

Index

- ABB-IRB 1000 robot, 472, 476
- acatastatic systems, 403
- acceleration analysis
 - of parallel manipulators, 339
 - of rigid bodies, 91
 - of serial manipulators, 156
- affine transformation, 21, 54
- AI, *see* artificial intelligence
- algorithm definition, 456
- angle of rotation, 30
- angular acceleration
 - computation, 280
 - invariant-rate relations, 92
 - matrix, 91
 - vector, 92
- angular velocity
 - dyad, 213
 - invariant-rate relations, 90, 438–441
 - matrix, 83
 - vector, 83
- Appendix A, 437
- Appendix B, 445
- arc-welding, 364
 - operation, 379
- path-tracking, 395
- architecture of a manipulator, 105, 107
- articulated-body method, 245
- artificial intelligence, 4, 456
- axial component of a vector, 23
- axial vector of a 3×3 matrix, 34
- base frame, 114
- basis of a vector space, 23
- Bezout's method, 335
- bivariate-equation approach, 289, 301, 302
- C, 456
- C++, 456
- Canadarm, *see* Canadarm2
- Canadarm2, 5, 6
- canonical form of a rotation, 33
- Carausius morosus, 14, 505
- Cartesian coordinates
 - of a manipulator, 105
 - also, *see* Cartesian variables
- Cartesian decomposition, 34
- Cartesian variables

- of a manipulator, 113
- caster wheel, 353, 417
- catastatic system, 403
- Cayley's Theorem, 458
- Cayley-Hamilton theorem, 28
- change of basis, 58
- characteristic equation, 25, 28
 - of a manipulator, 121, 312
- characteristic length, 175, 180, 184
- characteristic point, 188
- characteristic polynomial, 24
 - of a manipulator, 154, 288, 309, 312, 325, 326, 336
- Chasles' Theorem, *see* Mozzi-Chasles' Theorem
- Chebyshev norm, 175, 394
- Cholesky-decomposition algorithm, 246, 265
- closure equations
 - (manipulator -), 115
- compatibility conditions
 - for acceleration, 281
 - for velocity, 277
- composite rigid-body method, 245
- composition of reflections and rotations, 47
- condition number, 174, 313
- configuration of a manipulator, 105
- continuous path, 190, 289
 - operations, 363
 - tracking, 389
- control vector, 235, 266
- coordinate transformation, 48–57
- Coriolis
 - acceleration, 95
 - and centrifugal forces, 238, 239, 245
- Couette flow, 270
- Coulomb
 - dissipation function, 271
 - friction, 215, 271
- CP, *see* continuous path
- cross-product matrix, 28
- curvature, 365
 - derivative w. r. t.
- a parameter, 372
- derivative w. r. t. the arc length, 365
- parametric representation, 371
 - time-derivative, 368
- cycloidal motion, 199
- Darboux vector, 367
 - time-derivative, 368
- decoupled manipulators, 105, 109, 114
- Delta robot, 9
- delta-array (Δ -array), 427, 492
- Denavit-Hartenberg
 - frames, 107
 - notation, 106
 - parameters, 109
 - rotation matrix, 110
 - vector joining two frame origins, 111
- dexterity, 456
 - measures, *see* kinetostatic performance indices
- dextrous hands, *see* multifingered hands
- dextrous workspace, 171
- DH, *see* Denavit-Hartenberg
- dialytic elimination, 155, 475
- DIESTRO
 - inverse kinematics, 318
 - Jacobian, 473
 - manipulator, 185, 318
- differentiation with respect to vectors, 28, 29
- direct kinematic problem
 - of parallel manipulators, 322
- displacement equations of a manipulator, 115
- dissipation function, 215, 270
- dynamic systems, 1
- dynamics
 - of holonomic systems, 402
 - of multibody systems, 213
 - of parallel manipulators, 406
 - of rigid bodies, 99

- of robotic mechanical systems, 402
- of rolling robots, 417
- of serial manipulators, 211
- EE, *see* end-effector
- end-effector, 106
- Euclidean norm, 30
- Euler
 - angles, 33, 459, 465
 - equation (for graphs), 407
 - equation (in mechanics), 102
 - parameters, *see* Euler-Rodriges parameters
- Euler's
 - formula for graphs, *see* Euler equation for graphs
 - theorem, 27
- Euler-Lagrange equations, 212, 214
 - derived with the NOC, 238, 405
- Euler-Rodrigues parameters, 43
- Fanuc Arc Mate robot
 - characteristic length, 187
 - DH parameters, 187
 - inverse kinematics, 318
 - KCI, 187
- First Law of Thermodynamics, 161
- flight simulator, 8, 325
- floating-point operation, 159, 245, 447, 456
- flop, *see* floating-point operation
- forward dynamics
 - algorithm complexity, 261
 - of serial manipulators, 211, 244
- Frenet, *see* Frenet-Serret
- Frenet-Serret
 - formulas, 365
 - frame, 364
 - vectors, 365
- friction forces, 269
- Frobenius norm, 176
- fuzzy logic, 456
- genealogy of robotic mechanical systems, 1, 4
- generalized coordinates, 214, 215, 402
- generalized forces, 214, 215, 423
- generalized inertia matrix, 217, 431
 - Cholesky decomposition, 246
 - factoring, 246
 - time-rate of change, 253
- generalized speeds, 215, 403
- gluing operation, 373
- grasping matrix, 345
- gravity
 - terms, 268
 - wrench, 236
- hand-eye calibration, 68
- Hexa robot, 9
- holonomic systems, 402
- homogeneous coordinates, 48
- homotopy, 289
- IKP, *see* inverse kinematics problem
- Index, 515
- inertia dyad, 102, 213
- input, 1, 235
- instant screw axis, 85
- instrument calibration, 67
- intelligent machines, 2, 456
- intelligent robots, 2
- invariance, 63
- inverse dynamics
 - of serial manipulators, 211
 - recursive, 223
- inverse kinematics problem of
 - a decoupled manipulator, 105
 - a general 6R manipulator, 288
 - parallel manipulators, 327
- inverse vs. forward dynamics, 211
- inward recursions, 230, 233
- ISA, *see* instant screw axis
- isomorphism, 25
- isotropic
- manipulator, 174

- matrix, 173, 174
- isotropy, 178
- iteration, 394, 456
- Jacobian matrix
 - condition number, 174
 - evaluation, 145
 - invertibility, 172
 - of decoupled manipulators, 105
 - of serial manipulators, 105
 - transfer formula, 143
- joint
 - coordinates, 105, 109
 - parameters, 109
 - variables, 109
- Kane's equations, 223
- KCI, *see* kinematic conditioning index
- kernel of a linear transformation, 21
- Kinemate, 89
- kinematic
 - chain, 106
 - conditioning index, 175
 - constraints, 236
 - constraints for serial manipulators, 240
 - pair, 106
- kinetostatic performance indices, 171
- Lee vs. Li, 289
- Lee's manipulator, 321
- Lee's procedure, 316
- left hand, 9
- Li vs. Lee, *see* Lee vs. Li
- Li's manipulator, *see* Lee's manipulator
- linear invariants, 34
 - of rotation, 35
- linear transformations, 20
- local structure of a manipulator, 109
- lower kinematic pair, 106
- LU decomposition, 141
- machine (definitions of), 455
- main gauche, *see* left hand
- maneuverability, 491
- manipulability, 171
 - of decoupled manipulators, 478
- manipulator
 - angular velocity matrix, 216
 - architecture, 105
 - configuration, 105
 - dynamics, 211, 406
 - kinematics, 105
 - mass matrix, 216
 - posture, 105
 - twist, 216
 - wrench, 216
- matrix
 - norm, 176
 - representation, 24
- mechanical system, 2
- mechatronics, 456
- minimum-time trajectory, 239
- moment invariants, 63
- moment of a line
 - about a point, 77
 - about another line, 467
- moment of inertia, 100
- momentum screw, 103
- motor, 89
- Mozzi-Chasles' Theorem, 73
- MSS, 5
- multibody system
 - dynamics, 213
 - Euler-Lagrange equations, 223
- multicubic expression, 117
- multifingered hands, 11
- multilinear expression, 116
- multiquadratic expression, 117
- multiquartic expression, 117
- natural orthogonal complement, 213
 - applied to holonomic systems, 404

- applied to parallel manipulators, 406
- applied to planar manipulators, 248
- applied to rolling robots, 418, 429
- Newton
 - Euler algorithm, 233
 - Gauss method, 391
 - Raphson method, 69
 - equation, 102
 - methods, 289, 391
- NOC, *see* natural orthogonal complement
- nonholonomic systems, 212, 402, 417
- noninertial base link, 244
- norm
 - also, *see* Frobenius norm
- norm (matrix -), 176
- normal component of a vector, 23
- nullspace of a linear transformation, 21
- numerical conditioning, 301, 313
- object-oriented programming, 456
- Odetics series of hexapods, 14
- ODW, *see* omnidirectional wheels, *see also* omnidirectional wheels
- off-line, 4, 121, 146
- omnidirectional wheels, 16, 427
 - dynamics, 427
 - kinematics, 358
- on-line, 456
- operation point, 108
- orientation problem, 133
- orthogonal complement, 237
- orthogonal decomposition of a vector, 23
- orthogonal decoupled manipulator, 128
- orthogonal projection, 21
- orthogonal RRR manipulator
 - dynamics, 250, 253
 - inverse kinematics, 129, 131
- recursive dynamics, 260
- workspace, 135
- OSU ASV, 13
- OSU Hexapod, 13
- output, 1
- outward recursions, 224
- Pappus-Guldinus theorem, 476
- parallel axes, theorem, 102
- parallel manipulators, 8
 - acceleration analysis, 337
 - dynamics, 406
 - kinematics, 322
 - velocity analysis, 337
- parametric
 - path representation, 370
 - representation of curvature, 371
 - representation of curvature derivative, 372
 - representation of torsion, 371
 - representation of torsion derivative, 373
 - splines, 383
- path-tracking for arc-welding, 395
- pick-and-place operations, 189, 190
- Plücker coordinates
 - of a line, 76
 - transfer formula, 79
- planar manipulators, 162
 - acceleration analysis, 168
 - displacement analysis, 163
 - dynamics, 218
 - static analysis, 170
 - velocity analysis, 165
- platform manipulators, 325, 333, 406
- polar-decomposition theorem, 172
- polynomial interpolation
 - with 3-4-5 polynomial, 192
 - with 4-5-6-7 polynomial, 196
- pose
 - array, 80
 - of a rigid body, 80
- positioning problem, 118

- posture of a manipulator, 105
- PPO, *see* pick-and-place operations
- Principle of Virtual Work, 161
- prismatic pair, 106, 107, 149
- programmable robot, 2
- projection, 22
 - theorem, 447
- Puma robot, 108, 109, 126
 - DH parameters, 109
 - inverse kinematics, 118
 - workspace, 127
- pure reflection, 22
- quaternions, 45
- Raghavan and Roth's procedure, 289, 304
- range of a linear transformation, 21, 457
- Rayleigh dissipation function, *see* dissipation function
- real-time, 211, 456
- reciprocal bases, 68, 144, 416
- recursion, 456
- redundant sensing, 66
- References, 501
- reflection, 22, 290, 296
 - composition with rotations, 47
- regional structure of a manipulator, 109
- revolute pair, 106
- rheonomic systems, 402
- robotic hands, 11
- robotic mechanical systems, vii, 1
- Rodrigues, *see* Euler-Rodrigues vector, 459
- rolling robots, 15
 - dynamics, 417
 - kinematics, 352
- rotating pair, 106
- rotation, 25
- rotation matrix, 30
 - exponential representation, 32
- run-time, 456
- Runge-Kutta methods, 267
- RVS, viii, 191
- scleronomic systems, 402
- screw
 - amplitude, 74
 - axis, 74
 - motion, 72
 - pitch, 74
- self-inverse, 23
- serial manipulators, 6
 - acceleration analysis, 156
 - dynamics, 211
 - kinematics, 106
 - statics, 160
 - velocity analysis, 138
 - workspace, 153
- service angle, 171
- similarity transformations, 58
- simulation, 265
- singular-value decomposition, 173
- singular-values, 173
- singularity analysis of decoupled manipulators, 150
- sliding pair, 106
- SPDM, 5
- spherical wrist, 108, 134, 135
 - workspace, 135
- spline(s), 203
 - interpolation of 4-5-6-7 polynomial, 208
 - natural, 207
 - nonparametric, 203, 383
 - parametric, 383
 - periodic, 203
- square root of a matrix, 44
- Star robot, 9
- state
 - of a dynamical system, 235
 - of parallel manipulators, 413
 - of serial manipulators, 235, 266
 - variable, 215, 235, 266
 - variable equations, 266
 - vector, 235

- static analysis
 - of rigid bodies, 95
 - of serial manipulators, 160
- Stewart platform, *see* Stewart-Gough platform
- Stewart-Gough platform, xii, 326
 - direct kinematics, 322
 - leg kinematics, 327
- structure of mechanical systems, 8
- structured environment, 3
- Sutherland, Sprout & Ass. Hexapod, 14
- system, 1
- telemanipulators, 5
- tensors, 19, 20, 234, 235
- Titan series of quadrupeds, 14
- torsion, 365
 - derivative w. r. t.
 - a parameter, 373
 - derivative w. r. t. the arc length, 365
 - parametric representation, 371
 - time-derivative, 368
- trace of a square matrix, 34
- trajectories with via poses, 201
- trajectory planning, 189, 363
- truncation error, 267
- Trussarm, 9, 10
- TU Munich Hand, 12
- TU Munich Hexapod, 14
- twist, 85
 - axis coordinates, 89
 - of a rigid body, 88
 - ray coordinates, 89
 - transfer formula, 91
- twist-shape relations, 237
 - for serial manipulators, 240
- unimodular group (of matrices), 79
- unstructured environment, 3
- upper kinematic pair, 106
- vector of a 3×3 matrix, 34
- vector space, 20
- velocity analysis
 - of parallel manipulators, 337
 - of rolling robots, 353
 - of serial manipulators, 138
- via poses, 201
- virtual work, *see* Principle of Virtual Work
- viscosity coefficient, 270
- viscous forces, 269
- walking machines, 13
 - kinematics, 348
 - leg architecture, 349, 351
- walking stick, 14
- workspace of positioning manipulators, 152
- wrench
 - acting on a rigid body, 96
 - axis, 97
 - pitch, 96
 - transfer formula, 99