Index

active set method, 88 adjoint, see state admissibility of the unit stepsize, 48, 63, 307, 322, 337 admissible, see point, set algorithm, see also method - BFGS, see BFGS – Bunch & Kaufman, 231 bundle, see bundle method, constrained bundle - conjugate gradient, 84, 86 – – preconditioned, 76 - - truncated, 300, 303 - cutting-planes, see cutting-planes method - descent, 120 - ellipsoid, 129 Karmarkar, 457 largest step, 435 with safeguard, 435 - Newton, see Newton's algorithm - predictor-corrector, 397 - quasi-Newton, see quasi-Newton or secant (algorithm) simplex, 364 - SQP, see sequential quadratic programming algorithm - subgradient, see subgradient method - Uzawa, 232 analytic center, 391, 437 Armijo, 47, 80, 84, 138, 295, 304, 305 automatic differentiation, see computational differentiation auxiliary problem principle, 171 basis matrix, 365 BFGS, 55, 58, 75, 85, 86, 325 163

- limited memory, 195

bisection, 40 black box, 11, 126 - constrained, 178 - dynamic, 173 bracket, 39 Bunch & Kaufman, 231 Bunch & Parlett, 53 bundle, 137, 144 - aggregation, 139, 143 - compression, 147, 149 - disaggregate, 166 - selection, 149 bundle method - constrained, see constrained bundle method - dual, 147 - dynamic, 175 - finite termination, 176 - for generalized equations, 182 - general, 138 - level, 141 - penalized, 141 – – convergence, 155, 156 - - implementation, 186 - - parameter update, 150 - trust region, 140 Cauchy-Schwarz inequality, 205 generalized, 279 central path, 373, 375 - perturbed, 412 chain, see hanging chain project Cholesky, 53, 269, 317, 320 code n1cv2, 153 coercive, 117, 171 combinatorial optimization, 3, 10, 96,

complementarity condition, 115, 200

- strict, 201, 380 complementarity problem (linear), 89, 371, 374 - canonical form, 379, 380 - monotone, 374 - standard form, 378 complexity, 451 computational differentiation, 19, 20, 95cone, 202 - critical, 202 conjugate, see algorithm, direction constrained bundle method - feasible, 179 - filter, 180 - infeasible, 178 constraint, $\mathbf{3}$ - active, **4**, 89, 192, 194 - equality, 3 - inequality, 3 - strongly active, 201 - weakly active, 201 constraint qualification, 113, 116 - (A-CQ), 201 - (S-CQ), of Slater, 201 - (LI-CQ), 201 - (MF-CQ), of Mangasarian-Fromovitz, 201 control, see also state - problem, 4, 7, 8, 16, 224 – variable, 7, 16 convergence global, 12, 26, 45, 52, 53, 74, 296, 306 - in p steps, 204 - linear, 14, 204 - local, 14, 206, 227, 229, 241, 259, 262 - of bundle method, 155, 156 - of cutting-planes method, 133 - of subgradient method, 128 - quadratic, 14, 204, 253 speed of, 14, 33, 51, 86, 88, 203-204 superlinear, 14, 204, 265 convex, see function, problem, set convex hull, 110 correction – Powell, **328**, 330, 332, 340 - second-order, 310

critical, see cone, direction, point cubic fit, 40 curvature condition, 325 curvilinear search, see also line-search, 85, 141, 153, 333 cuts - feasibility, 170 - optimality, 170 cutting-planes method, 131 - convergence, 133 - implementation, 186 Davidon, Fletcher & Powell, 55 decomposition Benders, 169 - Dantzig-Wolfe, 166 - energy application, 187 price, 162, 165 algorithm, 164 - proximal, 172 - resource, 162, 167 decomposition of \mathbb{R}^n - by partitioning, 224 oblique, 226 - orthogonal, **225**, 253 Dennis & Moré, 60, 63, 82 dilation, 129 direct communication, 211 direction, 12, 85 - affine, 383 - centralization, 383 - conjugate, 69, 74 - critical, 202 - of ε -descent, 125 - of descent, 29, 37, 75, 111, 127, 289, 321of steepest descent, **30**, 121, 123 quasi-negative curvature, 300 directional derivative, 109, 198 divergent series, 129 duality, 356 - gap, **113**, 114, 116 - weak, 114, 168 elliptic, see function equivalent sequences, 204 Everett, 113 existence of solution, 25, 199

extrapolation, 40, 47

feasible, see point, set Fermat, 99, 111 filter strategy, 180 finite difference, 101, 119 Finsler, 285 Fletcher (initialization of), 39, 48 Fletcher-Reeves, 73 Fromovitz, see constraint qualification function – MAXANAL, 184 - MAXQUAD, **153**, 183 - affine, 4, 26, 83 - convex, 25, 26, 57 - - strongly, 27, 61, 63, 65, 67 - convex-concave, 359 - dual, 112 - elliptic, 27, 48, 53, 74 improvement, 177 - inf-compact, 25 - lower semi-continuous, 25 - merit, 13, 29, 37, 79, 271 - penalty, 271 – – exact, 272 - value, 167, 169 Gauss, 101 Gauss-Newton, 83, 86 Gauss-Seidel, 29 generalized equation, 180 globalization of an algorithm, 271 - by line-search, 52, 289 - by trust regions, 77 gradient, 3, 13, 23, 26 projected, 90 reduced, 233 group, 378 growth condition (quadratic), 27, 33, 46

hanging chain project, 208–213, 245–250, 267–270, 316–320, 340–344
Hessian, see also reduced Hessian, 3, 26, 27, 51–53, 57, 63–65, 73, 82, 83, 95, 102, 103
of the Lagrangian, 227

```
I^{0}(x), 194
I^{0}_{*}, I^{0+}_{*}, I^{00}_{*}, 201
```

identification, see parameter identification inf-compact, see function instability - of cutting-planes method, 134 - of steepest-descent, 31, 122 interpolation, 40, 296, 305, 317 invariant, 378 inverse problem, see also parameter identification, 7, 101 Karush, Kuhn, and Tucker (KKT), see multiplier, optimality conditions Lagrange multiplier, see multiplier Lagrangian, 11, 78, 112, 200, 272, 274, 357augmented, 118, 163, 272, 276, 285, 330 relaxation, 10, 112, 163, 173 - - dynamic, 173 length of a linear problem, 452 Levenberg-Marquardt, 84 line-search, see also curvilinear search, 12, 72, 77, 78, 91 - Armijo, 295, 305 - backtracking, 296, 304, 305, 329 - nonmonotone, 321 piecewise (PLS), 336 watchdog, 321 Wolfe, see also Wolfe conditions, 58, 63, 65, 75, 83, 85, 87, 326 linear complementarity problem, see complementarity problem linearization error, 144 local minimum, see solution Mangasarian, see constraint qualification Maratos effect, **308**, 329 master program, 161, 165, 167 matrix basis, 222 - inertia, 252

- positive definite, 26, 27, 67, 82, 83, 86, 88
- right inverse, **222**, 252, 253
- method, see also algorithm local, 216
- multiplier, 163

- primal-dual, 217 minimax - finite, 116 - infinite, 117 minimizing sequence, 13, 140, 147, 154, 155minimum, see solution model, 12, 52, 77, 85 cutting-planes, 130, 137, 144 - - aggregate, 150 - - disaggregate, 166 - - improving, 139 - piecewise affine, 130 modified field, 387, 388, 418 monotone, 374 Moreau-Yosida regularization, 150 multifunction, 124 – closed, 124 - continuous, 124 multiplier, 112, 116, 166, 200 - first-order, 235 - Lagrange, 12, 103, **200**, 360 - least-squares, **228**, 235, 253 second-order, 235 neighborhood, 397 - large, 375, 406 – small, 375, 398 Newton's algorithm, 39, 79 - for equality constrained problems - - primal version, 229 – primal-dual version, 221 - - reduced Hessian, 239 - - simplified Newton, 240 - for inequality constrained problems, see sequential quadratic programming - for nonlinear equations, 51, 205 for unconstrained optimization, 207 Newton's step - longitudinal component, 223 - transversal component, 223 nominal decrease, 49, 80, 131, 147 norm, 321 - associated with a scalar product, 205 - dual, 279, 286 $O(\cdot)$, big O, 203

 $o(\cdot)$, little o, 14, 203

objective function, 3, 16 optimal control, see control optimal partition, 364, 379 optimal stepsize, 30 optimality conditions, 13 - necessary - - 1st order (NC1), 26 - 2nd order (NC2), 26, 202 - - Karush, Kuhn, and Tucker (KKT), 200- - reduced, 236 - sufficient 2nd order (SC2), 26, 203 - - semi-strong 2nd order, **203**, 286 - - strong 2nd order, 203 - - weak 2nd order, 203, 286 optimality system, 360 oscillation, 31, 122 osculating quadratic problem, 219, 232, 256, 259 equality constrained, 218 - inequality constrained, 257 unconstrained, 208 parameter - augmentation, 276 penalty, 279 parameter identification, 6, 82, 100 partition of variables, 379 penalization, see also function (penalty) - exact, 272 - - augmented Lagrangian, 277, 287 - - Fletcher, 285, 320 $- - \ell_1, 287$ - - Lagrangian, 274 - - of the objective, 272 - logarithmic, 371 - quadratic, 101 performance profile, 341 piecewise line-search (PLS), see line-search pivoting, 92, 368 point - basic, 355 - - regular, 366

- critical or stationary, 26, 27, 52, 82, 201, 359
- feasible or admissible, 89, 193
- interior, 374

- optimal, 111 Polak-Ribière, 73 potential Karmarkar, 457 - logarithmic, 371, 390 Powell, see correction preconditioning, 34 problem - constrained convex, 26, 194 - convex, 88, 113, 116 - dual, 112, 357, 358 - least-squares, 82, 253 - linear, 354 - osculating quadratic, see osculating quadratic problem $(P_E), 215$ $-(P_{EI}), 193$ primal, 111, 358 quadratic, 354 saddle-point, 358 project, see seismic reflection tomography project, hanging chain project projection onto a convex set, 205 proximal point, 151 - implementable form, 151, 180 proximity measure, 375, 437 quasi-Newton or secant - algorithm - - quasi-Newton SQP, 328 - - reduced, for equality constrained problems, 338 equation, 54, 325 matrix, 54 - method, 56, 78, 86 - - poor man, 75, 84, 151 $\mathbb{R}^*_+, 276$ reduced cost, 365 reduced Hessian of the Lagrangian, **221**, 233, 237, 252 reflection tomography, see seismic reflection tomography project regular stationary point, 221, 252

relative distance, 444 relative interior, 113

row/column generation, 166

saddle-point, 274 safeguard, 41, 436 scaling, 35 search, see curvilinear search, line-search secant, see quasi-Newton seismic reflection tomography project, 97 - 103self-duality, 425 separating hyperplane, 111, 121 sequential quadratic programming (SQP) algorithm, 191 line-search SQP, 292 - local, 257 - truncated (TSQP), 305 set convex, 26 - feasible or admissible, 193, 353, 374 – – perturbed, 412 set-valued map, see multifunction simulator, 11, 16, 37, 67, 100, 211 Slater, see also constraint gualification, 113, 116, 201 slice, 25, 46, 58 solution, see also existence, uniqueness, 199, 353 global, 12, 199 - local, 26, 82, 199 - primal-dual, 201 - strict local, 199 - strong, 203 speed of convergence, see convergence spline (cubic), 98 SQP, see sequential quadratic programming algorithm stabilization principle, 12, 30, 37, 137 standard form - of linear constraints, 353 state - adjoint, 18 -- equation, 17, 18 constraint on the -, 9 equation, 7 - variable, 7 stationary, see point step null, 139 - serious, 138

490 Index

stopping test, 34, 41
formal, 120
implementable, 131, 138, 147
subdifferential, 110
approximate, 124, 125
subgradient, 110
inequality, 110
smeared, 147
subgradient method, 127
convergence, 128
implementation, 186
submersion, 193
test problem, see seismic reflection

tomography project, hanging chain project tomography, *see* seismic reflection tomography project

trap of nonsmooth optimization, 119

trust region, 53, 84, 87, 138, 140 uniqueness of solution, 199 update criterion, 339 value, 353 variable – control, decision, **3**, 224 – dual, 112 – state, 224 weak duality, *see* duality Wolfe – duality, 363 Wolfe conditions, **43** – generalized, 80, 334

zigzag, 31, 94, 122, 123, 129