

# INDEX

Page numbers referring to figures and tables are followed by an italicized *f* or *t*, respectively.

## A

- A/B (blue/green) testing, 263
  - ACLU (American Civil Liberties Union), 177
  - `add_edge` function, 33
  - `add_node` function, 33
  - AEQD (azimuthal equidistance), 152–153
  - `aeqd_to_wgs84` function, 152–153
  - AGP. *See* art gallery problem
    - application
      - art gallery problem (AGP) application, 209–232
      - advanced features, 233–256
        - graphics in Python, 245–250
        - process parallelism, 241–245
        - running example application, 254–255
        - saving and reloading data, 251–254
        - state manager development, 237–241
        - user interaction mapping, 234–237
    - algorithm and data structures, 216–231
    - area of responsibility, 219–223, 220*f*
    - complex polygons, 223–225, 224*f*
    - field of view and effective range, 229–231, 230*f*
    - greedy coloring, 218, 218*f*
    - triangular tessellation, 216–217, 217*f*
    - weighted and budgeted coverages, 225–229, 225*f*, 228*f*, 229*f*
  - delivery pipeline, 257–267
    - distributing with cloud microservices, 260–264, 261*f*
    - licensing with PyArmor, 264–265
    - open source delivery, 265–266
- all\_pairs\_lowest\_common\_ancestor function, 86
- all\_shortest\_paths function, 118
- alpha parameter, 120
- Amazon Web Services (AWS), 261
- American Civil Liberties Union (ACLU), 177
- Anaconda
  - installing, 4–8
    - Linux, 4–6
    - macOS, 8, 8*f*
    - Windows, 6–8, 6*f*, 7*f*
  - installing Spyder IDE with, 10
  - Jupyter Notebooks, 11–12
  - virtual environment setup, 9, 63
- anomaly detection, 47, 53
- application state planning, 235–236
- `apply` function, 70, 168–169, 192
- `apt-get`, 11
- area metrics, 190
- areas of responsibility (AORs)
  - art gallery problem, 219–223, 220*f*, 225
  - emergency service planning scenario, 171, 173

- art gallery problem (AGP)
  - application (*continued*)
  - delivery pipeline (*continued*)
    - packaging with Python
      - interpreters, 259–260
    - setup scripts, 258–259
  - existing research on, 212–214, 213*f*, 214*f*
  - geometric and graph
    - representations, 214–216, 215*f*
  - premise of, 209–210
  - use cases, 211–212
- assign\_triangles function, 221
- association function, 195
- association matrices, 194–197, 194*f*
- attribute characters, 22
- authority score
  - HITS algorithm, 80–83
  - social network simulation, 104, 106
  - updating authority scores, 81
- AWS (Amazon Web Services), 261
- axis parameter, 71, 167
- azimuthal equidistance (AEQD), 152–153
- azimuth projection, 152

## B

- background variable, 246
- bagging, 182
- balanced exchange, 75
- Baran, Paul, 121
- base stations (towers)
  - defined, 142
  - gathering locations, 149–150
  - identifying, 144
  - rogue, 143
- betweenness centrality, 35–38, 35*f*, 57
- biased random walks (biased walks), 97, 100, 104, 111
- BIM (building information modeling)
  - programs, 211
- Bledsoe, Woodrow Wilson, 176, 179
- blind spots, 211, 232
- blit function, 247, 250
- blue/green (A/B) testing, 263
- Booleans
  - defined, 18
  - intersections, 153–154
  - notation, 18–19, 21*t*

- branch nodes, 84–85
- Brandes, Ulrik, 36
- broadcast addresses, 60
- building information modeling (BIM)
  - programs, 211

## C

- c (--count) option, 63
- C language, 92, 216
- C++ language, 183
- capacity attribute, 112, 114
- capacity constraint, 121
- cascaded\_intersections function, 155, 157
- cell IDs (CIDs), 146
- cells, defined, 12
- centrality, 35–38, 51*f*
  - betweenness centrality, 35–38, 35*f*, 57
  - defined, 35
  - degree centrality, 37–38
  - by protocol, 52–61
    - identifying unusual levels of traffic, 54–57
    - neighbors and information exchange ratio, 57–61
    - port numbers subgraphs, 52–54
- centroid, defined, 136
- centroid location, 136–137, 137*f*
- check\_clicked\_existing\_vertex function, 240
- check\_clicked\_within\_room function, 240
- choice function, 103–104, 116, 122, 193
- chroma key filming (green-screen filming), 249
- Chvátal, Václav, 212
- Chvátal AGP theorem, 212–213
- Chvátal’s upper bound, 212–213
- CIDs (cell IDs), 146
- circle function, 247
- city\_gj variable, 167
- city\_shape variable, 167, 170
- clear\_surface function, 249
- cliques
  - analysis, 39–40, 39*f*, 61
  - defined, 76
  - identifying, 76–78, 78*f*
  - maximal cliques, 40, 77

- closed chains, 129
- closeness, 35, 38, 52
- cloud microservices, distributing with, 260–264
- co-location, 138–140, 139*f*
- common ancestors, 84–86
- complete subgraphs, 39
- complex function, 150–151
- computational geometry theory, 127–140. *See also* art gallery problem application
- common operations, 132–140, 133*f*
- centroid location, 136–137, 137*f*
- co-location, 138–140, 139*f*
- perimeter length, 137–138
- tessellation, 133–136, 134*f*
- defined, 127
- facial recognition, 175–205
- location triangulation, 141–160
- shapes, 128–132
  - line segments, 128–129
  - points, 128–129
  - polygons, 129–132, 130*f*, 131*f*
  - vertex order, 132
- Voronoi diagrams, 161–174
- computer vision, 179, 184. *See also* facial recognition
- concat function, 70–71
- concert security scenario, 132–140, 133*f*
  - centroid location, 136–137, 137*f*
  - co-location, 138–140, 139*f*
  - perimeter length, 137–138
  - tessellation, 133–136, 134*f*
- conda utility, 4–7, 9, 11
- connected components, 41
- connected graphs, 40–41
- connectedness, 40–41, 41*f*
- connections (edges), in graphs, 27
- conservation constraint, 121
- constrained Delaunay triangulation, 214, 216
- contains function, 81, 138–139
- continue keyword, 116, 118
- controlled variable, 239–240
- convex hulls, 187, 187*f*
- coords parameter, 216
- correlation ratio, 197–198

- correlation\_ratio function, 198
- create\_using function, 63
- cross-validation, 188, 200
- cross\_val\_score function, 200
- cutset, 121–122
- cv2 library, 184
- cv parameter, 200
- cycle of graphs, 32
- cyclic graphs, 32

## D

- DAGs (directed acyclic graphs), 85
- DataFrame objects, 69–73, 76, 81, 88, 107, 150, 167–170, 191–193, 195
- Data Manager service, 261*f*, 262
- DataSaver class, 227–228, 252
- DDoS (distributed denial-of-service) attacks, 38
- decision trees, 179–182, 180*f*, 201
- degree centrality, 37–38
- Delaunay triangulation, 216
- delivery pipeline, 257–267
  - distributing with cloud microservices, 260–264, 261*f*
  - licensing with PyArmor, 264–265
  - open source delivery, 265–266
  - packaging with Python interpreters, 259–260
  - setup scripts, 258–259
- descriptive security analysis, 90
- detector variable, 183, 186
- deterministic FSMs, 95, 97
- device tracking application, 148–159, 148*f*
  - geodesic polygons, 150–153
  - intersections, 153–157
  - mapping and comparing results, 157–159, 158*f*
  - reducing search area, 159
  - tower locations, 149–150
- dictionary comprehensions, 15–17, 137
- difference function, 144
- DiGraph objects, 38, 42, 42*f*, 52, 63, 108, 115
- Dijkstra’s algorithm, 77
- dim parameter, 51
- directed acyclic graphs (DAGs), 85

- directed graphs, 31–32
  - betweenness centrality, 36
  - cliques, 40, 76–77
  - creating in NetworkX, 33
  - degree centrality, 37–38
  - edge multiplicity, 43
  - HITS algorithm, 80
  - network analysis graphs, 63
  - port numbers subgraphs, 52
  - resource allocation, 108–109
  - social network analysis, 73
  - state machine graphs, 94, 94*f*
- directed preferential attachment (DPA), 114
- disconnected graphs, 40–41, 41*f*
- discrete classification, 176
- DisplayAGP class, 242–243
- Display class, 246–248, 247*f*
- distance function, 138, 164, 222
- distance metrics, 190
- distributed denial-of-service (DDoS) attacks, 38
- division of labor, 241
- .\_doc\_ attribute, 237
- Docker, 262–263
- docstrings, 236–237
- DPA (directed preferential attachment), 114
- draw function, 34, 247
- Drawn state, 235
- dtypes property, 72
- DummyClassifier class, 200
- dummy classifiers, 199–202
- dump function, 203
- dumps (dump string) function, 147, 252

## E

- edge attributes, 32–33, 43, 50, 226
- edge capacity, 112–113
- edge multiplicity, 32, 42–43, 42*f*
- edges (connections), in graphs, 27
- edges (sides; faces), in polygons, 129
- edge weight, 32–33, 43, 52–53, 62–63, 73
- effective range
  - cellular networks, 144
  - security sensors, 211, 213, 229–230
- Electronic Frontier Foundation, 177
- eliminate\_small\_areas function, 155–156

- emergency service planning scenario, 163–173
  - city shape, 164–167, 165*f*
  - distance function, 164
  - generators, 167–169, 169*f*
  - Voronoi tessellation, 170–173, 171*f*, 172*f*

- empirical mean (sample mean), 93
- ensemble classifiers, 201
- ethics

- facial recognition, 178–179
  - social network analysis, 89
  - tracking, 144–145

- Euclidean distance, 164

- event class, 237–238

- exchange\_ratios function, 60

- exploratory analysis (unsupervised learning), 176

## F

- face detector component, 183

- faces (edges), in polygons, 129

- Facial Identification Scientific Working Group (FISWG), 189

- facial recognition, 175–205, 178

- data loading, 191–193

- data set, 177–178

- decision tree classifiers, 179–182, 180*f*

- defined, 175

- ethics of, 178–179

- facial statistics, 189–190, 189*f*

- feature engineering, 193–198
  - association matrices,

- 194–196, 194*f*

- correlation ratio, 197–198

- mutual information

- classification, 196–197

- locating facial landmarks,

- 185–188, 187*f*

- memory management, 190–191

- model persistence, 203–204

- model training, 198–203

- establishing baseline, 199–200

- random forest, 201–202

- splitting data, 199

- testing holdout images, 202–203

- overview of, 176–177

- processing image data, 184–185, 185*f*
- proof of concept, 188–204
- representing facial geometry, 182–184, 182*f*
- features, in databases, 71
- field of view, 211, 213, 229–231, 230*f*
- file\_to\_graph function, 62
- find\_cliques function, 40
- finite state machines (FSMs), 93–95, 94*f*, 100–101
- Fisk, Steve, 212
- FISWG (Facial Identification Scientific Working Group), 189
- fitting classifiers, 200, 203
- flip function, 247
- Floor class, 234
- flow functions, 109
- font\_color function, 34
- format parameter, 165
- freezing applications, 259–260
- from\_dict function, 253–254
- FSMs (finite state machines), 93–95, 94*f*, 100–101
- functools library, 150

## G

- GCP (Google Cloud Platform), 261
- General Data Protection Regulation, 178
- General Game Playing (GGP), 98
- Generator objects, 40
- generators (seeds)
  - defined, 162
  - gathering, 167–169, 169*f*
  - Voronoi tessellation, 162–163
- geocoding, 145
- GeoDataFrame class, 150
- GeoDataFrame objects, 168–169
- GeoJSON, 150, 165–167
- geolocation, 145, 149–150, 159, 167
- GeoPandas library, 150, 169–170
- geovoronoi library, 163, 170
- get\_front\_face\_detector function, 183
- get\_image\_files function, 191
- get\_mods function, 239
- get\_shapely\_circle function, 153
- GGP (General Game Playing), 98
- Gini impurity coefficient, 181
- GIS Stack Exchange, 151

- GitHub, xxiv, 10, 48, 258, 265
- goal-oriented planning, 98
- Google Cloud Platform (GCP), 261
- Graph builder service, 261*f*, 262
- graphic elements, 245–250
  - Display class, 246–248, 247*f*
  - layers, 248–250
  - Sprite class, 248–250, 250*f*
  - Surface class, 246–248, 247*f*
- graphs, defined, 27
- graph theory, 27–44. *See also* art gallery problem application
  - creating graphs in NetworkX, 32–34, 34*f*
  - graph properties, 34–43
    - centrality, 35–38
    - cliques, 39–40
    - closeness, 35
    - connectedness, 40–41
    - edge multiplicity, 42–43
  - graphs, defined, 27
  - overview of, 31–32
  - uses for, 28–31, 28*f*, 30*f*, 31*f*
- Graphviz, 33
- greedy\_color function, 218
- greedy coloring, 212–214, 213*f*, 218, 218*f*, 245
- Greek letters and functions, 22, 22*t*
- green-screen filming (chroma key filming), 249
- Guggenheim Museum, 214, 214*f*. *See also* art gallery problem application

## H

- h (--help) option, 63, 254
- handle\_click function, 240–241
- handle\_keydown function, 238–239, 241
- handle\_keyup function, 239–241
- hard classification, 203
- hardware parallelism, 263
- has\_path function, 110
- Hay, Andrew, 29
- higher-order functions, 150
- histogram of oriented gradients (HOG), 183
- HITS (Hyperlink-Induced Topic Search), 80–83, 104, 109

- hits function, 81
- HNI (home network identities), 146
- holdout sets
  - testing holdout images, 202–203
  - true, 192–193
- hole\_p variable, 224
- holes. *See* linear ring polygons
- home network identities (HNIs), 146
- horizontal scaling, 262–263
- hubs
  - defined, 80
  - HITS algorithm, 80–83
  - social network simulation, 104, 106
  - updating hub scores, 82
- hub\_send function, 106
- Hyperlink-Induced Topic Search (HITS; Hubs and Authorities), 80–83, 104, 109
- hypothesis testing, 200

**I**

- i (--iface) option, 63
- i all option, 64
- ICMP (Internet Control Message Protocol) packets, 49–50
- IER (information exchange ratio), 59–61
- IFD (information flow distance), 100–104
- imutils library, 184, 236
- in-degree centrality, 37–38, 54–56, 59–60, 78, 85, 113, 115, 121
- in\_degree function, 55, 79
- in\_edges function, 59, 114
- Indicators of Compromise (IoCs), 47
- information entropy, 74
- information exchange ratio (IER), 59–61
- information flow distance (IFD), 100–104
- information flow game, 110–124
  - edge capacity, 112–113
  - game phases, 113–117
    - message movement phase, 115–117
    - network disruption phase, 117
    - network evolution phase, 113–115
  - game simulation, 118–120
  - improvements to player 2, 120–124, 124f
  - source and sink node selection, 117–118
  - weighted random choice, 111–112
- information propagation, 74–76
- informed consent
  - facial recognition, 178
  - tracking, 145
- \_\_init\_\_ function, 249
- init function, 246
- init\_surface function, 250, 253
- input alphabet, 94–96, 101–102, 113
- instances, in decision trees, 180
- Internet Control Message Protocol (ICMP) packets, 49–50
- interpreters
  - defined, xxiii
  - packaging with, 259–260
- intersection function, 144, 154
- intersections, finding, 153–157
- intersects function, 138
- IoCs (Indicators of Compromise), 47
- isinstance function, 157
- items function, 186

**J**

- joblib library, 203
- join function, 244
- json library, 251
- json parameter, 168
- Jupyter Notebooks, 11–12

**K**

- key\_features variable, 196
- key parameter, 53, 222, 239–240
- key space, 111–112
- kinetic information, 75–76, 78–79
- Klee, Victor, 212
- Kubernetes, 262–263, 266

**L**

- l (--load) argument, 63
- labels function, 34
- LACs (location area codes), 146
- lambda functions, 53
- landmark detector component, 183, 188, 191
- layers, in graphics, 248–250
- LCA (lowest common ancestor), 84–87

- leaf nodes, 85, 180–181, 201
- leave one out (LOO) algorithm, 188–189, 199–200
- left\_click function, 241
- len property, 50
- libpcap library, 47
- licensing, with PyArmor, 264–265
- linchpin employees, 109–110, 112
- linear ring polygons (rings; holes)
  - art gallery problem, 223–225, 224*f*
  - overview of, 130–131, 131*f*
- line segments
  - AGP algorithm, 218
  - creating, 129
  - overview of, 128–129
  - perimeter length, 138
  - polygons, 129–132
  - Voronoi tessellation, 162–164
- LineString class, 129
- LineString objects, 129, 190
- link prediction theory, 100
- Linux
  - installing Anaconda, 4–6
  - installing IDE without Anaconda, 11
  - Jupyter Notebooks, 47
  - network card in promiscuous mode, 63
  - open source delivery, 266
  - packet capture library, 11
- list comprehensions
  - dictionary comprehensions vs., 16–17
  - emergency service planning scenario, 167, 170
  - facial recognition, 193, 197
  - finding intersections, 157
  - identifying cliques, 77
  - identifying most absorbent node, 59
  - identifying unusual levels of traffic, 54
  - limitations of, 15
  - overview of, 14–15
  - port numbers subgraphs, 52
- load function, 203–204, 227, 246
- loads function, 70, 165, 253
- locate\_landmarks function, 186, 188, 191
- location area codes (LACs), 146
- locations variable, 169
- location triangulation, 141–160
  - device tracking application, 148–159, 148*f*
  - geodesic polygons, 150–153
  - intersections, 153–157
  - mapping and comparing results, 157–159, 158*f*
  - reducing search area, 159
  - tower locations, 149–150
- ethics of, 144–145
- network interface data, 142–144
- OpenCellID API structure, 145–148, 147*f*
- proof of concept, 148–159

- loc function, 73
- logical statements, 18–20
- LOO (leave one out) algorithm, 188–189, 199–200
- lookup\_tower function, 146, 148–149
- loose coupling, 253–254
- lowest common ancestor (LCA), 84–87
- LucidChart, 234

## M

- MAC (media access control) addresses, 48–50
- machine learning (ML), 18, 176–204
- macOS
  - installing Anaconda, 8, 8*f*
  - network card in promiscuous mode, 63
  - packet capture library, 47
- Maltego, 29–30
- Markdown, 12
- Mastodon data, analysis of, 67–90
  - converting data to graph, 69–73
    - building graphs, 72–73, 74*f*
    - examining data, 69
    - structuring data, 69–72
  - defined, 67
  - proof of concept, 87–88
  - research questions, 74–87
    - cliques and most influential users, 76–78, 78*f*
  - information propagation, 74–76
  - most influenced users, 78–79, 79*f*

- Mastodon data, analysis of (*continued*)
    - research questions (*continued*)
      - node ancestry, 83–87, 84*f*, 86*f*
      - topic-based information
        - exchange, 79–83, 82*f*
  - math conventions. *See* programming and math conventions
  - mathematical notation, 18–22
    - attribute characters, 22
    - Boolean notation, 18–20, 19*t*
    - Greek letters and functions, 22, 22*t*
    - overloaded symbols, 18*f*
    - set notation, 20–22, 21*t*
  - Matplotlib library, 32–34
  - max-flow, min-cut theorem, 112, 121–122
  - maximal cliques, 40, 77
  - maximum area threshold, 219
  - max\_iter parameter, 81
  - MCCs (mobile country codes), 146
  - media access control (MAC)
    - addresses, 48–50
  - membership rules, 20, 21*t*
  - meshes, 218, 220, 220*f*, 225–229, 225*f*, 229*f*
  - metric space, 163–164, 167
  - MI (mutual information) classification, 196–197
  - microservices, 261–264, 261*f*
  - Milgram, Stanley, 68
  - minimum\_cut function, 122
  - minimum viable product (MVP), 210, 257
  - min\_samples\_leaf parameter, 201
  - min\_samples\_split parameter, 201
  - ML (machine learning), 18, 176–204
  - mobile country codes (MCCs), 146
  - mobile network codes (MNCs), 146
  - model persistence, 203–204
  - model training, 198–203
    - establishing baseline, 199–200
    - random forest, 201–202
    - splitting data, 199
    - testing holdout images, 202–203
  - monetization, 258–259, 263–266
  - Monte Carlo simulations, 91–125
    - information flow game, 110–124
    - overview of, 92–93
    - proof of concept, 109–124
    - random walks and, 95–97, 96*f*, 99*f*
    - simulations, defined, 92
    - social network simulation, 100–109
  - most influenced users, identifying, 78–79, 79*f*
  - most influential users, identifying, 76–78, 78*f*
  - mp\_agp\_floorplan function, 245
  - mp\_agp\_solver function, 244
  - mp\_solve\_floors function, 244
  - multiclass classification, 179
  - MultiDiGraph objects, 38, 42, 42*f*, 49–50, 53, 58, 62
  - multiprocessing (processor parallelism), 243–245
  - mutual information (MI) classification, 196–197
  - MVP (minimum viable product), 210, 257
- ## N
- names parameter, 167
  - neighbors, 31, 57–61, 58*f*
  - nested objects, 70, 251
  - n\_estimators parameter, 201
  - NetGear Ocuity cameras, 229
  - net\_graph objects, 50, 58, 60
  - network analysis graphs, 45–65
    - building, 47–51, 51*f*
    - centrality, 52–61
      - examining neighbors, 57–61, 58*f*
      - identifying unusual levels of traffic, 54–57, 56*f*
      - port numbers subgraphs, 52–54
    - identifying data for, 48–49
    - network topology, 46, 46*f*
    - packet analysis, 46–51, 51*f*
    - proof of concept, 61–64
  - network interface cards (NICs), 48
  - NetworkX library
    - art gallery problem application, 236
    - betweenness centrality, 36
    - centrality by protocol, 52–53, 58–59
    - creating graphs in, 32–34, 34*f*
    - degree centrality, 38
    - greedy coloring, 212, 214–215
    - network analysis graphs, 62–63
    - packet analysis, 50



- social network analysis, 70, 75, 80–81, 86–88
- social network evolution, 93, 95, 109, 118
- NICs (network interface cards), 48
- node ancestry, 83–87, 84*f*, 86*f*
- node attributes, 32
- nodes. *See* vertices
- Nominatim, 164–165
- non\_edges function, 118
- nonsimple graphs (pseudographs), 32
- normalized argument, 36
- Npcap library, 47
- number\_of\_cliques function, 40
- NumPy library, xxiii, 55–56, 80, 103, 170, 186

**O**

- obfuscation, 264–265
- Obstacle class, 235
- Obstacle objects, 251, 253
- obstacles attribute, 253
- only\_poly1 variable, 155
- OpenCellID, 141–160
  - API structure, 145–148, 147*f*
  - device tracking application, 148–159, 148*f*
  - geodesic polygons, 150–153
  - intersections, 153–157
  - mapping and comparing results, 157–159, 158*f*
  - reducing search area, 159
  - tower locations, 149–150
  - network interface data, 142–144
  - proof of concept, 148–159
- open source delivery, 265–266
- open source intelligence (OSINT), 29–30, 30*f*
- OpenStreetMap, 163–164, 168
- optparse library, 62–63
- osm function, 168
- out-degree centrality, 37–38, 51–54, 57–59, 77, 85, 101–103, 113, 121
- out\_degree function, 53
- out\_edges function, 59
- outliers, 55–56, 60, 181
- overlaps function, 138
- overloaded symbols, 18, 18*f*

**P**

- packaging, 259–260
- packet analysis, 46–51, 51*f*
- packet capture (pcap) files, 47–48, 50, 61–63
- packet objects, 50
- packets, defined, 121
- packets variable, 50
- Pålsson, Mikael, 213
- pandas library, 5, 69–72, 81, 88, 150, 167–169, 191–192
- parallel development, 263–264
- parallelism
  - hardware parallelism, 263
  - process parallelism, 241–245
  - processor parallelism, 243–245
  - threading parallelism, 241–243
- partial function, 151–152
- partial functions, 151
- partition function, 155
- path lengths
  - lowest common ancestor, 85
  - returning list of average, 117–119
  - self-loops, 32
  - small-world phenomenon, 68
- paths, defined, 31
- PBX (Private Branch Exchange), 54
- pcap (packet capture) files, 47–48, 50, 61–63
- pcap\_graph function, 62
- perimeter length, 137–138
- personally identifiable information, 178
- Phil’s Game Utilities (PGU) library, 250
- physical penetration testing, 212
- pickled objects, 203–204
- pickle library, 203–204, 251
- Pinellas County Sheriff’s Office, 177
- pip tool, 10–12, 258
- planar straight-line graphs, 216
- player\_one\_turn function, 115–116
- png library, 236
- points, defined, 128–129
- Polygon class, 129
- polygon\_geojson parameter, 165
- polygons, 129–132, 130*f*, 131*f*
  - complex, 130, 132, 134–135, 138, 214, 223–225, 224*f*
  - concave, 130, 130*f*

- polygons (*continued*)
  - converting Point objects to
    - geodesic polygons, 150–153
  - convex, 130, 130*f*, 132, 136, 187
  - irregular, 130, 133–136
  - linear ring, 130–131, 131*f*, 223–225, 224*f*
  - orthogonal, 213–214
  - regular, 130
  - simple, 130–131, 134*f*, 210
- poly\_shapes variable, 170, 172
- polytrees, 85
- population mean, 120, 123–124
- port numbers subgraphs, 52–54
- post\_df objects, 71–73, 76, 107
- potential information, 75–76, 78
- predict function, 200, 202
- predictive analytics, 91
- predict\_proba function, 203
- preferential attachment, 68, 113–114
- preventative security analysis, 90
- Private Branch Exchange (PBX), 54
- process\_jpg function, 184, 186
- processor parallelism
  - (multiprocessing), 243–245
- process parallelism, 241–245
  - processor parallelism, 243–245
  - threading parallelism, 241–243
- programming and math conventions, 13–23
  - mathematical notation, 18–22
    - attribute characters, 22
    - Boolean notation, 18–20, 19*t*
    - Greek letters and functions, 22, 22*t*
    - overloaded symbols, 18, 18*f*
    - set notation, 20–22, 21*t*
  - syntactical constructs, 13–18
    - dictionary comprehensions, 15–17
    - list comprehensions, 14–15
    - zipping and unpacking, 17–18
- Proj class, 151–152
- project managers, 264
- proof of concept, ix
  - facial recognition, 188–204
  - location triangulation, 148–159
  - minimum viable product vs., 210
  - network analysis graphs, 61–64
  - social network analysis, 87–88
  - social network evolution, 109–124
  - Voronoi diagrams, 163–173
- protocol\_subgraph function, 52–55
- protocol subgraphs, 54–56, 56*f*
- proxy networks, 35–36, 35*f*
- pseudographs (nonsimple graphs), 32
- purity, 181
- PyArmor, 264–265
- PyGame library, 236–240, 246–250
  - events, 237–239
  - graphic elements, 246–247, 247*f*
- PyInstaller, 259–260
- PyPi, 258–259, 266
- Pyplot library, 32–33
- pyproj library, 150–152
- Pythagorean theorem, 18, 18*f*, 164
- Python
  - environment setup, 3–12
    - hardware requirements, 3
    - installing Anaconda, 4
    - Jupyter Notebooks, 11–12
    - Spyder IDE, 10–11
    - virtual environment setup, 9
    - virtualenv package manager, 10–11
  - interpreters, packaging with, 259–260
  - reasons for using, xxii–xxiii
  - shortcomings of, xxiii

**Q**

- Queue class, 244

**R**

- r (--raw-out) parameter, 63
- RA (resource allocation), 108–109
- randint function, 201
- RandomForestClassifier class, 201
- RandomForestClassifier objects, 202–203
- random forests, 179, 182, 201–203
- random\_layout function, 51
- random walks, 95–104, 117–119, 125
  - biased, 97, 100, 104, 111
  - Monte Carlo simulations and, 97–99, 99*f*

- social network simulation, 100–104
- state machines and, 96–97, 96*f*, 99*f*
- uniformly, 96–97, 96*f*, 101–104, 117
- range function, 16–17, 22
- RangeIndex property, 71
- ratios
  - correlation ratio, 197–198
  - facial recognition, 190
  - information exchange ratio, 59–61
- rdpcap function, 50, 62
- read\_csv function, 167, 192
- read\_weighted\_edgelist function, 63
- recursive functions, 31
- Red Hat, 266
- regression problems, 176
- repeated-sampling algorithms, 98
- representative\_point function, 223
- residual information (RI) score, 75–76
- resize function, 184
- resource allocation (RA), 108–109
- resource planning problems. *See* art gallery problem application; emergency service planning scenario
- return\_results parameter, 195
- reverse option, 53
- reverse parameter, 59, 137
- RI (residual information) score, 75–76
- right\_click function, 241
- rings. *See* linear ring polygons
- Room class, 249, 251, 253–254
- root node, 84–85, 180–181
- row\_to\_str function, 167
- r\_posts objects, 76

## S

- s (--graph-out) option, 63
- sample mean (empirical mean), 93
- sample size determination, 98
- Saved state, 235
- save\_file function, 227
- save\_graph function, 62
- save\_packet function, 62
- save\_project function, 227–228
- saving and reloading data, 251–254
  - loading from JSON files, 252–254
  - saving to dictionaries, 251–252
- scan codes, 239–240

- Scapy library, 47, 50, 62–63
- scikit-learn, xxiii, 196–197, 199–201, 203
- SciPy library, 55, 80, 170
- scored\_neighbor\_select function, 106
- scores parameter, 111
- screen attribute, 249–250
- seed argument, 33–34
- seeds. *See* generators
- select\_dtypes function, 192
- self-looping, 31–32
- Series objects, 71, 191, 198
- setattr function, 253
- set\_colorkey function, 249
- set\_file method, 242
- set generator notation (SGN), 22
- set\_mode function, 246
- set notation
  - overview of, 20–22, 21*t*
  - reserved sets, 21, 21*t*
  - set generator notation, 22
- set\_region\_areas function, 227
- setup scripts, 258–259
- setuptools library, 258
- 7Zip, 252
- SGN (set generator notation), 22
- Shapely library
  - art gallery problem application, 216, 219, 222–223, 235
  - computational geometry theory, 128–129, 131–132, 134, 138
  - emergency service planning scenario, 164, 170
  - facial recognition, 183, 188, 190
  - location triangulation, 144, 148–150, 152, 154
- shape\_to\_np function, 186
- shell layout, 58, 58*f*
- Shewchuk, Jonathan, 216
- shifted variable, 239, 241
- shoelace algorithm, 136
- shortest\_path\_scores function, 117–119
- sides (edges), in polygons, 129
- signature detection, 47
- simple function, 151
- simple graphs, 32, 85
- single point of failure, 109–110
- sink node, 110, 113, 117–119, 121
- six degrees of separation, 68

- small\_area parameter, 157
  - small-world experiments, 68
  - Snort, 48
  - Snow, John, 163
  - social network analysis (SNA), 67–90
    - cautions regarding, 89
    - converting data to graph, 69–73
      - building graphs, 72–73, 74f
      - examining data, 69
      - structuring data, 69–72
    - defined, 67
    - proof of concept, 87–88
    - research questions, 74–87
      - cliques and most influential users, 76–78, 78f
      - information propagation, 74–76
      - most influenced users, 78–79, 79f
      - node ancestry, 83–87, 84f, 86f
      - topic-based information exchange, 79–83, 82f
      - small-world phenomenon, 68
  - social network evolution, 91–125
    - finite state machines, 93–95, 94f
    - information flow game, 110–124
      - edge capacity, 112–113
      - game phases, 113–117
      - game simulation, 118–120
      - improvements to player 2, 120–124
      - source and sink node selection, 117–118
      - weighted random choice, 111–112
    - Monte Carlo simulations, 92–93, 97–100, 99f
    - proof of concept, 109–124
    - random walks, 95–97, 96f, 99f
    - simulations, defined, 92
  - social network graphs, 29, 39–40, 39f
  - social network simulation, 100–109
    - information flow distance, 100–104
    - resource allocation, 108–109
    - topic-based influence, 104–108
  - soft classifiers, 203
  - sorted function, 53, 137, 198
  - source node, 36, 73, 78, 110, 113, 117–119, 121
  - spaghetti models (storm path maps), 93
  - sparse adjacency matrices, 80
  - spring\_layout function, 33, 82–83
  - Sprite class, 248–250, 250f
  - sprites, 248–250, 250f
  - Spyder IDE, 4, 10–11
  - Stack Overflow, 153
  - Ståhl, Joachim, 213
  - Stanford University, 98, 125
  - Started state, 234–235
  - Start state, 234–235
  - state machines
    - finite state machines, 93–95, 94f, 100–101
    - state machine graphs, 30, 31f
  - state managers
    - application state planning, 235
    - development of, 237–241
    - event driven nature of, 237
    - purpose of, 235, 237
  - Steiner points, 219, 228–229
  - stochastic FSMs, 95, 97
  - storm path maps (spaghetti models), 93
  - strip function, 70
  - substates, 238
  - sum function, 59
  - Super Bowl XXXV, 176–177
  - supervised learning, 176, 179
  - Surface class, 246–248, 247f
  - surface\_size attribute, 249
  - sweep line algorithms, 154–155
  - syntactical constructs, 13–18
    - dictionary comprehensions, 15–17
    - list comprehensions, 14–15
    - zipping and unpacking, 17–18
- ## T
- target parameter, 244
  - TCP handshake graphs, 42, 42f
  - TCP packets, 49–50, 61
  - terminal states, 96, 99–100
  - term\_subgraph function, 106–107
  - tessellation, 133–136, 134f
    - art gallery problem, 214, 216–219, 223–224, 226–228, 245, 252
    - facial recognition, 189–190
    - Voronoi tessellation, 162–173
  - theil\_u parameter, 195

- Theil's U, 195
- Thread class, 242
- threading parallelism, 241–243
- three-color problem, 212–213
- tiles, 133
- timeline function, 88
- to\_dict function, 251, 253–254
- tol parameter, 81
- topic-based influence, 104–108
- topic-based information exchange, 79–83, 82*f*
- topography, 33, 113
- topological ordering, 85
- touches function, 138
- towers (base stations). *See* base stations
- transform function, 151–153
- transitions, 31*f*, 94–96, 99–101
- travel graphs, 28–29, 29*f*, 32
- Triangle library, 216, 219, 223–229, 236, 245, 252, 262
- Triangle Solver service, 261*f*, 262
- triangulate function, 134, 136, 216–217, 219, 221, 223–224, 226–227
- truth tables, 19
- ttest\_ind function, 123
- Twitter, 80
- two-sample t-testing, 123, 124*f*
- type function, 203

## U

- UDP packets, 49–50
- UML (Unified Modeling Language), 234
- unbalanced exchange, 75
- undirected graphs, 31–32
  - betweenness centrality, 36
  - cliques, 39–40, 39*f*, 76–77
  - connected components, 41
  - creating in NetworkX, 33, 34*f*
  - degree centrality, 37
- undirected preferential attachment (UPA), 114
- unicode attribute, 239
- Unified Modeling Language (UML), 234
- uniform argument, 200
- uniformly random walks, 96–97, 96*f*, 101–104, 117

- uninstall functions, 257–259
- unique function, 103
- University of Essex, 177
- University of Washington, 212
- unsupervised learning (exploratory analysis), 176
- unweighted graphs, 32, 43, 214
- Unwired Labs, 142, 147
- UPA (undirected preferential attachment), 114
- urlencode function, 165
- user interaction mapping, 234–237, 234*f*
  - application state planning, 235–236
  - documentation, 236–237
- User Interface service, 261*f*, 262–263
- user\_to\_series function, 70

## V

- vertex-coloring problem, 212
- vertex\_list attribute, 249
- vertices (nodes)
  - defined, 129
  - graph theory, 27
  - vertex order, 132
- VirtualBox, 260
- virtual environment setup, 9, 63
- virtualenv package manager, 10–11
- Voice over IP (VoIP), 54, 57
- Voronoi diagrams, 161–174
  - emergency service planning scenario, 163–173
    - city shape, 164–167, 165*f*
    - distance function, 164
    - generators, 167–169, 169*f*
    - tessellation, 170–173, 171*f*, 172*f*
  - limitations of, 173–174
  - proof of concept, 163–173
  - tessellation, 162–163, 162*f*
- voronoi\_regions\_from\_coords function, 170
- Voronoi tessellation, 162–163, 162*f*, 170–173, 171*f*, 172*f*

## W

- weighted\_choice function, 106, 111–112, 114, 118
- weighted graphs, 32–33, 52–53, 55, 62–63, 77

weighted random choice, 95, 97, 106,  
     111–115  
 weight parameter, 53, 77  
 WGS (world geodesic system), 152  
 wgs84\_to\_aeqd function, 152  
 where function, 55, 60  
 WiGLE, 144, 159  
 Windows  
     frozen delivery, 260  
     installing Anaconda, 6–8, 6*f*, 7*f*  
     Jupyter Notebooks, 11–12  
     network card in promiscuous  
         mode, 63–64  
     packet capture library, 47  
     setting up virtualenv, 10  
     Spyder IDE, 11  
     temp directory, 252  
 WinPcap library, 47  
 WinPython, 11  
 WireShark, 46–47  
 world geodesic system (WGS), 152  
 write once, read many (WORM)  
     workflow, 62  
 write\_weighted\_edgelist function,  
     62–63  
 wrpcap function, 62  
 wrs\_connect function, 114, 116  
 wrs\_disconnect function, 115–116

**X**

X\_test variable, 200  
 X\_train variable, 200

**Y**

y\_test variable, 200  
 y\_train variable, 200

**Z**

Zenmap, 46, 46*f*  
 zero-sum games, 98  
 ZipFile class, 252  
 zip function, 17, 197, 202  
 zipf variable, 252  
 zipping and unpacking, 17–18  
 zscore function, 55–56  
 Zychlinski, Shaked, 195