

CONTENTS

.....

PART I: EMBEDDED SYSTEMS

1	Introduction	3
1.1	Mobile Robots	4
1.2	Embedded Controllers	7
1.3	Interfaces	10
1.4	References	13
2	Programming Tools	15
2.1	System Installation	15
2.2	Compiler for C and C++	16
2.3	Assembler	18
2.4	Debugging	20
2.5	Download and Upload	22
2.6	References	23
3	RoBIOS Operating System	25
3.1	RoBIOS Structure	25
3.2	Monitor Program	28
3.3	System Function and Device Driver Library	34
3.4	Hardware Description Table	36
3.5	Boot Procedure	40
3.6	References	41
4	Multitasking	43
4.1	Cooperative Multitasking	43
4.2	Preemptive Multitasking	45
4.3	Synchronization	47
4.4	Scheduling	51
4.5	Interrupts and Timer-Activated Tasks	54
4.6	References	56
5	Sensors	57
5.1	Sensor Categories	58
5.2	Binary Sensor	59
5.3	Analog vs. Digital Sensors	59
5.4	Shaft Encoder	60
5.5	A/D Converter	62

5.6	Position Sensitive Device	62
5.7	Compass	65
5.8	Gyroscope, Accelerometer, Inclinator	67
5.9	Digital Camera	70
5.10	References	81
6	Actuators	83
6.1	DC Motors	83
6.2	H-Bridge	86
6.3	Pulse Width Modulation	88
6.4	Stepper Motors	90
6.5	Servos	91
6.6	References	92
7	Control	93
7.1	On-Off Control	93
7.2	PID Control	98
7.3	Velocity Control and Position Control	104
7.4	Multiple Motors – Driving Straight	105
7.5	V-Omega Interface	108
7.6	References	110
8	Real-Time Image Processing	111
8.1	Camera Interface	111
8.2	Auto-Brightness	113
8.3	Edge Detection	114
8.4	Motion Detection	116
8.5	Color Space	117
8.6	Color Object Detection	119
8.7	Image Segmentation	124
8.8	Image Coordinates versus World Coordinates	126
8.9	References	128
9	Wireless Communication	131
9.1	Communication Model	132
9.2	Messages	134
9.3	Fault-Tolerant Self-Configuration	135
9.4	User Interface and Remote Control	137
9.5	Sample Application Program	140
9.6	References	141

PART II: MOBILE ROBOT DESIGN

10	Driving Robots	145
10.1	Single Wheel Drive	145
10.2	Differential Drive	146
10.3	Tracked Robots	150
10.4	Synchro-Drive	151
10.5	Ackermann Steering	153
10.6	Model Cars as Robots	154
10.7	Localization	155
10.8	Navigation	160
10.9	Software Architecture	167
10.10	References	168
11	Omni-Directional Robots	171
11.1	Mecanum Wheels	171
11.2	Omni-Directional Kinematics	172
11.3	Omni-Directional Robot Design	175
11.4	Driving Program	175
11.5	References	177
12	Balancing Robots	179
12.1	Simulation	179
12.2	Inverted Pendulum Robot	180
12.3	Double Inverted Pendulum	183
12.4	References	184
13	Walking Robots	187
13.1	Six-Legged Robot Design	187
13.2	Biped Robot Design	190
13.3	Sensors for Walking Robots	193
13.4	Static Balance	194
13.5	Dynamic Balance	197
13.6	References	202
14	Autonomous Planes	205
14.1	Application	205
14.2	Control System and Sensors	208
14.3	Flight Program	209
14.4	References	213
15	EyeSim Simulator	215
15.1	Mobile Robot Simulators	215
15.2	EyeSim User Interface	216
15.3	Sensor-Actuator Modeling	218
15.4	Multiple Robot Simulation	220
15.5	Sample Application	221
15.6	Environment Representations	222
15.7	Parameter Files	225
15.8	References	229

PART III: MOBILE ROBOT APPLICATIONS

16	Maze Exploration	233
16.1	Micro Mouse Contest	233
16.2	Maze Exploration Algorithms	235
16.3	Simulated vs. Real Maze Program	243
16.4	References	244
17	Map Generation	245
17.1	Mapping Algorithm	245
17.2	Data Representation	247
17.3	Boundary-Following Algorithm	248
17.4	Algorithm Execution	249
17.5	Simulation Experiments	251
17.6	Physical Experiments	252
17.7	Results	255
17.8	References	256
18	Robot Soccer	259
18.1	RoboCup and FIRA Competitions	259
18.2	Team Structure	262
18.3	Mechanics and Actuators	263
18.4	Sensing	263
18.5	Image Processing	265
18.6	Trajectory Planning	267
18.7	References	272
19	Neural Networks	273
19.1	Neural Network Principles	273
19.2	Feed-Forward Networks	274
19.3	Learning	279
19.4	Neural Controller	284
19.5	References	285
20	Genetic Algorithms	287
20.1	Genetic Algorithm Principles	288
20.2	Genetic Operators	290
20.3	Applications to Robot Control	292
20.4	Example Evolution	293
20.5	Implementation of Genetic Algorithms	297
20.6	References	300
21	Genetic Programming	303
21.1	Concepts and Applications	303
21.2	Lisp	305
21.3	Genetic Operators	309
21.4	Evolution	311
21.5	Tracking Problem	312
21.6	Evolution of Tracking Behavior	314
21.7	References	320

22	Behavior-Based Systems	323
22.1	Behavior-Based Robotics	323
22.2	Behavior Framework	326
22.3	Adaptive Controller	329
22.4	Tracking Problem	333
22.5	Neural Network Controller	334
22.6	Experiments	336
22.7	References	338
23	Evolution of Walking Gaits	339
23.1	Splines	339
23.2	Control Algorithm	340
23.3	Incorporating Feedback	342
23.4	Controller Evolution	343
23.5	Controller Assessment	345
23.6	Evolved Gaits	346
23.7	References	349
24	Outlook	351

APPENDICES

Laboratories	355
Solutions	365
Hardware Design	369
RoBIOS Library	377
Hardware Description Table	405
Tips and Tricks	421
Index	427