Metrics for Success: Performance Analysis 101

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Agenda

- Application Performance
- Compiling for performance
- Profiling for performance
- Closing remarks

Sun Studio software

C/C++/Fortran tooling for the multi-core era

- Adoption increased 100+% over 2 years. Large footprint in enterprise/technical accts & growth in open src usage
- #1 IDE in the Evans survey for Performance of Resulting Applications category
- Intel, AMD, Sun & Fujitsu Partnerships

SUN STUDIO SHINES

Sun Studio software has emerged as a leading compiler and tool for application development on Solaris and Linux operating systems. Now, it's rising to a new level of capability and performance.

The latest release of Sun Studio 12 software accelerates application performance while reducing time-to-market through parallelizing C, C++, and Fortran compilers and tools for Solaris and Linux platforms running on x86 and x64 platforms. A free application, this software uses the processing power in AMD processor-based systems to provide enhanced performance for applications – thus realizing outstanding results from multithreaded applications.

Sun Studio 12 software uses innovative optimization techniques on x86 systems to provide up to 25 percent better performance on compute-intensive tasks and up to 80 percent better performance for memory-intensive, industry-recognized benchmarks than open source alternatives.

- Parallelism – feature-rich toolchain (auto-parallelizing compilers, thread analysis / debugging / profiling, OpenMP support, ...) & MPI support via Sun HPC ClusterTools
- Performance – dozens of industry benchmark records in the past year over Intel, AMD, Sun, & Fujitsu architectures
- Productivity – NetBeans-based IDE, code & memory debuggers, application profiler
- Platforms – Simplified dev across architectures & OSs (Solaris OS, OpenSolaris OS, Linux)

Sun Studio Software Overview

FREE

Integrated Toolchain

- Record-setting parallelizing C/C++/Fortran Compilers with autopar
- NetBeans-based IDE
- Stable, Scriptable, Multilingual Debugger (dbx)
- Memory Debugger- leak, access, usage (RTC)
- Application Profiling Tools (Performance Analyzer)
- Multi-core Optimizations, Multithreaded High Performance Libraries
- OpenMP API Support
- Multithreading Tools- Thread Analysis

http://developers.sun.com/sunstudio

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Why Care about Performance?

- Because your company cares
  - Faster code => greater productivity => lower cost
- Because your peers and customers care
  - Better performance => less HW => lower cost
- Because it's interesting and suprising
  - Coding is based on assumptions about behavior
  - Performance problems arise from disconnects
- Because it's easy to do
  - Simple runs, automated runs

What's a Performance Problem?

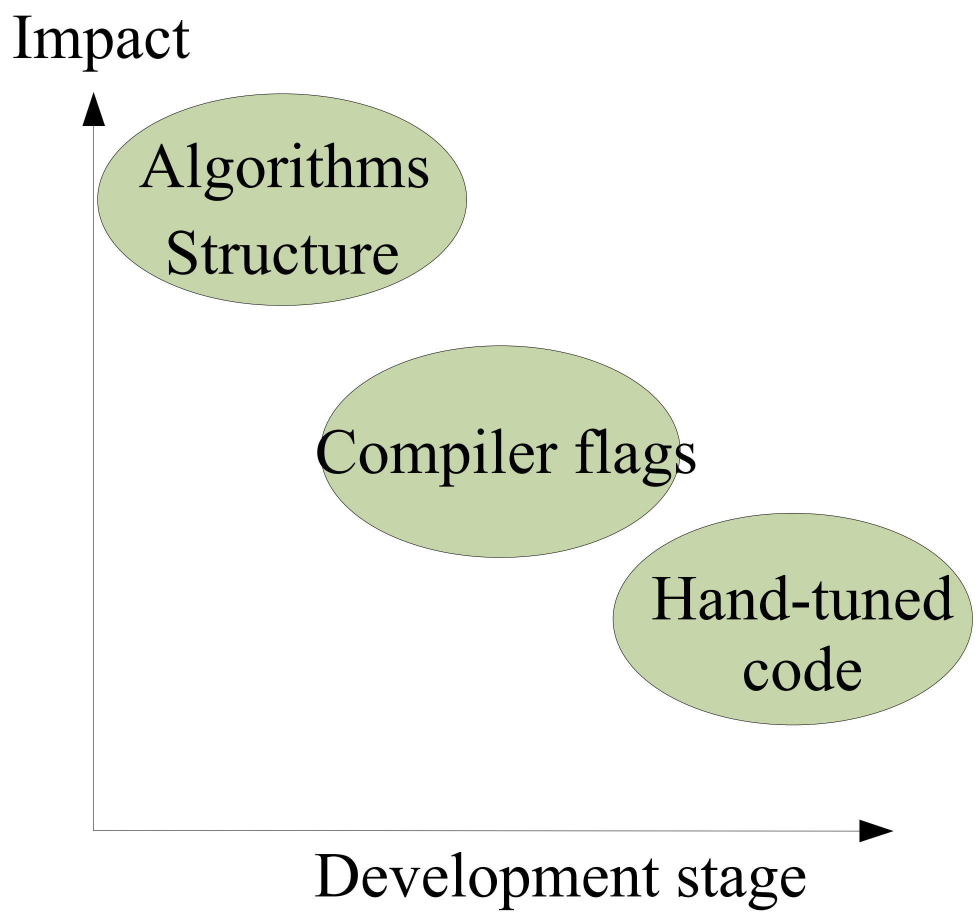
- Subjective criteria:
  - > It takes too long to finish
  - > It responds too slowly
- Objective critera:
  - > It can't handle the required load
  - > It consumes too many resources to do its work
- Is it worth fixing?
  - > Cost of fixing vs. aggregate cost of problem
- Most untuned codes have low-hanging fruit!

Where does performance come from?

- Not the real question...
  - Every application has a maximum theoretical performance
  - Design decisions and implementation can deliver lower actual performance
- Alternative: *Where has performance been lost?*
  - Need to identify where the time is spent
  - Then determine what can be done about it

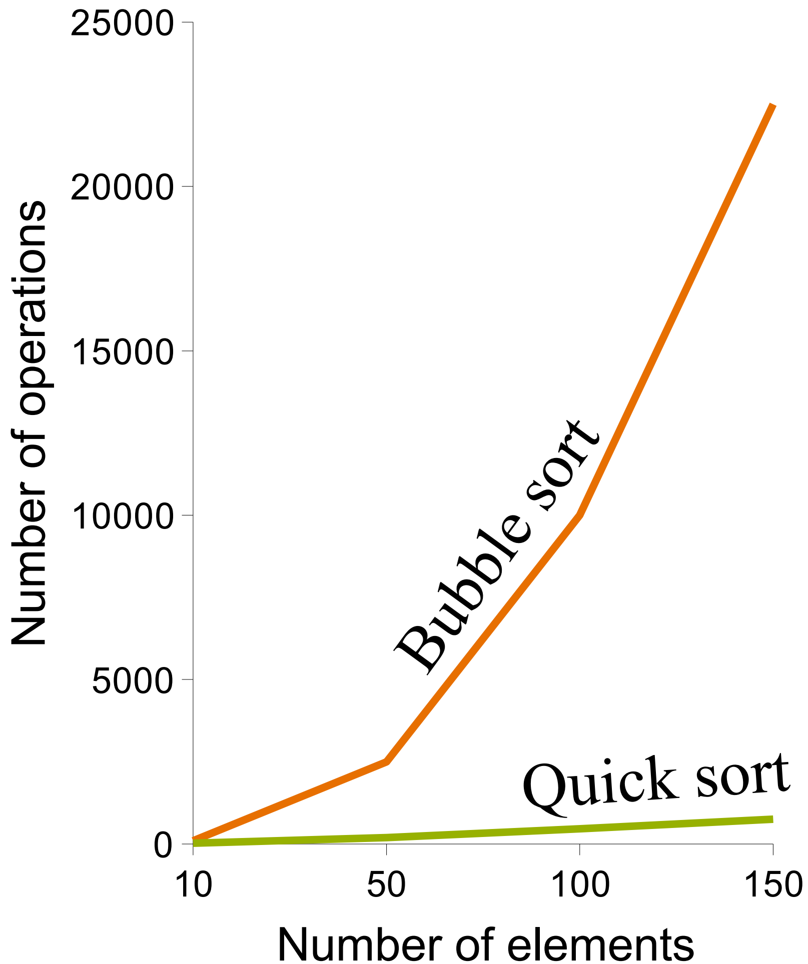
Where performance goes to

- Performance opportunities:
  - > Algorithms
  - > Structure
  - > Compiler flags
  - > Hand-tuned code



Algorithmic complexity

- How many operations?
- Classic example:
  - > Bubble sort $O(n^2)$
  - > Quick sort O(nlog(n))
- Sun Studio libraries have optimized code
  - > perflib (BLAS, FFTs, etc)
  - > medialib (images, codecs)
  - > Optimized maths libraries



Compiler flags

- The compiler's job:
  - > Produce the best code
  - > Given little knowledge of developer's intent
  - > Best code regardless of coding style
- Increasing optimization
  - > Leads to improved performance
  - > Relies on standard conforming source code
- Does a better job with
  - > Visibility of more of the code
  - > More information about the intent of the developer

Hand-tuned code

- Examples:
  - Special case code for the common situation
  - Assembly language versions of key routines
- Cons:
  - Time consuming
  - Inflexible (e.g. workload specific)
  - Platform specific
- Good examples:
  - Use of language standards to provide compiler with more information (e.g. `restrict` keyword)

Perspective on optimization

- Algorithms, structures, and compiler flags
  - High-level change
  - Useful for all platforms
  - Improve the application for all workloads
- Tweaks, hand-code
  - Low-level (localised) change
  - Platform specific
  - Often already done by the compiler
- So:
  - Focus on the high-level
  - Unless the low-level gains are clear

Methodology / Tools Used

Ensure Best Builds:
Latest Compiler
Optimization flags
Profile feedback
Insert #pragmas

Check Libraries Used:
optimized math libs
libsunperf
medialib
Write special routines?

Identify Hot Spots:
gprof(function timings)
tcov(line counts)
analyzer (many stats)

Get Execution Stats:
cputrack(perf counters)
locstat(lock containment)
trapstat(traps)

Study and rewrite Source as appropriate

Study and rewrite assembly as appropriate

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Choosing compiler flags

- Use the flags
  - > That you understand
  - > That you need (i.e. make a difference)
- Don't use flags
  - > That you don't understand
  - > That don't have an impact

Optimization

- Rule:
  - No optimization flags means no optimization
- Suggestions:
  - Use at least **-O**
  - Try **-fast**
- Notes:
  - Compile and link with the same flags

Debug information

- **Always** generate debug information
  - `-g` for C/Fortran
  - `-g0` for C++
- Also useful for profiling
- No/minimal performance impact

Exploring -fast

- `-fast` is a macro-flag:
  - Enables a number of potentially useful optimisations
  - May not be suitable for all situations
- Assumes build machine = run machine
  - Use `-xtarget=` to specify otherwise
- Enables floating point simplification
  - Use `-fsimple=0 -fns=no` otherwise
- Assumes basic pointer types do not alias
  - Use `-xalias_level=any` otherwise
- Flags are parsed from left to right
  - Override by placing flags on right

Target hardware

- Not all processors implement the same instructions
  > Application will not run if instructions are not implemented
- If build machine is machine that will run binary:
  > **`-xtarget=native`**
- For binaries that will run on a wide range of machines:
  > SPARC: **`-xtarget=generic -xarch=sparcvis2`**

  > x86: **`-xtarget=generic -xarch=sse2`**

Instruction set extensions (SSE/x86)

- Instruction set extensions on x86
- Single Instruction Multiple Data (SIMD)
  - e.g. two parallel add operations in a single instruction
- Enable generation with:
  - **`-xtarget=generic -xarch=sse2 -xvector=simd`**

Target hardware 32-bit or 64-bit

- 32-bit (`–m32`) can address 4GB of memory
- 64-bit (`–m64`) can address >>4GB of memory
- 64-bit: pointers and longs are 8 bytes
  - => larger memory footprint
  - => slower
- x86 64-bit has
  - More registers, Better ABI
  - => faster
  - For x86 64-bit faster except when dominated by increased memory footprint

Inlining and cross-file optimisation

- Inlining:
  - Avoids call overhead
  - Provides more opportunities to code optimisation
  - Increases code size
- Within file inlining at **`-xO4`**
- Crossfile inlining at **`-xipo`**
  - Inlines between source files
  - Reduces impact of source code structuring
  - Can increase compile time

Profile feedback

- Profile feedback enables the compiler
  - To see the runtime behavior of the application
  - To make better code layout decision
  - To make the right inlining decisions
- Three step process:
  - Compile with **`-xprofile=collect:/dir/profile`**
  - Run with training workload
  - Compile with **`-xprofile=use:/dir/profile`**
- Very useful for applications containing lots of decision logic

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Good practices

- **Always** profile your application
  - > Is the time being spent in the important code?
  - > Are there obvious hot-spots to improve?
  - > How does the profile change with the workload?
- Amdahl's law
  - > Limit on performance gain is the time spent in the slow code
- Fix performance issues
  - > But make the fixes at the highest possible level of abstraction

Why use Sun Studio Tools? (I)

- The work for production code, production runs
  - Runs from tens of seconds through hours
- They measure real behavior
  - Fully optimized and parallelized applications
  - Java HotSpot enabled
- They have minimal dilation and distortion
  - ~5% for typical apps, ~10% for Java apps
- Supports code compile with Sun Studio & GNU compilers
- They're ***FREE*** for Solaris & Linux

Why use Sun Studio Tools? (II)

- They make things as simple as possible
  - Show data in the user's source model
  - Including OpenMP, MPI, Java, threads, etc.
- ..., but no simpler
  - Show exactly what the compiler did
    - Inlines, outlines, clones, parallel routines
  - Show what JVM did
    - Interpreted methods, HotSpot-compiled methods
    - GC & HotSpot-compiler activities

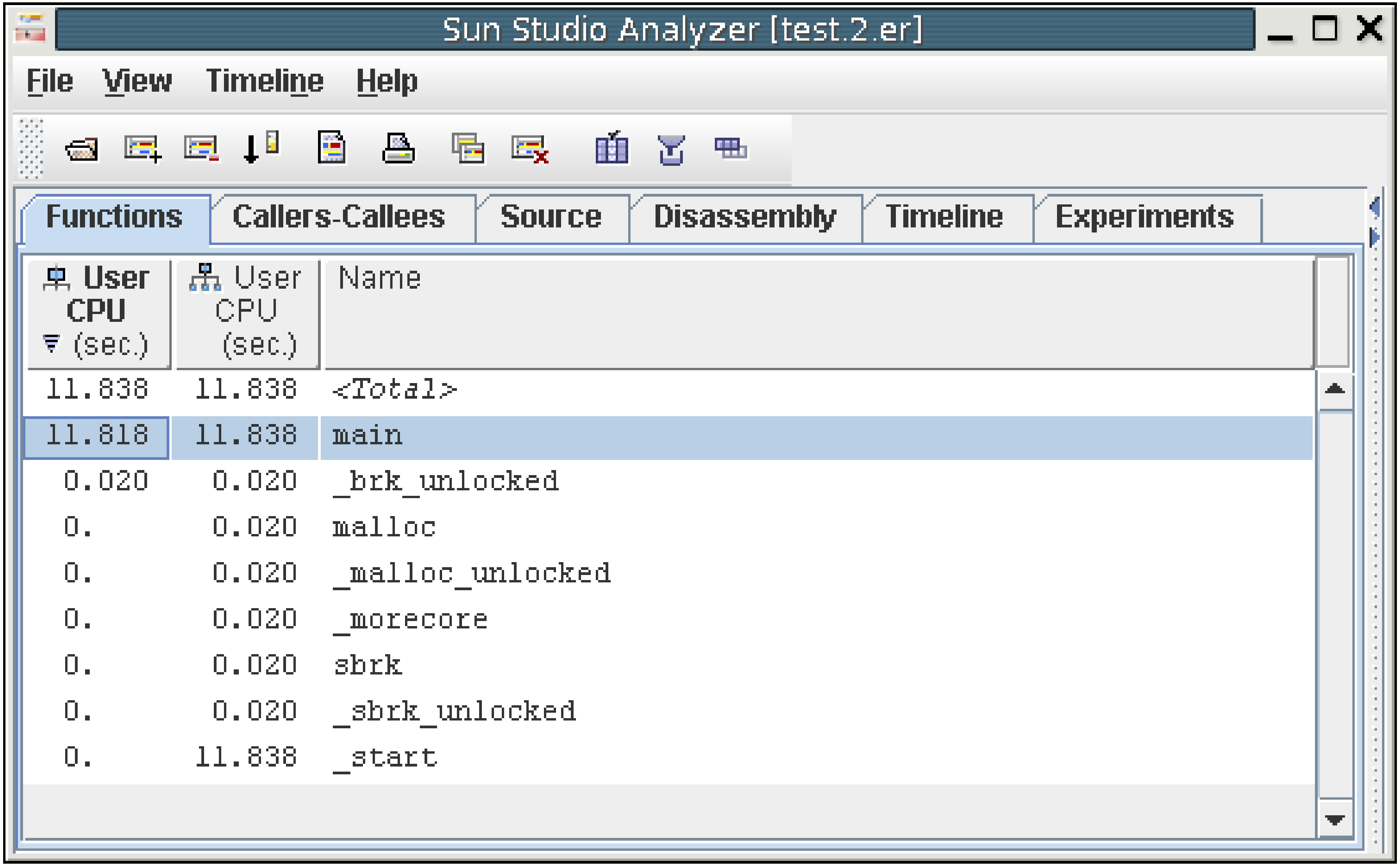
Questions

- What can I change to improve perforance?
- Which resources are being used?
- Where are they being used?
- Single-threaded
  - > Is the CPU being used efficiently?
  - > Memory subsystem delays? (TLBs, caches)
  - > I/O subsystem problems? (disk, network, paging)
- Multi-threaded
  - > Similar to single-threaded &
  - > Load unbalanced? Lock contention? memory/cache contention?

Gathering profiles

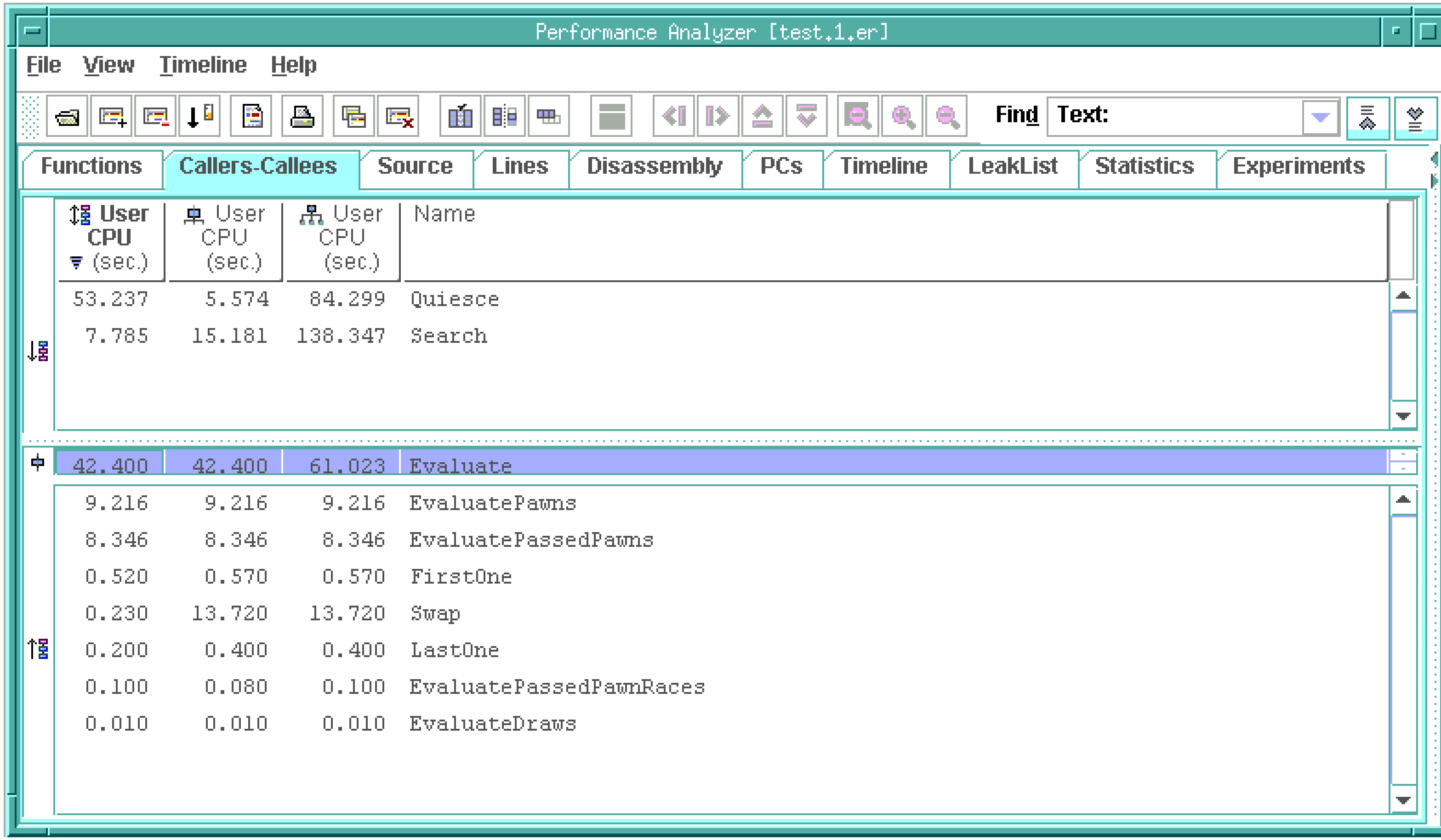
- Use **-g**/**-g0** for attribution of time to source line
- Gather profile with:
  - > **collect** <app> <params>
  - > **collect -P** <pid>
- Analyse profile with:
  - > **analyzer** test.<N>.er
  - > **er_print** test.<N>.er

Application profile

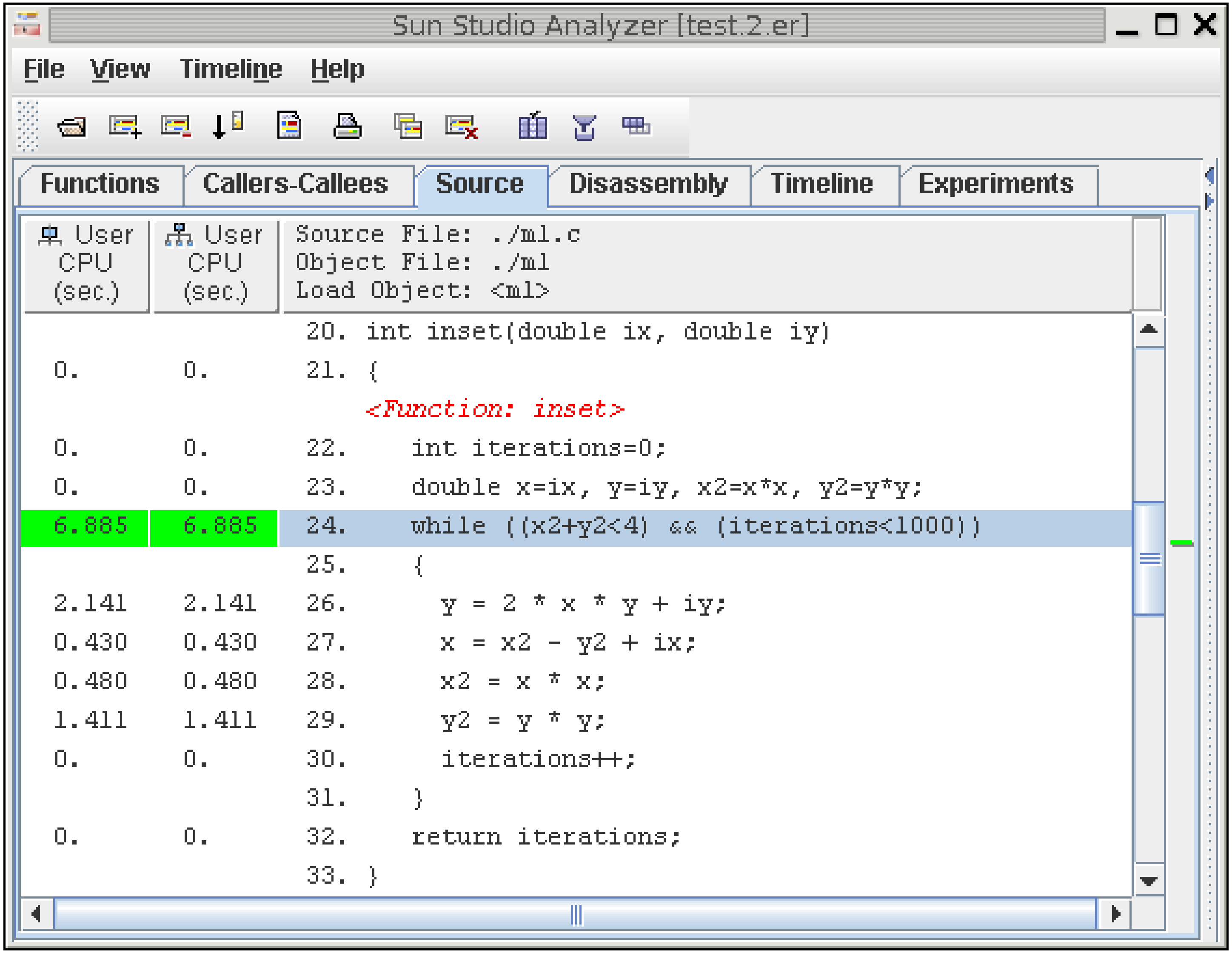


User CPU (sec.)	User CPU (sec.)	Name
11.838	11.838	<Total>
11.818	11.838	main
0.020	0.020	_brk_unlocked
0.	0.020	malloc
0.	0.020	_malloc_unlocked
0.	0.020	_morecore
0.	0.020	sbrk
0.	0.020	_sbrk_unlocked
0.	11.838	_start

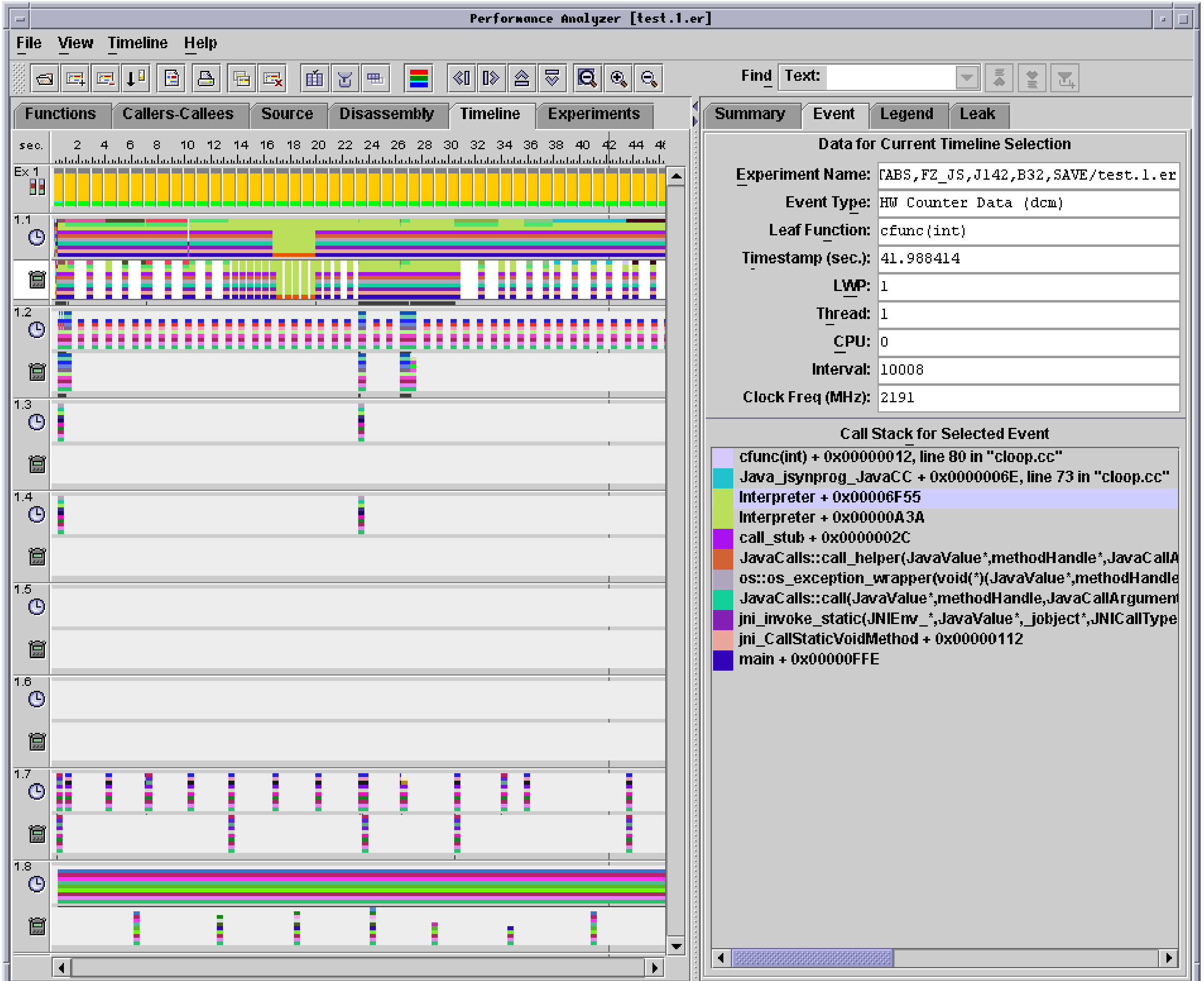
Caller-Callee



Source level profile



Performance Analyzer - Timeline



DEMO

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The checklist

- Build with optimization
  - At least **-O**
- Build with debug enabled
  - **-g** (**-g0** for C++)
- Profile
  - **collect** `<app> <params>`

Optimization: Increasing optimisation

- Increased optimization (**`-fast`**)
  - Typically improved performance
  - Be aware of the optimisations enabled
- Use crossfile optimization (**`-xipo`**)
  - Typically good for all codes

Optimization: Increasing information

- Profile feedback to give more information
  - > `-xprofile=[collect:|use:]`
  - > Good for all codes
  - > Particularly helpful for inlining and branches

Optimization: Leveraging libraries

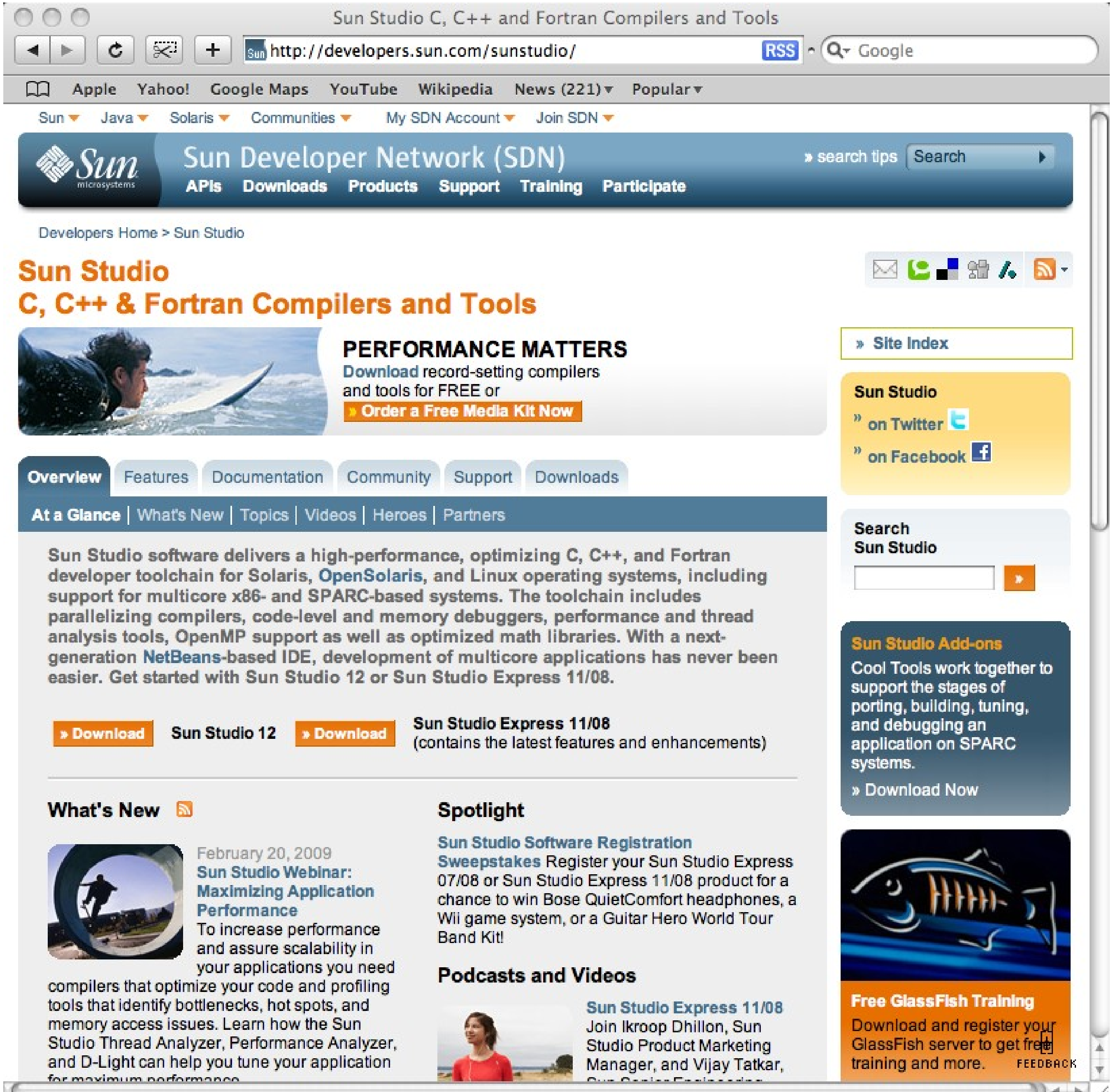
- If time is spent in library code:
  - Supplied optimized maths functions
    `-xlibmil -xlibmopt`
  - Optimized STL for C++
    `-library=stlport4`
  - The performance library
    `-library=sunperf`

Summary

- Always profile
- Always use optimization

Gains from Tuning Categories

Tuning Category	Typical Range of Gain
Source Change	*25-100%*
Compiler Flags	*5-20%*
Use of libraries	*25-200%*
Assembly coding / tweaking	*5-20%*
Manual prefetching	*5-30%*
TLB thrashing/cache	*20-100%*
Using vis/inlines/micro-vectorization	*100-200%*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Thanks!!

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