Index

A-stable, 255
absolute value, 338
absolutely stable, 255
absorption, 202
active constraints, 72
active set
  strongly active set, 73
  weakly active set, 73
active set strategy, 134
Adams, 256
  Adams–Bashforth, 258
  Adams–Moulton, 258
  predictor-corrector Adams methods, 259
adiabatic flash, 186
adiabatic flash loop, 187
adjoint equations, 222, 225, 228, 230, 244, 268
  second order, 284
adjoint sensitivity, 260, 265, 268, 270
  checkpointing, 265, 283
adjoint sensitivity calculations, 262
adjoint sensitivity codes, 283
adjoint sensitivity equations, 253
adjoint variables, 221, 263
algebraically stable, 255, 293
ammonia process optimization, 191
AMPL, 6, 15
AV-stable, 255, 293
Armijo condition, 48, 120
Armijo criterion, 115
Armijo inequality, 165
ASPEN, 15, 283
  augmented Lagrangian function, 110, 167
B-stationarity, 328, 329
  backward difference formula (BDF), 257
  bang-bang control, 230, 317
barrier solutions, 152
barrier problem, 154
basic variables, 161
batch crystallization, 287
batch process, 213, 239
batch process optimization, 218
batch reactor, 217, 219, 229, 268
BDF (backward difference formula), 258, 259, 262
benchmarks, 178
Beowulf cluster, 308
Betts–Campbell problem, 318
BFGS (Broyden–Fletcher–Goldfarb–Shanno), 52, 102, 105, 190, 207
  limited memory update, 45
bilevel optimization problems, 326
bioreactors, 323
blending problems, 207
Bolza problem, 221
boundary value problems (BVPs), 215, 244, 271, 273, 274, 275, 296, 299, 310, 313
  well-conditioned, 275, 299
brachistochrone problem, 247
breakpoints, 296, 317
Broyden update, 43
Broyden–Fletcher–Goldfarb–Shanno (BFGS), 44
Bunch–Kaufman, 97
BVPs (boundary value problems), 215, 244, 271, 273, 274, 275, 296, 299, 310, 313
calculus of variations, 247
car problem, 229, 238
cascading tank problem, 356
catalyst mixing problem, 240
Cauchy point, 165
Cauchy step, 54, 55
centrifuge, 196
chemical process optimization, 181
chemical reactor design, 216
CG (conjugate gradient), 57
Cholesky factorization, 44, 97
cluster, 308
coarse discretizations, 317
collocation, 288, 289
  convergence orders, 314
discretization, 311
equations, 290, 300, 323
  on finite elements, 322
superconvergence, 313
complementarity, 70
  conditions, 78, 134, 151, 226
  constraints, 325
  formulation, 338, 356
  operator, 326
composite-step trust region, 122
condenser, 9, 204
condition number, 22
cone, 75, 78
conjugate direction method of Powell, 31
conjugate gradient (CG), 57
CONOPT, 171, 173, 198, 334, 347, 353, 355
consistency, 254
consistent initial conditions, 234
constrained optimization, 63
constraint qualification, 71, 77, 328
constraints, 1
continuous, 25
continuous function, 25
continuously differentiable, 26
contour plot, 18, 25, 65
descent direction, 139
descent property, 41
descent step, 34
determinant, 20
direct search methods, 30
decision variables, 1
degrees of freedom, 1
derivative-free optimization (DFO), 33
differentiable distribution function (DDF), 345
differential algebraic equations (DAEs), 7, 214, 251
dichotomy property, 273, 275, 276, 300
difference equations, 254
convex, 4, 27, 76
concave, 4
regions, 4
convex optimization problems, 65
convex quadratic programming, 65, 86
convexity, 64
strict, 4
coordinate bases, 101
correction algorithm, 99
crystallization, 298, 323
cubic equations of state, 187, 190
CVP (control vector parameterization), 245, 283
DAE (differential algebraic equation), 246, 271, 306
  fully implicit, 214
  index-1 property, 215
  semiexplicit, 233
  semiexplicit form, 214
  semiexplicit, index-1 DAEs, 259
DAKOTA, 33
DASSL, 279
data fitting, 17
data reconciliation, 200
Davidon–Fletcher–Powell (DFP), 61
DDASAC, 279
decision variables, 1
degrees of freedom, 1
derivative-free optimization (DFO), 33
descent direction, 139
descent property, 41
descent step, 34
determinant, 20
direct search methods, 30
### Index

<table>
<thead>
<tr>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>direct sensitivity, 270</td>
</tr>
<tr>
<td>calculations, 261</td>
</tr>
<tr>
<td>codes, 283</td>
</tr>
<tr>
<td>equations, 253</td>
</tr>
<tr>
<td>simultaneous corrector, 262</td>
</tr>
<tr>
<td>staggered corrector, 262</td>
</tr>
<tr>
<td>staggered direct, 262</td>
</tr>
<tr>
<td>direct transcription, 246, 287, 316, 322</td>
</tr>
<tr>
<td>directional derivative, 115</td>
</tr>
<tr>
<td>discretize then optimize, 244, 310</td>
</tr>
<tr>
<td>distillation case studies, 343</td>
</tr>
<tr>
<td>distillation column, 9, 202</td>
</tr>
<tr>
<td>distillation optimization, 343, 348</td>
</tr>
<tr>
<td>distributed models, 7</td>
</tr>
<tr>
<td>distributed systems, 213</td>
</tr>
<tr>
<td>dogleg method, 55</td>
</tr>
<tr>
<td>DONLP2, 169</td>
</tr>
<tr>
<td>double integrator problem, 229</td>
</tr>
<tr>
<td>dynamic flash optimization, 235</td>
</tr>
<tr>
<td>dynamic optimization, 276</td>
</tr>
<tr>
<td>computational complexity, 303</td>
</tr>
<tr>
<td>direct NLP approach, 245</td>
</tr>
<tr>
<td>direct transcription, 245</td>
</tr>
<tr>
<td>indirect approach, 245</td>
</tr>
<tr>
<td>multiple shooting, 245, 303</td>
</tr>
<tr>
<td>sequential, 303</td>
</tr>
<tr>
<td>sequential approach, 245</td>
</tr>
<tr>
<td>simultaneous approach, 245</td>
</tr>
<tr>
<td>simultaneous collocation, 303</td>
</tr>
<tr>
<td>dynamic optimization problem, 213, 216, 295, 298</td>
</tr>
<tr>
<td>dynamic real-time optimization, 219</td>
</tr>
<tr>
<td>DynoPC, 323</td>
</tr>
<tr>
<td>dynopt, 323</td>
</tr>
<tr>
<td>efficiency factors, 306</td>
</tr>
<tr>
<td>eigenvalues, 21, 42</td>
</tr>
<tr>
<td>eigenvectors, 21, 42</td>
</tr>
<tr>
<td>elastic mode, 332</td>
</tr>
<tr>
<td>ellipsoidal shapes, 24</td>
</tr>
<tr>
<td>energy balance, 7</td>
</tr>
<tr>
<td>enthalpies, 187</td>
</tr>
<tr>
<td>enthalpy balances, 10, 203</td>
</tr>
<tr>
<td>equality constrained NLP problem, 91</td>
</tr>
<tr>
<td>equality path constraints, 232</td>
</tr>
<tr>
<td>equation-based flowsheet, 326</td>
</tr>
<tr>
<td>equation-based process optimization, 326</td>
</tr>
<tr>
<td>equation-oriented optimization models, 193, 200</td>
</tr>
<tr>
<td>equilibrium, 10, 187</td>
</tr>
<tr>
<td>equilibrium relations, 203</td>
</tr>
<tr>
<td>Euler discretization, 356</td>
</tr>
<tr>
<td>Euler–Lagrange equations, 224, 226, 238, 244, 246, 309, 310, 313, 315</td>
</tr>
<tr>
<td>exact penalty functions, 111</td>
</tr>
<tr>
<td>exclusive or (EXOR), 337</td>
</tr>
<tr>
<td>experimental data, 18</td>
</tr>
<tr>
<td>factorization, 97</td>
</tr>
<tr>
<td>failure interior point method, 156</td>
</tr>
<tr>
<td>feasibility, 70</td>
</tr>
<tr>
<td>fermentors, 323</td>
</tr>
<tr>
<td>Filippov system, 349, 360, 361</td>
</tr>
<tr>
<td>high-index constraint, 351</td>
</tr>
<tr>
<td>filter approach, 109, 112</td>
</tr>
<tr>
<td>$f$-type switching condition, 119</td>
</tr>
<tr>
<td>feasibility restoration phase, 120</td>
</tr>
<tr>
<td>feasibility restoration step, 157</td>
</tr>
<tr>
<td>line search method, 119, 148</td>
</tr>
<tr>
<td>local properties, 158</td>
</tr>
<tr>
<td>restoration phase, 113, 137</td>
</tr>
<tr>
<td>switching criterion, 113</td>
</tr>
<tr>
<td>filter trust region, 126, 148</td>
</tr>
<tr>
<td>filterSQP, 169</td>
</tr>
<tr>
<td>first order KKT conditions, 134</td>
</tr>
<tr>
<td>Fischer–Burmeister, 332</td>
</tr>
<tr>
<td>flash tank, 235</td>
</tr>
<tr>
<td>flowsheet, 197</td>
</tr>
<tr>
<td>flowsheet optimization, 184</td>
</tr>
<tr>
<td>fmincon, 169, 252</td>
</tr>
<tr>
<td>FOCUS, 33</td>
</tr>
<tr>
<td>Frobenius norm, 22</td>
</tr>
<tr>
<td>FSQP/CFSQP, 171</td>
</tr>
<tr>
<td>function, 4, 349</td>
</tr>
<tr>
<td>GAMS, 6, 15, 333, 347, 348</td>
</tr>
<tr>
<td>gasoline blending models, 183</td>
</tr>
<tr>
<td>gasoline blending problems, 206</td>
</tr>
<tr>
<td>Gauss–Legendre, 292, 293, 310</td>
</tr>
<tr>
<td>Gauss–Legendre collocation, 312, 313</td>
</tr>
<tr>
<td>Gauss–Legendre quadrature, 312</td>
</tr>
<tr>
<td>Gauss–Legendre roots, 312</td>
</tr>
<tr>
<td>Gauss–Lobatto, 292</td>
</tr>
<tr>
<td>Gauss–Newton, 265, 266, 279</td>
</tr>
<tr>
<td>Gauss–Radau, 292</td>
</tr>
<tr>
<td>Term</td>
</tr>
<tr>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Gaussian quadrature</td>
</tr>
<tr>
<td>generalized Legendre–Clebsch condition</td>
</tr>
<tr>
<td>generalized reduced gradient (GRG)</td>
</tr>
<tr>
<td>genetic algorithms</td>
</tr>
<tr>
<td>GESOP</td>
</tr>
<tr>
<td>global convergence property</td>
</tr>
<tr>
<td>global minimizer</td>
</tr>
<tr>
<td>global minimum</td>
</tr>
<tr>
<td>global optimization</td>
</tr>
<tr>
<td>globalization</td>
</tr>
<tr>
<td>globalization constrained optimization</td>
</tr>
<tr>
<td>Goldstein–Armijo conditions</td>
</tr>
<tr>
<td>GPOPS</td>
</tr>
<tr>
<td>gPROMS</td>
</tr>
<tr>
<td>grade transition</td>
</tr>
<tr>
<td>grade transition for high-impact polystyrene</td>
</tr>
<tr>
<td>gradient projection method</td>
</tr>
<tr>
<td>convergence properties</td>
</tr>
<tr>
<td>gradient vector</td>
</tr>
<tr>
<td>Green's function</td>
</tr>
<tr>
<td>GREG</td>
</tr>
<tr>
<td>GRG (generalized reduced gradient)</td>
</tr>
<tr>
<td>GRG2</td>
</tr>
<tr>
<td>guard function</td>
</tr>
<tr>
<td>Hamiltonian</td>
</tr>
<tr>
<td>function</td>
</tr>
<tr>
<td>stationarity condition</td>
</tr>
<tr>
<td>hard case</td>
</tr>
<tr>
<td>heat exchanger</td>
</tr>
<tr>
<td>heat-transfer coefficients</td>
</tr>
<tr>
<td>Hessian</td>
</tr>
<tr>
<td>Hessian matrix</td>
</tr>
<tr>
<td>high-impact polystyrene (HIPS)</td>
</tr>
<tr>
<td>high-index DAEs</td>
</tr>
<tr>
<td>high-index inequality path constraints</td>
</tr>
<tr>
<td>HIPS (high impact polystyrene)</td>
</tr>
<tr>
<td>Hooke and Jeeves</td>
</tr>
<tr>
<td>hybrid dynamic optimization</td>
</tr>
<tr>
<td>hybrid dynamic systems</td>
</tr>
<tr>
<td>hydrocracker fractionation plant</td>
</tr>
<tr>
<td>HySyS</td>
</tr>
<tr>
<td>implicit Euler</td>
</tr>
<tr>
<td>implicit Runge–Kutta (IRK)</td>
</tr>
<tr>
<td>inaccurate derivatives</td>
</tr>
<tr>
<td>index of differential-algebraic equations</td>
</tr>
<tr>
<td>index reduction</td>
</tr>
<tr>
<td>indirect approach</td>
</tr>
<tr>
<td>indirect methods</td>
</tr>
<tr>
<td>induced matrix norms</td>
</tr>
<tr>
<td>inequality path constrained</td>
</tr>
<tr>
<td>inertia</td>
</tr>
<tr>
<td>inertia KKT matrix</td>
</tr>
<tr>
<td>infeasible QPs</td>
</tr>
<tr>
<td>initial value problem (IVP)</td>
</tr>
<tr>
<td>integer programming</td>
</tr>
<tr>
<td>interior point</td>
</tr>
<tr>
<td>predictor-corrector method</td>
</tr>
<tr>
<td>interior point (or barrier) strategy</td>
</tr>
<tr>
<td>interior point methods</td>
</tr>
<tr>
<td>interior point NLP codes</td>
</tr>
<tr>
<td>inverse BFGS update</td>
</tr>
<tr>
<td>IP (integer programming)</td>
</tr>
<tr>
<td>IPOPT</td>
</tr>
<tr>
<td>IPOPT-C</td>
</tr>
<tr>
<td>IRK (implicit Runge–Kutta)</td>
</tr>
<tr>
<td>IRK discretization</td>
</tr>
<tr>
<td>IRK methods</td>
</tr>
<tr>
<td>isolated local minimizer</td>
</tr>
<tr>
<td>IVP (initial value problem)</td>
</tr>
<tr>
<td>JACOBIAN software</td>
</tr>
<tr>
<td>Jacobian</td>
</tr>
<tr>
<td>Karush–Kuhn–Tucker (KKT)</td>
</tr>
<tr>
<td>kinematic illustration</td>
</tr>
<tr>
<td>kinetic rate constants</td>
</tr>
<tr>
<td>KKT condition</td>
</tr>
<tr>
<td>first order conditions</td>
</tr>
<tr>
<td>KKT matrix</td>
</tr>
<tr>
<td>KNITRO</td>
</tr>
<tr>
<td>$\ell_1$ penalization</td>
</tr>
<tr>
<td>$\ell_2$ penalty function</td>
</tr>
<tr>
<td>$\ell_p$ merit function</td>
</tr>
<tr>
<td>$\ell_p$ penalty functions</td>
</tr>
<tr>
<td>L-BFGS-B code</td>
</tr>
<tr>
<td>Lagrange interpolation</td>
</tr>
</tbody>
</table>
Lagrange interpolation polynomials, 350
Lagrange multiplier estimates, 124
Lagrangian function, 70
LANCELOT, 171
large-scale SQP, 144
$L B L^T$ factorization, 99, 146
LDPE (low-density polyethylene), 305
Legendre–Clebsch conditions, 227
Levenberg–Marquardt correction, 41
Levenberg–Marquardt method, 54, 56
LICQ (linear independence constraint qualification), 78, 93, 96, 137, 311, 328
failure of LICQ, 320
ill-conditioned behavior, 320
lim inf property, 56
limited memory, 103
limiting directions, 74, 75, 78
line search
   backtracking, 50
   filter method, 155
   methods, 46, 114
linear constraints, 76
linear dependence, 326
linear independence, 92, 195
linear independence constraint qualification (LICQ), 77
linear multistep methods, 256
linear program (LP), 4, 65, 84
linear program with equilibrium constraints (LPEC), 328
linearly constrained augmented Lagrangian, 167
Lipschitz continuity, 25, 39, 93, 95, 194
local minimizer
   isolated local minimizer, 28
   strict local minimizer, 28, 63
local optimality conditions, 68
local truncation error, 254
log-barrier function, 151
LOQO, 170, 207
low-density polyethylene (LDP), 304
LP portfolio planning, 88
LPEC (linear program with equilibrium constraints), 328
LU factorization, 97
Mangasarian–Fromovitz constraint qualification (MFCQ), 79
Maratos effect, 128, 131
Markowitz, 86
mass balances, 10, 197, 203
mathematical programming, 2
mathematical programs with complementarity constraints (MPCCs), 325, 359
mathematical programs with equilibrium constraints (MPECs), 326
MATLAB, 15
matrices, 19
matrix
   diagonal, 20
   identity, 20
   inverse of a matrix, 20
   symmetric, 19
   transpose, 19
max operator, 338
Mayer problem, 221
mean value theorem, 314
merit function, 109
MESH (Mass-Equilibrium-Summation-Heat), 10, 202
method of moments, 305
MFCQ (Mangasarian–Fromovitz constraint qualification), 328
MILP (mixed integer linear program), 4
min operator, 338
minimum energy distillation, 346
MINOS, 168, 171, 205
MINLP (mixed integer nonlinear programming), 3, 325
Mittelmann NLP benchmarks, 173, 174
mixed integer linear program (MILP), 4
mixed integer nonlinear programing (MINLP), 3, 325
mixed integer optimization problems, 3
model predictive control (MPC), 5, 11, 12
modified Cholesky factorization, 41
modular, 184
modular process simulators, 326
modular simulation mode, 182
MOOCHO/rSQP++, 170
Index

Motzkin’s theorem of the alternative, 75
moving finite element, 296, 360
MPC (model predictive control), 5, 11, 12
MPCC (mathematical programs with complementarity constraints), 326, 328, 330, 331, 337, 352, 355, 361
MPCC formulations, 325
MPCC modeling, 336
MPEC (mathematical programs with equilibrium constraints), 360
MPEC-LICQ property, 329
MPEC-MFCQ, 330
MPEC-SOSC, 330
MPEC-SSOSC, 330
MPECLib, 334
multiple shooting, 271, 272
multiplier, 72, 110
least squares estimate, 110
Multistep methods, 254
MUSCOD, 169, 284

NCP (nonlinear complementarity problem), 348
NCP formulation, 347
necessary conditions for local optimality, 29
necessary conditions of optimality, 247
necessary second order condition, 83
negative curvature, 23, 57
negative definite, 21
negative semidefinite, 21
Nelder and Mead, 31
NEOS server, 169, 208
nested projection methods, 133
nested strategies, 160
NEWCON, 279
Newton divided difference formula, 257
Newton step, 55, 96
Newton’s method, 34, 39, 93
Newton-based barrier solvers, 303
NEWUOA, 33
NLP (nonlinear programming) codes, 178
NLP test problem, 172
NLPEC, 333, 353
NLPQL, 169, 252

NMPC, 278, 279
predictive horizon, 279
nonbasic variables, 161
nonconvex feasible region, 66
nonconvex objective function, 66
nonconvex problems, 91
nonlinear complementarity problem (NCP), 332
nonlinear model predictive control (NMPC), 220, 276, 323
nonlinear programming (NLP), 4, 5, 132
normal directions, 102
normal step ($\delta_k$), 99, 102, 124, 144, 158
normal trust region subproblem, 123, 150
NOVA, 323
NPSOL, 169, 252
null space, 162
null space basis matrix, 94, 101
objective function, 1
operation, 339
operations research, 2
optimal catalyst mixing, 243
optimal control problem, 220, 247, 267, 309
optimal cooling profile for crystallization, 297
OptimalControlCentre, 323
optimality conditions, 223, 227
optimization, 1
optimization with variable finite elements, 354
optimize then discretize, 244, 310
orthogonal bases, 101
orthogonal collocation, 293
orthogonal matrix, 20
$p$-norm, 21
parallel implementations, 309
parameter estimation, 213, 217, 265, 287, 304
partial differential equations (PDEs), 7
path constraints, 232, 318, 323
high-index, 318
path inequalities, 238
corner conditions, 237, 238, 317
entry, 237
exit points, 237
Index

PDE constrained optimization, 318
PDEs (partial differential equations), 7
penalty function, 109, 114
PENNON, 171, 173
perturbation, 260
$PF(\rho)$, 331, 334, 347, 348, 353, 357
phase changes, 342
PI (proportional plus integral), 341
PI controller saturation, 341
Picard–Lindelöf theorem, 215
piecewise functions, 340
planning, 182
polyhedron, 84
polymerization, 305
polymerization reactors, 300
polynomial approximation, 289
portfolio model, 86
positive curvature, 23
positive definite, 21
positive semidefinite, 21
positive step length, 46
Powell damping, 44
Powell dogleg steps, 54
Powell’s dogleg method, 123
pressure swing adsorption, 323
primal degenerate, 84
primal-dual equations, 153, 154
Pro/II, 15
problem of Lagrange, 221
process control, 213
process flowsheet, 7, 186
process model, 7
steady state, 181
process optimization, 326
process simulation, 184
modular mode, 184
process simulation models, 182
process synthesis, 5
profit function, 193
projected gradient, 164
projected gradient steps, 166
projected Newton methods, 166
projection operator, 164
PROPT, 323
ProSIM, 190
pseudospectral methods, 296
$q$th order inequality path constraint, 237
QP (quadratic program), 4, 12, 85, 95, 136
QP portfolio planning, 89
QPSOL, 279
QR factorization, 45, 101
quadratic forms, 22
quadratic penalty functions, 109
quadratic program (QP), 4, 12, 85, 95, 136
quasi-Newton methods, 42
quasi-Newton update matrix, 102
Radu collocation, 293, 310, 313, 315, 350, 354, 356
Radu collocation on finite elements, 351
range-space matrices, 101
reactor, 196
reactor control, 239
real-time optimization (RTO), 5, 182, 200, 336
reboiler, 9, 204
reduced gradient method, 190
reduced gradients, 162
reduced Hessians, 82, 130, 162
properties, 82
reduced-space decomposition, 96
reduced-space Newton steps, 99
reduced-space SQP (rSQP), 205
Reg($\epsilon$), 331, 347, 348
RegComp($\epsilon$), 331
RegEq($\epsilon$), 331
RNLP-SOSC, 330
RNLP-SSOSC, 330
ROMeo, 15
roundoff errors, 260
rSQP (reduced-space SQP), 207
RTO, 201, 204
Runge–Kutta, 251, 293
basis, 289
Butcher block, 256
discretizations, 323
explicit, 255
fully implicit methods, 255, 256
methods, 254–256, 259, 296
polynomial representation, 350, 354
representation, 350
semi-implicit methods, 255, 256
scaled normal trust region subproblem, 159
scaled tangential trust region subproblem, 159
scheduling, 182
Schur complement, 86, 147, 308
scientific computing, 2
second order conditions, 71, 92, 96, 330
second order correction, 129, 130
second order necessary conditions, 80
second order sufficient conditions (SOSC), 81
sensitivity, 260
sensitivity calculations, 304
sensitivity equations, 253, 266
sequential, 245
sequential dynamic optimization, 252, 253
sequential quadratic programming (SQP), 133
serial implementation, 309
signum, 339
simplex method, 84
simulated annealing, 32
Glauber distribution, 32
Metropolis distribution, 32
simulated moving beds, 323
simultaneous collocation, 307, 327, 349
simultaneous strategies, 245
single-step methods, 254
singular arc, 239, 240, 242, 315, 317
singular control, 239, 288, 316, 322
singular matrix, 20
singular optimal control
ill-conditioned, 315
regularization, 316, 317
singular optimization problems, 327
singular profile, 239
singular values, 21
SNOPT, 170, 173, 207
SOCS, 170, 323
SOSC (second order sufficient conditions), 81
SQP (sequential quadratic programming), 190, 252, 267, 284, 331
elastic mode, 138
reduced-space algorithm, 145
SQP algorithm, 137, 141
SQP codes, 169
SQP methods, 135
extensions of, 148
SR1 (symmetric rank 1), 43
SR1 update, 43, 103, 105
SSOSC (strong second order sufficient conditions), 330
state estimation, 213
state path inequalities, 237
stiff decay, 255, 258, 293
stiff system, 254
stochastic programming, 15
strict complementarity, 73, 83
strict local minimizer, 64
strictly convex objective, 65
strong stationarity, 329
strong Wolfe conditions, 48
strongly convex, 27
sufficient conditions for local optimality, 29
sufficient second order conditions, 72, 83, 94
Sunoco hydrocracker, 203
superbasic variables, 161
superlinear convergence, 42, 104, 105
switching behavior, 349
switching function, 349
switching points, 356
Sylvester’s law of inertia, 94
symmetric rank 1 (SR1), 43, 103, 105
tangential directions, 102
tangential step (qk), 99, 102, 124, 144, 158
tangential trust region subproblem, 150
Taylor’s theorem, 27
tear equations, 186
tear variables, 186
Tennessee Eastman reactor, 277
trajectory optimization, 213
transversality condition, 222
tray optimization, 345
TRON, 167
truncated Newton algorithm, 57, 123
truncation errors, 260
Index

trust region
    ared, 53, 125
    pred, 53, 125
trust region globalization, 122
trust region methods, 52, 158
    convergence rate, 160
    local convergence properties, 160
trust region with merit functions, 149
tubular reactors, 304
twice differentiable, 26

unconstrained optimization, 17, 30
unstable dynamic modes, 300
unstable systems, 272
UOBYQA, 33

variational approach, 244
vector and matrix norms, 21
vectors, 19
VF13AD, 169

Watchdog algorithm, 131
Watchdog strategy, 143
Williams–Otto, 197
Williams–Otto optimization problem, 196
Wolfe conditions, 48

zero curvature, 23
zero-stability property, 254, 255