Modelling Backward Traveling Holes in Mixed Traffic Conditions using an Agent Based Simulation

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Agenda

1. Queue models
   - Why queue models?
   - Point queue model
   - Spatial queue model

2. Backward traveling holes
   - How does it work?
   - Queue model with holes
   - Fundamental diagrams

3. Sensitivity
   - Flow density contours
   - Average bike passing rate contours

4. Conclusion and outlook
Queue models

1. Why queue models?
2. Point queue model
3. Spatial queue model

2. Backward traveling holes
   1. How does it work?
   2. Queue model with holes
   3. Fundamental diagrams

3. Sensitivity
   1. Flow density contours
   2. Average bike passing rate contours

4. Conclusion and outlook
Why queue models?

Queue models are –

- Simple, fast, easy to implement
- Suitable for large scale scenario
Queue models

Point queue model

Point queue

(Hurdle and Son, 2001)
Point queue

- Unlimited storage capacity $\Rightarrow$ length of queue $= 0$
- No spill-back $\Rightarrow$ no inter-link interaction
- FIFO
- Space available on upstream *immediately* $\Rightarrow$ no intra-link dynamics

(Hurdle and Son, 2001)
Spatial queue

- Unlimited storage capacity $\Rightarrow$ length of queue $\neq 0$
- No spill-back $\Rightarrow$ no inter-link interaction
- FIFO / passing / seepage
- Space available on upstream *immediately* $\Rightarrow$ no intra-link dynamics
Spatial queue

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MATSim

- In the present study, a multi-agent transport simulation framework (MATSim) is used.
- Only spatial queue is used in MATSim
Why MATSim?

- agent-based simulation framework
- suitable for large scale scenario [10 min to simulate 24 h of about 7 million persons of Switzerland (Balmer et al., 2009)]
- possible to simulate scenario with smaller sample size

MATSim queue models -

<table>
<thead>
<tr>
<th>Queue model ...</th>
<th>FIFO</th>
<th>Passing</th>
<th>Seepage</th>
</tr>
</thead>
<tbody>
<tr>
<td>... without holes</td>
<td>Original</td>
<td>Agarwal et al. (2015)</td>
<td></td>
</tr>
<tr>
<td>... with holes</td>
<td><strong>in the present study</strong></td>
<td>Agarwal and Lämmel (2015a,b)</td>
<td></td>
</tr>
</tbody>
</table>
Race track
FIFO $\Rightarrow$ Passing (Agarwal et al., 2015)
**FIFO ⇒ Passing (Agarwal et al., 2015)**

**Flow vs overall density**

- **FIFO**
  - Slope $= \text{max bike speed}$
  - $\text{Flow (in PCU/hr)}$

- **Passing**
  - $\text{max car speed}$
  - $\text{max bike speed}$

**Speed vs overall density**

- **FIFO**
  - $\text{Speed (in m/s)}$

- **Passing**
  - $\text{Speed (in m/s)}$
FIFO $\Rightarrow$ Passing (Agarwal et al., 2015)

Flow vs overall density

FIFO

Slope = max bike speed

Overall density (in PCU/km)

Flow (in PCU/hr)

Speed vs overall density

Overall density (in PCU/km)

Speed (in m/s)

Passing

max car speed

max bike speed

nearly vertical slope

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Backward traveling holes

time step = 1
Backward traveling holes

time step = 2
Backward traveling holes

time step = 3
Backward traveling holes

time step = 4
How does it work?

- A vehicle leaves ⇒ a hole is created
- The PCU of the hole is same as the leaving vehicle.
How does it work?

- A vehicle leaves $\Rightarrow$ a hole is created
- The PCU of the hole is same as the leaving vehicle.
- The hole is equipped with upstream arrival time as follow –

$$t_{\text{hole}} = \frac{\ell}{v_{\text{hole}}}$$

i.e. space on upstream end will be available after $t_{\text{hole}}$. 
How does it work?

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- The PCU of the hole is same as the leaving vehicle.
- The hole is equipped with upstream arrival time as follow –

$$t_{hole} = \frac{l}{v_{hole}}$$

i.e. space on upstream end will be available after $t_{hole}$.
- A constant speed of hole ($v_{hole}$) is assumed i.e. $(15 \text{ km/h} \approx 2 \text{ sec reaction time})$.
- A vehicle can enter the link if hole is available $\Rightarrow$ inflow capacity
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  i.e. space on upstream end will be available after \( t_{hole} \).
- A constant speed of hole (\( v_{hole} \)) is assumed i.e.
  (15 km/h ≃ 2 sec reaction time).
- A vehicle can enter the link if hole is available ⇒ inflow capacity

show movie
Queue model with holes

- Unlimited storage capacity $\Rightarrow$ length of queue $\neq 0$
- No spill-back $\Rightarrow$ no inter-link interaction
- FIFO / passing / seepage
- Space available on upstream immediately $\Rightarrow$ no intra-link dynamics
with hole vs without hole – only car simulation
with hole vs without hole – only car simulation
with hole vs without hole – only car simulation
Car bike simulation

Flow vs overall density

Speed vs overall density
Car bike simulation

Flow vs overall density

Flow (in PCU/hr)

0 500 1000 1500 2000 2500

Overall density (in PCU/km)

0 50 100 150

Flow (in PCU/hr)

0 500 1000 1500 2000 2500

Overall density (in PCU/km)

0 50 100 150

Speed vs overall density

Speed (in m/s)

0 5 10 15

Overall density (in PCU/km)

0 50 100 150

Speed (in m/s)

0 5 10 15

Overall density (in PCU/km)
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Flow density contours

without holes

Congested regime

Car density (PCU/km)

Bike density (PCU/km)

Overall flow (PCU/hr)
Flow density contours

without holes

with holes

Congested regime
Average bike passing rate contours

without holes
Average bike passing rate contours

without holes

with holes
Conclusion and outlook

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Conclusion

- Backward traveling holes in spatial queue models
- Suitable for mixed traffic and large scale scenarios
- Implicit inflow link capacity

Outlook

- Compare the computational efficiencies
- Apply it to a large scale real-world scenario
Conclusion

- Backward traveling holes in spatial queue models
- Suitable for mixed traffic and large scale scenarios
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Outlook

- Compare the computational efficiencies
- Apply it to a large scale real-word scenario


Thank you for your attention.
Questions / Comments / Suggestions?
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Back up
MATSim

initial demand → mobsim → scoring → analyses

replanning
Stead state in race track experiment
Speed variation in queue model without holes

![Diagram showing flow vs. density for different modes of transport: cars (60, 40, 20 km/h) and bikes (15 km/h).]
Single modes

![Flow and Speed Graphs](image)

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Backward traveling holes

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Multiple modes
Multiple modes