

Contents

Foreword on Notation and Prerequisites XVII

Chapter I

The Background of Temporal Logic 1

Chapter II

Topological Logic 13

1. Introduction 13
2. The P -Operator 13
3. Three Basic Axioms 14
4. The Relation of P -Unqualified to P -Qualified Formulas:
The Preferred Position ξ : A Fourth Axiom 16
5. The Iteration of P : A Fifth Axiom and the Two Systems **PI** and **PII** 17
6. The Possible Worlds Interpretation of Topological Logic 21

Chapter III

Fundamental Distinctions for Temporal Logic 23

1. The Temporal Equivocality of IS 23
2. Translating Temporal to Atemporal IS 24
3. Temporally Definite and Indefinite Statements 25
4. The Implicit Ubiquity of "Now" in Tensed Statements 26
5. Dates and Pseudo-Dates 27
6. Times of Assertion 28
7. Two Styles of Chronology 30

Chapter IV

The Basic System **R** of Temporal Logic 31

1. The Concept of Temporal Realization 31
2. The Temporal Transparency of "Now" 32
3. Temporal Homogeneity 35
4. Axioms for the Logical Theory of Chronological Propositions 37
5. Temporal and Topological Logic 43
6. The Completeness and Decidability of **R** 44

Chapter V

The Introduction of Tense Operators 50

1. Presentness and Precedence 50
2. Tense 52

Chapter VI

The System \mathbf{K}_t of Minimal Tense Logic 55

1. The Problem of a Minimal Tense Logic 55
2. Semantics for Tense Logic 56
3. Semantic Tableaux 58
4. The Completeness of \mathbf{K}_t 62
5. Some Corollaries 66
6. Completeness of \mathbf{K}_t with Respect to \mathbf{R} 67

Chapter VII

Branching Time: The System \mathbf{K}_b 68

1. Branching Structures 68
2. The Concept of an Open Future 70
3. The Logic of Branching Time 74
4. Axiomatization of \mathbf{K}_b 76
5. Semantic Tableaux 79
6. Systematic Tableaux 81
7. Completeness Proof for \mathbf{K}_b 83

Chapter VIII

Linear Time: The System \mathbf{K}_l and Its Variants 88

1. The Logic of Linear Time, \mathbf{K}_l 88
2. Extensions of \mathbf{K}_l 91

Chapter IX

Additive Time: The Systems \mathbf{R}^\oplus and $\mathbf{R}^{\oplus\pm}$ 98

1. Temporal-Groups and the System \mathbf{R}^\oplus 98
2. Additive Temporal Logic and the System $\mathbf{R}^{\oplus\pm}$ 100

Chapter X

Metric Time and Chronological Logic: The System \mathbf{R}^+ 103

1. The Concept of Metric Time 103
2. Deriving a U -Relation from the Metric 105
3. The System \mathbf{R}^+ 109
4. "Distance" into Past and Future 110
5. Archimedeanism 114
6. Linear Realizability 115

Chapter XI

Tense Logical Characterizability and Definability 117

1. Expressibility and Characterizability 117
2. Tense-Logical Definability 122

Chapter XII

Temporal Modality 125

1. The Tensed Interpretation of Modality 125
2. Modality in Tense Logic 126
3. Further Definitions of Modality 133

Chapter XIII

Temporally Conditioned Descriptions and the Concept of Temporal Purity 138

1. Temporally Conditioned Descriptions 138
2. Chronological Purity 144
3. The "Purely Phenomenological" Characterization of the Occurrences of a Moment 149
4. The Absolute vs. the Relative Conception of Time 151

Chapter XIV

The Theory of Processes 155

1. What is a Process? 155
2. The Representation of Processes: Process Implications 155
3. Activities and Processes: Some Applicable Distinctions 159
4. Quasi-Processes: On Coming to Be and Passing Away 161
5. Stochastic vs. Deterministic Processes 162
6. Stochastic Processes and Branching Time 166
7. The Structure of Events 167

Chapter XV

The Logic of World States 170

1. The Concept of a World State 170
2. Some Further Perspectives on Instantaneous World States 173
3. The Concept of a World History 179
4. Development of *R*-calculi Within Tense Logic 182

Chapter XVI

The Dimensionality of Time 184

Chapter XVII

The “Master Argument” of Diodorus
and Temporal Determinism 189

1. The “Master Argument” 189
2. Necessity and Determinism in the Context of the “Master Argument” 195
3. Evading the Deterministic Conclusion of the “Master Argument” 196
4. The Groundwork of a 3-Valued Conception of Temporal Truth 198
5. Alternative Futures and Future Contingency 200
6. Temporal Determination 203
7. Nomological Necessitation 206

Chapter XVIII

Many-Valued Approaches to Temporal Logic 213

1. A Mode of “Three-Valued” Tense Logic 213
2. A Many-Valued Articulation of Temporal Logic 216
3. A Three-Valued Tense Logic: Semantic Considerations 219
4. Generalizing the Preceding Approach 224

Chapter XIX

Propositional Quantification in Tensed Statements 228

Chapter XX

Quantification, Temporal Existence, and Identity 234

1. Individuals and Quantifiers 234
2. Quantification and Temporal Modality 237
3. Quantified Tense Logic 240
4. Temporal Change, Identity, and Leibniz’ Law 241
5. Alternative Histories in Branching Time 243
6. Quantified Modal Logic in Branching Time 246

Appendix I

A Summary of Axiom Systems for Topological, Temporal
and Modal Logics 249

Appendix II

The Modal Structure of Tense-Logical Systems 258

Bibliography of Temporal Logic 259

- A. Chronological Listing 259
- B. Author Listing (Alphabetical) 263

Index of Names 268

Subject Index 270