phoenix
fluid dynamics

V-Ray
ARTWORKFLOW

CHAOSGROUP
innovative rendering technologies

About Phoenix FD

- PLUGIN FOR 3DS MAX AND MAYA.
- SIMULATING AND RENDERING BOTH LIQUIDS AND FIRE/SMOKE.
- USED IN MOVIES, GAMES AND COMMERCIALS.

Phoenix FD core

- SIMULATION & RENDERING.
- SIMULATION CORE - GRID-BASED SOLVER:
  - EXTERNAL FORCES.
  - DIVERGENCE CLEANING (CONSERVATION).
  - ADVECTION.
- HYBRID SOLVER.
- FLIP SOLVER.

Phoenix FD conservation close-up

In any solver type the conservation takes a significant time.

Conservation methods are iterative algorithms doing many iterations on the entire grid.

Phoenix implements 2 double-buffered methods and 2 that work in-place.

Phoenix FD buffered conservations

GPU friendly and easy to multithread.

On the CPU – same multithreading method as for all other supporting algorithms:

Splitting the grid vertically into equal sections.

Phoenix FD standard multithreading

For example: 4 threads.

Data amount for each section:

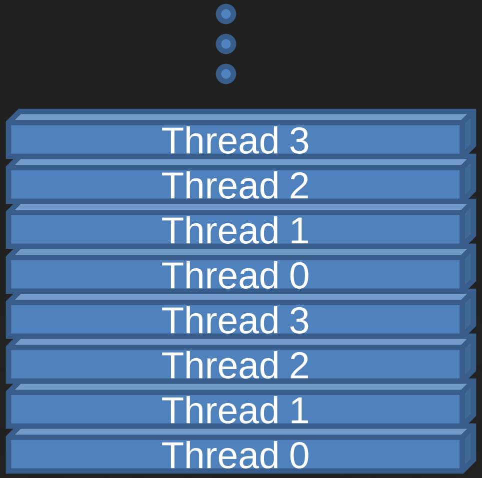
Phoenix FD standard MT

Issues:

- BAD LOAD BALANCING.
- BAD USE OF L3 CACHE.

Phoenix FD standard MT

Resolving both CPU and cache issues: each thread n works on those horizontal slices where z mod N = n



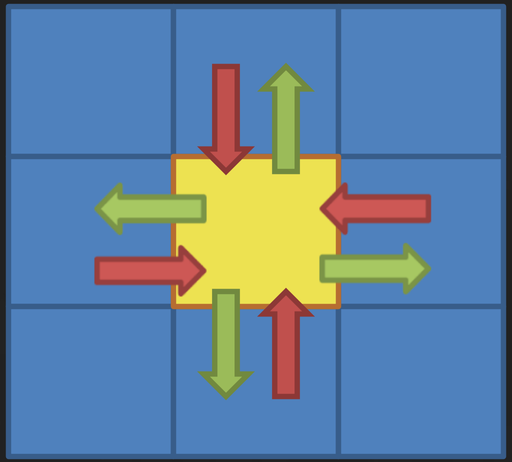
Phoenix FD in-place conservations

Read, calculate and write immediately the result in the same buffer:

- **MUCH STRONGER CONSERVATION.**
- **EACH CELL DEPENDS ON THE PREVIOUS ONE.**
- **VERY BAD FOR THE GPU.**
- **SINGLE-THREADED ON THE CPU.**

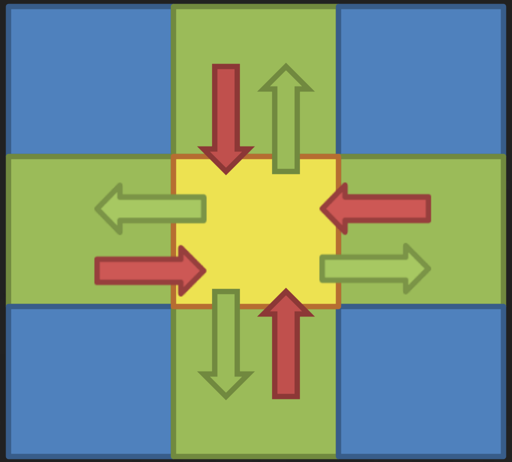
Phoenix FD in-place conservations

For each cell, calculate its divergence and correct the velocities proportionally so that the divergence is zeroed.



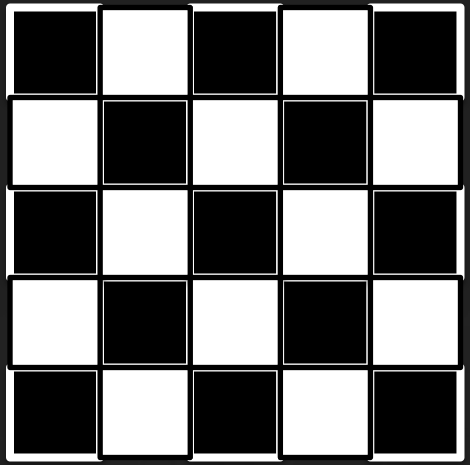
Phoenix FD in-place conservations

The cell's own velocities cancel out of the divergence calculation.



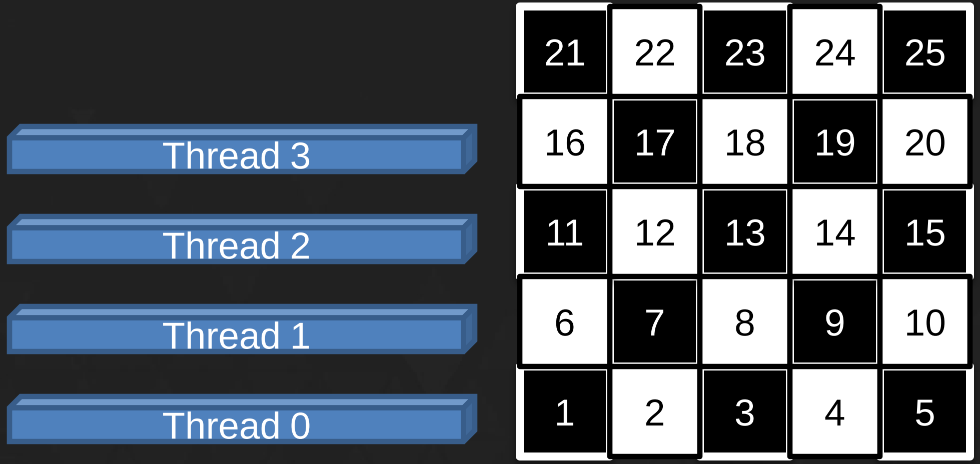
Phoenix FD in-place conservations

In the 3D grid, a checker pattern emerges, where the black and white cells don't interact:



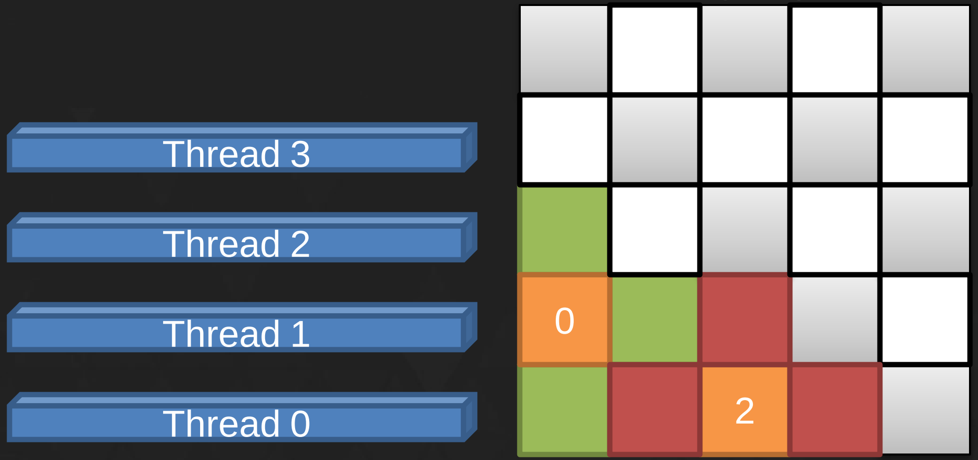
Phoenix FD in-place conservations

Let’s split the grid in horizontal slices as in the previous method and try to run each slice in a separate thread:



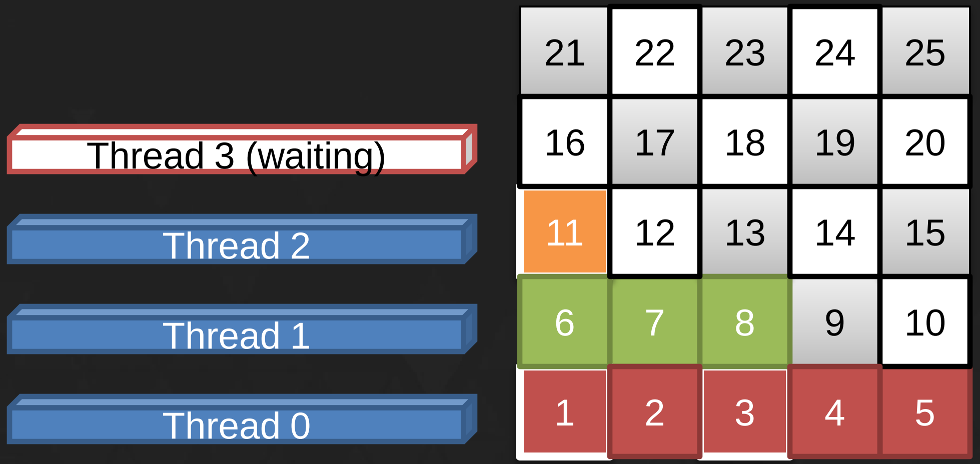
Phoenix FD in-place conservations

Influence pattern for Thread 0 and Thread 1, showing that Thread 1 must be delayed by 2 rows:



Phoenix FD in-place conservations

The ‘Harvester’ method:



Phoenix FD rendering

Real-time GPU-based volumetric rendering

- THE USUAL RENDERING WITH THE CPU
- THE ADVANTAGES AND LIMITATIONS OF THE GPU
- THE IMPLEMENTATION ON THE GPU

Phoenix FD usual CPU rendering

What kind of data we have:

- DENSITY FUNCTION REPRESENTED AS A 3D GRID
- OBSERVER'S POSITION AND ORIENTATION (CAMERA)
- LIGHT SOURCES

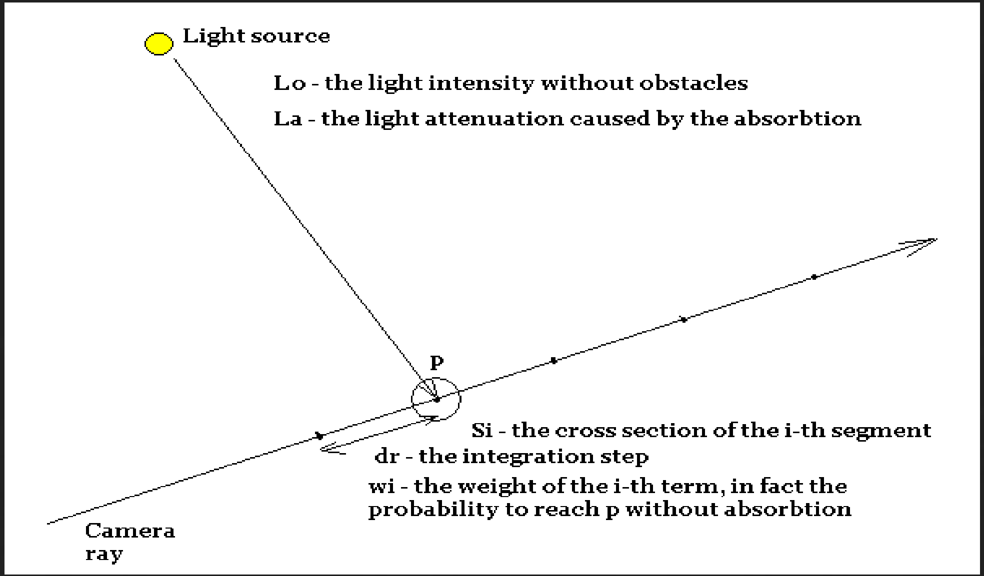
Phoenix FD usual CPU rendering

Calculating what we see in a certain direction:

- THE RESULT IS A WEIGHTED SUM
- CALCULATION OF THE WEIGHT
- CALCULATION OF THE LOCAL BRIGHTNESS

Phoenix FD usual CPU rendering

The contribution of a short segment:



Phoenix FD GPU advantages and limitations

Short history of the GPU:

- BASIC FUNCTION – CONVERT TRIANGLES FROM 3D to 2D AND TEXTURE THEM
- THE PROGRAMMABLE FIXED PIPELINE WITH 8 STAGES
- THE PIXEL SHADERS AND THEIR EVOLUTION INTO GENERAL-PURPOSE CALCULATION UNITS

Phoenix FD GPU advantages and limitations

Why the GPU is faster?

- MULTIPLE CORES WITH THE SAME CODE RUNNING ON THEM
- SIMPLER FLOW CONTROL – NO BRANCHES, NO COMPLICATED ADDRESSING MODES
- SOME INTENSIVELY USED MATH IS DIRECTLY SUPPORTED (INTERPOLATION, 3D VECTORS)

Phoenix FD GPU advantages and limitations

The difference from the CPU

- THE EXECUTED CYCLES ARE LIMITED
- LIMITED SYNCHRONIZATION ABILITIES
- NO RANDOM ACCESS TO THE MEMORY

Phoenix FD implementation on the GPU

General overview

- IN MOST CASES THE GPU IS USED IN MULTIPLE PASSES
- A DUMMY PRIMITIVE (USUALLY A BOX) THAT WILL BE ‘RENDERED’ IS PREPARED
- THE LARGE DATA ARRAYS ARE PASSED AS TEXTURES, THE SINGLE CONSTANTS ARE PASSED IN REGISTERS
- THE NEEDED PIXEL SHADER CODE IS ACTIVATED AND THE RENDERING OF THE DUMMY PRIMITIVE IS STARTED
- AFTER THE ‘RENDERING’ THE RESULT IS IN THE BACK-BUFFER

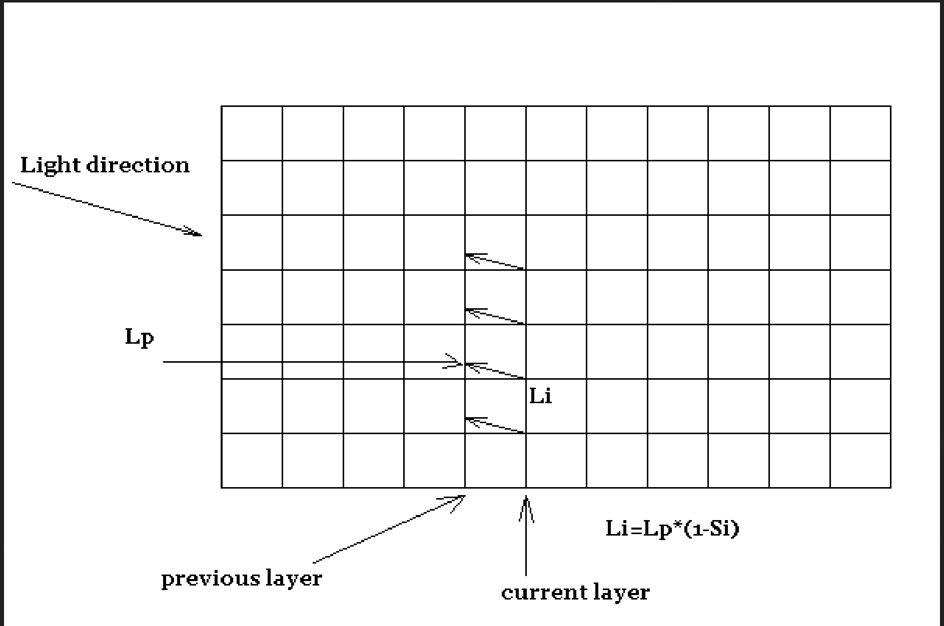
Phoenix FD implementation on the GPU

The light propagation

- FOR PERFORMANCE REASONS THE LIGHTS ARE REPRESENTED AS PARALLEL
- WE FIND THE BIGGEST COMPONENT OF THE DIRECTION VECTOR AND PROPAGATE THE LIGHT LAYER BY LAYER IN THIS DIRECTION
- EACH LAYER IS CALCULATED BY A SINGLE PASS ON THE GPU AND THE RESULT IS RETURNED INTO THE BACK BUFFER. WE KEEP IT INTO A TEXTURE AND PASS IT BACK TO THE GPU FOR THE NEXT LAYER CALCULATION

Phoenix FD implementation on the GPU

The light propagation



Phoenix FD implementation on the GPU

The light propagation

- ONCE HAVING THE LIGHT MAP, WE CAN USE IT MULTIPLE TIMES WITH DIFFERENT CAMERA POSITIONS (WE CAN ROTATE THE VIEW)
- WE PASS THE LIGHT MAP TO THE GPU, ALONG WITH THE DENSITY MAP, THE CAMERA , AND THE LIGHT DIRECTION
- THE CAMERA RAY INTEGRATION IS EXACTLY LIKE THE CPU IMPLEMENTATION

THANK YOU!

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