Using Bootstrapping to Evaluate Your Experiment

Introduction to Bootstrapping

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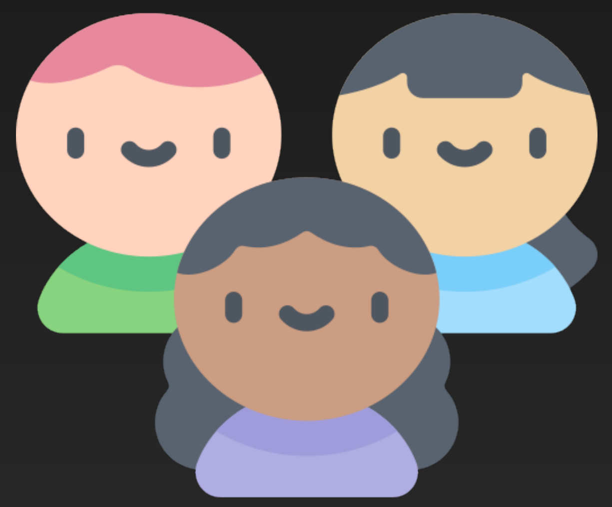
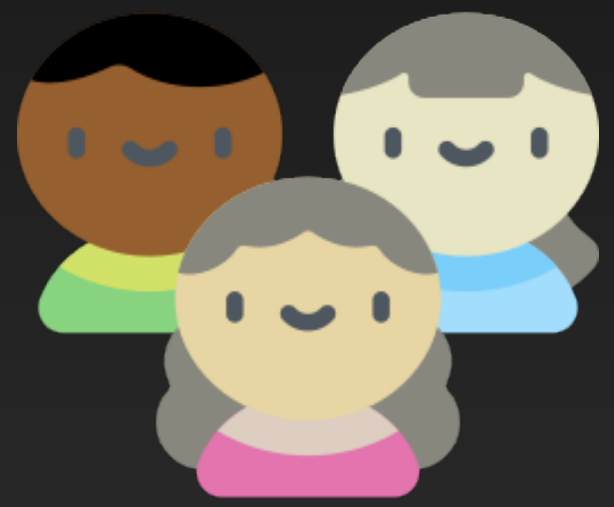
Agenda

- Imagine you are doing an experiment
- Hypothesis testing
- Introduction to bootstrapping
- Apply bootstrapping to evaluate your experiment
- Code sample

Imagine You're Doing Experiment for the Company...

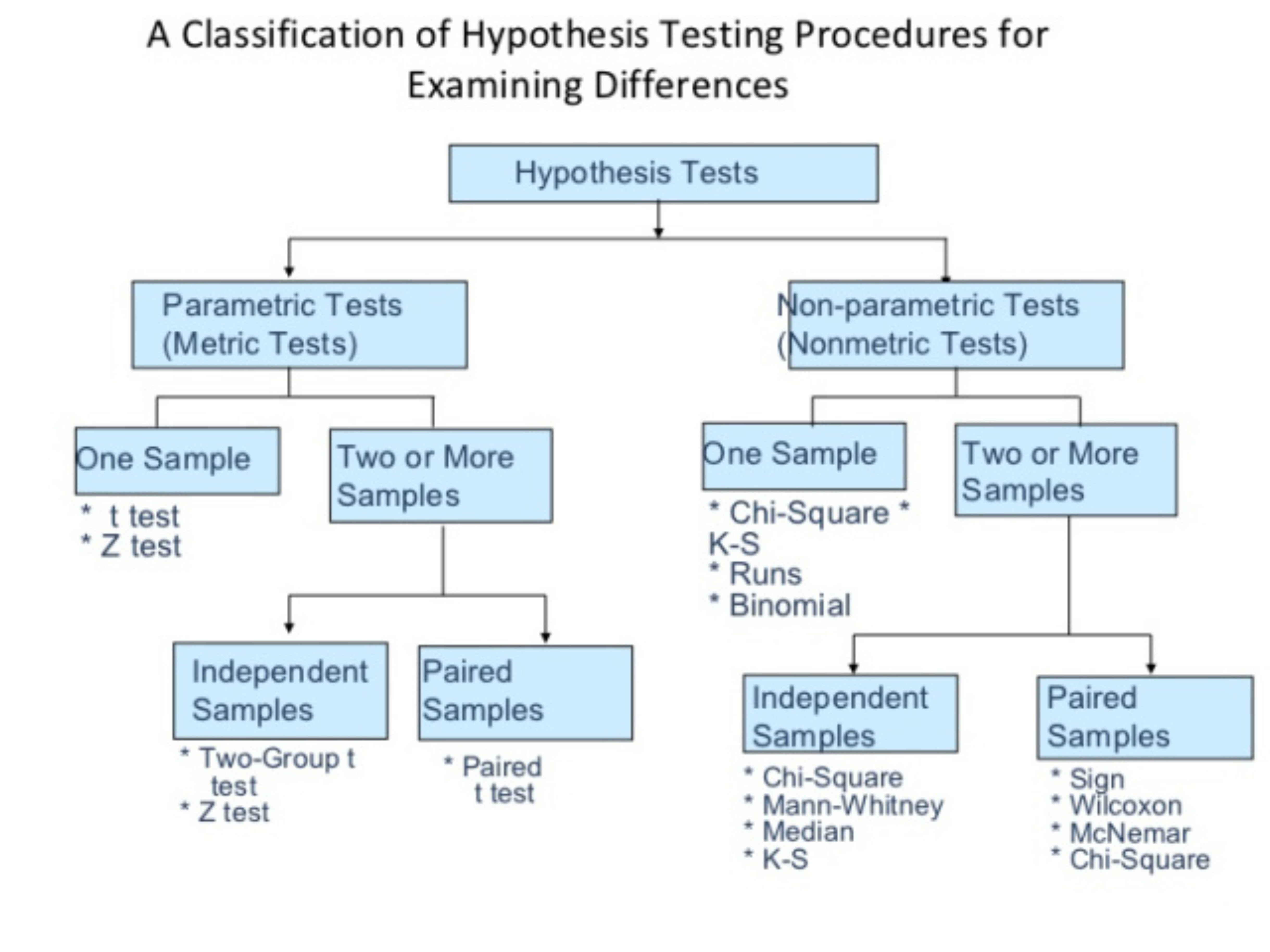
Test	Control
	
Converted 20 people out of total 1000 Conversion: 2%	Converted 15 people out of total 1000 conversion: 1.5%

Hypothesis Testing

Test group looks better than control group - but does it really perform better?

- You want to test whether test group works better, a.k.a. the difference between two groups are statistically significant.
- Parametric test - make assumptions about the parameters of the population distribution from which the sample is drawn. This is often the assumption that the population data are normally distributed.
- Non-parametric tests are “distribution-free” and, as such, can be used for non-Normal variables.

Hypothesis Testing II
Statistical Tests



https://mkhernandez.wordpress.com/2017/04/29/quant-parametric-and-non-parametric-stats/

Bootstrapping Method

“Bootstrapping is any test or metric that uses random sampling with replacement, and falls under the broader class of resampling methods.

It assigns measures of accuracy (bias, variance, confidence intervals, prediction error, etc.) to sample estimates. “ - Wikipedia.

- This resampling method is widely used in statistics and machine learning.
- For instance, Bagging (bootstrap aggregating) will create bootstrapped subsamples from the population and calculate the average.
- Random Forest tweaks Bagging a bit to reduce the variance by learning from only a handful of features while growing trees.

Apply Bootstrapping to the Evaluation

- Central Limit Theorem:

  if you have a population with mean μ and standard deviation σ and take sufficiently large random samples from the population with replacement, then the distribution of the sample means will be approximately normally distributed

- Non-parametric: no assumption about the population distribution
- Tackle small sample problems
- Can easily get p-value and confidence intervals
- Code is reused for different experiments
- Can also be applied to design the experiment & conduct power analysis; however, I will only focus on the evaluation today.
- Disadvantage: bootstrapping can be time-consuming if there are too many iterations (at least 30 to fulfill the Central Limit Theorem)

Apply Bootstrapping to the Evaluation II

Process

1. Resample your data
2. Calculate the metric that you are interested
3. Repeat 1 & 2 for multiple times (you can decide the iteration)
4. Compare your test and control group: calculate p-value and confidence interval

Apply Bootstrapping to the Evaluation III

Example

- If we are interested in knowing whether the test group convert more than control group, we test whether the mean difference in conversion rate is statistically significant.
- Outcome variable: 0 for non-converted, 1 for converted (the mean of all conversion data is the group conversion rate)

1. Resample the data
2. Get conversion rates in both groups
3. Calculate the difference in conversion rate
4. Repeat 1 - 3 for x times (normally I will do 2000+)
5. Calculate p-value and confidence interval from the bootstrapped data

	test	cntrl
0	0	0
1	0	0
2	0	0
3	0	0
4	1	0

Code Sample

Resampling

```python
def resampling(dataframe, i):

    '''
    This function is used for resampling.

    data: your dataset
    i: the number of iternation

    '''

    # 1.resample your data, replace will be True because boostrapping allows replacement

    df = dataframe.sample(frac = 1, replace = True)

    # 2. get the difference in conversion rate and the number of iteration
    df1 = df.mean().reset_index()
    df1.columns = ['group','value']
    df1 = df1.pivot_table(columns = ['group'])
    df1['diff'] = df1['test'] - df1['cntrl']
    df1['delta'] = df1['diff'] > 0

    return df1
```

Build bootstrapped data with 5000 iterations

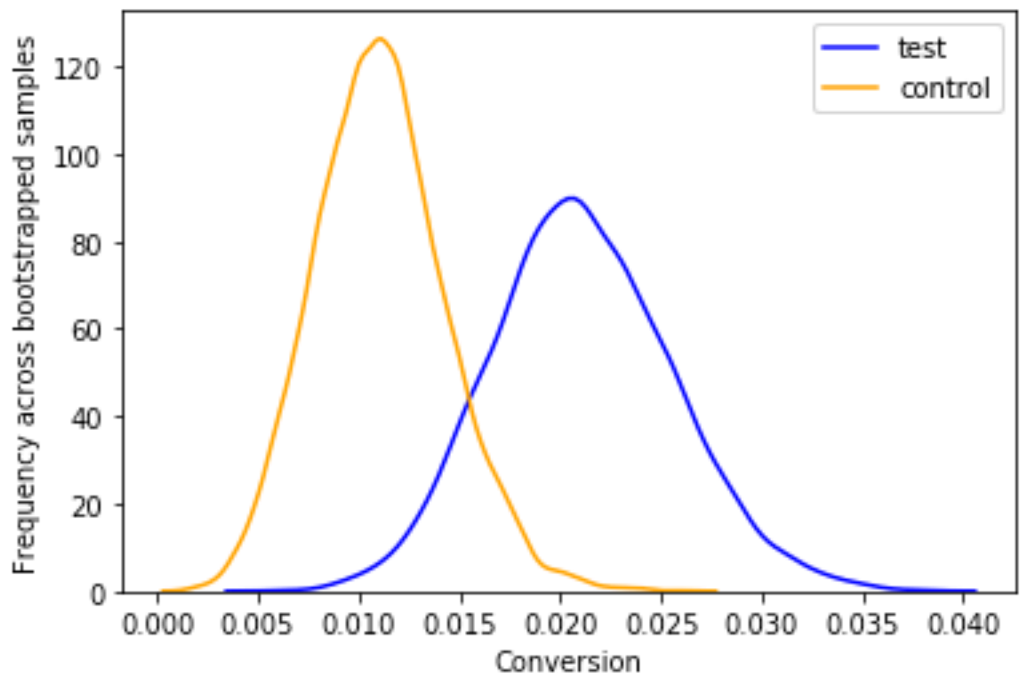
```python
# get all bootstrapped data

bootstrapped = pd.concat([resampling(dataframe = data, i = i) for i in range(0,5000)])
bootstrapped.index = np.arange(0, bootstrapped.shape[0])

bootstrapped.head()
```

group	cntrl	test	diff	delta
0	0.014	0.020	0.006	True
1	0.019	0.019	0.000	False
2	0.013	0.022	0.009	True
3	0.016	0.029	0.013	True
4	0.012	0.028	0.016	True

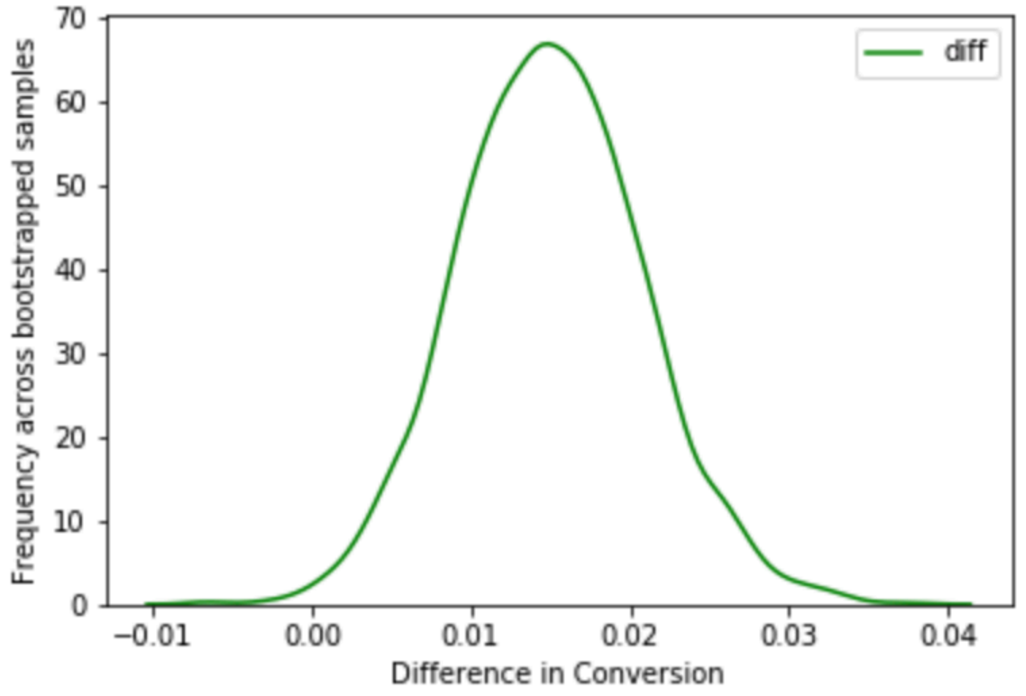
Code Sample

Plotting the distribution

```
plt.figure()
ax = sns.distplot(bootstrapped['test'], label = 'test', hist = False, color = 'blue')
ax = sns.distplot(bootstrapped['cntrl'], label = 'control', hist = False, color = 'orange')
ax.set_ylabel('Frequency across bootstrapped samples')
ax.set_xlabel('Conversion')
plt.legend()
plt.show()
```




```
plt.figure()
ax = sns.distplot(bootstrapped['diff'], label = 'diff', hist = False, color = 'green')
ax.set_ylabel('Frequency across bootstrapped samples')
ax.set_xlabel('Difference in Conversion')
plt.legend()
plt.show()
```



Calculate p-value & confidence interval

```
# calculate p-value and confidence interval

p_value = 1 - bootstrapped['delta'].mean()

print('p-value: ', '{:0.5f}'.format(p_value))
if p_value < 0.05:
    print('Mean difference in conversion is significant at 0.05 level')
else: print('Mean difference in conversion is NOT significant at 0.05 level')

lower, upper = sm.stats.DescrStatsW(bootstrapped['diff']).tconfint_mean()
print('95% confidence interval', '[{:0.5f}, {:0.5f}]'.format(lower, upper))
```

```
p-value:  0.00500
Mean difference in conversion is significant at 0.05 level
95% confidence interval [0.01482, 0.01515]
```

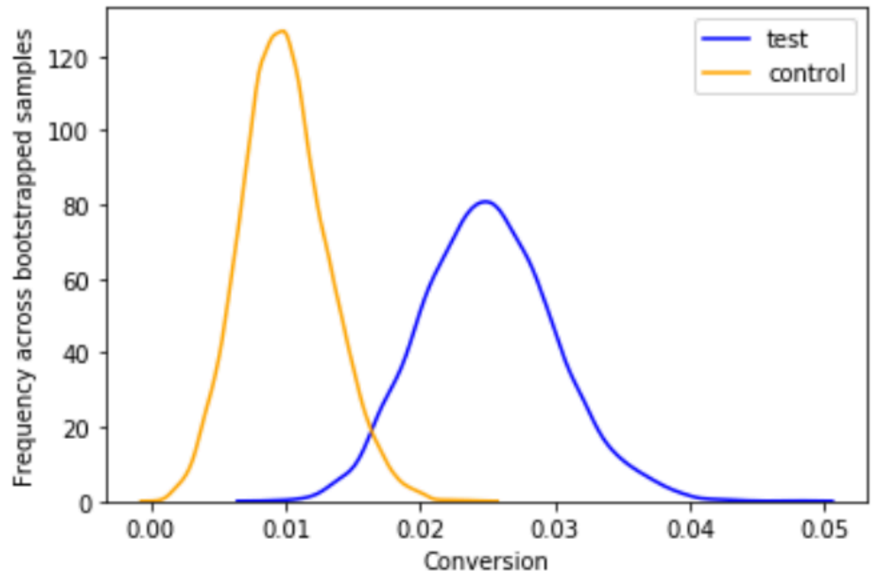
Code Sample

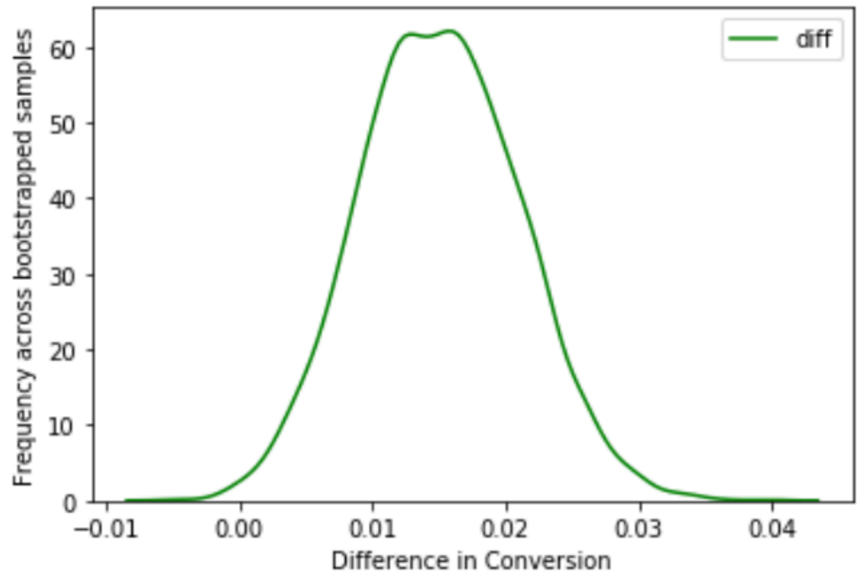
Full Code

```python
class bootstrapping:

    def resampling(self, dataframe, i):
        '''
        This function is used for resampling.

        dataframe: your dataset
        i: the number of iternation
        '''

        # 1.resample your data, replace will be True because boostrapping allows replacement

        df = dataframe.sample(frac = 1, replace = True)

        # 2. get the difference in conversion rate and the number of iteration
        df1 = df.mean().reset_index()
        df1.columns = ['group','value']
        df1 = df1.pivot_table(columns = ['group'])
        df1['diff'] = df1['test'] - df1['cntrl']
        df1['delta'] = df1['diff'] > 0

        return df1

    def measuring(self, data, iteration):

        # 3. get all bootstrapped data

        bootstrapped = pd.concat([self.resampling(dataframe = data, i = i) for i in range(0, iteration)])
        bootstrapped.index = np.arange(0, bootstrapped.shape[0])

        # plot test v. control
        plt.figure()
        ax = sns.distplot(bootstrapped['test'], label = 'test', hist = False, color = 'blue')
        ax = sns.distplot(bootstrapped['cntrl'], label = 'control', hist = False, color = 'orange')
        ax.set_ylabel('Frequency across bootstrapped samples')
        ax.set_xlabel('Conversion')
        plt.legend()
        plt.show()

        # plot the difference in conversion
        plt.figure()
        ax = sns.distplot(bootstrapped['diff'], label = 'diff', hist = False, color = 'green')
        ax.set_ylabel('Frequency across bootstrapped samples')
        ax.set_xlabel('Difference in Conversion')
        plt.legend()
        plt.show()

        # 4. calculate p-value and confidence interval

        p_value = 1 - bootstrapped['delta'].mean()

        print('p-value: ', '{:0.5f}'.format(p_value))
        if p_value < 0.05:
            print('Mean difference in conversion is significant at 0.05 level')
        else: print('Mean difference in conversion is NOT significant at 0.05 level')

        lower, upper = sm.stats.DescrStatsW(bootstrapped['diff']).tconfint_mean()
        print('95% confidence interval', '[{:0.5f}, {:0.5f}]'.format(lower, upper))
```

Result

```python
b = bootstrapping()
b.measuring(data, 5000)
```






```
p-value:  0.00480
Mean difference in conversion is significant at 0.05 level
95% confidence interval [0.01492, 0.01525]
```

Thank You!

Questions/Comments?

- Code on GitHub: szuminyu/bootstrapping_TDP_monthly_2021
- Connect me on LinkedIn: szuminyu
- Follow TDP on Facebook & join slack channel
- https://www.facebook.com/twdatany
- We are looking for volunteers!