An Agent-based Model for Simulating Travel Patterns of Stroke Patients

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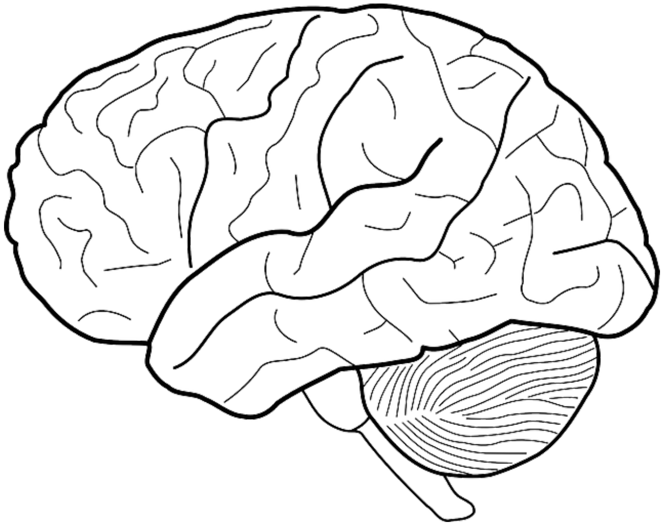
- PhD on Automated Design of Experiments and Simulation Studies
- Agent-based Social Simulation
- Logistics, Transportation, Health Care

Internet of Things and People Research Center

- Research center that studies how people can get the most out of the Internet of Things
- Involves computer scientists, interaction designers, professionals and users
- Addresses a range of current challenges in society within areas such as energy, transportation, health, learning and home automation

Acute strokes

- More than 1 million people in EU suffer from stroke every year
- Case fatality up to 35% (mostly over 70 years of age)
- Two types of acute strokes
  - Acute ischemic stroke (clot blocks flow of blood)
  - Hemorrhagic stroke (burst blood vessel)
- Thrombolysis treatment is essential to resolve blood clot but fatal in case of burst blood vessel
- Quickly making right diagnosis is crucial for efficient treatment of strokes



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Simulation of stroke logistics policies

- Computer simulation for investigating suitability and effects of different policies to reduce time to treatment
- Investigation in artificial system under realistic conditions without jeopardizing health of patients
- Example: Mobile Stroke Units
- Specialized ambulances with all equipment required to diagnose stroke patients
- Simulation to identify optimal locations of MSUs

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Synthetic population of stroke patients

- Simulation requires generation of realistic synthetic population of stroke patients
- Spatial distribution of strokes might affect the suitability of stroke logistics policies
- Inhabitants' whereabouts are often modeled using socio-demographic residence data
- No consideration that individuals might travel and not be home when having a stroke

- **We present an agent-based model for generating a synthetic population of stroke patients and to simulate their travel behavior.**
- **Generated population can be used to assess different stroke logistics policies**

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Case study: Skåne

- Region in southern Sweden
- Approximately 1 400 000 inhabitants
- 33 municipalities, area of 11 000 km^2
- 9 hospitals with emergency departments

- In 2015, a total of 3 973 strokes were recorded
- Most patients were 45years of age and older

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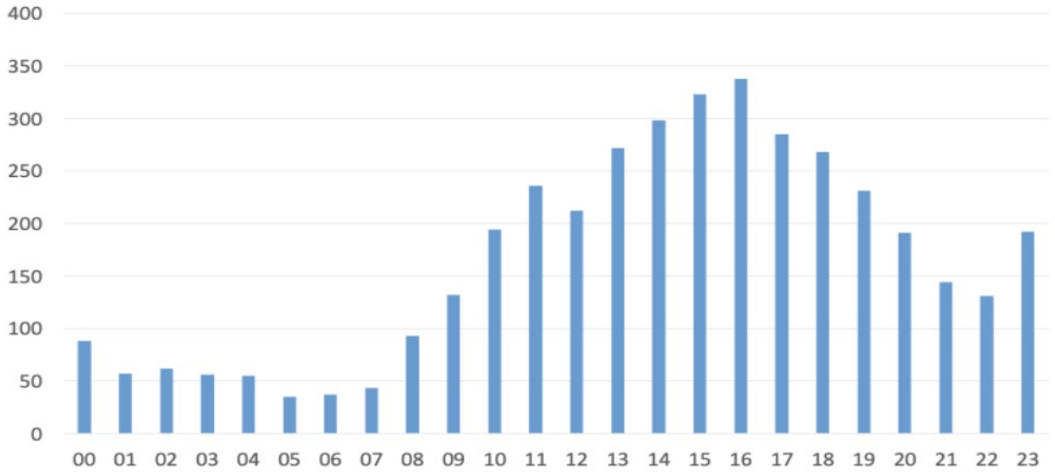
Total number of strokes per hour

- Extracted from data from regional healthcare provider *Södra Sjukvårdsregionen* (Southern Health Care Region)



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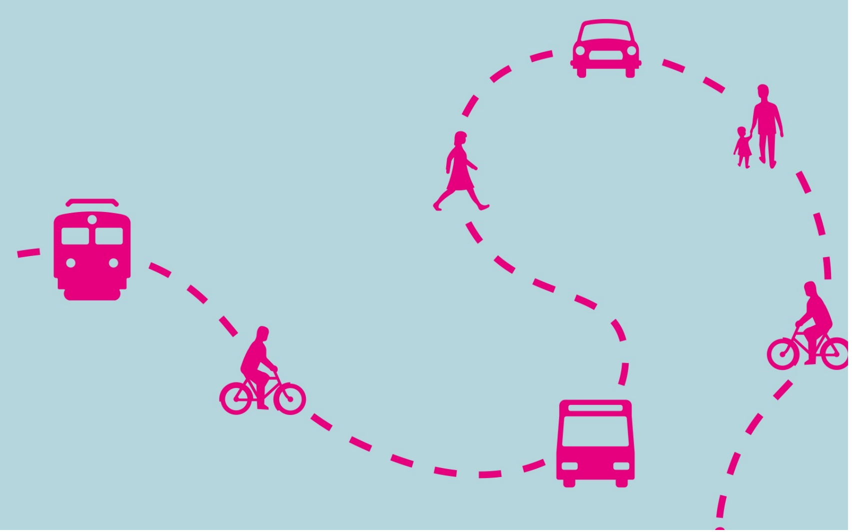
https://utveckling.skane.se/publikationer/rapporter-analyser-och-prognoser/resvaneundersokning-i-skane/

Regional Travel Survey

- Conducted in 2013
- Travelers were asked about their traveling habits
- Dataset with 56 000 distinct trips
- Origin, destination, purpose of trip, socio-demographic data of traveler, etc.



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Inter-arrival time of stroke incidents

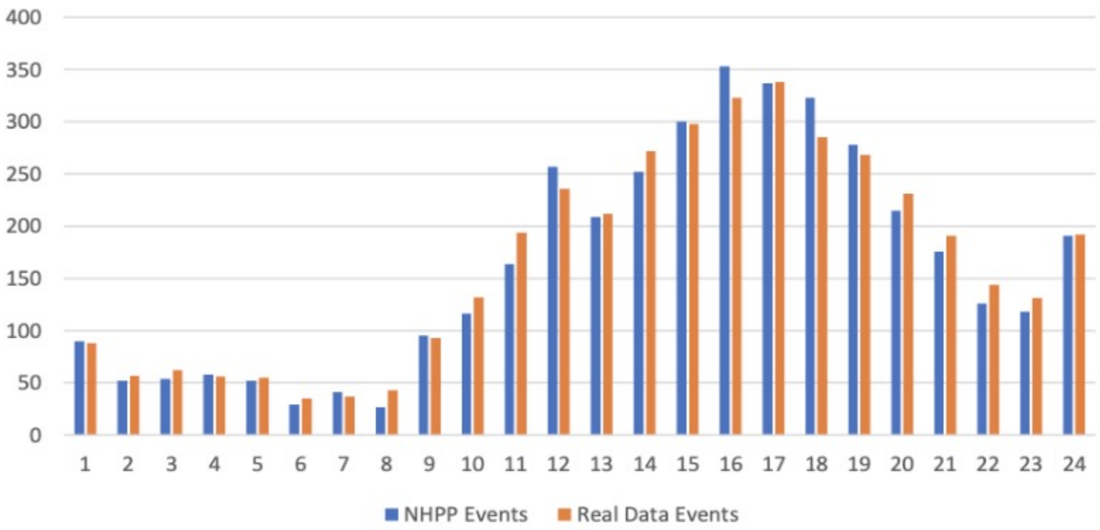
- Non-Homogeneous Poisson Process (NHPP)
- Extracted from data we received from the healthcare provider
- In contrast to ordinary Poisson processes, NHPP enable us to model probability processes where the rate of arrivals varies over time
- This is required to model the accumulation of strokes during the afternoon
- A day is divided into 24 segments, and each has a specific probability that a stroke occurs during this hour
- Two probability mass functions to distribute strokes among age groups and municipalities

Simulation Model

- Implemented in *Repast Simphony*
- Each time unit (tick) corresponds to one minute (1 day = 1440 ticks)
- For each tick, it is determined whether an individual will move to another location
- When NHPP-based stroke events occur, it is checked where the individual is

- **Result of the simulation: 3 912 strokes out of which 73 (1.9%) when not at home**

Strokes per age group



(a) hour of the day (RSE: 0.026, RRSE: 0.160)

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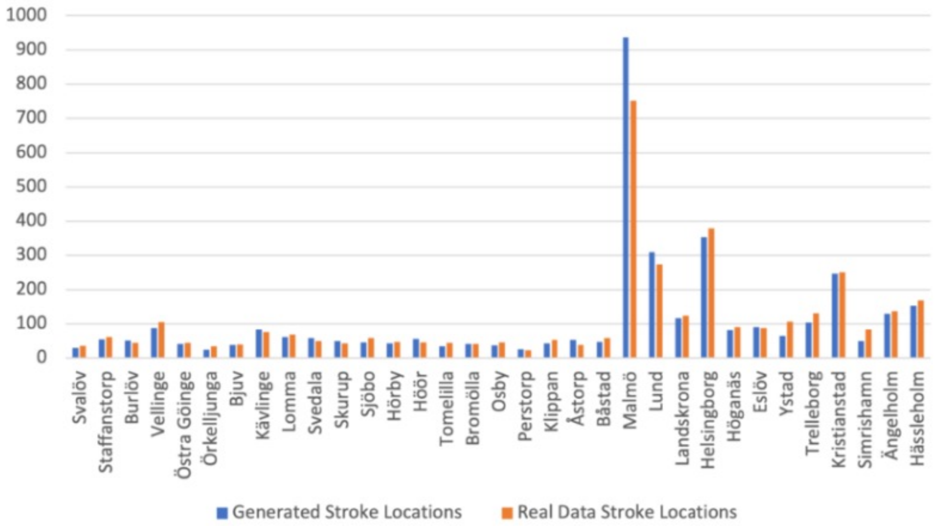
Strokes per commune



(b) municipalities in Skåne (RSE: 0.067, RRSE: 0.259)

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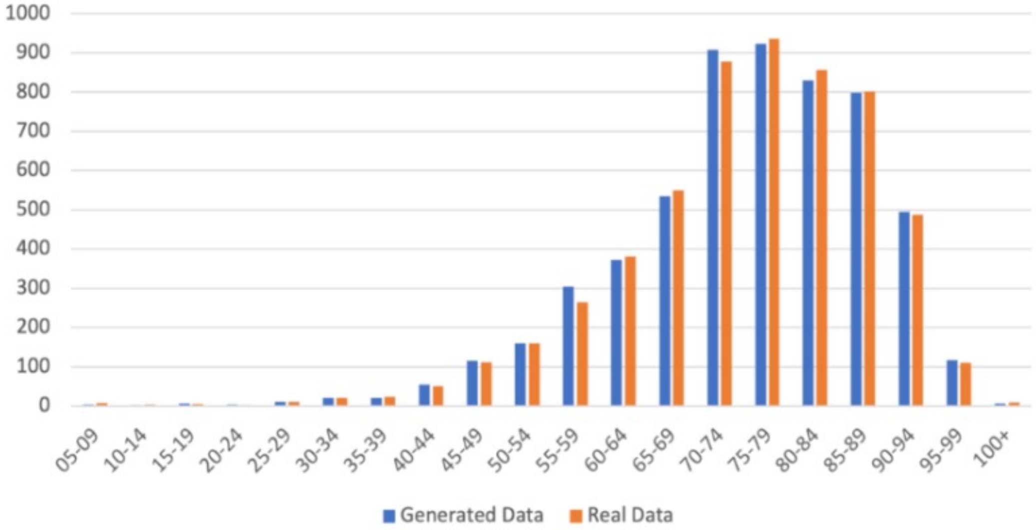
Strokes per hour of the day



(c) age group (RSE: 0.002, RRSE: 0.046)

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Plausibility of results: Comparison against stroke data from healthcare provider

SÖDRA SJUKVÅRDSREGIONEN

- 3 842 strokes of patients living in Skåne
- 3 830 got treatment in Skåne
- 3 106 got treatment in home municipality or hospital
- 736 received treatment at other hospitals
  - 497 live in municipalities where hospital does not provide emergency services all day
  - 80 were treated at Skåne university hospital providing highly specialized treatments (severe cases)
  - 57 received treatment at private facilities, whose location is unknown
  - 59 were treated in neighboring municipality (living close to border?)
- **46 patients (1.2%) received treatment obviously outside home municipality**

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Conclusions

- Generating realistic population of stroke patients with travel behavior is challenging
- Artificial population is required for agent-based simulation and allows for the assessment of stroke logistics policies (e.g., optimal placement of MSUs)
- We use aggregated data on individuals from different sources to generate a population
- Observation from simulations (1.9% of strokes do not occur at home) corresponds to data from healthcare provider
- We were able to show that traveling only has minor impact on where strokes occur and, thus, for policy making in stroke logistics

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We would like to thank Södra sjukvårdsregionen for the provision of the anonymized data on the occurrence of strokes in Skåne.