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Time Series

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Reference

- **Chapter 11: Time Series**
- Wes McKinney, **Python for Data Analysis**: Data Wrangling with Pandas, NumPy, and IPython, O'Reilly Media, 2nd Edition, 2018.
 - Material: <https://github.com/wesm/pypop-book>

Time Series

- Time series data is an **important** form of structured data in **many** different **fields**, such as finance, economics, ecology, neuroscience, and physics.
- Can be of **fixed frequency** or **irregular**.
- **Types:**
 - **Timestamps**, specific instants in time
 - **Fixed periods**, such as the month January 2007 or the full year 2010
 - **Intervals of time**, indicated by a start and end timestamp.
 - Experiment or **elapsed time**

Outline

11.1 Date and Time Data Types and Tools

- Converting Between String and Datetime

11.2 Time Series Basics

- Indexing, Selection, Subsetting
- Time Series with Duplicate Indices

11.3 Date Ranges, Frequencies, and Shifting

- Generating Date Ranges
- Frequencies and Date Offsets
- Shifting (Leading and Lagging) Data

11.1 Date and Time Data Types and Tools

- The Python **datetime**, **time**, and **calendar** modules support date and time data, as well as calendar-related functionality.
- **datetime** stores both the date and time down to the microsecond.
- **timedelta** represents the temporal difference between two datetime objects.

```
from datetime import datetime
now = datetime.now()
now
datetime.datetime(2020, 12, 16, 14,
                  5, 52, 72973)
now.year, now.month, now.day
(2020, 12, 16)
delta = datetime(2020, 12, 31, 1) -
        datetime(2020, 1, 1)
delta
datetime.timedelta(365, 3600)
delta.days, delta.seconds
(365, 3600)
```

11.1 Date and Time Data Types and Tools

- You can **add** (or **subtract**) **timedeltas** to a datetime object to yield a new shifted object.

```
from datetime import timedelta
start = datetime(2020, 12, 16)
start + timedelta(10)
datetime.datetime(2020, 12, 26,
                  0, 0)
start - 2 * timedelta(10)
datetime.datetime(2020, 11, 26,
                  0, 0)
```

Table 11-1. Types in datetime module

Type	Description
date	Store calendar date (year, month, day) using the Gregorian calendar
time	Store time of day as hours, minutes, seconds, and microseconds
datetime	Stores both date and time
timedelta	Represents the difference between two datetime values (as days, seconds, and microseconds)
tzinfo	Base type for storing time zone information

Converting Between String and Datetime

- You can format **datetime** objects and pandas **Timestamp** objects as strings using **str** or the **strftime** method.

```
stamp = datetime(2020, 1, 3)
str(stamp)
'2020-01-03 00:00:00'
stamp.strftime('%Y-%m-%d')
'2020-01-03'
```

- You can use the same format codes to convert strings to dates using **datetime.strptime**.

```
value = '2020-01-03'
datetime.strptime(value,
                  '%Y-%m-%d')
datetime.datetime(2011, 1, 3, 0, 0)
```

Datetime format specification (ISO C89 compatible)

Type	Description
%Y	Four-digit year
%y	Two-digit year
%m	Two-digit month [01, 12]
%d	Two-digit day [01, 31]
%H	Hour (24-hour clock) [00, 23]
%I	Hour (12-hour clock) [01, 12]
%M	Two-digit minute [00, 59]
%S	Second [00, 61] (seconds 60, 61 account for leap seconds)
%w	Weekday as integer [0 (Sunday), 6]

Datetime format specification (ISO C89 compatible) – cont.

Type	Description
%U	Week number of the year [00, 53]; Sunday is considered the first day of the week, and days before the first Sunday of the year are “week 0”
%W	Week number of the year [00, 53]; Monday is considered the first day of the week, and days before the first Monday of the year are “week 0”
%Z	UTC time zone offset as +HHMM or -HHMM; empty if time zone naive
%F	Shortcut for %Y-%m-%d (e.g., 2012-4-18)
%D	Shortcut for %m/%d/%y (e.g., 04/18/12)

Converting Between String and Datetime

- The `parser.parse` method can parse dates of **common** date formats.
- For our date format, you can pass **`dayfirst=True`**.

```
from dateutil.parser import parse
parse('2020-01-03')
datetime.datetime(2020, 1, 3, 0, 0)
parse('Jan 31, 1997 10:45 PM')
datetime.datetime(1997, 1, 31,
                  22, 45)
parse('6/12/2020', dayfirst=True)
datetime.datetime(2020, 12, 6,
                  0, 0)
```

Converting Between String and Datetime

- The pandas **to_datetime** method parses many date representations including standard date formats quickly.
- It also handles **missing values**.
- pandas stores timestamps using NumPy's **datetime64** data type at the nanosecond resolution.

```
datestrs = ['2011-07-06 12:00:00',  
           '2011-08-06 00:00:00']
```

```
idx = pd.to_datetime(datestrs +  
                    [None])
```

```
idx
```

```
DatetimeIndex(['2011-07-06  
12:00:00', '2011-08-06 00:00:00',  
'NaT'], dtype='datetime64[ns]',  
freq=None)
```

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11.2 Time Series Basics

- pandas **Series** can be **indexed** by timestamps.
- The datetime objects is put in a **DatetimeIndex**.
- pandas stores scalar values of datetime objects as **Timestamp** objects.

```
ts.index[0]  
Timestamp('2011-01-02 00:00:00')
```

```
dates = [datetime(2011, 1, 2),  
         datetime(2011, 1, 5),  
         datetime(2011, 1, 7)]  
ts = pd.Series(np.random.randn(3),  
              index=dates)
```

```
ts  
2011-01-02    -0.204708  
2011-01-05     0.478943  
2011-01-07    -0.519439
```

```
ts.index  
DatetimeIndex(['2011-01-02', '2011-01-05', '2011-01-07'],  
              dtype='datetime64[ns]', freq=None)
```

Indexing, Selection, Subsetting

- Time series behaves like any other pandas.Series when you are **indexing** and **selecting** data based on **label**.
- You can also pass a **string** that is interpretable as a date.
- Slicing:

Equivalent to:

```
ts['1/5/2011':'1/7/2011']
```

```
stamp = ts.index[2]
ts[stamp]
-0.51943871505673811
```

```
ts['1/7/2011']
-0.51943871505673811
```

```
ts['20110107']
-0.51943871505673811
```

```
ts[datetime(2011, 1, 5):]
2011-01-05    0.478943
2011-01-07   -0.519439
```

Indexing, Selection, Subsetting

- For long time series, **select slices** of data by passing a **year** or only a **year and month**.

- The **truncate** method slices a Series between two dates.

```
len(longer_ts.truncate(
    after='12/31/2020'))
```

366

```
longer_ts = pd.Series(
    np.random.randn(1000),
    index=pd.date_range(
        '1/1/2020', periods=1000))
```

```
len(longer_ts)
```

1000

```
len(longer_ts['2021'])
```

365

```
len(longer_ts['2021-5'])
```

31

Indexing, Selection, Subsetting

- **DataFrames** can be indexed by time series as well.

```
dates = pd.date_range('1/1/2000', periods=100, freq='W-WED')
long_df = pd.DataFrame(np.random.randn(100, 4), index=dates,
                       columns=['Colorado', 'Texas', 'New York', 'Ohio'])
```

```
long_df.loc['5-2001']
```

	Colorado	Texas	New York	Ohio
2001-05-02	0.981586	0.056159	-1.787511	0.348340
2001-05-09	0.758415	-1.591688	1.103367	0.945877
2001-05-16	-1.797193	-1.660692	-0.415911	0.521095
2001-05-23	0.675365	-0.169244	0.174330	-0.448221
2001-05-30	-0.699178	0.892690	1.535503	0.350494

Time Series with Duplicate Indices

- Duplicates in time series index are **allowed**.

```
dates = pd.DatetimeIndex(
    ['1/1/2000', '1/2/2000',
     '1/2/2000', '1/2/2000',
     '1/3/2000'])
dup_ts = pd.Series(np.arange(5),
                   index=dates)
```

```
dup_ts
2000-01-01    0
2000-01-02    1
2000-01-02    2
2000-01-02    3
2000-01-03    4
```

```
dup_ts.index.is_unique
False
dup_ts['1/3/2000'] # not duplicated
4
dup_ts['1/2/2000'] # duplicated
2000-01-02    1
2000-01-02    2
2000-01-02    3
```

```
grouped = dup_ts.groupby(level=0)
grouped.count()
2000-01-01    1
2000-01-02    3
2000-01-03    1
```

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11.3 Date Ranges, Frequencies, and Shifting

- pandas has a full suite of standard time series frequencies and tools for:
 - **generating** fixed-frequency date **ranges**.
 - **inferring frequencies**,
 - **resampling**.

Generating Date Ranges

- pandas **date_range** can generate time series index by specifying:
 - Start and end
 - Start or end and periods
- The **freq** option allows you to specify wide range of frequencies:
 - H, min, S
 - D, B, M, BM, MS, BMS
 - W-SUN, W-MON, ...
 - AS-JAN, AS-FEB, ...

```
pd.date_range('2020-12-16',
              '2020-12-19')
DatetimeIndex(['2020-12-16',
               '2020-12-17', '2020-12-18',
               '2020-12-19'],
              dtype='datetime64[ns]', freq='D')
pd.date_range(start='2012-04-01',
              periods=20)
pd.date_range(end='2012-06-01',
              periods=20)
pd.date_range('2020-01-01',
              '2020-12-01', freq='MS')
```

Frequencies and Date Offsets

- Frequencies in pandas are composed of a **base frequency** and a **multiplier**.

```
from pandas.tseries.offsets import
    Hour, Minute
pd.date_range('2000-01-01',
              '2000-01-03 23:59', freq='4h')

Hour(2) + Minute(30)
<150 * Minutes>
pd.date_range('2000-01-01',
              periods=10, freq='1h30min')
```

Shifting (Leading and Lagging) Data

- **Shifting** refers to moving data backward and forward through time. Both Series and DataFrame have a shift method that leaves the **index unmodified**.

```
ts = pd.Series(np.random.randn(4),  
              index=pd.date_range('1/1/2020',  
                                  periods=4, freq='M'))
```

```
ts  
2020-01-31    0.137923  
2020-02-29    0.887474  
2020-03-31   -0.090994  
2020-04-30    0.412466
```

```
ts.shift(2)  
2020-01-31    NaN  
2020-02-29    NaN  
2020-03-31    0.137923  
2020-04-30    0.887474
```

```
ts.shift(-2)  
2020-01-31   -0.090994  
2020-02-29    0.412466  
2020-03-31    NaN  
2020-04-30    NaN
```

Shifting (Leading and Lagging) Data

- If the **frequency** is **known**, it can be passed to shift to **advance** the **timestamps** instead of advancing the data.

```
ts.shift(2, freq='M')
```

```
2000-03-31 -0.066748
```

```
2000-04-30  0.838639
```

```
2000-05-31 -0.117388
```

```
2000-06-30 -0.517795
```

```
ts.shift(3, freq='D')
```

```
ts.shift(1, freq='90T')
```

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