

# Intro to Programming for Public Policy Week 5

## Pandas Merge, Transformation, and Time series

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## Combining and Merging

## State-year data

```
>>> state_years = pd.DataFrame({  
    'state': ['Ohio', 'Ohio', 'Ohio',  
             'Nevada', 'Nevada'],  
    'year': [2000, 2001, 2002, 2001, 2002],  
    'pop': [1.5, 1.7, 3.6, 2.4, 2.9]  
})
```

```
>>> state_years
```

	pop	state	year
0	1.5	Ohio	2000
1	1.7	Ohio	2001
2	3.6	Ohio	2002
3	2.4	Nevada	2001
4	2.9	Nevada	2002

## State data

```
>>> states = pd.DataFrame({  
    'state': ['Ohio', 'Utah'],  
    'abbrev': ['OH', 'UT'],  
    'area': [4.4, 11.0]  
})
```

```
>>> states
```

	abbrev	area	state
0	OH	4.4	Ohio
1	UT	11.0	Utah

# Merge

The merge function allows us to combine two datasets that share a column:

```
>>> state_years.merge(states, on='state')
```

	pop	state	year	abbrev	area
0	1.5	Ohio	2000	OH	4.4
1	1.7	Ohio	2001	OH	4.4
2	3.6	Ohio	2002	OH	4.4

- ▶ The state column is called the merge *key*
- ▶ The state\_years table is called the *left* and states is called the *right*
- ▶ The rows corresponding to Nevada and Utah don't appear in the result because the merge function performs an *inner* merge by default.

## Merge how

- ▶ Four ways to merge datasets: inner, outer, left, and right.
- ▶ They differ in how they treat rows that are not shared by both *left* and *right* tables.
- ▶ The default is an *inner* merge
  - ▶ Its result only includes rows that are in both left and right.
- ▶ All other merge types produce results that are supersets of the inner merge.

# Merge how Venn diagrams

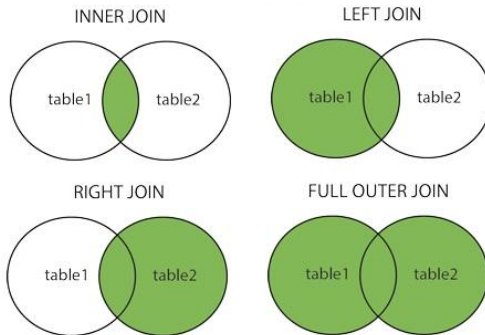


Figure 1: Merge types (source: [tech.queryhome.com](http://tech.queryhome.com))

## Inner

Again, an inner merge (the default) only includes rows that are present on both sides of the merge:

```
>>> state_years.merge(states, on='state', how='inner')
   pop  state  year abbrev  area
0  1.5   Ohio  2000     OH    4.4
1  1.7   Ohio  2001     OH    4.4
2  3.6   Ohio  2002     OH    4.4
```



## Left

A left merge includes all rows from the left table, producing nulls when a key is missing on the right:

```
>>> state_years.merge(states, on='state', how='left')
```

	pop	state	year	abbrev	area
0	1.5	Ohio	2000	OH	4.4
1	1.7	Ohio	2001	OH	4.4
2	3.6	Ohio	2002	OH	4.4
3	2.4	Nevada	2001	NaN	NaN
4	2.9	Nevada	2002	NaN	NaN

## Right

A right merge includes all rows from the right table, producing nulls when a key is missing on the left:

```
>>> state_years.merge(states, on='state', how='right')
   pop state   year abbrev  area
0  1.5  Ohio  2000.0     OH   4.4
1  1.7  Ohio  2001.0     OH   4.4
2  3.6  Ohio  2002.0     OH   4.4
3  NaN  Utah    NaN     UT  11.0
```

Note that `A.merge(B, how='right')` is equivalent to `B.merge(A, how='left')`

# Outer

An outer merge includes all rows, producing nulls when a key from the left is missing on the right and vice versa:

```
>>> state_years.merge(states, on='state', how='outer')
```

	pop	state	year	abbrev	area
0	1.5	Ohio	2000.0	OH	4.4
1	1.7	Ohio	2001.0	OH	4.4
2	3.6	Ohio	2002.0	OH	4.4
3	2.4	Nevada	2001.0	NaN	NaN
4	2.9	Nevada	2002.0	NaN	NaN
5	NaN	Utah	NaN	UT	11.0

## Another merge

Load the salaries file again:

```
>>> salaries = pd.read_csv('salaries.csv')
>>> dept_sizes = salaries.Department.value_counts()
>>> dept_sizes
```

POLICE	13414
FIRE	4641
STREETS & SAN	2198
OEMC	2102
WATER MGMNT	1879
AVIATION	1629
TRANSPORTN	1140
PUBLIC LIBRARY	1015
GENERAL SERVICES	980
FAMILY & SUPPORT	615
FINANCE	560
HEALTH	488
...	

to\_frame()

The `merge()` function only operates on DataFrames. By “resetting” the index, the series becomes a data frame:

```
>>> depts = dept_sizes.reset_index()
      index  Department
0         POLICE      13414
1          FIRE      4641
2  STREETS & SAN      2198
3          OEMC      2102
4    WATER MGMNT      1879
5        AVIATION      1629
6    TRANSPORTN      1140
7  PUBLIC LIBRARY      1015
8  GENERAL SERVICES       980
9  FAMILY & SUPPORT       615
...
```

## Rename columns

But the column names are confusing. Rename them:

```
>>> depts.columns
Index(['index', 'Department'],
      dtype='object')
>>> depts.columns = ['Department', 'Department Size']
>>> depts.columns
Index(['Department', 'Department Size'],
      dtype='object')
>>> depts
```

	Department	Department Size
0	POLICE	13414
1	FIRE	4641
2	STREETS & SAN	2198
3	OEMC	2102
4	WATER MGMNT	1879
5	AVIATION	1629
...		

# Merge department sizes

```
In [78]: salaries.merge(depts, on=['Department'])
```

```
Out[78]:
```

	Name	Job Titles	Department	Full or Part-Time	Salary or Hourly	Typical Hours	Annual Salary	Hourly Rate	Department Size
0	AARON, JEFFERY M	SERGEANT	POLICE	F	Salary	NaN	\$101442.00	NaN	13414
1	AARON, KARINA	POLICE OFFICER (ASSIGNED AS DETECTIVE)	POLICE	F	Salary	NaN	\$94122.00	NaN	13414
2	ABBATE, TERRY M	POLICE OFFICER	POLICE	F	Salary	NaN	\$93354.00	NaN	13414
3	ABDALLAH, ZAID	POLICE OFFICER	POLICE	F	Salary	NaN	\$84054.00	NaN	13414
4	ABDELHADI, ABDALMAHD	POLICE OFFICER	POLICE	F	Salary	NaN	\$87006.00	NaN	13414
5	ABDELMAJEID,	POLICE OFFICER	POLICE	F	Salary	NaN	\$84054.00	NaN	13414

## Data Transformations



cut()

```
>>> salaries['salary'] = \
    salaries['Annual Salary'].str[1:].astype(float)
```

```
>>> pd.cut(salaries['salary'],
            [0, 100000, 200000, 300000])
33176      (0, 100000]
33177      (0, 100000]
33178      (0, 100000]
33179      (0, 100000]
33180      (0, 100000]
33181      (0, 100000]
33182    (100000, 200000]
Name: salary, dtype: category
Categories (3, object): [(0, 100000] <
                        (100000, 200000] <
                        (200000, 300000]]
```

## cut() labels

```
>>> pd.cut(salaries['salary'],  
           [0, 100000, 200000, 300000],  
           labels=['low', 'medium', 'high'])  
33176      low  
33177      low  
33178      low  
33179      low  
33180      low  
33181      low  
33182    medium  
Name: salary, dtype: category  
Categories (3, object): [low < medium < high]
```

# Percentiles

To bin with percentiles use `qcut`. For example, to calculate quartiles:

```
>>> pd.qcut(salaries['salary'], 4)
33176      [7200, 76266]
33177      [7200, 76266]
33178      [7200, 76266]
33179      [7200, 76266]
33180      (76266, 90024]
33181      (90024, 96060]
33182      (96060, 300000]
Name: salary, dtype: category
Categories (4, object): [[7200, 76266] <
                        (76266, 90024] <
                        (90024, 96060] <
                        (96060, 300000]]
```

## fillna()

To replace missing values use `fillna`:

```
>>> salaries['Typical Hours'].fillna(40)
...
33173      40.0
33174      40.0
33175      40.0
33176      40.0
33177      40.0
33178      40.0
33179      40.0
33180      40.0
33181      40.0
33182      40.0
Name: Typical Hours, dtype: float64
```

For more complicated *imputation* look at the method argument in the documentation.

## fillna(inplace=True)

- ▶ So far we have mostly used pandas methods that return a new Series or DataFrame.
- ▶ Many methods take a boolean `inplace` argument, indicating whether to modify the existing data:

```
>>> salaries['Typical Hours'].fillna(40)
>>> salaries['Typical Hours']
...
33176    40.0
33177    40.0
33178    40.0
33179    40.0
33180    40.0
33181    40.0
33182    40.0
Name: Typical Hours, dtype: float64
```

Time series data

## pd.Timestamp

Dates are notoriously complicated on a computer. There are many issues with formatting, time zones, leap years/seconds, etc. Pandas provides a Datetime type:

```
>>> t1 = pd.Datetime('2014-01-01 12:15:00 AM')
```

The constructor function automatically detects the date format.

## Timestamp features

- ▶ If `t1` and `t2` are timestamps, you can compare them (`>`, `<`, etc.):

```
>>> t1 = pd.Timestamp('2004-01-01')
>>> t2 = pd.Timestamp('2002-03-12')
>>> t1 > t2
True
```



## Timestamp features

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>>> t1 = pd.Timestamp('2004-01-01')
>>> t2 = pd.Timestamp('2002-03-12')
>>> t1 > t2
True
```

- ▶ You can subtract them (the result is a new type called `Timedelta`)

```
>>> t1 - t2
Timedelta('660 days 00:00:00')
```

## Timestamp features

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```
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>>> t2 = pd.Timestamp('2002-03-12')
>>> t1 > t2
True
```

- ▶ You can subtract them (the result is a new type called `Timedelta`)

```
>>> t1 - t2
Timedelta('660 days 00:00:00')
```

- ▶ You can get their day of the week, month, etc: python      >>>  
`t1.dayofweek`      3      >>> `t1.month`      1

# Crime data

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

```
In [2]: df = pd.read_csv('/home/epotash/Crimes_-_2001_to_present.csv')
```

```
In [65]: df
```

```
Out[65]:
```

	ID	Case Number	Date	Block	IUCR	Primary Type	Description	Location Description	Arrest
0	11094370	JA440032	09/21/2017 12:15:00 AM	072XX N CALIFORNIA AVE	1122	DECEPTIVE PRACTICE	COUNTERFEIT CHECK	CURRENCY EXCHANGE	True
1	11118031	JA470589	10/12/2017 07:14:00 PM	055XX W GRAND AVE	1345	CRIMINAL DAMAGE	TO CITY OF CHICAGO PROPERTY	JAIL / LOCK-UP FACILITY	True
2	11134189	JA491697	10/30/2017 11:52:00 AM	043XX S TALMAN AVE	4651	OTHER OFFENSE	SEX OFFENDER: FAIL REG NEW ADD	APARTMENT	True
3	11156462	JA521389	09/29/2017 06:45:00 PM	055XX W BELMONT AVE	1110	DECEPTIVE PRACTICE	BOGUS CHECK	CURRENCY EXCHANGE	True

# Date dtype

By default, pandas reads the date column as strings:

```
>>> df.Date.dtype  
dtype('O')
```

- ▶ Here `dtype('O')` means the dtype is an object.
- ▶ pandas uses this dtype for columns that are not all numbers or dates. The types could even vary within the column.
- ▶ To get a better sense of the dtype, you can look at the dtype of the first element:

```
>>> type(df.Date[0])  
str
```

## Parsing dates

There are two ways to parse the dates in this table.

- ▶ First, we could use the `parse_dates` argument to the `read_csv()` function:

```
>>> df = pd.read_csv('Crimes_-_2001_to_present.csv', pa
```

## Parsing dates

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- ▶ First, we could use the `parse_dates` argument to the `read_csv()` function:

```
>>> df = pd.read_csv('Crimes_-_2001_to_present.csv', parse_dates=[1])
```

- ▶ Instead, we could, after reading in the dates unparsed, convert them using `pd.to_datetime()`:

```
>>> df['Date'] = pd.to_datetime(df.Date)
```

## Parsing dates

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- ▶ First, we could use the `parse_dates` argument to the `read_csv()` function:

```
>>> df = pd.read_csv('Crimes_-_2001_to_present.csv', parse_dates=[1])
```

- ▶ Instead, we could, after reading in the dates unparsed, convert them using `pd.to_datetime()`:

```
>>> df['Date'] = pd.to_datetime(df.Date)
```

- ▶ In either case, the resulting dtype is `'<M8[ns]'`, which is a cryptic way of saying that it is a nanosecond-resolution timestamp.

```
>>> df.Date.dtype  
dtype('<M8[ns]')
```

## Date attribute

- ▶ Similar to strings, we can access the datetime functionality of a datetime column using the `.dt` attribute.
- ▶ For example, to get the month of each crime:

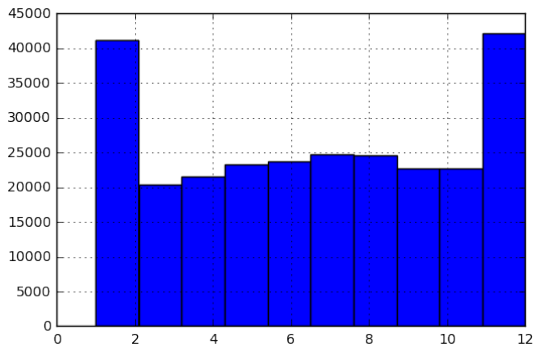
```
>>> df.Date.dt.month
266920    12
266921    10
266922    12
266923     8
266924    12
266925     9
266926     8
266927     1
266928    12
266929    12
Name: Date, dtype: int64
```



# Month histogram

We could plot a histogram of this:

```
df.Date.dt.month.hist()
```



# Truncate

To retain only the date part of the datetimes:

```
>>> df.Date.dt.date
...
266917    2017-11-06
266918    2017-12-29
266919    2017-11-30
266920    2017-12-20
266921    2017-10-01
266922    2017-12-23
266923    2017-08-18
266924    2017-12-21
266925    2017-09-20
266926    2017-08-09
266927    2017-01-14
266928    2017-12-15
266929    2017-12-23
Name: Date, dtype: object
```

## date.value\_counts()

To get a series with index date and value the number of crimes on that date:

```
>>> df.Date.dt.date.value_counts()
```

```
...
```

```
2017-01-08      588
```

```
2017-02-26      574
```

```
2017-12-29      564
```

```
2017-03-12      550
```

```
2017-11-23      542
```

```
2017-12-31      540
```

```
2017-03-13      539
```

```
2017-12-26      522
```

```
2017-12-27      513
```

```
2017-12-24      500
```

```
2017-03-14      466
```

```
2017-12-25      393
```

```
Name: Date, dtype: int64
```

# Time series plot

```
df.Date.dt.date.value_counts().plot(figsize=(12,8))
```

