Gating as a management strategy for controlling pedestrian flows

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Outline

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   - Flow separators

3. Results
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   - Flow separators results

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Introduction

Gating as a management strategy for controlling pedestrian flows
Context

Pedestrians suffer from congestion just as vehicles do:

- increased travel time,
- excessive density.

Which in turn can make you:

- be late for your job interview,
- despise traveling in public,
- miss you connecting train or plane,
- ...

Gating as a management strategy for controlling pedestrian flows
Context

Higher capacity & faster PT services, to serve higher demand.
Context

Some of the services available at the Lausanne (CH) train station...
Motivation

• Lack of comfort, hazardous situations

• How to ensure a satisfactory level-of-service & safety?
  – Decrease pedestrian demand (counter productive !)
  – Spread the load over time & space
  – Influence pedestrian’s routes
  – ...

• Simulation is needed to address the complexity of the problem

Goal: **Integrate management strategies specific to pedestrian traffic within a Dynamic Traffic Management System (DTMS).**
Framework

fig/framework.pdf
Strategies

What specific measures can be considered to impact dynamics:

- Adjustments to the PT schedule
- Control access to specific areas ⇒ gates
- Change link travel time ⇒ moving walkways
- Prevent counter flow ⇒ flow separators
- Attract pedestrians to specific locations
Existing strategies

Pedestrian management

- Little research on specific strategies.
- Some static measures (design) have been studied.

Road traffic management

- Ramp metering
- Perimeter control
- Variable message signs
- Traffic lights
- ...
Proposed management strategies

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Proposed strategies

Gating
Prevent excess travel time in junctions.

Flow separators
Avoid counter flow in corridors.
Proposed management strategies

Gating
Objective

At corridor intersections, highly disordered flows take place.

\[\downarrow\]

Prevent too many individuals from crossing the intersection simultaneously (qualitative). \[\rightarrow\] Prevent increase in travel time.

\[\downarrow\]

Measure pedestrian density (quantitative). \[\rightarrow\] How?
Measurement
Some possibilities for measuring density:

Pedestrian accumulation
• snapshot

Voronoi based
• snapshot

Edie’s definition
• average over time
Measurement
Some possibilities for measuring density:

Pedestrian accumulation

- snapshot
- sensitive to delimited area

Voronoi based

- snapshot
- expensive to compute

Edie’s definition

- average over time
- sensitive to delimited area
Measurement
Some possibilities for measuring density:

**Pedestrian accumulation**
- snapshot
- sensitive to delimited area
- provides average values

**Voronoi based**
- snapshot
- expensive to compute
- provides individual values
- aggregation may be required

**Edie’s definition**
- average over time
- sensitive to delimited area
- provides average values
- strong physical interpretation
Measurement

The indicator used is the following:

For a density threshold $\bar{\rho}$, for a given snapshot taken at time $t$, count the number of individuals where $\rho_i(t) > \bar{\rho}$.

This gives a pedestrian-centric measurement (nearly) independent of any “zone”.
Setup

The level-of-service must be measured and controlled inside area $A$.

fig/gating-zone.pdf
Control law

Parameters

• density threshold: $\bar{\rho}$
• uncontrolled flow: $f(0)$
• cut off value: $f(?) = 0$

Calibration based on:
• fundamental diagram
• distribution of individual densities
Proposed management strategies

Flow separators
Objective

Head-on-head “collisions” induce significant extra travel time.

\[ \Downarrow \]

Reduce this counter-flow to a minimum.

\[ \Downarrow \]

Dynamically allocate part of the available corridor width to each direction.
Setup

Figure: Schematic presentation of the devices used to separate the opposing flows. The inflow at each end determines the width available to each directed flow.

Gating as a management strategy for controlling pedestrian flows
Width available for each direction is proportional to flows:

\[
W_{AB} = \begin{cases} 
  w \cdot f_{\min, AB}, & \text{if } \frac{\sum q_{in, A}}{\sum q_{in, A} + \sum q_{in, B}} \leq f_{\min, AB} \\
  w \cdot f_{\max, AB}, & \text{if } \frac{\sum q_{in, A}}{\sum q_{in, A} + \sum q_{in, B}} \geq f_{\max, AB} \\
  w \cdot \frac{\sum q_{in, A}}{\sum q_{in, A} + \sum q_{in, B}}, & \text{otherwise}
\end{cases}
\]
Results

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Case study setup

Gating

• crossed shaped junction
• demand pattern:
  – sinusoidal for two directions
  – uniform for other two

Flow separators

• straight corridor
• shifted sine-shaped flows
Case study setup

- Disaggregate pedestrian motion model: NOMAD.
- Graph-based route choice (but no significant role here).
- Multiple simulations runs.
Results

Gating results
Travel times

(a) Without gating

(b) With gating

No significant difference in mean travel time: 21.04s VS 21.18s
Reduction in travel time variance: 5.16s → 4.41s (−14%)
Average density

(a) Without gating

(b) With gating

Decrease of

• mean density: $1.57\, pax/m^2 \rightarrow 1.42\, pax/m^2 \quad (-9.5\%)$
• density variance: $0.93\, pax/m^2 \rightarrow 0.72\, pax/m^2 \quad (-22\%)$
Individual density

(a) Without gating  
(b) With gating

Decrease of

- mean density: $2.18\text{pax/m}^2 \rightarrow 1.82\text{pax/m}^2$ ($-16\%$)
- density variance: $1.22\text{pax/m}^2 \rightarrow 1.02\text{pax/m}^2$ ($-16\%$)
Improvements

• less risk of gridlock.
• better level-of-service in the junction.

without increasing travel time.

Open questions:

• shape of the control law?
• parameter calibration?
• can travel time be improved?
Results
Flow separators results
Travel times

(a) Without flow separators

(b) With flow separators

Significant improvement in

- mean travel time: $37.86s \rightarrow 30.31s (−19\%)$
- travel time variance: $9.94s \rightarrow 3.39s (−66\%)$
Conclusion & next steps

Gating as a management strategy for controlling pedestrian flows
Conclusions

- Integration of two pedestrian control strategies in a DTMS.
- Gating improves the level-of-service and helps prevent gridlock.
- Flow separators significantly improves the travel time.

Next steps

1. Investigate more complex control laws.
2. Model predictive control.
3. Simulation based optimization.
Thank you for your attention!

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