

Index

- acceleration, effect on centroid, 61
- acceleration of gravity, measured with
 - vision system, 71
- accuracy, vision system, 68
 - drag and spin, 71
 - drag but no spin, 71
 - in a vacuum, 70
 - in play, 72
 - stationary ball, 68
- accVP, 162, 187
- Ackland, B.D., *xiii*
- Agin, G.J., 40
- Aho, A.V., 44
- Ahuja, S.R., 29
- air drag, 17, 18
- An, C.H., 104
- Andersson, A.T., *xiii*
- Andersson, R.L., 30, 44
 - photograph, 2
- architecture, system, 27
- Atkeson, C.G., 104
- autoface, 125, 128, 162

- back-EMF, 89, 91, 105, 190
 - avoidance, 101
 - margin, 106
 - motor model, 86
 - tuning stick angle, 176
- Bajcsy, R.K., *xiii*
- Baker, H.H., 40
- ball, *see* ping-pong ball
- Ballard, D.H., 106, 108
- baseball player, 206
- Bekey, G.A., 106
- Berton, L., 16
- Billingsley, J., *xi*, 5, 13
- biologic trajectories, 93–94

- Birrell, A.D., 36
- Bixby, J.A., 29
- blackboards, 113, 117, 121, 141
- Bolles, R.C., 40
- bounce,
 - off paddle, *see* ping-pong paddle
 - prediction, 18–22, 67, 192, 195
- Brandan, M.E., 18
- Briggs, L.J., 17
- Brody, H., 18, 19
- Brooks, R.A., *xiii*
- Buchanan, B.G., 134
- builder, 126–128, 138
- buildlog, 33
- Burdick, J.W., 82
- Burg, B., 115

- calibration,
 - lens, 50–52
 - robot, 172
 - stereo, 49
- camera,
 - CCD, 59, 64
 - frame rate and size, 42, 49, 62
 - geometric parameters, 57
 - interlacing, 49, 63
 - latency, 64
 - leakage, 64
 - MOS, 59, 61, 64
 - pan and tilt, 207
 - photograph, 2, 7, 78
 - saturation, 58, 69, 70
 - vidicon, 59, 64
- Casasent, D., 42
- catapult, 71
- CCD camera, *see* camera
- cement kiln, 115

- CEO, 149, 152, 153–154, 166,
 184–187
 certainty measures, 134
 Chande, A.M., 114
 Charlie (ping-pong robot), 14
 chief, 29, 37
 protocol, 37
 clock synchronization, 30–32
 cIox board, 31–32, 92
 interrupts, 31
 CMOS, 44
 coaching, 139
 baseball, 206
 by machines, 116
 coefficient of restitution, 18
 collision avoidance, 170, 197–198, 199
 combine, 137–138, 139, 170, 173,
 179
 Config, 82
 continuous-time model, 4
 conveyor belt, 4
 conVP, 162
 Cosine Law (lighting), 54
 Craig, J.J., 91
 Cramer's Rule, 49

 debugger, 29, 36–38
 log, 32
 log analysis, 38
 decide, 135–136, 139, 151, 188
 demons, 156–158
 log reading, 34–35, 191
 Denavit, J., 84
 Denavit-Hartenberg matrices, 84
 depth maps, 206
 differencing, image, 41
 discrete-time system, 4
 distortion,
 lens, 50
 scan rate, 63
 Durrant-Whyte, H.F., 134
 dwarf processor, 78, 189

 dynamics, 85, 104
 future work, 206
 gravity, 82–84
 joint inertias, 85
 update rate, 105
 worst-case, 105

 Electro-Craft, 86
 Eshraghian, K., 44
 exceptions, 113, 132, 140, 147–154
 CEO, *see* CEO
 detection, 147, 148
 example, 192, 193–195
 tuners, 151
 VP, *see* VP

 Ferrer, R., 17
 follow-through, 191, 198, 200
 Forgy, C.L., 116
 Foulloy, L., 115
 Fowler, C.A., 155
 free variables, 131, 132, 140, 161
 Frohlich, C., 16, 17
 Fukushima, T., 39
 fuzzy sets, 134

 Gaglianello, R.D., *xiii*, 29
 Gaines, B.R., 134
 Ganapathy, S.K., 51, 57
 Gleason, G.J., 40
 gravity, measured with vision system,
 71
 Grimson, W.E.L., 48
 Gupta, M.M., 134
 Gupta, V.K., 17
 Gutierrez, M., 18

 Hartenberg, R.S., 84
 Hayes-Roth, F., 111, 112
 hit plane depth, 161, 163–167, 189
 hitVP, 162
 Hollerbach, J.M., 104

- Hopcroft, J.E., 44
 Horn, B.K.P., 40
 Horner's Method, 44
 HPD, *see* hit plane depth
 Hu, M., 42
- image,
 binary, 40, 41
 gray-scale, 42, 45
 processing, 39
 understanding, 40
 vertical distortion, 63
- implementors, 36
- impVP, 162
- initial planning, 131, 132–139
 example, 189–190
- integrator, 104
- International Table Tennis Federation,
 13, 18
- interrupts, 31
 robot, major cycle, 189
- Izaguirre, A., 82, 86
- Jacobian, 190
 defined, 84
 inverse, 84
 use, 146
- Jarvis, J.F., *xi, xiii*
- Jupiter processor, 77
- Kackar, R.N., 155
- Kalman filters, 65
- Katseff, H.P., *xiii*, 29
- Kaufman, A., 134
- Kechemair, D., 115
- Kernighan, B.W., 116
- kinematics, *see* PUMA 260
- Knight, J., 14
- Kodeschek, D., *xii*
- laser cutting, 115
- latency, 190
- learning, 135, 154–158
 of parameters, 155
 of structures, 154
 possible use, 201
- Lee, C.S.G., 81, 84, 172
- Lembessis, E., 115
- Lenat, D.B., 111, 112
- lens calibration, 50–52
- lighting,
 background, 58
 compensation, 54–58
 lamps, 41
- LISP, 113, 114
- log, 32–36, 189
 demon, 34
 reading, 35
 writing, 33
- LOGID*, 33
- longjmp, 118–119, 151, 162
- Lord Rayleigh, 17
- Lowery, D., 14
- Lozano-Pérez, T., *xiii*
- Macsyma, 56, 100
- Magnus Effect, 16, 17–18, 61, 66
- Mamdani, E.H., 115
- McDermott, J., 114
- MEGLOS operating system, 29
- Meyer, D.E., 93
- models, 120–128, 162
 builder, 126
 C interface generator, 125,
 see also *autoFace*
 C structure, 122
 effect on notes, 122
 exceptions, 149
 for temporal updating, 142–143
 in initial planning, 134, 137
 input-output, 125
 multi-input, 138
- LaMotte, E., 115
- laser, calibration, 49

- moments, 42–47
 - board, 46
 - chip, 42–45
 - chip photograph, 44
 - mass versus intensity, 54
 - preprocessor, 46
 - sampling time, 62
 - VAX, 42
- MOS camera, *see* camera
- motion blur, 59–60
- motion interpretation, 40
- motor model, 86
- Motorola 68020, 29
- Mukerjee, A., 106, 108
- MULGA design system, 44
- Murphy's Law, 132

- Nelson, B.J., 36
- network, S/Net, 29
- Newcomb, R.W., 114
- normalization, 174
- notes, 117–119, 141
 - in exceptions, 149, 151, 152
 - in models, 122

- octree, 121
- Oh, S.-Y., 11
- Olsen, H.B., 106
- O'Neill, J.H., *xiii*
- operating system, MEGLOS, 29
- O-rings, 68
- Ortiz, C.D., 16
- Ostergaard, J.J., 115

- pad_con_xgen, 161, 167–170
- pad_con_ygen, 161, 167–170
- pan and tilt cameras, 207
- Paul, R.P., *xiii*, 4, 82, 84, 86, 91
- PD control, 104
- Pennock, G.R., 11
- peripheral design, 30
- Phong, B.T., 54, 58

- photograph,
 - author, 2
 - cameras, 2, 7, 78
 - moment generator chip, 44
 - paddle, 2, 7, 78
 - ping-pong table, 2, 7
 - robot, 2, 7, 78
- pigeon, 15
- ping-pong,
 - ball speeds, 13, 16, 17
 - human, 13, 207
 - human versus robot, 195, 197
 - paddle trajectory, 108
 - pigeon, 15
 - robot rules, 13
 - table, 7, 13, 18, 41
 - Turing test, 207
- ping-pong ball,
 - bounce, *see* bounce
 - cheap, 58
 - coefficient of restitution, 18
 - diameter, 70
 - equations of motion, 18
 - mass, 70
 - seam, 18, 22
 - terminal velocity, 18
- ping-pong paddle,
 - hitting a ball, 22–25, 155
 - photograph, 2, 7, 78
 - size, 13
 - surface, 22
- ping-pong robot,
 - Charlie, 14
 - Sitco RT-III Loop, 71
- pipelining, 31
- plan, 141
- planet board, 77
- pointers to functions, 80
- polynomials,
 - cubic, 99
 - octic, 106
 - quartic, 99
 - quintic, 91–93, 94, *see also*
 - quintic polynomials
- Pong, K., *xiii*
- Pose, 81

- Prazdny, K., 40
 printlog, 33
 processor,
 68020, 29
 architecture, 27
 micro-VAX, 29
 Sun, 29
 Psaltis, D., 42
 PUMA 260,
 encoder counts, 108
 kinematics, 81
 photograph, 2, 7, 78
 specifications, 76–77
 weight, 208
- quadtree, 121
 quintic polynomials, 94, 190
 acceleration-minimizing position,
 100, 175
 acceleration-minimizing velocity,
 101, 175, 200
 change in position, 94
 change in velocity, 95
 matched initial and final
 conditions, 97–100
 trajectory analyzed, 91–93
- R1 expert system, 114
 Ramakrishnan, K., *xiii*
 Reconsider, 162
 Reeves, A.P., 42
 remote procedure calls, 36
 return stroke, 179–184
 Rex, A.F., 17
 Ritchie, D.M., 116
 Robbins, D., 22
 Robbins Sport, 22
 Robinson, B.S., *xiii*
 robot, *see* PUMA 260
 flexibility, 109
 joint limits, 175
 parameter estimation, 106
 position error, 109
 requirements, 76
 robot control, *see* dynamics, Jacobian,
 trajectory generators
 friction, 104
 hardware architecture, 77
 hierarchy, 1
 integrator, 104
 kinematics/dynamics processor, 78
 on-line performance analysis, 106
 PD controller, 104
 servo rates, 80
 shared memory, 79
 slave processors, 77
 software architecture, 80
 trident interface, 77
 Unimation controller, 77
 Robotics Today, 208
 Rostampour, A., 42
 RPC, 36
 rtd, 29, 36–38
 rule-based systems, 112–115, 137
- sai, *see* strategy analyzer
 Saturn processor, 77
 scanlog, 35
 Schunck, B.G., 40
 SCINT (scaled integer), 125
 Seide, R.D., *xiii*
 Selby, S.M., 99
 set jmp, 118–119, 162
 settling time, 161
 Shanker, G., 17
 shared memory, 79
 Shariat, H., 40
 Sharma, N.K., 17
 Shaw, A.C., 117
 Shaw, M.L.G., 134
 Shoemaker, A.C., 155
 Shortliffe, E.H., 134
 Sitco RT-III Loop robot, 71
 sizes, program, 203
 Skinner, B.F., 15
 Smith, J.E.K., 93
S/Net, 29
Soneira, R.M., *xiii*
SP-2000, 29

- spin, *see* bounce, Magnus Effect
 - estimate latency, 14
 - estimation accuracy, 71, 195
 - estimation from opponent's stroke, 16
 - estimation from trajectory, 16, 66
 - generation, 25, 200
 - on balls hit by robot, 179
- Stanisic, M.M., 11
- steel ball, 70
- stereo, 48–50, 54
 - calibration, 49
 - pairs, 41
 - perspective transform, 49, 57
 - simultaneous observation, 63
- stick angle, 132, 161, 171–178, 190
- Strang, G., 49
- strategy analyzer, 28, 68, 201–203
- striker, 29
- Sun processor, 29
- synchronization, clock, 30–32
- system architecture, 27

- target_alpha, 161, 179
- target_vy, 161, 179
- target_vz, 161, 179
- task partitioning, 27
- temporal updating, 131, 132, 134, 139–147
 - example, 190–191
- thresholding, 41
- TOPLEVEL, 151, 161, 162–163
- trajectory analyzer, 28, 65–68
 - accuracy requirement, 41
 - curve fitting, 65
 - latency, 14
 - segmentation, 67
 - spin estimation, 66
- trajectory generators, 199
 - bang-bang, 91
 - biologic, 93–94
 - comparison, 89
 - full power, 89
 - joint interpolated, 80
 - quintic, 91–93
 - specifications, 88
 - straight-line, 80
- tranal, 28
- Transform, 81
- transformation matrices, 170, 172
- trident, 77
- Tsai, R.Y., 50
- tunealpha, 162, 180, 190, 192
- tunecontact, 162, 167–170
- tunehpd, 162
- tuners, 140, 144–147, 148, 162,
 - see also* tunealpha, tunecontact, tunehpd, tunestang, tunevyz
 - exceptions, 151
- tunestang, 162, 175–178, 188, 190, 194
- tunevyz, 162, 180–184, 187, 191
- Turing test, 207
- Turvey, M.T., 155

- Ullman, J.D., 44
- Uspensky, J.V., 99

- VAX, 29
- vertical image distortion due to scan, 63
- vidicon camera, *see* camera
- vision processors, 27
- vision system, *see* accuracy, (of) vision system, camera, image, lighting, moments, stereo, trajectory analyzer
- voice response, 28

VP, 149–151, 152, 162, 185,
187–188, *see also* accVP,
conVP, hitVP, impVP

Waterman, D.A., 111, 112

Watts, R.G., 17

Weste, N.H.E., *xiii*, 44, 45

Whyte, G.V., *xiii*

worthwhile, 152–153, 187, 192,
194

Wright, C.E., 93

Yager, R., 134

Zavidovique, B., 115

Zayas, J.M., 17

Zhang, H., 84, 104