

Index

Table of Contents

Table of Contents.....	i
List of Figures.....	viii
Executive summary.....	1
1 Introduction to service robotics	3
1.1 Definitions and classifications	3
1.1.1 Level of autonomy	3
1.1.2 Service robot segments included in this study	4
1.2 Brief history of service robotics	5
1.3 Current state of the service robotics market	7
1.4 Government and industry robotics initiatives	9
1.4.1 National Robotics Initiative (US).....	9
1.4.2 SPARC (EU)	10
1.4.3 Industrie 4.0 (Germany)	11
1.4.4 Robot Revolution Initiative (Japan)	11
1.4.5 Made in China 2025 (China)	11
1.4.6 South Korean government initiatives	12
1.5 Investments and company transactions	13
1.5.1 Investments and venture capital	13
1.5.2 Mergers and acquisitions	16
2 Robotic concepts and components	19
2.1 Robotic architectures.....	19
2.1.1 Hardware	19
2.1.2 Software	20
2.2 Operating Systems	20
2.2.1 Robot Operating System (ROS).....	21
2.3 Sense-Plan-Act paradigm.....	22
2.4 Sensing.....	22
2.4.1 Laser range sensor (lidar)	23

2.4.2	Ultrasonic range sensor	24
2.4.3	Infrared sensor (IR).....	24
2.4.4	Camera sensors	24
2.4.5	Inertial navigation systems	25
2.5	Planning.....	25
2.5.1	On-board computing.....	25
2.5.2	Cloud robotics	26
2.5.3	Computer vision	26
2.5.4	Simultaneous localization and mapping (SLAM).....	28
2.5.5	Artificial Intelligence (AI)	28
2.5.6	Machine learning	30
2.5.7	Deep learning	30
2.6	Acting.....	33
2.7	Mobile Connectivity	34
2.7.1	Cellular M2M/IoT from 2G to 4G and beyond.....	34
2.7.2	WLAN/WPAN technologies	36
3	Service robot segments.....	39
3.1	Floor cleaning robots.....	39
3.1.1	Product segment overview.....	40
3.1.2	Current and future market applications	42
3.2	Robot lawn mowers	43
3.2.1	Product segment overview.....	44
3.2.2	Current and future market applications	46
3.3	Milking robots	47
3.3.1	Product segment overview.....	48
3.3.2	Current and future market applications	50
3.4	Humanoid robots, assistant robots and companion robots	50
3.4.1	Product segment overview.....	52
3.4.2	Current and future market applications	53
3.5	Telepresence robots.....	54
3.5.1	Product segment overview.....	56
3.5.2	Current and future market applications	57

- 3.6 Powered human exoskeletons 58
 - 3.6.1 Product segment overview..... 59
 - 3.6.2 Current and future market applications 61
- 3.7 Surgical robots 63
 - 3.7.1 Product segment overview..... 65
 - 3.7.2 Current and future market applications 67
- 3.8 Automated guided vehicles (AGVs) 69
 - 3.8.1 Product segment overview..... 71
 - 3.8.2 Current and future market applications 73
- 3.9 Autonomous mobile robots (AMRs) 75
 - 3.9.1 Product segment overview..... 77
 - 3.9.2 Current and future market applications 78
- 3.10 Unmanned aerial vehicles (UAVs) 80
 - 3.10.1 Product segment overview..... 83
 - 3.10.2 Current and future market applications 84
- 4 Company profiles and strategies..... 91
 - 4.1 Floor cleaning robots..... 91
 - 4.1.1 iRobot 91
 - 4.1.2 Neato Robotics..... 92
 - 4.1.3 Samsung Electronics 93
 - 4.1.4 LG Electronics 94
 - 4.1.5 Ecovacs Robotics..... 94
 - 4.1.6 Dyson 95
 - 4.1.7 Yujin robot 96
 - 4.1.8 Miele 96
 - 4.1.9 Cleanfix..... 97
 - 4.1.10 Taski Intellibot (Sealed Air Diversey Care)..... 97
 - 4.2 Robot lawn mowers..... 98
 - 4.2.1 Husqvarna 98
 - 4.2.2 Robomow 100
 - 4.2.3 Honda..... 101
 - 4.2.4 Zucchetti Centro Sistemi (Ambrogio Robot) 101

4.2.5	Stihl (Viking)	102
4.2.6	Global Garden Products (Stiga).....	102
4.2.7	Positec Tool Corporation (Worx).....	103
4.2.8	Bosch	103
4.2.9	John Deere.....	104
4.3	Milking Robots.....	105
4.3.1	DeLaval.....	105
4.3.2	Lely	106
4.3.3	GEA Group.....	108
4.3.4	Fullwood.....	109
4.3.5	Hokofarm Group	110
4.3.6	SAC	110
4.3.7	BouMatic Robotics	111
4.4	Humanoid robots, assistant robots and social companion robots	112
4.4.1	Softbank Robotics	112
4.4.2	Honda Motor	113
4.4.3	Kompaï Robotics	114
4.4.4	Fraunhofer IPA	115
4.4.5	Pal Robotics	117
4.4.6	Blue Frog Robotics.....	118
4.4.7	Mayfield Robotics.....	119
4.4.8	Ubtech Robotics.....	120
4.5	Telepresence robots.....	121
4.5.1	Camanio Care (Giraff)	121
4.5.2	Vgo (Vecna Technologies).....	122
4.5.3	Suitable Technologies (BEAM)	123
4.5.4	Double Robotics.....	124
4.5.5	Anybots	125
4.5.6	inTouch Health (iRobot)	126
4.5.7	Inbot Technology	126
4.6	Powered human exoskeletons	127
4.6.1	Ekso Bionics.....	127

4.6.2 Cyberdyne 128

4.6.3 ReWalk Robotics 129

4.6.4 Parker Hannifin 130

4.6.5 Rex Bionics 131

4.6.6 SuitX 132

4.6.7 Hocoma 133

4.6.8 Fourier Intelligence 134

4.6.9 Bioservo Technologies 134

4.7 Surgical robots 136

4.7.1 Intuitive Surgical 136

4.7.2 Mazor Robotics 137

4.7.3 Medrobotics 138

4.7.4 Stryker 139

4.7.5 THINK Surgical 140

4.7.6 Verb Surgical 141

4.7.7 Medtronic 142

4.7.8 Titan Medical 143

4.8 Automated guided vehicles (AGVs) 144

4.8.1 Toyota Industries Corporation 144

4.8.2 JBT Corporation 146

4.8.3 KION Group 147

4.8.4 EK Automation 148

4.8.5 Jungheinrich 149

4.8.6 Daifuku 149

4.8.7 ASTI 150

4.8.8 Elettric80 151

4.8.9 Swisslog (KUKA Group) 152

4.8.10 Amazon Robotics 153

4.8.11 AGVE Group 154

4.8.12 Kollmorgen Automotion 155

4.9 Automated mobile robots (AMRs) 156

4.9.1 Vecna Technologies 156

4.9.2	Seegrid	157
4.9.3	Otto Motors (Clearpath Robotics)	159
4.9.4	Mobile Industrial Robots	160
4.9.5	Magazino	161
4.9.6	Locus Robotics.....	162
4.9.7	Fetch Robotics	163
4.9.8	IAM Robotics	163
4.9.9	Omron Adept Technologies	164
4.9.10	Aethon	165
4.9.11	Savioke	166
4.10	Unmanned aerial vehicles (UAVs)	167
4.10.1	DJI	167
4.10.2	Parrot.....	168
4.10.3	Yuneec International.....	169
4.10.4	GoPro	170
4.10.5	3D Robotics.....	170
4.10.6	EHang.....	171
4.10.7	senseFly (Parrot)	172
4.10.8	Intel.....	173
5	Market forecasts and trends	175
5.1	Service robotics market sizing	175
5.1.1	Installed base	175
5.1.2	Shipments	176
5.1.3	Revenues.....	178
5.1.4	Connectivity strategies	179
5.2	Forecasts by service robot segment	180
5.2.1	Market forecasts – Floor cleaning robots.....	180
5.2.2	Market forecasts – Robot lawn mowers	186
5.2.3	Market forecasts – Milking robots	190
5.2.4	Market forecasts – Humanoid, assistant and social companion robots.....	195
5.2.5	Market forecasts – Telepresence robots.....	200
5.2.6	Market forecasts – Powered human exoskeletons	204

5.2.7 Market forecasts – Surgical robots 210

5.2.8 Market forecasts – Automated guided vehicles 214

5.2.9 Market forecasts – Autonomous mobile robots 219

5.2.10 Market forecasts – Unmanned aerial vehicles 223

5.3 Market drivers and barriers..... 228

5.3.1 Political factors 228

5.3.2 Economical factors..... 229

5.3.3 Social factors..... 229

5.3.4 Technological factors 229

5.3.5 Legal factors 230

5.3.6 Environmental factors 230

5.4 Market trends..... 231

5.4.1 Increased cost of labour drives automation and service robotics 231

5.4.2 Decreasing prices on robot tech makes service robotics more attractive..... 232

5.4.3 AI increases the capabilities and potential use cases of service robots..... 232

5.4.4 The future of service robotics is collaborative, not competitive 233

5.4.5 Cloud robotics, teleoperation and IoT enabled by increased connectivity 234

5.4.6 Open source robotic platforms speed up new development 235

5.4.7 Increased investments in the field of service robotics 235

Glossary 241

Index

List of Figures

Figure 1.1: All included service robot segments and various application areas	4
Figure 1.2: Revenues by segment 2016 (US\$ million)	8
Figure 1.3: Robot related funding 2016	14
Figure 1.4: Robot related M&As 2016.....	17
Figure 2.1: Relationship between AI and Computer Vision	31
Figure 2.2: Graphical representation of underfitting and overfitting.....	33
Figure 3.1: Major cleaning robot actors.....	40
Figure 3.2: Examples of domestic and professional floor cleaning robots	41
Figure 3.3: Major robot lawn mower actors.....	44
Figure 3.4: Examples of domestic and professional robot lawn mowers	46
Figure 3.5: Major milking robot actors.....	47
Figure 3.6: Examples of AMS and AMR milking robots.....	49
Figure 3.7: Major humanoid robot actors	51
Figure 3.8: Examples of humanoid robots, assistant robots and social companion robots....	53
Figure 3.9: Major telepresence robot actors.....	55
Figure 3.10: Examples of telepresence robots	57
Figure 3.11: Major powered human exoskeleton actors	59
Figure 3.12: Examples of mobile and stationary exoskeletons	61
Figure 3.13: Major surgical robot actors.....	64
Figure 3.14: Examples of surgical robots	68
Figure 3.15: Major AGV actors.....	71
Figure 3.16: Examples of AGVs	72
Figure 3.17: Major AMR actors	76
Figure 3.18: Examples of AMRs.....	78
Figure 3.19: Major UAV actors	81
Figure 3.20: Examples of multi-rotor and fixed wing UAVs	84
Figure 4.1: The Gardena Smart System from Husqvarna	99
Figure 4.2: Lely Astronaut robotic arm in action.....	107

Figure 4.3: Care-O-bot mobile service robot from Fraunhofer IPA 116

Figure 4.4: Beam from Suitable Technologies 123

Figure 4.5: Carbonhand for industrial use by Biservo Technology 135

Figure 4.6: Sport Surgical System robotic arm with camera and two instruments 143

Figure 4.7: Seegrid VGV in action..... 158

Figure 4.8: Ghostdrone 2.0 from EHang 171

Figure 5.1: Service robot installed base by region (2016–2026) 176

Figure 5.2: Service robot sales by region (2016–2026) 177

Figure 5.3: Service robot revenues by region (2016–2026) 178

Figure 5.4: Service robot connectivity technologies (2016–2026) 180

Figure 5.5: Floor cleaning robots installed base by region (2016–2026) 182

Figure 5.6: Floor cleaning robots sales by region (2016–2026) 183

Figure 5.7: Floor cleaning robots revenues by region (2016–2026) 184

Figure 5.8: Floor cleaning robots connectivity technologies (2016–2026) 185

Figure 5.9: Robot lawn mowers installed base by region (2016–2026) 187

Figure 5.10: Robot lawn mowers sales by region (2016–2026) 188

Figure 5.11: Robot lawn mowers revenues by region (2016–2026) 189

Figure 5.12: Robot lawn mowers connectivity technologies (2016–2026) 190

Figure 5.13: Milking robots installed base by region (2016–2026) 192

Figure 5.14: Milking robots sales by region (2016–2026) 193

Figure 5.15: Milking robots revenues by region (2016–2026) 194

Figure 5.16: Milking robots connectivity technologies (2016–2026) 195

Figure 5.17: Humanoid robots installed base by region (2016–2026) 196

Figure 5.18: Humanoid robots sales by region (2016–2026) 197

Figure 5.19: Humanoid robots revenues by region (2016–2026) 198

Figure 5.20: Humanoid robots connectivity technologies (2016–2026) 199

Figure 5.21: Telepresence robots installed base by region (2016–2026) 201

Figure 5.22: Telepresence robots sales by region (2016–2026) 202

Figure 5.23: Telepresence robots revenues by region (2016–2026) 203

Figure 5.24: Telepresence robots connectivity technologies (2016–2026) 204

Figure 5.25: Powered human exoskeletons installed base by region (2016–2026) 206

Figure 5.26: Powered human exoskeletons sales by region (2016–2026) 207

Figure 5.27: Powered human exoskeletons revenues by region (2016–2026)	208
Figure 5.28: Powered human exoskeletons connectivity technologies (2016–2026)	209
Figure 5.29: Surgical robots installed base by region (2016–2026)	211
Figure 5.30: Surgical robots sales by region (2016–2026)	212
Figure 5.31: Surgical robots revenues by region (2016–2026)	213
Figure 5.32: Surgical robots connectivity technologies (2016–2026)	214
Figure 5.33: Automated guided vehicles installed base by region (2016–2026)	215
Figure 5.34: Automated guided vehicles sales by region (2016–2026)	216
Figure 5.35: Automated guided vehicles revenues by region (2016–2026)	217
Figure 5.36: Automated guided vehicles connectivity technologies (2016–2026)	218
Figure 5.37: Autonomous mobile robots installed base by region (2016–2026)	220
Figure 5.38: Autonomous mobile robots sales by region (2016–2026)	221
Figure 5.39: Autonomous mobile robots revenues by region (2016–2026)	222
Figure 5.40: Autonomous mobile robots connectivity technologies (2016–2026)	223
Figure 5.41: UAVs installed base by region (2016–2026)	224
Figure 5.42: UAVs sales by region (2016–2026)	225
Figure 5.43: UAVs revenues by region (2016–2026)	226
Figure 5.44: UAVs connectivity technologies (2016–2026)	227
Figure 5.45: Robot related funding (January–June 2017)	236
Figure 5.46: Robot related M&As (January–June 2017)	238