# pandas: a python data analysis library

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New York Financial Python Users Group 12/15/2009

# Outline

1. Motivation
   - Technology for quantitative finance
2. pandas
   - Origins
   - Data structures
   - Applications

# Some common financial research tasks

- Data manipulation
  - Raw data series are transformed into asset scores
  - Handle missing observations, time series of different frequencies, other sources of heterogeneity
- Portfolio construction, backtesting
  - Transform scores into tradable portfolios
  - Analyzing historical strategy performance
- Statistical estimation
  - Econometric analysis: linear regression and other more advanced models
  - Modeling risk: forecasting portfolio volatility

# Widely used research technology

- Commercial: MATLAB, Stata, eViews, etc.
- Open-source: R, others
- Frequently little code reuse (with exceptions, of course, e.g. CRAN)
- Typical workflow: research in one of the above, implement for real in C++, Java, etc.

# How does Python compare?

- NumPy provides a comparable (and often superior) array object and wonderfully extensible API
- Ability to use low-level code (C, Fortran, Cython, SWIG) can bridge performance gaps
- Python as a language is great for building larger systems
- But existing statistical modeling and econometrics libraries are relatively weak
- Pythonistas are often left creating their own tools, or using Python to prepare data sets for use in the other languages

# My goal

- Help Python become a compelling environment for finance, economics research and other statistical applications
- Implement convenient statistical estimation routines
- Provide tools for interfacing with other libraries / languages

# pandas origins

- Open-sourced by AQR in 2009
- Idea: data structures which understand labeled data, are lightweight and easy-to-visualize
- Link identifiers (dates, tickers, data name) to numerical data
- Works well with both time-series and cross-sectional data
- Prevent common errors associated with heterogeneous data
- Etymology: **pan**el **da**ta system

# Basic building blocks: overview

- 1-dimensional: Series, TimeSeries
  - NumPy array subclass with item label vector (Index)
  - Both ndarray and dict-like
- 2-dimensional: DataFrame, DataMatrix
  - Represents a dict of Series objects
  - Conforms Series to a common Index
- 3-dimensional: WidePanel, LongPanel
  - Behave as a dict of DataMatrix objects
  - Three indices: `items`, `major_axis`, `minor_axis`

# Series functionality

- ndarray subclass with various conveniences
- Combining Series matches Index values
- Many ndarray functions overridden to respect the Index and to exclude missing values (represented as NaN)
- Operates in essence as an ordered, fixed-length dict

# Series example

```
>>> s              >>> s2             >>> s + s2
AAPL     3.4       AAPL     3.4       AAPL     6.8
GOOG     9.4       GOOG     9.4       GOOG     18.8
IBM      7.2       IBM      7.2       IBM      14.4
MSFT     1.5                          MSFT     nan
```

```
>>> s + s2.reindex(s.index).fill(0)
AAPL     6.8
GOOG     18.8
IBM      14.4
MSFT     1.5
```

# DataMatrix

- A 2D container for Series objects which enforces data alignment
- Arithmetic operations between DataFrames match on both row and column labels
- Operations between DataFrames and Series broadcast depending on context
- Aggregation, group by, reindexing methods
- "Frame" versus "Matrix": different implementations of the same fundamental data structure (with slightly different performance characteristics)

# DataMatrix example

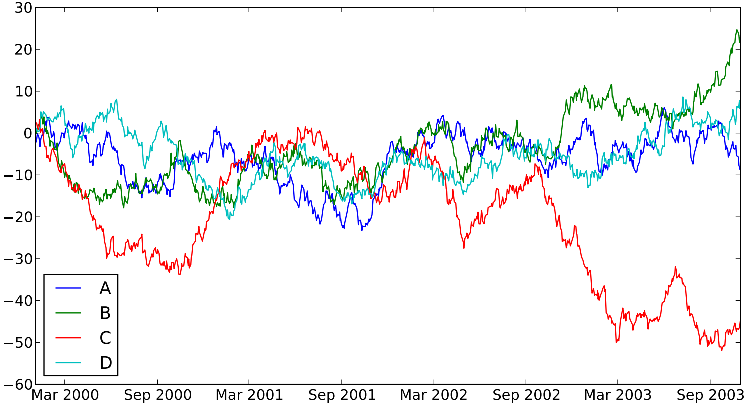
```
>>> dm
                         A            B            C            D
2000-01-03 00:00:00    -0.0415269   0.88057      -1.7492      0.548433
2000-01-04 00:00:00    0.166356     -0.955948    0.0679696    -0.26994
2000-01-05 00:00:00    0.954089     -0.0122938   -0.906397    -1.29401
2000-01-06 00:00:00    0.026427     0.643754     -0.167905    -0.35435
2000-01-07 00:00:00    1.786        -0.399267    0.858169     0.306875
2000-01-10 00:00:00    -0.850005    0.963422     -0.228602    1.12401
2000-01-11 00:00:00    -0.309066    1.28251      1.38328      -0.114106
2000-01-12 00:00:00    -0.0533492   0.328646     -1.52632     1.67064
2000-01-13 00:00:00    0.192041     0.79258      -1.0988      0.533673
2000-01-14 00:00:00    0.182775     0.325071     -0.288246    -1.05236
```

```
>>> dm.sum(axis=0)
A   2.05374198744
B   3.84904518163
C   -3.65605643845
D   1.09887239512
```

```
>>> dm.sum(axis=1)
2000-01-03 -0.361724
2000-01-04 -0.991562
2000-01-05 -1.258608
...
```

```
>>> dm['A']
2000-01-03   -0.0415269
2000-01-04   0.166356
2000-01-05   0.954089
...
```

- `dm.plot(); legend()`



# WidePanel

- Panel data stored in 3D ndarray ("wide" format)
- Slicing and aggregation produce DataMatrix objects
- Any axis can be reindexed
- Fast conversion to "long" (stacked) format for output to CSV or for regression analysis
- Recent addition to pandas, still a work in progress

# WidePanel example

```
>>> wp
<class 'pandas.core.panel.WidePanel'>
Dimensions: 2 (items) x 30 (major) x 4 (minor)
Items: Item1 to Item2
Major axis: 2000-01-03 00:00:00 to 2000-02-11 00:00:00
Minor axis: A to D
```

```
>>> wp.mean(axis='major')
     Item1          Item2
A    -0.079891      -0.175715
B    0.101753       0.102943
C    0.202509       0.133795
D    0.418179       -0.0465659
```

```
>>> wp.getMajorXS(wp.major_axis[0])
     Item1          Item2
A    -0.154756      -0.587252
B    -2.45935       0.666575
C    0.300465       2.51455
D    -1.14056       -1.33442
```

# LongPanel

- 2D “stacked” representation of panel data (balanced or unbalanced)
- Supports much of WidePanel functionality
- Built-in support for constructing dummy variables for regression modeling
- Can be lexicographically sorted

# LongPanel example

| Major | Minor | Item1 | Item2 |
|---|---|---|---|
| 2000-01-03 00:00:00 | A | -0.154756 | -0.587252 |
| 2000-01-03 00:00:00 | B | -2.45935 | 0.666575 |
| 2000-01-03 00:00:00 | C | 0.300465 | 2.51455 |
| 2000-01-03 00:00:00 | D | -1.14056 | -1.33442 |
| 2000-01-04 00:00:00 | A | -0.600915 | -0.156101 |
| 2000-01-04 00:00:00 | B | 1.37085 | 1.80986 |
| 2000-01-04 00:00:00 | C | -0.531156 | -1.93413 |
| 2000-01-04 00:00:00 | D | 0.713402 | 0.0890342 |
| 2000-01-05 00:00:00 | A | 0.470185 | -0.584578 |
| 2000-01-05 00:00:00 | B | 0.602647 | 0.510549 |
| 2000-01-05 00:00:00 | C | -0.0772073 | -2.62006 |
| 2000-01-05 00:00:00 | D | 0.157917 | -0.383053 |
| 2000-01-06 00:00:00 | A | -0.155252 | 0.50461 |
| 2000-01-06 00:00:00 | B | -0.0498417 | -0.616731 |
| 2000-01-06 00:00:00 | C | -0.44834 | -2.08052 |
| 2000-01-06 00:00:00 | D | -1.97119 | 0.353407 |
| 2000-01-07 00:00:00 | A | 0.995084 | -1.19059 |
| 2000-01-07 00:00:00 | B | -0.935756 | 2.31528 |

# Linear regression

- Idea: provide convenient high-level interface to commonly used stats routines
- Standard ordinary least squares: OLS
  - $y_t = \alpha + \overrightarrow{\beta} X_t + \varepsilon_t$
- Time-pooled cross-sectional regression: PanelOLS
  - $y_{it} = \alpha + \overrightarrow{\beta} X_{it} + \varepsilon_{it}$
  - With entity, time fixed effects: $y_{it} = \overrightarrow{\beta} X_{it} + \mu_i + \tau_t + \varepsilon_{it}$
- Corresponding with scikits.statsmodels developers, who are implementing other econometric models

# Regression output

```
>>> model = ols(y=Y, x=data)
Formula: Y ~ <A> + <B> + <C> + <intercept>

Number of Observations:         700
Number of Degrees of Freedom:   4

R-squared:         0.0026
Adj R-squared:    -0.0017

Rmse:              0.9800

F-stat (3, 696):     0.6013, p-value:     0.6143

Degrees of Freedom: model 3, resid 696

-----------------------Summary of Estimated Coefficients------------------------
      Variable       Coef    Std Err     t-stat    p-value    CI 2.5%   CI 97.5%
--------------------------------------------------------------------------------
             A     0.0252     0.0377       0.67     0.5031    -0.0486     0.0991
             B    -0.0154     0.0392      -0.39     0.6945    -0.0922     0.0614
             C     0.0403     0.0368       1.10     0.2731    -0.0317     0.1124
     intercept     0.0526     0.0371       1.42     0.1564    -0.0201     0.1252
```

# Additional regression functionality

- Supports rolling and expanding time series regressions (for forecasting)
- A few common adjustments for heteroskedasticity and autocorrelation (Newey-West correction, clustering)
- Does not try to reinvent every wheel available in R, Stata, etc., but rather to reduce how often you need to use another language

# Comparison with other Python libraries

- scikits.statsmodels
  - Implements statistical models using only NumPy and SciPy
  - pandas can hopefully be a companion library with high-level interfaces to scikits.statsmodels classes
- scikits.timeseries
  - Supports many kinds of time series-specific manipulations, built on numpy.MaskedArray
  - pandas provides support for generic date offsets and creating fixed frequency dates using the DateRange class. Could likely be enhanced by using scikits.timeseries functionality
  - pandas makes no intention of competing: rather it tries to be simple and easy-to-use for the majority of applications

# Comparison with other Python libraries

- tabular
  - A new library released recently providing spreadsheet-like functionality for 2D data
  - pandas is mostly intended for manipulating numerical data and building models with it
- Others?

# Ideas for future

- Expand existing functionality to address other applications
- Implement more statistical models / wrap scikits.statsmodels classes
- Develop seamless **rpy** interface to leverage CRAN wealth
- Better / more efficient IO functions for getting data into pandas

# Summary

- pandas provides a good starting place for working with time series and cross-sectional data sets
  - Let me know if you find it useful, or have suggestions
- Python use is growing in finance: with some more work we can further overcome the C++ / Java / MATLAB monoculture

# Thank you

- Cython and NumPy developers
- Jonathan Taylor and the scikits.statsmodels guys
- IPython devs: F. Perez et al
- Enthought, for inviting me

- Contact: wesmckinn@gmail.com
- Website: pandas.googlecode.com
- Official release on PyPI forthcoming

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