High performance N-body simulation on computational grids

Groen, D.J.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (http://dare.uva.nl)
Contents

1 Introduction
   1.1 Simulating $N$-body systems ........................................... 2
      1.1.1 Direct-method integration methods .................................. 2
      1.1.2 Alternative $N$-body integration methods .......................... 4
   1.2 High-performance $N$-body simulations ................................. 4
      1.2.1 Parallelization and speedup ....................................... 5
      1.2.2 Communication in parallel simulations ............................ 7
      1.2.3 $N$-body simulations using special-purpose hardware ............. 7
   1.3 Distributed infrastructures and computational grids .................. 8
   1.4 Thesis overview .......................................................... 9
      1.4.1 Chapter 2 ............................................................ 10
      1.4.2 Chapter 3 ............................................................ 10
      1.4.3 Chapter 4 ............................................................ 10
      1.4.4 Chapter 5 ............................................................ 11
      1.4.5 Chapter 6 ............................................................ 12

2 Distributed Direct $N$-body Simulations on a Global Grid of GRAPEs 13
   2.1 Introduction ............................................................. 13
   2.2 Experiment setup ......................................................... 15
   2.3 Results of grid calculations .......................................... 17
      2.3.1 Timing results of $N$-body calculations ............................ 17
      2.3.2 Profiling of the $N$-body simulations .............................. 18
   2.4 Modelling the performance of the grid ................................ 19
      2.4.1 Single PC ............................................................ 20
      2.4.2 Grid of PCs with copy algorithm ................................... 22
      2.4.3 Grid of PCs with ring algorithm .................................. 23
### 5.4.2 DAS-3 results
---

### 5.4.3 Gravitational Billion Body Project experiment setup

- **5.4.3.1 Network configuration**
---

### 5.4.4 GBBP results
---

### 5.5 Scalability of \( N \)-body simulations across supercomputers

- **5.5.1 Speedup and efficiency predictions for TreePM simulations**
- **5.5.2 Speedup and efficiency predictions for tree and direct-method simulations**
  - **5.5.2.1 Performance model for the tree algorithm**
  - **5.5.2.2 Modelling of block time steps**
  - **5.5.2.3 Predictions**
- **5.5.3 Bandwidth analysis for cosmological simulations**

### 5.6 Conclusion
---

---

### 6 A Light-Weight Communication Library for Distributed Computing

- **6.1 Introduction**
- **6.2 Related work**
- **6.3 Architecture of MPWide**
  - **6.3.1 Design**
    - **6.3.1.1 Data transport in the wide area network**
    - **6.3.1.2 Functionality and programming interface**
  - **6.3.2 Forwarder**
  - **6.3.3 Implementation**
- **6.4 Benchmarking MPWide**
  - **6.4.1 Results**
    - **6.4.1.1 Local tests**
    - **6.4.1.2 National tests**
    - **6.4.1.3 International tests**
- **6.5 Testing performance in a production environment**
  - **6.5.1 Test experiments**
    - **6.5.1.1 Results on DAS-3 Dutch grid**
    - **6.5.1.2 Results on Amsterdam and Helsinki supercomputers**
    - **6.5.1.3 Results on Amsterdam and Tokyo supercomputers**
  - **6.5.2 Production**
- **6.6 Conclusions and future work**

---

### 7 Conclusions

- **7.1 Thesis summary**
- **7.2 Conclusions and Recommendations**
  - **7.2.1 Simulations on a planet-wide distributed supercomputer**
  - **7.2.2 Recommendations for planet-wide \( N \)-body simulations**
  - **7.2.3 Creating a planet-wide distributed supercomputer**
    - **7.2.3.1 Configuration of a global supercomputer**
    - **7.2.3.2 Scheduling and running on a global supercomputer**
# Future perspectives and applications

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nederlandse Samenvatting</td>
<td>111</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>115</td>
</tr>
<tr>
<td>List of Publications</td>
<td>119</td>
</tr>
<tr>
<td>Bibliography</td>
<td>123</td>
</tr>
</tbody>
</table>