

# Table of Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>I</b>	<b>Fundamentals</b>	<b>3</b>
<b>2</b>	<b>Hydrodynamics</b>	<b>5</b>
2.1	Classification . . . . .	5
2.2	Properties of Fluids and Flows . . . . .	6
2.3	The Continuum Hypothesis . . . . .	8
2.4	The Navier-Stokes Equations . . . . .	9
<b>3</b>	<b>Stochastic Rotation Dynamics</b>	<b>13</b>
3.1	Particle Model and Continuum Model . . . . .	13
3.2	Mesoscopic Algorithms . . . . .	14
3.3	The SRD Method . . . . .	15
3.3.1	Simulation Parameters and Transport Coefficients . . . . .	17
3.3.2	Simulation of Complex Structures . . . . .	19
3.4	Simulation of Binary Mixtures . . . . .	19
<b>4</b>	<b>The Cell Broadband Engine</b>	<b>23</b>
4.1	Architecture . . . . .	23
4.1.1	Power Processor Element (PPE) . . . . .	24
4.1.2	Synergistic Processor Element (SPE) . . . . .	25
4.1.3	Element Interconnect Bus (EIB) . . . . .	26
4.1.4	Storage Domains . . . . .	26
4.2	Application Areas . . . . .	27
4.3	Programming Applications for the Cell/BE . . . . .	30
4.3.1	Programming Models . . . . .	31
4.3.2	Software Development with Cell SDK . . . . .	32
4.4	JUICE – Jülich Initiative Cell Cluster . . . . .	33
4.4.1	JUICEnext . . . . .	34
<b>5</b>	<b>Cell Superscalar Framework</b>	<b>37</b>
5.1	Programming with CellSs . . . . .	37
5.1.1	Syntax . . . . .	38
5.1.2	Compiler . . . . .	40
5.1.3	Runtime . . . . .	41
5.2	Advantages Compared to Native Programming . . . . .	42

<b>II</b>	<b>Implementation</b>	<b>43</b>
<b>6</b>	<b>Implementation of SRD</b>	<b>45</b>
6.1	Overview of the Implemented Features . . . . .	45
6.2	Boundary Conditions . . . . .	46
6.2.1	Periodic Boundary Conditions . . . . .	47
6.2.2	Bounce Back Boundary Conditions . . . . .	47
6.2.3	Reflective Boundary Conditions . . . . .	47
6.2.4	Stick Boundary Conditions . . . . .	48
6.3	Data Structures . . . . .	48
6.4	Data Management via Linked-Cell Lists . . . . .	51
6.5	Program Description . . . . .	53
6.5.1	Initialization Step . . . . .	55
6.5.2	Free Streaming Step . . . . .	56
6.5.3	Cell Filling Step . . . . .	57
6.5.4	Multiparticle Collision Step . . . . .	58
6.5.5	System-Variable Calculation Step . . . . .	60
6.5.6	Fluid Interaction Step . . . . .	61
6.6	Running a Simulation . . . . .	62
<b>7</b>	<b>Porting of SRD Implementation to Cell/BE</b>	<b>65</b>
7.1	Algorithm Match . . . . .	66
7.1.1	Important Cell/BE Features . . . . .	66
7.1.2	Cell/BE Features Exploited . . . . .	67
7.2	Programming Model . . . . .	69
7.3	Data Management for Cell/BE . . . . .	70
7.3.1	Data Sorting . . . . .	71
7.3.2	Cellwise Storage . . . . .	73
7.3.3	Choice . . . . .	75
7.4	Implementation via CellSs . . . . .	75
7.4.1	SPE Functions . . . . .	76
<b>8</b>	<b>Results</b>	<b>79</b>
8.1	SRD Implementation . . . . .	79
8.1.1	Simulation of a Poiseuille Flow . . . . .	79
8.1.2	Flow Around a Cylinder . . . . .	82
8.1.3	Simulation of a Binary Mixture . . . . .	83
8.2	Cell/BE Implementation . . . . .	85
8.2.1	Performance Results . . . . .	85
8.2.2	Experiences with CellSs . . . . .	88
<b>9</b>	<b>Outlook</b>	<b>91</b>
9.1	Enhancement of SRD Implementation . . . . .	91
9.2	Enhancement of Cell/BE Implementation . . . . .	92
<b>10</b>	<b>Summary and Conclusions</b>	<b>95</b>
	<b>Acronyms</b>	<b>97</b>

<b>Glossary</b>	<b>99</b>
<b>Bibliography</b>	<b>103</b>
<b>III Appendix</b>	<b>107</b>
<b>A Simulation of Binary Mixtures (3D)</b>	<b>109</b>
<b>B Example Program for the Cell/BE Using the Cell SDK</b>	<b>111</b>
B.1 Header File . . . . .	111
B.2 PPE Source Code . . . . .	112
B.3 SPE Source Code . . . . .	114
<b>C Calculation of Boundary Conditions</b>	<b>115</b>
C.1 BBC and RBC for Rectangular Simulation Boxes . . . . .	115
C.2 BBC and RBC for Circular and Spherical Simulation Boxes . . . . .	116
C.3 BBC and RBC for Cylindrical Simulation Boxes . . . . .	117
C.4 Stick Boundary Conditions for a Circular Barrier . . . . .	119
<b>D Calculation of System Parameters</b>	<b>121</b>
<b>E Implementation of Data Sorting and Cellwise Storage Approach</b>	<b>123</b>
E.1 C-source Code of Function <code>cc_fill()</code> for the Data Sorting Approach . . . . .	123
E.2 C-source Code of Function <code>cc_fill()</code> for the Cellwise Storage Approach . . . . .	124
E.3 C-source Code for Reallocation of Memory for the Cellwise Storage Approach . . . . .	125
<b>F Cell/BE Implementation of SRD via CellSs</b>	<b>127</b>
F.1 CellSs Code for Free Streaming Step . . . . .	127
F.2 CellSs Code for Multiparticle Collision Step (2D) . . . . .	130
F.3 CellSs Code for Multiparticle Collision Step (3D) . . . . .	131
<b>Index</b>	<b>133</b>