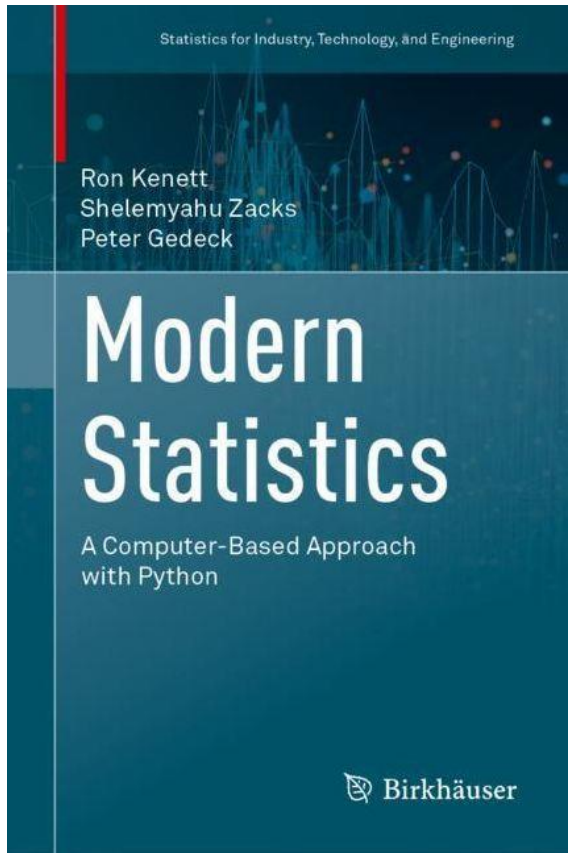

Modern Statistics:

A Computer-Based Approach with Python

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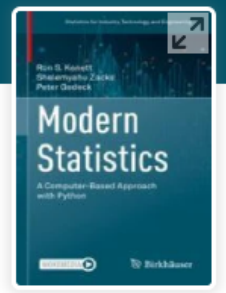

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Modern Statistics

A Computer-Based Approach with Python

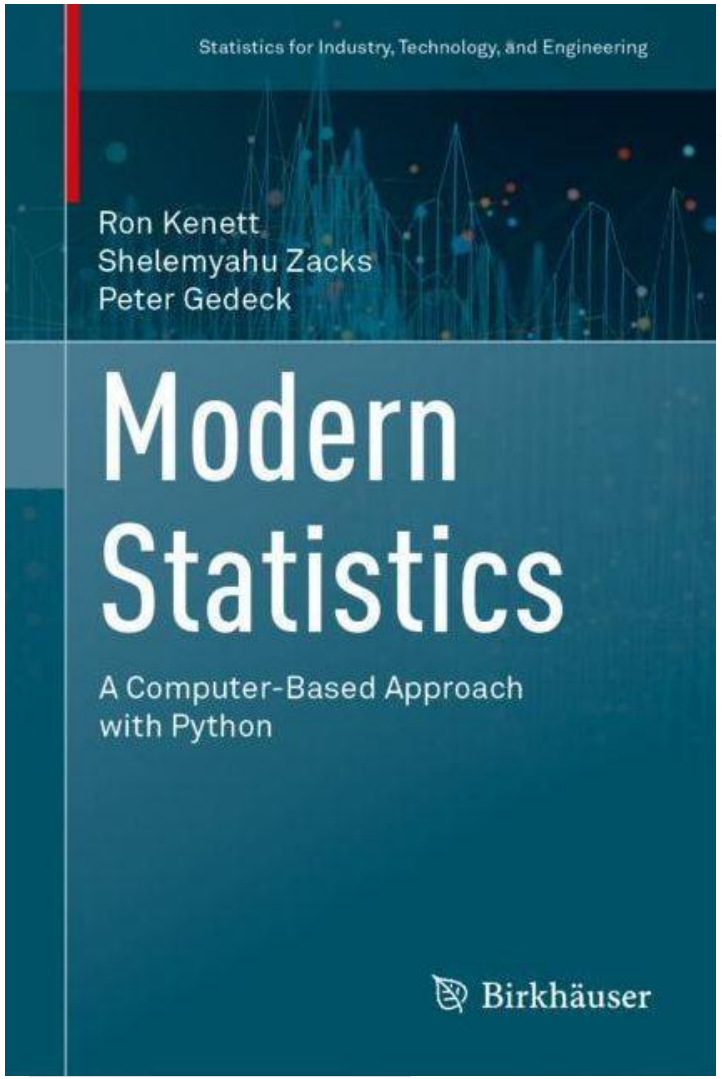
Authors: Ron S. Kenett, Shelemyahu Zacks, Peter Gedeck

Demonstrates how to incorporate Python into the modern statistics curriculum

Includes over 40 case studies to facilitate experiential learning

An accompanying Python package is available for download, allowing students to engage directly with the material

Part of the book series: Statistics for Industry, Technology, and Engineering (SITE)



https://gedeck.github.io/mistat-code-solutions/ModernStatistics

- `notebooks` : Python code of individual chapters in Jupyter notebooks - download all as notebooks.zip
- `code` : Python code for solutions as plain Python files - download all as code.zip
- `solutions manual` : Solutions_Modernstatistics.pdf: solutions of exercises
- `solutions` : Python code for solutions in Jupyter notebooks - download all as solutions.zip
- `all` : zip file with all files combined - download all as all.zip

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Code repository

Installation instructions

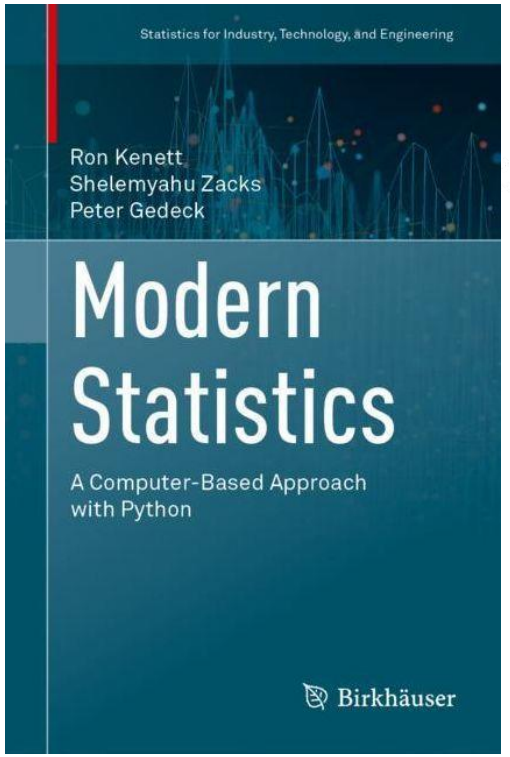
Introductory videos

https://gedeck.github.io/mistat-code-solutions/IndustrialStatistics/

Industrial Statistics: A Computer Based Approach with Python is a companion volume to the book Modern Statistics: A Computer Based Approach with Python.

Table of contents (with sample excerpts from chapters)

Companion book



Modern Statistics: A Computer Based Approach with Python

Solutions

Import required modules and define required functions

```
import math
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import mistat
from scipy import stats

def trim_std(data, alpha):
  *** Calculate trimmed standard deviation ***
  data = np.array(data)
  data.sort()
  n = len(data)
  low = int(n * alpha) + 1
  high = int(n * (1 - alpha))
  return data[low:(high + 1)].std()
```

Solution 1.1 `random.choices` selects k values from the list using sampling with replacement.

```
import random
random.seed(1)
values = random.choices([1, 2, 3, 4, 5, 6], k=50)
```

`Counter` counts the number of occurrences of a given value in a list.

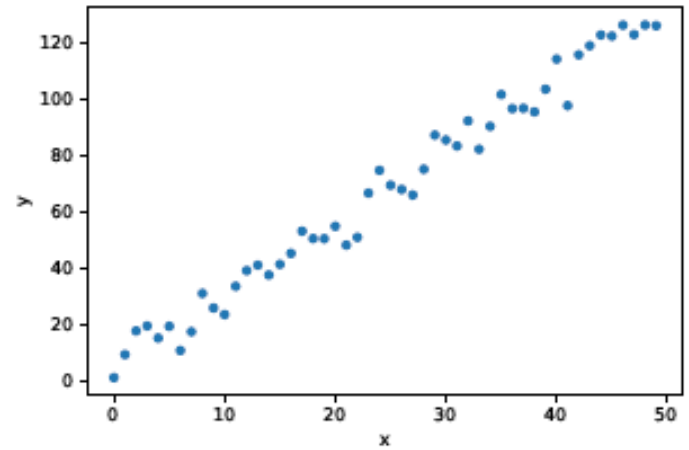
```
from collections import Counter
Counter(values)
```

```
Counter({1: 9, 6: 9, 5: 8, 2: 10, 3: 10, 4: 4})
```

The expected frequency in each cell, under randomness is 50/6 = 8.3. You will get different numerical results, due to randomness.

Solution 1.2 The Python function `range` is an iterator. As we need a list of values, we need to explicitly convert it.

```
x = list(range(50))
y = [5 + 2.5 * xi for xi in x]
y = [yi + random.uniform(-10, 10) for yi in y]
pd.DataFrame({'x': x, 'y': y}).plot.scatter(x='x', y='y')
plt.show()
```



Solution 1.3 In Python

```
from scipy.stats import binom
np.random.seed(1)

for p in (0.1, 0.3, 0.7, 0.9):
  X = binom.rvs(1, p, size=50)
  print(p, sum(X))
```

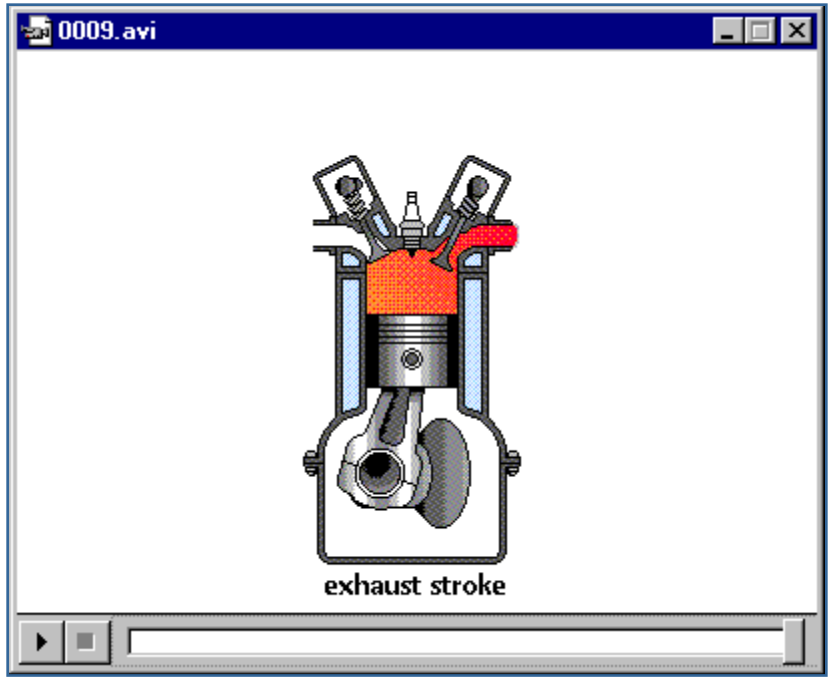
```
0.1 4
0.3 12
0.7 33
0.9 43
```

Notice that the expected values of the sums are 5, 15, 35 and 45.

Solution 1.4 We can plot the data and calculate mean and standard deviation.

```
inst1 = [9.490950, 10.436813, 9.681357, 10.996083, 10.226101, 10.253741,
         10.458926, 9.247097, 8.287045, 10.145414, 11.373981, 10.144389,
         11.265351, 7.956107, 10.166610, 10.800805, 9.372905, 10.199018,
         9.742579, 10.428091]
inst2 = [11.771486, 10.697693, 10.687212, 11.097567, 11.676099,
         10.583907, 10.505690, 9.958557, 10.938350, 11.718334,
         11.308556, 10.957640, 11.250546, 10.195894, 11.804038,
         11.825099, 10.677206, 10.249831, 10.729174, 11.027622]
ax = pd.Series(inst1).plot(marker='o', linestyle='none',
                           fillstyle='none', color='black')
pd.Series(inst2).plot(marker='+', linestyle='none', ax=ax,
                      fillstyle='none', color='black')
```

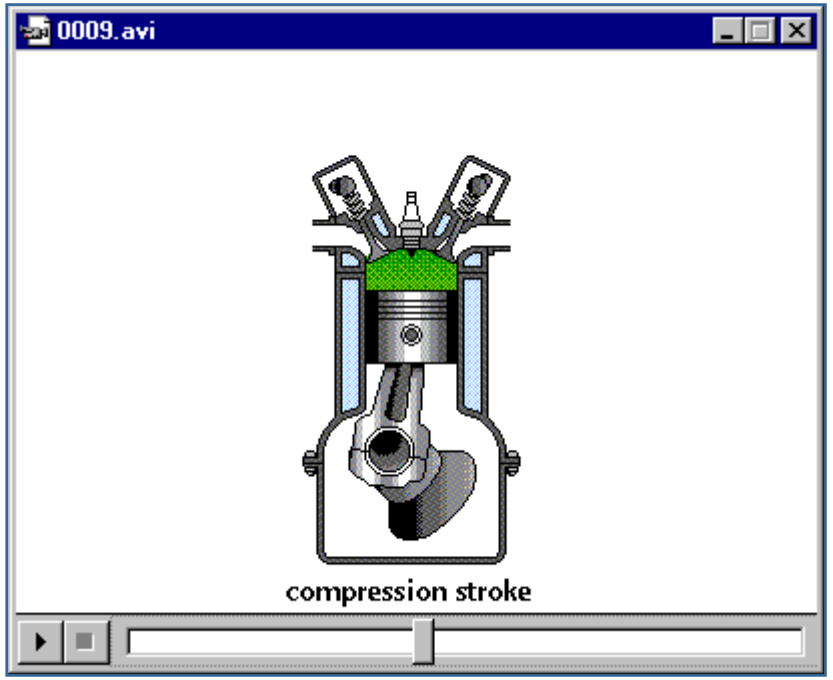
The Piston Simulator



A: Piston Weight (Kg)

B: Piston Surface Area (m^2)

C: Initial Gas Volume (m^3)



D: Spring Coefficient (N/m)

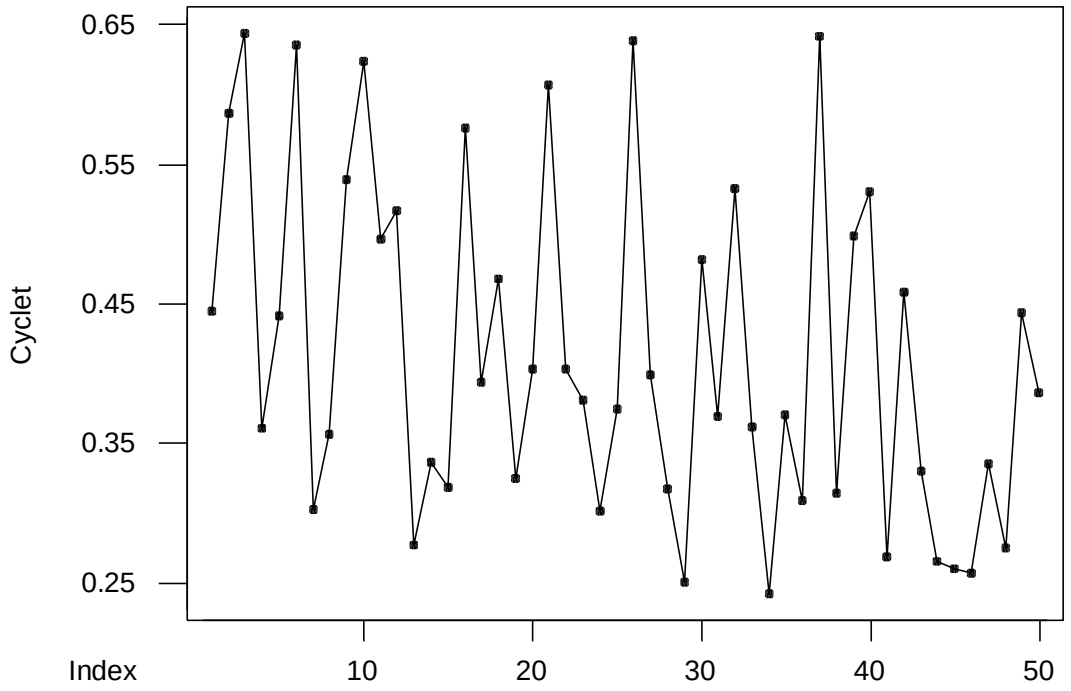
E: Atmospheric Pressure (N/m^2)

F: Ambient Temperature (^0K)

G: Gas Temperature (^0K)

The Piston Simulator

1



A run chart of 50 cycle times, in seconds, with all factors set at their **maximum value**. The cycle times in this sequence have an average of **0.413** seconds and a standard deviation of **0.121** seconds

1.1 Random Phenomena and the Structure of Observations

1

Many phenomena which we encounter are only partially predictable. It is difficult to predict the weather or the behavior of the stock market. In this book we focus on industrial phenomena, like performance measurements from a product which is being manufactured, or the sales volume in a specified period of a given product model. Such phenomena are characterized by the fact that measurements performed on them are often not constant but reveal a certain degree of variability. Variability is also a reflection of uncertainty. For a comprehensive treatment of uncertainty in engineering applications see del Rosario and Iaccarino (2022). The objectives of this chapter is to present methods for analyzing this variability, in order to understand the variability structure and enhance our ability to control, improve and predict future behavior of such phenomena. We start with a few simple examples.

Example 1.1 A piston is a mechanical device that is present in most types of engines. One measure of the performance of a piston is the time it takes to complete one cycle. We call this measure **cycle time**. In Table 1.1 we present 50 cycle times of a piston operating under fixed operating conditions (a sample data set is stored in file **CYCLT.csv**). We provide with this book code in Python for running a piston software simulation. If you installed Python, install the `mistat` package using the Python package installer `pip`.

You will get access to a piston simulator with 7 factors that you can change. We will also use this simulator when we discuss Statistical Process Control (Chapters 2, 3 and 4 in the Industrial Statistics book) and the Design of Experiments (Chapters 5, 6 and 7 in the Industrial Statistics book). We continue at a pedestrian pace by recreating Table 1.1 using Python. All the Python applications referred to in this book are contained in a package called `mistat` available from the Python package index and on GitHub at `https://github.com/gedeck/mistat`. The following Python commands will import the `mistat` package, read the cycle time data and print the first five values on your monitor:

```
import mistat
data = mistat.load_data('CYCLT')
print(data.head())
```

```
0    1.008
1    1.098
2    1.120
3    0.423
4    1.021
Name: CYCLT, dtype: float64
```

Notice that functions in Python have parenthesis. The `import` statement imports the `mistat` package and makes its functionality available. `mistat.load_data` is a function that loads the CYCLT data set as a *Pandas* data series. A *Pandas* data series is a simple vector of values.

Example 3.26 Let us determine (0.95,0.95)-tolerance interval for samples of size $n = 100$, of piston cycle times. Use the sample in the data file **CYCLT.csv**. The original sample is of size $n_0 = 50$. Since future samples are of size $n = 100$, we draw from the original sample RSWR of size $n = 100$.

In Python, the calculations from Example 3.26 are straightforward:

```
cyclt = mistat.load_data('CYCLT')
cyclt = [*cyclt, *cyclt]  # create a dataset of size 100 by duplication

def getQuantile(x, p):
    return np.quantile(x, p)

B_025 = pg.compute_bootci(cyclt, func=lambda x: getQuantile(x, p=0.025),
          n_boot=500, seed=1, return_dist=True)
B_975 = pg.compute_bootci(cyclt, func=lambda x: getQuantile(x, p=0.975),
          n_boot=500, seed=1, return_dist=True)
print('0.025%', np.quantile(B_025[1], 0.025))
print('0.975%', np.quantile(B_975[1], 0.975))
```

```
0.025% 0.175
0.975% 1.141
```

The bootstrap (.95,.95)-tolerance interval for n = 100 piston cycle times was estimated as (0.175,1.141). ■

3

Bootstrapping

M-test

1. Compute the expected number of returns in category i,
   $\mathbf{E_i = Np_i}$, i = 1,...K.

2. Compute
   $\mathbf{S_i = SQRT [\ Np_i(1-p_i)\ ]}$, i = 1,...K.

3. Compute the adjusted residuals
   $\mathbf{Z_i = (n_i-E_i)/S_i}$, i = 1,...K.

4. Determine the critical value C of Z_i from the M-Test table.

N = Total number of returns
K = Number of categories
n_i = Number of returns in category i
p_i = proportion of category i in sampling frame

M-test

K	10%	5%	1%
4	1.95	2.24	2.81
5	2.05	2.32	2.88
6	2.12	2.39	2.93
7	2.18	2.44	2.99
8	2.23	2.49	3.04
9	2.28	2.53	3.07
10	2.32	2.57	3.10
20	2.57	2.81	3.30
30	2.71	2.94	3.46

If all adjusted residuals, Z_i, are smaller, in absolute value, than C, no significant bias is declared.
Cells with values of Z_i, above C or below -C are declared significantly different and a follow up effort is initiated.

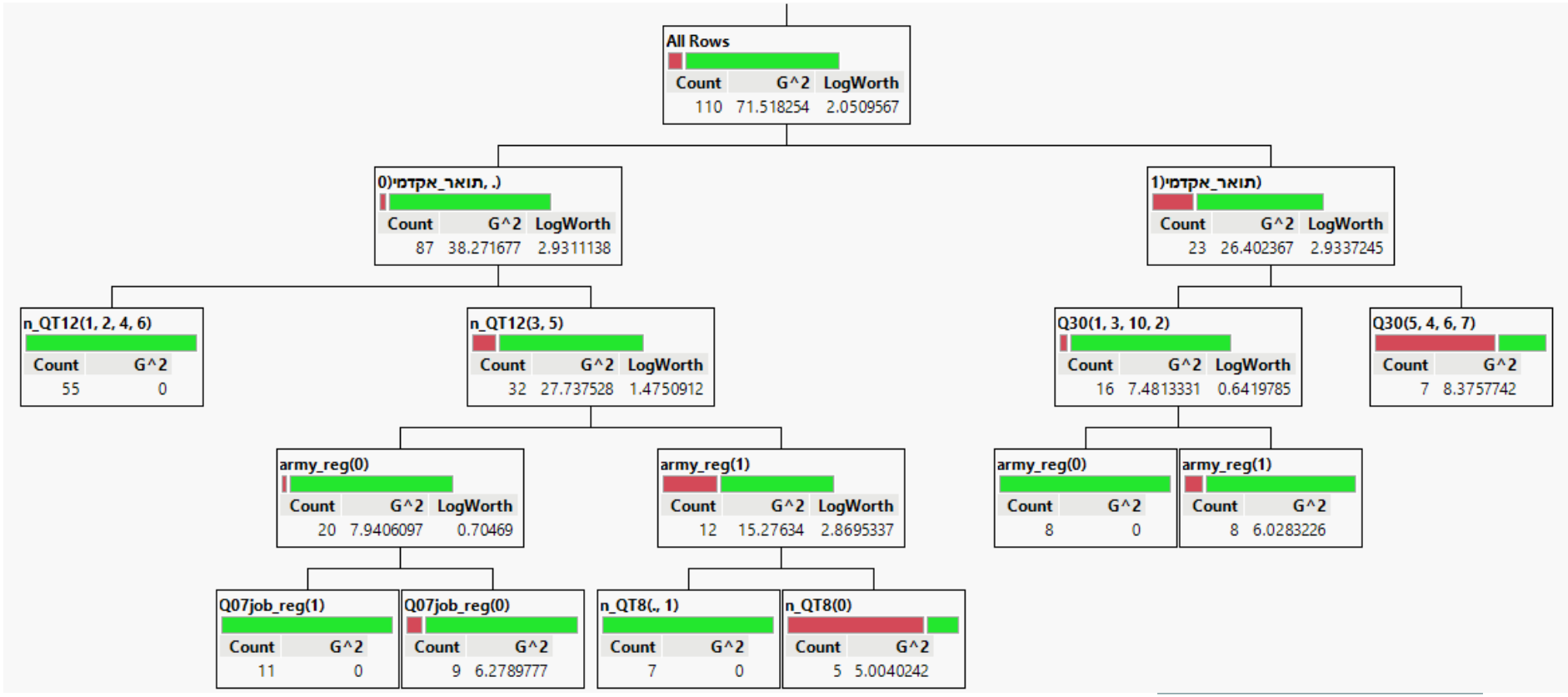
Bonferroni correction

Carlo Bonferroni
1892 - 1960

"A Test for Detecting Outlying Cells in the Multinomial Distribution and Two-Way Contingency Tables", Fuchs and Kenett, *Journal of the American Statistical Association*, 75, pp. 395-398, 1980.

"Two Methods for Comparing Pareto Charts", Kenett, *Journal of Quality Technology*, 23, pp. 27-31, 1991.

Decision trees



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Environments

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lab

JupyterLab

3.3.2

An extensible environment for interactive and reproducible computing, based on the Jupyter Notebook and Architecture.

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jupyter

Notebook

6.4.8

Web-based, interactive computing notebook environment. Edit and run human-readable docs while describing the data analysis.

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A Computer Based Approach with Python

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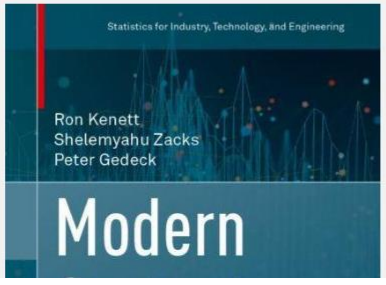

Modern Statistics: A Computer Based Approach with Python
by Ron Kenett, Shelemyahu Zacks, Peter Gedeck

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1st edition (September 15, 2022)
ISBN-13: 978-3-031-07565-0 (print)
ISBN-13: 978-3-031-07566-7 (eBook).
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Python notebooks

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by Ron Kenett, Shelemyahu Zacks, Peter Gedeck

Publisher: Springer International Publishing; 1st edition (September 15, 2022)
ISBN-13: 978-3031075650

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The code needs to be executed in sequence.

Python packages and Python itself change over time. This can cause warnings or errors. We "Warnings" are f
execution and need to be fixed in order to get results.

If you come across an issue with the code, please follow these steps

- Check the repository (https://gedeck.github.io/mistat-code-solutions/) to see if the code has been upgr
- Check the errata at (https://gedeck.github.io/mistat-code-solutions/ModernStatistics/) and the issue tra
  to see if the issue is known and a solution available.
- Report the problem using the issue tracker at https://github.com/gedeck/mistat-code-solutions/issues

binder

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Check the log messages below to see what is happening.

Binder

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Python notebooks

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- Check the errata at (https://gedeck.github.io/mistat-code-solutions/ModernStatistics/) and the issue tracker at https://github.com/gedeck/mistat-code-solutions/issues to see if the issue is known and a solution available.
- Report the problem using the issue tracker at https://github.com/gedeck/mistat-code-solutions/issues
- Paste the error message into Google and see if someone else already found a solution

Modern Statistics

A Computer Based Approach with Python

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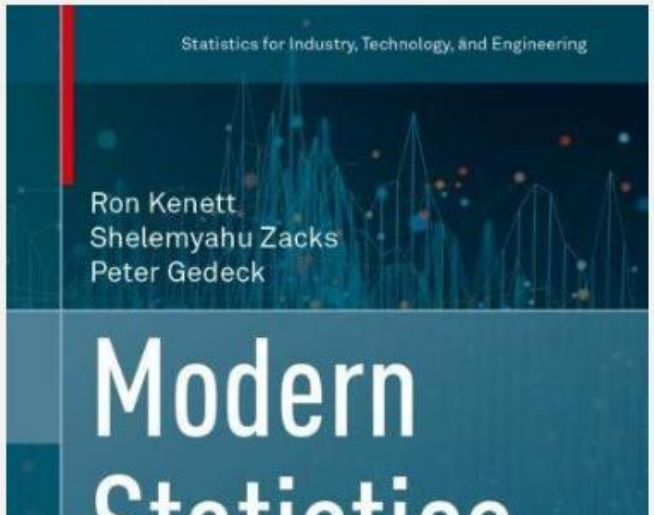

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Modern Statistics: A Computer Based Approach with Python is a companion volume to the book Industrial Statistics: A Computer Based Approach with Python.

This part of the repository contains:

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- `code` : Python code for solutions as plain Python files - download all as code.zip
- `solutions manual` : Solutions_Modernstatistics.pdf: solutions of exercises
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- `all` : zip file with all files combined - download all as all.zip
- `datafiles` : zip file with all data files - download all as data_files.zip - the `mistat` package gives you already access to all datafiles, you only need to download this file if you want to use it with different software

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Try the code

You can explore the code on Binder launch binder.

Installation instructions

Instructions on installing Python and required packages are here.

These Python packages are used in the code examples of *Modern Statistics*:

- mistat (for access to data sets and additional functionality)
- numpy
- scipy
- scikit-learn

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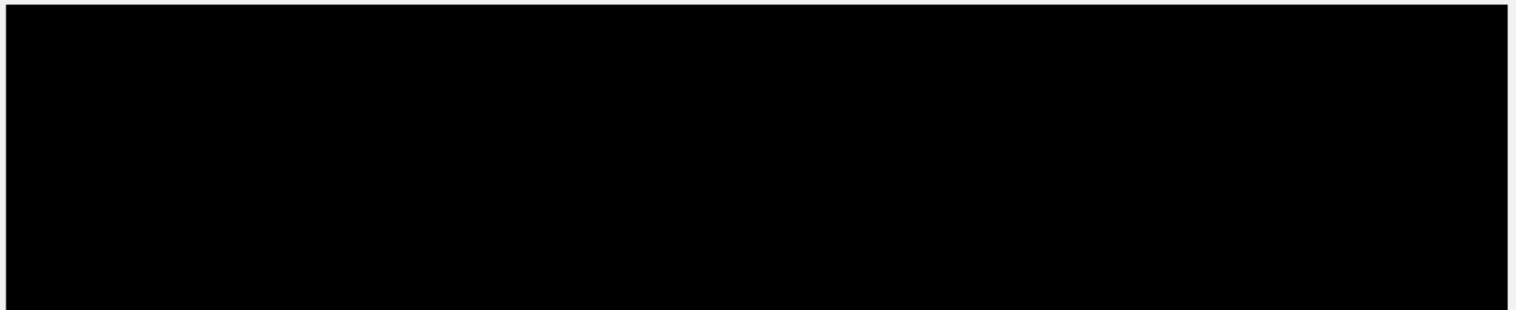
Chapter 1: Analyzing Variability: Descriptive Statistics

The chapter focuses on statistical variability and on various methods of analyzing random data. Random results of experiments are illustrated with distinction between deterministic and random components of variability. The difference between accuracy and precision is explained. Frequency distributions are defined to represent random phenomena. Various characteristics of location and dispersion of frequency distributions are defined. The elements of exploratory data analysis are presented.

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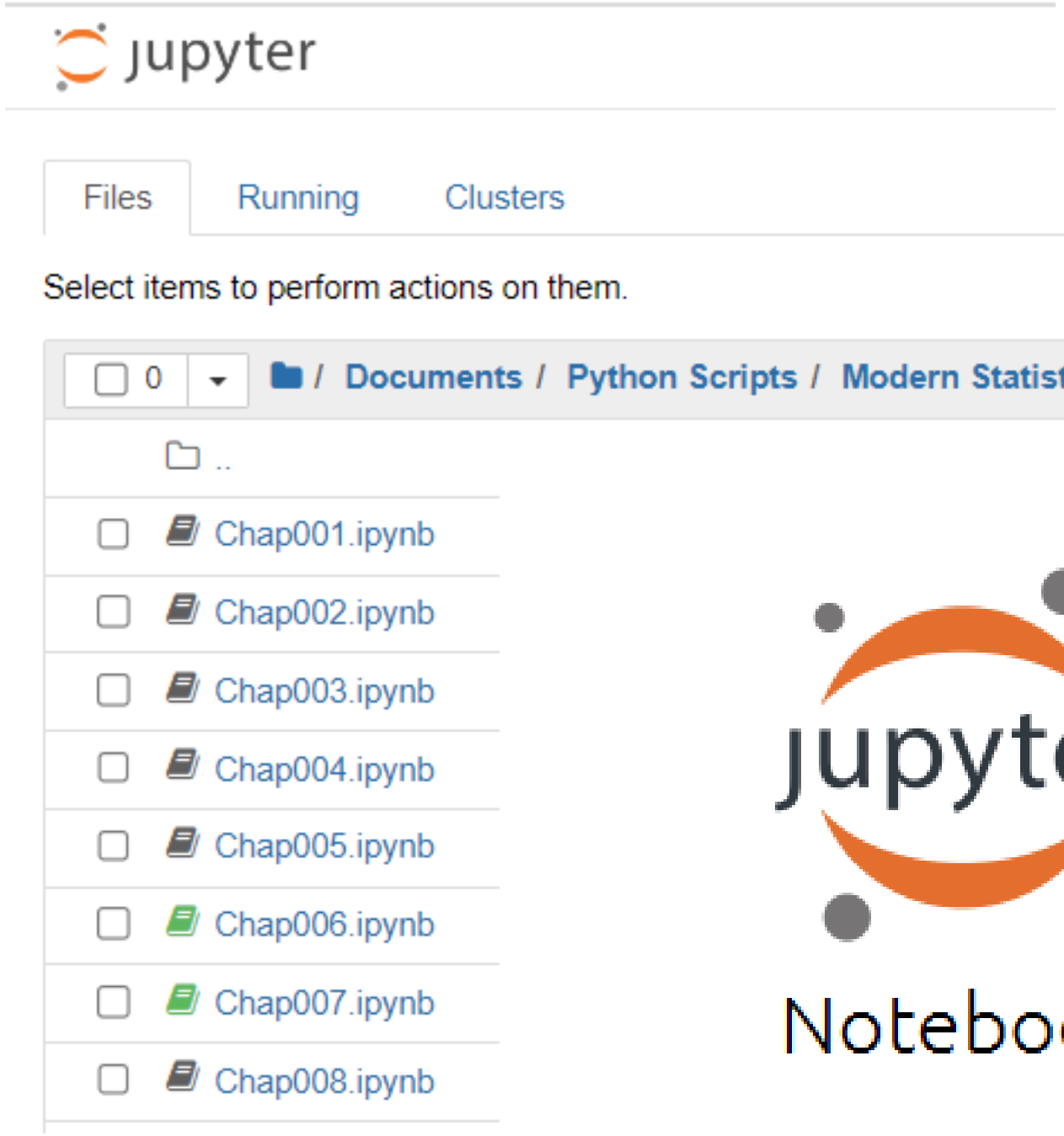

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Chapter 6

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The code needs to be executed in sequence.

Time Series Analysis and Prediction

Ron Kenett, Shelemyahu Zacks, Peter Gedeck
Pages 329-360

In [1]:
```
import os
os.environ['OUTDATED_IGNORE'] = '1'
import warnings
from outdated import OutdatedPackageWarning
warnings.filterwarnings('ignore', category=FutureWarning)
warnings.filterwarnings('ignore', category=OutdatedPackageWarning)
```

Time Series Analysis and Prediction

In [2]:
```
import datetime
import statsmodels.formula.api as smf
from statsmodels.tools.sm_exceptions import ValueWarning
import pandas as pd

import random
import numpy as np
import pingouin as pg
from scipy import stats
import matplotlib.pyplot as plt
import mistat
```

Chapter 7

Modern Statistics: A Computer Based Approach with Python
by Ron Kenett, Shelemyahu Zacks, Peter Gedeck

Publisher: Springer International Publishing; 1st edition (September 15, 2022)
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warnings.filterwarnings('ignore', category=FutureWarning)
warnings.filterwarnings('ignore', category=OutdatedPackageWarning)
```

Modern analytic methods: Part I

In [2]:
```
import warnings
import random
import pandas as pd
import numpy as np
from sklearn.ensemble import RandomForestClassifier
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import accuracy_score
from sklearn.impute import SimpleImputer
from sklearn.neural_network import MLPClassifier
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
```

Modern Analytic Methods: Part I

Ron Kenett, Shelemyahu Zacks, Peter Gedeck
Pages 361-393

Chapter 8

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by Ron Kenett, Shelemyahu Zacks, Peter Gedeck

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warnings.filterwarnings('ignore', category=FutureWarning)
warnings.filterwarnings('ignore', category=OutdatedPackageWarning)
```

Modern analytic methods: Part II

In [2]:
```
import networkx as nx

import statsmodels.api as sm
from statsmodels.tsa.stattools import grangercausalitytests
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import mistat
```

Modern Analytic Methods: Part II

Ron Kenett, Shelemyahu Zacks, Peter Gedeck
Pages 395-419

A Biomed Data Analyst Training Program

Modern Statistics: A Computer Based Approach with Python

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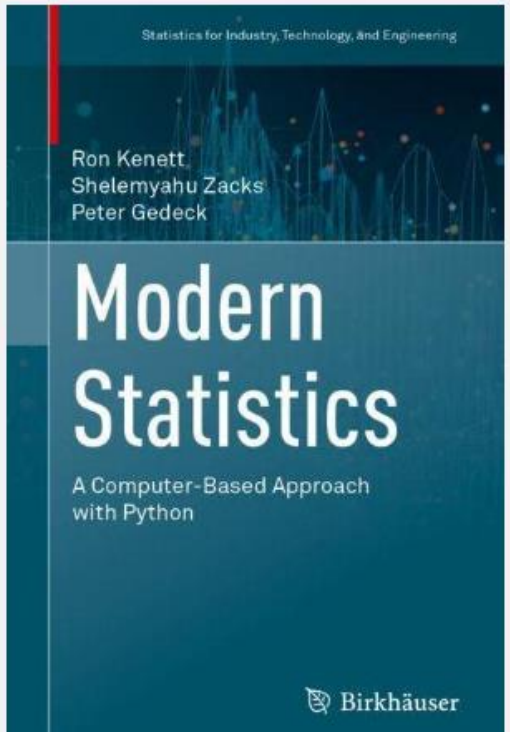
https://gedeck.github.io/mistat-code-solutions/BioMed_DataAnalyst_Course/

A Biomed Data Analyst Training Program



Modern Statistics: A Computer Based Approach with Python

by Ron Kenett, Shelemyahu Zacks, Peter Gedeck

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Errata: See known errata here

Slides

1. Introduction
2. Data types and data integration
3. Supervised learning
4. Model performance
5. Time series
6. Data visualization
7. Causality and experimental design

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Code and data files

This part of the repository contains:

- `notebooks` : Python code of individual chapters in Jupyter notebooks - download all as notebooks.zip

The Python package `mistat` contains datafiles and utility functions referred to in the Modern Statistics book. It is available for installation from the Python package index https://pypi.org/project/mistat/. The `mistat` packages is maintained in a GitHub repository at https://github.com/gedeck/mistat.

Try the code

You can explore the code on Binder launch binder.

Thank you for listening