Adding Parallelism with Intel® Parallel Studio: No Parallelism Experience Required

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Agenda

- Overview
- Find where parallelism can be usefully added to a program
- Fix the parts of the program that prevent parallelism
- Add parallelism
- Test the revised program for correctness and performance
- Don’t panic

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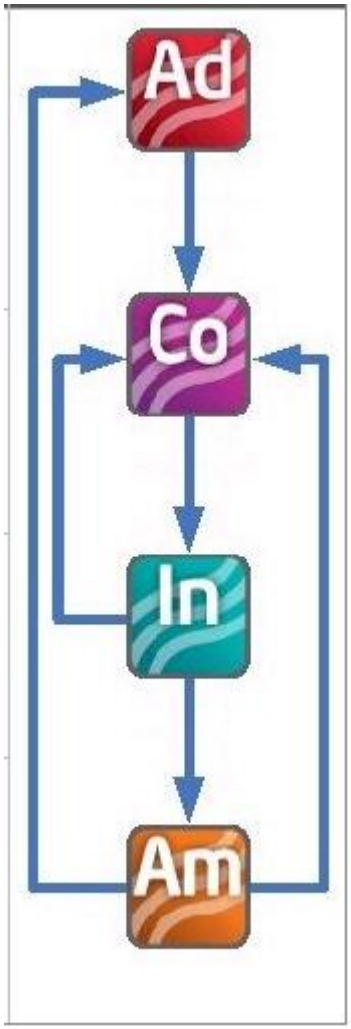
Overview – adding parallelism

- What is parallelism?
  - Overlapping portions of a serial algorithm, so it runs faster
    - Eg: Search both sides of a tree at the same time
- Start with a serial algorithm
- Modify it to be a parallel-ready serial algorithm
- Add code to
  - Perform statements in parallel
  - Synchronize the sharing of common resources

Analysis, preparation and testing of the serial code is key to simplifying adding parallelism

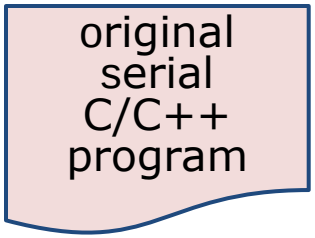
Overview – the tools

- Decide where to add the parallelism
  - Analyze the serial program
  - Prepare it for parallelism
  - Test the preparations
- Add the parallelism
  - Cilk, Intel® Threading Building Blocks, OpenMP*, o/s threads
- Find logic problems
  - Only fails sometimes
  - Place of failure changes
- Find performance problems



Adding and using parallelism requires enhanced tools

Overview – Intel Parallel Advisor



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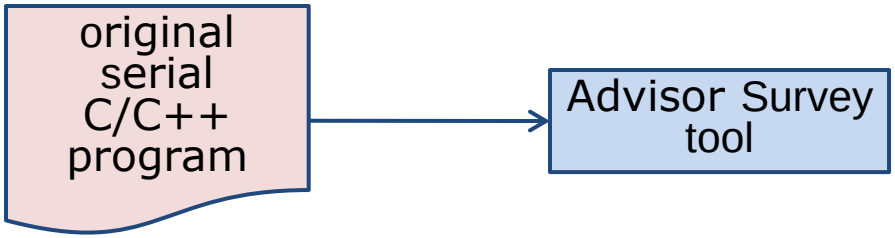
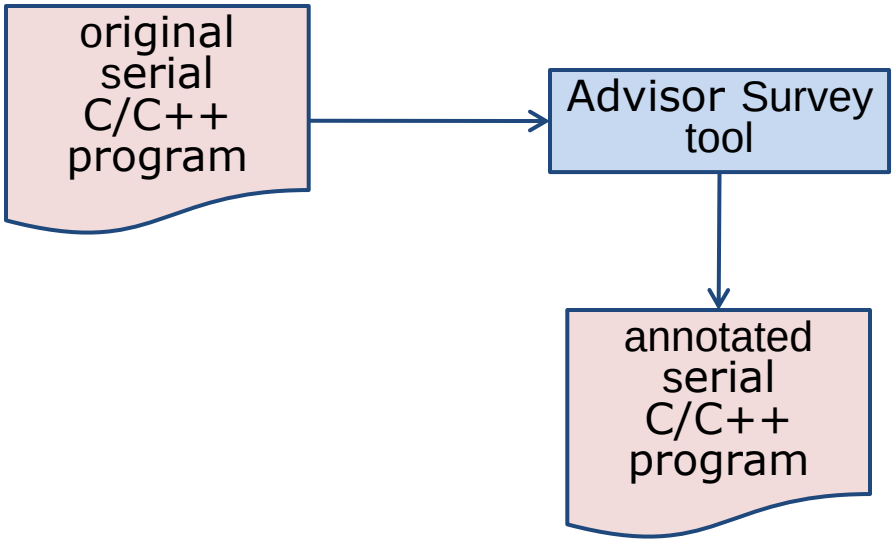


Run Survey tool to measure where your application is spending time

Overview – Intel Parallel Advisor

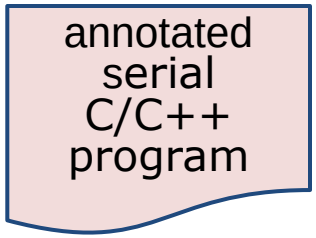


Run Survey tool to measure where your application is spending time

Add annotations to describe how you might divide the work of the hot-spot into parallel tasks

Overview – Intel Parallel Advisor

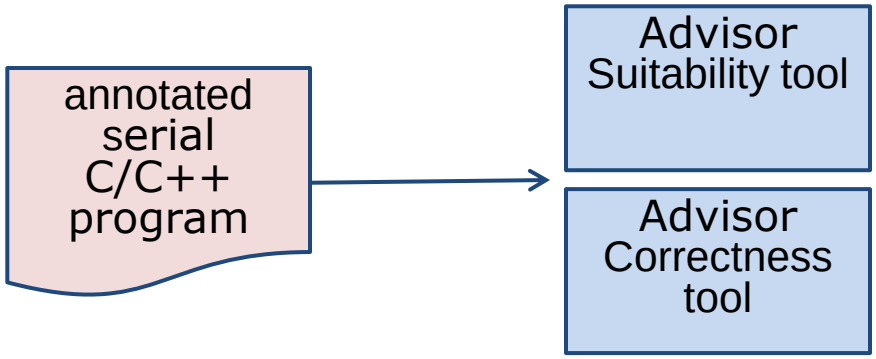
The annotated program still has serial semantics. Working on it is just normal programming.



Overview – Intel Parallel Advisor

The annotated program still has serial semantics. Working on it is just normal programming.

Use the performance modeling (suitability) and race detection (Correctness) tools to identify potential issues



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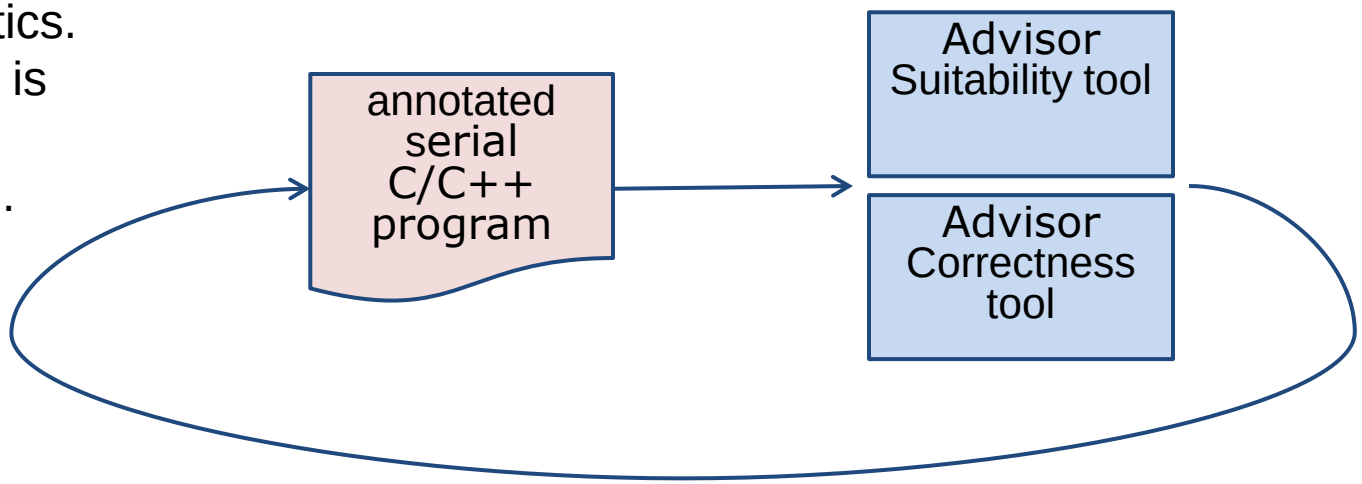
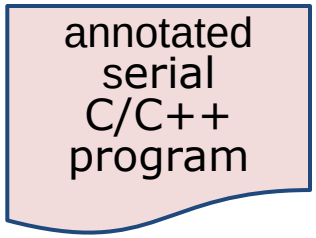


Adjust the annotations or the program code itself to resolve performance and correctness issues

Overview – Intel Parallel Advisor

The final version of the annotated program is projected to have good performance and no races.



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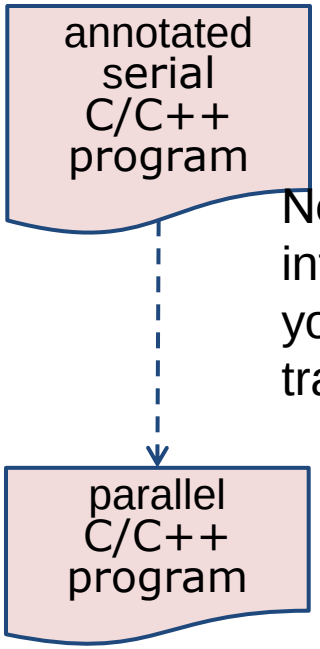
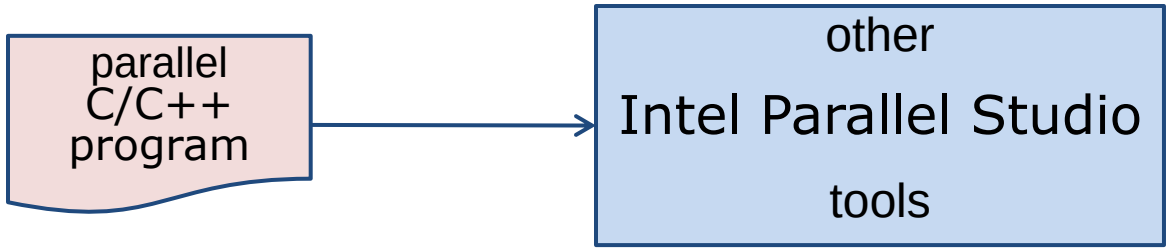


Now, it's time to change the annotations into real parallel code – TBB or Cilk or your favorite model. This straightforward translation is done by the programmer.

Overview – Intel Parallel Advisor

Use the other tools in Intel Parallel Studio to work with your parallel application (compile, debug, tune, etc)



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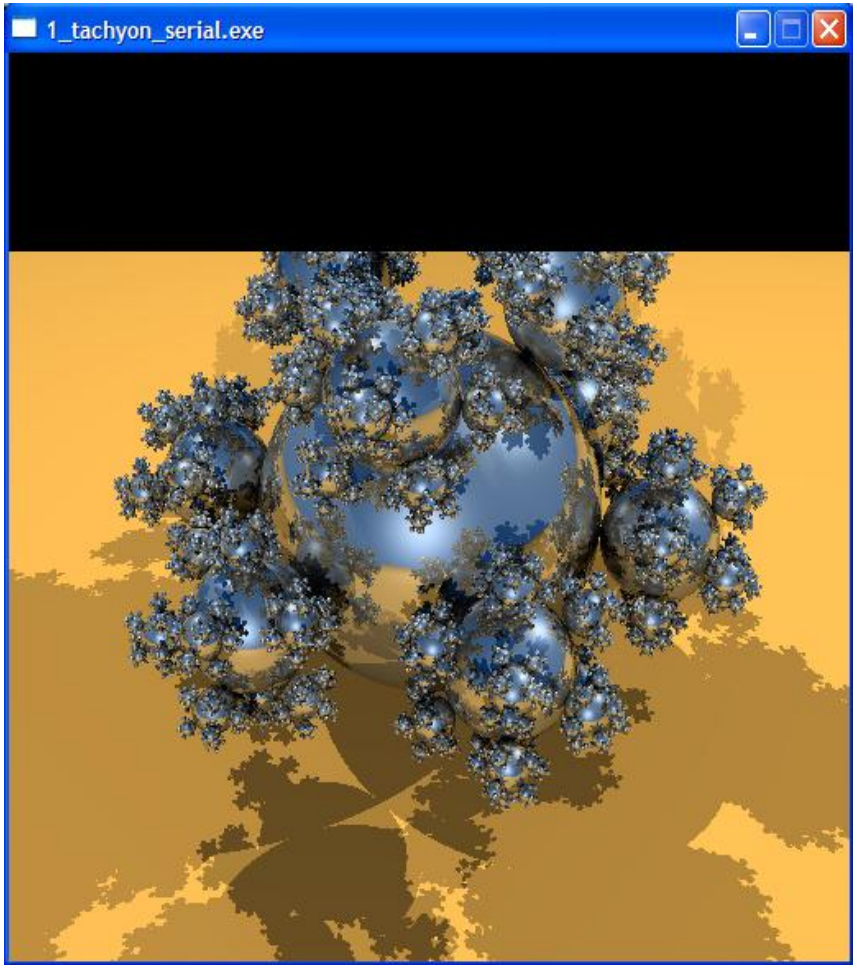
Finding where to add parallelism

- Find steps which are using lots of time
- Measure the number of steps needed to make a good size task
- Find how the steps interact

Analyze, don't guess.
Computers are good at analysis.

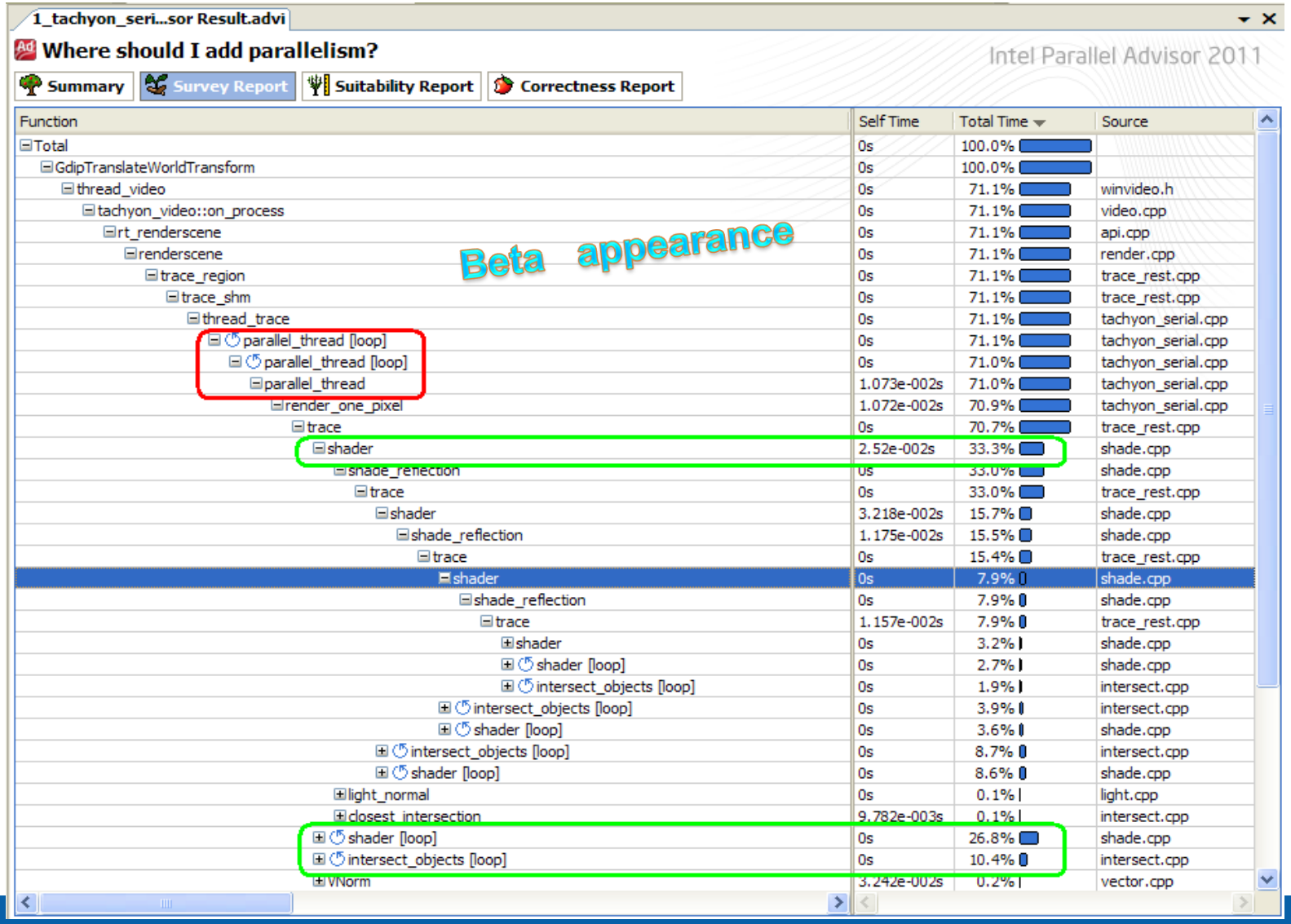
Tachyon Ray-tracer: Serial



Finding where to add parallelism

- Find steps which are using lots of time
  - Profile the serial algorithm : production build+ data
  - Find outer calls/loops that take lots of time, and that the architect thinks could be done in parallel

Survey Report – Profile: Hot Call Chain(s)



Function	Self Time	Total Time	Source
Total	0s	100.0%	
GdipTranslateWorldTransform	0s	100.0%	
thread_video	0s	71.1%	winvideo.h
tachyon_video::on_process	0s	71.1%	video.cpp
rt_renderscene	0s	71.1%	api.cpp
renderscene	0s	71.1%	render.cpp
trace_region	0s	71.1%	trace_rest.cpp
trace_shm	0s	71.1%	trace_rest.cpp
thread_trace	0s	71.1%	tachyon_serial.cpp
parallel_thread [loop]	0s	71.1%	tachyon_serial.cpp
parallel_thread [loop]	0s	71.0%	tachyon_serial.cpp
parallel_thread	1.073e-002s	71.0%	tachyon_serial.cpp
render_one_pixel	1.072e-002s	70.9%	tachyon_serial.cpp
trace	0s	70.7%	trace_rest.cpp
shader	2.52e-002s	33.3%	shade.cpp
shade_reflection	0s	33.0%	shade.cpp
trace	0s	33.0%	trace_rest.cpp
shader	3.218e-002s	15.7%	shade.cpp
shade_reflection	1.175e-002s	15.5%	shade.cpp
trace	0s	15.4%	trace_rest.cpp
shader	0s	7.9%	shade.cpp
shade_reflection	0s	7.9%	shade.cpp
trace	1.157e-002s	7.9%	trace_rest.cpp
shader	0s	3.2%	shade.cpp
shader [loop]	0s	2.7%	shade.cpp
intersect_objects [loop]	0s	1.9%	intersect.cpp
intersect_objects [loop]	0s	3.9%	intersect.cpp
shader [loop]	0s	3.6%	shade.cpp
intersect_objects [loop]	0s	8.7%	intersect.cpp
shader [loop]	0s	8.6%	shade.cpp
light_normal	0s	0.1%	light.cpp
closest_intersection	9.782e-003s	0.1%	intersect.cpp
shader [loop]	0s	26.8%	shade.cpp
intersect_objects [loop]	0s	10.4%	intersect.cpp
VNorm	3.242e-002s	0.2%	vector.cpp

Finding where to add parallelism

- Annotate the chosen sites and tasks
  - Sites contain where the tasks start, won't exit until the contained tasks end
  - Tasks are modeled as if they run in parallel

```
for (int s2 = 0; s2 < s2Count; s2++) {
    ANNOTATE_SITE_BEGIN(s2)
        delay();
        char lock;
        for (int t2 = 0; t2 < t2Count; t2++) {
            ANNOTATE_TASK_BEGIN(t2)
```

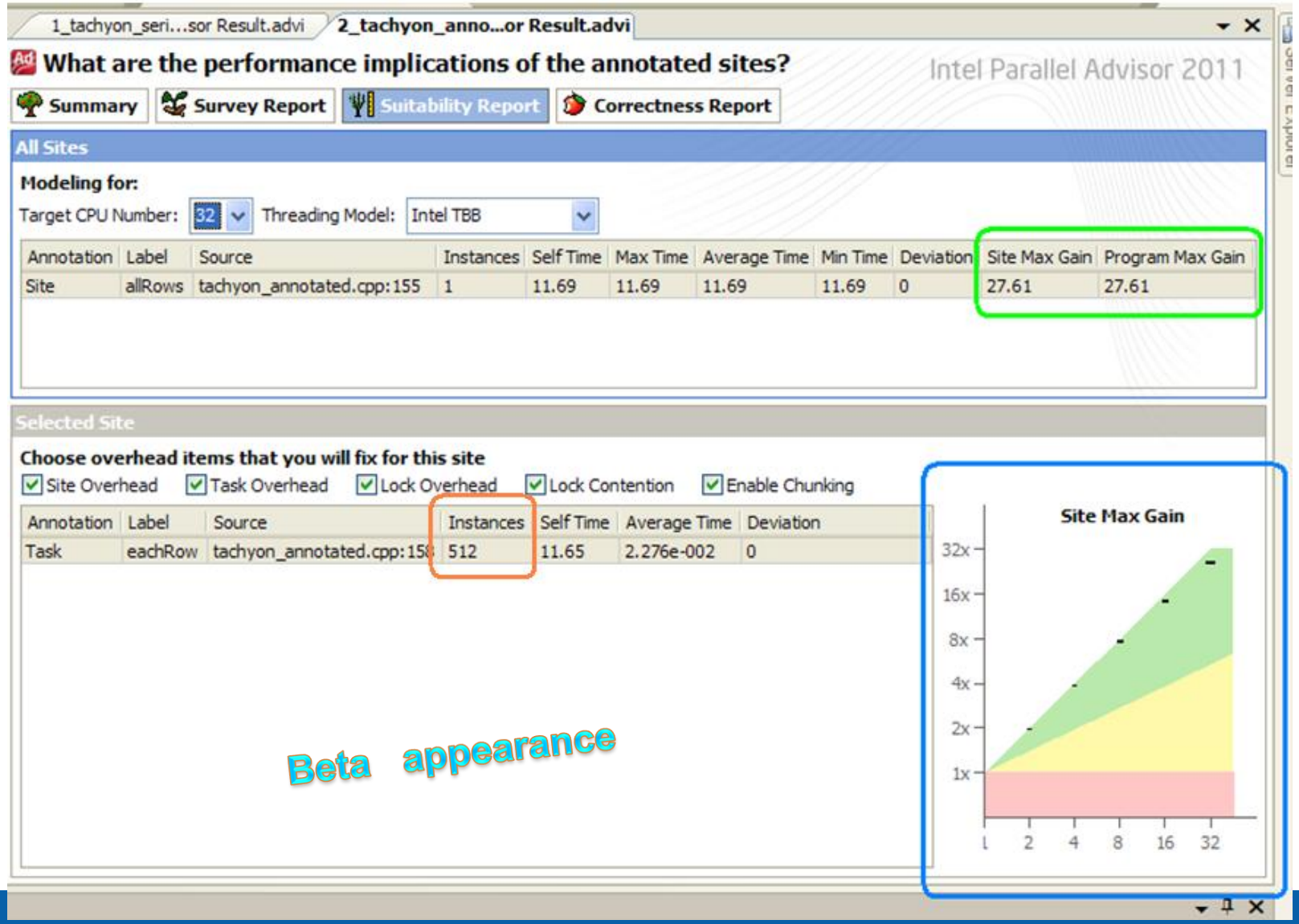
Macro use expands to a call to a stub function that can be hooked

```
                ANNOTATE_LOCK_ACQUIRE(&lock)
                delay();
                ANNOTATE_LOCK_RELEASE(&lock)
            }
            ANNOTATE_TASK_END(t2)
        }
    ANNOTATE_SITE_END(s2)
}
```

Finding where to add parallelism

- Measure the site and task times
  - Profile the annotated algorithm : release program + data
  - Annotations in bad places may slow execution
- How the measurement is done
  - Runtime binary instrumentation (Pin)
    - Intercept the calls to the stub functions
  - Measure the times between the calls
    - Uses the QPC() function and *_rdtsc* instruction
  - Compress and write to disk
    - Same as the other Intel Parallel Studio tools
  - Analyze
    - To understand the counts and times of the site, task, and lock execution

Suitability Report – *Model* Parallel Performance



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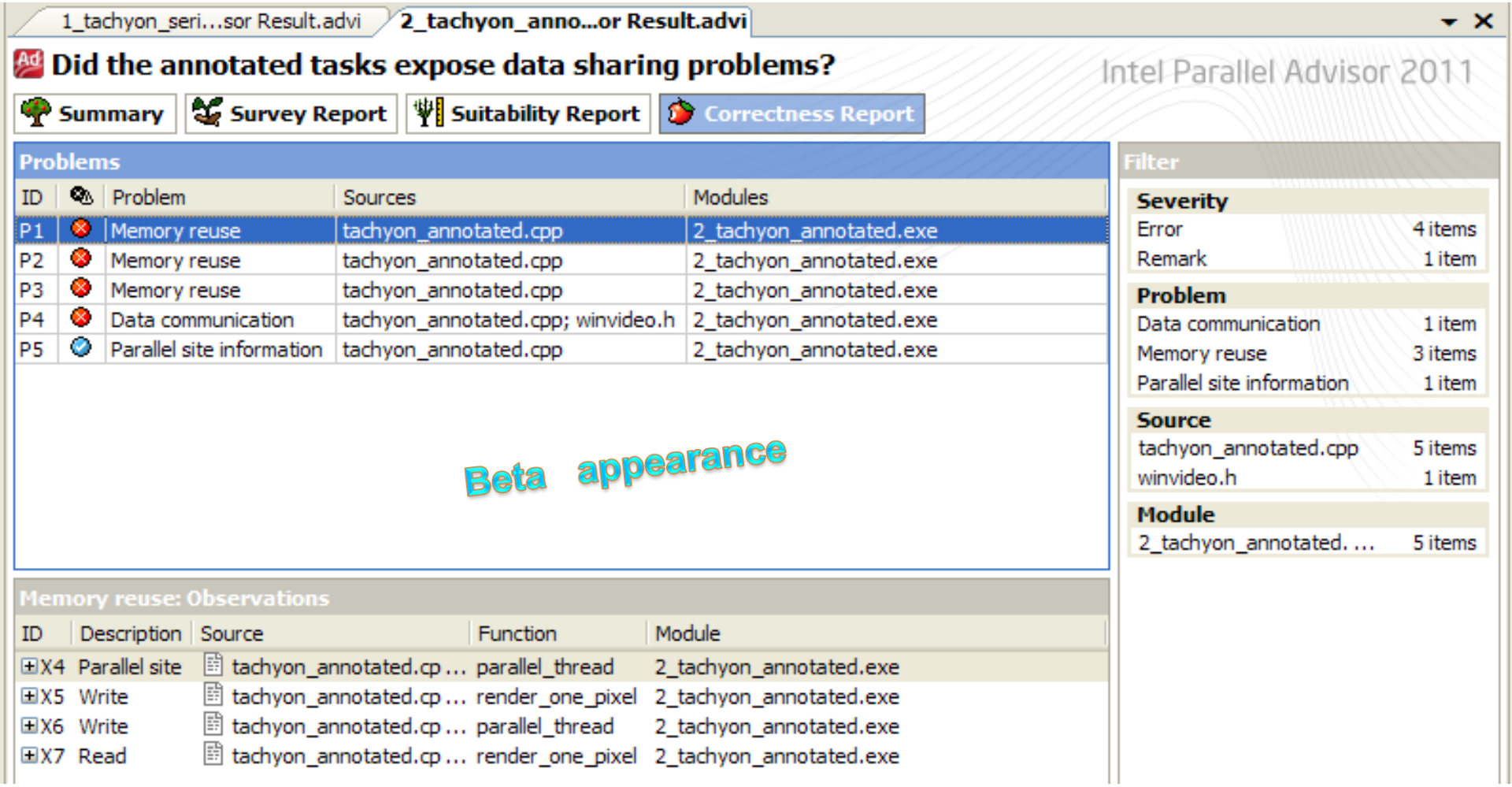
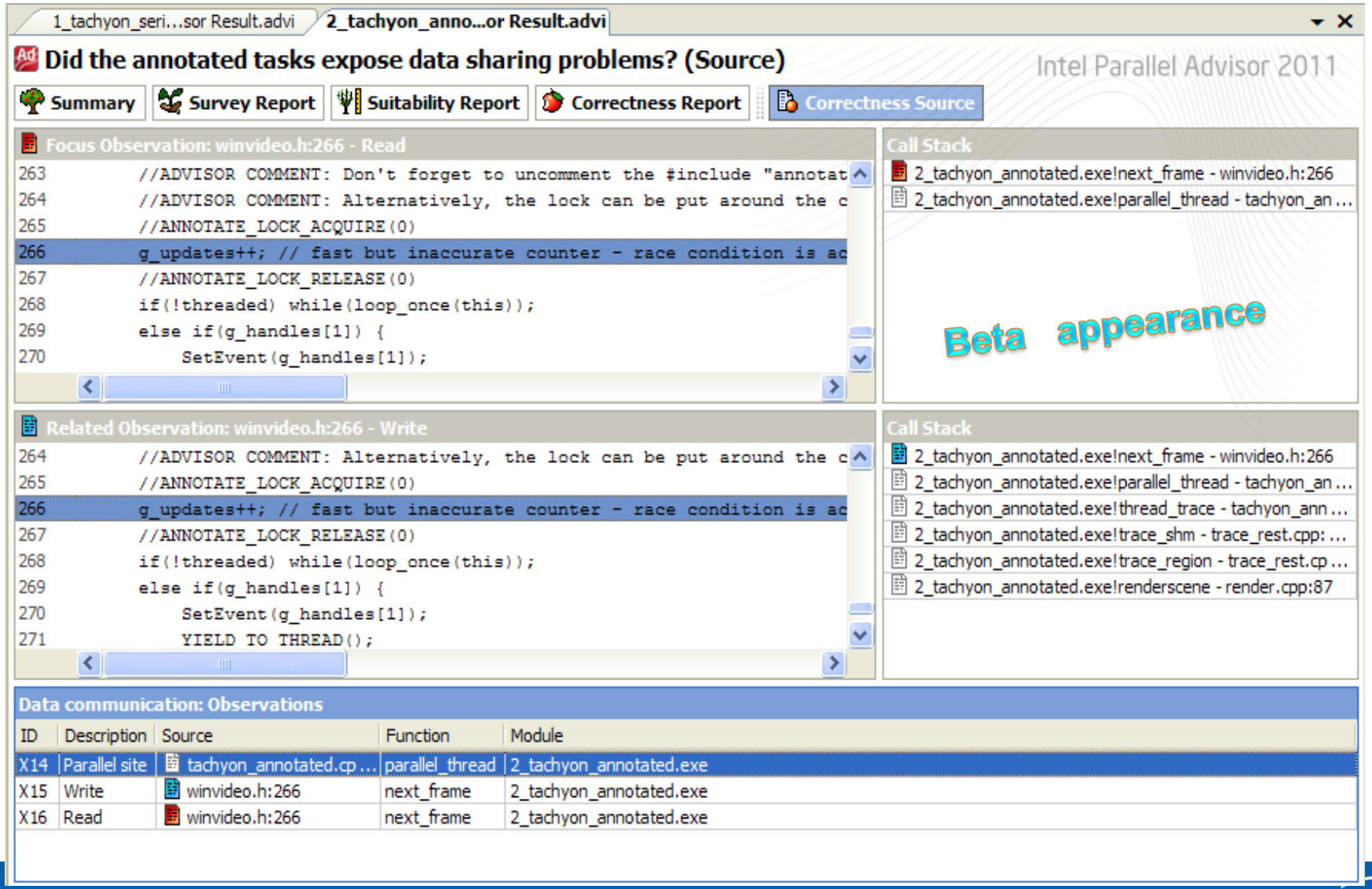
Finding code preventing parallelism

- Intel® Parallel Advisor runs the annotated *serial* program
  - It is serial, so violations of data dependencies don't crash the run
- Binary instrumentation (Pin) watches memory traffic and annotations
  - Use small data sets
    - Slow-down can be substantial
- Analyzes the data to determine what could go wrong when the tasks are done in parallel
  - Use debug builds, so problems can be mapped to sources
- Only memory sharing issues and locking problems are found

Correctness Report – *Model* Parallel Behavior



Source for *Data Communication* Error (Race)



Resolving roadblocks to parallelism

- Change the serial code to remove these
  - Debug these changes like you do any other change
- Learn about and use existing parallelized libraries; or thread-safe libraries
- Use per-task resources rather than shared resources
  - local variables, own files, other resources
- Use reductions
  - Supported directly by Cilk, Intel® TBB, OpenMP™
- Use locks only if none of the above are suitable

Fix the issues in the serial code

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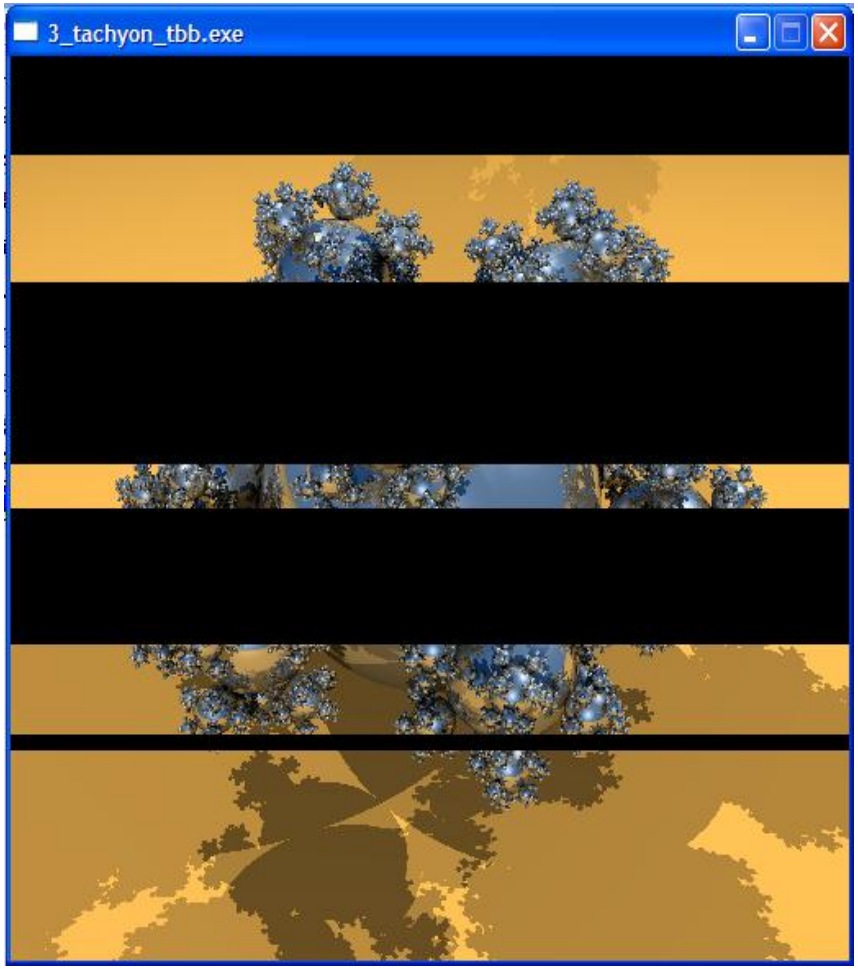
Adding parallelism

- Choose your parallel framework
  - Will depend on your programming language, portability needs, future growth needs
    - Cilk, Intel® Threading Building Blocks (Intel® TBB), OpenMP*, o/s threads
    - Intel® Parallel Composer supports these
- Modify your build and deployment environments
  - Compiler switches
  - Libraries may need to be installed on target machines
- Insert parallel framework statements for each annotation, implementing its "parallel" semantics

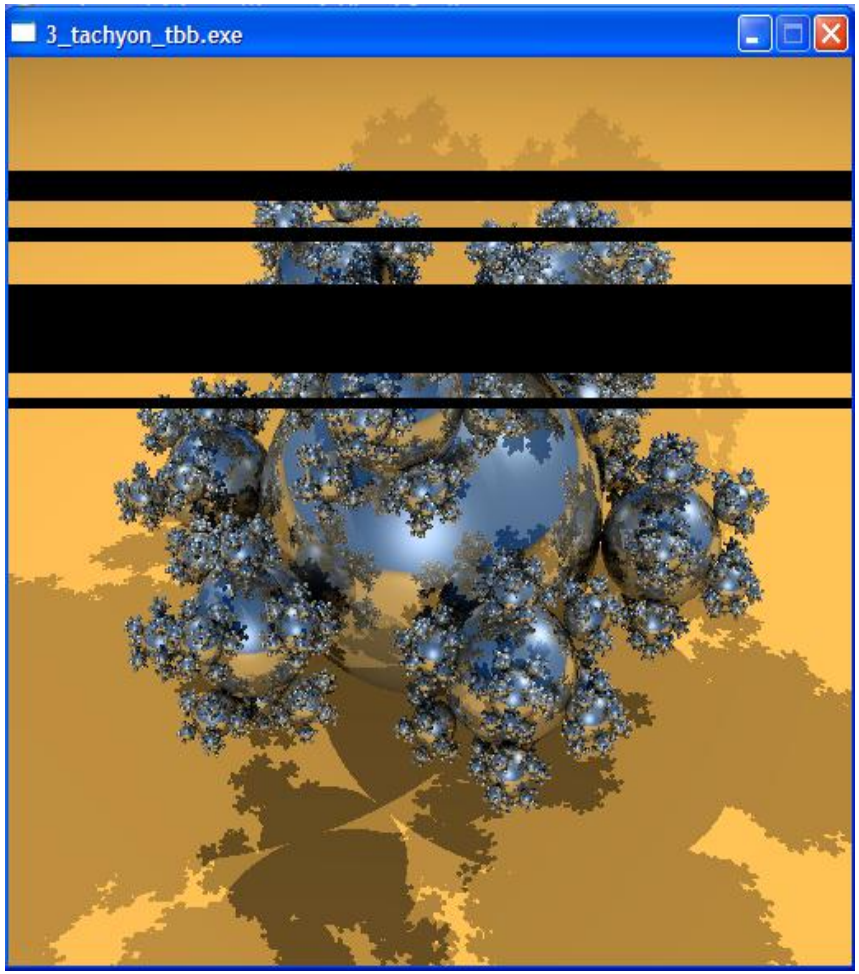
Choose the best framework for you

Tachyon – Parallel (Intel TBB), 4 cores

Appears divided into quarters



Thread stealing to finish



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Correctness and Performance

- Parallel programs are sensitive to timing issues
  - A failure may only happen only a few times in a million runs of the program, or only on some hardware
  - Intel® Parallel Advisor correctness analysis depends on the annotations matching what you implemented
  - Intel® Parallel Inspector detects problems that may happen, even if they did not happen this time
- Parallel program timings are sensitive to task sizes, thread interactions, memory caches
  - Intel® Parallel Amplifier measures where the time is spent

Measure, don't guess

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Don't Panic

- Parallel programming has been around for a long time, and is perceived as very difficult
- But any programmer can do it and get worthwhile benefits IF
  - They go step by step
  - They use modern frameworks and tools
  - They avoid the more complex techniques
- Intel® Parallel Advisor documentation introduces the programmer to this world

Intel® Parallel Studio helps with each step

Summary

- Analysis, preparation and testing of the serial code simplifies adding parallelism
- Adding and using parallelism requires enhanced tools

- Analyze, don't guess, where to add
- Fix the issues in the serial code
- Choose the best parallel framework for you
- Measure, don't guess, performance issues
- Intel® Parallel Studio helps with each step

Additional sources of information on this topic:

- More web based info: http://software.intel.com and http://software.intel.com/en-us/intel-learning-lab/

- Search the internet for
  - "Intel Parallel Studio"
  - "Intel Parallel Advisor"
  - "TBB"
  - "Cilk"
  - …

  - Especially anything from James Reinders

Q&A

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