

James S. Albus

**BRAINS,
BEHAVIOR,
& ROBOTICS**

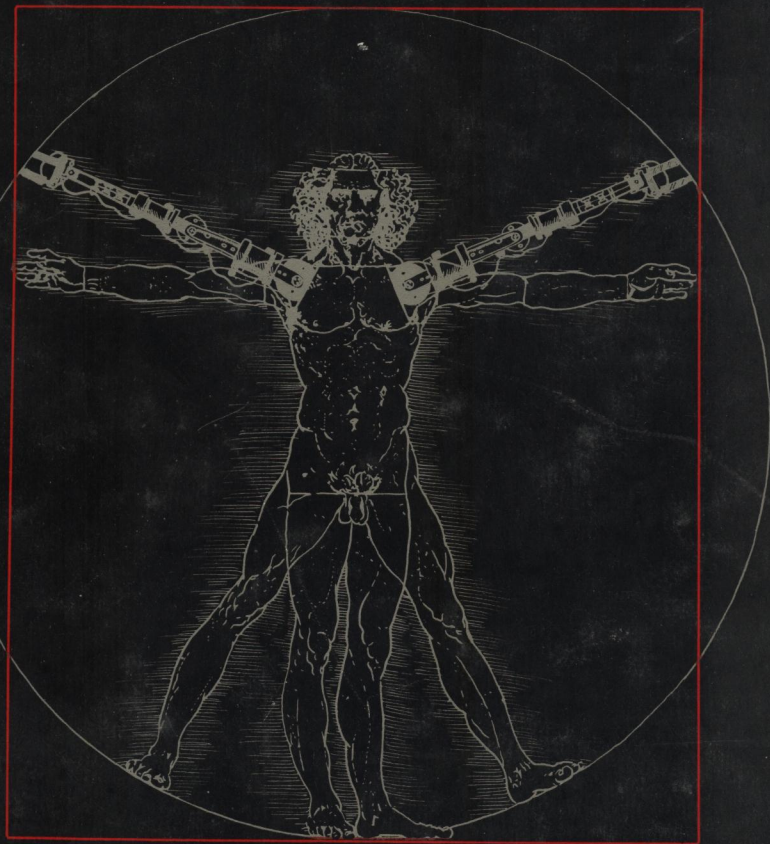
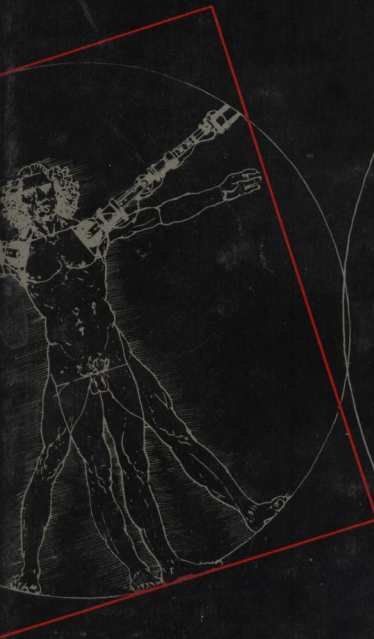


TABLE OF CONTENTS

Chapter 1	Mind and Matter The Shopping Center Problem	1
Chapter 2	The Basic Elements of the Brain Neurons Dendrites Axons Synapses Membrane Potential The Action Potential	15
Chapter 3	Sensory Input Touch Law of Specific Nerve Energies Vision The Retina Color Vision Higher Level Processing Hearing Taste and Smell Sensory Processing	35
Chapter 4	The Central Nervous System The Spinal Cord The Stretch Reflex Spinal Tracts The Brain Stem The Medulla The Reticular Formation The Midbrain Red Nucleus The Thalamus The Forebrain The Basal Ganglia The Cerebral Cortex The Frontal Lobe The Parietal Lobe The Occipital Lobe The Temporal Lobe The Limbic Lobe Prospects for Modeling the Brain	65

Chapter 5	Hierarchical Goal-Directed Behavior Vectors States and Trajectories Functions and Operators Goal-Seeking Control Systems Hierarchical Control Intentional or Purposive Behavior Goal-Directed Behavior Obtaining Successful Performance Alternative Trajectories The Sensory-Processing Hierarchy The Use of Context Expectations and Predictions Internal World Models Summary	101
Chapter 6	A Neurological Model The Cerebellar Model Arithmetic Computer (CMAC) The S → M Mapping The M → A Mapping The A → p Mapping Data Storage in CMAC Memory Size Requirements in CMAC Generalization in the CMAC Memory The Learning of Behavior CMAC as a Computer Conditional Branching Finite-State Automata Computing Integrals IF/THEN Productions	139
Chapter 7	Modeling the Higher Functions Triune Brain Hypothesis Motor-Generating Hierarchies in the Brain Sensory-Processing Hierarchies in the Brain Cross-coupling Loops and Rhythms Locked Loops and Understanding Rhythm and Harmony The Origin of Language Writing Speech Storytelling Primitive Human Speech Mechanisms of Choice Emotions Will Origins of Will and Emotion Belief and Faith Acting, Observing, and Imagining	181

Acting—The Task Execution Mode
 Observing—The Sensory Analysis Mode
 Attention
 Imagining—The Free-Running Mode
 Planning
 Daydreaming and Fantasizing
 Creativity

Chapter 8	Robots	229
	The Frankenstein Motif	
	Robot Reality	
	Industrial Robots	
	Robot Senses	
	Robot Assembly	
	Sensory Interaction	
	Conclusions	
Chapter 9	Hierarchical Robot-Control Systems	261
	Programming a Hierarchical Control System	
	The State-Machine Hierarchy	
	The Sensory Hierarchy	
	Use of the World Model	
	Software Design	
	CMAC Control Systems	
	A Microcomputer Network Implementation	
	Single Computer Implementation	
	Future Developments	
Chapter 10	Artificial Intelligence	281
	Planning and Problem Solving	
	Production Systems	
	Language Understanding	
	Can Machines Understand?	
Chapter 11	Future Applications	301
	Future Robot Cost Trends	
	Robots in Construction Trades	
	Future Research Problems	
	Household Robots	
	Robots in Energy, the Oceans, and Space	
Chapter 12	Economic, Social, and Political Implications	327
	Barriers to a Robot Labor Force	
	Potential Solutions	
	Capital Requirements	

Opportunities for the Future

References

Index

341

349

Chapter 8

Chapter 9

Chapter 10

Chapter 11

Chapter 12

Abstract—The Sensory Analysis Model
 Attention—The Sensory Analysis Model
 Imagining—The Sensory Analysis Model
 Planning
 Designing and Implementing a System
 Creativity
 Sensory Analysis Model
 The Frankenstein Model
 Robot Reality
 Industrial Robots
 Robot Senses
 Robot Assembly
 Sensory Interaction
 Conclusions
 Historical Robot Control Systems
 Programming a Hierarchical Control System
 The State Machine Model
 The Sensory Analysis Model
 Use of the World Model
 Software Design
 CMAC Control Systems
 A Hierarchical Model of the Sensory Analysis Model
 Single Computer Implementation
 Future Developments
 Artificial Intelligence
 Planning and Problem Solving
 Language Understanding
 Can Machines Understand?
 Future Applications
 Future Robot Control Systems
 Robot in Construction
 Future Robot Problems
 Homing Robot
 Robot in Energy, the Ocean, and Space
 Economic, Social, and Ethical Implications
 Path to a Robot Labor Force
 Essential Solutions
 Capital Requirements