Contents

Foreword vii

Preface ix

Introduction xi

Chapter 1. Serial Implementation 1

1.1. System design 1
1.1.1. Data structures 2
1.1.2. Algorithms. 5
1.2. Contact detection 8
1.2.1. Simplified grid cell method 8
1.2.2. Particle-to-particle contact. 10
1.2.3. Wall-to-particle contact. 12
1.3. Constitutive model 14
1.3.1. Particle-to-particle constitutive model 14
1.3.2. Wall-to-particle constitutive model 19
1.4. Time step, damping and energy calculation 21
1.5. Benchmark examples 23
1.5.1. Falling ball under gravity 23
1.5.2. Pendulum problem 25
1.5.3. Elastic deformation of normal spring under tension 28
1.5.4. Elastic deformation of spring under shear 29
1.5.5. Failure of normal spring under tension 32
1.5.6. Failure of shear spring under shear. 34
1.5.7. Newton balls 36
1.5.8. Bounce back ball 39
1.5.9. Sliding particle 43

1.5.10. Sliding particle with rolling 45
1.5.11. Rock fall problem 48
1.5.12. Beam collision 49
1.6. Conclusion 52

Chapter 2. Multi-core Implementation 53

2.1. Multi-core personal computer 53
2.2. Multi-core implementation using MATLAB 55
2.3. Performance analysis 57
2.4. Parallel implementation 60
2.5. Numerical examples 64
2.5.1. Uniaxial compression test 64
2.5.2. Beam bending test 68
2.5.3. Collapse of a granular tree under gravity 74
2.5.4. Block caving 77
2.6. Conclusion 83

Chapter 3. GPU Implementation 85

3.1. Graphics processing unit computing 85
3.2. GPU implementation of DICE2D 86
3.3. Examples 92
3.3.1. Uniaxial tension test 92
3.3.2. Brazilian disk test 101
3.3.3. Uniaxial compressive strength test 105
3.3.4. Triaxial compressive test 107
3.4. Conclusion 111

Chapter 4. DICE2D and Cluster 113

4.1. Leonardi cluster 114
4.2. Run DICE2D on cluster 115
4.3. Numerical examples 117
4.3.1. Collapse of trees under gravity 117
4.3.2. Rock cutting 118
4.3.3. Slope stability analysis 122
4.3.4. Interaction between ground structure and underground structure 130
4.4. Conclusion 136

Bibliography 137

Index 143