Operating on Data in Pandas

One of the essential pieces of NumPy is the ability to perform quick element-wise operations, both with basic arithmetic (addition, subtraction, multiplication, etc.) and with more sophisticated operations (trigonometric functions, exponential and logarithmic functions, etc.). Pandas inherits much of this functionality from NumPy, and the ufuncs that we introduced in "Computation on NumPy Arrays: Universal Functions" on page 50 are key to this.

Pandas includes a couple useful twists, however: for unary operations like negation and trigonometric functions, these ufuncs will *preserve index and column labels* in the output, and for binary operations such as addition and multiplication, Pandas will automatically *align indices* when passing the objects to the ufunc. This means that keeping the context of data and combining data from different sources—both potentially error-prone tasks with raw NumPy arrays—become essentially foolproof ones with Pandas. We will additionally see that there are well-defined operations between one-dimensional `Series` structures and two-dimensional `DataFrame` structures.

Ufuncs: Index Preservation

Because Pandas is designed to work with NumPy, any NumPy ufunc will work on Pandas `Series` and `DataFrame` objects. Let's start by defining a simple `Series` and `DataFrame` on which to demonstrate this:

```
In[1]: import pandas as pd
       import numpy as np

In[2]: rng = np.random.RandomState(42)
       ser = pd.Series(rng.randint(0, 10, 4))
       ser

Out[2]: 0    6
        1    3
        2    7
        3    4
        dtype: int64

In[3]: df = pd.DataFrame(rng.randint(0, 10, (3, 4)),
                         columns=['A', 'B', 'C', 'D'])
       df

Out[3]:    A  B  C  D
        0  6  9  2  6
        1  7  4  3  7
        2  7  2  5  4
```

If we apply a NumPy ufunc on either of these objects, the result will be another Pandas object *with the indices preserved:*

```
In[4]: np.exp(ser)
```

```
Out[4]: 0     403.428793
        1      20.085537
        2    1096.633158
        3      54.598150
        dtype: float64
```

Or, for a slightly more complex calculation:

```
In[5]: np.sin(df * np.pi / 4)
```

```
Out[5]:           A             B         C             D
        0 -1.000000  7.071068e-01  1.000000 -1.000000e+00
        1 -0.707107  1.224647e-16  0.707107 -7.071068e-01
        2 -0.707107  1.000000e+00 -0.707107  1.224647e-16
```

Any of the ufuncs discussed in "Computation on NumPy Arrays: Universal Functions" on page 50 can be used in a similar manner.

UFuncs: Index Alignment

For binary operations on two `Series` or `DataFrame` objects, Pandas will align indices in the process of performing the operation. This is very convenient when you are working with incomplete data, as we'll see in some of the examples that follow.

Index alignment in Series

As an example, suppose we are combining two different data sources, and find only the top three US states by *area* and the top three US states by *population*:

```
In[6]: area = pd.Series({'Alaska': 1723337, 'Texas': 695662,
                         'California': 423967}, name='area')
       population = pd.Series({'California': 38332521, 'Texas': 26448193,
                               'New York': 19651127}, name='population')
```

Let's see what happens when we divide these to compute the population density:

```
In[7]: population / area
```

```
Out[7]: Alaska              NaN
        California    90.413926
        New York            NaN
        Texas         38.018740
        dtype: float64
```

The resulting array contains the *union* of indices of the two input arrays, which we could determine using standard Python set arithmetic on these indices:

```
In[8]: area.index | population.index
```

```
Out[8]: Index(['Alaska', 'California', 'New York', 'Texas'], dtype='object')
```

Any item for which one or the other does not have an entry is marked with `NaN`, or "Not a Number," which is how Pandas marks missing data (see further discussion of missing data in "Handling Missing Data" on page 119). This index matching is imple-