## **CONTENTS**

Chapter One – Introduction to robotics and robotised assembly systems	1
PART I – ROBOT THEORY AND MATHEMATICAL MODELLING	
Chapter Two – Mathematical preliminary of robot modelling	13
2.1 Position of a point 13	
2.2 Planes 15	
2.3 Homogeneous transformation 15	
2.4 Orthonormal property of orientation submatrix 19	
2.5 Geometric interpretation of relative transformation 21	
2.6 Inverse transformation	
Chapter Three – Link equations and relationships	23
3.1 Specification of the 'A' matrices 23	
3.2 Wrist kinematic control equations 26	
3.3 Basic motion of the robot arm 30	
3.4 Arm kinematic control equations 31	
3.5 Kinematic control equation for robot manipulators 39	
Chapter Four – Kinematic and position control	41
4.1 Solution for wrist equations 42	
4.2 Solution for arm equations 48	
4.3 Solution for the robot manipulator 56	
4.4 Numerical example 67	
4.5 Concluding remarks 71	
Chapter Five – Differential relationships and speed control	73
5.1 Relative motion between frames 73	10
5.2 Formulating the Jacobian 81	
5.3 Examples of formulating the Jacobian matrix 81	
5.4 Speed control and the pseudo-inverse Jacobian matrix 90	
Chapter Six – Trajectory control	95
6 1 Trajectory planning 06	

6.1 Trajectory planning 966.2 Example 102



Chapter Seven – Dynamic and control model	107
<ul><li>7.1 Lagrangian mechanics 108</li><li>7.2 The manipulator dynamics equation 108</li></ul>	
7.3 Robotic arm control 113	
7.4 Nonlinear state equation of dynamic model of mechanical arm 113	
PART II – APPLICATION ORIENTATED DISCUSSION OF PROGRAMMING, TOOLING AND ROBOTISED SYSTE DESIGN	EM
Chapter Eight – Robot programming, languages, and sample programs	121
8.1 Robot programming methods 122	
8.2 Robot system architecture 124	
8.3 Robot programming languages 134	
8.4 Unimation's VAL language 143	
8.5 Sample programs written in VAL 153 8.6 New developments in robot programming 181	
8.6 New developments in 1000t programming 101	
Chapter Nine Task planning and compliance	103
0.1 Pohot planners 104	1)5
9.1 Kobol plainers 194 9.2 World modelling 196	
9.3 Task specification 197	
9.4 Manipulator program synthesis 199	
9.5 Task definitions 200	
9.6 Compliance 205	
9.7 Hybrid control 208	
9.8 Fine motion strategies 208	
Chapter Ten – Systematic planning of robot projects and robotised system installations	211
10.1 The robot project 212	
10.2 Robot project planning and scheduling 213	
10.3 Selection of the robot manufacturer and/or vendor 220	
10.4 Selection of necessary devices and ensuring integration 220	
10.5 Safety aspects when designing robotised systems 224	
Chapter Eleven – Computer-assisted testing of three-dimensional robot hand positioning and orientation errors	227
11.1 Repeatability and positioning error analysis 229	
11.2 Mathematical model of the TESTROBOT program 231	
11.3 Features of the TESTROBOT program 234	
11.4 Program menu 23/ 11.5 Semala relation and analysis 242	
11.5 Sample robot lest procedure and analysis 245	

Chapter Twelve – End-effectors, sensors and automated robot hand changers	245
<ul><li>12.1 Tool changing end-effectors for machine tools 251</li><li>12.2 Pneumatically and hydraulically operated mechanical grippers 253</li></ul>	5
12.3 Suction cup pneumatic grippers 255	
12.4 Modular and universal end-effectors 260	
12.5 Workpiece loading robot end-effectors 260	
12.6 Welding robot tools 269	
12.7 Machining robots and tools 271	
12.8 Non-contact sensing tools 276	
12.9 Soft-finger grippers 295	
12.10 Compliance hands and robotised assembly tools 296	
12.11 Automated robot hand changers (AHRCs) 304	
Chapter Thirteen – Robotised manufacturing, assembly system design and simulation software	319
13.1 Scheduling FMS and FAS cells 322	
13.2 Capacity planning software 327	
13.3 Robotised assembly line balancing 336	
Appendix	351
1. The algorithm used in the OPT_BASE program 351	
2. Some important procedures used in the OPT_BASE program 354	

3. Sample runs of the OPT\_BASE program 356