-31 19:00:00',
               '2018-12-31 20:00:00', '2018-12-31 21:00:00',
               '2018-12-31 22:00:00', '2018-12-31 23:00:00'],
              dtype='datetime64[ns]', length=3672, freq=None)
```

We had the expected number of rows (the output of `shape` matched the description of the data on the NYC Data website), but the data seems to be missing samples from August 2018 through December 2018, which is worth keeping in mind if we decide to use it:

```
pd.unique(missing_hours.date)
```



```

datetime.date(2018, 11, 15), datetime.date(2018, 11, 16),
datetime.date(2018, 11, 17), datetime.date(2018, 11, 18),
datetime.date(2018, 11, 19), datetime.date(2018, 11, 20),
datetime.date(2018, 11, 21), datetime.date(2018, 11, 22),
datetime.date(2018, 11, 23), datetime.date(2018, 11, 24),
datetime.date(2018, 11, 25), datetime.date(2018, 11, 26),
datetime.date(2018, 11, 27), datetime.date(2018, 11, 28),
datetime.date(2018, 11, 29), datetime.date(2018, 11, 30),
datetime.date(2018, 12, 1), datetime.date(2018, 12, 2),
datetime.date(2018, 12, 3), datetime.date(2018, 12, 4),
datetime.date(2018, 12, 5), datetime.date(2018, 12, 6),
datetime.date(2018, 12, 7), datetime.date(2018, 12, 8),
datetime.date(2018, 12, 9), datetime.date(2018, 12, 10),
datetime.date(2018, 12, 11), datetime.date(2018, 12, 12),
datetime.date(2018, 12, 13), datetime.date(2018, 12, 14),
datetime.date(2018, 12, 15), datetime.date(2018, 12, 16),
datetime.date(2018, 12, 17), datetime.date(2018, 12, 18),
datetime.date(2018, 12, 19), datetime.date(2018, 12, 20),
datetime.date(2018, 12, 21), datetime.date(2018, 12, 22),
datetime.date(2018, 12, 23), datetime.date(2018, 12, 24),
datetime.date(2018, 12, 25), datetime.date(2018, 12, 26),
datetime.date(2018, 12, 27), datetime.date(2018, 12, 28),
datetime.date(2018, 12, 29), datetime.date(2018, 12, 30),
datetime.date(2018, 12, 31)], dtype=object)

```

Let's also check if any hour appears more than once in the data. We can use pandas's `value_counts` function to find out how many times each unique value appears in the data:

```
df['hour_beginning'].value_counts()
```

```

2019-11-03 01:00:00    2
2019-05-04 01:00:00    1
2019-09-21 04:00:00    1
2018-06-18 19:00:00    1
2018-02-22 01:00:00    1
..
2017-12-24 21:00:00    1
2018-06-06 11:00:00    1
2017-10-22 09:00:00    1
2019-02-19 03:00:00    1
2019-02-21 22:00:00    1
Name: hour_beginning, Length: 16056, dtype: int64

```

It looks like at least one hour appears twice in the data, which is unexpected! Let's use filtering again to find out all of the instances where that occurs:

```

hour_counts = df['hour_beginning'].value_counts()
hour_counts[hour_counts > 1]

```

```

2019-11-03 01:00:00    2
Name: hour_beginning, dtype: int64

```

It seems to happen exactly once. Let's filter the dataframe to find the rows corresponding to the duplicate day.



Here's a useful clue - we can see that this hour appears twice because the clock is shifted for Daylight Savings time. (It's not clear why there is no duplicate hour for that same event in 2018. Perhaps only one of those hours is recorded.)

```
df[df['hour_beginning']=="2019-11-03 01:00:00"]
```

	hour_beginning	location	Pedestrians	Towards Manhattan	\
701	2019-11-03 01:00:00	Brooklyn Bridge	0	0	
3019	2019-11-03 01:00:00	Brooklyn Bridge	1	0	

	Towards Brooklyn	weather_summary	temperature	precipitation	lat	\
701	0	NaN	NaN	NaN	40.708164	
3019	1	clear-night	44.0	0.0	40.708164	

	long	events	\
701	-73.999509	Daylight Saving Time ends	
3019	-73.999509	Daylight Saving Time ends	

	Location1	hour	month	date	day_name
701	(40.7081639691088, -73.9995087014816)	1	11	2019-11-03	Sunday
3019	(40.7081639691088, -73.9995087014816)	1	11	2019-11-03	Sunday

Now that we have evaluated the “completeness” of our data, we have to decide what to do about missing values. Some machine learning models cannot tolerate data with missing values. Depending on what *type* of data is missing, we can

- drop rows with missing values from the dataset
- fill in those missing values with another value: a 0, the mode of that column, the median of that column, or forward/back fill data from the nearest row that is not missing

For this data, let's try the forward/back fill method. This makes some sense because the data has a logical order in time, and the missing value - weather - changes relatively slowly with respect to time. We can expect that the weather at any given hour is probably similar to the weather in the previous (or next) hour.

For this to work, we'll first have to sort the data by time. (Note that the data was not sorted originally.)

```
df = df.sort_values(by='hour_beginning')
df.head()
```

	hour_beginning	location	Pedestrians	Towards Manhattan	\
8846	2017-10-01 00:00:00	Brooklyn Bridge	44	30	
9473	2017-10-01 01:00:00	Brooklyn Bridge	30	17	
10098	2017-10-01 02:00:00	Brooklyn Bridge	25	13	
10733	2017-10-01 03:00:00	Brooklyn Bridge	20	11	
11527	2017-10-01 04:00:00	Brooklyn Bridge	18	10	

	Towards Brooklyn	weather_summary	temperature	precipitation	\
8846	14	clear-night	52.0	0.0001	
9473	13	partly-cloudy-night	53.0	0.0002	
10098	12	partly-cloudy-night	52.0	0.0000	
10733	9	partly-cloudy-night	51.0	0.0000	
11527	8	partly-cloudy-night	51.0	0.0000	

	lat	long	events	Location1	\
--	-----	------	--------	-----------	---

```

8846  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
9473  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
10098 40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
10733 40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
11527 40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)

```

```

      hour  month      date day_name
8846     0     10  2017-10-01  Sunday
9473     1     10  2017-10-01  Sunday
10098    2     10  2017-10-01  Sunday
10733    3     10  2017-10-01  Sunday
11527    4     10  2017-10-01  Sunday

```

We can also “reset” the index now, so that if we ask for `df[0]` we’ll get the first row in time, and so on.

```

df.reset_index(drop=True)
df.head()

```

```

      hour_beginning      location  Pedestrians  Towards Manhattan \
0      2017-10-01 00:00:00  Brooklyn Bridge          44           30
1      2017-10-01 01:00:00  Brooklyn Bridge          30           17
2      2017-10-01 02:00:00  Brooklyn Bridge          25           13
3      2017-10-01 03:00:00  Brooklyn Bridge          20           11
4      2017-10-01 04:00:00  Brooklyn Bridge          18           10
...
16052  2019-12-31 19:00:00  Brooklyn Bridge          11            9
16053  2019-12-31 20:00:00  Brooklyn Bridge          15           14
16054  2019-12-31 21:00:00  Brooklyn Bridge          12            0
16055  2019-12-31 22:00:00  Brooklyn Bridge          10            9
16056  2019-12-31 23:00:00  Brooklyn Bridge           2            0

```

```

      Towards Brooklyn      weather_summary  temperature  precipitation \
0              14      clear-night          52.0          0.0001
1              13  partly-cloudy-night          53.0          0.0002
2              12  partly-cloudy-night          52.0          0.0000
3              9   partly-cloudy-night          51.0          0.0000
4              8   partly-cloudy-night          51.0          0.0000
...
16052           2      cloudy          43.0          0.0000
16053           1      cloudy          43.0          0.0000
16054          12      cloudy          42.0          0.0036
16055           1      cloudy          42.0          0.0005
16056           2      cloudy          42.0          0.0004

```

```

      lat      long events      Location1 \
0  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
1  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
2  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
3  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
4  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
...
16052  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
16053  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)
16054  40.708164 -73.999509  NaN (40.7081639691088, -73.9995087014816)

```

```
16055 40.708164 -73.999509 NaN (40.7081639691088, -73.9995087014816)
16056 40.708164 -73.999509 NaN (40.7081639691088, -73.9995087014816)
```

```

      hour  month      date day_name
0         0    10  2017-10-01  Sunday
1         1    10  2017-10-01  Sunday
2         2    10  2017-10-01  Sunday
3         3    10  2017-10-01  Sunday
4         4    10  2017-10-01  Sunday
...      ...   ...      ...      ...
16052    19    12  2019-12-31  Tuesday
16053    20    12  2019-12-31  Tuesday
16054    21    12  2019-12-31  Tuesday
16055    22    12  2019-12-31  Tuesday
16056    23    12  2019-12-31  Tuesday
```

```
[16057 rows x 16 columns]
```

```

      hour_beginning      location  Pedestrians  Towards Manhattan \
8846  2017-10-01 00:00:00  Brooklyn Bridge         44             30
9473  2017-10-01 01:00:00  Brooklyn Bridge         30             17
10098 2017-10-01 02:00:00  Brooklyn Bridge         25             13
10733 2017-10-01 03:00:00  Brooklyn Bridge         20             11
11527 2017-10-01 04:00:00  Brooklyn Bridge         18             10
```

```

      Towards Brooklyn      weather_summary  temperature  precipitation \
8846                  14      clear-night         52.0         0.0001
9473                  13  partly-cloudy-night         53.0         0.0002
10098                 12  partly-cloudy-night         52.0         0.0000
10733                  9  partly-cloudy-night         51.0         0.0000
11527                  8  partly-cloudy-night         51.0         0.0000
```

```

      lat      long events      Location1 \
8846  40.708164 -73.999509 NaN (40.7081639691088, -73.9995087014816)
9473  40.708164 -73.999509 NaN (40.7081639691088, -73.9995087014816)
10098 40.708164 -73.999509 NaN (40.7081639691088, -73.9995087014816)
10733 40.708164 -73.999509 NaN (40.7081639691088, -73.9995087014816)
11527 40.708164 -73.999509 NaN (40.7081639691088, -73.9995087014816)
```

```

      hour  month      date day_name
8846     0    10  2017-10-01  Sunday
9473     1    10  2017-10-01  Sunday
10098     2    10  2017-10-01  Sunday
10733     3    10  2017-10-01  Sunday
11527     4    10  2017-10-01  Sunday
```

Now we can fill in missing data using the `fillna` function ([reference](#)). We will fill the missing weather data using the “forward fill” method, which carries the last valid observation forward to fill in NAs.

```
df['temperature'] = df['temperature'].fillna(method="ffill")
df['precipitation'] = df['precipitation'].fillna(method="ffill")
df['weather_summary'] = df['weather_summary'].fillna(method="ffill")
```

Now we can count the NAs again and find that there are only missing values in the `events` column.

```
df.isnull().sum()
```

```
hour_beginning      0
location            0
Pedestrians         0
Towards Manhattan   0
Towards Brooklyn    0
weather_summary     0
temperature         0
precipitation       0
lat                0
long               0
events             14933
Location1           0
hour               0
month              0
date               0
day_name           0
dtype: int64
```

Next, let us look at summary statistics. The “five number summary” - extremes (min and max), median, and quartiles -can help us gain a better understanding of numeric fields in the data. We can use the describe function in pandas to compute this summary.

```
df.describe()
```

	Pedestrians	Towards Manhattan	Towards Brooklyn	temperature \	
count	16057.000000	16057.000000	16057.000000	16057.000000	
mean	687.106309	334.772436	352.286853	53.205892	
std	862.244605	417.807545	456.624509	18.036476	
min	0.000000	0.000000	0.000000	2.000000	
25%	16.000000	9.000000	5.000000	39.000000	
50%	227.000000	112.000000	111.000000	53.000000	
75%	1254.000000	611.000000	632.000000	69.000000	
max	4330.000000	3657.000000	2872.000000	97.000000	

	precipitation	lat	long	hour	month
count	16057.000000	1.605700e+04	1.605700e+04	16057.000000	16057.000000
mean	0.004613	4.070816e+01	-7.399951e+01	11.499346	6.347076
std	0.023389	7.105649e-15	1.421130e-14	6.922682	3.544812
min	0.000000	4.070816e+01	-7.399951e+01	0.000000	1.000000
25%	0.000000	4.070816e+01	-7.399951e+01	5.000000	3.000000
50%	0.000000	4.070816e+01	-7.399951e+01	11.000000	6.000000
75%	0.000000	4.070816e+01	-7.399951e+01	17.000000	10.000000
max	0.680400	4.070816e+01	-7.399951e+01	23.000000	12.000000

We are especially interested in Pedestrians, the target variable, so we can describe that one separately:

```
df['Pedestrians'].describe()
```

```
count    16057.000000
mean      687.106309
```

```
std      862.244605
min       0.000000
25%      16.000000
50%     227.000000
75%    1254.000000
max     4330.000000
Name: Pedestrians, dtype: float64
```

For categorical variables, we can use `groupby` to get frequency and other useful summary statistics.

For example, we may be interested in the summary statistics for Pedestrians for different weather conditions:

```
df.groupby('weather_summary')['Pedestrians'].describe()
```

	count	mean	std	min	25%	50% \
weather_summary						
clear-day	3127.0	1386.569875	861.890079	0.0	611.50	1401.0
clear-night	3755.0	102.689214	206.438992	0.0	2.00	19.0
cloudy	2383.0	540.437684	727.986539	0.0	9.00	141.0
fog	76.0	234.473684	307.735795	0.0	15.00	110.0
partly-cloudy-day	3169.0	1422.154307	844.930127	0.0	699.00	1433.0
partly-cloudy-night	2508.0	93.880383	173.265652	0.0	3.00	23.0
rain	920.0	256.165217	421.571020	0.0	10.00	67.5
sleet	14.0	117.928571	157.850204	0.0	7.25	28.0
snow	93.0	195.473118	292.630818	0.0	16.00	77.0
wind	12.0	668.333333	682.617067	0.0	8.00	596.5
	75%	max				
weather_summary						
clear-day	1982.5	4330.0				
clear-night	93.5	1779.0				
cloudy	944.5	3894.0				
fog	276.5	1321.0				
partly-cloudy-day	2008.0	4286.0				
partly-cloudy-night	97.0	1522.0				
rain	311.0	2727.0				
sleet	254.5	404.0				
snow	258.0	1561.0				
wind	1010.0	1910.0				

Make special note of the `count` column, which shows us the prevalence of different weather conditions in this dataset. There are some weather conditions for which we have very few examples.

Another categorical variable is `events`, which indicates whether the day is a holiday, and which holiday. Holidays have very different pedestrian traffic characteristics from other days.

```
df.groupby('events')['Pedestrians'].describe()
```

	count	mean	std	min	\
events					
Black Friday	48.0	723.583333	952.014814	0.0	
Christmas Day	48.0	832.312500	1199.381546	0.0	
Christmas Eve	48.0	705.520833	945.112444	0.0	
Cinco de Mayo	48.0	807.750000	1047.286392	3.0	

Columbus Day (regional holiday)	44.0	694.181818	854.264712	0.0
Daylight Saving Time ends	48.0	548.687500	719.950003	0.0
Daylight Saving Time starts	48.0	504.500000	708.192515	0.0
Easter Monday	24.0	581.916667	704.003515	0.0
Easter Sunday	48.0	1321.812500	1443.738832	0.0
Father's Day	48.0	930.645833	836.469111	0.0
Halloween	48.0	566.104167	789.258533	0.0
Independence Day	48.0	749.604167	886.326983	0.0
Labor Day	24.0	513.666667	540.116869	0.0
Martin Luther King Jr. Day	48.0	195.166667	281.788387	0.0
Memorial Day	48.0	1314.333333	1346.292282	0.0
Mother's Day	48.0	334.895833	430.048896	1.0
New Year's Day	48.0	845.395833	1229.824148	2.0
New Year's Eve	48.0	827.062500	1159.014556	0.0
Presidents' Day (regional holiday)	48.0	535.541667	622.282927	0.0
St. Patrick's Day	48.0	747.458333	864.023344	0.0
Tax Day	48.0	567.625000	626.338316	0.0
Thanksgiving Day	48.0	564.708333	783.503098	0.0
Valentine's Day	48.0	451.479167	509.012979	0.0
Veterans Day	48.0	631.833333	803.411114	0.0
Veterans Day observed	24.0	421.083333	477.603703	2.0

	25%	50%	75%	max
events				
Black Friday	4.00	172.5	1515.50	2913.0
Christmas Day	6.00	82.5	1480.75	3807.0
Christmas Eve	10.75	113.0	1406.50	2625.0
Cinco de Mayo	64.25	408.5	848.25	3390.0
Columbus Day (regional holiday)	28.75	332.0	878.75	2587.0
Daylight Saving Time ends	14.75	170.0	983.00	2311.0
Daylight Saving Time starts	10.00	123.5	814.25	2232.0
Easter Monday	15.25	380.5	850.25	2242.0
Easter Sunday	55.00	410.5	2809.50	3894.0
Father's Day	111.75	807.5	1831.50	2128.0
Halloween	13.75	144.0	803.00	2465.0
Independence Day	32.00	259.0	1305.50	2727.0
Labor Day	18.50	283.5	1080.50	1486.0
Martin Luther King Jr. Day	5.50	41.5	281.25	955.0
Memorial Day	53.75	745.0	2752.00	3657.0
Mother's Day	49.50	169.5	494.50	1693.0
New Year's Day	28.25	149.0	1353.00	4141.0
New Year's Eve	1.75	178.0	1517.00	3587.0
Presidents' Day (regional holiday)	27.00	138.5	1237.50	1648.0
St. Patrick's Day	11.25	221.5	1557.00	2617.0
Tax Day	16.75	284.5	1208.75	1910.0
Thanksgiving Day	5.00	112.0	1093.50	2298.0
Valentine's Day	17.50	193.0	1053.00	1448.0
Veterans Day	11.75	159.0	1172.50	2265.0
Veterans Day observed	56.75	124.5	878.75	1269.0

It can be useful to get the total pedestrian count for the day of a holiday, rather than the summary statistics for the hour-long intervals. We can use the `agg` function to compute key statistics, including summing over all the samples in the group:

```
df.groupby('events').agg({'Pedestrians': 'sum'})
```

	Pedestrians
events	
Black Friday	34732
Christmas Day	39951
Christmas Eve	33865
Cinco de Mayo	38772
Columbus Day (regional holiday)	30544
Daylight Saving Time ends	26337
Daylight Saving Time starts	24216
Easter Monday	13966
Easter Sunday	63447
Father's Day	44671
Halloween	27173
Independence Day	35981
Labor Day	12328
Martin Luther King Jr. Day	9368
Memorial Day	63088
Mother's Day	16075
New Year's Day	40579
New Year's Eve	39699
Presidents' Day (regional holiday)	25706
St. Patrick's Day	35878
Tax Day	27246
Thanksgiving Day	27106
Valentine's Day	21671
Veterans Day	30328
Veterans Day observed	10106

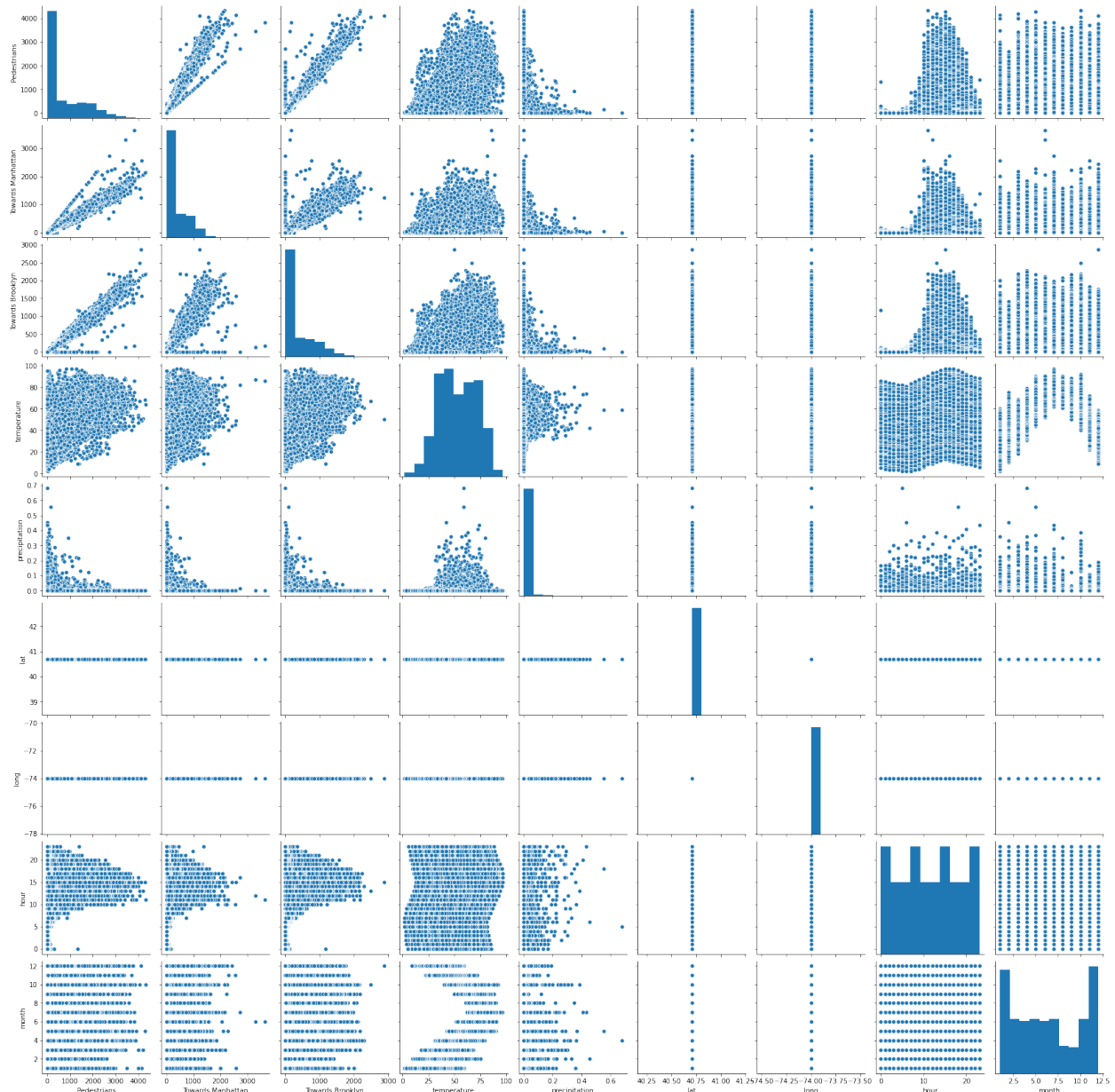
For tabular data, and especially tabular data with many numeric features, it is often useful to create a *pairplot*. A pairplot shows pairwise relationships between all numerical variables. It is a useful way to identify:

- features that are predictive - if there is any noticeable relationship between the target variable and any other variable.
- features that are correlated - if two features are highly correlated, we may be able to achieve equally good results just using one of them.

We can create a “default” pairplot with

```
sns.pairplot(df)
```

```
<seaborn.axisgrid.PairGrid at 0x7fe790861eb0>
```



Here, each pane shows one numerical variable on the x-axis and another numerical variable on the y-axis, so that we can see if a relationship exists between them. The panes along the diagonal shows the empirical distribution of values for each feature in this data.

But, it is difficult to see anything useful because there is so much going on in this plot. We can improve things somewhat by:

- specifying only the variables we want to include, and excluding variables that don't contain useful information, such as `lat` and `long`, and
- making the points on the plot smaller and partially transparent, to help with the overplotting.

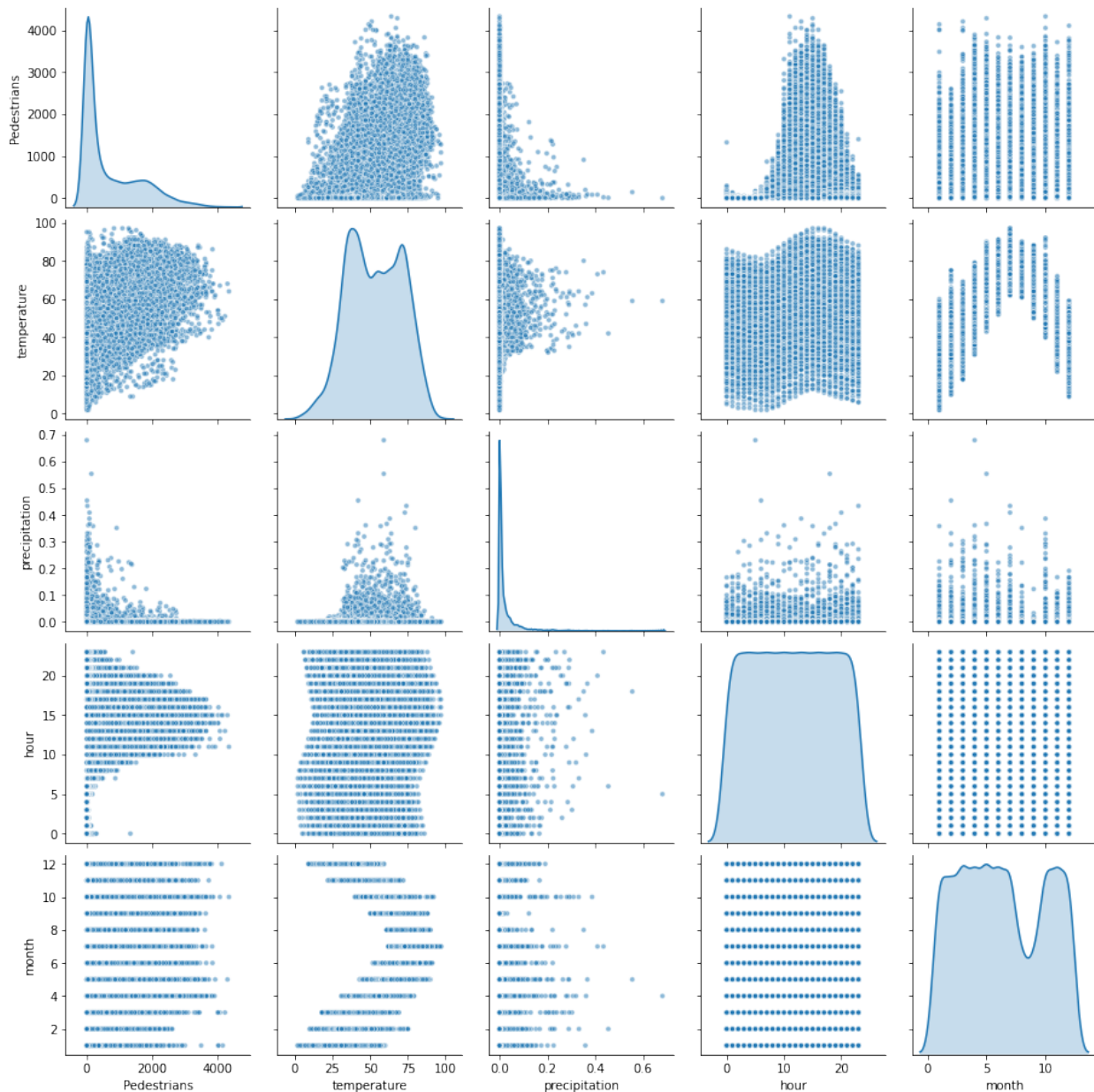
We'll also change the histograms on the diagonal, which show the frequency of values for each variable, into a density plot which shows the same information in a more useful format.

```
sns.pairplot(df,
              vars=['Pedestrians', 'temperature', 'precipitation', 'hour', 'month'],
              diag_kind = 'kde',
```



```
plot_kws={'alpha':0.5, 'size': 0.1})
```

```
<seaborn.axisgrid.PairGrid at 0x7fe785bcb5e0>
```



We are mainly interested in the top row of the plot, which shows how the target variable (Pedestrians) varies with the temperature, precipitation levels, and hour. However, it is also useful to note relationships between features. For example, there is a natural relationship between the time of data and the temperature, and between the month and the temperature.

### Explore relationships and look for issues

Finally, let's further explore relationships between likely predictors and our target variable. We can group by `day_name`, then call the `describe` function on the `Pedestrians` column to see the effect of day of the week on traffic volume:

```
df.groupby('day_name')['Pedestrians'].describe()
```

	count	mean	std	min	25%	50%	75%	max
day_name								
Friday	2280.0	696.521053	845.244195	0.0	17.0	243.5	1318.00	3722.0
Monday	2304.0	642.983941	777.944829	0.0	12.0	232.0	1232.00	3657.0
Saturday	2280.0	943.185965	1159.857344	0.0	22.0	241.5	1894.50	4330.0
Sunday	2305.0	753.213015	947.772750	0.0	19.0	206.0	1452.00	3894.0
Thursday	2280.0	601.263158	728.067954	0.0	16.0	214.0	1102.25	3173.0
Tuesday	2328.0	599.210911	731.047235	0.0	14.0	232.5	1122.50	4141.0
Wednesday	2280.0	574.956140	694.807586	0.0	16.0	217.0	1050.00	3807.0

Similarly, we can see the effect of temperature:

```
df.groupby('temperature')['Pedestrians'].describe()
```

	count	mean	std	min	25%	50%	75%	\
temperature								
2.0	3.0	19.333333	25.929391	1.0	4.50	8.0	28.50	
3.0	4.0	16.000000	32.000000	0.0	0.00	0.0	16.00	
4.0	8.0	27.375000	25.767851	0.0	6.25	24.5	40.50	
5.0	5.0	20.000000	41.418595	0.0	0.00	1.0	5.00	
6.0	10.0	54.200000	85.590498	0.0	4.25	10.5	79.75	
...	...	...	...	...	...	...	...	
93.0	3.0	1271.333333	707.043374	455.0	1062.00	1669.0	1679.50	
94.0	4.0	1035.750000	746.532596	101.0	599.75	1202.0	1638.00	
95.0	3.0	476.666667	765.789353	0.0	35.00	70.0	715.00	
96.0	4.0	1161.500000	426.649349	538.0	1104.25	1301.5	1358.75	
97.0	3.0	1063.666667	225.331607	828.0	957.00	1086.0	1181.50	
	max							
temperature								
2.0	49.0							
3.0	64.0							
4.0	77.0							
5.0	94.0							
6.0	275.0							
...	...							
93.0	1690.0							
94.0	1638.0							
95.0	1360.0							
96.0	1505.0							
97.0	1277.0							

[96 rows x 8 columns]

And the effect of precipitation:

```
df.groupby('precipitation')['Pedestrians'].describe()
```

	count	mean	std	min	25%	50%	75%	\
precipitation								

0.0000	12338.0	731.183336	901.428828	0.0	15.00	236.0	1390.75
0.0001	226.0	548.982301	652.851843	0.0	52.25	256.0	931.00
0.0002	224.0	753.151786	849.076567	0.0	41.75	347.0	1389.50
0.0003	154.0	705.051948	733.243531	0.0	50.00	493.5	1230.00
0.0004	130.0	717.253846	766.100731	0.0	22.25	438.0	1243.00
...	...	...	...	...	...	...	...
0.4090	1.0	81.000000	NaN	81.0	81.00	81.0	81.00
0.4340	1.0	18.000000	NaN	18.0	18.00	18.0	18.00
0.4543	1.0	6.000000	NaN	6.0	6.00	6.0	6.00
0.5543	1.0	141.000000	NaN	141.0	141.00	141.0	141.00
0.6804	1.0	0.000000	NaN	0.0	0.00	0.0	0.00

max

precipitation

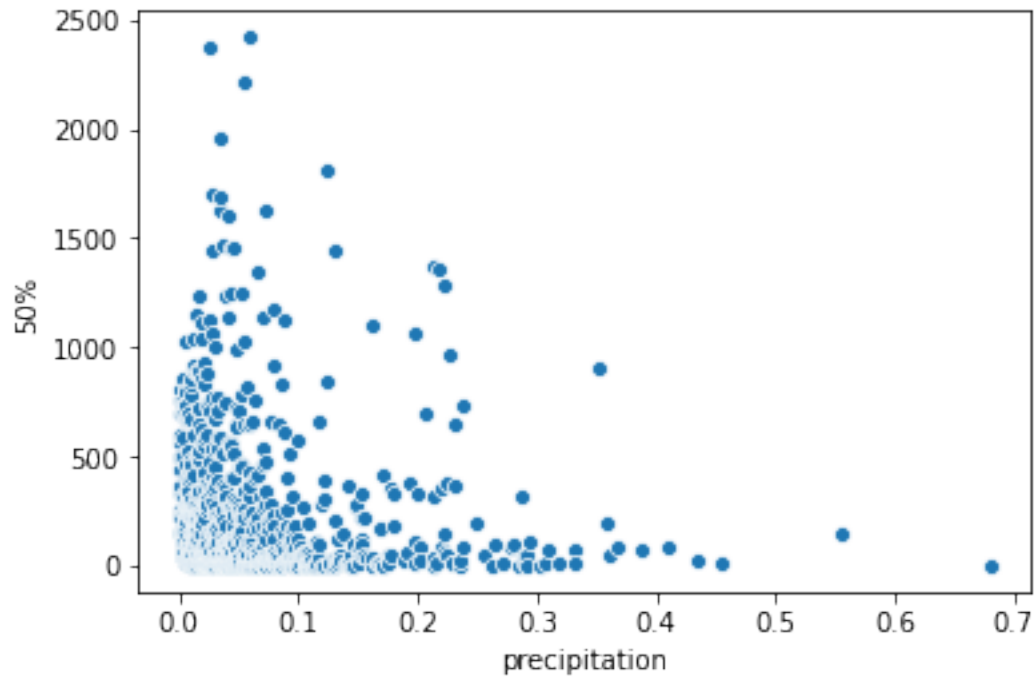
0.0000	4286.0
0.0001	4330.0
0.0002	3816.0
0.0003	3485.0
0.0004	2733.0
...	...
0.4090	81.0
0.4340	18.0
0.4543	6.0
0.5543	141.0
0.6804	0.0

[776 rows x 8 columns]

We can even plot it separately, by saving it in a new data frame and plotting *that* data frame:

```
df_precip = df.groupby('precipitation')['Pedestrians'].describe()
df_precip = df_precip.reset_index()
sns.scatterplot(data=df_precip, x='precipitation', y='50%')
```

```
<AxesSubplot:xlabel='precipitation', ylabel='50%'
```



We see that certain weather conditions (very high temperature, heavy precipitation, fog) are extremely underrepresented in the dataset. This would be something to consider if, for example, we wanted to use this dataset to predict the effect of extreme weather on pedestrian traffic.