

Large Scale Pattern of Life Simulation for Real-Time Applications

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Overview

- > Overview
- > Why pattern of life?
- Related work
- Use cases and architecture
- Population generation and crowd simulation
- Scalability platform
- > Visualization
- > Conclusion





Why Pattern of Life?

- Develop urban warfighting capability
 - JFCOM Urban Resolve (2003-2007)
 - Massively distributed urban simulation
 - 1M buildings, 120K civilians, 1100 enemy combatants, 250 vehicles and sensors controlled by human-in-the-loop operators
- Study emergence of riots (Pires & Crooks)
 - Kenyan election riots
 - Agent-based population model
 - Incorporating physical, emotional, cognitive, social elements

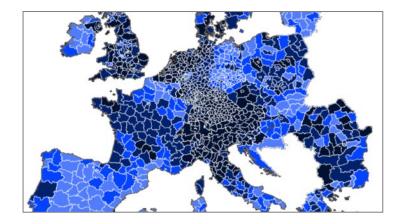


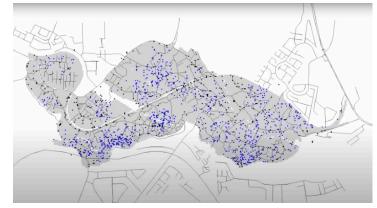




Related Work

> 3 broad categories of pattern of life







Non real-time analytic

Real-time, low update rate Real-time, 3D interactive

Migration studies

Urban planning

Video games







Demonstrator Use Cases

Civil

Civil resilience scenario involving a cyberattack on the London power network causing a disruption in the patterns of life



Military

Military course of action with ethnically motivated paramilitary operations and civil unrest in the Baltics

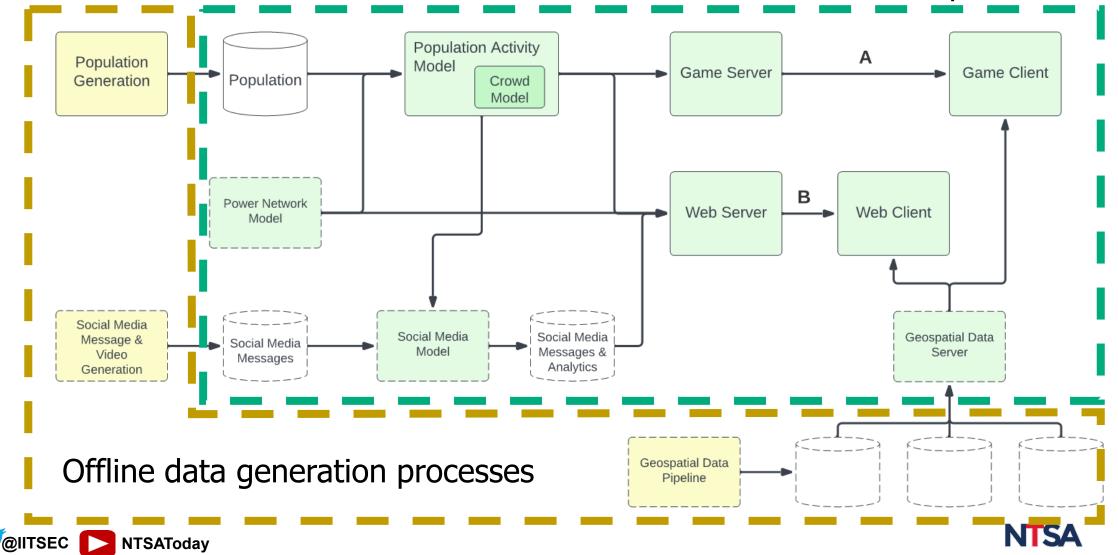






Civil Demonstrator Architecture

Runtime simulation processes



Population Generation

> Multiple existing population generation models available, methodology is similar

Population generation, points of interest, static associations (home↔ work, home↔ school)

Census data, location databases, etc

	INPUT	PROCESS	OU	TPUT		Runtime
ata,	Census Data • MSOA extents	Generate population For each MSOA: • Generate individuals in the correct proportion of age and sex	Households Household ID Type X location	Schools School ID Area code Type		databases
s,	For each MSOA: • Number of individuals of a specific age & sex • Number of households and type	Generate businesses For each MSOA: • Generate businesses in the correct proportion of employee size. Randomly assign size within each business size range	Y location Workplaces Workplace ID No. of employees Area code Empl. assigned X location Y location Individuals Individual ID	X location Y location Assigned Retail Retail ID Area code Type X location Y location Assigned		used at
	Gazetteer Data UK business counts – number of businesses & employee count (range, not exact) London addresses – location and type	Randomly assign a workplace address for each business. A single workplace can host multiple businesses (e.g. office tower) Generate households For each MSOA: Generate the correct number of households of each household type Randomly select a residential address for each household. A single address can host multiple households (e.g.apartment block)				initialization
						and by
		Generate other points of interest For each MSOA: • Generate retail establishments from address and type • Generate schools from address and type	Sex Age Area code Household ID	Consumers Individual ID Area code Retail ID	J	activity model
		Populate households For each MSOA: For each household: • Minimally satisfy household type (e.g.allocate 2 adults to couple with	Workplace ID			
SAToday		dependent children) Repeat for each household: • Allocate remaining individuals consistent with household type (e.g.add 2 children under 18 to the above household)				



Population Activity Model

- \succ Pattern of life centers around home \leftrightarrow work commuting on preset schedules
 - School, shopping, leisure activities not implemented yet
- Short distance commute = walking, long distance = public transit
 - Vehicle activity not modeled; commuting by car not implemented
- > Comparison with Silverman's pattern of life characteristics:

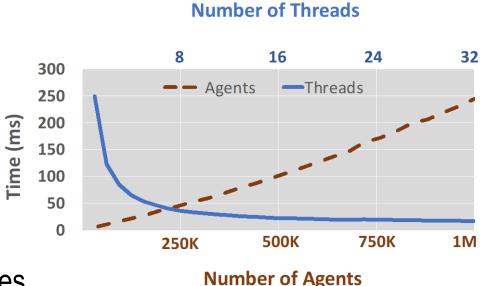
	Low	Medium	High
Activities of Daily Life (ADLs)	Pre-scripted ADLs following clock Navigates on own to destinations, avoiding obstacles.	Simple rules to handle a few common ADL issues in 1 area (e.g., errands, OR combat, OR crowds)	Dynamically (re)sets priorities and (re)plans ADLs due to shifts in internal needs and external events
Nets/Social Skills	Reacts to nearest neighbors on a landscape	Connects to agents across a single-layer network	Has relationships and connections across multi-layer nets
Cognition	Can express values & reactions passed into it from a "god" source	Limited rules to react to a domain (single-layer net)	Adaptively appraises world against its own values.





Crowd Simulation

- > Use cases required large, dense crowds at real-time interactive frame rates
- > Many simplifying approaches broke down under our requirements:
 - Up to 100K simultaneous pedestrians in an urban square, multiple simultaneous viewpoints
 - Accurate pedestrian evacuation dynamics
 - Data and update rates sufficient to smoothly drive 3D animated characters
- > Dedicated, high performance crowd simulation
 - 10 Hz updates, validated dynamics
 - Highly optimized Navmesh
 - Near ideal performance scaling with # of agents, cores









Crowd Simulation

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London

Westminste

The

cane Wa

ames

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Birc

lames's

emple

South Ban

Temple

Waterloo

lambeth

Waterloo

Bridge

lacktu

Blackfriars

Blackfriars

Southwark

Banksid

Elephant

Bond Street

drk Corne

Buckingham

Palace Garden

The Mound

London

Hyde

Hyde Park

Cornel

Belgravia

100K civilians converging on Trafalgar Square Bridge

Embankment



Borough

Borough

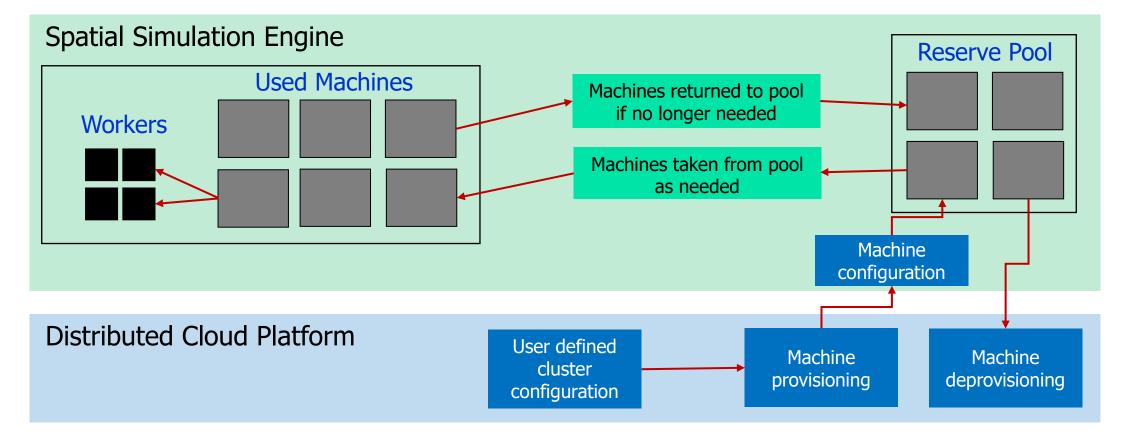
Stre

Railw

Bride

Scalability Platform – Architecture

- > Scaling to millions of agents requires scaling across virtual infrastructure
- > Scalability platform provides machine scaling and simulation distribution/partitioning







Scalability Platform – Spatial Partitioning

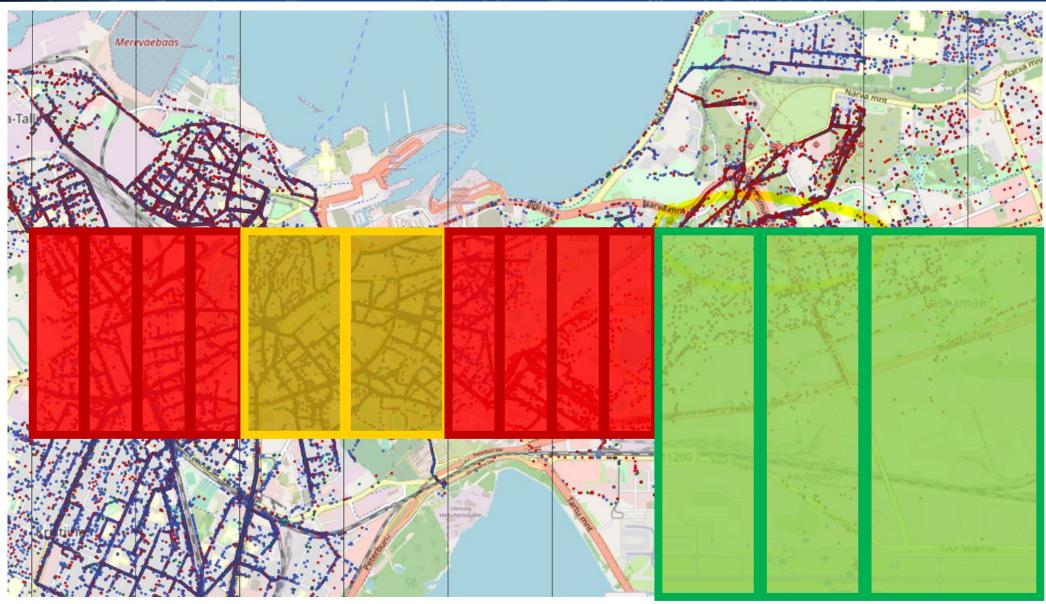
Aether Engine partitions a simulation into regions







Spatial Partitioning – Tallinn Area







Visualization – "God's Eye View"

- > "God's Eye View" presents unique challenges for large scale simulations
- > Smart filtering (right data, right place) plus highly optimized network protocols







Visualization – Game Engine



Conclusions

- > Large scale, real-time, interactive pattern of life can be achieved
 - Modern frameworks, simulations, game engines and the cloud make it possible
 - At a fraction of the cost and complexity of pioneering efforts like Urban Resolve
- > Expect to modify some or all components to meet your use case
 - Crowd simulation was modified to be spatially distributable
 - Game engine networking and rendering pipeline were replaced and/or modified
 - God's Eye View required custom networking/filtering not provided by the scalability framework
- System integration is the majority of the effort when assembling these commercial components
- > Rapid advancements are easing the path to scalability



