dandelon.com
© 2008 AGI-Information Management Consultants
May be used for personal purposes only or by
libraries associated to dandelon.com network.

Gheorghe Paun

Membrane Computing

An Introduction

With 37 Figures and 5 Tables

Springer

Contents

Preface . . . . . **VII**

1. Introduction: Membrane **Computing — What It Is and What It Is Not** **1**

2. Prerequisites 7
2.1 The Biological Membrane 7
2.1.1 The Structure of the Plasma Membrane 8
2.1.2 Trans-membrane Transport 10
2.1.3 Cellular Division: Mitosis 14
2.2 The Neuron 15
2.3 Elements of Computability 16
2.3.1 Basic Notions and Notations 17
2.3.2 Operations with Strings and Languages 18
2.3.3 Chomsky Grammars 19
2.3.4 Characterizations, Necessary Conditions 22
2.3.5 Lindenmayer Systems 24
2.3.6 Finite Automata, Turing Machines 26
2.3.7 Regulated Rewriting 29
2.3.8 On the Difference Between CS and RE 39
2.3.9 Universal Turing Machines and Type-0 Grammars 40
2.3.10 Splicing, Insertion-Deletion, Context Adjoining 42
2.3.11 Elements of Complexity 45
2.3.12 Multisets 49
2.4 Bibliographical Notes 50

3. Membrane Systems with Symbol—Objects 51
3.1 A Simple Class 51
3.2 Two Examples 55
3.3 The Power of the Simple Class 58
3.4 Basic Extensions 64
3.4.1 Dissolving a Membrane 64
3.4.2 Priorities Among the Evolution Rules 70
3.4.3 Two Further Examples 71

3.4.4 The Power of Priority . . . 74
3.4.5 The Power of Synchronization . . . 77
3.5 A Formal Definition . . . 85
3.6 Further Extensions . . . 91
3.6.1 Weak Target Commands . . . 91
3.6.2 Controlling the Permeability of Membranes . . . 93
3.6.3 Communication Controlled by Concentration . . . 99
3.6.4 Creating Rules During the Computation . . . 102
3.6.5 Using Promoters/Inhibitors . . . 104
3.7 Systems with External Output . . . 114
3.8 Bibliographical Notes . . . 125

4. Trading Evolution for Communication . . . 129
4.1 Systems with Symport/Antiport . . . 130
4.2 Computational Universality . . . 133
4.3 Controls on the Use of Rules . . . 141
4.4 Following the Traces of Objects . . . 144
4.5 Systems with Carriers . . . 153
4.6 Bibliographical Notes . . . 159

5. Structuring the Objects . . . 161
5.1 Rewriting Membrane Systems . . . 162
5.2 Some Variants and Their Power . . . 180
5.2.1 Rule Creation . . . 181
5.2.2 Conditional Rewriting . . . 181
5.2.3 Conditional Communication . . . 186
5.2.4 Replicated Rewriting . . . 199
5.2.5 Parallel Rewriting . . . 208
5.3 Splicing Membrane Systems . . . 211
5.4 Contextual Membrane Systems . . . 223
5.5 Insertion-Deletion Membrane Systems . . . 226
5.6 Bibliographical Notes . . . 231

6. Networks of Membranes . . . 235
6.1 The Splicing Case . . . 236
6.2 Using Symport/Antiport Rules . . . 238
6.3 Neural-like Networks of Membranes . . . 249
6.3.1 Definitions and Examples . . . 249
6.3.2 The Computational Power . . . 256
6.3.3 The Computational Efficiency . . . 267
6.4 Bibliographical Notes . . . 269

7. Trading Space for Time . . . 271
7.1 Complexity Classes for Membrane Systems . . . 271
7.2 Using Membrane Division . . . 273
7.2.1 Solving SAT in Linear Time . . . 281
7.2.2 Solving the Hamiltonian Path Problem . . . 286
7.2.3 Using Cooperative Rules . . . 290
7.2.4 Is Membrane Division Necessary? . . . 298
7.3 Using Membrane Creation . . . 301
7.3.1 Solving SAT . . . 311
7.3.2 Solving HPP . . . 316
7.3.3 The Case of String-Objects . . . 318
7.4 Using String Replication . . . 321
7.5 Using Pre-computed Resources . . . 323
7.6 Bibliographical Notes . . . 327

8. Further Technical Results . . . 329
8.1 Decidability Results . . . 329
8.2 Unary Systems . . . 340
8.3 A Representation of Context-free Languages . . . 344
8.4 Valuating the String-Objects . . . 348
8.5 Systems with Enhanced Membrane Handling . . . 351
8.6 Brief Excursion Through the Literature . . . 354
8.6.1 Generalized Sequential Membrane Systems . . . 354
8.6.2 Bidimensional Objects . . . 357
8.6.3 Membrane Systems and Stream X-machines . . . 357
8.6.4 Membrane Systems and Ambient Calculus . . . 359
8.6.5 A Direct Construction of a Universal System . . . 361
8.6.6 Further Research Topics . . . 363

9. (Attempts to Get) Back to Reality . . . 367
9.1 Getting Closer to the Cell by Energy Accounting . . . 367
9.2 Getting Closer to the Cell by Gemmation . . . 373
9.3 Getting Closer to the Cell: Bilayer Membranes . . . 375
9.4 *In Silico* Implementations . . . 379
9.5 Artificial Life Applications . . . 384
9.6 A Simulation of Photosynthesis . . . 392

Open Problems . . . 399

Universality Results . . . 401

References . . . 403

Index . . . 417