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University of Minnesota

Data Analytics with pandas

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Outline

- **pandas** Library
- **Series** Object
  - **Index** object
  - Vectorized operations
- **DataFrame** Object
  - Column/row operations
  - Loading data from CSV and Excel files
  - Subsetting with relational and logical operators
  - Splitting with group by and aggregation

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pandas Library

- Most popular Python data analytics toolkit
  - Built on top of NumPy vectorized operations
- Extremely flexible data structures
  - Reading/writing from/to numerous data sources (CSV, JSON, …)
  - Splitting, combining, merging, reshaping, joining data
- Fast computations with Series & DataFrames
  - Subsetting, summarizing, pivot tables, …
  - Tightly integrated with **matplotlib** and **datetime** libraries
- Not part of standard Python installation
  - OS command prompt> **pip install pandas**
  - **LectPD_Cust_Loans.py**

```
>>> import pandas as pd
```

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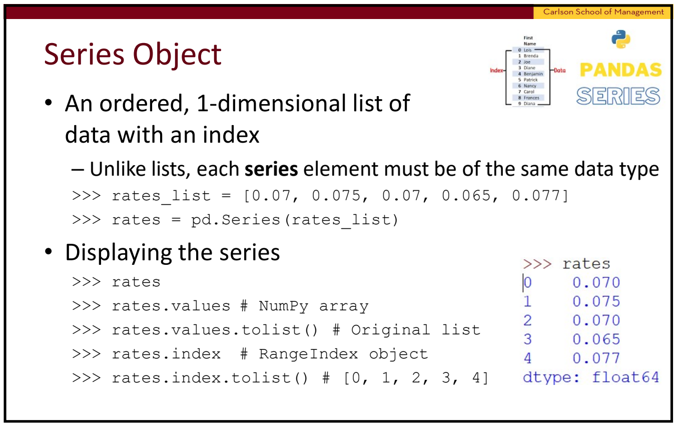
Carlson School of Management
First Name
0 Lois
1 Brenda
2 Joe
3 Diane
4 Benjamin
5 Patrick
6 Nancy
7 Carol
8 Frances
9 Diana
Index
Data
PANDAS
SERIES

Series Object

- An ordered, 1-dimensional list of data with an index
  - Unlike lists, each **series** element must be of the same data type

```
>>> rates_list = [0.07, 0.075, 0.07, 0.065, 0.077]
>>> rates = pd.Series(rates_list)
```

- Displaying the series

```
>>> rates
>>> rates.values # NumPy array
>>> rates.values.tolist() # Original list
>>> rates.index  # RangeIndex object
>>> rates.index.tolist() # [0, 1, 2, 3, 4]
```

```
>>> rates
0     0.070
1     0.075
2     0.070
3     0.065
4     0.077
dtype: float64
```

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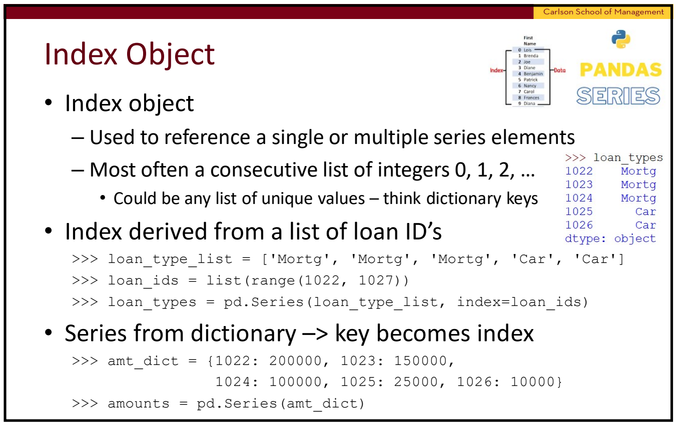
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Index Object

- Index object
  - Used to reference a single or multiple series elements
  - Most often a consecutive list of integers 0, 1, 2, …
    - Could be any list of unique values – think dictionary keys
- Index derived from a list of loan ID’s

```
>>> loan_types
1022     Mortg
1023     Mortg
1024     Mortg
1025       Car
1026       Car
dtype: object
```

```
>>> loan_type_list = ['Mortg', 'Mortg', 'Mortg', 'Car', 'Car']
>>> loan_ids = list(range(1022, 1027))
>>> loan_types = pd.Series(loan_type_list, index=loan_ids)
```

- Series from dictionary –> key becomes index

```
>>> amt_dict = {1022: 200000, 1023: 150000,
               1024: 100000, 1025: 25000, 1026: 10000}
>>> amounts = pd.Series(amt_dict)
```

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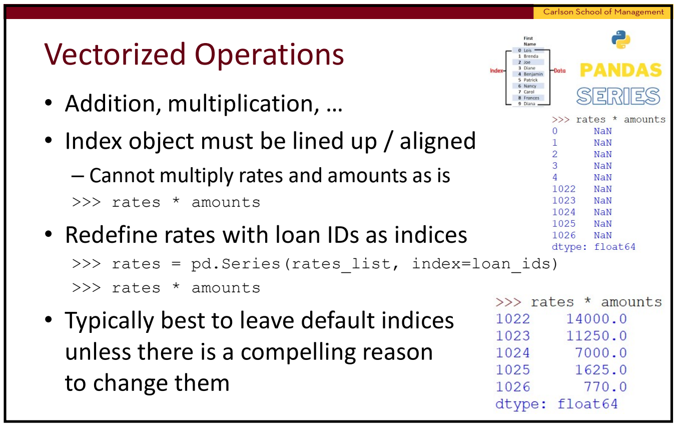
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Data
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Vectorized Operations

- Addition, multiplication, …
- Index object must be lined up / aligned
  - Cannot multiply rates and amounts as is

```
>>> rates * amounts
```

```
>>> rates * amounts
0      NaN
1      NaN
2      NaN
3      NaN
4      NaN
1022   NaN
1023   NaN
1024   NaN
1025   NaN
1026   NaN
dtype: float64
```

- Redefine rates with loan IDs as indices

```
>>> rates = pd.Series(rates_list, index=loan_ids)
>>> rates * amounts
```

- Typically best to leave default indices unless there is a compelling reason to change them

```
>>> rates * amounts
1022     14000.0
1023     11250.0
1024      7000.0
1025      1625.0
1026       770.0
dtype: float64
```

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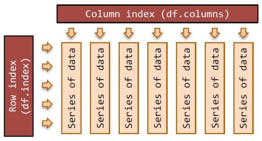
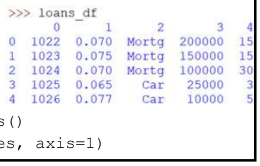
DataFrame Object



- Two-dimensional table of data
  - Columns represent attributes or characteristics of entities
    - Created from a distinct set of Series objects
  - Rows represent different instances of these entities
    - Both columns and rows indexed
- Loans data frame
  - See **loans.py**
  - Assemble individual series into a list
  - Create data frame with **concat**



```
>>> loans_df
      0      1      2       3   4
0  1022  0.070  Mortg  200000  15
1  1023  0.075  Mortg  150000  15
2  1024  0.070  Mortg  100000  30
3  1025  0.065    Car   25000   3
4  1026  0.077    Car   10000   5
```

```
>>> loan_series = loans.loan_series()
>>> loans_df = pd.concat(loan_series, axis=1)
```

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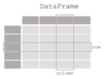
DataFrame Function



- Redefine column indices as attribute names

```
>>> loan_cols = ['loanID', 'intRate', …, 'loanTerm']
```

- Creating data frame from dict of individual series

```
>>> loan_series_dict = dict(zip(loan_cols, loan_series))
```

  - Use **DataFrame** function to create the same data frame object

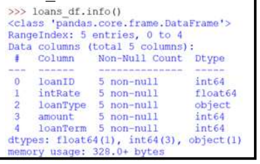
```
>>> loans_df = pd.DataFrame(loan_series_dict)
```

- Examine data frame contents

```
>>> loans_df.info()
```

- Basic column summary stats

```
>>> loans_df.describe()
```



```
>>> loans_df.info()
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 5 entries, 0 to 4
Data columns (total 5 columns):
 #   Column    Non-Null Count  Dtype
---  ------    --------------  -----
 0   loanID    5 non-null      int64
 1   intRate   5 non-null      float64
 2   loanType  5 non-null      object
 3   amount    5 non-null      int64
 4   loanTerm  5 non-null      int64
dtypes: float64(1), int64(3), object(1)
memory usage: 328.0+ bytes
```

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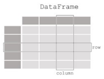
Working with DataFrame Columns



- Selecting a single column by name

```
>>> loans_df['intRate']
```

- Selecting multiple columns using names
  - Must assemble column names into a list

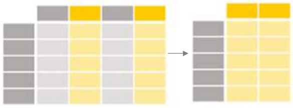
```
>>> loans_df[['loanType','amount']]
```

- Selecting a column by number
  - loanTerm is the 5th column at index 4

```
>>> loans_df[loans_df.columns[4]]
```

- Selecting multiple columns by slicing
  - First 3 columns (0, 1, and 2)

```
>>> loans_df[loans_df.columns[:3]]
```



- Selecting non-adjacent columns

```
>>> loans_df[loans_df.columns[[1,2,4]]]
```

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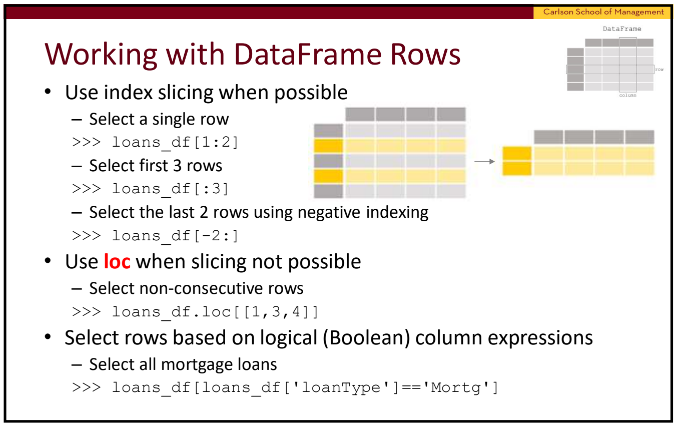

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Working with DataFrame Rows

- Use index slicing when possible
  - Select a single row

```
>>> loans_df[1:2]
```

  - Select first 3 rows

```
>>> loans_df[:3]
```

  - Select the last 2 rows using negative indexing

```
>>> loans_df[-2:]
```

- Use **loc** when slicing not possible
  - Select non-consecutive rows

```
>>> loans_df.loc[[1,3,4]]
```

- Select rows based on logical (Boolean) column expressions
  - Select all mortgage loans

```
>>> loans_df[loans_df['loanType']=='Mortg']
```

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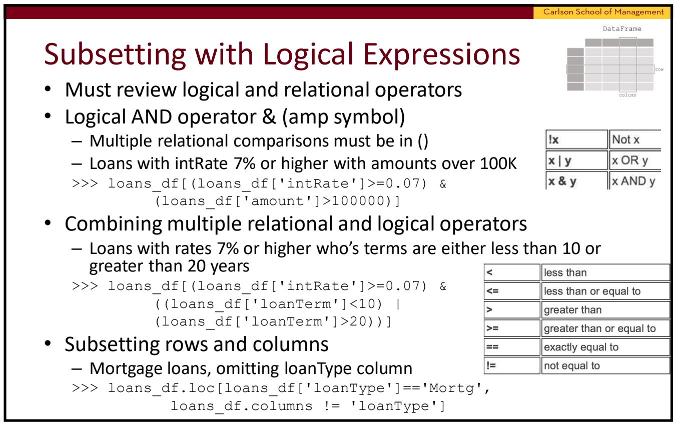

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Subsetting with Logical Expressions

- Must review logical and relational operators
- Logical AND operator & (amp symbol)
  - Multiple relational comparisons must be in ()
  - Loans with intRate 7% or higher with amounts over 100K

```
>>> loans_df[(loans_df['intRate']>=0.07) &
            (loans_df['amount']>100000)]
```

!x	Not x
x | y	x OR y
x & y	x AND y

- Combining multiple relational and logical operators
  - Loans with rates 7% or higher who's terms are either less than 10 or greater than 20 years

```
>>> loans_df[(loans_df['intRate']>=0.07) &
            ((loans_df['loanTerm']<10) |
            (loans_df['loanTerm']>20))]
```

<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
==	exactly equal to
!=	not equal to

- Subsetting rows and columns
  - Mortgage loans, omitting loanType column

```
>>> loans_df.loc[loans_df['loanType']=='Mortg',
              loans_df.columns != 'loanType']
```

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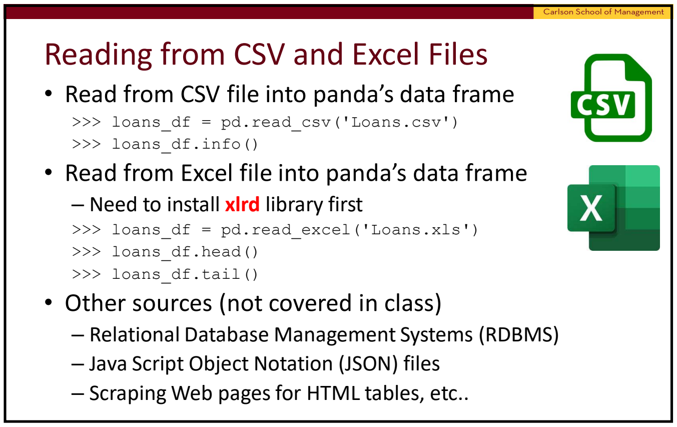

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Reading from CSV and Excel Files

- Read from CSV file into panda's data frame

```
>>> loans_df = pd.read_csv('Loans.csv')
>>> loans_df.info()
```

- Read from Excel file into panda's data frame
  - Need to install **xlrd** library first

```
>>> loans_df = pd.read_excel('Loans.xls')
>>> loans_df.head()
>>> loans_df.tail()
```

- Other sources (not covered in class)
  - Relational Database Management Systems (RDBMS)
  - Java Script Object Notation (JSON) files
  - Scraping Web pages for HTML tables, etc..

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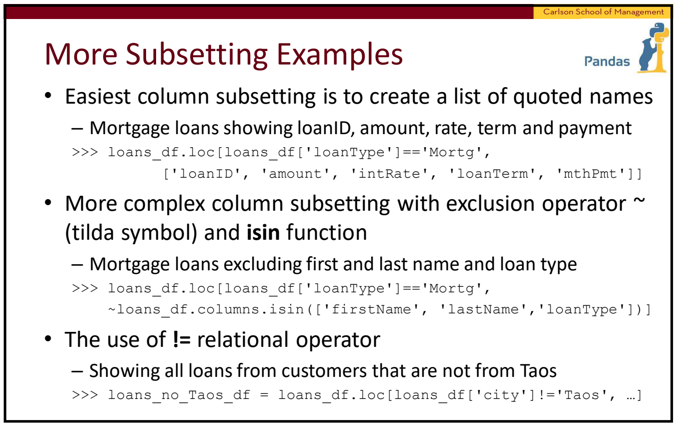

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More Subsetting Examples

Pandas

- Easiest column subsetting is to create a list of quoted names
  - Mortgage loans showing loanID, amount, rate, term and payment

```
>>> loans_df.loc[loans_df['loanType']=='Mortg',
          ['loanID', 'amount', 'intRate', 'loanTerm', 'mthPmt']]
```

- More complex column subsetting with exclusion operator ~ (tilda symbol) and **isin** function
  - Mortgage loans excluding first and last name and loan type

```
>>> loans_df.loc[loans_df['loanType']=='Mortg',
    ~loans_df.columns.isin(['firstName', 'lastName','loanType'])]
```

- The use of **!=** relational operator
  - Showing all loans from customers that are not from Taos

```
>>> loans_no_Taos_df = loans_df.loc[loans_df['city']!='Taos', …]
```

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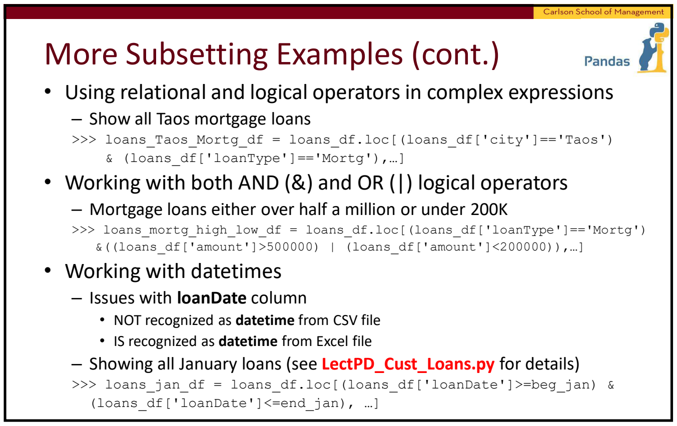

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More Subsetting Examples (cont.)

Pandas

- Using relational and logical operators in complex expressions
  - Show all Taos mortgage loans

```
>>> loans_Taos_Mortg_df = loans_df.loc[(loans_df['city']=='Taos')
     & (loans_df['loanType']=='Mortg'),…]
```

- Working with both AND (&) and OR (|) logical operators
  - Mortgage loans either over half a million or under 200K

```
>>> loans_mortg_high_low_df = loans_df.loc[(loans_df['loanType']=='Mortg')
   &((loans_df['amount']>500000) | (loans_df['amount']<200000)),…]
```

- Working with datetimes
  - Issues with **loanDate** column
    - NOT recognized as **datetime** from CSV file
    - IS recognized as **datetime** from Excel file
  - Showing all January loans (see **LectPD_Cust_Loans.py** for details)

```
>>> loans_jan_df = loans_df.loc[(loans_df['loanDate']>=beg_jan) &
  (loans_df['loanDate']<=end_jan), …]
```

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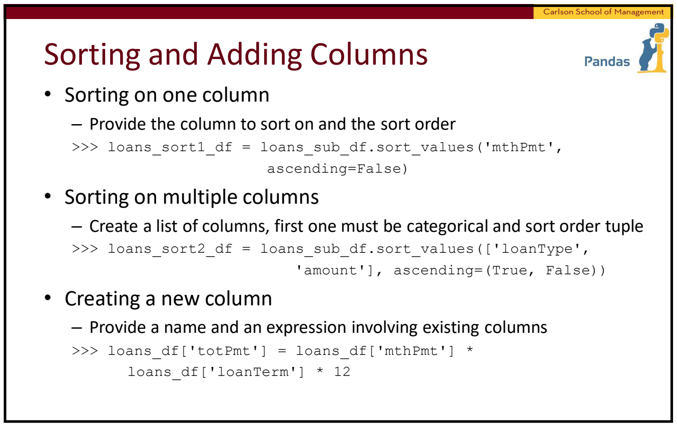

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Sorting and Adding Columns

Pandas

- Sorting on one column
  - Provide the column to sort on and the sort order

```
>>> loans_sort1_df = loans_sub_df.sort_values('mthPmt',
                     ascending=False)
```

- Sorting on multiple columns
  - Create a list of columns, first one must be categorical and sort order tuple

```
>>> loans_sort2_df = loans_sub_df.sort_values(['loanType',
                        'amount'], ascending=(True, False))
```

- Creating a new column
  - Provide a name and an expression involving existing columns

```
>>> loans_df['totPmt'] = loans_df['mthPmt'] *
      loans_df['loanTerm'] * 12
```

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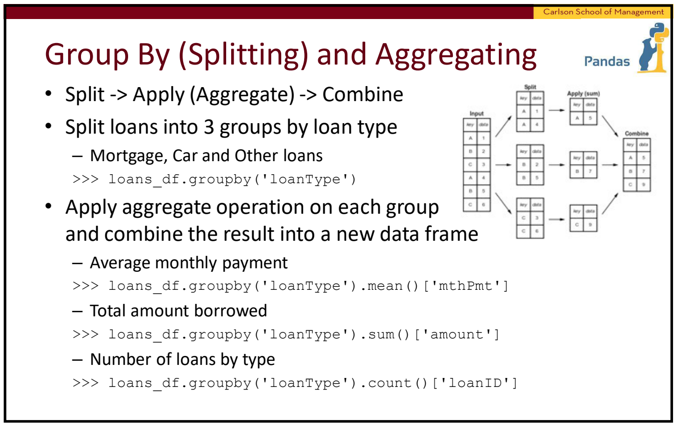

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Group By (Splitting) and Aggregating

Pandas

- Split -> Apply (Aggregate) -> Combine
- Split loans into 3 groups by loan type
  - Mortgage, Car and Other loans

```
>>> loans_df.groupby('loanType')
```

- Apply aggregate operation on each group and combine the result into a new data frame
  - Average monthly payment

```
>>> loans_df.groupby('loanType').mean()['mthPmt']
```

  - Total amount borrowed

```
>>> loans_df.groupby('loanType').sum()['amount']
```

  - Number of loans by type

```
>>> loans_df.groupby('loanType').count()['loanID']
```

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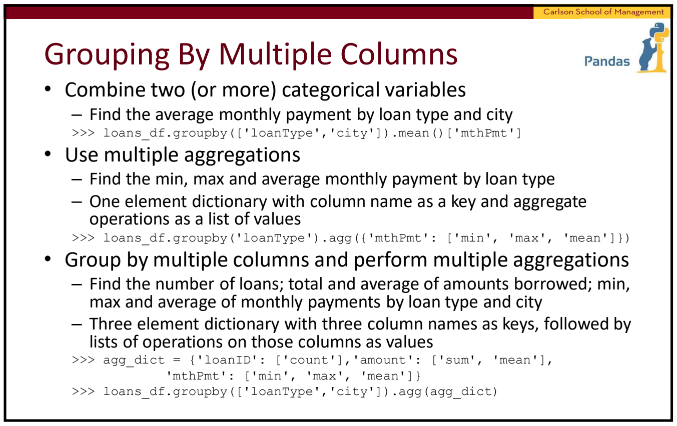

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Grouping By Multiple Columns

Pandas

- Combine two (or more) categorical variables
  - Find the average monthly payment by loan type and city

```
>>> loans_df.groupby(['loanType','city']).mean()['mthPmt']
```

- Use multiple aggregations
  - Find the min, max and average monthly payment by loan type
  - One element dictionary with column name as a key and aggregate operations as a list of values

```
>>> loans_df.groupby('loanType').agg({'mthPmt': ['min', 'max', 'mean']})
```

- Group by multiple columns and perform multiple aggregations
  - Find the number of loans; total and average of amounts borrowed; min, max and average of monthly payments by loan type and city
  - Three element dictionary with three column names as keys, followed by lists of operations on those columns as values

```
>>> agg_dict = {'loanID': ['count'],'amount': ['sum', 'mean'],
              'mthPmt': ['min', 'max', 'mean']}
>>> loans_df.groupby(['loanType','city']).agg(agg_dict)
```

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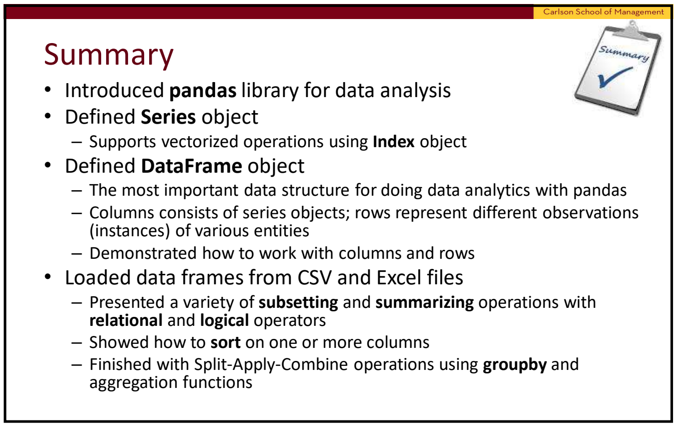

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Summary

- Introduced **pandas** library for data analysis
- Defined **Series** object
  - Supports vectorized operations using **Index** object
- Defined **DataFrame** object
  - The most important data structure for doing data analytics with pandas
  - Columns consists of series objects; rows represent different observations (instances) of various entities
  - Demonstrated how to work with columns and rows
- Loaded data frames from CSV and Excel files
  - Presented a variety of **subsetting** and **summarizing** operations with **relational** and **logical** operators
  - Showed how to **sort** on one or more columns
  - Finished with Split-Apply-Combine operations using **groupby** and aggregation functions

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