Autonomic Parallelism Adaptation on Software Transactional Memory

Naweiluo Zhou – *Grenoble University/INRIA, France*
Gwenael Delaval –*Grenoble University,France*
Bogdan Robu –*Grenoble University,France*
Eric Rutten –*INRIA,France*
Jean-Francois Mehaut –*Grenoble University/INRIA,France*

Naweiluo.Zhou@inria.fr

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Overview

1.Introduction

Multi-core Processor

- Multi-core processors are ubiquitous, more parallelisms/concurrency levels give higher performance?
- Many threads execute concurrently. Threads share data. More threads maybe more conflict!

Synchronization VS Computation

A high concurrency level may decline computing time, but increase synchronization time. How to handle the trade-off between synchronization and computation?

1.Introduction

Locks

A traditional way for synchronization. But:

- Deadlocks, vulnerability to failures, faults...
- Difficult to detect deadlocks
- Hard to figure out the interaction among concurrent operations

Transactional Memory

Lock-free, therefore no deadlocks! HTM, STM and HyTM.

1.Introduction

Runtime Parallelism Adaptation:

- choice of parallelism significantly impacts on performance.
- onerous to set a parallelism offline, especially for a program with online behaviour fluctuation.
- feedback control loops to manipulate parallelism autonomically.

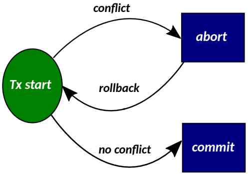
Contribution of this paper

- An adaptive profiling framework for searching and applying optimal parallelism online
- a feedback control loop to enable autonomy and reduce overhead

2.Transactional Memory

Concepts

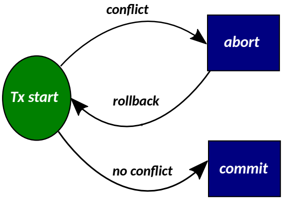
- Shared variables are wrapped by **transactions** (atomic blocks)
- concurrent accesses are performed inside transactions
- Transactions are executed speculatively and can either commit or abort. no other intermediate status
- can be implemented in STM (e.g. TinySTM, SwissTM...), HTM and HyTM



2.Transactional Memory

Three concepts

1. Commit: a transaction succeeds—changes are made
2. Abort: a transaction has a conflict — changes are discarded
3. Rollback: re-execute the aborted transactions



2.Transactional Memory

Example

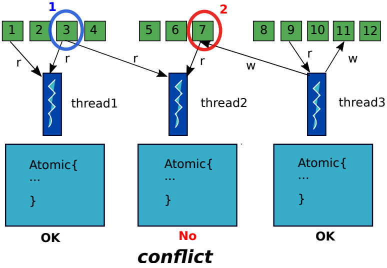
consider three threads read/write data from/to the objects of different memory locations. Access occur inside transactions

Case1

thread1 reads object3
thread2 reads object3

Case2

thread2 reads object7
thread3 reads object7



Autonomic Computing

A system is regarded as an autonomic control system if it has one of the features:

- **Self-optimization:** seek to improve performance & efficiency
- **Self-configuration:** a new component learns the system configurations
- **Self-healing:** recover from failures
- **Self-protection:** defend against attacks

Autonomic Computing

Elements of a feedback control loop:

1. Managed element: any software or hardware resource
2. Autonomic manager— a software component: monitor, plan, knowledge
3. Sensor: collect information
4. Effector: carry out changes

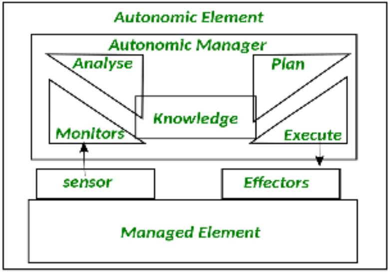


Figure : A feedback control loop

Autonomic Computing

Components of the autonomic manager:

1. Monitor: sampling
2. Analyser:
3. Knowledge
4. Plan: use the knowledge of the system to do computation
5. Execute: make changes

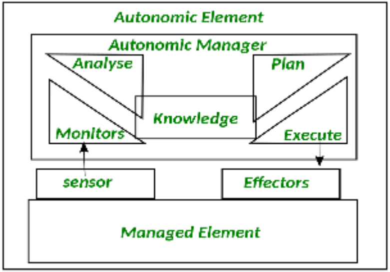
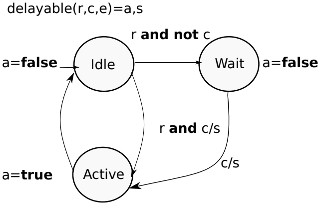


Figure : A feedback control loop

Autonomic Computing

Heptagon Programming Language

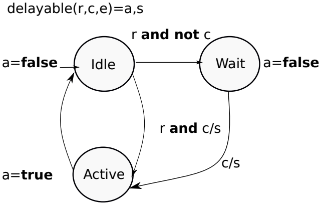
1. straightforward for programming control loops.
2. composed of different states.
3. values in the input flows are used to compute the outputs which decides the next state.



Autonomic Computing

Heptagon Programming Language

```
node delayable(r,c,e:bool) returns (a,s:bool)
let
 automaton
  state Idle
   do a = false ; s = r and c
   until r and c then Active
       | r and not c then Wait
  state Wait
  do a = false ; s = c
  until c then Active
  state Active
  do a = true ; s=false
  until e then Idle
 end
tel
```



3.Profiling Algorithm

What we measure

1. parameters: commits, aborts, time
2. commit ratio= commits/(commits+aborts), throughput=commits/time
3. CR thresholds

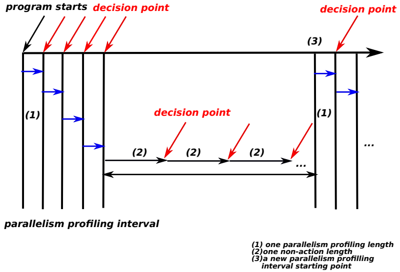


Figure : Periodical profiling procedure

3.Profiling Algorithm

1. profiling starts once a program starts. Two threads are active, others are suspended
2. first profiling interval, parallelism is only increased until throughout significantly falls
3. at non-action interval, only check CR
4. increase or decrease parallelism until throughput shows significantly drop
5. set parallelism and CR range

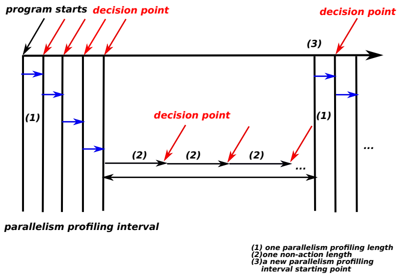


Figure : Periodical profiling procedure

3.The feedback control loop

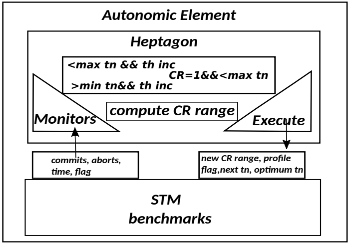


Figure : The feedback control loop on adjusting parallelism

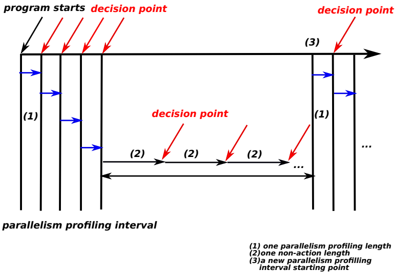
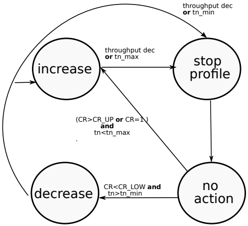


Figure : Periodical profiling procedure

3.The feedback control loop



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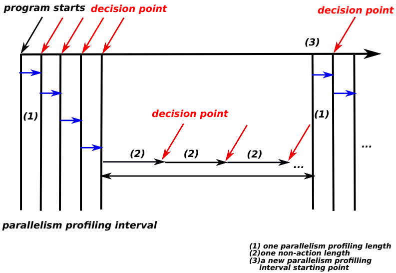


Figure : Periodical profiling procedure

3.Feedback Control Loop

1. control objective: maintain the maximum throughput and keep global CR staying in a certain range within which the conflicts are minimized
2. inputs: commits, aborts, time
3. outputs: optimum parallelism, next parallelism, CR up_threshold, CR low_threshold, profile_flag

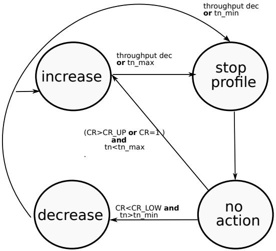


Figure : The feedback control loop on adjusting parallelism

Two decision functions

1. for parallelism: increase or decrease parallelism based on CR and throughput
2. for CR thresholds:

$$CR\_UP = CR\_optimum * 1.1$$
$$CR\_LOW = CR\_optimum * 0.9$$

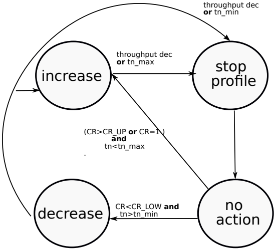


Figure : The feedback control loop on adjusting parallelism

Two decision functions

Increase State

e.g.

1. CR=1;
2. throughput increase && $tn < max\ tn$

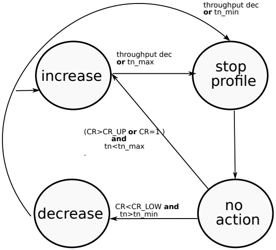


Figure : The feedback control loop on adjusting parallelism

3.Implementation

A monitor to control parallelism: three entry points

```
stm_commit() { // when a tx commits
   ...
}
stm_thread_init(){ when a tx thread init
   ...
}
stm_thread_exit(){when a tx thread terminates
   ...
}
```

Implemntation

balance threads execution time, avoid threads starvation

- First In First Out queues
- round-robin rotate

Experimental Platform

Hardware

- 4 processors with 2.4 GHz frequency, 32 cores and 128 GB RAM.

Software

- STM: tinySTM
- Control: Heptagon
- Benchmarks: EigenBench, STAMP

Benchmark setting

EigenBench

- stable behaviour
- online fluctuation: minor modification to Eigenbench to enable online changes

STAMP

- labyrinth
- genome
- intruder
- vacation

Online throughput variation

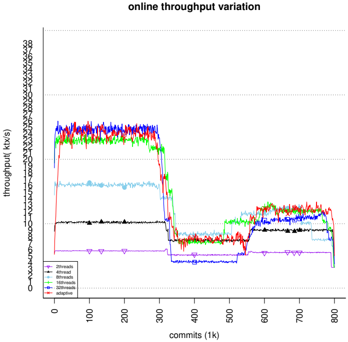


Figure : EigenBench with online behaviour

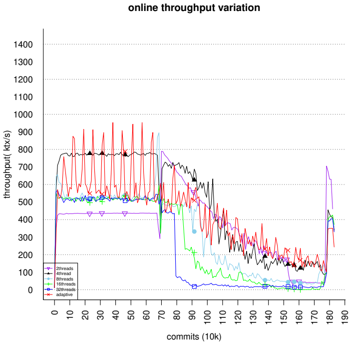


Figure : genome

Runtime thread number change

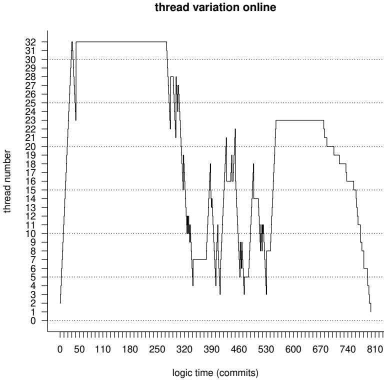


Figure : thread number change on EigenBench with online behaviour

Time comparison for **EigenBench** on static and adaptive parallelism

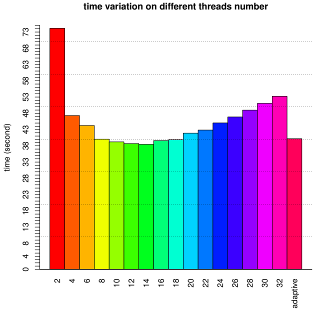


Figure : the data set with stable online behaviour

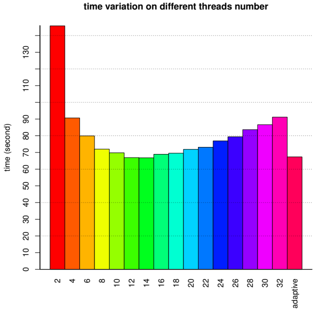
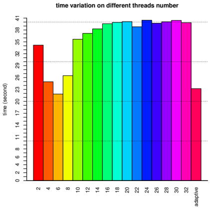
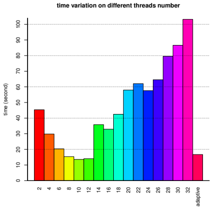


Figure : the data set with online variation

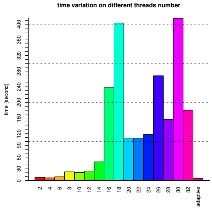
Time comparison for **STAMP**



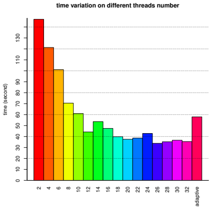
intruder



vacation



genome



labyrinth

Time comparision

benchmarks	best case	median value	worse case
eigenBench (stable)	-5%	+8%	+46%
eigenBench (online variation)	0%	+10%	+54%
genome	+19%	+95%	+99%
vacation	-23%	+62%	+84%
labyrinth	-71%	-33%	+61%
intruder	-6%	+41%	+43%

Table : Performance comparison on difference benchmarks. The performance of adaptive parallelism is compared with the minimum value, median value and the maximum value of the static parallelism

Overhead analysis

overhead mainly originates:

- incorrect parallelism.
- thread migration.
- the choice of profiling length and non-profiling length.
- the choice of the thread number to manipulate at each parallelism profiling length.
- the choice of throughput variation rate

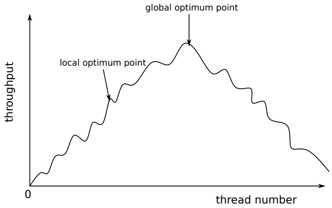


Figure : throughput fluctuation

Discussion

pros and cons

- demonstrate an effective way to obtain the optimum parallelism online.
- short-size transaction suffers from overhead by calling the monitor (eg.intruder);
  reduce frequency of calling the monitor.
- long-size transaction: too much time spent for profiling (eg.labyrinth) .
- thread migration issues (eg. vacation, genome)

Conclusion

- investigate an autonomic parallelism adaptation approach on a STM system
- examined the performance of different static parallelism and concludes that runtime regulation of parallelism is crucial to performance
- introduce a feedback control loop to automate the choice of parallelism at runtime
- analyse the implementation overhead and discussed the advantages and limitation of our work

Future Work

- investigate thread migration issues.
- design more loops to control thread affinity and further enhance performance.
- ...

Questions?