Development of Singapore General Hospital (SGH) Evacuation Simulation Models

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Modeling

- Agent types and behavior models
- Indoor environment
- Simulation model development

Agent types and behaviors

- Medical staffs (doctors, nurses, porters, others)
- Visitors
- Patients: ambulant, non-ambulant
  - ambulant: can move by themselves
  - non-ambulant: cannot move by themselves in case of emergency
  - the majority of non-ambulant patients are bedded

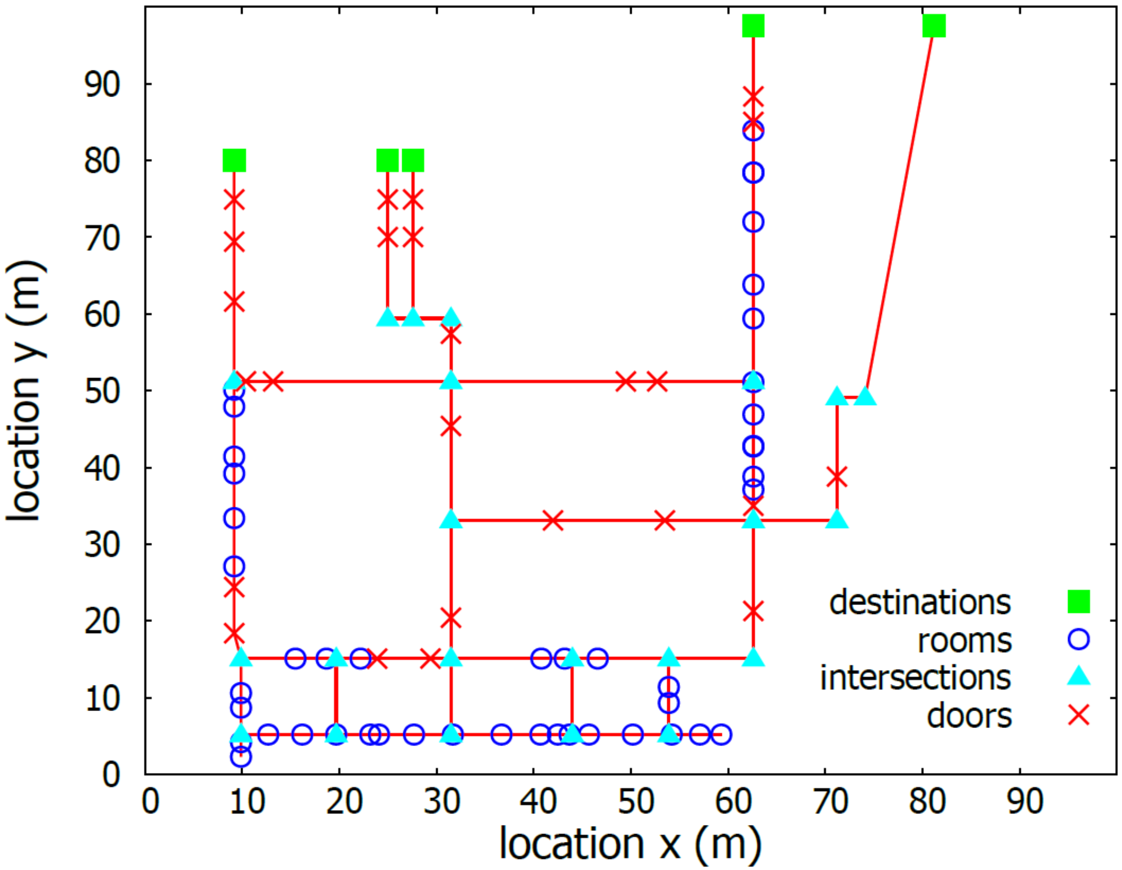
Modeling approaches

- Quasi-1D: links and nodes
  - evacuation strategies
  - optimization
- 2D
  - horizontal movements: rooms, corridors, corners, doors
  - interactions among agents and geometry
- 2.5D/3D
  - vertical movements: stairwells, elevators
  - What-if scenarios: elevator becomes out-of-order, stairwell closure, fire location, …

Simplified bedded patient flow

- Queueing network model
  - origins (rooms)
  - destinations (areas of safety)
  - intersections
  - physical bottlenecks (corridor doors)

- Consider individual entities



Potential delays/congestions due to…

- turning maneuvering at corners/intersections (Hunt et al. 2013)
- opening doors (Hunt et al. 2013)
- fatigue effects (Luo et al. 2016)

Objective functions

- Minimize evacuation time for each individual

$$\text{Minimize} \sum_i T_i$$

T_i: evacuation time of pedestrian i (waiting time + travel time)

- Minimize speed drop due to fatigue effect

$$\text{Minimize} \sum_i \sum_{t \in T} \Delta v_{i,d}$$

$\Delta v_{i,d}$: pedestrian i's desired speed drop due to fatigue effect

Modified from Abdelghany et al. (EJOR 2014) and Løvås (EJOR 1995)

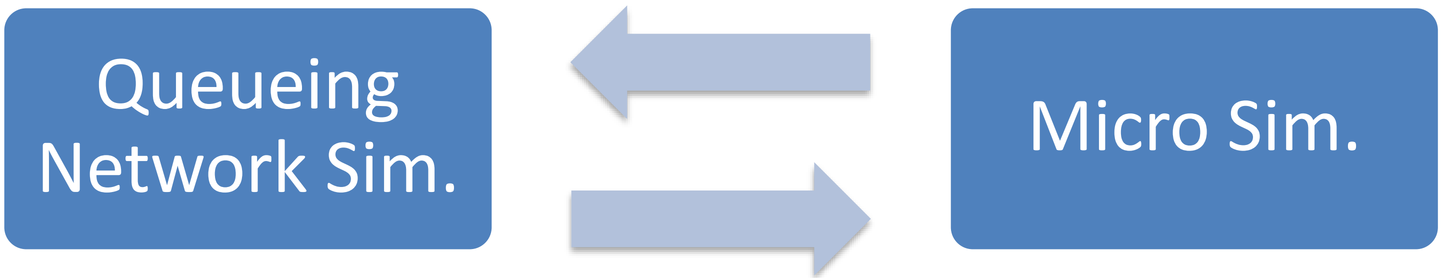
Simulating queuing network flow (1)

- Quasi-one-dimensional simulation
  (Lammel et al. 2010; Kunwar et al. 2016)
  - link effective width
  - link length
  - speed: based on Weidmann’s equation
  - flow capacity
  - storage capacity (standstill)

Simulating queuing network flow (2)

- Additional considerations
  - speed profile: acceleration and deceleration due to turning movements, doors, and congestions
  - fatigue effects: desired speed decreases (Luo et al. 2016)
  - effects of counter-flow traffic (incoming porters)
  - evaluate evacuation time for different porter-patient ratios and search best strategies

Coupling with Microsimulation

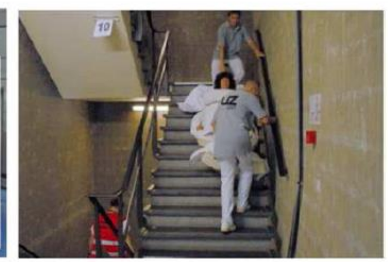


- Parameter space search
- Optimization
- Evacuation strategies

- Interactions among agents
- What-if scenarios

Modified from Borrmann et al. (2012) and Gao et al. (2014)

Consider other evacuation devices?

Stretcher *"Ferno Stretcher Scoop Model 65"*		**Evacuation Chair** *"Evac+Chair (R) 300H AMB"*	
			
Lightweight Alloy 8.9 kg	Min Length: 120cm Max Length: 201cm Width: 43cm	Aluminium tubing 10.6kg	Height: 138 cm Width: 52cm Depth: 77cm
Carry Chair *"Ferno model 42 (4204)"*		**Rescue Sheet** *"GSI Rescue 108088"*	
			
Aluminium 7.3 kg	Height: 95 cm Width: 48cm Depth: 61cm	Fabric 13.1 kg	Max Length: 200cm Width: 75cm

Source: Hunt et al. (2013)

THANK YOU

References

- Abdelghany et al. (EJOR 2014) Modeling framework for optimal evacuation of large-scale crowded pedestrian facilities
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- Gao et al. (OR 2014) Simulating the Dynamic Escape Process in Large Public Places
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- Kunwar et al. (PRE 2016), Evacuation time estimate for total pedestrian evacuation using a queuing network model and volunteered geographic information
- Lammel et al. (TrC 2010), The representation and implementation of time-dependent inundation in large-scale microscopic evacuation simulations
- Løvås (EJOR 1995), On performance measures for evacuation systems
- Luo et al. (J.STAT 2016), Fatigue effect on phase transition of pedestrian movement: experiment and simulation study