Programming Principles in Python (CSCI 503/490)

Data

Dr. David Koop

Data Frame

```
df = pd.read_csv('penguins_lter.csv')
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
1	PAL0708	2	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A2	Yes	11/11/07	39.5
2	PAL0708	3	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A1	Yes	11/16/07	40.3
3	PAL0708	4	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N2A2	Yes	11/16/07	NaN
4	PAL0708	5	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N3A1	Yes	11/16/07	36.7
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339	PAL0910	120	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N38A2	No	12/1/09	NaN
340	PAL0910	121	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N39A1	Yes	11/22/09	46.8
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343	PAL0910	124	Gentoo penguin (Pygoscelis papua)	Anvers	Biscoe	Adult, 1 Egg Stage	N43A2	Yes	11/22/09	49.9

344 rows × 17 columns

Data Frame

Column Names

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344 rows × 17 columns

Column: `df['Island']`

Data Frame

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```

Column Names

Row: `df.loc[2]`

Index

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
0	PAL0708	1	Adelie Penguin (Pygoscelis adeliae)	Anvers	Torgersen	Adult, 1 Egg Stage	N1A1	Yes	11/11/07	39.1
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344 rows × 17 columns

Row: `df.loc[2]`

Index

Cell: `df.loc[341,'Species']`

Column: `df['Island']`

Data Frame

```
df = pd.read_csv('penguins_lter.csv')
```

Column Names

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
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344 rows × 17 columns

Row: `df.loc[2]`

Index

Missing Data

Cell: `df.loc[341,'Species']`

Column: `df['Island']`

Filtering

```
df[df['Culmen Length (mm)'] > 40]
```

	studyName	Sample Number	Species	Region	Island	Stage	Individual ID	Clutch Completion	Date Egg	Culmen Length (mm)
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344 rows × 17 columns

Filtering

```
df[df['Culmen Length (mm)'] > 40]
```

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Reading and Writing Data

- Reading:
  - `df = pd.read_csv(fname)`
- Writing
  - `df.to_csv(fname)`
- Many options also possible on both
  - `sep:` the separator (defaults to comma)
  - `skiprows`: when reading, number of list of lines to skip
  - `index`: set to `None` when writing if unimportant
- Also methods for other formats (json, parquet, sql)
- Methods are `read_*` and `to_*`

Writing CSV data with pandas

- Basic: `df.to_csv(<fname>)`
- Change delimiter with sep kwarg:
  - `df.to_csv('example.dsv', sep='|')`
- Change missing value representation
  - `df.to_csv('example.dsv', na_rep='NULL')`
- Don't write row or column labels:
  - `df.to_csv('example.csv', index=False, header=False)`
- Series may also be written to csv

Derived Data

- Create new columns from existing columns
  - `r["PctFail"] = r['Fail'] / r['Total']`
- Note that operations are computed in a vectorized manner
- Similarities to functional paradigm (map/filter):
  - specify the operation once
  - no loops
  - interpreted as an operation on the entire column

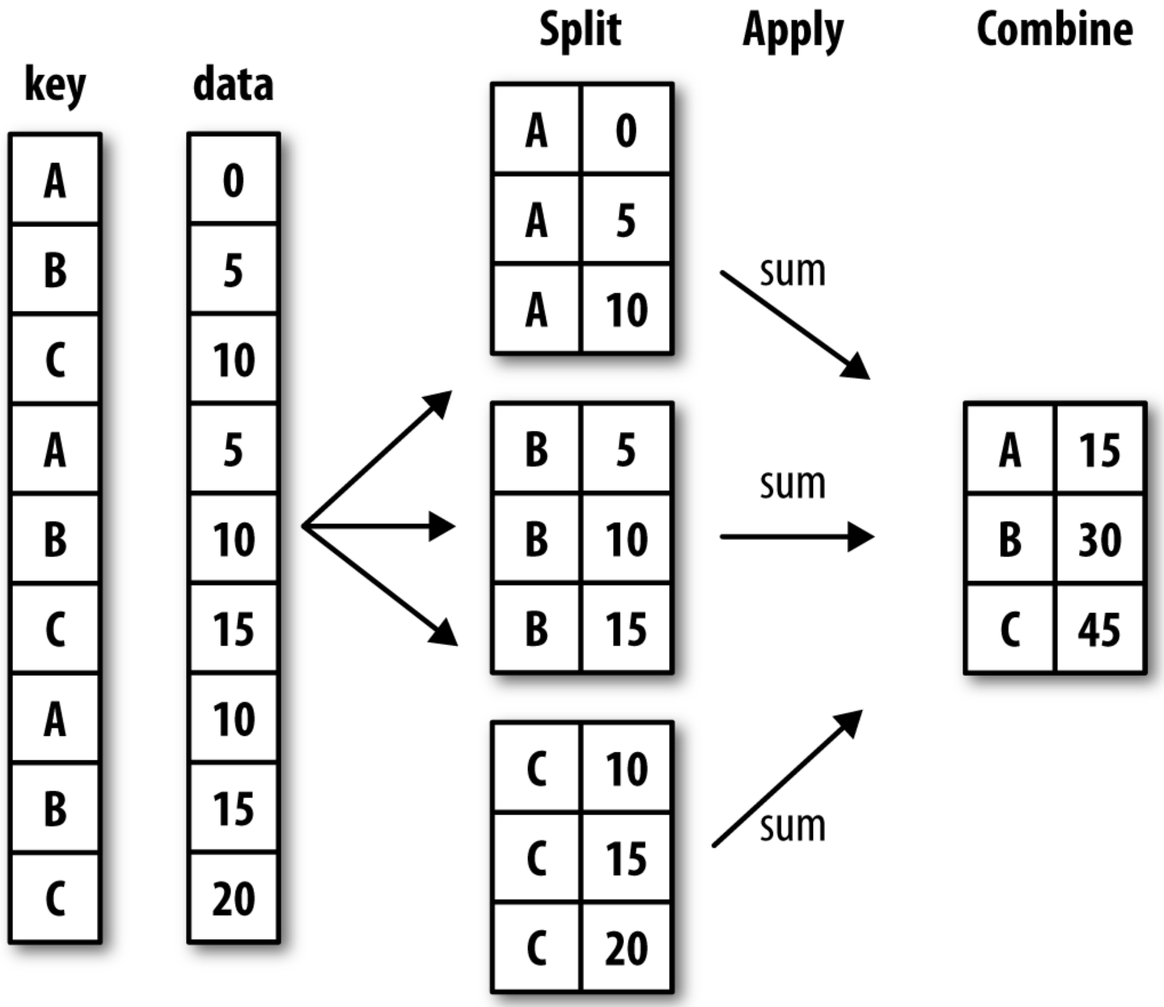
Assignment 7

- Musical Artists Datasets
- Downloading and uncompressing files
- Finding files using OS libraries
- Load per-artist numpy arrays, each saved in the .npy format
- Store per-month dataframes, each in a csv file

Aggregation

- Descriptive statistics
  - `df['Culmen Length (mm)'].mean()`
  - `.median()`
  - `.describe()`
  - `.count()`
  - `.min(), .max()`
- Also general methods
  - `.sum()`
  - `.product()`

Split-Apply-Combine



[W. McKinney, Python for Data Analysis]

Split-Apply-Combine

- Similar to Map (split+apply) Reduce (combine) paradigm
- The Pattern:
  1. **Split** the data by some grouping variable
  2. **Apply** some function to each group independently
  3. **Combine** the data into some output dataset
- The apply step is usually one of:
  - Aggregate
  - Transform
  - Filter

[T. Brandt]

In Pandas

- `groupby` method creates a `GroupBy` object
- `groupby` doesn't actually compute anything until there is an apply/aggregate step or we wish to examine the groups
- Choose keys (columns) to group by
- `size()` is the count of each group
- Other aggregates also work

Examples

- `df.groupby('Island')`
- `df.groupby('Island').size()`
- `df.groupby('Island')['Culmen Length (mm)'].mean()`

Split-Apply-Combine

- `df.groupby('Island')[['Culmen Length (mm)',`
  `'Culmen Depth (mm)']].mean()`
- `df.groupby('Island').agg({'Culmen Length (mm)': 'mean',`
  `'Culmen Depth (mm)': 'mean'})`
- `df.groupby('Island').agg(`
  `cul_length=('Culmen Length (mm)', 'mean'),`
  `cul_depth=('Culmen Depth (mm)', 'mean'))`

Island	cul_length	cul_depth
Biscoe	45.257485	15.874850
Dream	44.167742	18.344355
Torgersen	38.950980	18.429412

Different Data Layouts

	treatmenta	treatmentb
John Smith	—	2
Jane Doe	16	11
Mary Johnson	3	1

Initial Data

	John Smith	Jane Doe	Mary Johnson
treatmenta	—	16	3
treatmentb	2	11	1

Transpose

name	trt	result
John Smith	a	—
Jane Doe	a	16
Mary Johnson	a	3
John Smith	b	2
Jane Doe	b	11
Mary Johnson	b	1

Tidy Data

[H. Wickham, 2014]

Problem: Variables stored in both rows & columns

Mexico Weather, Global Historical Climatology Network

id	year	month	element	d1	d2	d3	d4	d5	d6	d7	d8
MX17004	2010	1	tmax	—	—	—	—	—	—	—	—
MX17004	2010	1	tmin	—	—	—	—	—	—	—	—
MX17004	2010	2	tmax	—	27.3	24.1	—	—	—	—	—
MX17004	2010	2	tmin	—	14.4	14.4	—	—	—	—	—
MX17004	2010	3	tmax	—	—	—	—	32.1	—	—	—
MX17004	2010	3	tmin	—	—	—	—	14.2	—	—	—
MX17004	2010	4	tmax	—	—	—	—	—	—	—	—
MX17004	2010	4	tmin	—	—	—	—	—	—	—	—
MX17004	2010	5	tmax	—	—	—	—	—	—	—	—
MX17004	2010	5	tmin	—	—	—	—	—	—	—	—

[H. Wickham, 2014]

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MX17004	2010	2	tmin	—	14.4	14.4	—	—	—	—	—
MX17004	2010	3	tmax	—	—	—	—	32.1	—	—	—
MX17004	2010	3	tmin	—	—	—	—	14.2	—	—	—
MX17004	2010	4	tmax	—	—	—	—	—	—	—	—
MX17004	2010	4	tmin	—	—	—	—	—	—	—	—
MX17004	2010	5	tmax	—	—	—	—	—	—	—	—
MX17004	2010	5	tmin	—	—	—	—	—	—	—	—

Variable in columns: day; Variable in rows: tmax/tmin

[H. Wickham, 2014]

Solution: Melting + Pivot

id	date	element	value
MX17004	2010-01-30	tmax	27.8
MX17004	2010-01-30	tmin	14.5
MX17004	2010-02-02	tmax	27.3
MX17004	2010-02-02	tmin	14.4
MX17004	2010-02-03	tmax	24.1
MX17004	2010-02-03	tmin	14.4
MX17004	2010-02-11	tmax	29.7
MX17004	2010-02-11	tmin	13.4
MX17004	2010-02-23	tmax	29.9
MX17004	2010-02-23	tmin	10.7

(a) Molten data

id	date	tmax	tmin
MX17004	2010-01-30	27.8	14.5
MX17004	2010-02-02	27.3	14.4
MX17004	2010-02-03	24.1	14.4
MX17004	2010-02-11	29.7	13.4
MX17004	2010-02-23	29.9	10.7
MX17004	2010-03-05	32.1	14.2
MX17004	2010-03-10	34.5	16.8
MX17004	2010-03-16	31.1	17.6
MX17004	2010-04-27	36.3	16.7
MX17004	2010-05-27	33.2	18.2

(b) Tidy data

[H. Wickham, 2014]

Melt

- Want to keep each observation separate (tidy), aka pivot_longer

	location	Temperature	Jan-2010	Feb-2010	Mar-2010
0	CityA	Predict	30	45	24
1	CityB	Actual	32	43	22

```
df.melt(id_vars=["location", "Temperature"],
        var_name="Date", value_name="Value")
```

	location	Temperature	Date	Value
0	CityA	Predict	Jan-2010	30
1	CityB	Actual	Jan-2010	32
2	CityA	Predict	Feb-2010	45
3	CityB	Actual	Feb-2010	43
4	CityA	Predict	Mar-2010	24
5	CityB	Actual	Mar-2010	22

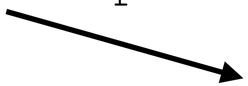
[AB Abhi]

Pivot

- Sometimes, we have data that is given in "long" format and we would like "wide" format (aka pivot_wider)
- Long format: column names are data values…
- Wide format: more like spreadsheet format
- Example:

```
         date     item     value
0  1959-03-31  realgdp  2710.349
1  1959-03-31     infl     0.000
2  1959-03-31    unemp     5.800
3  1959-06-30  realgdp  2778.801
4  1959-06-30     infl     2.340
5  1959-06-30    unemp     5.100
6  1959-09-30  realgdp  2775.488
7  1959-09-30     infl     2.740
8  1959-09-30    unemp     5.300
9  1959-12-31  realgdp  2785.204
```

```
.pivot('date', 'item', 'value')
```



```
item        infl   realgdp  unemp
date
1959-03-31  0.00  2710.349    5.8
1959-06-30  2.34  2778.801    5.1
1959-09-30  2.74  2775.488    5.3
1959-12-31  0.27  2785.204    5.6
1960-03-31  2.31  2847.699    5.2
```

[W. McKinney, Python for Data Analysis]

Reshaping Data

- Reshape/pivoting are fundamental operations
- Can have a nested index in pandas
- Example: Congressional Districts (Ohio's 1st, 2nd, 3rd, Colorado's 1st, 2nd, 3rd) and associated representative rankings
- Could write this in different ways:

number	one	two	three
state			
Ohio	0	1	2
Colorado	3	4	5

state	Ohio	Colorado
number		
one	0	3
two	1	4
three	2	5

state	number	
Ohio	one	0
	two	1
	three	2
Colorado	one	3
	two	4
	three	5

Reshaping Data

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state			
Ohio	0	1	2
Colorado	3	4	5

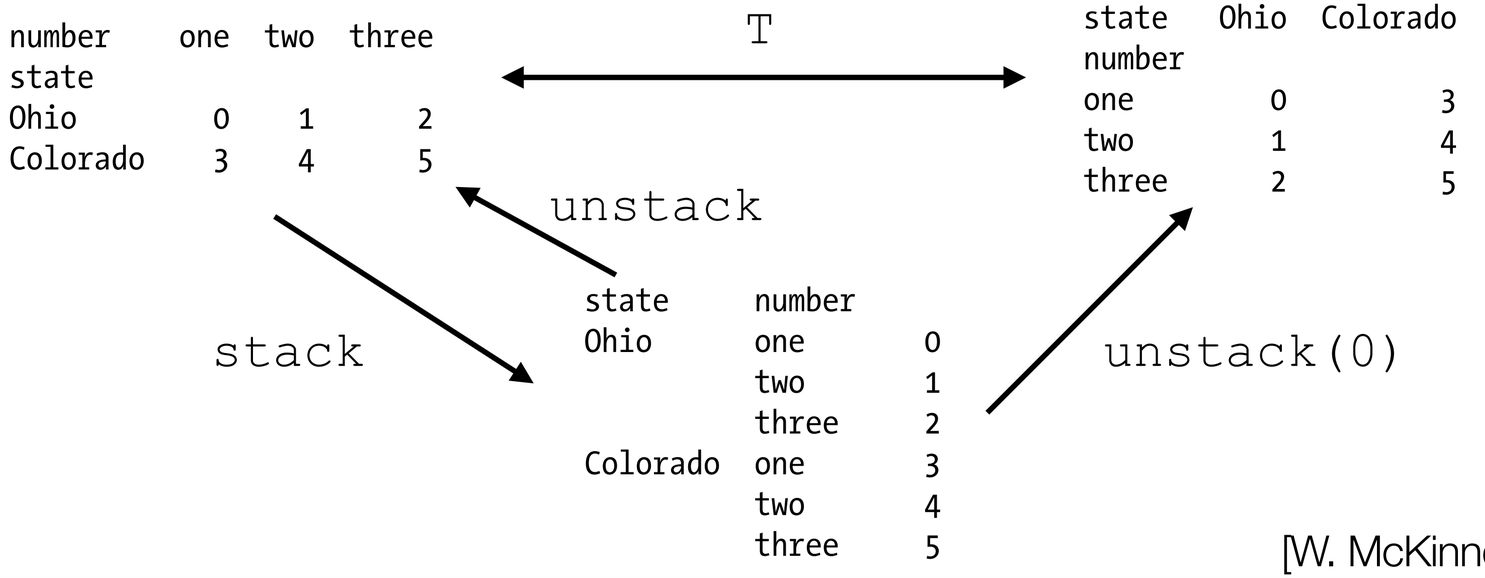
state	Ohio	Colorado
number		
one	0	3
two	1	4
three	2	5

MultiIndex

state	number	
Ohio	one	0
	two	1
	three	2
Colorado	one	3
	two	4
	three	5

Stack and Unstack

- `stack`: pivots from the columns into rows (may produce a Series!)
- `unstack`: pivots from rows into columns
- unstacking may add missing data
- stacking filters out missing data (unless `dropna=False`)
- can unstack at a different level by passing it (e.g. 0), defaults to innermost level



[W. McKinney, Python for Data Analysis]

String Methods

- Can do many of the same methods used for single strings on entire columns
- Requires `.str` prefix before calling the method
  - `violations.value.str.strip().str.split(' - Comments:')`
- Also helps when extracting from a list
  - `comments.str[1]`

String Methods

Argument	Description
`count`	Return the number of non-overlapping occurrences of substring in the string.
`endswith`	Returns `True` if string ends with suffix.
`startswith`	Returns `True` if string starts with prefix.
`join`	Use string as delimiter for concatenating a sequence of other strings.
`index`	Return position of first character in substring if found in the string; raises `ValueError` if not found.
`find`	Return position of first character of *first* occurrence of substring in the string; like `index`, but returns –1 if not found.
`rfind`	Return position of first character of *last* occurrence of substring in the string; returns –1 if not found.
`replace`	Replace occurrences of string with another string.
`strip`, `rstrip`, `lstrip`	Trim whitespace, including newlines; equivalent to `x.strip()` (and `rstrip, lstrip`, respectively) for each element.
`split`	Break string into list of substrings using passed delimiter.
`lower`	Convert alphabet characters to lowercase.
`upper`	Convert alphabet characters to uppercase.
`casefold`	Convert characters to lowercase, and convert any region-specific variable character combinations to a common comparable form.
`ljust`, `rjust`	Left justify or right justify, respectively; pad opposite side of string with spaces (or some other fill character) to return a string with a minimum width.

[W. McKinney, Python for Data Analysis]

Support for Datetime

- Python has datetime library to support dates and times
- pandas has a Timestamp data type that functions somewhat similarly
- Pandas can convert timestamps
  - `pd.to_datetime`: versatile, can often guess format
- Like string methods, also a `.dt` accessor for datetime methods/properties
- With a timestamp, filtering based on datetimes becomes easier
  - `df[df['Inspection Date'] > '2021']`

Method chaining in pandas

- Tom Augspurger's post
- Effective Pandas book by Matt Harrison
- Functions written for chaining, and pipe allows custom functions
-
```
def read(fp):
    df = (pd.read_csv(fp)
            .rename(columns=str.lower)
            .drop('unnamed: 36', axis=1)
            .pipe(extract_city_name)
            .pipe(time_to_datetime, ['dep_time', 'arr_time',
                                     'crs_arr_time', 'crs_dep_time'])
            .assign(fl_date=lambda x: pd.to_datetime(x['fl_date']),
                    dest=lambda x: pd.Categorical(x['dest']),
                    origin=lambda x: pd.Categorical(x['origin']),
                    tail_num=lambda x: pd.Categorical(x['tail_num']),
                    unique_carrier=lambda x: pd.Categorical(x['unique_carrier']),
                    cancellation_code=lambda x: pd.Categorical(x['cancellation_code'])))
    return df
```

Example: Inspect Intermediate Results

- ```
  def csnap(df, fn=lambda x: x.shape, msg=None):
      """ Custom Help function to print things in method chaining.
          Returns back the df to further use in chaining.
      """
      if msg:
          print(msg)
      display(fn(df))
      return df
  ```
- ```
  wine.pipe(csnap) # display data frame
      .rename(columns={"color_intensity": "ci"})
      .assign(color_filter=lambda x: np.where(x.hue > 1, 1, 0))
      .pipe(csnap) # display data frame
      …
  ```

Food Inspections Example