Simulation on Reconfigurable Heterogeneous Architectures

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Motivation

- Heterogeneous computer architectures are integrated into single chips

**Overview of current heterogeneous architectures**

- CPU
- GPU
- FPGA

- Fast and reliable execution of simulation applications on innovative reconfigurable heterogeneous computer architectures

Challenges

- Reliability
  - Simulation applications are often executed for days and months
  - CMOS devices, manufactured in 12nm technology and below:
    - vulnerable to transient effects, process variations and latent defects, as well as stress and aging mechanisms
  - Fault-tolerant execution, memories and communication are required
  - Focus: Fault-tolerant simulation algorithms

- Achieving optimal performance
  - Performance depends on the combination of implementation and utilized architecture

Current Work

Efficient Fault-Tolerance for the Preconditioned Conjugate Gradient Method (PCG)

**Motivation**

- PCG is one of the most popular sparse linear system solvers ($Ax = b$)
- Widely used in structural mechanics, computational fluid dynamics, electronic design automation
- PCG is still vulnerable to transient errors
- Single errors may significantly increase computation times and corrupt the computed solution without indication to the user

**Method: Error Detection**

- Exploitation of global orthogonality and residual relationships to derive an efficient error detection method

Current Collaborations

Adaptive Parallel Simulation of a Two-Timescale Model for Apoptotic Receptor-Clustering on GPUs

Cooperation with M. Daub • G. Schneider

**Motivation**

- Apoptosis: Structured decomposition of damaged or infected cells in multi-cellular organisms
- Deeper understanding of the activation necessary
- Simulation: Dominated by extensive computing times
  - Significant computational requirements
  - Large numbers of simulations required to draw reliable conclusions

**Goals**

- Reduction of computation time
- ... to obtain extensive and detailed conclusions about the clustering behavior

Methods

- Simulation on multiple time scales for optimal balance between biological process resolution and computation costs
- Separation of particle dynamics
- Adaptive refinement of time steps on each timescale in case of violations

**Biological Evaluation**

- Temporal evolution of ligand-receptor clusters in less than 0.5s

**Computational Performance Results**

- Reduction of simulation time from hours to seconds

- Previous work (s)
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**Simulation times with different numbers of parallel instances on multiple GPUs**

**Error Correction**

- Adaptive error correction scheme
  - Dependent on the detected corruption an online correction
  - ... or a rollback recovery is performed

**Experimental Results**

- Experiments: Random injection of bit flips and comparison against error-free execution ($\epsilon$)

**Mapping of particle simulation to heterogenous architectures**

**Evaluation**

- Field Programmable Gate Arrays (FPGA)
- GPU
- CPU

**Computation times**

- 30: 43
- 57

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