THE CROWD CONGESTION LEVEL - A NEW MEASURE FOR RISK ASSESSMENT IN VIDEO-BASED CROWD MONITORING

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Motivation

- Large scale events are an integral part of everyday life.
- Public events in urban areas become more and more polular and increase significantly in size, e.g.
  - Sport events (marathons, etc.),
  - public viewing of sports events,
  - Cultural events / festivals,
  - Political demonstrations
  - …

Challenge

- Safety and security agencies are facing new challenges, since many large scale events
- take place in open public (urban) areas,
- have with no dedicated entry/exit points as control gates.
- Become hard to control, due to the distri-buted complex complex urban infrastrucure.

Density Estimation & Flow Dynamics

- Our approach:
  - In general, **people** in crowded scenes are regarded as **endangered** in case of **too high** (absolute) **people density**.
    - Problem: **Absolute density** (e.g. no. of people per m²) is **very difficult to determine** from crowd videos.
  - But, **crowd density alone is not sufficient**, since (e.g. dense crouds at concerts or public festivals are not critical per se.
    - Our observation: If people can **move freely and smoothly** through a (dense) crowd → situation can be regarded as **non-critical**.
- Consequence:
  - Information on the **flow dynamics** should be taken into account **for risk assessment**.

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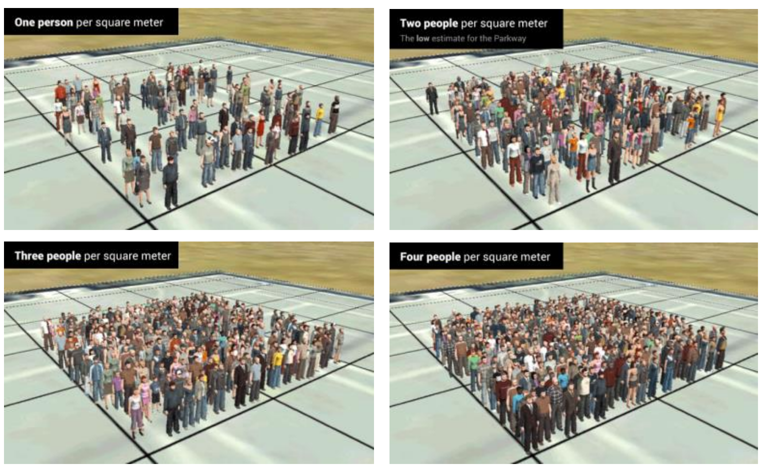
Proposed Method

- Assumption:
  - Local spot in the crowd might become critical, if the density is continuously increasing (relative density) over time
  - and simultaneously, a (significant) reduction of motion dynamics (increasing inertia) is observed.



SOURCES: U.S. Secret Service; Manchester Metropolitan University

Feature Tracklets

1. Harris Corner Detector [8] to detect local features of textures objects.

   $$\mathcal{F} = \{\mathbf{f}_1, \mathbf{f}_2, ..., \mathbf{f}_n\} \quad \text{with} \quad \mathbf{f}_i = (x, y)^T$$

2. For moving object detection, Lukas-Kanade optical flow is used to extract motion vectors of the detected features.

   $$\mathcal{V} = \{\mathbf{v}_1, \mathbf{v}_2, ..., \mathbf{v}_n\} \quad \text{with} \quad \mathbf{v}_i = (\Delta x, \Delta y)$$

2. In addition to filtering moving features

   $$\mathcal{F}' = \{\mathbf{f}_i \in \mathcal{F} \mid |\mathbf{v}_i| \geq \beta\} \text{ with } i = \{1, ..., n\}$$

   we extend the motion vector extraction by multi-frame feature tracking and for estimation of densities and dynamics.

Feature Tracklets

1. Extend existing trajectories by feature association (Euclidian distance between feature motion prediction and new detection).
2. If no previously created trajectories are found in a defined neighborhood
→ initialize new track.
3. If no new detection assigned to a track for several frames
→ delete track.

As a result: at each frame we obtain a set of tracks:

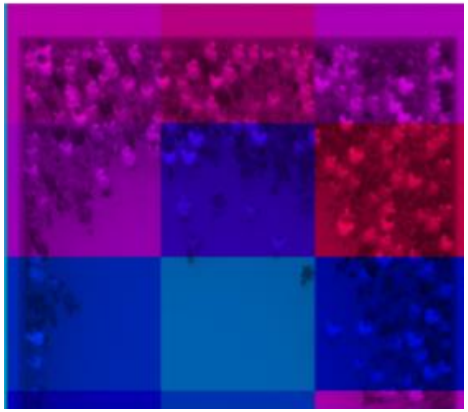
$$\mathcal{T}^k = \{\mathcal{T}_1^k, \mathcal{T}_2^k, ..., \mathcal{T}_m^k\} \quad \text{with}$$

$$\mathcal{T}_j^k = \{\mathbf{f}_\cdot^k, \mathbf{f}_\cdot^{k-1}, ..., \mathbf{f}_\cdot^{k-s_j}\}, j \in \{1, ..., m\}$$

Feature Tracklets and (Relative) Density Estimation

- Based on track information, we create statistics on **track density, dynamics** and **flow behavior**.
- To generate local statistics the image is split into smaller image patches $\mathcal{P}$ first, whereas $\mathcal{P}_r,\ r = \{1, ..., R\}$ represent the set of pixels of each patch.
- For each image patch the number of estimated persons (local density) is defined as

$$\mathrm{d}_r = \kappa \cdot |\mathcal{G}_r| \qquad [\frac{\text{persons}}{\text{patch}}]$$



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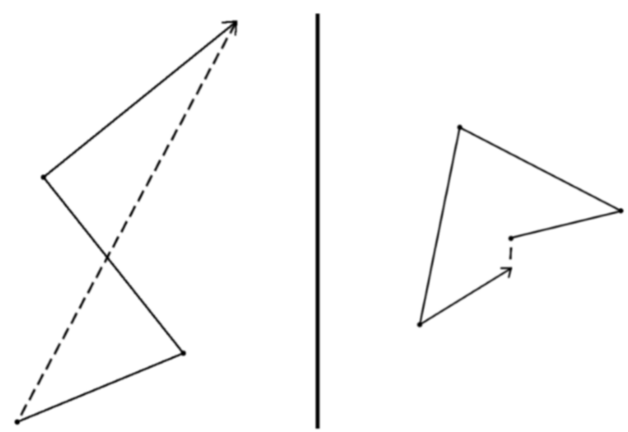
Feature Tracklets and Local Inertia

- In addition to track density, motion dynamics in each patch is measured.
- The dynamics we want to measure, is potential free moving space of individuals.
- We estimate this measure by the average ex-centric direct motion of all tracks, because congestions can be interpreted as a discontinuity in track flow, which equals low ex-centric dynamics.
- We define *Local Inertia* as:

$$\mathrm{i}_r^k = \frac{1}{|\mathcal{G}_r'|} \sum_{\forall \mathbf{f} \in \mathcal{G}_r'} ||\mathbf{f}^k, \mathbf{f}^{k-q}||_2 \qquad [\frac{\text{px}}{q \cdot \text{frame}}]$$

with $\mathcal{G}_r' = \{\mathcal{T} \in \mathcal{G}_r \mid |\mathcal{T}| \geq q\}$.



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The Congestion Level

- We believe that a situation in a crowd can be regarded as potentially dangerous, if
  - **density continuously increase**, exceeding a certain threshold, and
  - at the same time **flow dynamics decreases** (overcrowded space).
- In order to obtain **normalized coefficients** for relative density and relative flow inertia, extrema have to be determined.

$$i_r^{rel,k} = I_{min}/i_r^k \qquad d_r^{rel,k} = d_r^k/D_{max}$$

minimum mean object speed (jam)

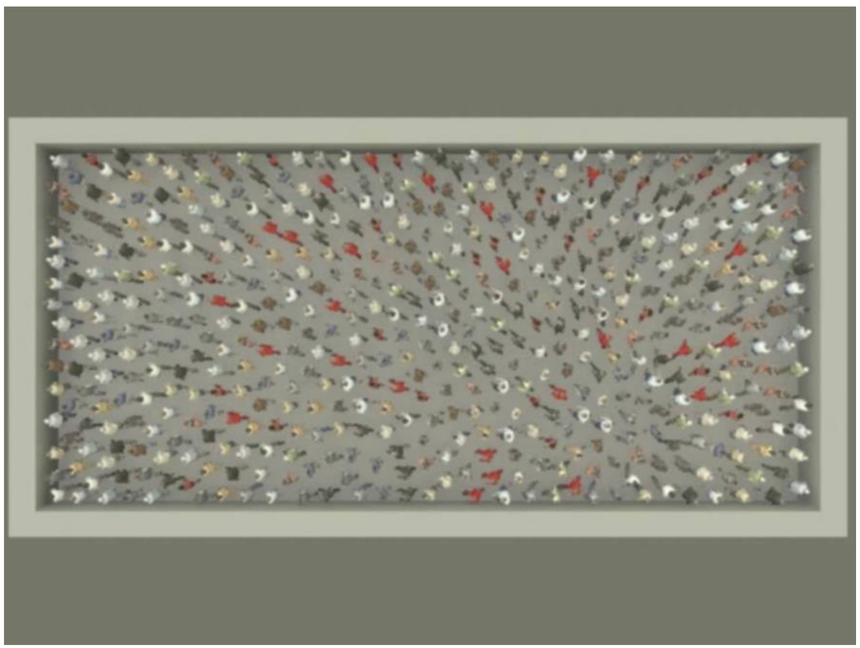
Max. density in a patch

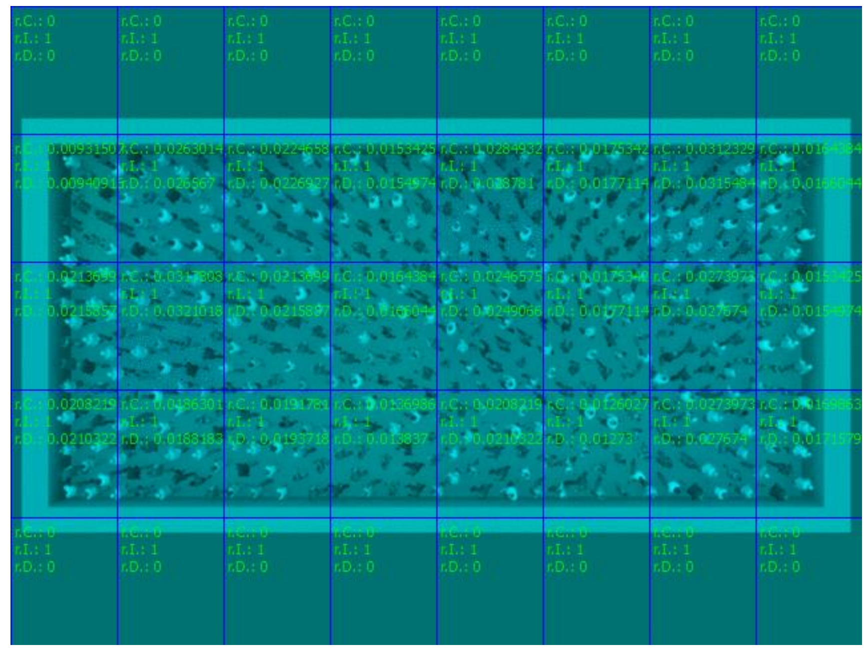
- To measure the risk level for the people in the crowd, we propose a combined coefficient, we call **congestion level** (cl):

$$cl = d^{rel} \cdot i^{rel} \quad \text{with: } cl \in \{0..1\}$$

Results on Artificial Datasets

- Artificaldataset:AGORASET/Dispersion





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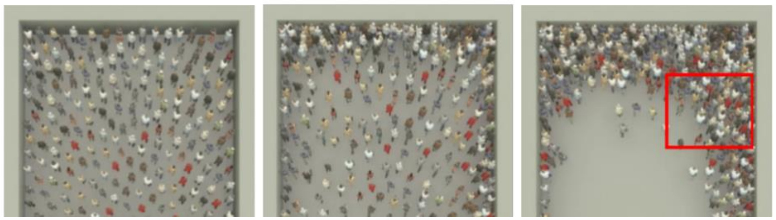
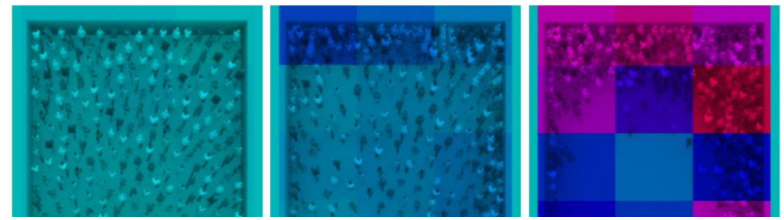
Results on Artificial Dataset AGORASET/Dispersion



a) Img. No. 01 b) Img. No. 30 c) Img. No. 87



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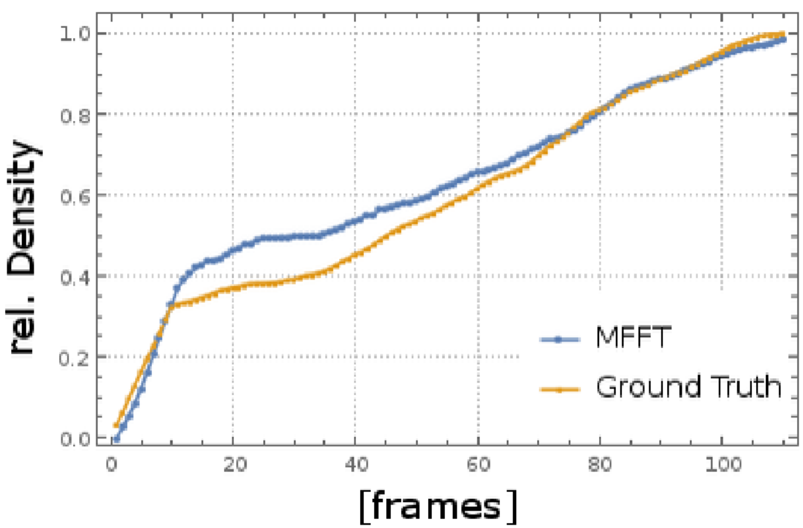

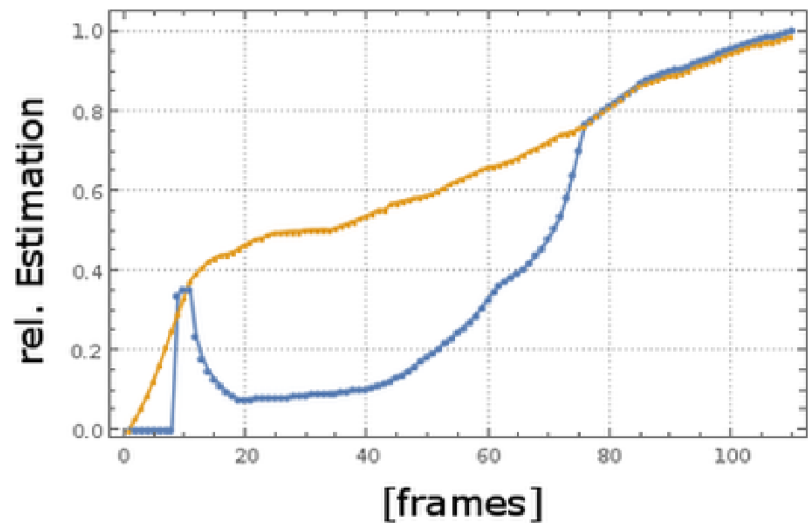

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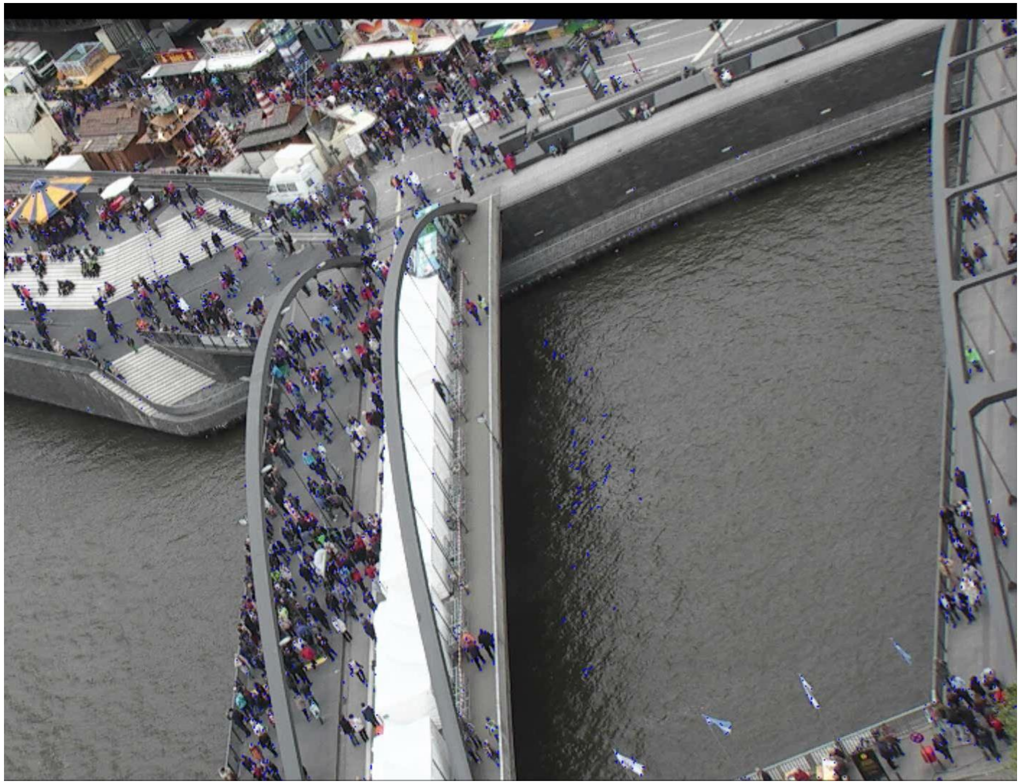
Outlook: Real-TimeEvaluations at Hamburg Habour Festival 2017-2019



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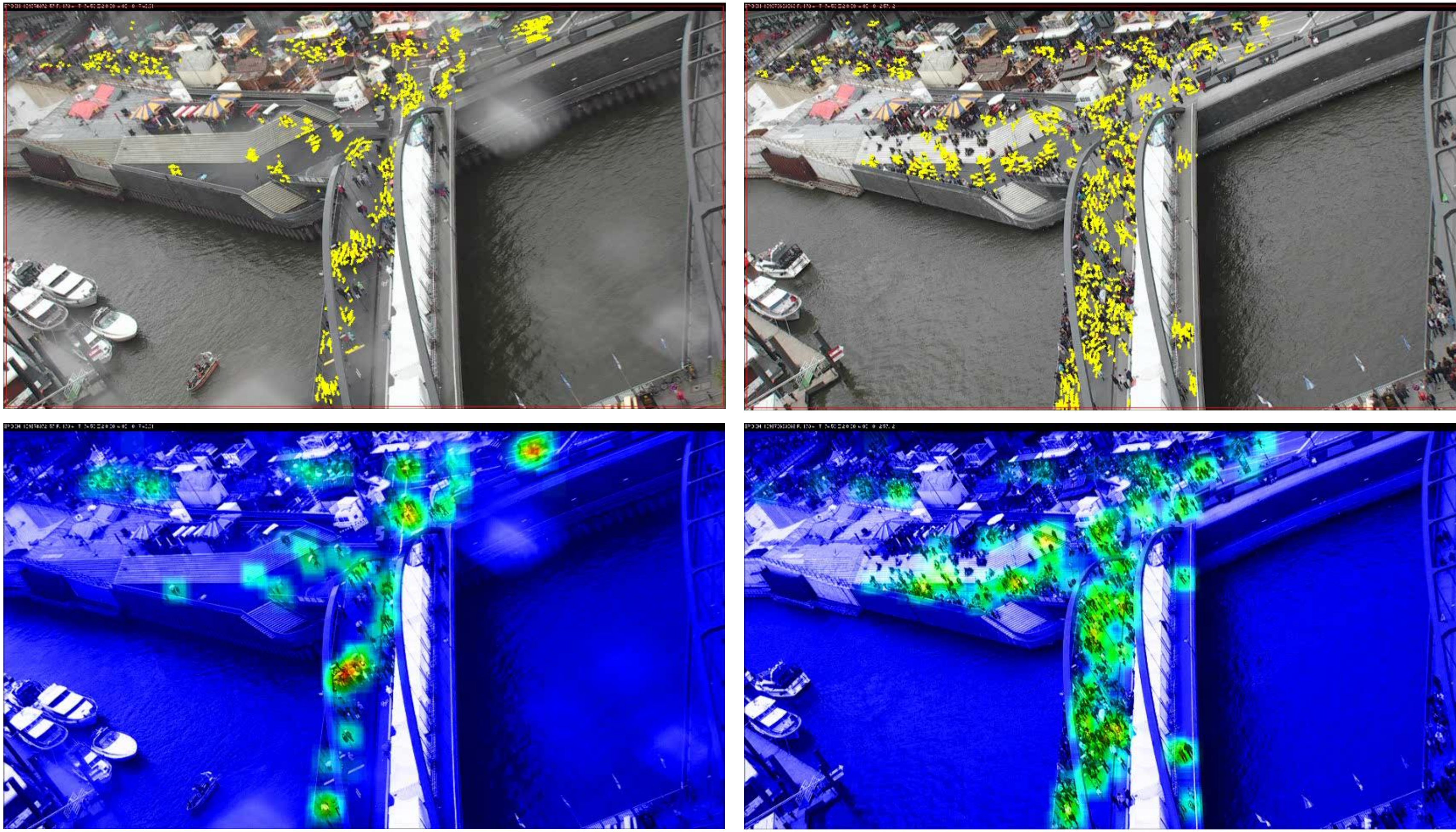

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Conclusions

- We **proposed a characteristic measure** for density-related risk assessment in crowd analysis, we call **Congestion Level**.
- This **measure indicates the endangering of local areas** in a crowd, due to
  - increasing people density and
  - simultaneous reduction of motion dynamics.
- It has been shown that the proposed Congestion Level **provides a suitable measure risk assessment** of crowed dynamics and density.

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Outlook

- As future work, we plan
  - to increase training data for determination of absolute normalization factors
  - Take into account camera calibration parameters to allow for absolute density and inertia estimation.
  - Work towards self-parametrization of the overall approach.
- Also, we plan to perform
  - user studies with safety and security personnel (crowd manager)
  - System trials on large events (in 2017-2019, proof of concept at Hamburg Habour Festival (1.5 Mio people over weekend).

THANK YOU FOR YOUR ATTENTION!

Contact & Support

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