Towards Unlocking Concurrency to the Masses

Second Year PhD Report

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Research Context (1)

- Moore's law no longer involves an enhancement in computing performances [15]

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How to bring the power of parallelism to the masses?

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  - *Event-Driven Programming Paradigm*
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- So far, I have concentrated on special cases:
  - ○ *Event-Driven Programming Paradigm*
    - The advancement of the execution is determined by the flow of timestamped events which produce changes in the stateb
    - *Discrete Event Simulation Environments*
  - ○ *Software Transactional Memories*:
    - Allow a correct sequential object to be mapped into a correct concurrent object
    - Based on the notion of transactions

Goals (1)

- Performance
  - Explore new synchronization patterns and protocols
  - Specifically rely on non-blocking algorithms
- Transparency
  - Allow the programmer to easily produce a program which is then run as efficiently as possible
  - Need to rely on the most restricted set of new APIs
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- Tools
  - Practical tools to help the unexperienced
- Methodologies
  - General approaches to efficiently support parallel execution

Related Work (1)

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    - Mutual exclusion problem [20, 21, 22]
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    - Composite locks [24]
- They have been proven to be an effective and viable approach

Related Work (2)

- Virtual Time Synchronization [33]
  - A set of rules specifying correctness for concurrent execution of Event-Based simulation models
  - Some implementations rely on global data structures, or special-purpose threads (e.g., [34])
  - Either *conservative* synchronization, or *optimistic* syncronization [35] protocols/runtime environments have been proposed

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  - Either *conservative* synchronization, or *optimistic* syncronization [35] protocols/runtime environments have been proposed
  - Efficient memory management in the optimistic case has been supported in several ways
    - Full State Saving [36, 37, 38, 39]
    - Incremental State Saving [40, 41, 42]
    - Mixture of the two [43, 44]

Where are we now?!

- I have moved on two main tracks:
  - Event-Driven Programming (Optimistic Simulation flavour):
    - Supports for transparents management of private and shared simulation state
    - Performance enhancements transparently introduced, relying on the autonomic computing paradigm [45, 46, 47]
  - Transactional Memories
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- Common ground
  - Static instrumentation methodologies/tool to reshuffle the code

Intrumenting Tool (1)

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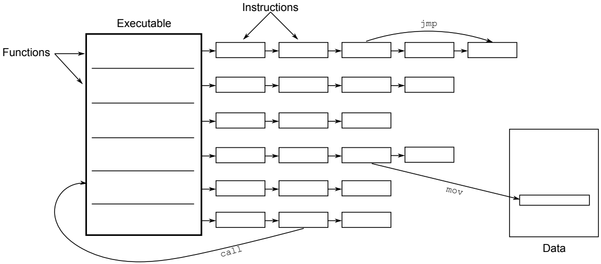


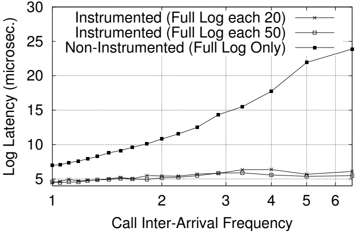
Instrumenting Tool (2)

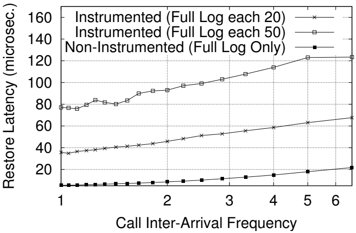
- Possible application scenarios:
  - Profiling
  - Performance Enhancements
  - Synchronization Transparency
  - Post-Mortem Debugging [48]

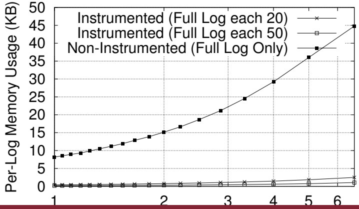
Private Data Management

- Based on static instrumentation + dynamic reconstruction of memory update targets
- Efficient
  - ○ Recycling of cached disassembly information injected in the executable
  - ○ Memory-update detection's cost is $O(1)$
- Standard malloc services are wrapped, for transparency
- Fast reconstruction of the state using bit-wise masking of unimportant memory areas
- Wise usage of memory resources
- Several layers involved: compilation, linking and runtime execution
- Evaluated on a complex wireless network simulation model

Private Data Management (2)

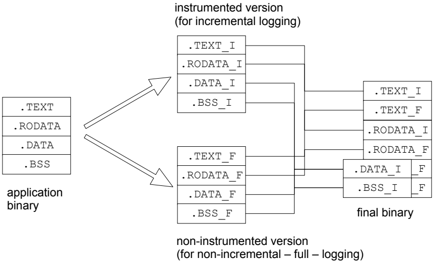






Autonomic Approach based on Dual Coding

- First proposal in literature on this topic in this context
- Two versions of the same executable, differently instrumented coexist
- Switch amongst the modes involves reassigning function pointers
- Based on an analytical integral model, which accounts for stability regardless of perturbations and fluctuations



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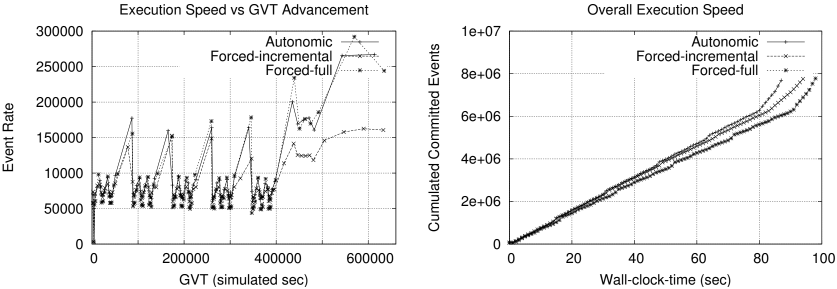

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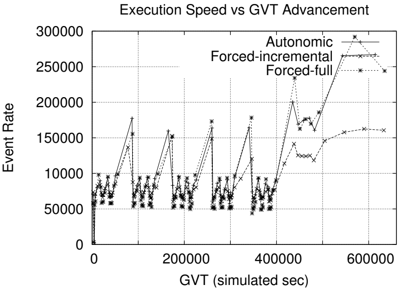

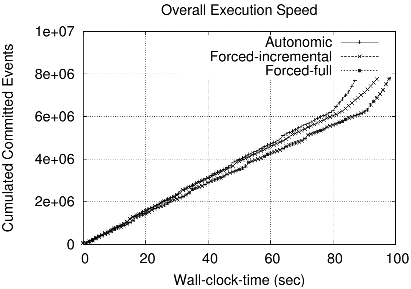

Superlinear speedup wrt the serial execution

Shared Data Management

$$\forall i, j \; i \neq j \; : \; S_i \cap S_j = \emptyset \qquad S = \bigcup_{i=1}^{numLP} S_i$$

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Goal:

- Enable the application programmer to access both the object's private state and the global portion

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- Implement variables as multi-versioned lists
- Use non blocking algorithms for synchronization
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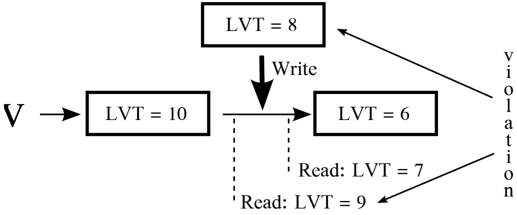
- Remap shared data to shared memory
- Efficient new rollback scheme: waste as minimum as possible



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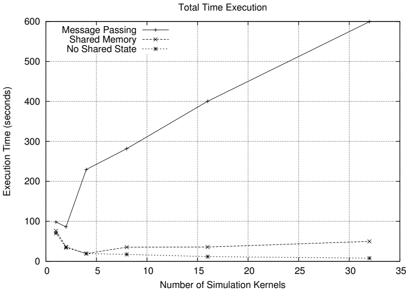

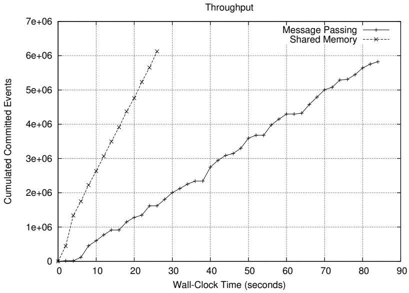

Partial Rollback in STMs

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- Rely on snapshot extension
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  - What a transaction sees might dynamically change
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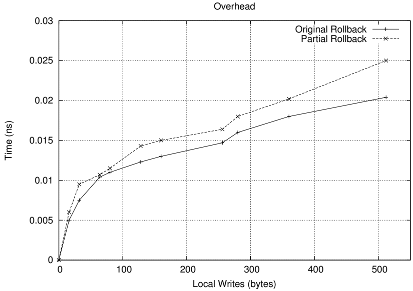

Future Work

- Interaction Transparency
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- Deployment Transparency
  - Study how to transparently select the best amount of concurrent resources to avoid thrashing
  - Relevant as well in the Cloud Computing field: possible waste of money as well
- Programming Model Transparency
  - What if the programmer *knows* about parallelization?
  - How to mix *induced* parallelism with *explicit* parallelism?
  - This is where all my proposals integrate

List of Publications

[1] Roberto Vitali, Alessandro Pellegrini, and Francesco Quaglia.
A load sharing architecture for optimistic simulations on multi-core machines.
In Proceedings of the 19th International Conference on High Performance Computing, HiPC. IEEE Computer Society, December 2012.
To Appear.

[2] Roberto Vitali, Alessandro Pellegrini, and Francesco Quaglia.
Assessing load sharing within optimistic simulation platforms (invited paper).
In Proceedings of the 2012 Winter Simulation Conference, WSC. Society for Computer Simulation, December 2012.
To Appear.

[3] Alessandro Pellegrini, Roberto Vitali, and Francesco Quaglia.
Transparent and efficient shared-state management for optimistic simulations on multi-core machines.
In Proceedings 20th International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems, MASCOTS, pages 134–141. IEEE Computer Society, August 2012.

[4] Roberto Vitali, Alessandro Pellegrini, and Francesco Quaglia.
Towards symmetric multi-threaded optimistic simulation kernels.
In Proceedings of the 26th International Workshop on Principles of Advanced and Distributed Simulation, PADS, pages 211–220. IEEE Computer Society, August 2012.

[5] Roberto Vitali, Alessandro Pellegrini, and Gionata Cerasuolo.
Cache-aware memory manager for optimistic simulations.
In Proceedings of the 5th International ICST Conference of Simulation Tools and Techniques, SIMUTools, March 2012.
Winner of the Best Paper Award.

List of Publications (2)

[6] Alessandro Pellegrini, Roberto Vitali, and Francesco Quaglia.
The ROme OpTimistic Simulator: Core internals and programming model.
In Proceedings of the 4th International ICST Conference on Simulation Tools and Techniques, SIMUTools. ICST, 2011.

[7] Alessandro Pellegrini, Roberto Vitali, and Francesco Quaglia.
An evolutionary algorithm to optimize log/restore operations within optimistic simulation platforms.
In Proceedings of the 4th International ICST Conference on Simulation Tools and Techniques, SIMUTools. SIGSIM, 2011.

[8] Roberto Vitali, Alessandro Pellegrini, and Francesco Quaglia.
Autonomic log/restore for advanced optimistic simulation systems.
In Proceedings of the Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems, MASCOTS, pages 319–327. IEEE Computer Society, 2010.

[9] Roberto Vitali, Alessandro Pellegrini, and Francesco Quaglia.
Benchmarking memory management capabilities within root-sim.
In Proceedings of the 13th IEEE/ACM International Symposium on Distributed Simulation and Real Time Applications. IEEE Computer Society, 2009.

[10] Alessandro Pellegrini, Roberto Vitali, and Francesco Quaglia.
Di-DyMeLoR: Logging only dirty chunks for efficient management of dynamic memory based optimistic simulation objects.
In Proceedings of the 2009 ACM/IEEE/SCS 23rd Workshop on Principles of Advanced and Distributed Simulation, PADS, pages 45–53. IEEE Computer Society, 2009.
Candidate for (but not winner of) the Best Paper Award.

List of Pending/In Preparation Publications

[11] Alessandro Pellegrini, Roberto Vitali, and Francesco Quaglia.
A symmetric multi-threaded architecture for load-sharing in multi-core optimistic simulations.
ACM Performance Evaluation Review.
Fast Track invitation as InfQ 2012 Selected Paper. In Preparation.

[12] Roberto Vitali, Alessandro Pellegrini, and Francesco Quaglia.
Autonomic state management for optimistic simulation platforms.
IEEE Transactions on Parallel and Distributed Systems.
In Preparation.

[13] Alessandro Pellegrini and Giuseppe Piro.
Multi-threaded simulation of 4G cellular systems within the LTE-Sim framework.
In Proceedings of the 8th IEEE International Workshop on the Performance Analysis and Enhancement of Wireless Networks, PAEWN. IEEE Computer Society, March 2013.
Under Review.

[14] Alice Porfirio, Alessandro Pellegrini, Pierangelo Di Sanzo, and Francesco Quaglia.
Efficient partial rollback in software transactional memories.
In Preparation for Submission to the 22nd Conference on Compiler Construction, 2013.

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An experimental analysis of self-adjusting computation.
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Thanks for your attention

Questions?

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