Dense crowds

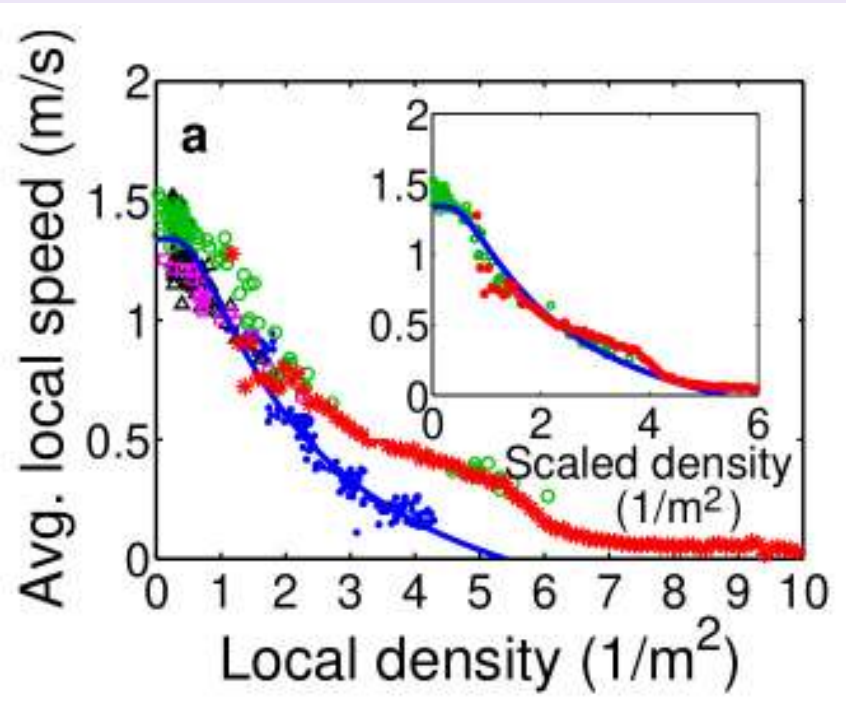
Jamaraat Bridge: more than a million people can gather in this area.

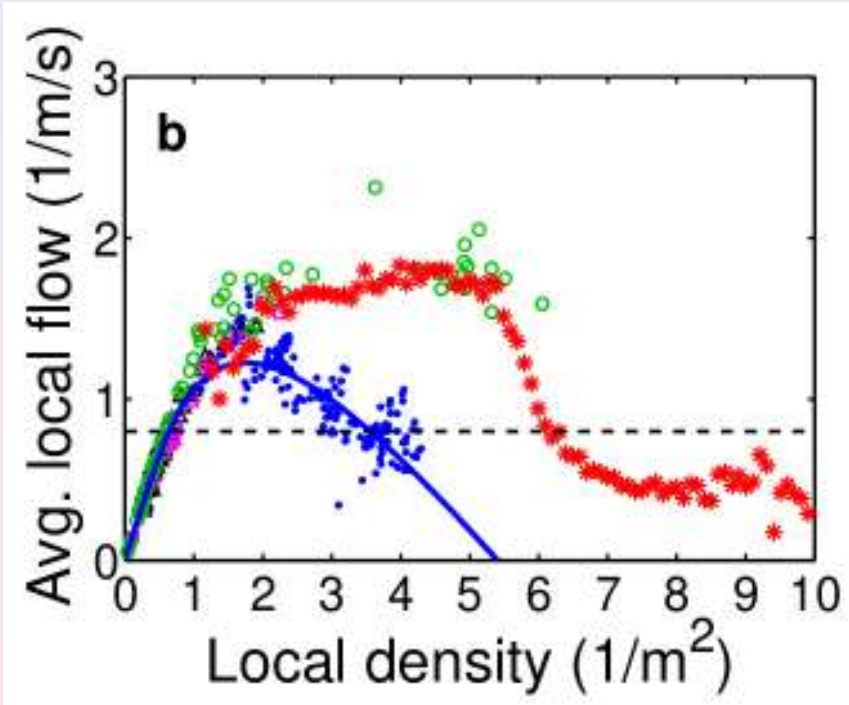
[Wikimedia, from saudipics, by Yasser Bakhsh]

4 levels - air conditioning

Dense crowds

From video analysis of crowd disaster in Mina/Makkah on January 12, 2006.

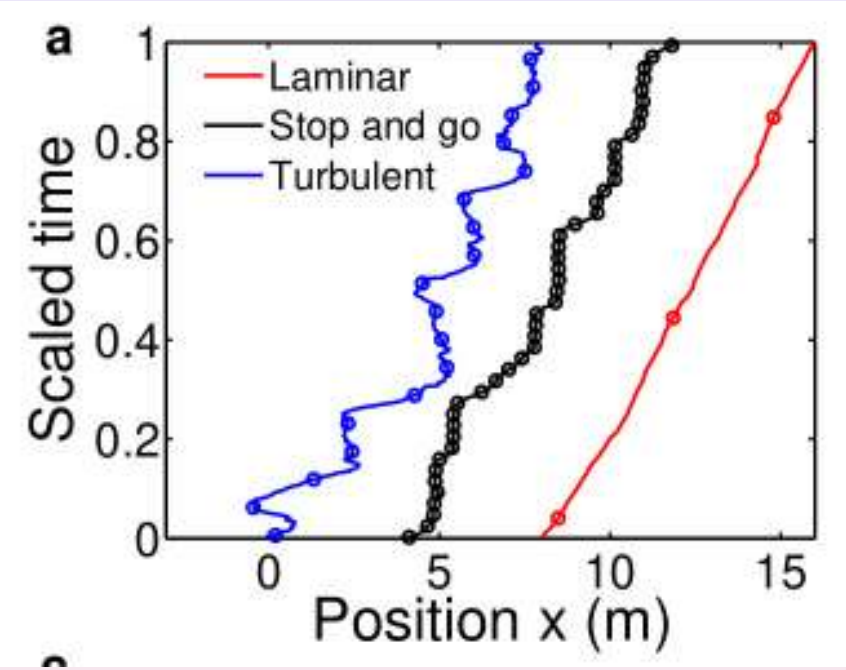


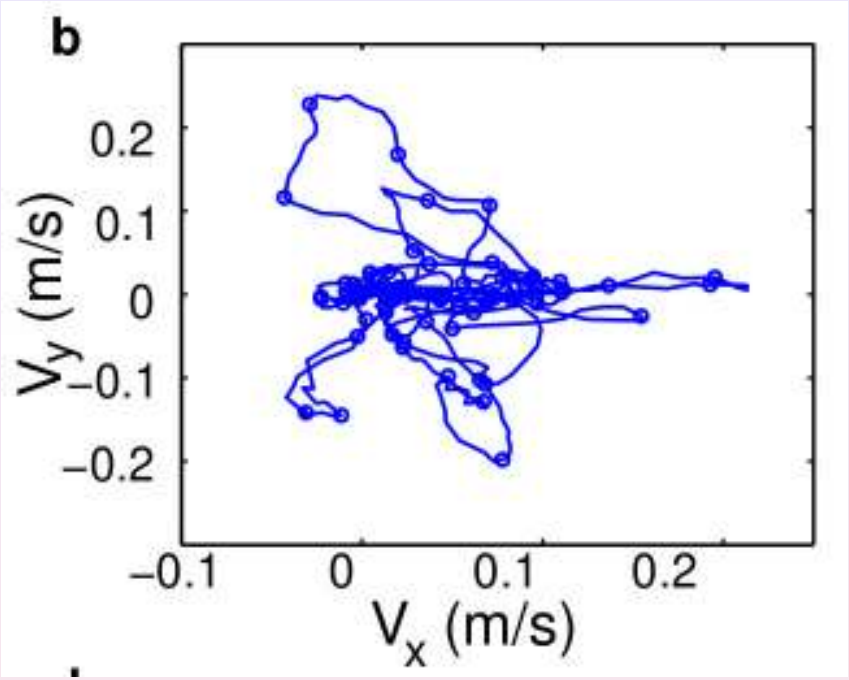


[Helbing et al (2007), "The Dynamics of Crowd Disasters: An Empirical Study"]

Dense crowds

From video analysis of crowd disaster in Mina/Makkah on January 12, 2006.





Typical trajectories.
1 symbol every 5s

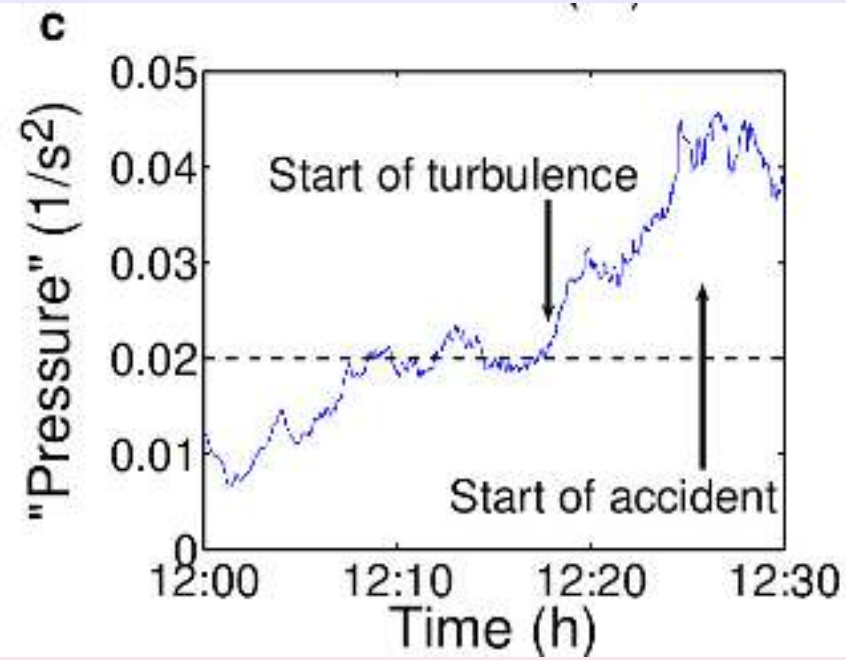
- laminar flow
- stop-and-go motion
- "turbulent" flow

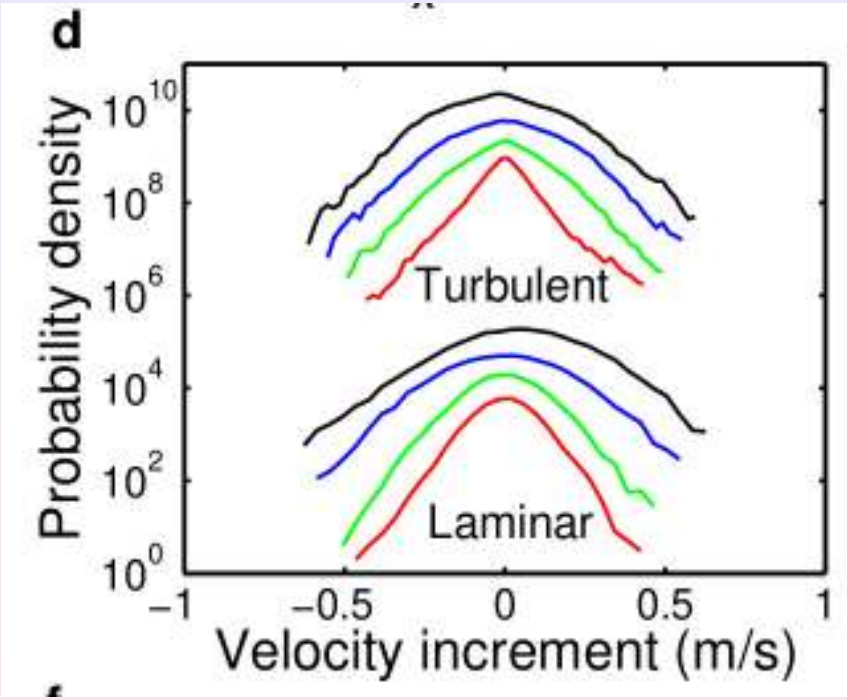
[Helbing et al (2007)]

In "turbulent" regime
$\mathbf{V}(t)$
1 symbol every 1s

Dense crowds

From video analysis of crowd disaster in Mina/Makkah on January 12, 2006.





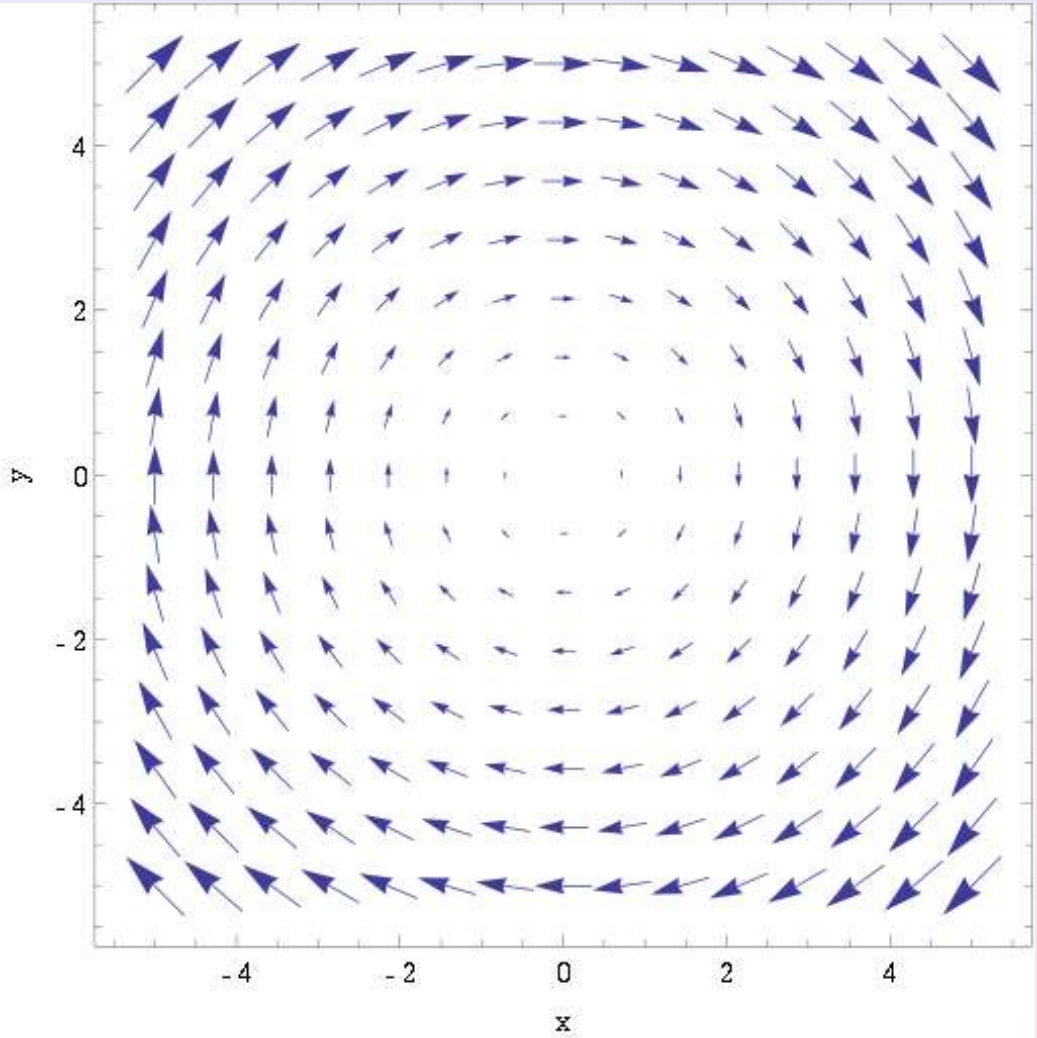
"Pressure" $P(t) = \rho(t)\, Var_t(V)$

- Probability density of velocity increment
  $V_x^\tau = V_x(\mathbf{r}, t+\tau) - V_x(\mathbf{r}, t)$
- laminar and turbulent regime

[Helbing et al (2007)]

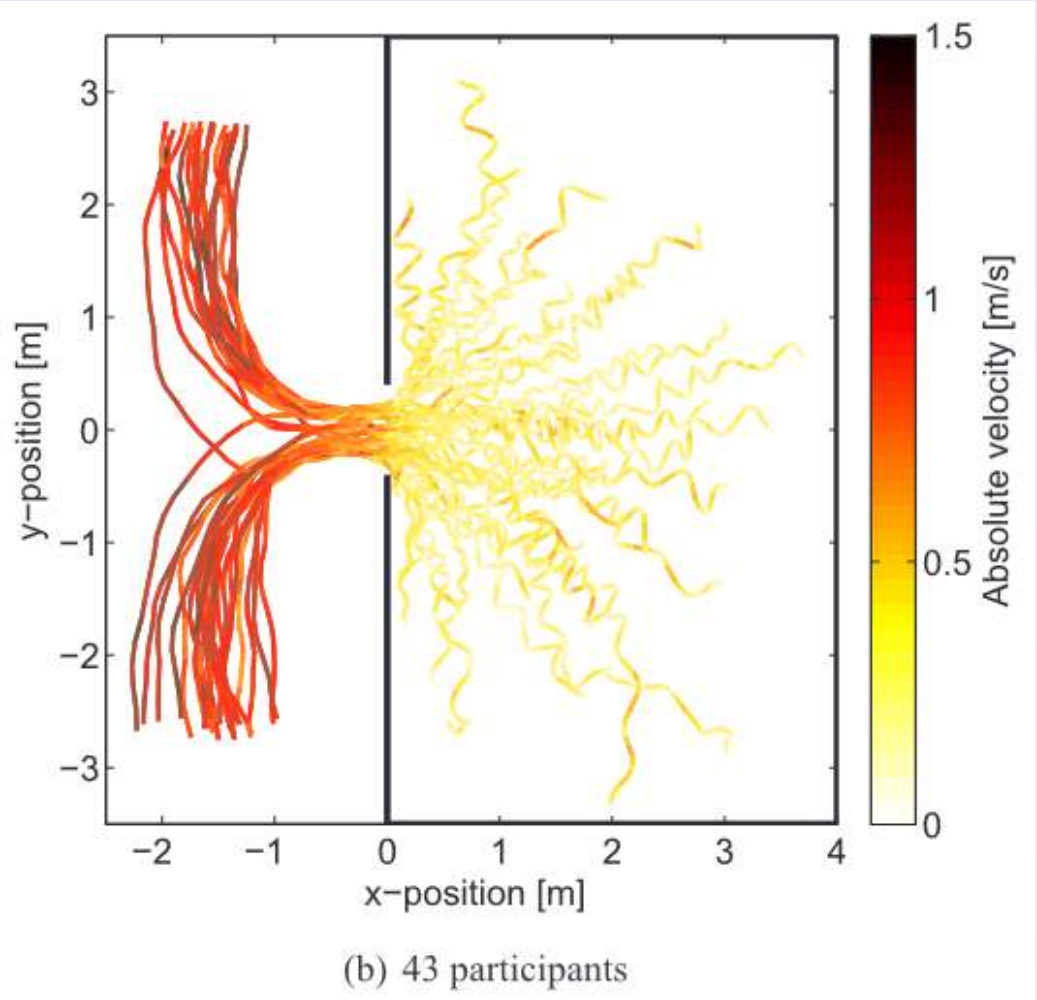
Dense crowds

Velocity field corresponding to a uniform vorticity.



From Wikipedia, by Loodog

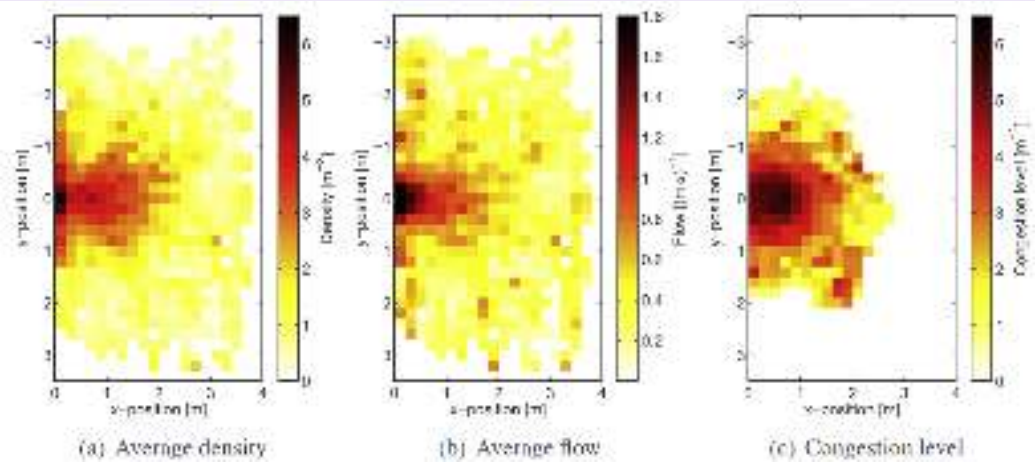
Dense crowds



(b) 43 participants

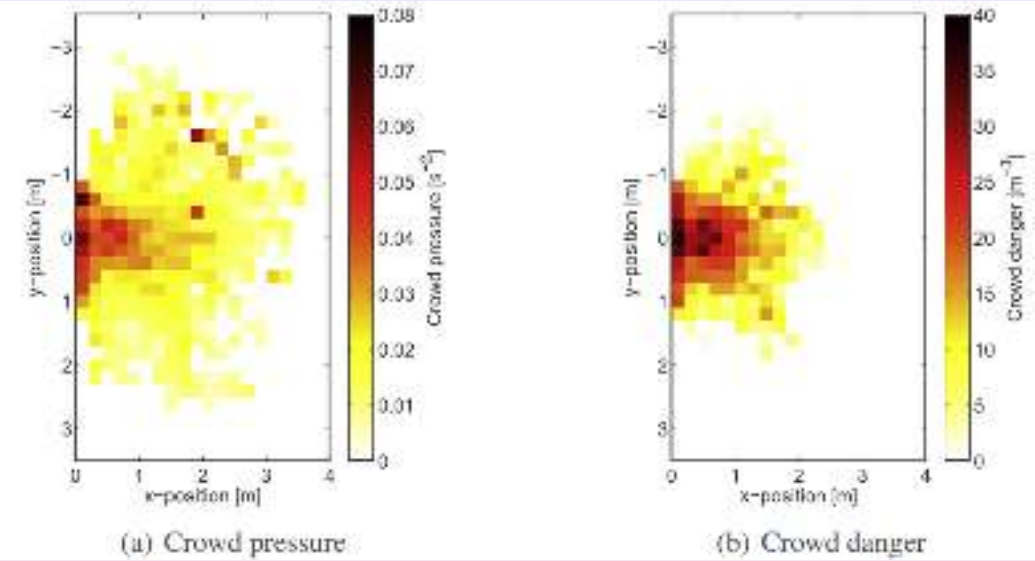
From [Feliciani and Nishinari 2018]

Dense crowds



From [Feliciani and Nishinari 2018]

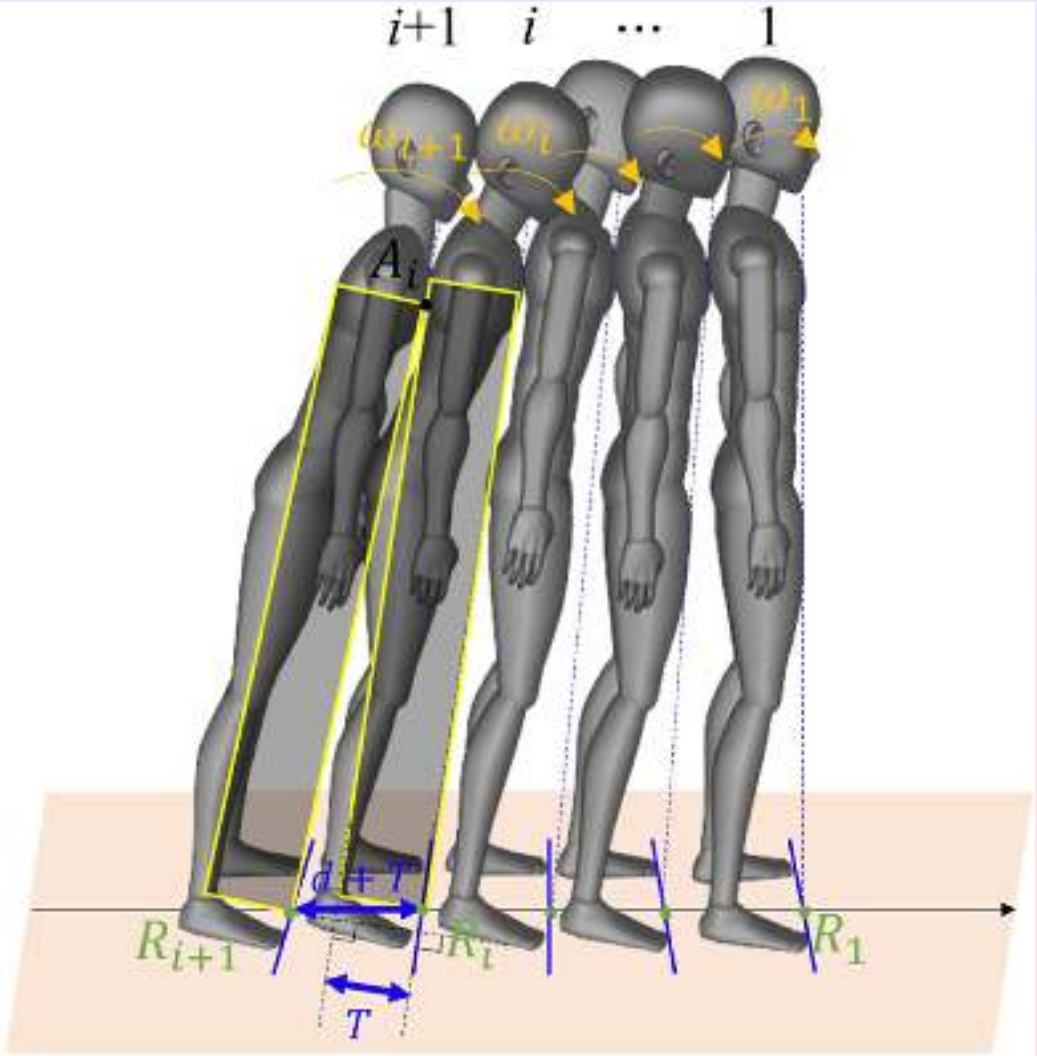
Dense crowds



From [Feliciani and Nishinari 2018]

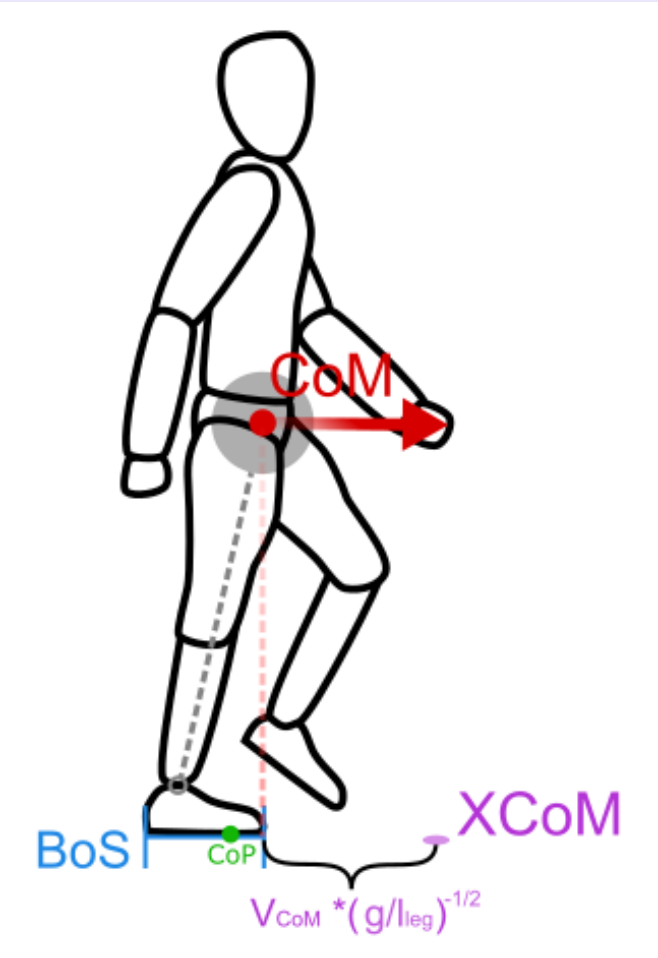
Dense crowds

Domino effect.



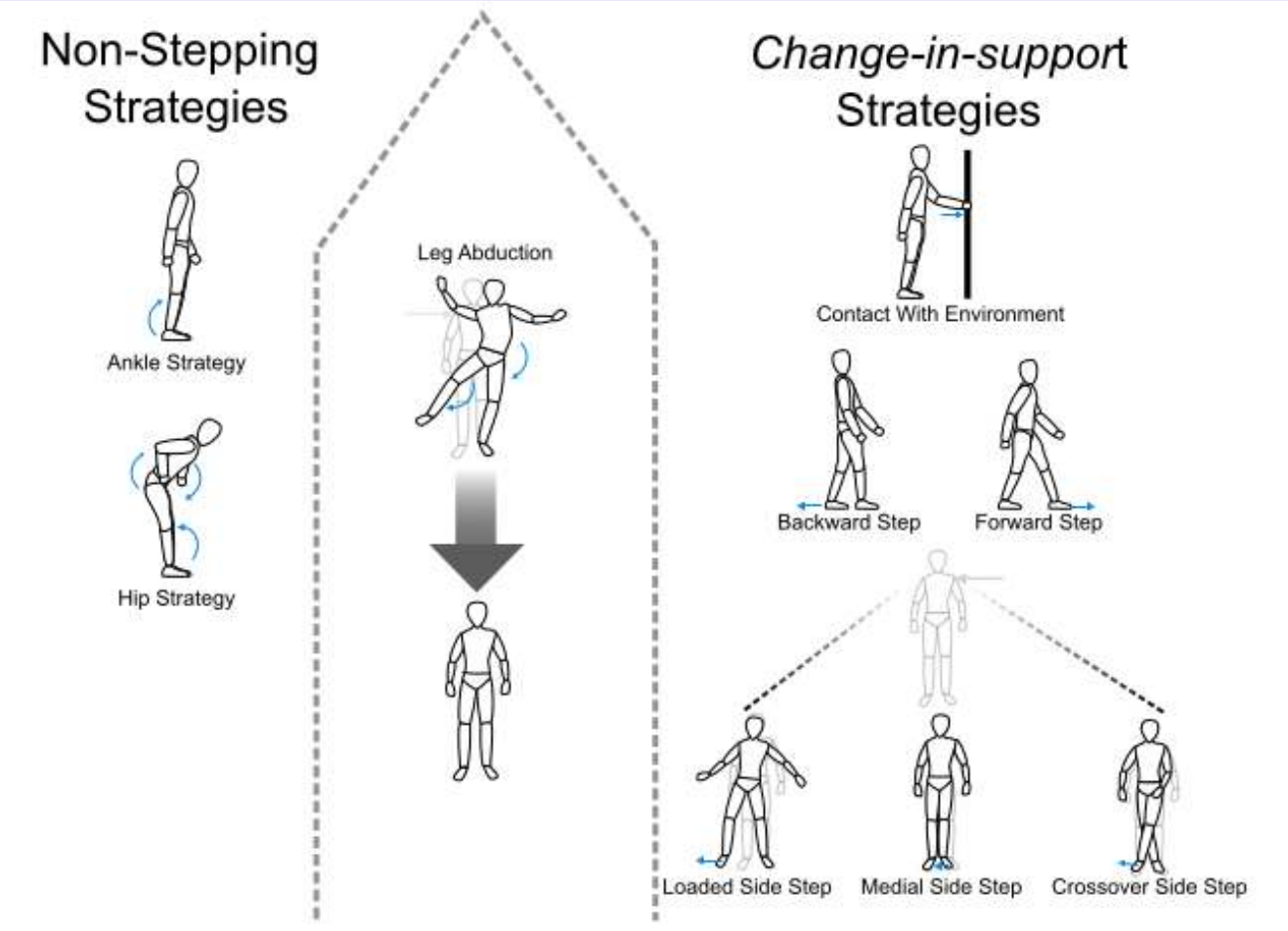
[Wang et al (2019)]

Dense crowds: Stability of pedestrians



[T. Chatagnon PhD thesis (2023)]

Dense crowds: Stability of pedestrians



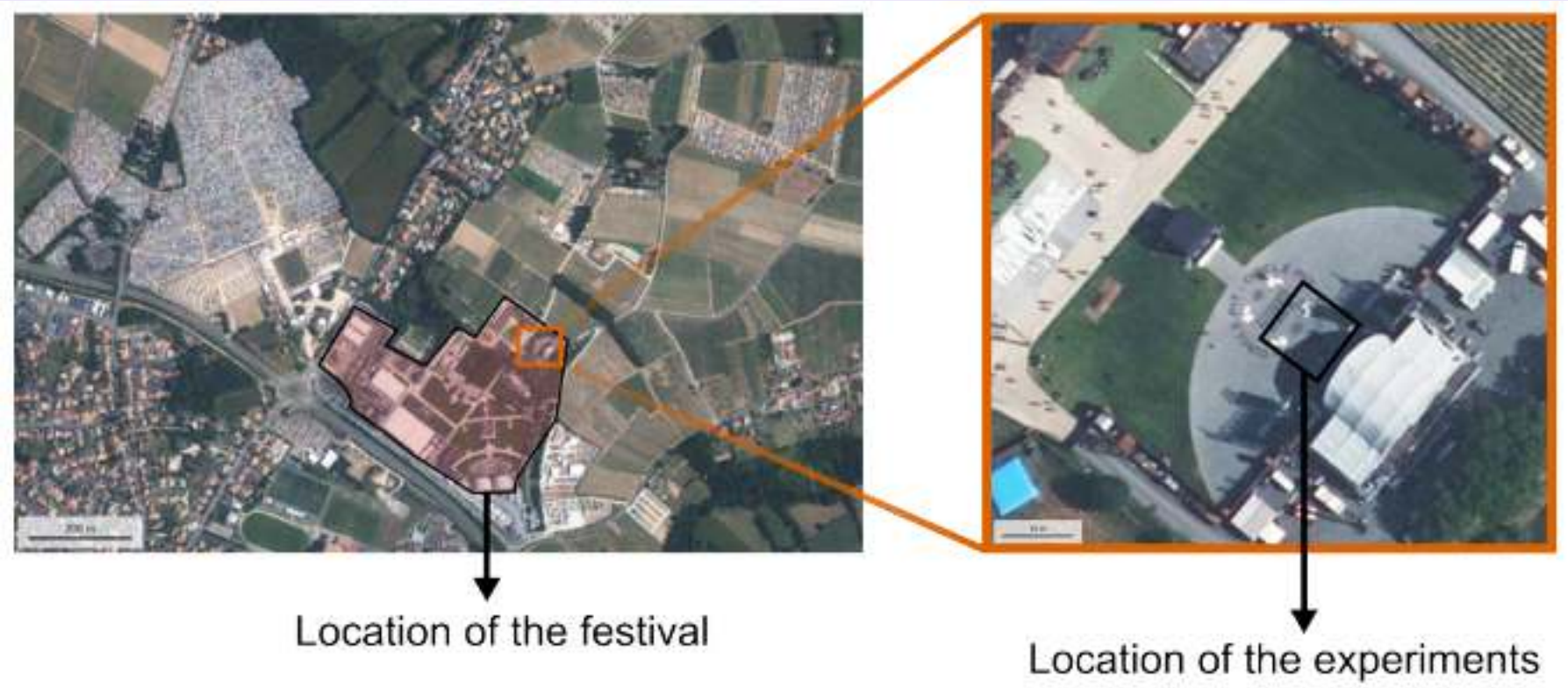
[T. Chatagnon PhD thesis (2023)]

Dense crowds: CrowdDNA project

Pushing experiments

Dense crowds: CrowdDNA project

Hellfest festival

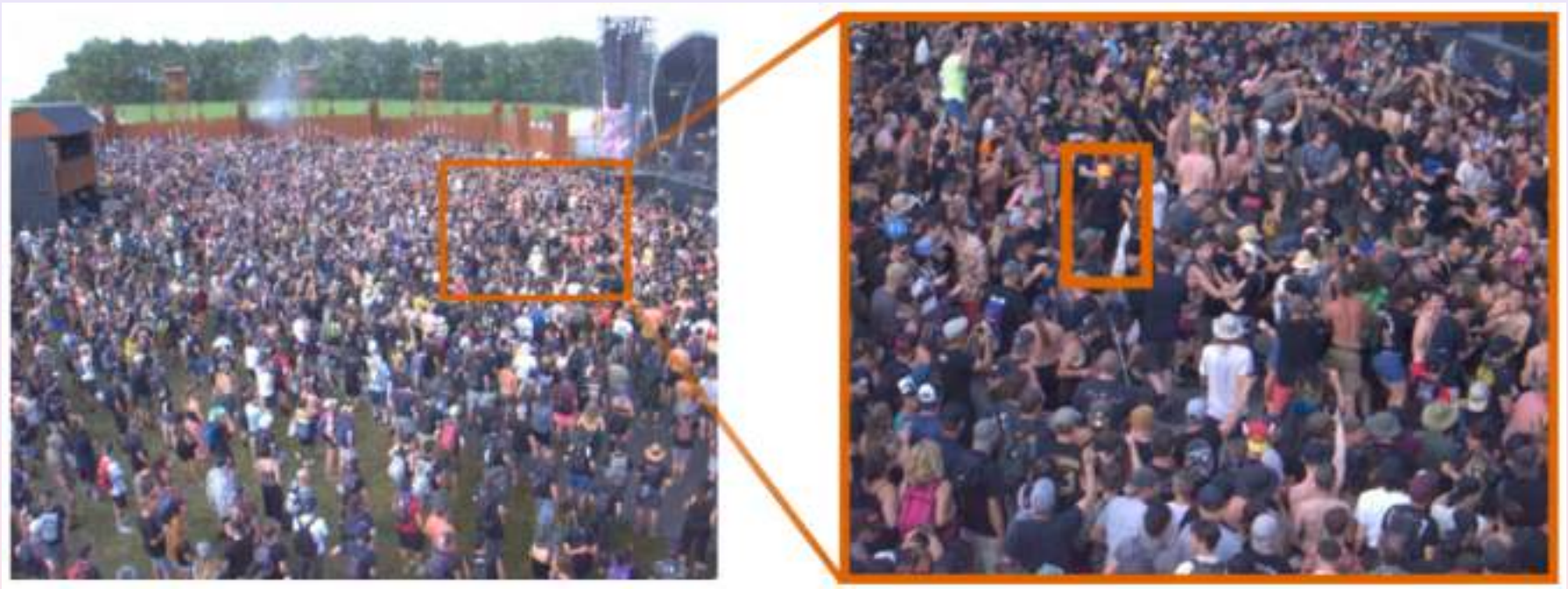


[T. Chatagnon PhD thesis (2023)]

Dense crowds: CrowdDNA project

[T. Chatagnon PhD thesis (2023)]

Dense crowds: CrowdDNA project



[T. Chatagnon PhD thesis (2023)]

Dense crowds