Particle-in-Cell System for Snowball Movement Simulation

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Outline

- Introduction
- Architecture
- Shape estimation
- Parallelization
- Power Savings
- Verification
- Summary
Introduction

What is PIC?

- Particle-in-cell system presents the movement of the scattered objects

Problem

- Imbalanced calculation workload

Solutions

- Design an optimized PIC system by using 5 optimization techniques from teammates' domain knowledge

Performance experiment: Post-post K computer
Architecture

<table>
<thead>
<tr>
<th>Worker 0</th>
<th>Worker 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker 2</td>
<td>Worker 3</td>
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</tbody>
</table>

Scheduler

Worker X

Shape estimation

Worker cluster

Worker0  Worker1  Worker2  Worker3
Architecture

- Estimate the shape on the next “moment”
- Parallelized calculation for result for estimation
- Resize each area to fit the workloads
- Score current strategy for further adjustment
Markov Chain for Shape Estimation

Mathematically,
\[ p(i, j) = P[X_{n+1} = j | X_n = i] \]
Markov Chain for Shape Estimation

- Markov Chain is used to model the state of the system/Particle at any given time in space/medium.
- The element of the transition Matrix is obtained using the transition diagram.
- The probability of being in the next state is determined as a function of the conditional probability of the being in the current state.
- The Markov Chain helps the scheduler to determine where to assign the computing resources.

Mathematically,  
\[ p(i, j) = P[X_{n+1} = j | X_n = i] \]
Parallelization

- The overall grid computation tasks are parallelized; more CPUs share heavy computation area
Power Saving

Interconect Network

Compute Nodes

Meta-Data Nodes

Data Nodes

Storage Design

SSD Devices

HDD Devices
Power Saving  (Scheduler Tasks)

Figure 1

Figure 2
Verification

● In this project, the scheduler is critical
● We should find bugs in the scheduler
● Separation Logic is a tool for software verification
  ○ It can find some memory leak bugs in a given program with high accuracy
Summary

We propose a new PIC system which utilize Markov Chain, high parallelization, power-efficient strategy to handle dynamic and complicated particle movements simulation.

[Picture of colliding snow balls]
Reference