Using Games to Teach Parallelism to Computer Science Sophomore Students

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Agenda

- Teaching parallelism through game demos
    - Case study of a particle system

- Learn about performance profiling tools
    - Identify code bottlenecks to target optimization efforts

- Integrating code and lesson plans into sophomore curriculum
    - Preliminary evaluations from ASU, USC

What is a particle system?

Simulation phase – as fast as possible

- Spawn new particles
  - Initialize physical properties – position, orientation, velocity

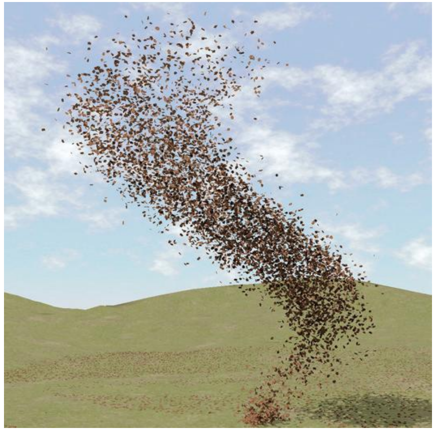
- Check to see if particle lifetime exceeded
  - Remove particle from simulation

- Update physical properties for all particles
  - Position, velocity, orientation, angular velocity

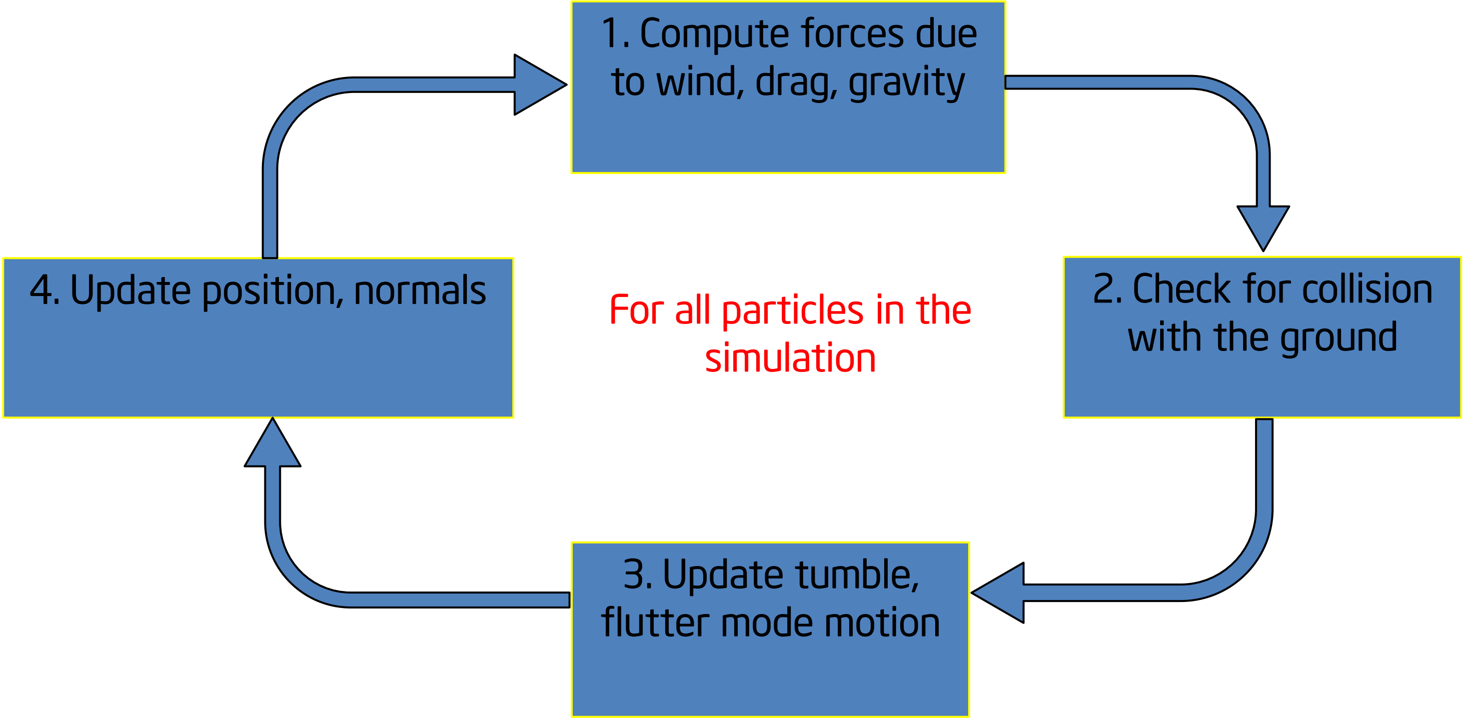
- Collision detection (if needed)

Rendering phase – usually 30fps

- Draw each particle
  - Points, billboards, sprites



Physics update sequence



Particle systems: A good parallelism teaching tool

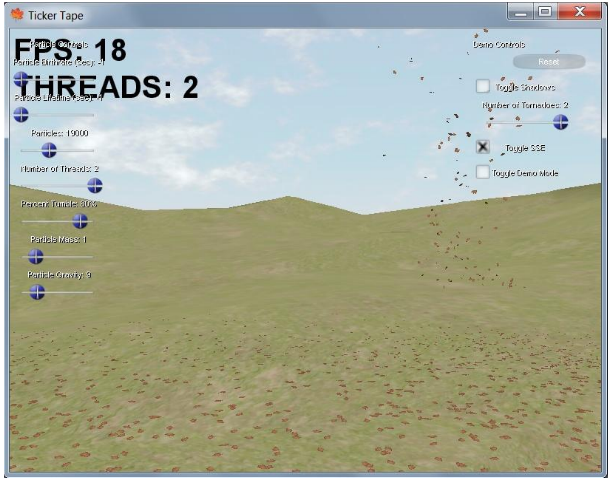
- Lots of parallel work
    - Each particle is separate, does not influence others

- Repetitive work being performed at each time step
    - Update physics for each particle
    - Compute collision for each particle
    - Update position of each particle
    - Render each particle

- Visual feedback of code changes
    - Improved fps through increased parallelism

Case study of particle system: Ticker Tape

- Particle system simulation in DX10
  - Falling leaves under gravity and wind effects
- Includes task-based threading with Intel TBB
  - Computation and updates broken into tasks
- Uses SSE for improved performance
  - UI features - thread count, # of particles, etc.



Using TickerTape in classroom

Target audience – undergraduate students (sophomore and beyond)

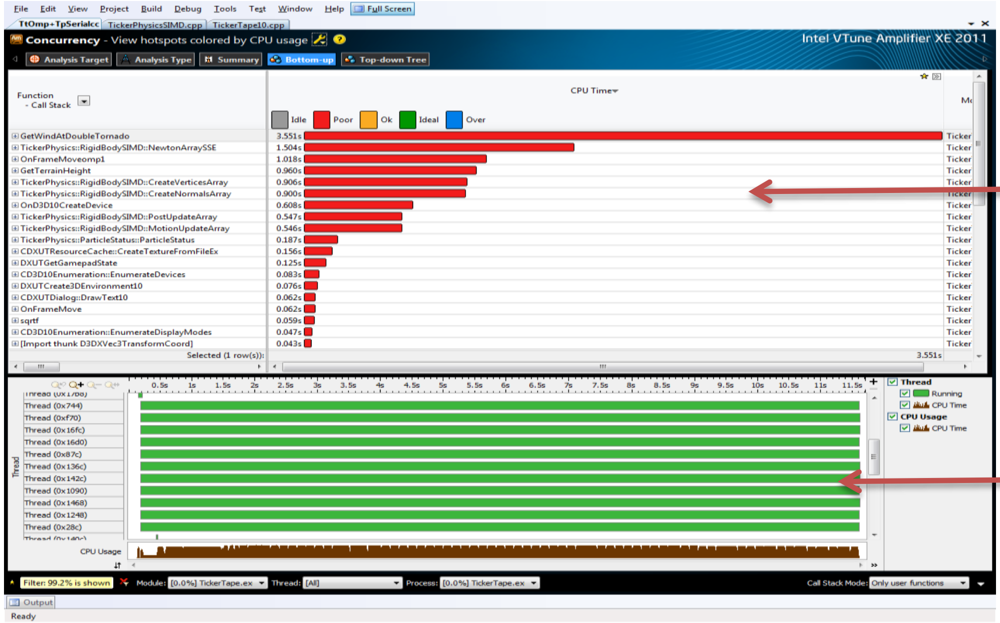
Requirement: Understanding of C++

Problem: Existing code is complex to cover in 1-2 classroom sessions

Solution:

- Use profiling tools for hotspot/ concurrency analysis
- Identify hotspots - 50 lines or less
- Make changes and verify improvement

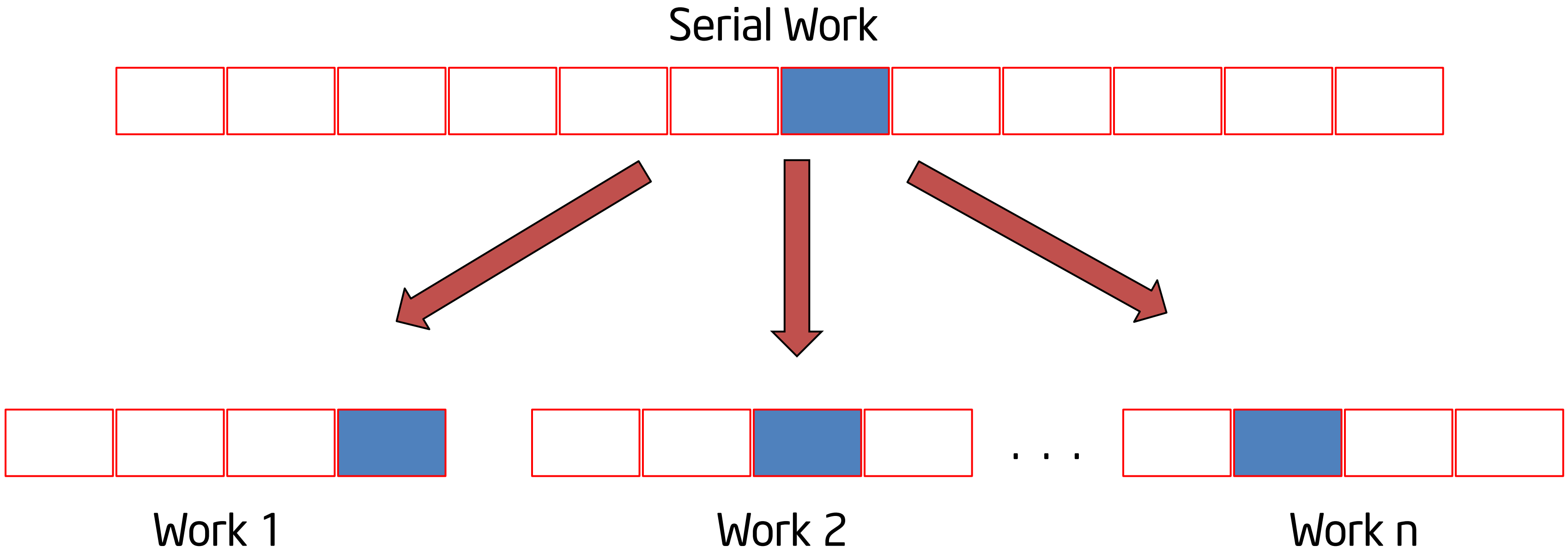
Identify bottlenecks with Intel AmplifierXE



Hotspots with poor concurrency
Red: serial execution

No concurrent work,
threads idling

Update VB to copy data from CPU to GPU



Code overview

```
#pragma omp parallel for
for(unsigned int i = 0; i < g_uNumActiveParticles; i++) {//do this computation for all the particles
    __declspec(align(16))D3DXMATRIX mTransform, mTranslate, mRotate;
    float fScaleFactor = 0.15f;
    D3DXMatrixScaling( &mScaling, fScaleFactor, fScaleFactor, fScaleFactor );

    //Compute the combined translation/ rotation matrix
    D3DXMatrixTranslation( &mTranslate, particles[i-start].pos_x, particles[i-start].pos_y, particles[i-start].pos_z );
    D3DXMatrixRotationYawPitchRoll( &mRotate, particles[i-start].rot_y , particles[i-start].rot_x , particles[i-start].rot_z
      );
    D3DXMatrixMultiply( &mTransform, &mScaling, &mRotate );
    D3DXMatrixMultiply( &mTransform, &mTransform, &mTranslate );

    //update all the vertices in the leaf
    for (unsigned int j = 4*i; j < 4*i+4; j++)
    {
        pContext->pVertexBuf[j].tex = g_vertices[j].tex;
        D3DXVec3TransformCoord( &(pContext->pVertexBuf[j].pos), &g_vertices[j].pos, &mTransform );
        D3DXVec3TransformNormal( &(pContext->pVertexBuf[j].normal), &g_vertices[j].normal, &mTransform )
    }
}
```

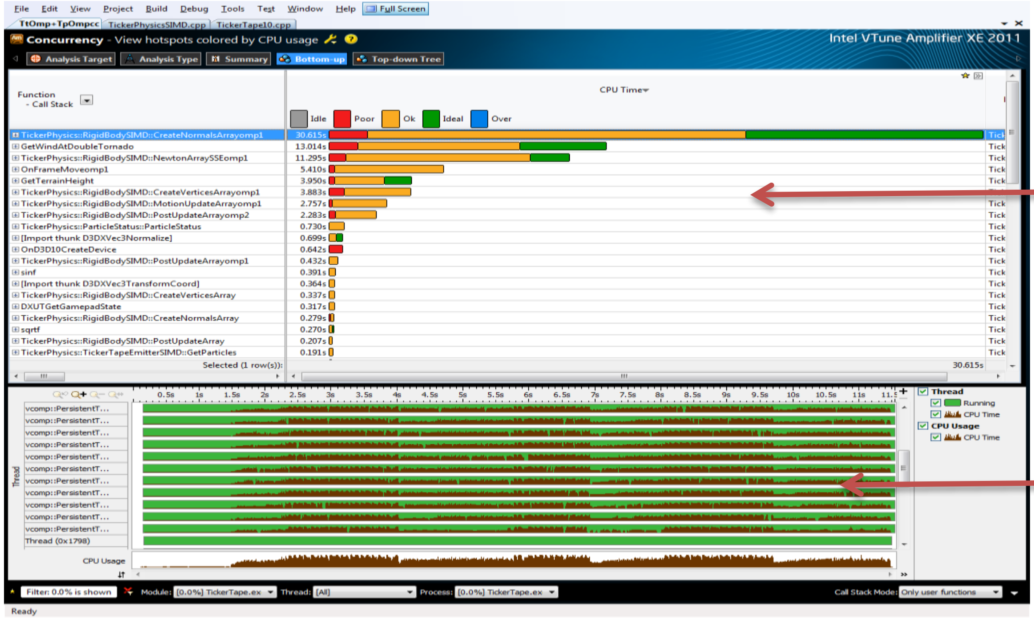
init local vars

matrix multiply

update

Analyzing improvement with OpenMP

TickerTape omp + TickerPhysicsSIMD omp



Hotspots with some concurrency

Red: Poor

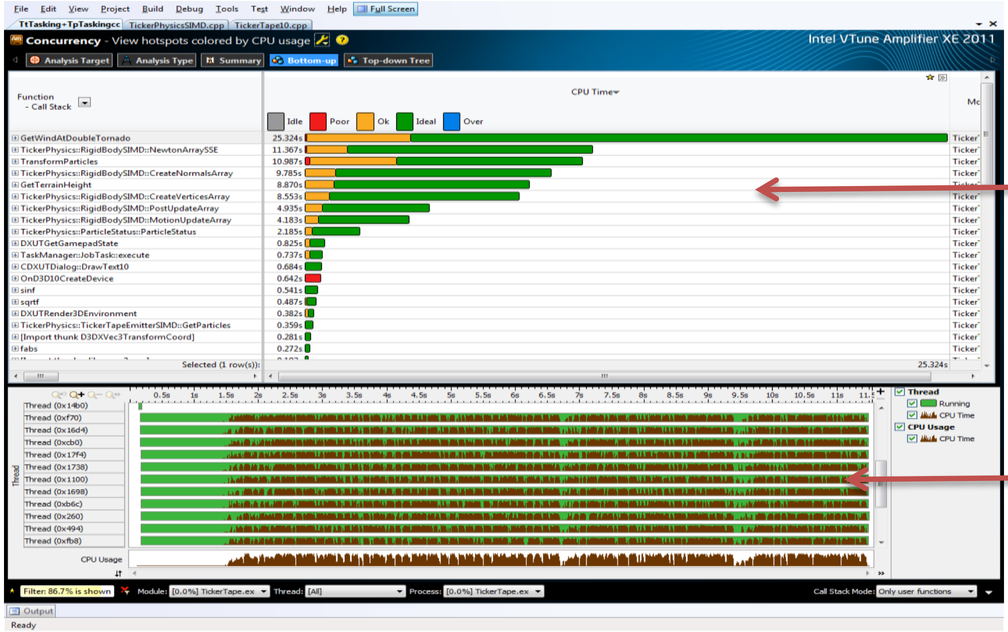
Orange: OK

Green: Best

Concurrent work

Analyzing improvement with TBB tasking

TickerTape tasking + TickerPhysicsSIMD tasking



Hotspots with ideal concurrency

Red: Minimal

Orange: OK

Green: Largest sections

Concurrent work

7.6x improvement in fps on high end desktop

Copy VBs from CPU to GPU TickerTape10.cpp	Physics updates TickerPhysicsSIMD.cpp	fps (50000 particles, 6C)*	fps (10000 particles, 2C)+
Serial	Serial	13	38
Parallel with OpenMP	Serial	14	42
Parallel with OpenMP	Parallel with OpenMP	56	56
Tasking with TBB	Tasking with TBB	99	77

* Testing carried out on a Gulftown Core i7 980X, with 4GB RAM and discrete graphics 6C-12T, and 50000 particles in the simulation, SSE ON

+ Testing carried out on a Core2Duo @2.8 GHz, 4GB RAM and 10000 particles

Suggested integration into curriculum

Classroom sessions

- Focus on API fundamentals, threading concepts
- Overview of the code, critical hotspots in the program

Lab sessions

- Compiling and running the game demos
- Understanding profiling tools and identifying bottlenecks

Homework and assignments

- Change serial code to introduce parallelism: OpenMP, Intel TBB
- Verify changes and performance improvement with code profilers

Preliminary results from select schools

2 schools integrated game demos into the curriculum for Spring 2011

- USC – OS, game design courses

- ASU – Integrated game demos into undergraduate courses
CSE 430: Emphasis on threading, synchronization and deadlock

For more details, join us on Thursday 6:30-7:00pm, Kuskokwim Ballroom

Call to action

- Include graphics demos in academic curriculum
  – Visual feedback of additional parallelism through increased fps

- Comprehensive solution provided with TickerTape
  – Serial, OpenMP and task-based solution code, lesson plans, lab solutions

- Let us know what kind of demos you want to include in the classroom
  – gamedevinput@intel.com

Additional resources

Download academic-ready TickerTape source code and notes

Join the Intel Academic Community

Download latest graphics and game demos

- Colony
- Fireflies

Profiling tools

- Intel Parallel Amplifier 2011
- Intel Parallel Advisor 2011
- Intel Parallel Inspector 2011

Backup

System requirements for TickerTape

To run:

- DX10 features graphics card
- Multi-core processor for visual differentiation (ideally)

To compile:

- DX SDK from Microsoft (tested with June, 2010)
- Visual Studio 2008 and beyond (sln files provided)
- Full source (provided)

Other resources

- Tools usage examples
    - Finding correctness issues using Intel® Parallel Inspector 2011
    - Identifying performance issues using Intel® Parallel Amplifier XE

- Intel® Cilk™ Plus solution with Ticker Tape
    - Simple Cilk keywords to achieve parallelism
    - Easier SIMD implementation using array notations, pragmas, and compiler notations