Accuracy of Pedestrian and Traffic Flow Models

Meaningful Quantifications

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Background

How good is a traffic/pedestrian flow model?

Observations
• reality
• experiment

Model
• simulations

Predictions
How good is a traffic/pedestrian flow model?

Observations
- reality
- experiment

Predictions
- qualitative
- quantitative

Compare
- simulations

Model
How good is a traffic/pedestrian flow model?

Background

- Observations
  - reality
  - experiment

- Model
  - simulations

- Predictions

- Compare
  - qualitative
  - quantitative

- Calibration and validation
- Parameter estimation
Accuracy measures review

- Goodness of Fit of speed, spacing, density, flow
  - (Root Mean) Squared (Normalized) Error, Mean (Absolute) (Normalized) Error,
  - GEH statistic
  - Correlation Coefficient
  - Theil’s Bias/Variance/Covariance Proportion, Theil’s Inequality Coefficient
- Likelihood
- Total flux, time spent, evacuation time

Usually do not take into account specific features
Shock waves

A5 South (June 11, 2001)
Lane formation

source: Moussaïd (2012)
Turbulence

Numerical simulations

source: Helbing & Treiber (1999)
Contribution: new accuracy measures

- Allow focus on certain feature of flow instead of averaging
- Gives insight into type of error
- \( \Rightarrow \) Insight into how to improve accuracy
Outline

Introduction

New accuracy measures

Test cases
  Traffic congestion simulation
  Bi-directional pedestrian flow modelling

Conclusion & outlook
New accuracy measures

Exact

\( y \)

\( x \)
New accuracy measures

Exact

Is location of high/low density/speed area correct?

Phase error

Is location of high/low density/speed area correct?
New accuracy measures

**Exact**

Is location of high/low density/speed area correct?

**Phase error**

Do sharp transitions between high/low density/velocity areas stay sharp?
From concept to quantification

Centre of mass for phase error

- In $x$- and $y$-direction
- Large difference $\Rightarrow$ large phase error
From concept to quantification

Centre of mass for diffusion error

- In density- (or speed-) direction
- Large difference $\Rightarrow$ large diffusion error
Test case 1: Traffic congestion simulation

Exact solution of LWR model ⇔ simulation results

2km jam

free flow → time → congestion
0 critical density jam density
Test case 1: Traffic congestion simulation

Exact solution of LWR model ⇔ simulation results

2km jam

congestion solves

congestion spills back

time

Free flow

0 critical density

jam density

Solve with different numerical methods
Numerical solutions: space time density

- Min supply demand
- Upwind explicit
- Upwind implicit

Free flow → Congestion
0 → Critical density → Jam density
Numerical solutions: density cross section $t = 600$ s

Min supply demand  Upwind explicit  Upwind implicit
Numerical solutions: density cross section $t = 600$ s

- Min supply demand
- Upwind explicit
- Upwind implicit

Centre of mass $\Rightarrow$ phase & diffusion error
Comparison of different numerical methods:

- **Upwind implicit**
- **Min supply demand**
- **Upwind explicit**

Phase error vs. CFL number:
- Small time steps: upwind is best.
- Big time steps: use implicit, but at cost of phase error.

Diffusion error vs. CFL number:
- Low diffusion error for both methods.

Results help selecting the appropriate numerical method.
Results help selecting appropriate numerical method

- Small time steps: upwind is best
- Big time steps: use implicit, but at cost of phase error
Test case 2:
Bi-directional pedestrian flow modelling

Experimental data ↔ model

class 1 →

Densities class 1 (→), t=350 (s)

location (m)

0

-5

0

5

location (m)

-2

0

2

Densities class 2 (←), t=350 (s)

location (m)

0

0.5

1

-2

0

2

Continuum flow model

2 parameters for avoidance

$\beta_u = 0.8$, $\beta_o = 2.3$ (set 1)

Test with other parameter settings
Test case 2: Bi-directional pedestrian flow modelling

Experimental data ↔ model

class 1 →

Continuum flow model
2 parameters for avoidance
\[ \beta_u = 0.8, \quad \beta_o = 2.3 \text{ (set 1)} \]
Test case 2: Bi-directional pedestrian flow modelling

Experimental data ↔ model

Densities class 1 (→), t=350 (s)

Densities class 2 (←), t=350 (s)

Continuum flow model

2 parameters for avoidance

\( \beta_u = 0.8, \beta_o = 2.3 \) (set 1)

Test with other parameter settings
Experimental data ⇔ model with different parameter settings

$\beta_u = 0.8, \ \beta_o = 2.3$ (set 1)
almost perfect

$\beta_u = 0.7, \ \beta_o = 1.36$ (set 2)
lanes swapped

$\beta_u = 0.63, \ \beta_o = 0.63$ (set 3)
no lanes
Experimental data ↔ model with different parameter settings

- \( \beta_u = 0.8, \beta_o = 2.3 \) (set 1)
  almost perfect

- \( \beta_u = 0.7, \beta_o = 1.36 \) (set 2)
  lanes swapped

- \( \beta_u = 0.63, \beta_o = 0.63 \) (set 3)
  no lanes

Parameters are calibrated for total flux
Results

No difference for parameter settings according to:

- MAE & RMSE of class specific speed
- Diffusion error
- Total flux
Results
No difference for parameter settings according to:
  ▶ MAE & RMSE of class specific speed
  ▶ Diffusion error
  ▶ Total flux
But: ME & RMSE of $v_x$ and phase error show set 1 is best
Results \( \text{ME} \ & \ \text{RMSE} \ \text{of} \ v_x \)

- **Set 1**
  - Set 1 best
- **Set 2**
- **Set 3**
Results  Phase error $y$-direction

- Set 1 best
- Large phase error for set 2
Conclusion & outlook

- Phase error and diffusion error
- Applications
  - Road traffic & pedestrian flow. Future: NFD?
  - Comparing data vs model, model vs simulation, ...
  - Parameter estimation or assessment of model/simulation method
- Distinguish between different outcomes → interpretation needed:
  - Phase error sometimes ok, sometimes not
  - Insight into possible improvements
Conclusion & outlook

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- Future research:
  - Larger networks with many features?
  - Include time
Thanks!
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