INDEX

A

adjacency matrices centrality, 27, 30, 33-35 directed and undirected networks, 27 disease spread tracking, 67, 69 persistent homology, 91-92 spectral theory, 49-50 weighted networks, 27 Akaike information criterion (AIC), 137, 140 algebraic connectivity, 50, 51 alpha (attenuation parameter), 35, 39 alpha centrality. See Katz centrality authority centrality defined, 35 measuring in social networks, 39-41 averaged perceptron tagger, 183-184

B

Barabási-Albert model, 52 basis (Hamel basis), 133 BERT (Bidirectional Encoder Representations from Transformers), 189-190 beta, 70 Betti numbers, 85-86 defined, 85 Euler characteristic, 87 examples of, 85-86 persistent homology, 88-89 subgroup mining, 156-157 validating measurement tools, 161 betweenness of vertices applications of, 32-33 bridges, 64 community mining, 60 disease spread tracking, 68

graph filtration, 79 measuring in social networks, 37, 38, 41, 42 overview of, 32-33 predictions with social media network metrics, 57, 59 topological data analysis, 194 **Bidirectional Encoder Representations** from Transformers (BERT), 189 - 190binomial distributions dispersion, 137 entropy, 107-110 Bonacich centrality. See Katz centrality bridges betweenness, 38, 64, 68 disease spread tracking, 68 predictions with social media network metrics, 56-57 walktrap algorithm, 61 browseVignettes(), xxii

C

calculate_homology(), 157 Canberra distance, 101–102, 103, 118 Čech complexes, 82 centrality, 29–42 applications of, 30 applying clustering to social media dataset, 60 authority centrality, 35 betweenness of vertices, 32–33 closeness of vertices, 31 defined, 30 degree of vertices, 30–31 disease spread tracking, 68 distance and, 24 eigenvector centrality, 33–34 centrality (continued) graph filtration, 77-79 hub centrality, 35 Katz centrality, 35 measuring in example social network, 36-42 PageRank centrality, 34-35 predictions with social media network metrics, 56-59 spectral theory, 27, 49 topological data analysis, 194 topological dimension, 82 Chebyshev distance, 101, 116 choice ranking comparison, 149-152 HodgeRank, 152 missing information, 150-151 no consistent preferences, 151 overview of, 149-150 preference loops, 150-151 circuit-centric quantum classifiers, 203-204 classification and classifiers bot account detection, 64, 66 convolutional neural network classifiers, 110 curse of dimensionality, 16-17 decision boundaries, 10-11 defined. 2 homology, 85-86 homotopy, 167, 169 image classification, 18-20, 200-204 logistic regression classifiers, 16-17 metric geometry, 116-119 overfitting and underfitting, 13 overview of, 10-11 poetry analysis project, 186, 189-190 predicting edge formation, 59 quantum classifiers, 203-204 supervised classifiers, 59, 65 support vector machine classifiers, 103 closed triangles, 43, 49 closeness of vertices measuring in social networks, 37, 38 overview of, 31 CNNs (convolutional neural networks), 18-19, 110, 202-204

cohomology, 141, 146 community mining (clustering vertices), 59-64 evaluating quality outcome of clusters, 61-62 exploring networks with random walks, 61 overview of, 59-60 running clustering algorithms, 62 - 64spinglass clustering, 62 conditional Fisher information, 134-135 conditional Rao score, 135 connected components graph Laplacian, 50, 51 homology, 85-86, 89 random walk algorithms, 34 subgroup mining, 156 convex optimization problems, 148 convolutional neural networks (CNNs), 18-19, 110, 202-204 COVID-19 pandemic, 72-73, 127 curl flow, 152 curse of dimensionality, 7, 14, 95 geometric perspective, 17 overview of, 13-17 perturbed points in Euclidean space, 14-16

D

data geometry, 1-21 machine learning, 2-4 matching algorithms, 4 supervised learning, 2-3 unsupervised learning, 3 structured data, 4-17 dummy variables, 5-7 numerical spreadsheets, 8–10 supervised learning, 10-17 unstructured data, 17-21 image data, 18-20 network data, 17-18 text data, 20-21 data integrity, 4 data points in structured data, 4, 7-9 supervised learning, 9, 11, 14, 17 unsupervised learning, 3

data science geometry, 95-129 distance metrics, 96-116 entropy, 107-110 norm-based distance metrics, 99 - 105shape comparison, 110–116 small dataset simulation, 98-99 Wasserstein distance, 105-107 fractals, 125-129 k-nearest neighbors with metric geometry, 116-119 manifold learning, 119-125 Isomap, 121-122 locally linear embedding, 122 - 124multidimensional scaling, 120 - 122t-distributed stochastic neighbor embedding, 124 - 125decision boundaries classification, 10-11 overfitting, 13 decision trees decision boundaries, 10, 11 overfitting, 13 deep learning convolutional neural networks, 18, 202 - 203defined. 4 geometric, 18 Riemannian manifolds, 18 vector embeddings, 20-21 degree of networks, 48-49 degree of vertices (degree centrality). See also Katz centrality applications of, 31 community mining, 60 Forman-Ricci curvature, 46 graph filtration, 76, 78-79 graph Laplacian, 50 in-degree and out-degree, 30 k-means clustering, 60, 61 limitations of, 31 measuring in social networks, 41 overview of, 30-31 scale-free graphs, 52

topological dimension, 82-84 triadic closure, 43 dendrograms, 89, 107, 158-160 density of networks disease spread tracking, 69, 71 graph filtration, 77 overview of, 48-49 dependent variables defined, 2 dummy variables, 5 image classification, 203 link functions, 135 regression, 11, 12 supervised learning, 2-3 vertex centrality metrics, 56, 58 dgLARS algorithm, 133-140 credit default prediction, 138-140 cross-validated vs. non-crossvalidated, 136-140 depression prediction, 136-138 overview of, 133-136 poetry analysis project, 186 risk propensity measurement, 134-135 dglars package, 136 diameter of networks graph filtration, 79-80 network comparison, 65-66 overview of, 49 differential geometry, 88. See also dgLARS algorithm differential geometry least angle regression algorithm. See dgLARS algorithm Dijkstra's algorithm, 199 dimensionality curse of, 7, 13-17, 95 defined, 14 reduction of, 95, 119-120, 184 unsupervised learning, 3 directed networks, 19 applications of, 26 authority centrality, 39-40 converting undirected to, 39-40 defined, 26 degree of vertices, 30 edges, 28

directed networks (continued) eigenvector centrality, 34 hub centrality, 39-40 interconnectivity of networks, 48 networks in R, 26-27 PageRank algorithm, 33 Twitter, 17, 26 disaster logistics planning, 142-146 discrete exterior derivatives, 140-146 cohomology, 141, 146 differential forms, 141 disaster logistics planning, 142-146 engineering problems, 146 overview of, 140, 141 social network analysis, 141-142 dist(), 99, 101, 104 distance metrics, 96-116 entropy, 107-110 norm-based distance metrics, 99 - 105overview of, 96-98 shape comparison, 110-116 small dataset simulation, 98-99 Wasserstein distance, 105-107 distributed computing, 194-195 diversity of vertices, 42 Dow Jones Industrial Average (DJIA), 127 - 128dummy variables, 5-7 categorical variables, 5-6 geometry of, 5-7 multicollinearity, 7 D-Wave, 197

E

Ebola outbreak, 29 eccentricity of vertices diameter and, 49 graph filtration, 80 overview of, 45 radius and, 49 edge lists, 26–27 edges adjacent, 28 closeness of vertices, 31 degree of vertices, 30 density of networks, 48–49

depiction of, 25 directed and undirected networks, 17, 26 disease spread tracking, 67-69, 70 diversity of vertices, 42 Erdös-Renyi graphs, 51-52 Euler characteristic, 87 Forman-Ricci curvature, 46-47 graph filtration, 76–78, 80 intracommunity and intercommunity edges, 61 link prediction in social media, 58 - 59network comparison, 65 overview of, 25 path length, 28 weighted and unweighted networks, 28-29 efficiency of networks, 49 efficiency of vertices, 44-45 eigen(), 50 eigenvalues, 33, 49-50 eigenvectors, 33, 49-50 eigenvector centrality, 33-39 authority and hubness, 35 Katz centrality and, 36 measuring in social networks, 38-39 overview of, 33-34 PageRank centrality and, 34-35 elastic net regression, 101 EM algorithm, 171 entities named entity recognition, 180 spread of, 66-68 vertices and edges, 25 entropy, 107-110 diversity of vertices, 42 relative. 135 Shannon entropy, 42 epidemiology centrality, 30 disease spread tracking, 67-74 spectral radius, 50 Erdös-Renyi graphs, 51-52 network comparison, 65-66 persistent homology, 90-93

Euclidean distance curse of dimensionality, 14, 16 k-nearest neighbors, 118-119, 186 multidimensional scaling, 121, 122 network distance and, 29 norm-based distance metrics. 99-103 spreadsheet geometry, 9 Euclidean vector space curse of dimensionality, 15, 16 defined. 8 manifolds, 119 multidimensional scaling, 120-122 shape comparison, 113-116 spreadsheet geometry, 8 tangent spaces, 133 vector embeddings, 21 Euler characteristic, 87-88 Betti numbers, 87 Gauss-Bonnet theorem, 88 maximal cliques, 87 negative, 87 simplicial complexes, 87 expectation-maximization (EM) algorithm, 172

F

Facebook bot account detection, 18, 24 degree of vertices, 30 global network metrics, 47 link prediction, 58 network distance, 24 text search, 20 undirected networks, 17, 26 fast greedy clustering, 61-64 feature importance, 3 filtration graph filtration, 76-81 network filtration, 75-94 Fisher information, 134-135 flag complexes, 82–83 fMRI. See functional magnetic resonance imaging Forman-Ricci curvature differential geometry, 88 disrupting communication and disease spread, 72-73

overview of, 45–47 stock market change point detection, 129 Forman–Ricci flow, 73–74 fractals, 125–129 Fréchet distance, 111–112 functional magnetic resonance imaging network comparison, 64, 66 persistent homology, 90–93

G

gamma, 70 gate-based circuits, 196-197 Gauss-Bonnet theorem, 88 Gaussian distribution, 172–173 Gaussian noise, 14 gcd(), 199-200 genomics, 17, 88, 136 datasets, 86, 101, 119 geodesics, 33, 44, 121 tangent spaces and, 96–97 geometric deep learning, 18 geospatial data, 8-9, 9 gerrymandering, 24 global network metrics, 47-51 graph filtration, 79 interconnectivity of networks, 48-49 network comparison, 93 spectral measures of networks, 49 - 51spreading processes on networks, 49 Google image search, 202-203 PageRank algorithm, 33 PageRank centrality, 34-35 text search, 20 GPT-3. 189 gradient descent, 169-171 gradient flow, 152 graph diameter, 79–80 graph filtration, 76–81 brain imaging studies, 80 degree centrality, 78-79 graph diameter, 79-80 graph Laplacian, 50-51 graph theory, 24, 195, 198-199

greatest common denominator, 199–200 greedy algorithms, 61–64 Gromov-Hausdorff distance, 113–116, 160 gromovlab package, 114

H

Hamel basis, 133 Hamming distance, 163-164 harmonic flow, 152 Hausdorff distance, 113, 160 hclust().156 heatmaps, 11, 89 help(), xxii hierarchical clustering, 3, 89, 156-158.163 Hodge-Helmholtz decomposition, 152 HodgeRank, 152 homology, 85-94 Betti numbers, 85-86 cohomology, 140-141, 146 defined, 85 differential geometry, 88 Euler characteristic, 87-88 persistent homology, 88-89, 129, 159.195 measurement validation and, 160-161 network comparison and, 89-94, 155-156 subgroup mining and, 156-157, 159, 162 homotopic Fréchet distance, 111 homotopy algorithms, 167-177 comparing, 173 homotopic, defined, 167 homotopy-based regression, 169-174 logistic regression vs. homotopybased regression, 174-176 overview of, 167-168, 169 hub centrality community mining, 60 defined, 35 graph filtration, 77 measuring in social networks, 39 - 42unsupervised learning, 60

hyperparameters classification, 11 defined, 3 overfitting, 13 regression, 12

I

IBM, 197 igraph library, 27, 29-30, 35, 43, 52, 85, 87, 90, 165 cluster edge betweenness(), 64default value, 39 eccentricity(), 49 edge density(), 48, 69efficiency(), 49 sample gnp(), 51 sample pa(), 52 sample smallworld(), 52 sir(),70 spectrum(), 50 transitivity(), 49 image classification convolutional neural networks, 18 - 20quantum computing approaches, 200-204 image data convolutional neural networks, 18 - 19.20Forman-Ricci flow, 73-74 overview of. 18-20 persistent homology, 88-89 in-degree, 30 independent variables decision trees, 11 defined. 2 dgLARS algorithm, 135 dimensionality, 14, 101 dummy variables, 5, 7 geometric deep learning, 18 image classification, 19, 203 multicollinearity, 7 supervised learning, 2-3 unsupervised learning, 3 vertex centrality metrics, 57-58 instances. See data points interconnectivity of networks, 40, 44, 47 - 49, 52

inverse Hamming distance, 164 Isomap, 121–122 isometric embedding, 113, 116

K

Katz centrality eigenvector centrality and, 35 measuring in social networks, 39 overview of, 35 k-means clustering, 3 community mining, 59-60 vs. Mapper algorithm, 161, 163 k-nearest neighbors (k-NN), 2-3 decision boundaries, 10, 11 dummy variables, 7 metric geometry, 116-119 overfitting, 13 poetry analysis project, 186 regression, 11-12 knnGarden package, 117 KONECT Windsurfer Network, 69-71 Kullback-Leibler divergence dgLARS algorithm, 135 entropy, 108-110 t-distributed stochastic neighbor embedding, 124

L

Lasso algorithm homotopy-based optimization, 172.174-176 Lasso regression, 101 poetry analysis project, 190 lasso2 package, 172 linear dependence, 7 linear regression, 2-3 dgLARS algorithm, 136, 138 making predictions with social media network metrics, 57 multicollinearity, 7 supervised regression, 12 vs. homotopy-based regression, 173-174.176 link functions, 136 link prediction, 58-59 locally linear embedding (LLE), 122-124 local optima, 169-172, 174, 176

logistic regression, 2 curse of dimensionality, 16 decision boundaries, 10, 11 dgLARS algorithm, 140 link functions, 136 multicollinearity, 7 overfitting, 13 vs. homotopy-based regression, 174–176 Louvain clustering, 62–64

M

machine learning categories, 2-4 matching algorithms, 4 supervised learning, 2-3 unsupervised learning, 3 mahalanobis(), 103 Mahalanobis distance, 103-104, 105 Manhattan distance, 100-102 k-nearest neighbors, 116, 118–119 multidimensional scaling, 121, 122 subgroup mining, 156–157 manifold hypothesis, 95 manifold learning, 119–125 Isomap, 121–122 locally linear embedding, 122-124 multidimensional scaling, 120-122 vs. principal component analysis, 119 t-distributed stochastic neighbor embedding, 124-125 manifolds defined, 8 distance metrics, 96, 98, 194 Gauss-Bonnet theorem, 88 homology, 85, 88 Riemannian manifolds, 18 tangent spaces, 132-133 Mapper algorithm, 161–166 stepping through, 162–163 using TDAmapper to find cluster structures in data, 163–166 matching algorithms, 4 Matlab, 152 maximal cliques, 82-84 disaster logistics planning, 144 Euler characteristic, 87 quantum network algorithms, 197

MDS (multidimensional scaling), 120 - 122median(), 70metric geometry, 98 fractals, 125-129 k-nearest neighbors, 116-119 manifold learning, 119-125 Minkowski distance, 101-102, 121 MNIST dataset, 204 model fit dgLARS algorithm, 137-138 homotopy-based regression, 172 nonlinearity, 147, 149 modularity, 61-64 Morse functions, 162 multicollinearity, 7, 133 multicore approaches, 193-195 multidimensional scaling (MDS), 120 - 122

N

named entity recognition, 180 natural language processing pipelines, 180-181 topology-based tools, 188-191 network analysis, 55-74 spread analysis, 66-74 disease spread tracking between towns, 67-69 disease spread tracking between windsurfers, 69-72 disrupting communication and disease spread, 72-74 supervised learning, 56-59 diary entry prediction in social media, 56-58 link prediction in social media, 58-59 unsupervised learning, 59-64 applying clustering to the social media dataset, 59-60 community mining, 61-64 network comparison, 64-66 network depth, 31, 33 network distance, 28-29 applications of, 24, 28-29 defined, 28

link prediction in social media, 59 persistent homology, 91-93 weighted and unweighted networks, 28 network filtration, 75-94 graph filtration, 76-81 homology, 85-94 Betti numbers, 85-86 Euler characteristic, 87-88 persistent homology, 88-89 comparison with, 90-94 simplicial complexes, 81-85 network geometry, 23-54 directed and undirected networks, 18 global network metrics, 47-51 interconnectivity of a network, 48-49 spectral measures of a network, 49-51 spreading processes on a network, 49 models for real-world behavior, 51 - 53Erdös-Renyi graphs, 51-52 scale-free graphs, 51-52 Watts-Strogatz graphs, 52-53 network science, 24-25 network theory, 25-29 directed networks, 26 networks in R. 26-27 paths and network distance, 28 - 29overview of. 17-18 Riemannian manifolds, 18 vertex metrics, 30-47 centrality, 30-42 diversity of vertices, 42 eccentricity of vertices, 45 efficiency of vertices, 44-45 Forman-Ricci curvature, 45-47 triadic closure, 43-44 networks, defined, 8 neural networks, 2 convolutional, 18-19, 202-204 decision boundaries, 10, 11, 13 homotopy-based optimization, 172

quantum, 203-204 topology-based NLP tools, 189 neuroscience and brain imaging graph filtration, 80 network comparison, 64 persistent homology, 90-93 NLP. See natural language processing NLTK toolkit, 181, 183-184 nodes. See vertices nonconvex objects, 147-148 nonlinear algebra, 146-149 convex optimization problems, 148 nonconvex objects, 147-148 numerical algebraic geometry, 147 - 149vs. linear algebra, 146-147 nonlinear spaces, 132-140 dgLARS algorithm, 133–140 credit default prediction, 138 - 140depression prediction, 136-138 overview of, 133-136 tangent spaces, 132-133, 135 nonselected predictors, 135 norms, defined, 99 numerical algebraic geometry, 147-149 numerical spreadsheets. See spreadsheets

0

observations. *See* data points open triangles, 43 out-degree, 30 outlier detection, 24 network comparison, 66 stealth outliers, 104 subgroup mining, 159 overfitting curse of dimensionality, 14, 16–17 overview of, 13

P

PageRank algorithm, 33, 198 PageRank centrality, 34–35 community mining, 60 link prediction in social media, 59

measuring in social networks, 38-39, 41, 42 paths, defined, 28 PCA (principal component analysis), 3, 119 perplexity, 124-125 Perron-Frobenius theorem, 34 persistence diagrams measurement tool validation, 159 - 161persistent homology, 89, 91-93 poetry analysis project, 187-188 shape comparison, 110 subgroup mining, 157 persistent homology, 88, 155-159 measurement tool validation, 160 - 162multicore approaches, 195 network comparison, 90-94 outlier detection, 159 overview of, 88-89 stock market change point detection, 129 subgroup mining, 156-159 PET (positron emission tomography), 64,90-93 philentropy package, 108 plot persist(), 157 poetry analysis project, 180-188 analysis in R, 184-188 forms of poetry, 181-182 natural language processing pipeline, 180-181 normalizing vectors, 184 tagging parts of speech, 183-184 tokenizing text data, 183 topology-based NLP tools, 188 point clouds, 82, 88-89, 146, 156-157, 162 - 163Poisson distribution, 56-57 Poisson regression, 57, 58 polynomials, 147-148 positron emission tomography, 64, 90–93 predictors. See independent variables pretrained transformer models, 189 principal component analysis, 3, 119

probability density functions, 106-108, 109 probability distributions entropy, 107-110 t-distributed stochastic neighbor embedding, 124 Wasserstein distance, 105-107 propagation analysis. See spread analysis Pythagorean distance, 100. See also Euclidean distance Python BERT model, 189 distributed computing, 194 help resources for, xxiii natural language processing, 180 - 181poetry analysis project, 183-184 quantum computing, 196-199

Q

quantum algorithms, 197-200, 204 quantum annealing, 197 quantum approximation optimization algorithms (QAOA), 198 quantum classifiers, 203-204 quantum computing approaches, 193 - 205image classifiers, 200-204 quantum algorithm development, 199 - 200quantum network algorithms, 197 - 199qubit-based model, 196–197 qumodes-based model, 197 quantum maximum flow and minimum cut algorithms, 197–198 QuantumOps package, 198-200, 203 - 204qubits circuit-centric quantum classifiers, 203 quantum network algorithms, 198 qubit-based model, 196-197 gumodes-based model, 197 Quora dataset, 136, 156, 160, 163, 166, 174

R

R (programming language) downloading, xxi-xxii help resources for, xxii installing, xxii installing packages, xxii vignettes, xxii-xxiii radius of networks, 35, 49-50 random forests, 2 decision boundaries, 11 regression, 11-12 random walk algorithms diversity of vertices, 42 eigenvector centrality, 34, 38 link prediction, 59 map networks, 24 PageRank centrality, 35, 38-39 quantum algorithms, 198 walktrap algorithm, 61-64 redundant predictors, 133, 135 regex tokenizer, 183 regression defined, 2 dummy variables, 5-6 elastic net regression, 101 homotopy-based regression, 169 - 176journal ranking, 66 linear regression, 2-3, 12 dgLARS algorithm, 136, 138 making predictions with social media network metrics, 57 multicollinearity, 7 vs. homotopy-based regression, 173-174, 176 logistic regression, 2 curse of dimensionality, 16 decision boundaries, 10, 11 dgLARS algorithm, 140 link functions, 136 multicollinearity, 7 overfitting, 13 vs. homotopy-based regression, 174-176 overview of, 11-12 Poisson regression, 57, 58

reinforcement learning, 4 Ricci curvature, 45. See also Forman–Ricci curvature Riemannian manifolds, 18 Rigetti, 197 RStudio, xxii

S

SBERT (sentence-based Bidirectional **Encoder Representations** from Transformers), 189 scale-free graphs, 52-53 network comparison, 65-66 persistent homology, 90-93 scatterplots, 11, 100, 119, 171 selected predictors, 135 Shannon entropy, 42 shape comparison, 110–116 Fréchet distance, 111-112 Gromov-Hausdorff distance, 113 - 116Hausdorff distance, 113 simplicial complexes, 81-85 Čech complexes, 82 cochains, 141 Euler characteristic, 87 filtering, 82 flag complexes, 82-83 Mapper algorithm, 162 maximal cliques, 82-84 overview of, 81-82, 84 persistent homology, 88-89, 156 - 157topological dimension, 82-84 Vietoris-Rips complexes, 82 simulated annealing, 62 single-linkage hierarchical clustering, 89, 156, 163 SIR model. See susceptible-infectedresistant model **SMOTE** (Synthetic Minority Oversampling Technique), 8 social networks algebraic connectivity, 50 bot account detection, 18, 24, 64, 66 centrality, 30-42

clustering vertices, 59-64 diary entry prediction, 56-58 directed and undirected networks, 17-18 discrete exterior derivatives, 141-142 Forman-Ricci curvature, 46, 47 graph filtration, 76-80 influencers, 24, 30-31 link prediction, 58-59 network depth, 33 simplicial complexes, 82-83, 84 spread of misinformation, 9, 66-67 subgroup mining, 156-157 transitivity, 43, 44 triadic closure, 43 vertex vs. global metrics, 47 Watts-Strogatz graphs, 52 spectral gap of networks, 50 spectral measures of networks, 49-51 spectral radius, 35, 49-50, 79 spinglass algorithms, 62 spinglass clustering, 62-64 spread analysis, 66-74 disease spread tracking between towns, 67-69 between windsurfers, 69-72 disrupting communication and disease spread, 72-74 spreading processes on networks, 49 spreadsheets adjacency matrices, 27 classification, 10 dummy variables, 5-7 Euclidean vector space, 8 geometry of, 8-10 geospatial data, 8-9 structured data, 4 stats package, 99 stock market change point detection, 127-129 strength (weighted degree) of vertices, 30, 82 structured data, 4-17 defined, 4 dummy variables, 5-7 numerical spreadsheets, 8-10

structured data (continued) supervised learning, 10-17 classification, 10-11 curse of dimensionality, 14-17 overfitting, 13 regression, 11-12 subgroup mining Mapper algorithm, 161-166 persistent homology, 156-159 supervised learning, 10-17 algorithm viewed as function, 2-3 classification. 10-11 combining with unsupervised learning, 3 curse of dimensionality, 14-17 overfitting, 13 overview of, 2-3 prediction diary entry prediction in social media, 56-58 link prediction in social media, 58-59 regression, 11-12 training and testing data, 3 support vector machines, 2, 172 susceptible-infected-resistant model defined, 68 disease spread tracking between towns, 67-69 windsurfers, 69-72 disrupting communication and disease spread, 72-74 Synthetic Minority Oversampling Technique (SMOTE), 8

T

tabular data. *See* structured data tangent lines, 96, 132–133 tangent planes, 96, 132, 133 tangent spaces, 96, 124, 131–135, 149 Euclidean space and, 113 geodesics and, 96 linear algebra and, 133 nonselected predictors, 135 redundant predictors, 135

targets. See dependent variables TDA. See topological data analysis TDAmapper package, 163–166 TDAstats package, 156-157, 161 t-distributed stochastic neighbor embedding (t-SNE), 124-125, 185-186, 189-190 test error curse of dimensionality, 14 overfitting, 13 testing data defined. 3 overfitting, 13 text data overview of, 20-21 poetry analysis project, 179-191 vector embeddings, 20-21 topological data analysis, 159-166 graph filtration, 76 Mapper algorithm, 161-166 measurement tool validation, 159 - 161multicore approaches, 194–195 persistent homology, 155-159 subgroup mining, 156–159 topological dimension, 82-85 tori, 86, 168 training data, defined, 3 training error, 13 transitivity community mining, 60 global network metrics, 49 vertex metrics, 43-45 Treebank tokenizer, 183 triadic closure, 43-44, 79 triangle inequality condition, 101 TSdist package, 111 t-SNE (t-distributed stochastic neighbor embedding), 124-125, 185-186, 189, 190 Twitter, 17–18, 26, 30–31

U

UCI credit default dataset, 138–139 underfitting, 13–14 undirected networks, 19 converting to directed, 39-40 defined, 26 Facebook, 17, 26 interconnectivity of networks, 48 networks in R, 27 unstructured data, 17-21 image data, 18-20 network data, 17-18 text data, 20-21 unsupervised learning, 59 clustering vertices, 59-64 evaluating quality outcome of clusters, 61-62 exploring networks with random walks. 61 overview of, 59-60 running clustering algorithms, 62-64 spinglass clustering, 62 combining with supervised learning, 3 overview of, 3 unweighted networks, 27-28, 30-32, 34 - 35

V

vector embeddings, 20-21 vertex metrics, 30-47 centrality, 30-42 authority centrality, 35 betweenness of vertices, 32-33 closeness of vertices, 31 degree of vertices, 30-31 eigenvector centrality, 33-34 hub centrality, 35 Katz centrality, 35 measuring centrality in example social network, 36 - 42PageRank centrality, 34-35 community mining, 59-60 defined, 47 diversity of vertices, 42 eccentricity of vertices, 45 efficiency of vertices, 44-45 Forman-Ricci curvature, 45-47

prediction diary entry prediction in social media, 56-58 link prediction in social media, 58-59 triadic closure, 43-44 vertices betweenness of, 32-33, 64 closeness of, 31 community mining, 59-64 degree of, 30-31 depiction of, 25 directed and undirected networks, 26 distance between, 28 diversity of, 42 eccentricity of, 45, 49 efficiency of, 44-45 neighboring, 28 overview of, 25 strength of, 30 Vietoris-Rips complexes, 82

W

walktrap algorithm, 61-64 Wasserstein distance, 93, 105-107 Watts-Strogatz graphs, 52-53, 61 network comparison, 65-66 persistent homology, 90-93 wave functions, 197 weighted degree (strength) of vertices, 30, 82 weighted networks adjacency matrices, 27 degree of vertices, 30 disease spread tracking, 67-69 diversity of vertices, 42 eigenvector centrality, 34 graph filtration, 76–81, 84–85 PageRank centrality, 35 paths and network distance, 28-29 simplicial complexes, 84-85 strength of vertices, 30

X

Xanadu, 197 **Y**

YouTube, 4