Statistical Structures of Low Density Pedestrian Dynamics

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Introduction & Motivation

• Walking pedestrians: *rich & complex dynamics*
  – Reliable models: relevant in science & technology

• Stochastic, nearly unpredictable motion
  – *Quantitative-(statistical) assessment of fluctuations?*
    • Measurements?
    • Rare behaviors?
    • Modeling?
Introduction & Motivation

• This presentation:
  – “low density” pedestrian dynamics in a corridor
    • Quantitative-(statistical) models?

• Content:
Introduction & Motivation

• This presentation:
  - “low density” pedestrian dynamics in a corridor
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• Content:
  1. High statistic resolution measurements
  2. Analysis of stochastic fluctuations
    Quantitative model up to rare events
High statistics measurements approach

- Real-life setting
- 1y recording ~h24,
- ~2.2K people every weekday
- ~230K tracks dataset

Metaforum building, TU/e

[Seer et al. 2014, Corbetta et al. 2014, Corbetta et al. 2015]
Pedestrian tracking technique

• **1. Heads detection**
  – Overhead, 3d view
    • Depthmap-based, Via Microsoft Kinect
    • (Complete) clustering of “depth-cloud”
    • 15Hz sampling

Clusterization tree cut at “body scale”

Heads marked as low depth (closest) percentiles

(Seer et Al., 2014)
Pedestrian tracking technique

- **2. Head tracking**
  - Head Spatio-Temporal matching via 3DPTV
  - Nearest search with velocity prediction

- Implementation:

Acknowledgment: A. Liberzon (TAU)
Traffic - local occupancy

Occupancy = 2

Occupancy = 5

1 week

Week 3rd Feb ’14

Lunch peak

Break peak

Week 5th Feb ’14
Many flow conditions

Ensemble of trajs.

Co-Flows

Counter-flows

Undisturbed pedestrians

Partitioning ensemble trajectories in flow classes

=> statistics per-class
Fundamental diagrams

Simple per-class statistics on velocities

- L-R symmetry broken
- Descending direction faster
- Counter-flow > Co-flow (at same load)
  - Ped. ascending might have trays

[Corbetta et. al 2014]
Beyond average values...

• Full probability distribution functions
  – Analyze stochasticity
  – Mathematical models

• Now: undisturbed pedestrians
Undisturbed pedestrian dynamics

- Simple scenario
  - Pedestrians **cross** the corridor (L -> R)
  - No reasons to stop
Undisturbed pedestrian dynamics

- Rare events: trajectory inversions
1. Preferred walking path
2. “Confined” transversal motion
3. longit. & transv. fluctuations
High-statistics perspective

1. Preferred walking path
2. “Confined” transversal motion
3. longit. & transv. fluctuations
Can we reproduce this behavior in statistical sense?

Langevin-like equation

Second order stochastic dynamics:

\[ \dot{x} = v \]

\[ \dot{v} = -\nabla_v K(v) - \nabla_x V(x) + \dot{W} \]

- Activity (active friction for propulsion)
- Spatial confinement
- Random external factors
Transversal fluctuations

Stochastic motion around preferred path:
Quadratic potential for position (V) and velocity (K)

Confined Gaussian fluctuation: \[ \dot{v} = -2\gamma v - 2\beta y + \sigma_y \dot{w} \]
Bi-stable longitudinal motion

$4^{\text{th}}$ order velocity potential velocity (K)
Simplest bi-stable stochastic velocity dynamics

Small fluctuations

Stable velocity states
Bi-stable longitudinal motion

4\textsuperscript{th} order velocity potential velocity (K)  
Simplest bi-stable stochastic velocity dynamics

Trajectory inversions

Stable velocity states
• Inversion dynamics captured in velocity pdf
• Rare and uncorrelated => Poisson statistics

\[ \dot{u} = 4\alpha u(u^2 - u_p^2) + \sigma_x \dot{w} \]

[A. Corbetta et. al, to be submitted]
Conclusion

• Analyzed pedestrian dynamics via large experimental datasets
  – Statistic insights possible
  – Analogous features expected in low density crowds

• Simple Langevin-like model to reproduce stochastic features of undisturbed pedestrians motion
  – Quantitative
  – Small fluctuations and rare inversions captured within same model

• Next:
  – Avoidance dynamics in pairs & higher order interactions
    [A. Corbetta, Phd Thesis, 2015 – soon online]
  – Statisticity investigation at high density regimes?
References

4. The OpenPTV initiative, 2012 - , [www.openptv.net](http://www.openptv.net)
8. A. Corbeta, C. Lee, R. Benzi, A. Muntean, F. Toschi, Fluctuations and mean behaviours in diluted pedestrian flows, to be submitted