A Framework for Accurate Measurements with Low Resolution Clocks

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Talk at The IASTED conference on Software Engineering and Applications (SEA 2006)

November 15th, 2006
Outline

Introduction

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Motivation & Goals

Motivation

- Need for accurate measurements of execution time in order to compare the speed of one algorithm with another
- Clock resolution may be too low for some small problems

```
T: 0 units
T: 1 unit

clock++ clock++ clock++
```

Time
Motivation & Goals

Motivation

- Need for accurate measurements of execution time in order to compare the speed of one algorithm with another
- Clock resolution may be too low for some small problems

Alternative: Hardware counters

- High accuracy
- Not always available
Motivation & Goals

Motivation

- Need for accurate measurements of execution time in order to compare the speed of one algorithm with another
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Goal:

- Ensure accurate measurements with low resolution timers
Idea

Repeat execution a number of times

- T: 2 units
- T: 0.5 units (Approx.)

Clock++ Clock++ Clock++

Time
**Idea**

Repeat execution a number of times

- T: 2 units
  - Time
    - clock++
    - clock++
    - clock++
  - T: 0.5 units (Approx.)

Another run may get different results

- T: 3 units
  - Time
    - clock++
    - clock++
    - clock++
  - T: 0.75 units (Approx.)
Idea

Repeat execution a number of times

Another run may get different results

How many repetitions?
Refined Goal

Determine

- Minimum number of iterations necessary to obtain results to a desired precision
Refined Goal

Determine

- Minimum number of iterations necessary to obtain results to a desired precision
- Automatically
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Our Context: High Performance Computing

Obtain the highest \textit{Mflop} rate

\[ M\text{flops} = \frac{\#\text{flops} \cdot 10^{-6}}{\text{Time}} \]

- Choose the fastest algorithm/implementation
  - Need to get accurate measurements of their executions
    \[ |\Delta M\text{flops}| \leq \text{Threshold} \quad (1) \]
- On different platforms.
Approach

Perform execution several times.

\[ Mflops = \frac{\#flops \cdot Iterations \cdot 10^{-6}}{Time} \]  \hspace{1cm} (2)

How many times?

\[ Iterations = ? \]
Theoretical Foundations

\[
\frac{\partial \text{Mflops}}{\partial \text{Time}} = -\frac{\#\text{flops} \cdot \text{Iterations} \cdot 10^{-6}}{\text{Time}^2} \tag{3}
\]

\[
\frac{\Delta \text{Mflops}}{\Delta \text{Time}} = \frac{\#\text{flops} \cdot \text{Iterations} \cdot 10^{-6}}{\text{Time}^2} \tag{4}
\]

\[
\text{Time} = \frac{\#\text{flops} \cdot \text{Iterations}}{\text{Mflops} \cdot 10^6}
\]

\[
\frac{\Delta \text{Mflops}}{\Delta \text{Time}} = \frac{\text{Mflops}^2 \cdot 10^6}{\#\text{flops} \cdot \text{Iterations}}
\]

Hence:

\[
\text{Iterations} = \frac{\text{Mflops}^2 \cdot 10^6}{\#\text{flops}} \cdot \frac{\Delta \text{Time}}{\Delta \text{Mflops}} \tag{5}
\]
Example

Determine the number of iterations necessary to obtain results within the desired precision.

- timing routine with a precision of $10^{-2}$ seconds ($\Delta Time = 10^{-2}$).
- desired error in the estimation of its Mflops of approximately 1 Mflop ($\Delta Mflops \approx 1$):

\[
Iterations = \frac{Mflops^2 \cdot 10^6}{\#flops} \cdot \frac{10^{-2}}{1} = \frac{Mflops^2 \cdot 10^4}{\#flops} \quad (6)
\]
Predefined macros

#include <...>
main()
...
it = GET_NUMITERATIONS (_NUM_OPERATIONS);
...
GET_MFLOPS (CALL_ROUTINE, ti,it,
    _NUM_OPERATIONS, mflops);
...

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Template files and their relation

Benchmark.h

Precision.h

Archinfo.h

Macros.h

Profiler_template.c

<filename>_benchmark.h

<filename>_archinfo.h

<filename>_precision.h

<filename>_macros.h

<filename>_profiler.c

<filename>.
User files: mtxms_profiler.c

```c
#ifndef _BenchName
#define _BenchName mtxms
#endif

#include <profiler_templ.c>
```
User files: mtxms.h

/* $Id: mtxms.h,v 1.1 2005/01/21 08:05:31 myusername Exp $ */

 ifndef _BenchRoutine
 define _BenchRoutine _BenchName
 endif
 ifndef _NUM_OPERATIONS
 define _NUM_OPERATIONS 2*i*j*k
 endif
 ifndef CALL_ROUTINE
 define CALL_ROUTINE \
 ad2(_BenchRoutine,_)( pdA, pdB, pdC )
 endif
 ifndef CALL_TEST_ROUTINE
 define CALL_TEST_ROUTINE \
 mtxms_test_ (pdA,pdB,pdD, &i,&j,&k, &lda,&ldb,&ldc)
 endif
 ifndef MATRIX_INITIALIZATION
 define MATRIX_INITIALIZATION \
 inimat_at_bn_(pdA,pdB,pdC,&i,&j,&k,&lda,&ldb,&ldc)
 endif
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- Lack of precision can be avoided by repetition

- Adequate number of iterations can be automatically determined
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