PAAMS International Conference

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# Overcoming Computational Complexity: A Scalable Agent-Based Model of Traffic Activity using FLAME-GPU

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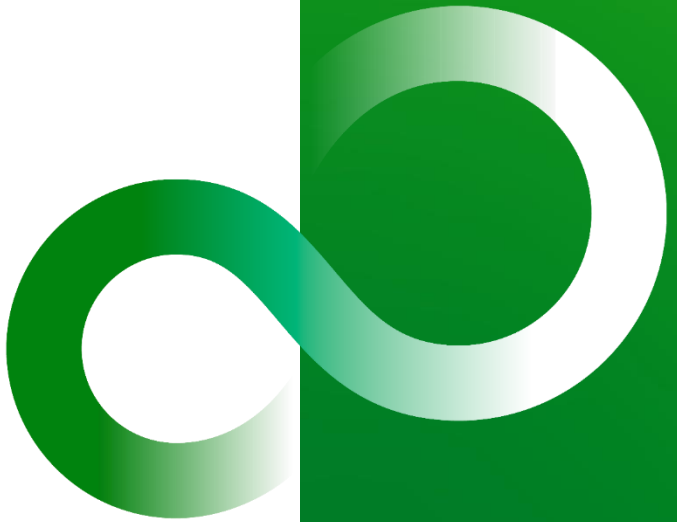

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# FLAME GPU software for agent-based simulations

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FLAME GPU provides a programming suite for GPU-level computing performance and parallelisation algorithms, while focussing on an ABM-centred framework that abstracts from hardware-level programming tasks. FLAME-GPU is scalable and uses a template style programming paradigm. The environment puts emphasis on the model and the modeller, rather than on code implementation.

**Features**

- Domain-independent
- Describe agents as a form of communicating machines
- Describe state transition functions (agent functions) using simple API
- Describe communication as message dependencies between agent functions
  - Exposes high levels of parallelism for small (ensembles) or complex (concurrency) models
  - Support for very large simulations and high throughput parameter exploration
- Abstract the underlying implementation
  - Let modellers write models not parallel CUDA programs
- Framework developed by Prof. Paul Richmond's team at the University of Sheffield
- http://www.flamegpu.com

# FLAME-GPU traffic simulation core principles

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- The fundamentals of our vehicle behaviour model modifies the Krauss car-following paradigm, also adopted in Simulation of Urban Mobility's (SUMO) simulation mechanics. This adaptation is encapsulated by the following formula:

$$
\begin{aligned}
v_{safe}(t) &= v_l(t) + \frac{g(t) - g_{des}(t)}{\tau_b + \tau}, \\
v_{des}(t) &= \min[v_{max}, v(t) + a(v)\Delta t, v_{safe}], \\
v(t + \Delta t) &= \max[0, v_{des}(t) - \eta], \\
x(t + \Delta t) &= x(t) + v\Delta t,
\end{aligned}
$$

- The simulation's computational framework, detailed in the above equation, along with rules for lane changes, intersection crossings, and agent state updates, leverages FLAME-GPU's global messaging pool for efficient agent communication. This architecture ensures scalability by dynamically allocating thread blocks to GPUs' Streaming Multiprocessors (SMs), adapting to the hardware's thread capacity limitations.

# High-level flowchart of Traffic Simulation in FLAME-GPU

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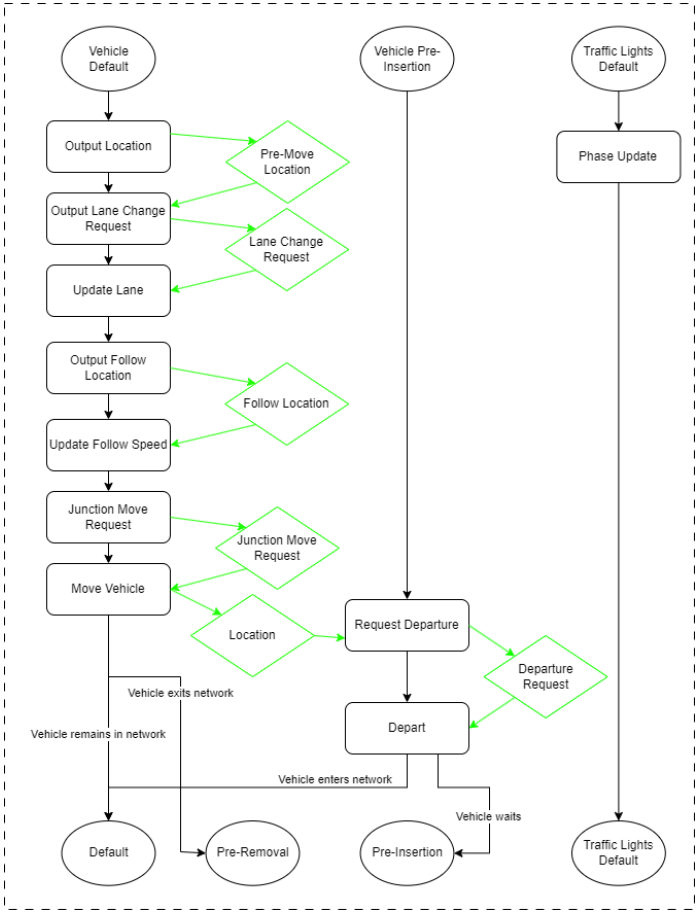

# Experiment setup

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**Objective**:

- Assess computational efficacy of a proposed solution in simulating large, agent-based vehicular traffic models.
- Utilise the real-time factor (RTF) for evaluation (RTF > 1 indicates simulation faster than real-time).

**Benchmarking**:

- Compare model performance against SUMO (Simulation of Urban MObility) platform.
- SUMO widely used with ~11,956 literature references.
- Isle of Wight's transport network chosen for real-world complexity.
- Real-world networks preferred over synthetic for demonstrating scalability and versatility.

**Simulation Setup**:

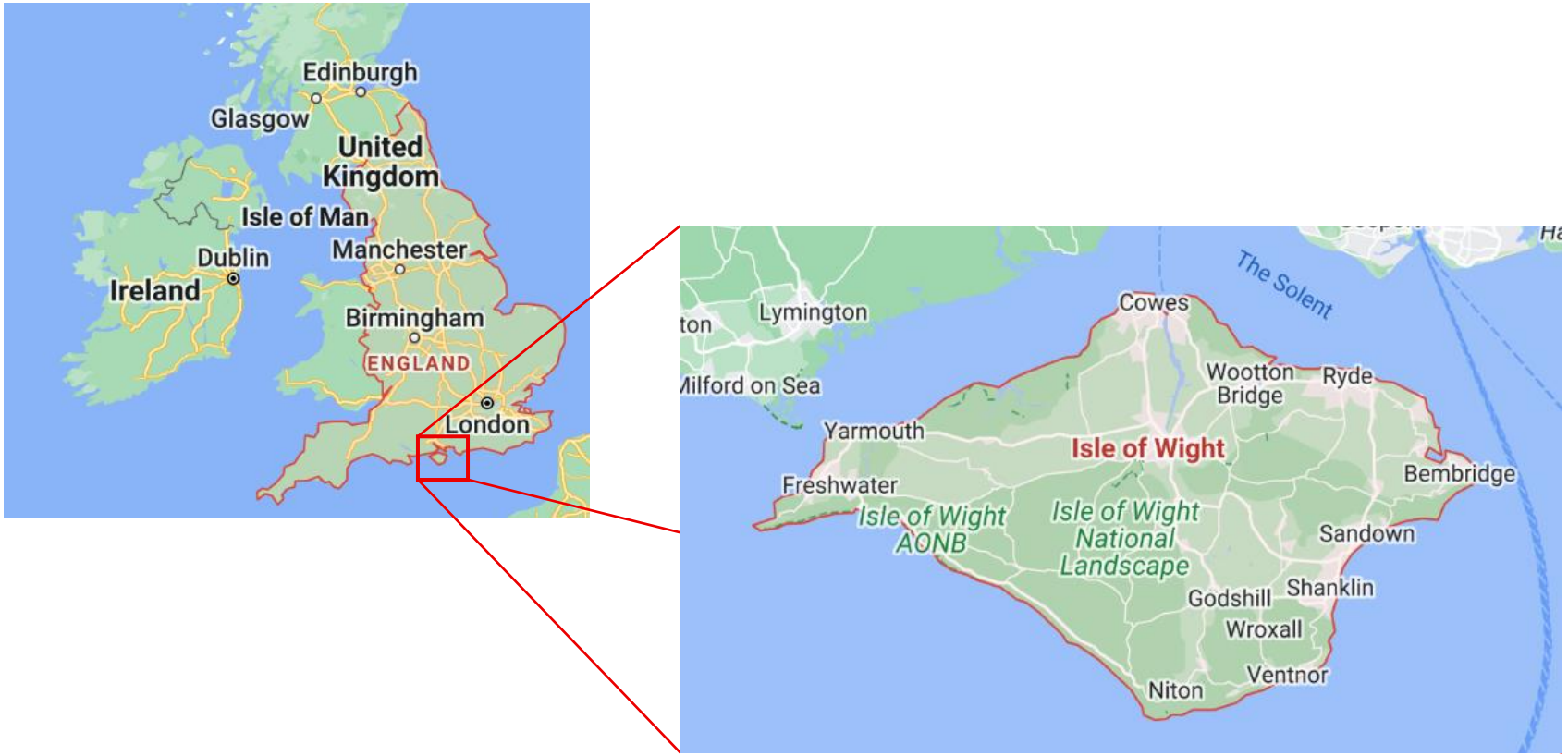
- Used SUMO's **randomTrips** and **duarouter** utilities.
- Vehicle density varied from 60 to 600 vehicles/hour/km.
- Density increased in steps of 60 vehicles for the first 360 seconds.
- Simulations executed three times each, from timestep 0 to 3600 seconds in simulation time (1 hour).

**Test Environment**:

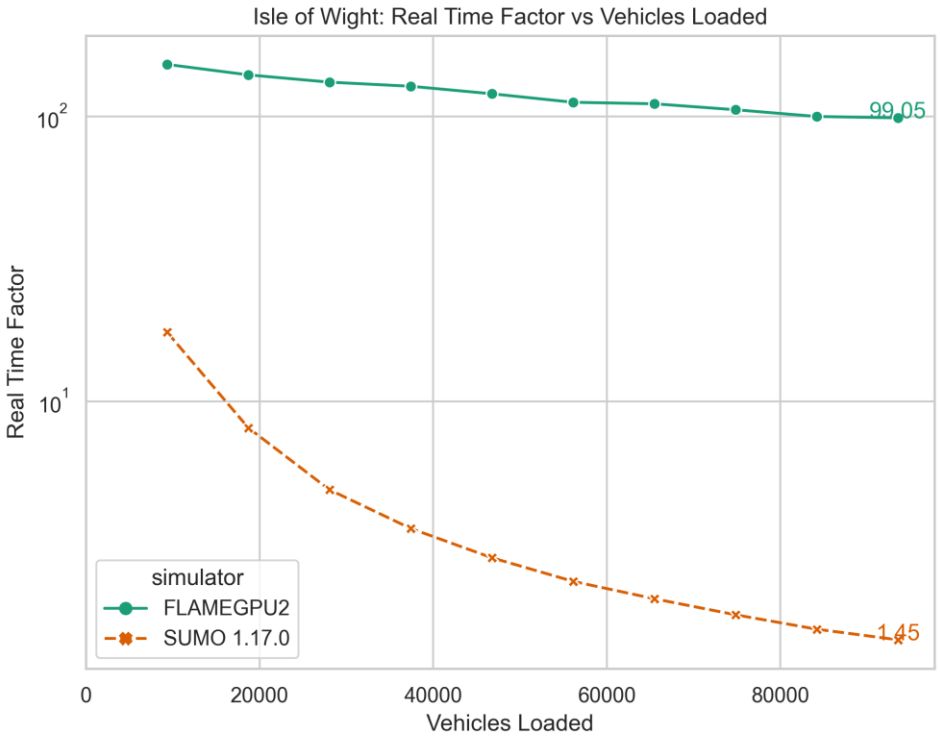
**Hardware**:

- Workstation: Intel Core i7-5930K CPU, NVIDIA GeForce RTX 3090 (24 GiB) GPU, 64 GB RAM.

# Isle of Wight study area



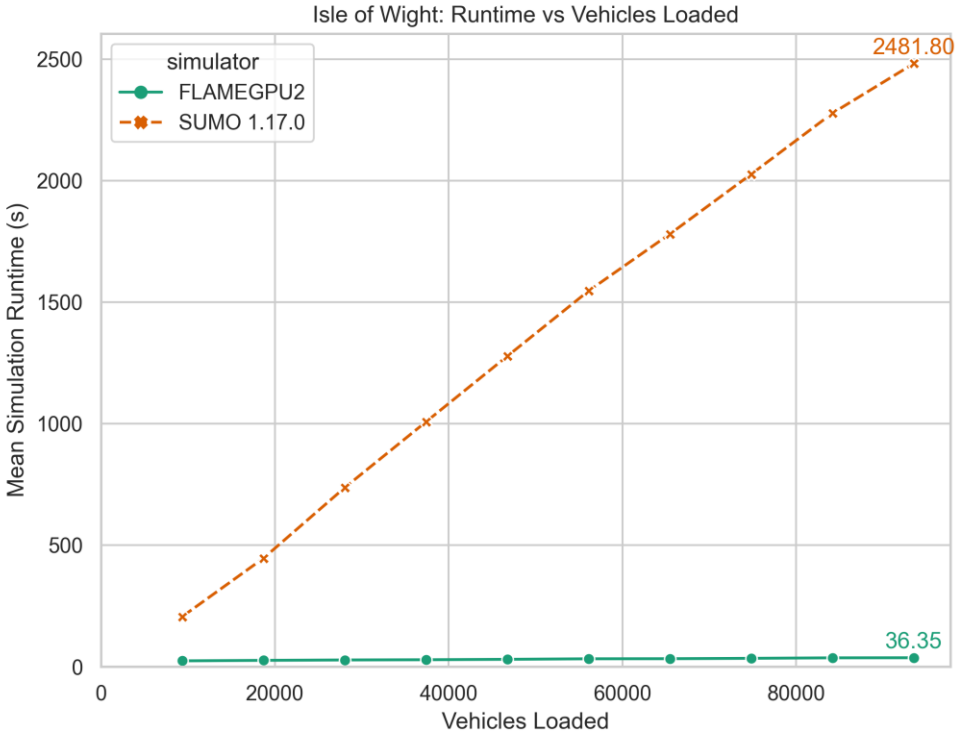
# Experiment results I




*Real-time factor compared to the number of vehicles loaded.*

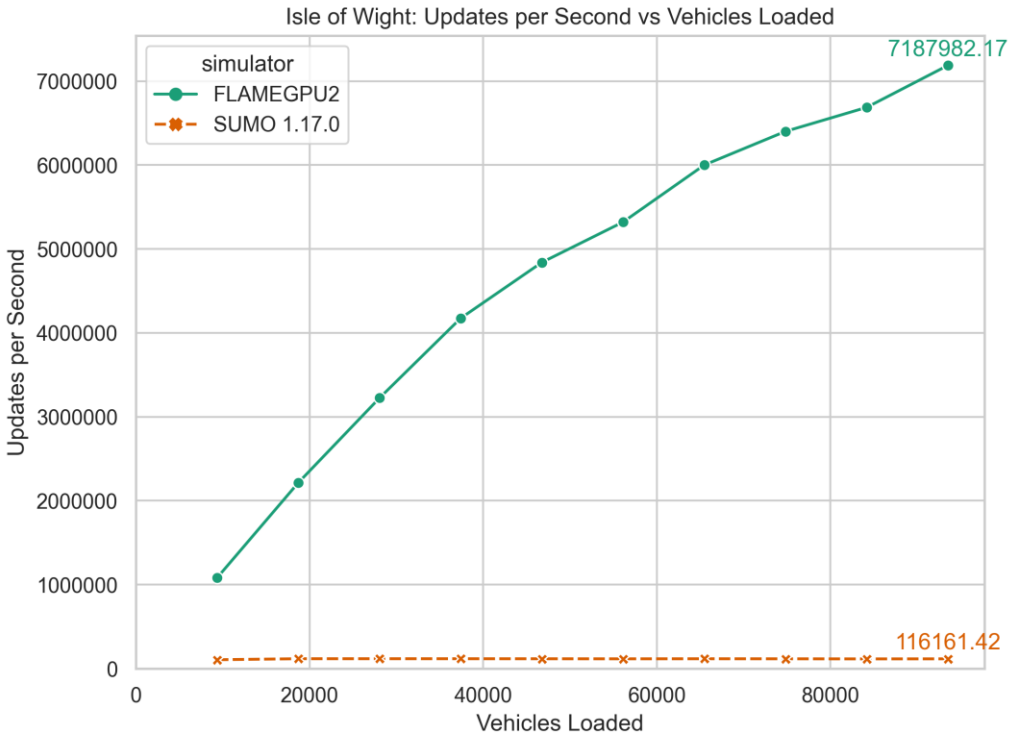
On average, FLAME-GPU was **68x** faster than SUMO

# Experiment results II




*Average simulation run-time in seconds compared to the number of vehicles loaded.*

# Experiment results III




*Simulation state-change per second compared to the number of vehicles loaded.*

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# Thank you