Visualising Real Time Large Scale Micro-Simulation of Transport Networks

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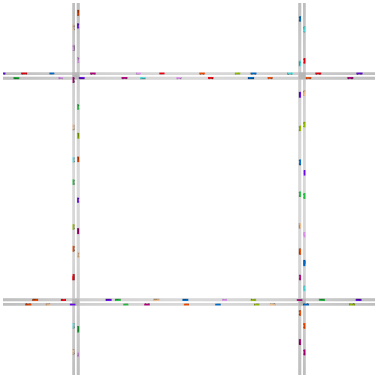
Overview

Introduction

Road Traffic Network Simulation

Visualisation & Performance

Conclusions



Introduction

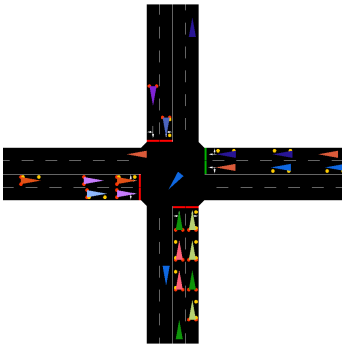
Why **Simulate** Transport Networks?

- Increasing traffic demand globally
  - UK projected increase between 2010 & 2040: [Dep15]
  - Up to 42% increase of car ownership
  - 19% to 55% growth in UK road traffic
- Poor utilisation of existing infrastructure
- Need for improved road simulation systems [NFN*15, UK 15]
- Used for planning & trialling road network changes
- Cheaper & less disruptive than real world trials

Rush hour traffic on the M6 motorway
(Mat Fascione - CC BY-SA 2.0)

Why **Visualise** Transport Network Simulations?

- Decision makers are often not modelling specialists [NFN*15]
- Visualisation increases accessibility of simulations
- Improves decision making



An example of traffic microsimulation visualisation (`sumo-gui`)

Our Aims

- Use the GPU for Agent Based Simulation of Road Network
  - Using FLAME GPU (Flexible Large Scale Agent Modelling Environment for the GPU)
  - Large-scale simulation of a road network
  - Car following behaviour on an artificial road network
- Demonstrate performance of road network simulation using FLAME GPU
  - Described in forthcoming paper “Road Network Simulation using FLAME GPU” [HRM15]
- **Develop custom visualisation for the simulation**
  - **Enable interactive simulation observation**
  - **Minimal impact on performance**

Road Traffic Network Simulation

Microsimulation, Agent Based Modelling & the GPU

Microsimulation & Agent Based Modelling (ABM)

- *Bottom up* simulations - *individual level* with *local interactions* [SYGD08]
- **ABM** provides a natural method for describing agents and behaviours
  - allows emergence of more complex behaviour
- Good for modelling congested transport networks

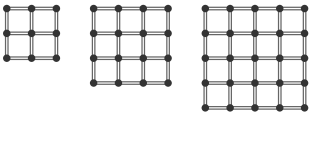
Why *General Purpose computing on Graphics Processing Units* (*GPGPU*)?

- Increased performance due to massively parallel architecture
- Microsimulation is *well suited* for GPGPU computing [SN09, WS12]
  - However it is **not** embarrassingly parallel

The Simulation

Artificial Road Network

- Scales consistently unlike real world networks
- Uniform grid of N^2 junctions & $4N(N-1)$ roads



Gipps' Car Following Model [Gip81]

- *Safety distance* car following model
- Considers driver and vehicle limitations
- Extensively used [CPM12]

FLAME GPU

- "*Template based simulation environment*" for agent based simulation on GPU architecture [Ric11]
- Provides a high level interface for describing agents, abstracting the CUDA programming model [Ric14]
- State-based agent representation
- Message-based communication

FLAME GPU

www.flamegpu.com
github.com/flamegpu

Visualisation & Performance

General Purpose computing on Graphics Processing Units

- Massively parallel architecture
- Perform same operation on many items of data (SIMD)
  - *Kernels* (GPU functions) execute same code in parallel using many threads
- Multiple memory spaces
  - Memory access pattern is important for performance
- Dedicated cards connected over PCI bus
  - *Host-Device* memory transfers are relatively slow

Nvidia Tesla C2075 (Source - CC0 1.0)
CC0 1.0

What is **Geometry Instancing**?

- Rendering multiple copies of the same geometry
- Vertex data is copied but modified to reduce repetition
  - Position
  - Colour
  - Animation state
- Data needs to be accessible on the GPU
  - OpenGL Buffers
- Requires fewer API calls [Khr08]

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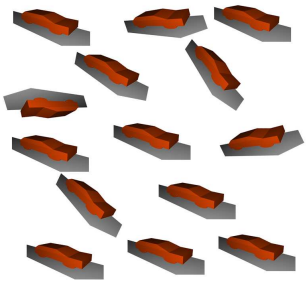
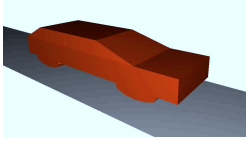
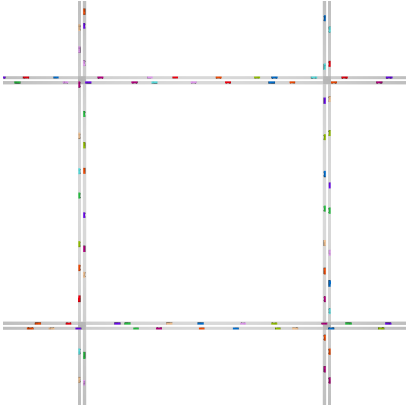


Interactive Visualisation

- Cross platform `C++`, `OpenGL` & `libSDL`[SDL]
- Mouse & Keyboard controls (*no-clip*)
- Simulation updated per frame (currently)
- Geometry loaded from wavefront (`.obj`) files
- Flat shading

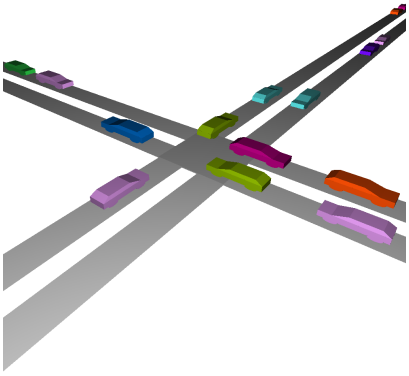




Overview of visualisation

Interactive Visualisation

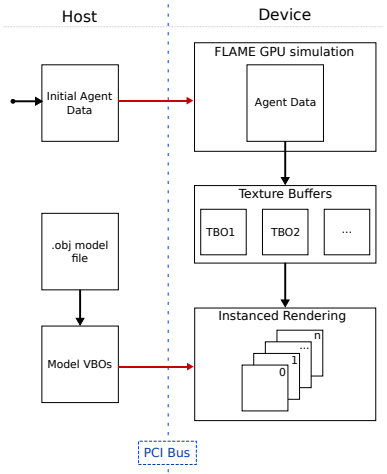
- *OpenGL Texture Buffers* populated with agent data via *CUDA OpenGL Interop* [Nvi15]
- *Geometry Instancing* [Khr] used to apply data to models
  - gvec4 texelFetch(gsamplerBuffer sampler, int P); [Khr14]
  - Reduced number of API calls [Khr08]
  - Minimises host-device memory transfers
- Fragment shader used to differentiate vehicles & apply lighting model



Nearby view of visualisation

How we use the GPU

- Road network stored in CUDA Constant Memory
  - Does not change during kernels
  - Maximum size to 64Kb currently -> CUDA Read-only Memory
- Geometry Instancing & CUDA interop
  - Avoids unnecessary host-device transfers
- FLAME GPU
  - One thread per agent
  - State-based representation minimises branching
  - Synchronisation points defined by message dependence
  - Transparently converts between AoS & SoA
  - Minimal transfer of data to host (CPU)



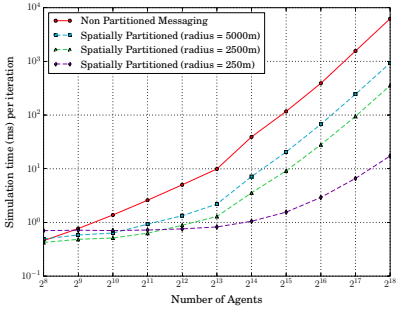
Instanced rendering memory transfers

Demonstration

Performance Impact

- Instanced visualisation has minimal performance impact
- $N = 8$, length $1000m$, 8192 vehicles & 1000 iterations
- NVIDIA GeForce GTX 660

Console	15079ms
Visualisation	16291ms
Run-time Increase	**1.08x**



Performance comparison between FLAME GPU message partitioning schemes

What Next?

Procedural Instancing

- Increase variation of instanced vehicles
- Procedurally generate data at runtime to modify instances
- Use simulation data such as vehicle length / type
- Applicable to many types of agents
  - Vehicles
  - Pedestrians
  - Environment

Other Future Work

- Analyse and visualise aggregate data using the GPU to increase accessibility
- Further performance optimisations for large populations

Conclusions

Conclusions

- Highlighted difficulties of large scale GPGPU microsimulation of transport networks
  - Expensive host-device memory transfers
  - Number of GPU draw calls
- Described & demonstrated techniques used to combat these issues
  - CUDA OpenGL Interoperability
  - Geometry Instancing
- Demonstrated minimal performance impact for an example visualisation

Thank You

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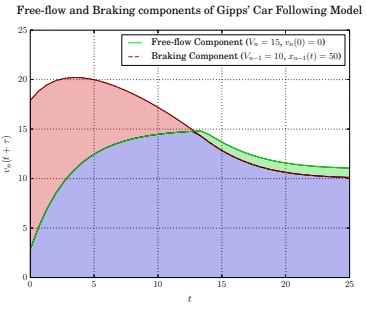
Additional Slides

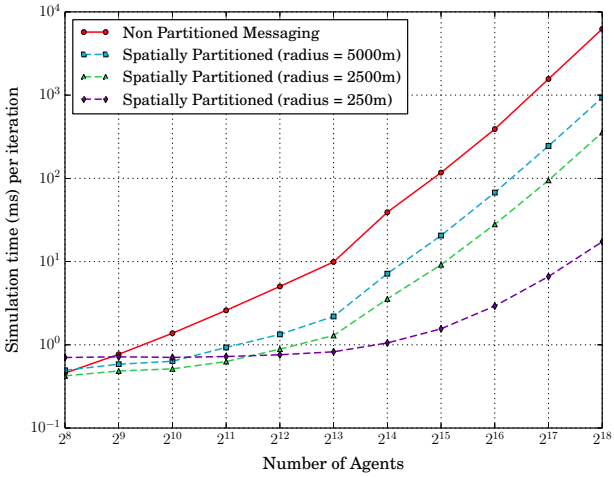
Gipps' Car Following Model Equation

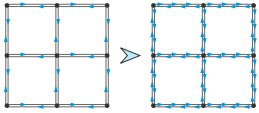
$$v_n(t+\tau) = \min\Big\{ v_n(t) + 2.5a_n\tau(1 - v_n(t)/V_n)(0.025 + v_n(t)/V_n)^{\frac{1}{2}},$$
$$b_n\tau + \sqrt{{b_n}^2\tau^2 - b_n[2[x_{n-1}(t) - s_{n-1} - x_n(t)] - v_n(t)\tau - v_{n-1}(t)^2/\hat{b}]} \Big\}$$

a_n	the maximum acceleration of vehicle n
b_n	the most severe braking that the vehicle n will undertake
s_n	the effective size of vehicle n, including a margin
V_n	the target speed of vehicle n
$x_n(t)$	the location of the front of vehicle n at time t
$v_n(t)$	the speed of vehicle n at time t
τ	constant reaction time for all vehicles
$\hat{b}$	estimate of leading vehicles most severe braking



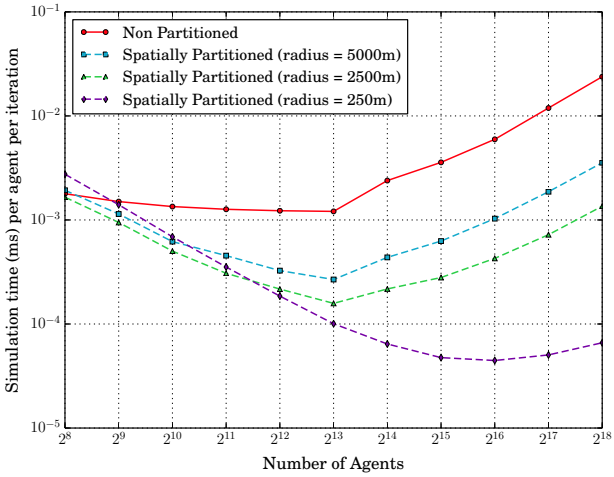
Results: Fixed Grid Network





- Spatially partitioned messaging outperforms non-partitioned messaging
- Smaller radii outperforms larger radii beyond overhead

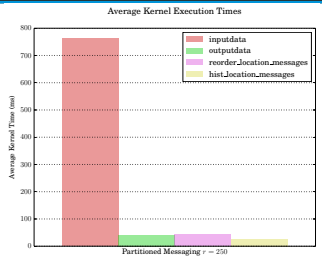
Results: Fixed Grid Network - Per Agent



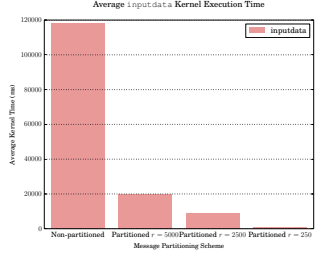
- Distinct gradient change at 2^{13} agents - **hardware utilisation** vs **larger message lists**
- Maximum message count

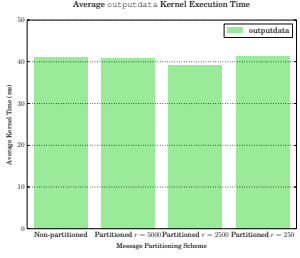
Non-partitioned	262144
Partitioned $r = 5000$	19662
Partitioned $r = 2500$	9720
Partitioned $r = 250$	309

Results: Fixed Grid Network - Kernel Profiling

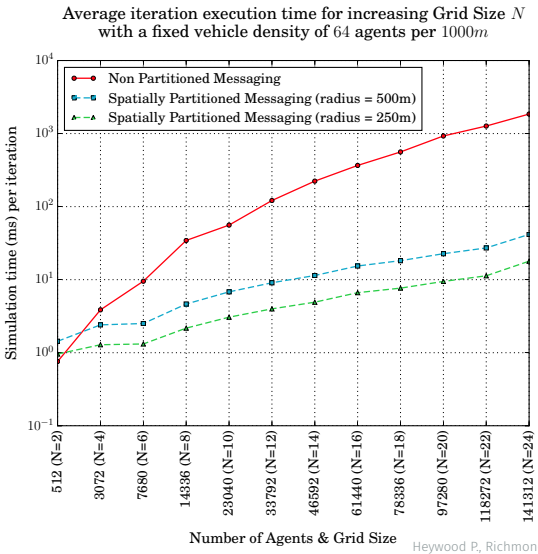


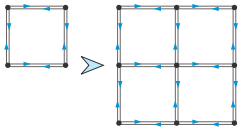
- Kernel times averaged over 10 iterations
- 32768 Agents
- `inputdata` kernel is dominant





Scaled Grid Network





- Spatially partitioned messaging outperforms non-partitioned beyond overhead
- Up to 103x performance increase for spatial partitioning than non-partitioned

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