# Index

#### A

Advanced Encryption Standard (AES), 68 Amplitude-frequency responses (AFRs), 16, 19 Approximate solutions error measure, 165–167 parabolic profile, 165 profile exponent, 167 refined velocity profile, 168 stress field, 168 3D solution profiles, 168–169 velocity field, 168–172 Aquifers, 211

#### B

Basis functions (BFs), 34-35 Batch effects adjacency matrix, 35-36 biological networks, 35 classified objects, 36 coordinate descent algorithm, 25 cyanobacteria, 26 empirical copula, 27-28 estimated regression coefficients, 35 F-measure, 36-37 GGM graphical lasso approach, 29-30 multivariate normal distribution, 28 parameters, 29 partial correlation, 28-29 PBM, 31–32 p-dimensional vector, 28

precision matrix, 28 probability distribution function, 28 LMARS method, 35-36 logistics regression, 26 MARS, 33-35 MCC, 36-37 misclassified objects, 36 neighborhood selection method, 25 precision, 36-37 programming language, 35 scale-free network, 35 spline functions, 32-33 water reservoir, 26 Bayesian information criterion (BIC), 25 Biochemical networks CART complete decision trees, 90 DRUGSURV database, 98-99 Gillespie algorithm, 98 node splitting, 92 proteins, 98-99 simulated data, 95-97 splitting rules, 90-92 stopping tree growth, 92–93 tree construction, 90 directed/undirected edges, 87 GGM ArrayExpress database, 97 conditional independence, 88 GeneMANIA database, 97, 99 genes, 88 inference, 89 ovarian-cervical cancer, 98

© Springer International Publishing AG, part of Springer Nature 2019 K. Taş et al. (eds.), *Mathematical Methods in Engineering*, Nonlinear Systems and Complexity 24, https://doi.org/10.1007/978-3-319-90972-1 Biochemical networks (*cont.*) *p*-dimensional random vector, 88 precision matrix, 89 proteins, 88, 97–98 regulation, 88 simulated data, 93–97 Block coordinate descent algorithm, 25

# С

Calkin-Gorbachuk method, 76-78 Caputo fractional derivative backward approach, 202-203 definition, 201-202 forward approach, 203 second-order approximation, 203-205 Classical diffusion model, 158 Classification and regression tree (CART) complete decision trees, 90 DRUGSURV database, 98-99 Gillespie algorithm, 98 node splitting, 92 proteins, 98–99 simulated data, 95-97 splitting rules, 90–92 stopping tree growth, 92-93 tree construction, 90 Complex systems functional equation arbitrary periodic function, 6, 8 discrete equation, 19 external "force," 6-7 FLSM. 5 found functions, 7-8 Fourier decomposition, 4 IM. 3-4 imposed fractal experiments, 5-6 principal difference, 5 Prony decomposition, 4-5 quasiperiodic solutions, 4 quasi-reproducible measurements, 5-6 self-consistent solution, 5 separate periodic function, 4 special functions, 23 unknown functions averaging procedure, 9-10 closed system equations, 8 fractional calculus and fractal geometry, 10 functional dispersion, 9 quadratic equation, roots of, 7 VAGs clusterization procedure, 14-23 dimensionless potential, 11, 13-14

GCE. 10-11 reduction procedure, 11, 14 self-similar, 11 three incident points, 11 uniform logarithmic scale, 11-13 voltammetric analyzer IVA-5, 10 Conic quadratic problem, 135 Convex quadratic programming (CQP) problem Cholesky decomposition, 133 continuous optimization, 133 dual problem, 134 inverse problem, 133 IPMs. 135 IRR. 132 L2-penalty, 132-133 optimization problem, 133-134 primal dual optimal solution, 134 Coordinate descent algorithm, 25 Covariance selection problem, see Gaussian graphical model (GGM) Crank-Nicolson approach, 200-201, 203-204 Cryptic text, 67 Cryptography AES. 68 ASCII code decryption, 71-73 encryption, 69-71, 73 confidential data, 68 confidentiality of communications, 68 exponential function, 68 extended power series transformation, 69 flow diagrams, 68 Laplace transformation, 68, 74 non-secure channels, 67 numerical values, 69 privacy of applications, 67 symmetrical cryptosystem, 68

# D

Double integration method (DIM) boundary condition, 158 with fractional-order mixed time-space derivative, 161 HBIM approach, 159 with integer-order mixed time-space derivative, 160–161

# Е

Exact travelling wave solutions fractal Boussinesq equation, 185–189

fractal diffusion equation, 178–179 fractal KdV, shallow water surfaces, 180 - 185fractional-order model, 157 integer-order model, 156-157 Exponential cubic B-spline (ECB-spline) function collocation method, 44 Crank-Nicolson scheme, 44 defined, 42-43 first and second derivatives, 44 linearization technique, 44-45 Neumann boundary conditions, 45 nonzero functional values, 44 numerical solutions approximate solutions, 46-48 efficiency and accuracy, 46 initial conditions, 47 oscillation movement, 48-50 parameters, 46-47 projected solutions, 46, 48, 50 relative errors, 46-48 partial differential equations, 42 problem domain, knots, 42-44 septa-diagonal system, 45 Thomas algorithm, 45-46

#### F

False positive (FP), 36 Fault-tolerant control, see (<sup>13</sup>C) Isotope separation cascade Ferroelectric materials, see Fractional operators Finite element method, see Schnakenberg model Fourth-order differential equation, 157 Fox-Wright function, 214-215 Fractional derivatives, see Nonlinear model Fractional dielectric permittivity models (Cole-Cole) dielectric coefficient, 144-145 first-order derivative model, 147, 151 frequency bandwidth, 147 Havriliak-Negami relaxation, 140-141 permittivity vs. frequency, 140 simulation parameters, 147, 149 Fractional integration Erdêlyi-Kober fractional integral operators, 216numerical values, 218-221 results, 216-218

Riemann-Liouville fractional integral operators, 215 Saigo hypergeometric fractional integral operators, 215, 218, 219, 221-224 Fractional kinetic equation destruction rate and production rate, 231 graphical interpretation, 241-242 Laplace transform, 232 mathematical model, 230-231 Mittag-Leffler function, 235-237 numerical solutions, 237-241 Riemann-Liouville integral operator, 231 solutions of generalized equations, 232 - 235spatial fluctuations and inhomogeneities, 231 standard kinetic equation, 231-232 Fractional operators dielectric relaxation, 140 hysteresis loops, 140 nonlinear model (see Nonlinear model) polarization behavior, 140 soft piezo ceramic composition, 145-146, 149 Fractional order PD controllers modelling errors, 245 parameters, 247 performance specifications, 247 process modulus and phase experimental scheme, 250-251 frequency responses, 250 input and output signals, 248–250 Laplace transform, 250 phase slope, 251 real and imaginary parts, 251 user-specified frequency, 248 smart beam continuous-to-discrete-time operator, 254 derivative gain, 253 efficiency, 254 experimental results, 254-255 input and output signals, 252 mathematical model, 247-248 oscillations, 255 **Oustaloup Recursive Approximation** method, 254 swept sine disturbance signal, 254-255 transfer function, 247 Free parameter, 43 Frozen Front Approach (FFA), 157, 169 Functional least square method (FLSM), 5

#### G

Gaussian copula, 26 Gaussian graphical model (GGM) ArrayExpress database, 97 conditional independence, 88 GeneMANIA database, 97, 99 genes, 88 graphical lasso approach, 29-30 inference, 89 multivariate normal distribution, 28 ovarian-cervical cancer, 98 parameters, 29 partial correlation, 28-29 PBM, 31-32 p-dimensional random vector, 28, 88 precision matrix, 28, 89 probability distribution function, 28 proteins, 88, 97-98 regulation, 88 simulated data, 93-97 Generalized Lasso (G-Lasso) problem, 124 COP problem Cholesky decomposition, 133 continuous optimization, 133 dual problem, 134 inverse problem, 133 IPMs, 135 IRR. 132 L<sub>2</sub>-penalty, 132–133 optimization problem, 133-134 primal dual optimal solution, 134 PRSS GSVD, 130 maximum descent, 132 nondifferentiable objectives, 131 objective function, 131 penalty function, 130-131 single active constraint, 131–132 Tikhonov regularization problem, 129 - 130Generalized Mittag-Leffler function, 157 Generalized singular value decomposition (GSVD), 130 Gini rules, 90-91 Gram-Schmidt orthogonalization process, 107 Gray-Scott autocatalysis system, 42

#### H

Havriliak-Negami relaxation, 140–141 Heat-balance integral method (HBIM), 159, 161–162 See also Integral-balance method Hybrid model coefficient, 74 decryption, 71–73 encryption, 69–71, 73 Hyperbolic equations, 193

# I

Indirect discretization method, 254 Integral-balance method approximate flow profile, 163 approximate solutions error measure, 165-167 parabolic profile, 165 profile exponent, 167 refined velocity profile, 168 stress field, 168 3D solution profiles, 168-169 velocity field, 168-172 assumed profile, 160 Deborah number, 163-164 DIM boundary condition, 158 with fractional-order mixed time-space derivative, 161 HBIM approach, 159 with integer-order mixed time-space derivative, 160-161 elastic and viscous effects, penetration depths, 164 finite penetration depth, 158 Leibniz rule, 158 Integral transform beta transform, 224-226 Laplace transform, 227-228 Whittaker transform, 228–230 Interior point methods (IPMs), 135 Intermediate model (IM), 3-4 (<sup>13</sup>C) Isotope separation cascade column cascade, 55 common distillation process, 55-56 communication network, 61 complex chemical process, 54 decentralized approach, 59 fractional order controllers, 60-61 gain crossover frequency, 59 gaseous upstream, 56 hardware redundancy, 53 input-output pair, 59-60 liquid downstream flow, 56 LMI-based optimization, 54 natural concentration, 55 NIRDIMT, 55

#### Index

NPC inverter system, 54 phase margin, 59 PI controller, 59 PID controller, 54 productivity losses, 53-54 pure carbon monoxide (CO), 55-56 RGA. 59 robustness, 59 robust positioning controller, 54 simulation results first and second column fault, 61, 64 first column boiler, 61, 63 first column condenser. 61–62 transducers, 56 transfer function matrix, 56-59 Iterated ridge regression (IRR), 132

#### K

Kinematical tensors, 154 Korteweg-de Vries (KdV) equation, 175

#### L

Lasso-based MARS (LMARS) method, 35-36 Limit cycle behavior, 41 Linear regression model, 123 Local fractional derivative (LFD) defined, 176-177 exact travelling wave solutions fractal Boussinesq equation, 185-189 fractal diffusion equation, 178–179 fractal KdV, shallow water surfaces. 180-185 properties, 177 Local fractional integral (LFI), see Local fractional derivative (LFD) Local fractional partial differential equations (PDEs) fractal phenomena, 175 LFD and LFI defined, 176-177 exact travelling wave solutions of fractal Boussinesq equation, 185-189 exact travelling wave solutions of fractal diffusion equation, 178-179 exact travelling wave solutions of fractal KdV, 180-185 properties, 177 non-differentiable functions Cantor sets, 176-177 Korteweg-de Vries equation, 175 travelling wave transformation technology, 177-178

#### М

Matthews correlation coefficient (MCC), 36 - 37Maximally accretive extensions boundary condition, 81 Calkin-Gorbachuk method, 76-78 continuous spectrum, 84-86 dissipative extension, 77, 78, 80 Hilbert space, 75-76 linear multipoint differential operator expression, 75-76 point spectrum, 81-83 quasi-differential expression, 76-77, 81 residual spectrum, 83-84 space of boundary values for the operator, 78 - 80vector-functions, 75-76 Maximal operator, 76 Mechanical dry frictions, 142 Minimal operators, see Maximally accretive extensions Mixed time-space derivative constitutive equations, 154 exact solutions fractional-order model, 157 integer-order model, 156–157 HBIM, 161-162 integral-balance method approximate flow profile, 163 approximate solutions, 165-172 assumed profile, 160 Deborah number, 163-164 DIM. 158-161 elastic and viscous effects, penetration depths, 164 finite penetration depth, 158 Leibniz rule, 158 start-up flows, 153 Stokes' first problem, 155-156 Monte Carlo studies, 36 Multiscale characterization dielectric relaxation, 140 hysteresis loops, 140 nonlinear model (see Nonlinear model) polarization behavior, 140 soft piezo ceramic composition, 145-146, 149 Multivariate adaptive regression spline (MARS), 33-35 exterior point methods, 122 G-Lasso regularization problem, CQP Cholesky decomposition, 133 continuous optimization, 133 dual problem, 134

Multivariate adaptive regression spline (MARS) (cont.) IPMs, 135 IRR. 132 L<sub>2</sub>-penalty, 132–133 optimization problem, 133-134 primal dual optimal solution, 134  $L_1$ -regularization backward stepwise algorithm, 126 continuous optimization, 124 first/second derivative, 123 forward stepwise algorithm, 125-126 generalized cross-validation, 125 high-dimensional input, 124 interaction basis functions, 125 lack-of-fit criterion, 125 Lasso method (see Generalized Lasso problem) least squares estimator, 123 linear basis function, 124 linear regression model, 123 nonparametric regression model, 125 penalty function, 124 PRSS (see Penalized residual sum of squares problem) random error vector, 123 Ridge estimator, 123 Tikhonov regularization problem, 123 L2-regularization, 123-124 MATLAB regularization toolbox, 122

# Ν

Neighborhood selection method, 25 Nesterovs first-order method, 25 Newtonian fluids, 157 Non-differentiable functions (NFs) Cantor sets, 176-177 Korteweg-de Vries equation, 175 travelling wave transformation technology, 177-178 Non-entire derivatives, see Nonlinear model Nonlinear local fractional ordinary differential equation, 180-185 Nonlinear model Cole-Cole model dielectric coefficient, 144-145 first-order derivative model, 147, 151 frequency bandwidth, 147 Havriliak-Negami relaxation, 140-141 permittivity vs. frequency, 140 simulation parameters, 147, 149

high-amplitude fractional dielectric hysteresis model dielectric coefficient, 144–145 dynamic contribution, 142–144, 147, 150 quasi-static contribution, 141–142, 147–149 static (instantaneous) contribution, 144 weak electric field, 143–144 Non-newtonian fluid, *see* Mixed time-space derivative Nonparametric approach, 95

## 0

Ovarian cancer, 97, 98, 100

## P

Penalized residual sum of squares (PRSS) problem GSVD, 130 maximum descent, 132 nondifferentiable objectives, 131 objective function, 131 penalty function, 130–131 single active constraint, 131–132 Tikhonov regularization problem, 129–130 Piecewise linear knot, 33 Precision matrix, 89 Probabilistic Boolean model (PBM), 31–32

# R

**RBMXL1**, 100 Relative Gain Array (RGA), 59 Relaxation in the glassy state, 157 Reproducing kernel method (RKM) analytical solution, 104 approximate solutions, 108–117 coefficients, 117-119 definition, 104-106 nonlinear system, 103-104 probability and statistics, 104 time scales, 104 Reproducing property, 104 Ridge regression, 123 Riemann-Liouville differential operator, 154, 157 Riemann-Liouville fractional derivative compact form, 198-200 definition, 194–195

#### Index

forward upwind, 195 numerical solutions, 207–211 second-order upwind, 195–198

# S

Schnakenberg model biological areas, 41 Dirichlet/Neumann boundary conditions, 42 ECB-spline function collocation method, 44 Crank-Nicolson scheme, 44 defined, 42-43 first and second derivatives, 44 linearization technique, 44-45 Neumann boundary conditions, 45 nonzero functional values, 44 numerical solutions, 46-50 partial differential equations, 42 problem domain, knots, 42-44 septa-diagonal system, 45 Thomas algorithm, 45-46 generalized regularized long wave equation, 42 limit cycle behavior. 41 nonlinear term, 41 numerical method, 41-42 parameters, 41 reaction-diffusion model, 42 Second-grade fluid, see Mixed time-space derivative Sequence of the ranged amplitudes (SRA), 16 S-function definition. 214 Fox-Wright function, 214-215 fractional integration Erdêlyi-Kober fractional integral operators, 216 numerical values, 218-221 results, 216-218 Riemann-Liouville fractional integral operators, 215 Saigo hypergeometric fractional integral operators, 215, 218, 219, 221-224 fractional kinetic equations destruction rate and production rate, 231 graphical interpretation, 241-242 Laplace transform, 232 mathematical model, 230-231 Mittag-Leffler function, 214, 235-237 numerical solutions, 237-241

Riemann-Liouville integral operator, 231 solutions of generalized equations, 232 - 235spatial fluctuations and inhomogeneities, 231 standard kinetic equation, 231-232 generalized K-function, 214 generalized M-series, 214 integral transforms, image formulas beta transform, 224-226 Laplace transform, 227-228 Whittaker transform, 228-230 k-gamma function, 213-214 *k*-Pochhammer symbol, 213–214 SINful. 25 Singular value decomposition (SVD), 123 Space of boundary values for the operator, 78-80 Spectrum, 142 Spline functions, 32–33 Spline of the degree 0, 32-33 Spline of the degree 1, 32–33 Squared residuals minimization algorithm, 92 Steady-state models, 26

#### Т

Third-order boundary value problems bounded linear operator, 106-107 complete orthonormal basis, 107-108 harmonic and biharmonic functions, 104 inner product and norm, 104 reproducing kernel function coefficients, 117-119 definition, 104-106 time scales, 104 reproducing kernel Hilbert space analytical solution, 104 approximate solutions, 108-117 definition, 104-106 nonlinear system, 103-104 probability and statistics, 104 Tikhonov regularization problem, 123 True negative (TN), 36 True positive (TP), 36

#### U

Upwind numerical scheme advection equation, 205–207 Caputo fractional derivative backward approach, 202–203 Upwind numerical scheme (*cont.*) definition, 201–202 forward approach, 203 second-order approximation, 203–205 Crank-Nicolson approach, 200–201 flow direction, 194 hyperbolic equation, 193 Riemann-Liouville fractional derivative compact form, 198–200 definition, 194–195 forward upwind, 195 numerical solutions, 207–211 second-order upwind, 195–198

#### V

Vibration suppression airplane wings, 246 fractional order PD controllers, autotuning approach parameters, 247 performance specifications, 247

process modulus and phase, 248-251 smart beam, 247-248, 252-255 transfer function, 247 unwanted vibrations, 256 Voltammograms (VAGs) clusterization procedure AFRs, 16, 19-21 data set. 19, 20 desired triad, 15-17 electrochemistry, 19 initial measurements, 14-15 mean measurement, 16 parameters, 19, 23 results of, 16, 18 SRA, 16 dimensionless potential, 11, 13-14 GCE, 10-11 reduction procedure, 11, 14 self-similar, 11 three incident points, 11 uniform logarithmic scale, 11-13 voltammetric analyzer IVA-5, 10