# Determining the density experienced by pedestrians in unstable flow situations

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# Background

- Several density computation methods exist, among others:

| | |
|---|---|
| Fruin | $\rho = N / A$ |
| Helbing et al. 2007 | $\rho = A \exp(\beta(X_q - X_p))$ |
| Voronoi | $\rho = 1 / A_{voronoi}$ |
| XT-method | $\rho = \text{sum}(t_{end} - t_{begin}) / (A * T)$ |

- Each method has its own characteristics[1]

1. Duives, Daamen and Hoogendoorn, Quantification of the level of crowdedness for pedestrian movements, Physica A 427 (2015) 162-180

# Background

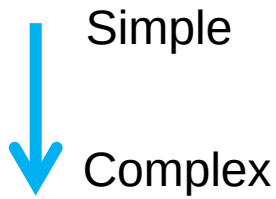
- Zhang et al. 2011 and Duives et al. 2014 both show that the fundamental diagrams produced by means of these methods differ greatly depending on the chosen density computation method and the location of measurement.

- Based on their results, two methods come out on top, namely the Voronoi and the XT-method.

# Can these two methods be used under all circumstances?

# Methodology

- Comparison of three metrics:
  - Fruin
  - Voronoi
  - XT-method
- Three flow situations
  - 1D-row
  - 2D-row
  - 2D-bottleneck



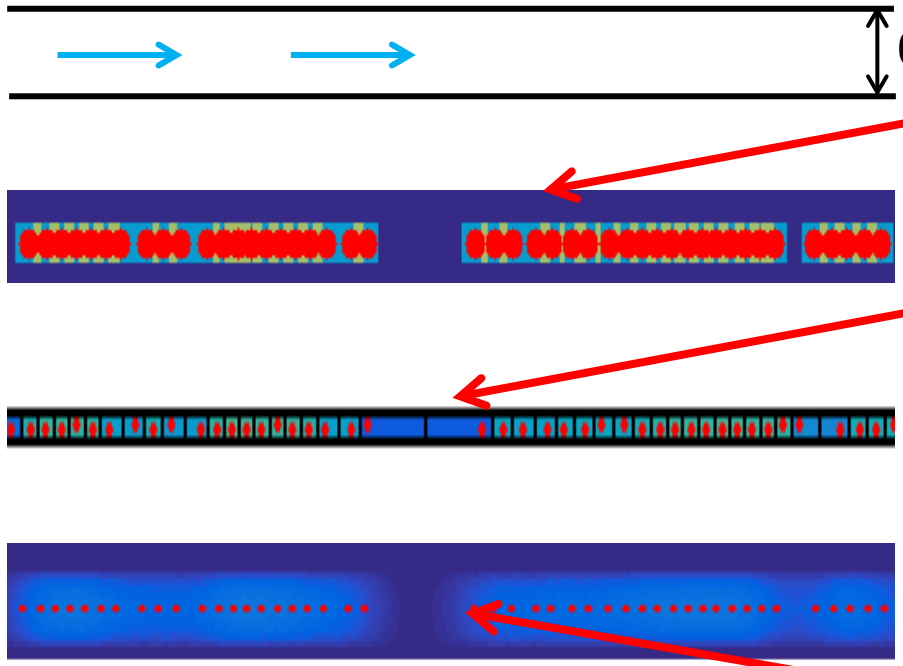

- Several demand levels which cover both free flow and congested conditions
- Simulation by means of Nomad (Campanella et al. 2014)

# Results – 1D-row

ρ = N / A

Voronoi

XT-method



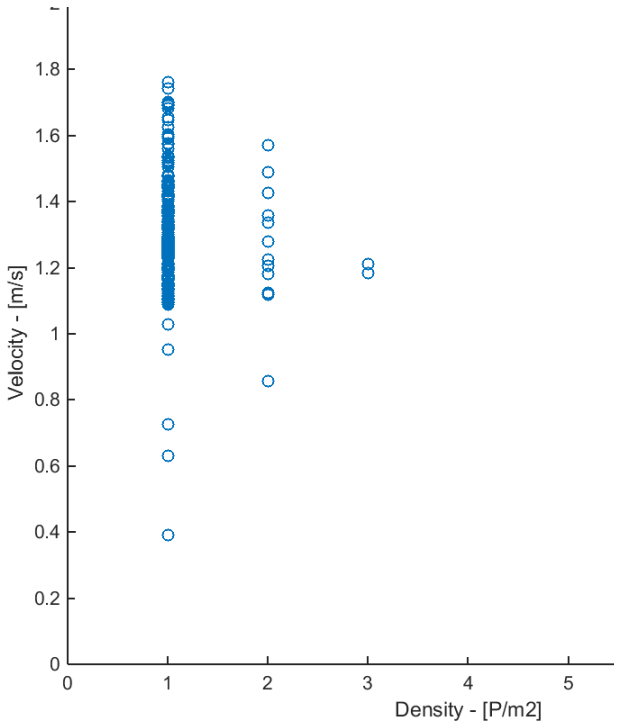

Large dependence on settings of the grid

Dependence on the location of nearest other pedestrian

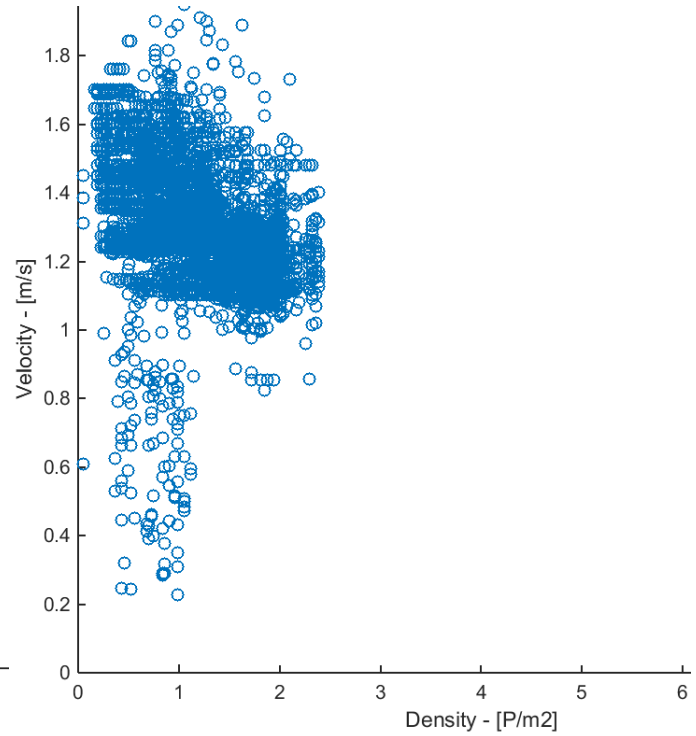
Gradual spatial decrease of density.

# Results – 2D-row

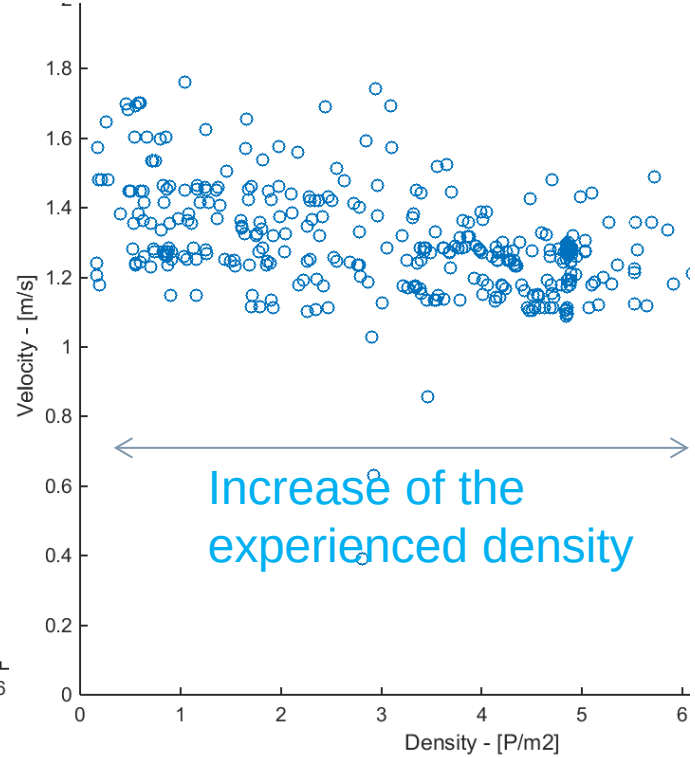
ρ = N / A



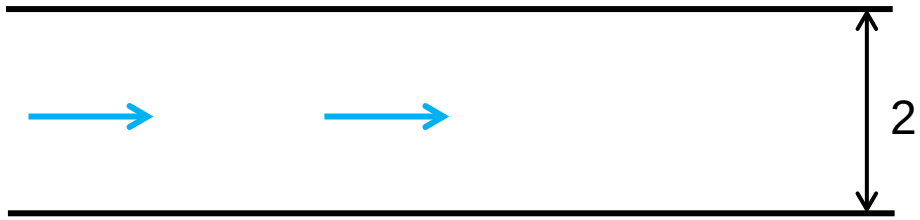

Voronoi



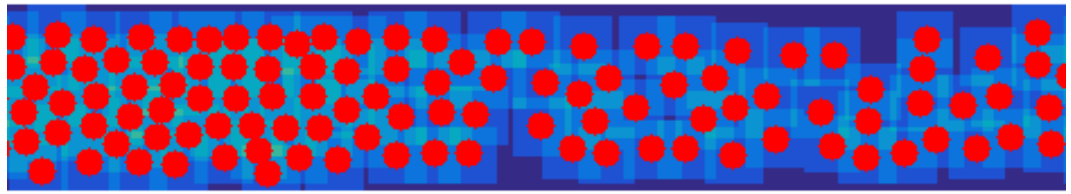

XT-method



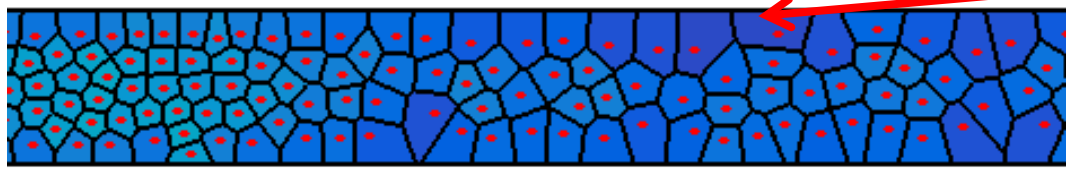
# Results – 2D-row




ρ = N / A

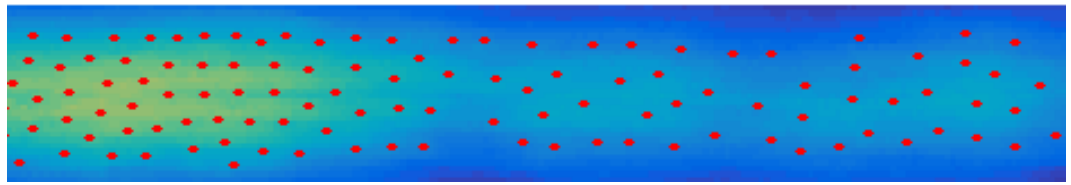


Voronoi



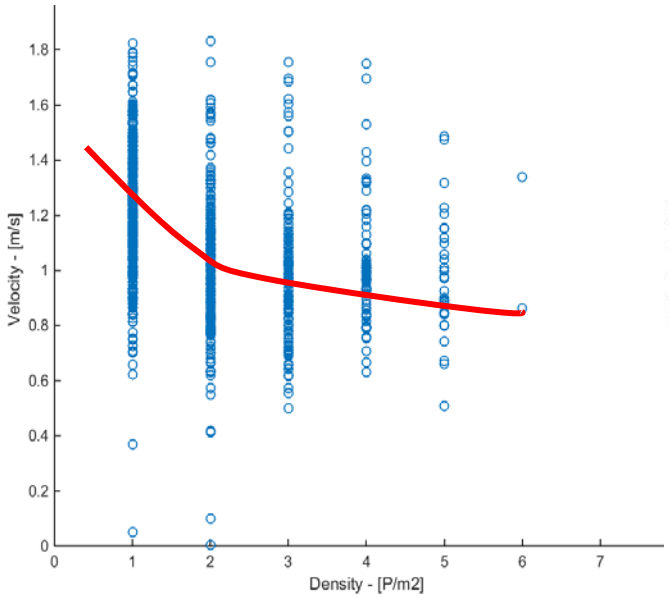
Dependence on the location of nearest other pedestrian

XT-method

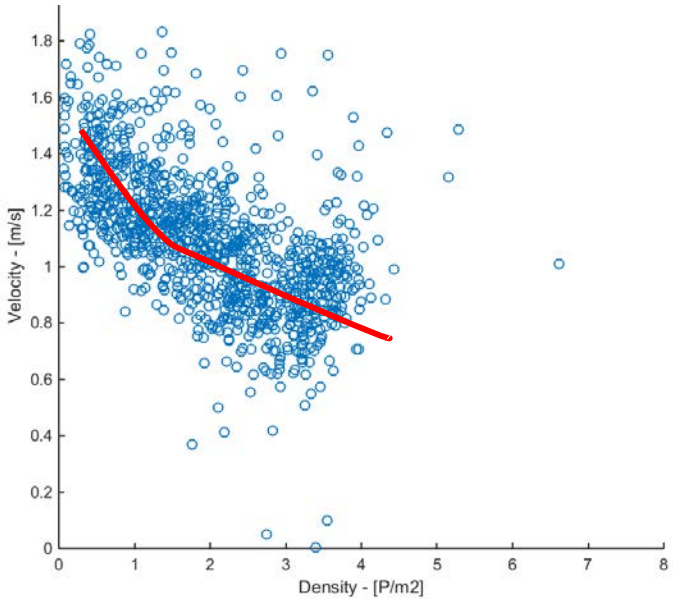


# Results – 2D-row

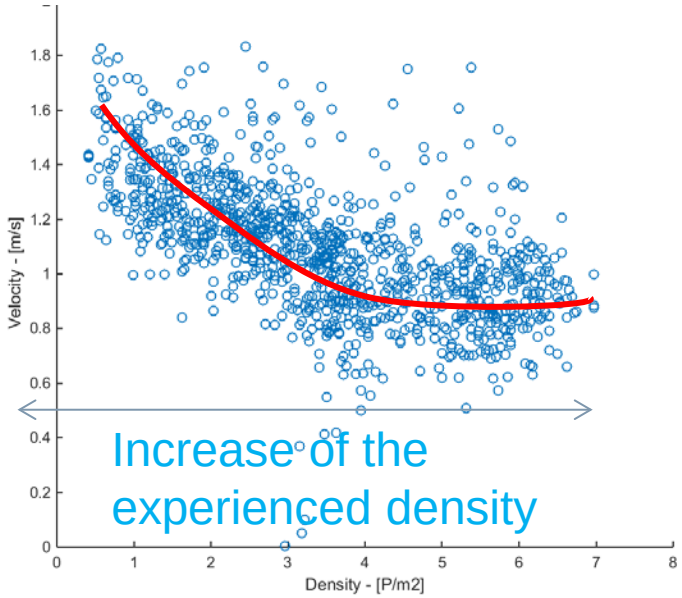
ρ = N / A




Voronoi




XT-method

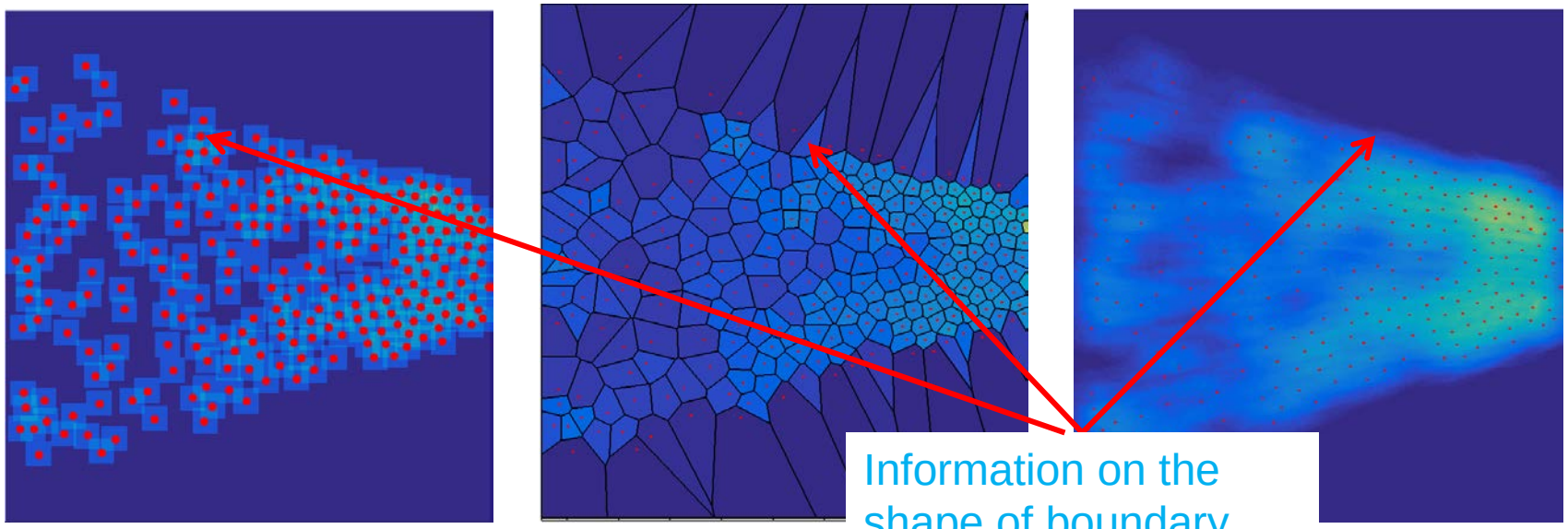


# Results – 2D-bottleneck


ρ = N / A

Voronoi

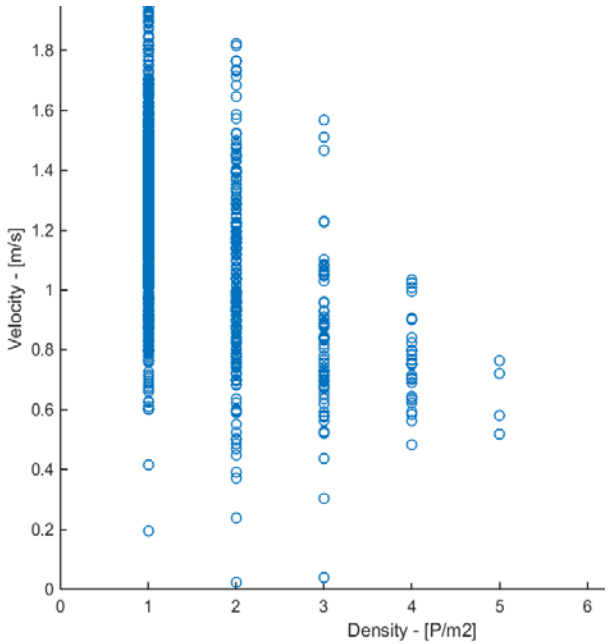
XT-method



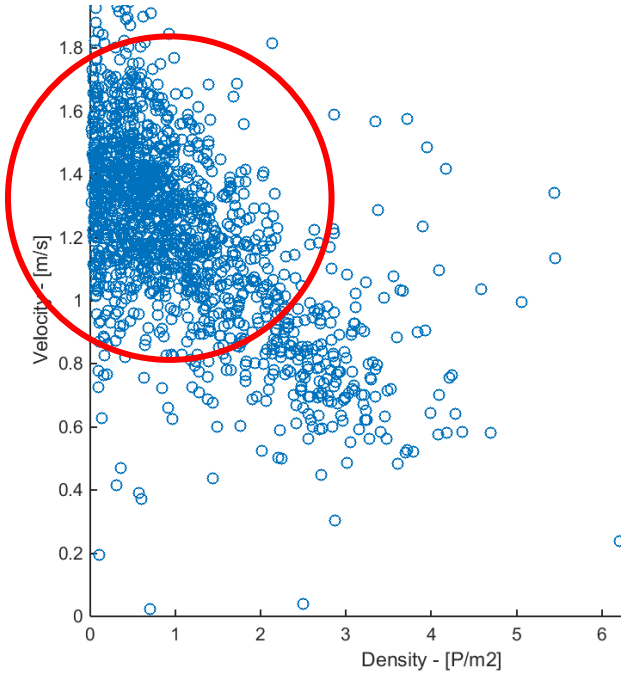
Information on the shape of boundary different per situation

# Results – 2D-bottleneck

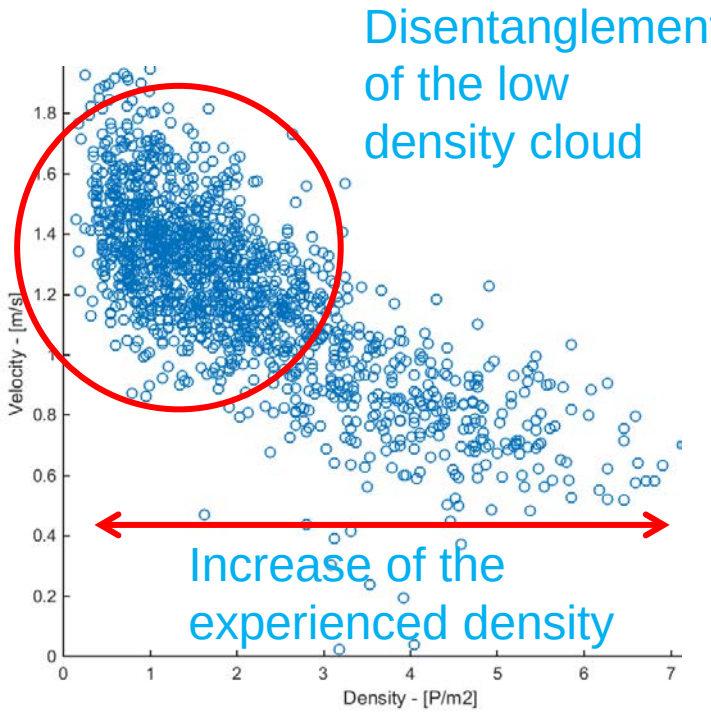
ρ = N / A




Voronoi




XT-method



# Conclusions

- Voronoi takes into account more space than is actually used by the pedestrian to move, as such introduction of noise and general underestimation of the density.

- Difference between the methods limited when boundaries of the infrastructure are more strict than the boundaries of the method.

# Conclusions

- In transitional situations where density changes quickly over time and space the XT-method catches these changes, while the for the Voronoi method this is dependent on the spatial distribution of pedestrians.

- Choice of the method dependent on the type of information one is looking for, and the stability of the situation.