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Using GPU Frameworks

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Spark

- This talk sparked by using ray tracing library OPTIX (NVIDIA)
- Ability to build Straw-man in no time
  - Good SDK
- Extreme Performance
  - Possible to apply design processes
- Intrigued by need to just supply Kernels
  - Simpler than pure CUDA kernels.
  - Kernels can launch further rays.
- I am a Programmer at heart
  - So don’t necessarily want to take easiest option.
- C++ support
- Got me to thinking

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Examples - OPTIX SDK

- Shadowing
- Collision detection
- Glass refraction

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Also aware of Colleagues work

- GPU Flame – Particle (Agent) interactor
  - Even simpler – supply kernel partly in code and in text form
  - Particles in 2D cells.
- Colleague asking NVIDIA about volume ray tracing
  - Streamlines
  - Plume propagation
- Our in-house Smoothed Particle Hydrodynamic (SPH) code
  - Ask my self is this crying out for a similar Framework
  - Supporting particles in 3D cells
  - Local interactions trigger kernel.

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Definition & Span

- GPU Framework as far as this talk is concerned
  - Calls user supplied kernel for interaction.
  - I can specify state I require
  - Geometry is split in any fashion it thinks is sensible

- Span
  - Work carried out in a Physics modelling tool using OPTIX
  - End user of FLAME GPU
  - Looking ahead thinking what frameworks could be useful.

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Our Groups' Bread & Butter

- Historically HPC cell based simulation codes
  - Air flow over wings
  - Water flow
- HPC to GPU
  - We have bitten the bullet (pity PHI)
  - Kernels and independent loops
  - Proxy data that might reside CPU or GPU
  - Our own GPU cluster: 8 servers, 32 Fermi cards
- **However**, will there be a Mesh GPU Framework where you supply
  - Cell and Face kernels only.
- OP2 maybe be candidate
  - Oxford (Mike Giles) : http://www.oerc.ox.ac.uk/research/op2
- VTK a mesh framework
  - Supports some parallel processing.

A Ray Tracing tool

Based on OPTIX

Solving Physics important to the company

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Physics important to the company

- Already invested in ray tracing tools
- Rays bounce statistics on fixed and moving geometries
- Infrared signature
- Lower Frequency Electromagnetic propagation
  - Radar
  - Wifi
- Convinced our partners that OPTIX can give a step change.

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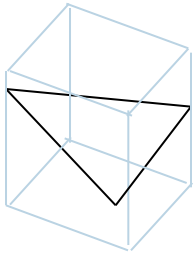
OPTIX – Geometry

- Geometry agnostic
- Rather for each primitive you need to return a Bounding box.



Tri face Bounding Box

- Groups of elements can belong to different materials which have totally different colouring/physics routines

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OPTIX - State

- All state is stored in buffers that are mapped to the GPU
  - Automatically
  - And back again if need be.
- Kernel sees these as global multi dimensional arrays.

rtBuffer< float , 2 > out

Context[“out”]

- C++ side links to these buffers using
  - A map accessed with strings
  - An issue but there is a very good validator.

- This state will include Geometry

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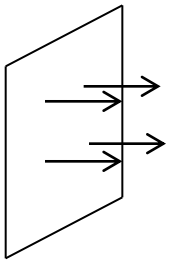
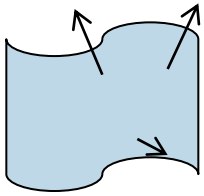
OPTIX – Ray Launch

- Rays are fired from 1 or 2d arrays, with associated camera model which can be
  - A image plane
  - Random positions over a geometry
  - Anything i.e. not tied to solving Image generation problems.



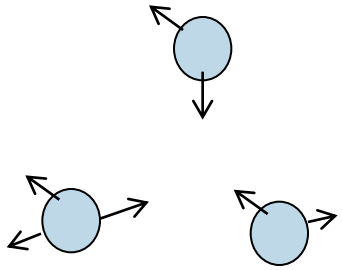
Orthogonal Camera

or



Rays randomly launched from Surface

or



Collison example earlier

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OPTIX - Intersection

- A launched Ray is tested against the bounding boxes.
- If it enters a bounding box, the intersection kernel is triggered
  - User supplied
  - If you indicate it intersects, OPTIX launches the relevant Colouring Kernel

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OPTIX - Colouring

- User supplied kernel
- Colouring can involve launching further rays

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OPTIX - Conclusions

- Extremely fast: 100 M rays a second
  - You could not code this yourself!
  - Vendor optimized
- Very flexible - Bug free
- Kernels are not complicated by concept of Warps
- Simple memory model
- SDK contains lots of examples
- Issues
  - We would rather have less rays per seconds and more ray depth
  - Complexity of Kernels limited.

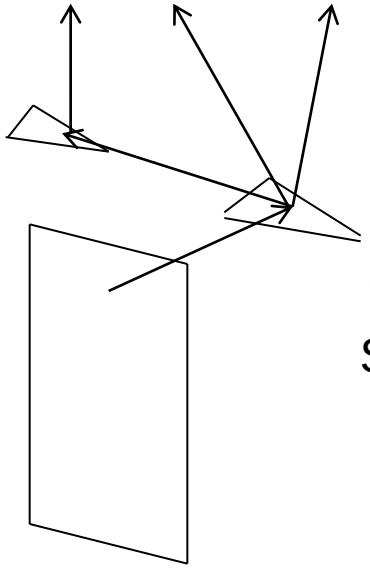
Application example: Infrared

- Signatures Important

- To build Temperature Image
- Fire rays from viewed surfaces
  - In diffuse and specular fashion
  - To any depth
  - Collect temperature from hit surfaces
  - Collection Cut-off
  - Concave regions get hotter

- We can upgrade tools with 60 X

- Starting to think about real time analysis



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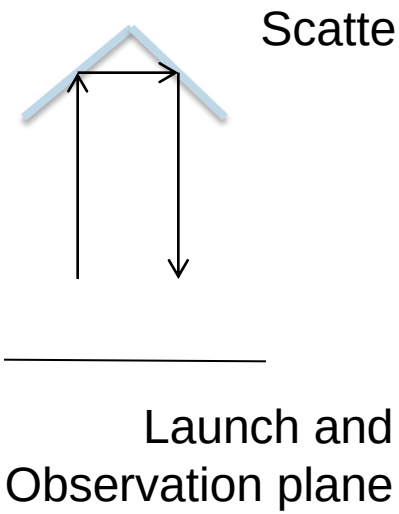
Application example: Electromagnetic Propagation

- Shooting Bouncing Ray method => EM Signature
  - Integrate rays hitting observation plane
  - Take into account absorption along the way.



  - In process of updating existsing tools

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Modelling Agents
Using Flame GPU

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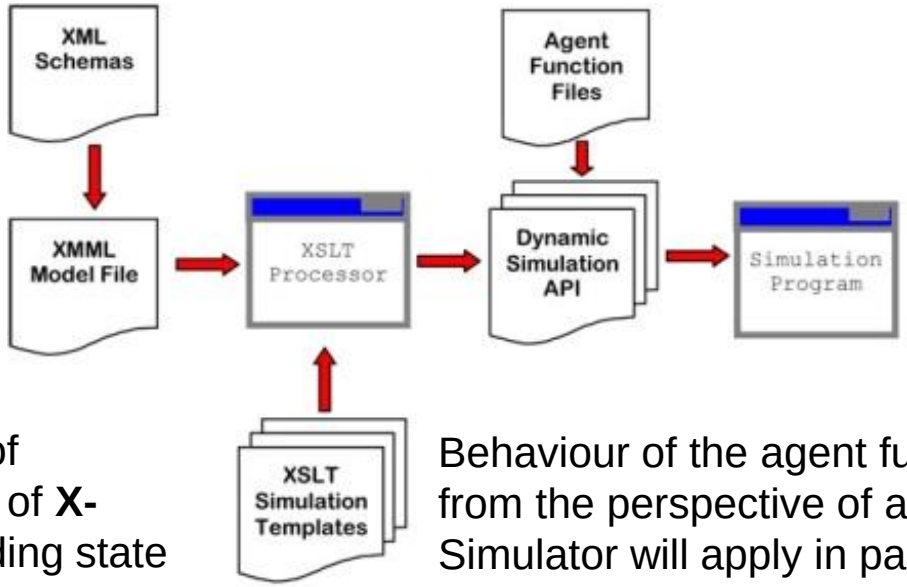
Flame GPU

- FlameGPU
  - Is a data parallel implementation of FLAME using CUDA
  - Consider divergence
  - Is cost effective solution for high performance ABM simulation
  - Offers real time visualisation

- FLAME
  - Is a Flexible Large-scale Agent Modelling Environment
  - Uses **XML** Model specification based on agents as **X-Machines** (extended state machine)
  - Is a template system for generating simulation code

FLAME GPU – High level Overview



XMML model file consists of

- a definition of a number of **X-Machine agents** (including state and memory information and a set of agent transition functions)
- a number of **message** types (each of which has a globally accessible message list)
- a set of simulation layers and define the execution order of agent functions for a single simulation iteration

Behaviour of the agent function is described from the perspective of a **single agent**. Simulator will apply in parallel the same agent function code to each agent which is in the correct start state.

Agent function scripts are defined using a simple C based syntax with the agent function definitions, and more specifically the function arguments dependant on the XMML function definition.

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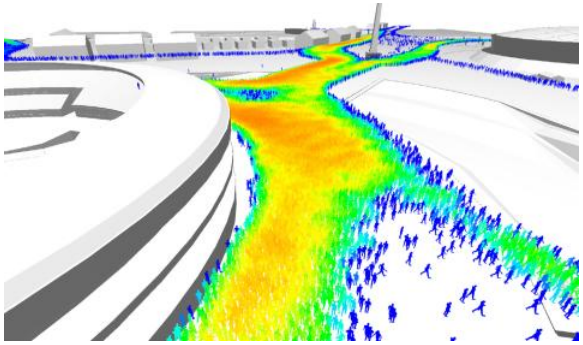
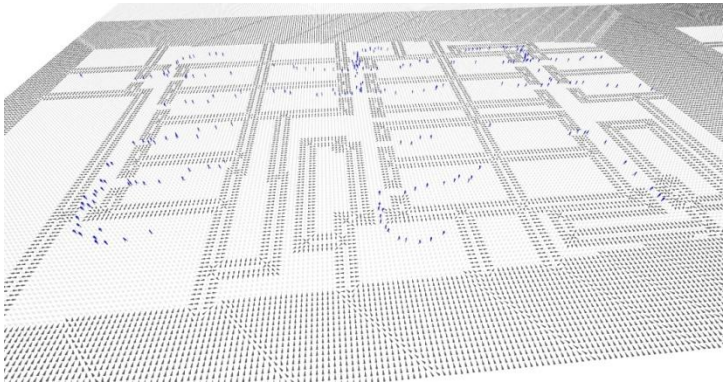
Agent Based Modelling (of multi agent systems)

- Agents are **individuals** with their own memory and perception
- Agents change their behaviour depending on **interactions** with neighbours
- Distance filters used to specify neighbours.
- Complex system level behaviour naturally **emerges** as a result of many interacting individuals



Agent Based modelling: applications

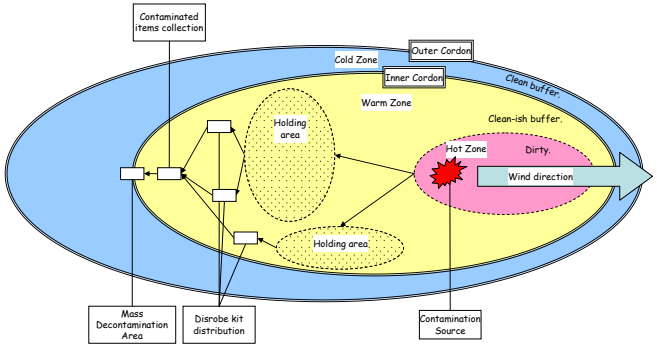
- Maritime

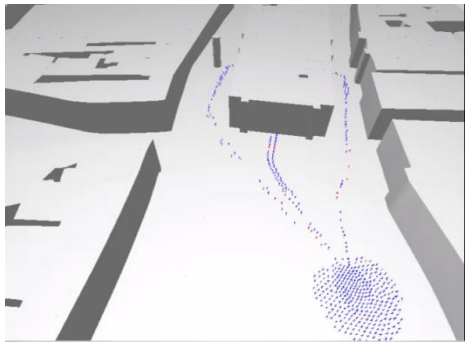


Live Traffic Modelling

- Civil: CBRN Incident

Aim: Modelling of large numbers of persons who must move towards and through decontamination structures as a results of an incident. All the configurations are run simultaneously, faster than real time and ranked to provide meaningful outputs to help in the decision making process.





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Mesh GPU Frameworks

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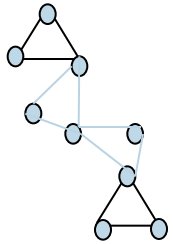
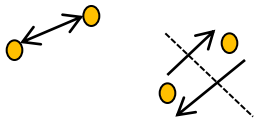
Our experience – returning to our Bread and Butter

- Need Kernels to be independent
  - Colour elements
    - Implies writes to points are independent and safe
    - Downside elements in a colour group might be small



  - Do twice as much work
    - In SPH this corresponds to every particle looking at all neighbours
    - Even though computation is symmetrical.



- Programmed both these schemes and have running on our own Hardware.
- OPLUS2 alternative
  - Keen to find time to contrast solutions and performances.

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Conclusions

- OPTIX performance made it easy for us to adopt
  - Vendor tuned to Hardware
- GPU Flame
  - Versatile, cost effective and allows real time simulation for planning and in the field live operation
- Like to stimulate people to think about SPH framework
  - combination FLAME and OPTIX
- Watching brief on OP2