Integrated Microsimulation Modelling of Crowd & Subway Network Dynamics for Disruption Management Support

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Background

- Understanding the impact of crowd dynamics on transit systems is becoming increasingly important
- Particularly true in the case of disruption situations
- Ad hoc disruption management methods currently used with manual intervention
- Network level analysis difficult with existing tools
Research Objectives

Computing

Nexus: Transit Network-Crowd Dynamics Simulation Platform

Pedestrian Modelling

Platform Operations

Passenger Behaviour at Level-Change Bottlenecks

Disruption Management: TTC Case Study

Analysis of Network & User Impact of Disruptions

Proof of Concept of Response Strategy Testing
The *Nexus* Platform

- Connected platform to link existing separate simulators (surface transit, separated rail, stations) in a network
- Pedestrians are agents, passing between simulators as they travel
- Permits simulation to be run across multiple computers to handle large crowds
- Platform for future transit research
Nexus Framework

Simulation Core

MassMotion

RailSIM, OpenTrack

Aimsun, MATSIM

MILATRAS

SUBWAY STATION PEDESTRIAN SIMULATOR

SUBWAY LINE SIMULATOR

SURFACE VEHICLE SIMULATOR

TRANSIT ASSIGNMENT

COORDINATION SERVER

TRANSIT NETWORK ANALYZER

COMMON DATA SERVER

2D/3D VISUALIZATION ENGINE

TRANSIT NETWORK DESIGNER
Nexus Prototype

- Built to show proof-of-concept
- Network structure built automatically using GTFS data
- Stand-in simulators for each component
  - MassMotion integrated for modelling key stations
- Visualization of vehicles, graphs of metrics
- Incorporated two passenger models
Modelling Level Transitions

- Passenger choice between adjacent stairs and escalators
- Used standard binary and mixed-logit models
- Factors considered
  - mobility group of pedestrian
  - facility physical characteristics
  - conditions at time of choice (queuing, existing use of stairs and escalators, opposing flow on stairs)
Modelling Level Transitions

- Estimated using field data from several stations
- Incorporated within MassMotion
- 90% success rate in predicting 10-sec flows
Passenger Distribution on Platforms

- The main interface between stations and lines
- Passenger distribution key input into boarding/alighting models
- Developed a model of the process of dispersion of passengers along a subway platform
  - Considers entrance flows and positioning, relative to the arrival time of trains
  - Accounts for awareness of layout of destination platform for commuters
Passenger Distribution on Platforms

- Used a diffusion-inspired approach for spacing of passengers as they enter the platform
  - Movement based on density gradient caused by surrounding pedestrians
- Also incorporated waiting-section preference for a sub-population of aware commuters
- Calibrated model against Toronto survey data and field data collected at several stations
TTC Case Study

- **Skeleton network constructed in the prototype**
  - Show proof-of-concept of examining impact of disruptions, resulting crowding
  - Simulated testing of response strategies

- **Also modelled connecting transit**
  - GO Rail, Brampton, Mississauga, York

- **Transit assignment not calibrated**
TTC Case Study

- Agent population for morning peak commute synthesized using 2011/2012 TTS data fused with land-use data.
TTC Case Study

- Bloor/Yonge and St George stations built within MassMotion
TTC Case Study
Network Performance

![Chart showing network performance over simulation time]

- **Average Platform Counts**
- **Simulation Time**
- **Base Model**
Agent Performance

(a) Agent Travel Time for Base Model

(b) Agent Waiting Time for Base Model
Yonge-University-Spadina

(a) Dwell Times

(b) Headways at Yonge/Bloor

(c) Passenger Load
Disruption Impact Study

- Held southbound train at Yonge/Bloor station starting at 7:55 AM

(a) Average Network Platform Counts

(b) Agent Travel Times
Response with Agent Re-routing

- With 30 min disruption, announcement made for agents on connecting line to avoid transfer at Bloor/Yonge

Average Counts at all Platforms

Southbound platform at Bloor/Yonge
Moving Forward

- Expansion of prototype to a commercial product and usable research platform
  - Used for projects/studies that require large-scale crowd and transit network simulation
- Full model of the GTHA transit network
Questions?