

Table of Contents

Abstract	V
Acknowledgements	IX
List of Figures	XV
1. Introduction	1
1.1 The Approach	3
1.2 Technical Challenges	6
1.3 Introductory Example	8
1.4 Motivation	11
1.4.1 Relevance for Autonomous Robot Control	11
1.4.2 Relevance for AI Planning	12
1.5 The Computational Problem and Its Solution	13
1.5.1 The Computational Problem	13
1.5.2 The Computational Model	14
1.6 Contributions	15
1.7 Outline of the Book	19
2. Reactivity	21
2.1 The DELIVERYWORLD	22
2.1.1 The World	22
2.1.2 Commands and Jobs	25
2.1.3 The Robot	26
2.1.4 Justification of the DELIVERYWORLD	27
2.2 The Implementation of Routine Activities	28
2.2.1 Plan Steps vs. Concurrent Control Processes	29
2.2.2 Interfacing Continuous Control Processes	31
2.2.3 Coordinating Control Processes	33
2.2.4 Synchronization of Concurrent Control Threads	35
2.2.5 Failure Recovery	36
2.2.6 Perception	37
2.2.7 State, Memory, and World Models	37
2.2.8 The Structure of Routine Activities	39

2.3	The Structured Reactive Controller	40
2.3.1	Behavior and Planning Modules	41
2.3.2	The Body of the Structured Reactive Controller	42
2.3.3	Global Fluents, Variables, and the Plan Library	43
2.3.4	The RPL Runtime System	43
2.4	Summary and Discussion	44
3.	Planning	47
3.1	The Structured Reactive Plan	47
3.1.1	Plans as Syntactic Objects	48
3.1.2	RPL as a Plan Language	50
3.2	The Computational Structure	53
3.2.1	The “Criticize-Revise” Cycle	53
3.2.2	The “Criticize” Step	55
3.2.3	The “Revise” Step	66
3.3	The XFRM Planning Framework	66
3.4	Anticipation and Forestalling of Behavior Flaws	67
3.4.1	The Detection of Behavior Flaws	68
3.4.2	Behavior Flaws and Plan Revisions	68
3.4.3	The Diagnosis of Behavior Flaws	69
3.5	Summary and Discussion	72
4.	Transparent Reactive Plans	75
4.1	Declarative Statements	75
4.1.1	RPL Construct Descriptions	78
4.1.2	Achievement Goals	81
4.1.3	Perceptions	83
4.1.4	Beliefs	84
4.1.5	Other Declarative Statements	85
4.1.6	Using Declarative Statements	86
4.2	Routine Plans	88
4.3	The Plan Library	93
4.3.1	Behavior Modules	93
4.3.2	Low-level Plans	93
4.3.3	High-level Plans	95
4.4	Discussion	97
5.	Representing Plan Revisions	99
5.1	Conceptualization	101
5.2	Making Inferences	105
5.2.1	Some Examples	107
5.2.2	Accessing Code Trees	108
5.2.3	Predicates on Plan Interpretations	110
5.2.4	Predicates on Timelines	111
5.2.5	Timelines and Plan Interpretation	112

5.3	Expressing Plan Revisions	114
5.4	XFRML — The Implementation	116
5.5	Discussion	117
6.	Forestalling Behavior Flaws	121
6.1	FAUST	121
6.1.1	The Behavior Critic	121
6.1.2	Detecting Behavior Flaws: Implementation	123
6.1.3	Diagnosing the Causes of Behavior Flaws: Implementation	128
6.1.4	The Bug Class “Behavior-Specification Violation”	134
6.1.5	The Elimination of Behavior Flaws	135
6.2	The Plan Revisions for the Example	135
6.3	Some Behavior Flaws and Their Revisions	140
6.3.1	Perceptual Confusion	141
6.3.2	Missed Deadlines	142
6.4	Summary and Discussion	144
7.	Planning Ongoing Activities	147
7.1	Extending RPL	149
7.1.1	The RUNTIME-PLAN Statement	151
7.1.2	Plan Swapping	154
7.1.3	Making Planning Assumptions	156
7.2	Deliberative Controllers	158
7.2.1	Improving Iterative Plans by Local Planning	158
7.2.2	Plan Execution à la Shakey	158
7.2.3	Execution Monitoring and Replanning	159
7.2.4	Recovering from Execution Failures	160
7.2.5	Some Robot Control Architectures	161
7.3	The Controller in the Experiment	163
7.4	Discussion	164
8.	Evaluation	167
8.1	Analysis of the Problem	167
8.2	Assessment of the Method	170
8.2.1	Description of the Method	170
8.2.2	Evaluation of the Method	170
8.3	Demonstration	176
8.3.1	Evaluating SRCs in Standard Situations	176
8.3.2	Comparing SRCs with the Appropriate Fixed Controller	179
8.3.3	Problems that Require SRCs	181
8.4	Related Work	189
8.4.1	Control Architectures for Competent Physical Agents .	189
8.4.2	Control Languages for Reactive Control	194
8.4.3	Robot Planning	195

9. Conclusion 201

 9.1 What Do Structured Reactive Controllers Do? 201

 9.2 Why Do Structured Reactive Controllers Work? 202

 9.3 Do Structured Reactive Controllers Work for Real Robots? .. 204

References 205

List of Figures

1.1	Top-level view of structured reactive controllers.	3
1.2	Example task in the DELIVERYWORLD.	9
1.3	Comparison between control architectures.	16
1.4	Research directions in planning situated robot control.	17
2.1	The world simulator DELIVERYWORLD.	23
2.2	Implementation scheme for routine activities.	31
2.3	The behavior module LOOK-FOR-PROPS.	32
2.4	Architecture of the structured reactive controller.	41
2.5	Interface of planning modules.	42
3.1	Code tree for a RPL code piece	49
3.2	Replacement of subplan in a code tree.	49
3.3	The “criticize-revise” control strategy.	54
3.4	The “criticize” step.	55
3.5	A projection rule describing the behavior module LOOK-FOR.	60
3.6	An E->P-rule describing the effects of an event.	61
3.7	Task network and a timeline.	63
3.8	Detailed timeline.	64
3.9	Conceptual view of a projected task.	65
3.10	Behavior flaw taxonomy for achievement tasks	70
4.1	Structure of RPL construct descriptions.	79
4.2	detection of flaws in projected robot’s behavior.	81
4.3	The set of RPL plans.	88
4.4	Code tree of a transparent RPL plan	90
4.5	Restartable variants of RPL plans.	92
4.6	Low-level plans for the DELIVERYWORLD.	94
4.7	Low-level plan LOOK-FOR.	94
4.8	Low-level plan for tracking objects	95
4.9	High-level plan for delivering an object	96
4.10	Routine transformation rule.	97
4.11	Entry in HACKER’s plan library.	98

5.1	The XFRML system.	100
5.2	Plan revision rule transforming a code tree.	104
5.3	Graphical representation of a timeline.	112
5.4	Example plan revision rule.	115
5.5	Plan revision rule that transforms more than one subplan.	116
6.1	Algorithm for detecting and diagnosing behavior flaws.	122
6.2	Behavior flaw model for “ACHIEVE-FOR-ALL flaws.”	129
6.3	Specializations of the model “ACHIEVE-FOR-ALL flaw.”	130
6.4	Specializations of the model “clobbered subgoal.”	131
6.5	Specializations of the model “never achieved subgoal.”	132
6.6	Data structure BEH-SPEC-VIOLATION.	134
6.7	Configuration of the structured reactive controller used for solving this problem.	136
6.8	RPL code for the structured reactive controller.	137
6.9	An example execution scenario for the RPL plan in figure 6.8.	138
6.10	Modification of the code tree by the plan revision rule.	139
7.1	Interface of a planning process.	151
7.2	Extraction of a local plan.	153
8.1	Configuration of an SRC.	177
8.2	Performance comparison of different types of robot controllers. ...	180
8.3	Spectrum of robot control problems.	190
8.4	Behavior-based robot control architecture.	191



<http://www.springer.com/978-3-540-67241-8>

Concurrent Reactive Plans

Anticipating and Forestalling Execution Failures

Beetz, M.

2000, XVI, 220 p., Softcover

ISBN: 978-3-540-67241-8