Large-scale agent-based social simulation for traffic and pedestrian in a city

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Agenda

- Introduction of agent-based social simulation
- Large-scale agent simulation framework
- IBM Mega Traffic Simulator
- Pedestrian Simulation for shopping mall and city

Introduction of Agent-based Simulation

New Paradigm for Social Science and Computing

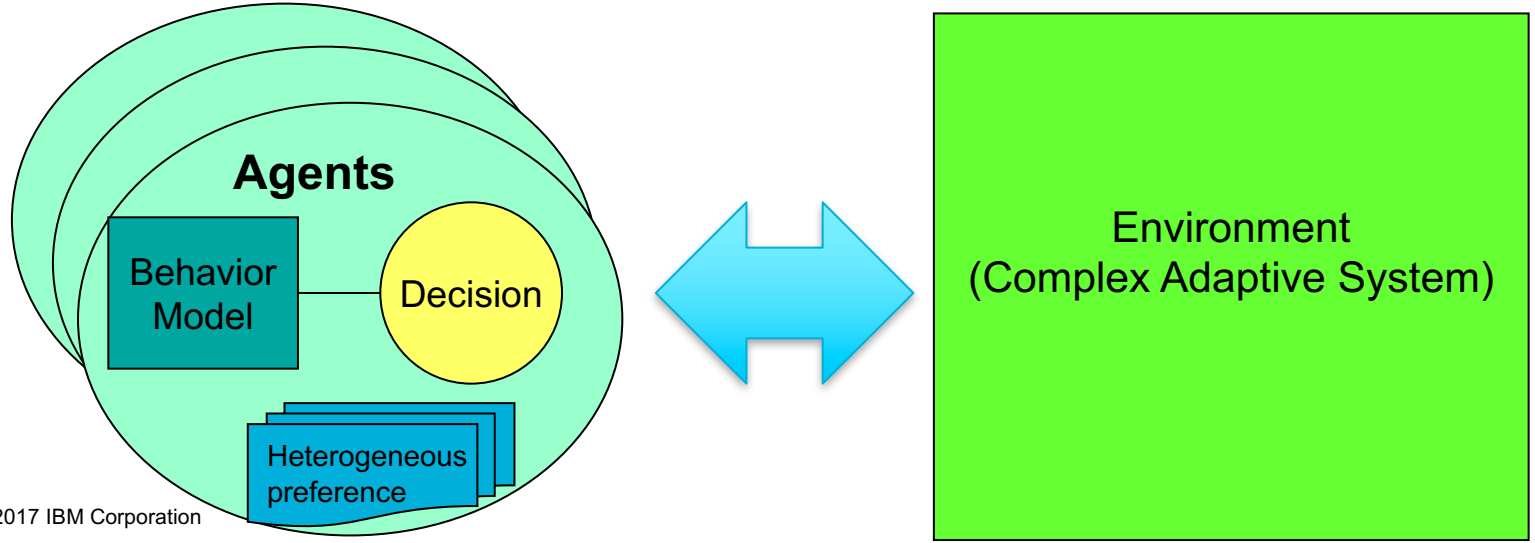
- Background
  - Emerging of complex dynamic social behavior
    - Market crisis
    - Global environment
    - Social interaction
  - Beyond the limit of traditional social science with IT and Physics
    - Single rational agent → Heterogeneous agents with bounded rationality
    - Static equilibrium → Dynamic interaction among agents and environment

- Objectives
  - Understand and reproduce complex social behavior
  - Provide effective design and decision support tools for city planner

- Examples:
  - Artificial Market
  - Traffic Simulation
  - Evacuation Simulation

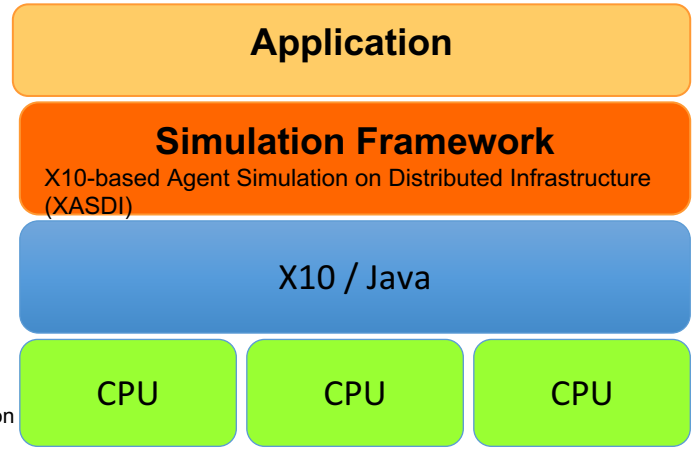
Interacting Agents in Complex Adaptive System

- To investigate the complex behavior of social system, we consider heterogeneous agents that determine the action based on the interactions with other agents and environment
- Dynamic interaction and feedback among microscopic agents and macroscopic environment generate the micro-macro loop



X10-based Agent Simulation on Distributed Infrastructure (XASDI)

- XASDI is large-scale agent-based social simulation framework with
  - Enormous number (billions) of agents to represent citizens in cities or countries
  - Highly parallel and distributed simulation with X10 platform for post-Peta Scale machines
  - Easy-to-use API with Java that is familiar to application programmer of social simulations
- XASDI is published as an open source software under the Eclipse Public License (EPL) https://github.com/x10-lang/xasdi



Social Simulation (Traffic, Evacuation, etc)

Large-scale agent environment

Programming with X10 and Java

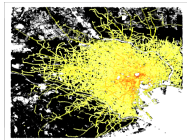
Distributed Infrastructure (HPC, Cloud)

Traffic and Pedestrian in a city

- It is important to estimate various human activities in a city for government and business to establish smarter cities with high value and low pain
  - Increase citizen satisfaction (service level) and economic activities
  - Reduce congestion (traffic jam) and risk due to disaster
- Human activities with enormous elements and interactions are too complicated for simple analysis or equations
- We developed traffic and pedestrian simulator in a city to observe individual behavior and support decision makers with what-if analysis

IBM Mega Traffic Simulator (Megaffic)

Map Data



Probe Car Data

Traffic Demands Data

GIS point data

Analysis and Data Preparation

- •Link Cost Prediction
- •Driver Behavior Modeling
- •Traffic Demands Estimation
- •Geo coding
- •OD Table generation

Road Transition cost

Driver Behavior Model

Trip Definition

Road Network Definition

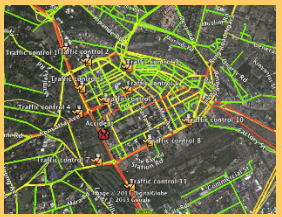
IBM Mega Traffic Simulator

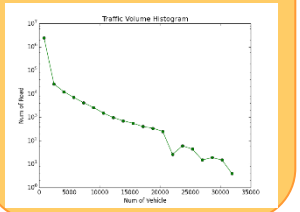
Simulation Base

X10-based Agent Simulation on Distributed Infrastructure (XASDI)

Scalable simulation engine for supporting parallel execution environment

Visualization





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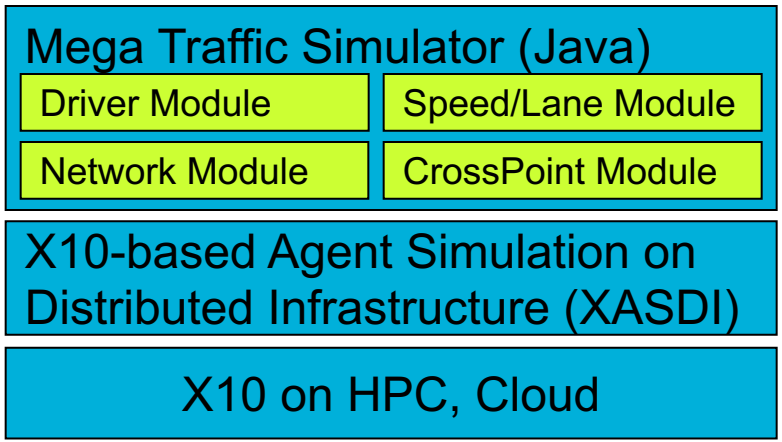
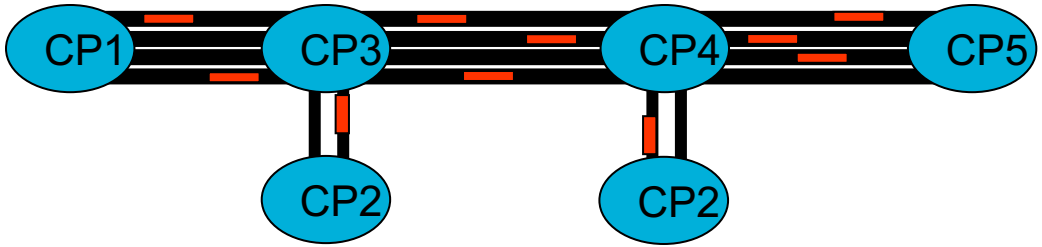
Modules of Traffic Simulator

- Megaffic is developed on the X10-based framework XASDI that can be executed on distributed HPC environment
- Road network consists of cross points (CPs) and road links
- In Megaffic, CPs execute each time step (1 sec) of traffic simulation in parallel
- Vehicle on road is defined as an agent that has driver model including speed-changing module and lane-changing module





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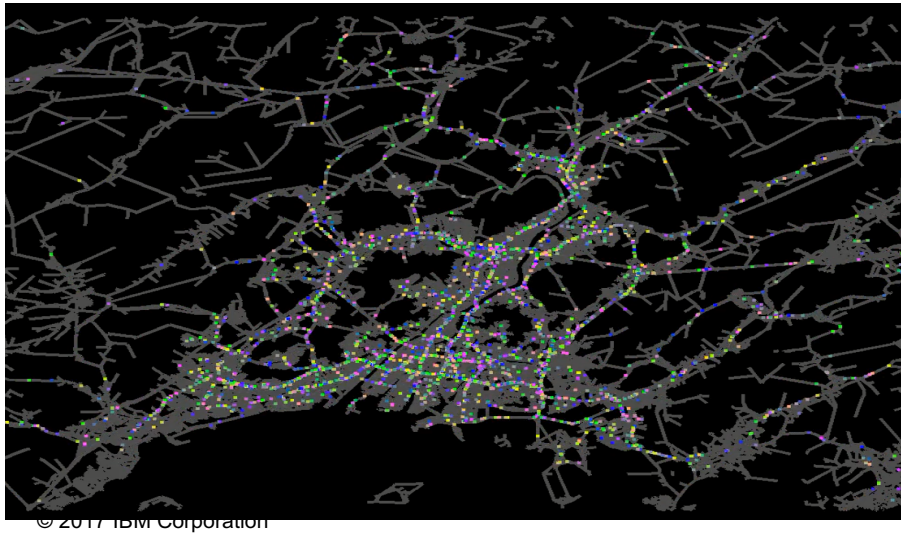
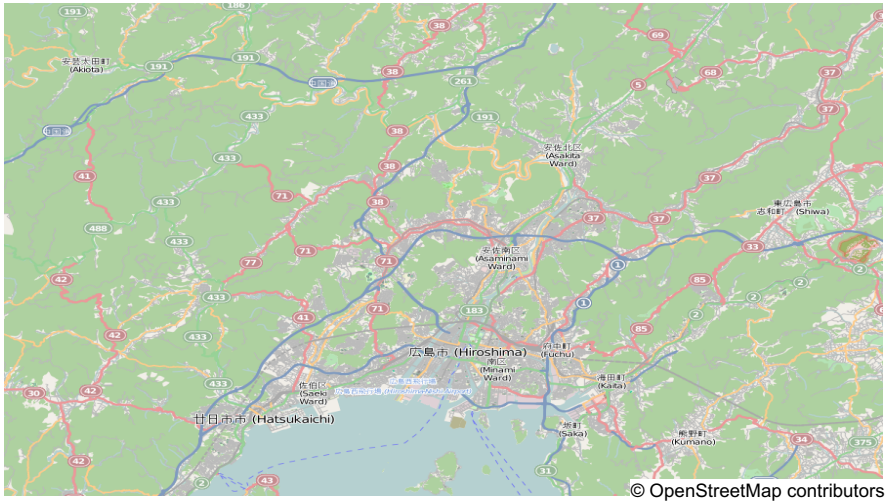
Demonstration Experiments of Traffic Flow at Hiroshima City

- We performed demonstration experiments with Hiroshima city
- Simulation area is whole Hiroshima city
  - 40,619 cross points and 121,543 roads
- Simulation Screenshot





What-If Simulations at Hiroshima City

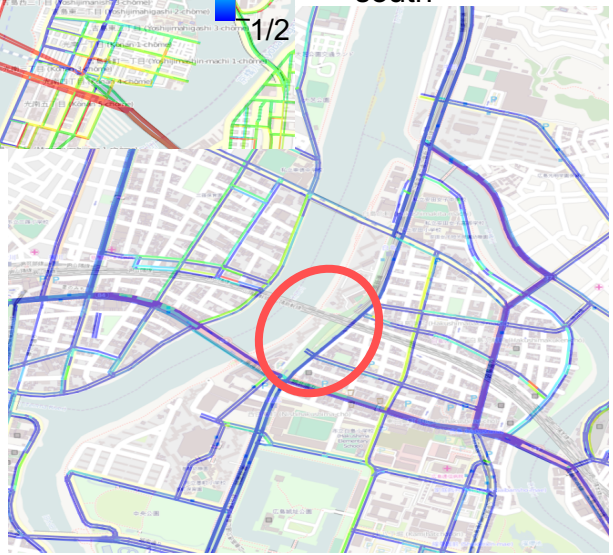
Traffic changes caused by the opening of new highway (Minami Road)

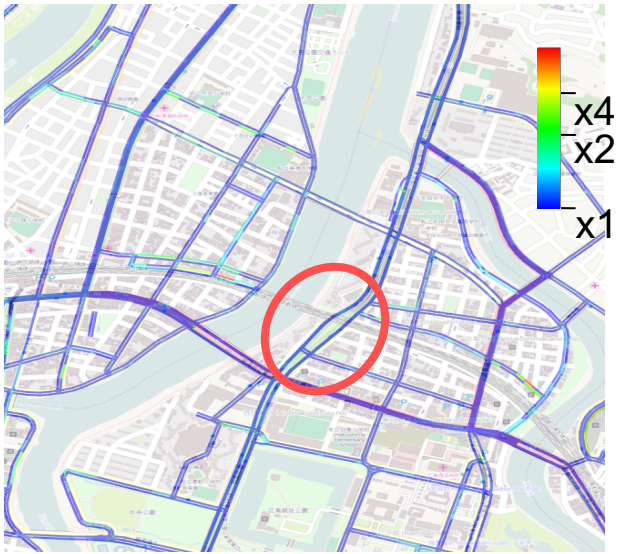
Traffic changes caused by traffic restriction with two scenarios

Gion Shin-Do has both 3 lanes for north and south. 3 lanes for north are closed.

1. Use remaining 3 lanes only for south

2. Divide remaining lanes into 1 lane for north and 1 lane for south

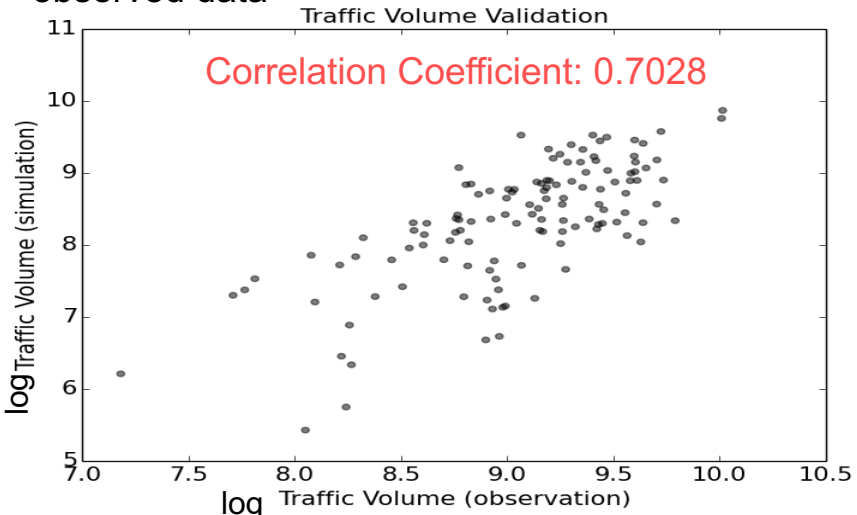


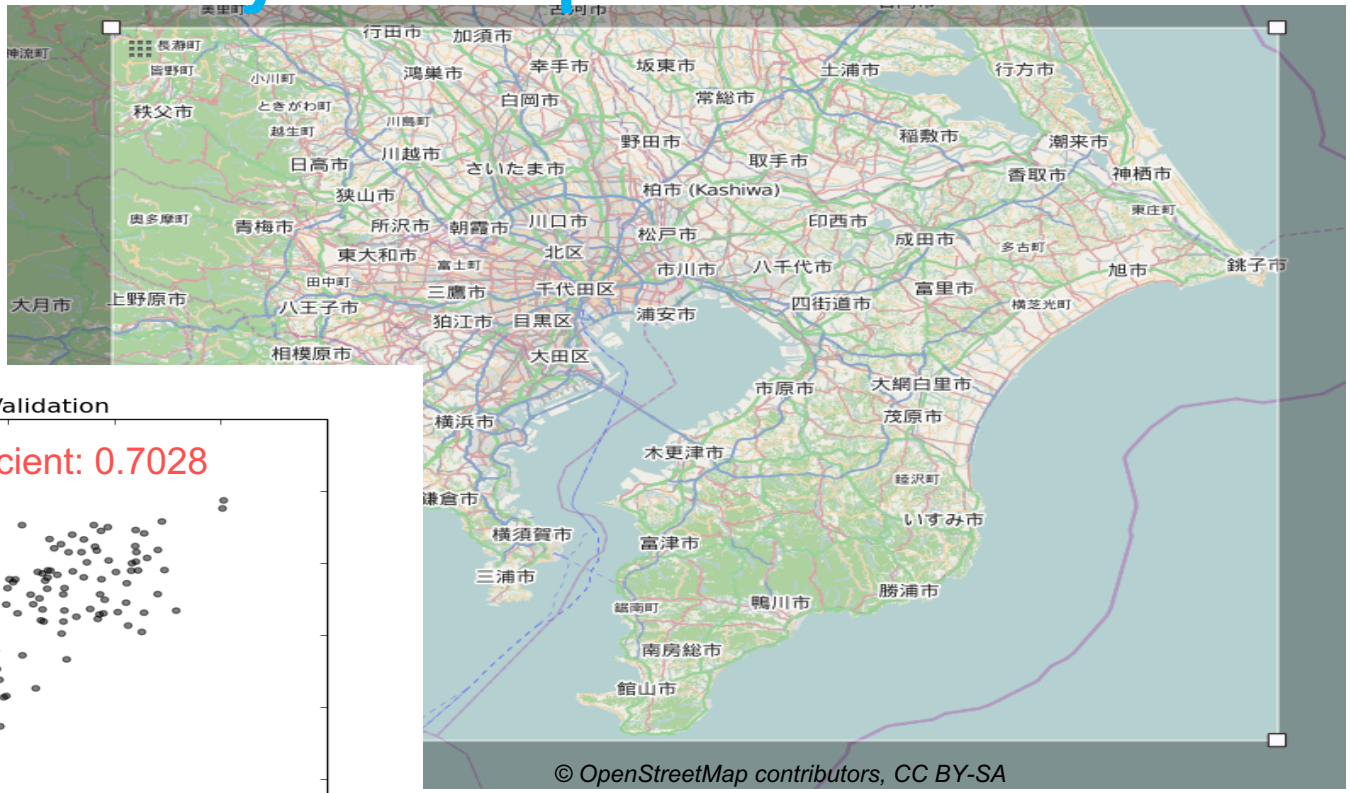


Validation with Tokyo metropolitan traffic flow

Road network extracted from Open Street Map
891,335 Cross points
2,465,767 Roads

Comparison of logarithmic traffic volume between simulation results and observed data





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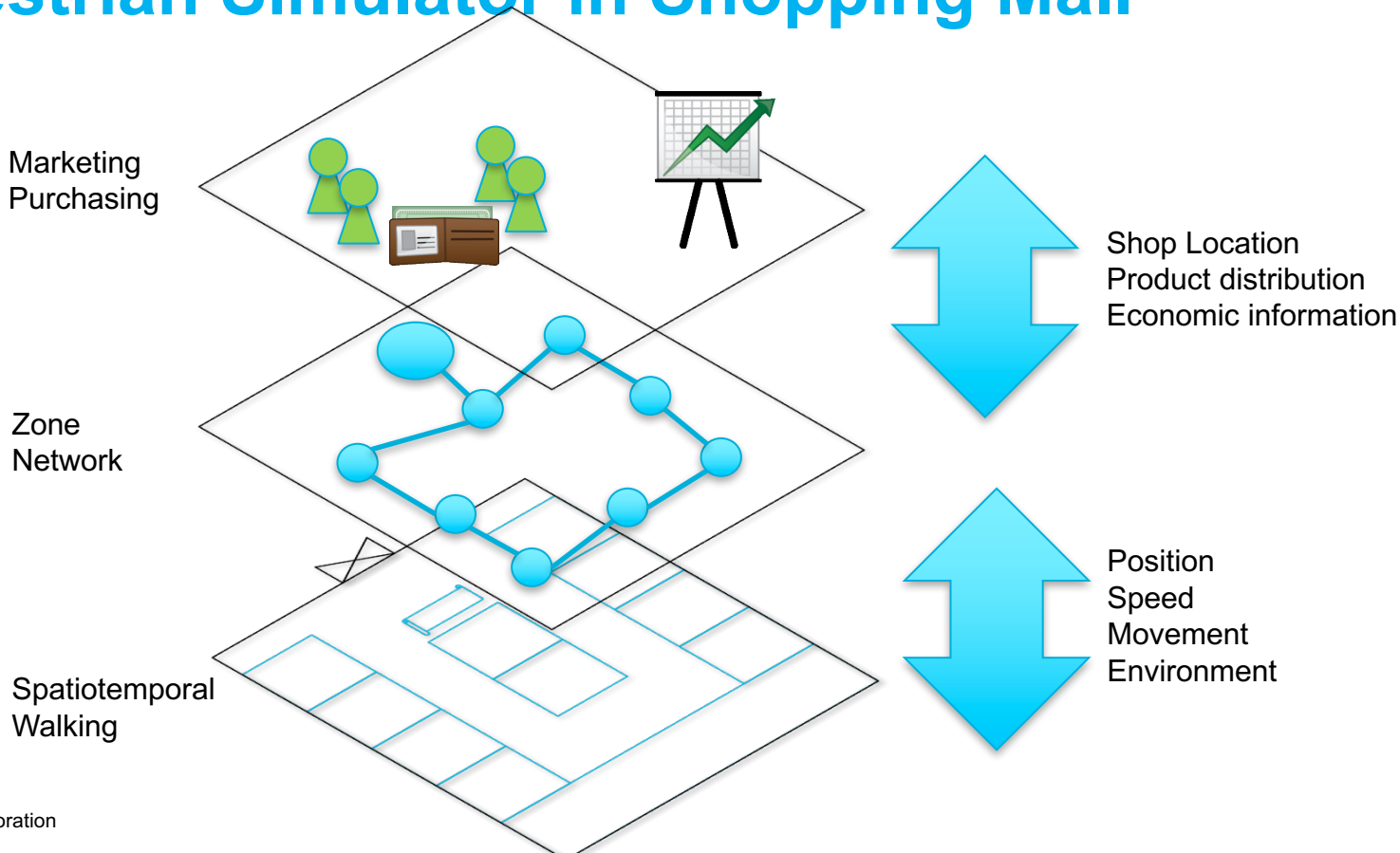
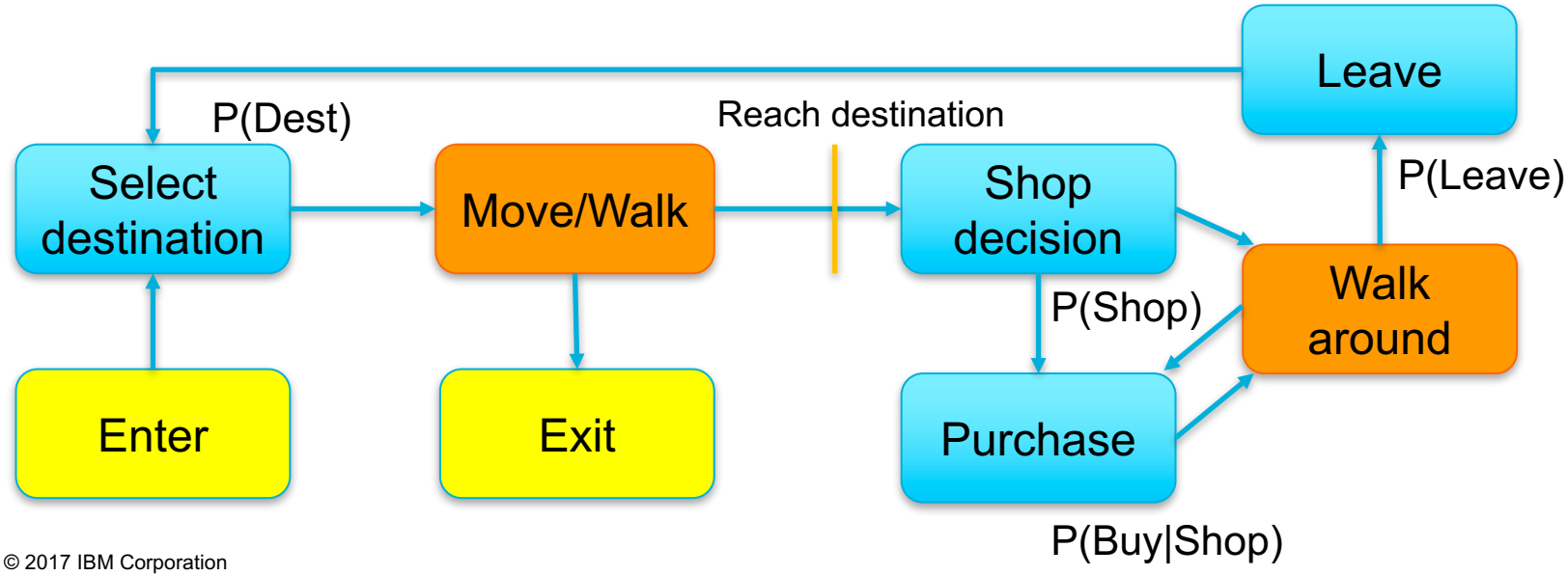
Pedestrian Simulator in Shopping Mall



Consumer's decision and action

- At each timestep, consumer agents update attraction value for products and zones, and perform following decision making and action

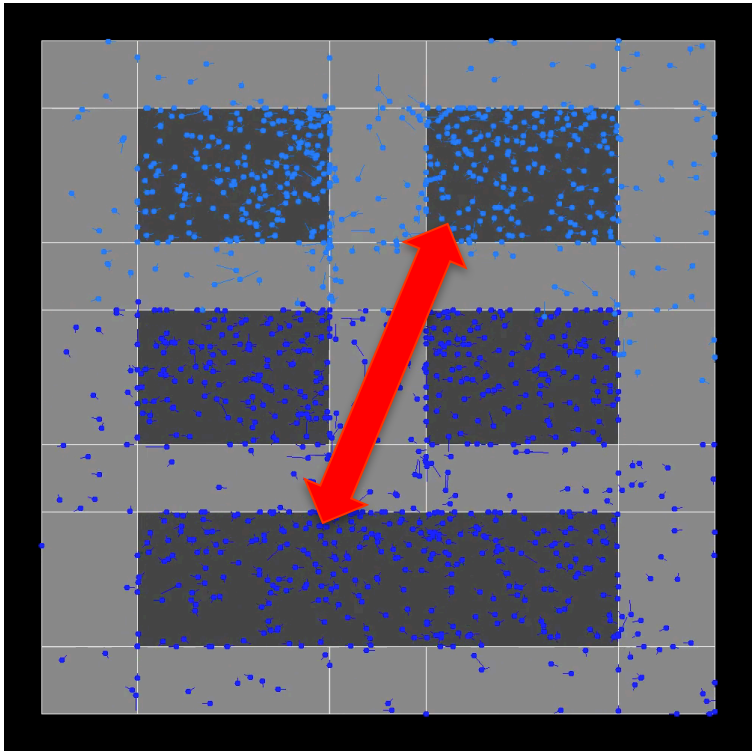


What-if simulation experiments in simple map

What-if simulation to exchange the location of two shops (small and large) in simple map with 5 shops

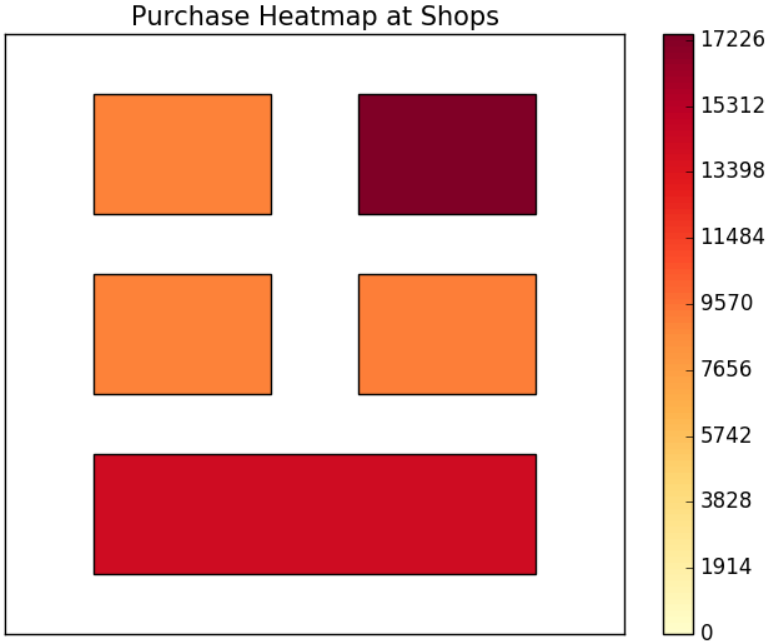
one shop has 20 products and others have 10 products that make difference in zone attraction

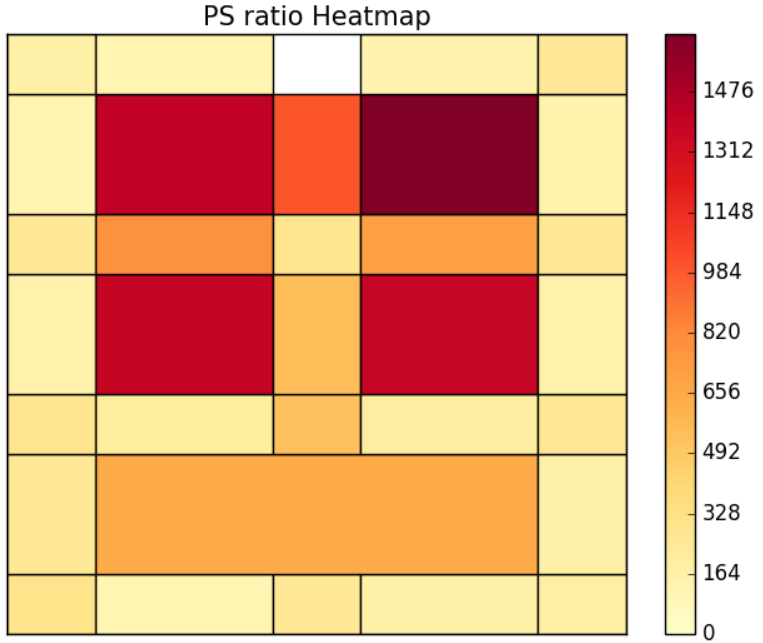
3600 consumer agents enter into the shopping mall during the 3600 seconds of simulation time



Case 1: many products in the small shop

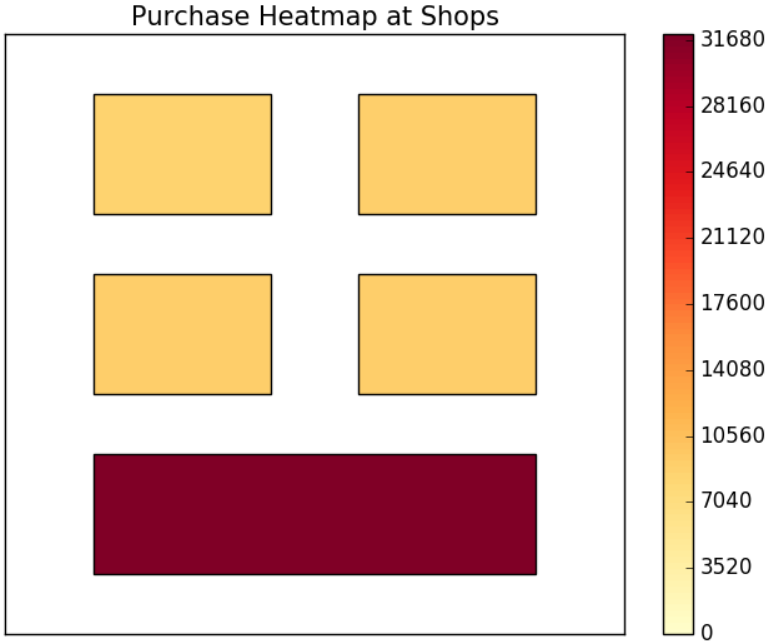
- Total purchase is restricted: 58,960
- The small shop attracts many consumer and heavy congestion occurs

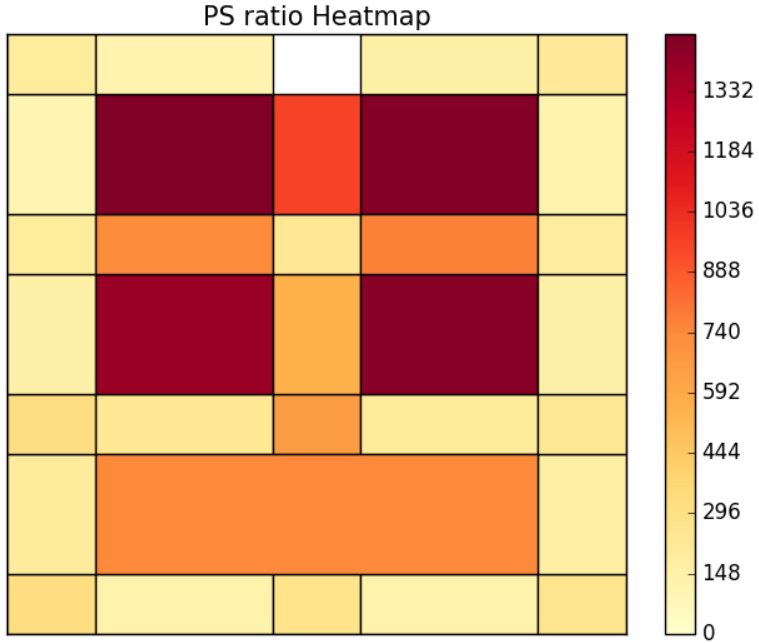




Case 2: many products in the large shop

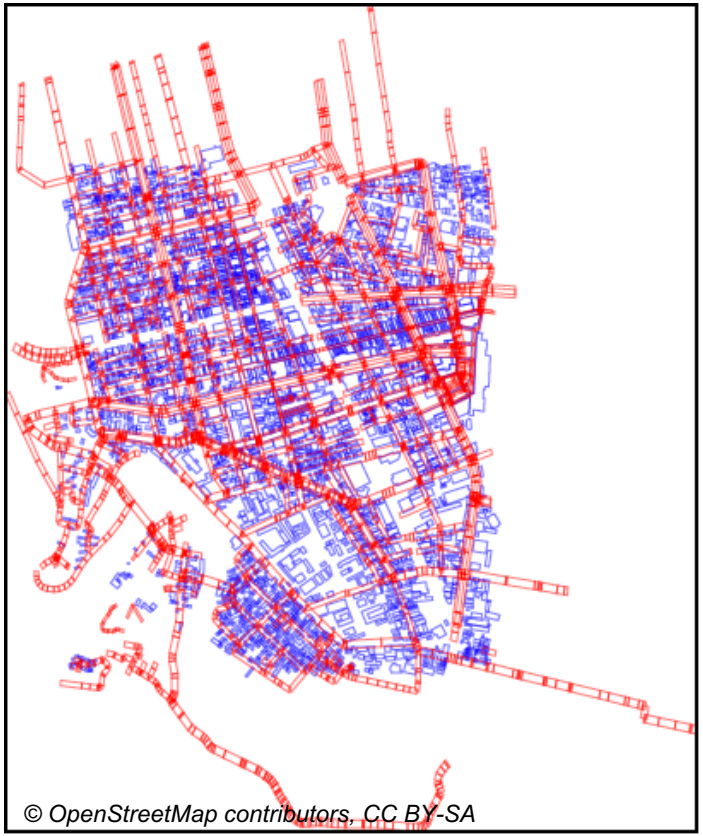
- Total purchase increases up to 68,303
- The large shop attracts consumers and reduced congestion improve the total revenue





Pedestrian Simulation in a city area

- By extending the shopping mall simulation, we generate general polygon map with roads and buildings extracted from Open Street Map
- We can utilize this extended pedestrian simulator to consider the congestion mitigation or evacuation planning in times of major disaster



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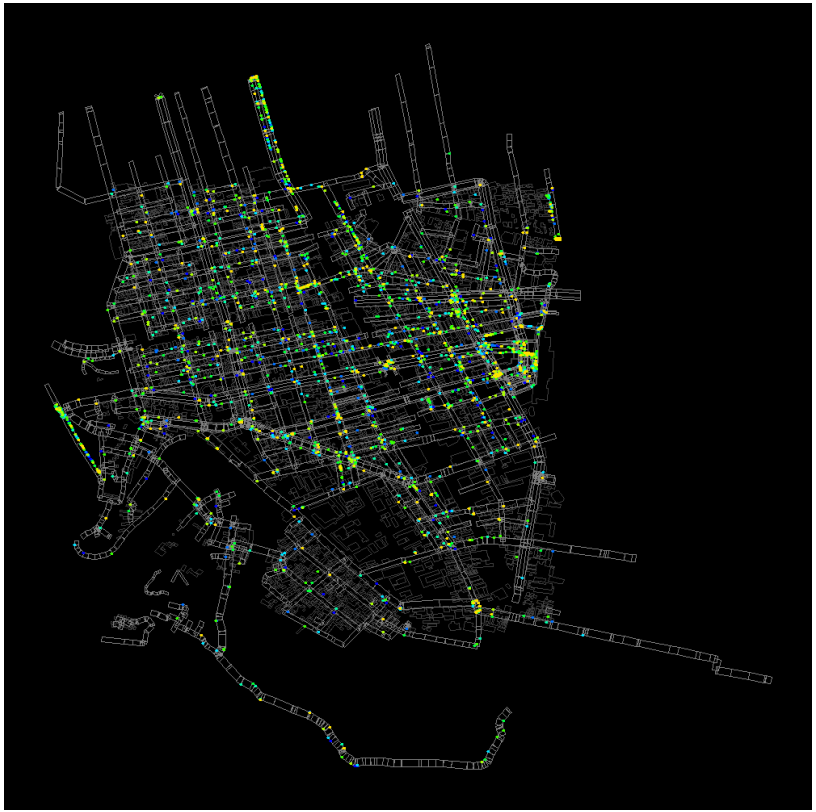
Pedestrian Flow at Sendai city



Summary

- We develop the agent-based simulation platform XASDI for large-scale distributed social simulation
- XASDI is available at GitHub with EPL
    - https://github.com/x10-lang/xasdi
- We introduced two social simulations developed with XASDI
  - Mega Traffic Simulation
  - Pedestrian Simulation
- By utilizing these simulator, we can support complex decision making for evacuation planning in times of major disaster