

Index

- acceleration, 397
 - curve, 400
- accuracy, 101, 102
- activation map, 109
- advection, 210
- aesthetics, 417–419
 - attributes, 172
- aggregation, 70, 191
- al-Biruni, Abu Rayhan Muhammad ibn Ahmad, 12
- Andrews curve, 296
- Andrienko, N., 263
- animation, 459
 - ease-in, ease-out, 399
- APT, 161–162, 164, 166
- arc diagrams, 350
- arc length, 398
- area data, 239–247
- artifact, 144
- Ashmolean Museum, 7
- AutoVisual, 166–167
- AVE, 169–170
- axes
 - operations, 170
 - types, 170
- balance, 417
- bar charts, 141, 223, 299–301, 455
- bar graphs, 186
- barycentric displays, 291
- benchmarking, 438–439
 - example, 439–444
 - procedure, 438
- Bergeron, Daniel, 162
- Bertin, Jacques, 160, 167, 333
- blind spot, 91–93
- Blinn, James, 203
- blobby objects, *see* implicit surfaces
- block, 329
- boids, 123
- boundary-detection, 73
- BOZ, 164–166
- brain, 95
- brightness, 100, 151–152
- brushing, 370, 371, 459
 - structure-based, 376
- Buja, Andreas, 454
- CareCruiser, 271–273
- CartoDraw algorithm, 243–246
- cartograms, 239, 241–247
 - circular, 242
 - continuous, 242
 - noncontiguous, 242
 - noncontinuous, 241
 - rectangular, 246–247
- case studies, 437
- Casner, Stephen, 164
- cave paintings, 7
- change blindness, 110, 114–118

- channel capacity, 126
- chart junk, 423
- Chauvet-Pont-d'Arc Cave, 7
- Chernoff face, 309
- Chi, Ed, 464
- choropleth maps, 239, 240
- chunking, 134
- ciliary body, 88
- circular
 - area graphs, 298
 - bar charts, 297
 - bar graphs, 298
 - line graph, 297
- cityscapes, 188, 300
- classification, 201
- Cleveland, William, 130
- clustering, 56, 432, 440, 442–443
- cognition, *see* perception
- color, 118–121, 152–154
 - bar, 184
 - design guides, 415–417
 - histogram equalization, 392
 - perception, 233
 - scales, 378
- color maps, 153
- colormap control, 410
- compilation, 134
- compositing, 200
- computational fluid dynamics, 204
- computational steering, 34
- cone tree, 325
- cones, 89–92
- conjunction searches, 99, 100, 104, 106, 110
- connected component, 329
- connection, 365, 370–371
- continuous cartogram problem, 243–246
- contour, 189
- contour lines, 214–216
- contrast, 104
 - enhancement, 392
- conversion
 - raster to vector, 71–73
- convolution, 70, 72–73, 211
- Cook, Dianne, 454
- cornea, 88
- corpus, 341
- correlation analysis, 56
- correlation coefficient, 395
- correspondence analysis, 69
- coxcomb chart, 14
- curvature, 104
- cut planes, 195–196, 211, 213
- cutvertex, 329
- Da Vinci, Leonardo, 15, 204
- data
 - characteristics, 434–435
 - dimensionality, 434
 - distortion, 3
 - distribution, 435
 - foundations, 51–79
 - geospatial, 221–251
 - mean, 56
 - missing values, 57–58
 - multivariate, 300, 301
 - nominal, 52, 476
 - nonstructured, 477
 - number of parameters, 434
 - observations, 51
 - one-dimensional, 184–187
 - ordering, 312
 - ordinal, 52
 - preprocessing, 56–73, 140
 - quality, 378, 477
 - range, 435
 - raw vs. derived, 424–426
 - realsynth, 435
 - scale, 52
 - scaling, 3
 - scrubbing, 420
 - size, 434
 - standard deviation, 57
 - structure, 53–56, 434
 - subsetting, 64
 - temporal, 477
 - three-dimensional, 192–204
 - time-oriented, *see* time-series visualization
 - transformations, 464
 - two-dimensional, 187–192
 - type, 434

- uncertainty, 378
 - variables, 51
 - volume, 194–202
- data aspects, 261
- Data Mountain, 465
- data sets
 - cars, 75
 - cereal, 75
 - Colorado, 73
 - CT scan, 75
 - Detroit, 75
 - Dow Jones, 73
 - Iris, 66
 - temperature, 74
 - turbulent flow, 74
 - US census, 76
 - VAST challenges, 75
 - World databank, 75
- deceleration, 397
- dense pixel displays, 311–315
 - circle segments, 313
 - recursive pattern, 312
- design
 - automatic, 171
 - problems, 419–426
- dimension
 - embedding, 286
 - excessive, 421
 - orderings, 309, 313, 394
 - reduction, 65–68, 286, 450, 457
 - reordering, 451
 - subsetting, 286
- dimensional stacking, 304–305, 450
- direct manipulation, 402, 403, 411
- display walls, 482
- distortion, 16, 335–338, 371–375, 377–381, 387
 - linear, 372
 - nonlinear, 372
 - pipeline, 383
- DocuBurst, 465
- document cards, 354, 355
- document visualization, *see*
 - visualization, text and document
- dot maps, 232–233
- drill-down, *see* navigation, drill-down
- dynamic data, 476
- dynamic query specification, 368
- EAVE, 171
- edge bundling, 237–238
- effectiveness, 142, 161, 166
- electrocardiogram, 17
- Elting, Linda, 4
- encoding, 365, 369–370
- enhanced interactive spiral, 270, 272
- evaluation, 431–444
 - procedures, 436–438
 - research issues, 480–481
- expert reviews, 437
- exploration, *see* navigation
- exploratory data analysis (EDA), *see*
 - visualization, exploratory
- exponential smoothing, 71
- expressiveness, 142, 161, 166
- eye
 - anatomy, 87–93
 - movement, 95–97
 - physiology, 86–96
- face, 329
- feature hierarchy, 113–114
- feature integration theory, 101–104, 106
- feature maps, 102, 108
- field tests, 437
- filtering, 70–71, 365, 368–369, 375, 376, 459
- fish-eye lens, 337, 373, 387, 396, 457
- flocking boids, 275–276
- flow field, 205
- flow maps, 237–238
- flow visualization, 204–211
- fly-through, 389
- focus, 135, 417
- focus+context, 336, 337
- footprints, 372
- force-based methods, 286–291
- forward mapping, 199
- fovea, 89–91
- Frank, A. U., 255
- Friendly, Michael, 7, 48
- Fua, Ying-Huey, 450

- gene expression, 48
- genetic network, 22
- geographic information systems, 221, 248
- geovisualization, *see* data, geospatial
- Gestalt Laws, 36
- GGobi, 454, 456, 457
- GlyphMaker, 378
- glyphs, 194, 306–311
 - arrow, 207, 213
 - examples, 307–308
 - layout, 309
 - star, 66, 440, 443, 450
- Goralwalla, I. A., 255
- gradient, 201, 216
 - central difference estimator, 202
 - intermediate difference operator, 201
- grand tours, 367, 390, 455
- graphical processing units, 482
- graphical symbol, 143
- graphics
 - analysis, 147
 - attributes, 30
 - grammar, 172–173
 - language, 27
 - pipeline, 31–32
 - primitives, 23, 30
 - relation to visualization, 23–28
 - rules, 146
- graphs, 319, 326–338, 455
 - arbitrary, 326
 - attachments, 329
 - biconnected, 329
 - bipartite, 330
 - connected, 328, 329
 - converting nonplanar to planar, 331
 - drawing, 338
 - force-directed, 327
 - planar, 328
 - entity, 359
 - interlace, 329
 - matrix representation, 333–334
 - pieces, 329
 - planarity test, 329, 330
 - pseudo-dual, 244
 - spring layouts, 351
 - triconnected, 329
 - visualization, 338
- GraphViz, 452, 454
- Great Wall of Space-Time, 264, 265
- grid
 - Cartesian, 54
 - hyperbolic, 54
 - spherical, 54
- grid marks, 413
- Grinstein, Georges, 162
- GROOVE, 265–267
- GTK, 457
- guided search theory, 101, 108–110, 115
- hand-held displays, 481
- Hanrahan, Pat, 462
- hardware
 - research issues, 481–483
- Harris, R. L., 268
- Hearst, Marti, 356
- Heatmaps, 301
- Hereford map, 9, 10
- Hering illusion, 85
- Hermann grid, 85
- heuristic evaluation, 437
- Hibbard, William, 168
- hierarchical parallel coordinates, 450, 451
- hierarchies, 320
- hieroglyphics, 9
- highlighting, 295
- histogram, 57, 191, 300–301, 306
 - N*-dimensional, 305
 - three-dimensional, 301
 - volume, 394
- Hoffman, Patrick, 173
- hue, 152
- hyperbolic projections, 380
- hypothesis testing, 43
- IBM Visualization Data Explorer, 447
- icons, 194, *see also* glyphs
 - stick figure, 121
- image, 187
- immersive environments, 482

- implantation, 160
- implicit surfaces, 202–204, 209
- imposition, 160
- imputation, 58, 79
- Imrich, P., 277
- information density, 411–412
- InfoScope, 457–459
- InfoVis Toolkit, 467
- Inselberg, Al, 294
- interaction, 30, 365–405
 - blender, 382
 - concepts, 365–385
 - control, 402–404
 - devices, 483
 - direct vs. indirect, 369
 - extends, 382
 - focus, 382
 - framework, 382
 - operands, 372–373
 - operators, 366–372
 - techniques, 387–405
 - transformation, 382
- interference, 113, 114
- interpolation, 55, 61, 195, 198, 200, 206, 388
 - bilinear, 62, 192
 - Catmull-Rom, 63
 - linear, 62, 397
 - nonlinear, 63
- InterRing, 376, 377, 452
- inverse mapping, 200
- iris, 88
- isosurface, 195–199, 203, 211, 213–214, 467
- isovalue, 189
- ITK, 467
- Jigsaw, 358, 359, 361, 460, 461
- judgment
 - absolute, 127–130
 - absolute vs. relative, 426
 - color, 128, 129
 - line geometry, 128
 - position, 128, 129
 - relative, 130–132
 - size, 128, 129
- juxtaposition, 186, 189, 292
- Kanizsa illusion, 85
- Keim, Daniel, 177, 311
- Keller, Mary, 175
- Keller, Peter, 175
- keys, 412–415
- Kish tablet, 7, 8
- Kitware, 467
- knowledge discovery, *see also*
 - visualization, exploratory pipeline, 34
- KronoMiner, 263, 264
- labeling, 248, 334, 412–415
- lattice model, 168
- learning, 479
- legends, 412–415
- lens, 88
- level-of-detail, 410
- Lewis, Clayton, 162
- lie factor, 420
- line chart, 223
- line data, 235
- line graphs, 184, 292–294
- line integral convolution, 209–211
- line plot, 268, 306
- line-based techniques, 292–298
- linked brushing, 294
- linked selection, 370
- linking, 370
- literature fingerprinting, 351, 352
- local linear embedding, 65, 68
- logograms, 7
- luminance, 100
- MacEachren, A. M., 263
- Mackinlay, Jack, 161–162, 167, 168
 - composition algebra, 161
- ManyEyes, 349
- mapping control, 410
- mappings, 30, 140
 - intuitive, 408–410
- maps, 189, 222
 - cluster, 351
 - dasymetric, 239
 - feature, 102
 - generalization, 248
 - Google, 16, 17

- maps (*continued*)
 - isarithmic, 239
 - isometric, 239
 - isopleth, 239
 - John Snow's, 10, 11, 48
 - labeling, 248
 - primitives
 - area, 222
 - line, 222
 - point, 222
 - surface, 222
 - projections, 221, 224–229
 - self organizing, 351, 353
 - thematic, 239
 - Tokyo underground, 16
 - types, 223
 - visual variables, 229–230
- Marching Cubes, 196–199
- marks, 147, 150–151, 194, *see also*
 - glyphs
- matrix displays, 326
- MDS, *see* multidimensional scaling
- memory, 124–125, 479
 - long-term, 110, 124
 - sensory, 124
 - short-term, 107, 124, 133–134
- metaballs, *see* implicit surfaces
- metadata, 56–57, 341
- metrics, 125–136
- Miller, George, 126
- Minard, Charles Joseph, 12
- morphemes, 9
- motion, 122–124, 157
 - direction, 123
 - flicker, 122
 - velocity, 122
- multidimensional scaling, 65, 287, 313, 351, 369, 457, 459
 - gradient descent, 67
- multiple displays, 286
- multivariate data visualization, 450
- n-Vision, 166
- named entity recognition, 342
- Napoleon's march, 13
- National Visualization and Analytics Center (NVAC), 48
- Natural Scene Paradigm, 163
- navigation, 365–367, 373, 375, 378, 379, 381
 - drill-down, 70, 337, 375, 397, 451
 - roll-up, 337, 375, 397, 451
- neighbor set, 329
- network maps, 235–236
- networks, 319, 326–338
- node-link diagram, 321, 326–331
 - aesthetics, 324
 - constraints, 324
 - drawing conventions, 324
- nominal variables, 451
 - mapping to numbers, 68–69
- nonlinear magnification, 244
- nonlinear scaling, 337
- normalization, 39, 58–59, 78
- NVAC, *see* National Visualization and Analytics Center (NVAC)
- opacity, 200
- OpenDX, 447
 - module interface, 449
 - modules, 447, 449
 - network, 448
 - Network Editor, 447
- OpenGL, 467
- optic nerve, 91
- optical illusions, 82–85
- optimization, 396
- ordering, 293
- orientation, 104, 154–155
- Österreichische Nationalbibliothek, 9
- outlier detection, 56, 440–441
- panning, 336, 337, 372
- parallel coordinates, 223, 294, 369, 381, 396, 439, 443, 450, 455, 459
- parametric equation, 192
 - cylinder, 194
- ParaView, 467
- Pareto, Vilfredo, 345
- particle advection, 205–206
- pathline, 205
- PCA, *see* principal component analysis
- perception, 35–36, 81–86
 - definition, 81

- human performance, 126
 - research issues, 478–479
- perceptual biases, 309
- perceptual processing, 97–118
- perspective wall, 380, 388, 389
- Peutinger Map, 8, 9
- pexels, 121
- photopic vision, 90
- pixel bar charts, 313
- pixel-oriented techniques, 450, *see also*
 - dense pixel displays
- PixelMaps, 234–235, 315
- planar embedding, 329
- Playfair, William, 13, 15
- point data, 232–235
- point graph, 268
- point plot, 268
- point plots, 285
- polar graphs, 297
- position, 148–149
- position curves, 399
- postattentive vision, 101, 110–112
- PostHistory, 274, 275
- preattentive processing, 98–101
 - features, 100
 - theories, 101–104
- Prefuse, 463–466
- Priestley, Joseph, 14, 15
- principal component analysis, 65, 66, 369, 457
- probe, 184, 191–192, 195
- problem solving, 479
- projection, 149
 - Albers Equal-Area Conic , 228
 - azimuthal, 224
 - cone, 225
 - conformal , 224
 - Cosinusodial, 228
 - cylinder, 225
 - equal area, 224
 - equidistant, 224
 - equirectangular, 226
 - gnomonic, 224
 - Hammer-Aitoff, 227
 - Lambert Cylindrical, 227
 - Mollweide, 227
 - plane, 225
 - retroazimuthal, 224
- projection pursuit, 291, 367
- pupil, 88
- radar, 297
- radial axis techniques, 297–298
- RadViz, 288, 289, 349
- range distortion, 421
- ray casting, 200
- ray tracing, 32
- RecMap algorithm, 246–247
- recoding, 134
- reconfiguring, 365, 369
- reference model, 170
- region-based techniques, 299–305
- region-growing, 72
- regression line, 19
- regularity, 104
- relationship types, 319
- remapping, 378, 379
- Rensink, Ron, 115
- reordering, 333, 337, 371
- reparameterization, 398
- resampling, 55, 64, 195, 200, 424
- research issues
 - applications, 483–485
 - data, 476–478
 - systems design, 479–480
- response time, 101
- retina, 89, 91–93
- retinal variables, 160
- ribbons, 208
- Robertson, Philip, 163
- rods, 89, 90, 92
- roll-up, *see* navigation, roll-up
- Roth, Steve, 163
- rubber sheet, 187, 214–216, 373
- Rundensteiner, Elke, 449
- Runge-Kutta integration, 206
- saccadic masking, 96
- saccadic movement, 35, 96
- SAGE, 163
- Saito, T., 270
- sampling, 61–65, 186, 200, 425
- saturation, 152, 153

- scalar, 53
- scale, 410, 476
- scaling, 148, 391
 - unbalanced, 420
- scatterplot, 19, 40–45, 189, 268,
 - 285–286, 306, 369, 396, 455
 - matrices, 285–286, 439, 443, 450, 455
- Schulz, H.-J., 264
- Schumann, H., 270
- scientific visualization, 183
- scotopic vision, 90
- screen space, 337
- SeeNet, 236
- SeeSoft, 354, 356
- segmentation, 59–61
 - refinement, 60
- selection, 295, 336, 365, 367–368, 373, 376, 378, 381
 - blender type, 403
 - extent, 402
 - focus, 402
 - interaction level, 403
 - interaction type, 402
- self-organizing maps, 65, 68
- semiology, 143
- sentiment analysis, 358, 360
- separating cycle, 330
- separating pair, 329
- shapes, *see* marks
- similarity
 - N-N, 106, 108, 110
 - T-N, 106, 108, 110
- similarity theory, 101, 105–108
- Simons, Dan, 116
- simplicity, 417
- simulated annealing, 68
- size, 151
- size perception, 232
- smoothing, 70–71, 389
- Snow, John, 10, 48
- Sobel operator, 202
- software visualization, 354
- space
 - attribute, 378, 392–394
 - data, 391
 - data structure, 375–378, 394–396
 - data value, 373–375
 - iteration, 372
 - object, 379–380, 388–391
 - screen, 373, 387
 - visualization structure, 380–381, 396–397
- spatial data visualization, 183
- spatial substrate, 170
- spectrum, light, 86–87
- SpiraClock, 273–274
- splatting, 200
- stacked bar graph, 300
- star graphs, 297
- stemming, 343
- Stevens' Law, 132
- stop words, 343
- streakline, 205, 209
- stream graph, 357
- streamball, 209
- streaming data, 476
- streamline, 205, 208–210, 467
- stress, 288, 327
- structure
 - geometric, 54
 - grid, 54
 - irregular, 54
 - nonuniform, 54
 - types, 375
- structure space, 337
- structure-based brush, 450–452
- summarization, 70
- sunburst displays, 321
- superimposition, 186, 189, 292
- surface, explicit, 192–194
- survey plots, 303
- Swayne, Deborah, 454
- SWIFT-3D, 236
- synoptic tasks, 263

- table lens, 303, 381
- table visualizations, 173–174
- Tableau, 462
- TableLens, 381, 396
- tag cloud, 348
- target detection, 101

- taxonomy, 175
 - data type by task, 176–177
 - Keim, 177–179
- tensor, 53
- term frequency inverse document frequency, 344
- text clouds, *see* tag clouds
- text representations, 342–343
 - lexical, 342
 - semantic, 342
 - syntactical, 342
- text visualization, *see* visualization, text and document
- TextArc, 349–350
- texton theory, 101, 104–105
- textons, 104
- texture, 121–122, 156–157
 - orientation, 122
 - segmentation, 121
 - segregation, 105
- tf-idf, *see* term frequency inverse document frequency
- ThemeRiver, 357
- themescapes, 351–353
- 3D ThemeRiver, 277–278
- thresholding, 72
- TileBars, 356, 357
- time aspects, 256–261
- time-series visualization, 376
 - temporal data visualization, 253–284
- TimeBench, 278–280, 282
- timeline, 205
- timestamp, 55
- TimeViz Browser, 281, 282
- TimeWheel, 266–268
- TiMoVA, 269
- tokens, 342
- Tominski, C., 264, 270
- toolkits, 463–470
- topology, 55
- transfer functions, 201, 393, 394
- transformations
 - animating, 397–402
 - coordinate system, 186
- translation, 391
- transparency, 201
- traveling salesman problem, 334, 396
- tree visualization
 - non-space-filling, 320–326
 - space-filling, 320–321
 - radial, 321
 - rectangular, 320
- treemaps, 238, 321
 - nested, 321
 - squarified, 321
- trees, 319–326
- Treisman, Anne, 101
- tubes, 208
- Tufte, Edward, 10, 420, 423

- usability tests, 437
- use cases, 437
- user characteristics, 433–434
- user tasks, 432–433

- Value and Relation techniques, 313
- Vande Moere, A., 275
- variable
 - dependent, 51
 - independent, 51
- vector, 53
- vector space model, 343–347
- Vectorized RadViz, 291
- velocity curve, 399
- view modification, 410–411
- Visage, 163
- visibility approach, 331
- VISTA, 167–168
 - composition rules, 167–168
- visual
 - analytics, *see* visualization, exploratory
 - clutter, 412, 451
 - mappings, 464
 - nonsense, 422–423
 - processing, 93–95
 - tasks, 100
 - transformations, 464
 - variables, 147–158
 - associative, 157
 - ordinal, 158
 - proportional, 158

- selective, 157
 - separating, 158
- visualization
 - 2.5-dimensional, 233
 - categories, 46
 - combining, 211–216
 - definition, 1
 - design, 407–428
 - document collections, 351–354
 - everyday, 1–3
 - exploratory, 31, 47
 - flow, 22
 - goals taxonomy, 175
 - history, 7–23
 - importance, 3–6
 - integrated with computation, 479
 - lies, 419–422
 - medical, 28
 - multivariate, 285–317
 - pipeline, 28–36, 140
 - presentation, 46
 - process, 28–36
 - relation to graphics, 23–28
 - research directions, 475–485
 - scientific vs. information, 27–28
 - systems, 140, 447–473
 - tasks taxonomy, 176–177
 - text and document, 341–362, 460
 - volume, 397
- visualization characteristics, 435–436
 - computational performance, 436
 - data limitations, 436
 - degree of accuracy, 436
 - degree of complexity, 436
 - degree of occlusion, 436
 - degree of usability, 436
 - memory performance, 436
- Visualization Reference Model, 162
- Visualization Toolkit, 465–467
- VisuExplore, 276, 277
- volume rendering, 21, 195, 467
 - direct, 199–202
- VolView, 467
- vorticity, 205, 208
- voxels, 194
- VTK, *see* Visualization Toolkit

- Ward, Matthew, 449
- Weave, 467–470
- Weber's Law, 132
- Wehrend, Stephen, 162
- Wilkinson, Leland, 172–173
- Wolfe, Jeremy, 108, 110
- word clouds, *see* tag clouds
- Wordle, 348
- WordTree, 349
- Wyvill, Brian, 203

- XGobi, 454
- XmdvTool, 374, 375, 384, 411, 449–451

- Yang, Jing, 450

- Zhao, J., 264
- Zipf's Law, 345
- Zipf, George Kingsley, 346
- zooming, 336, 337, 371, 372, 410
 - dimensional, 375