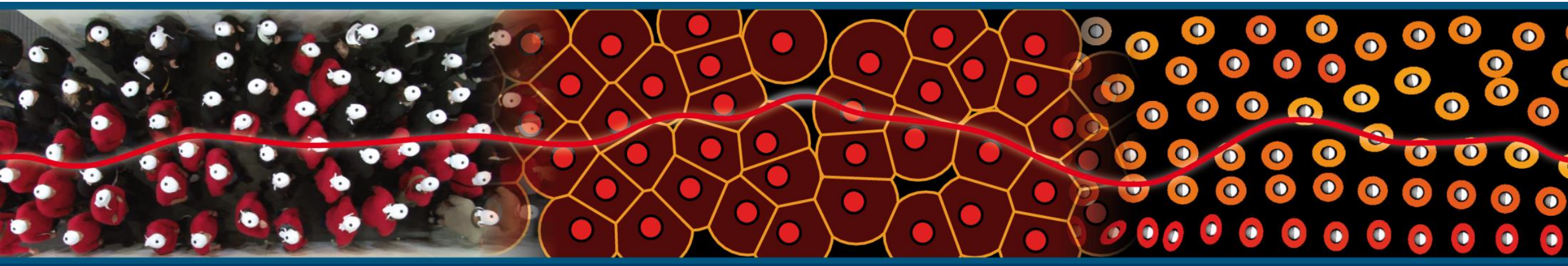
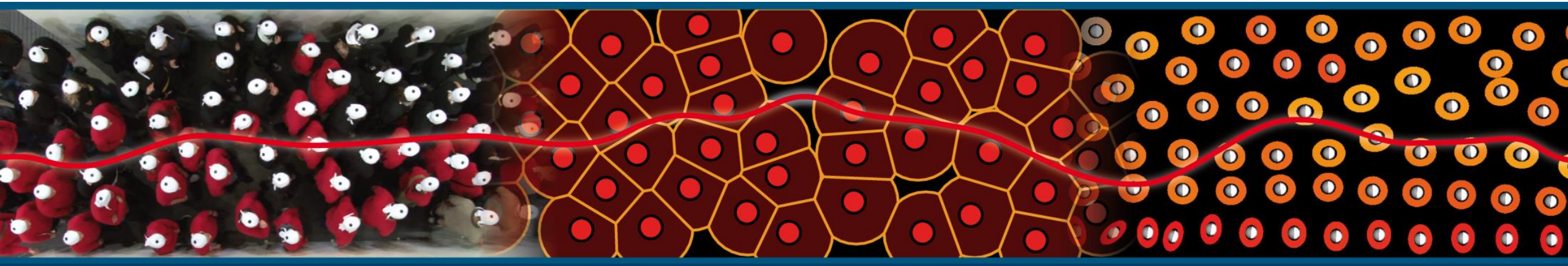


3D Motion in Crowds & FAIR Data

At Research Day On Crowd Management

Maik Boltes - 18 February 2025
Forschungszentrum Jülich, Institute for Advanced Simulation, IAS-7: Civil Safety Research, Germany



3D Motion in Crowds

Goal

- **Increase of Safety,** e.g. of escape routes, **Comfort,** e.g. design of transport infrastructures and **Performance,** e.g. throughput of facilities
- **Computer simulations** are the most general method for optimizing pedestrian streams
- **Reliable empirical data** of pedestrian movement are necessary

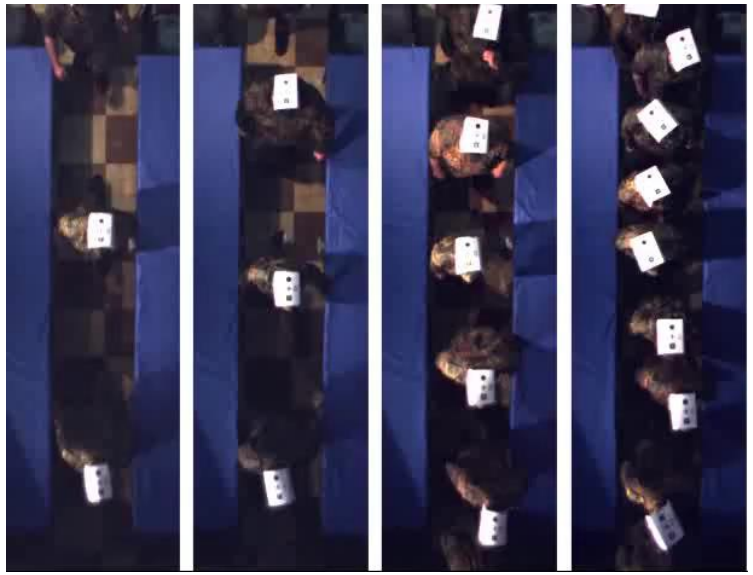
→ **Analyze** pedestrian dynamics

→ **Understand** PED

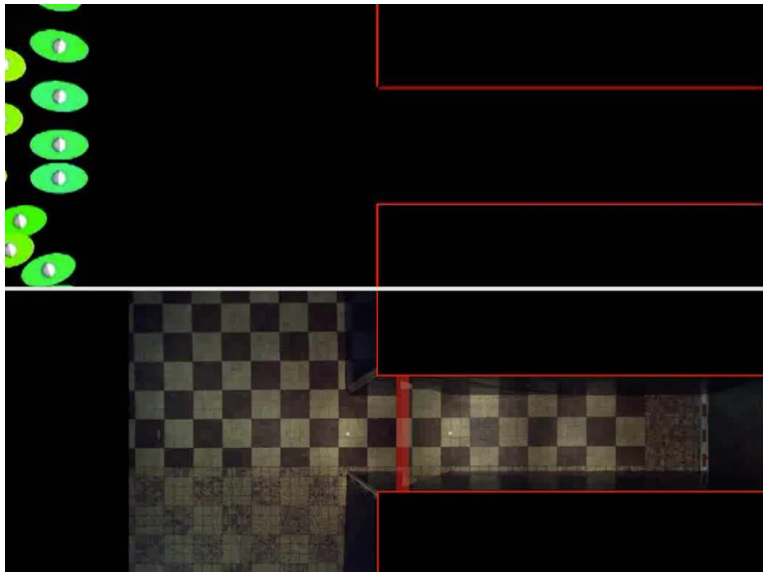
→ **Model design**

→ **Model calibration**

→ **Model validation**



[Andrea Portz]

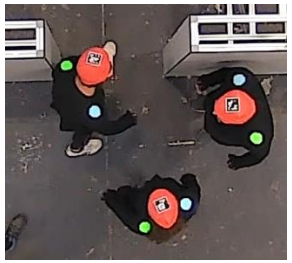


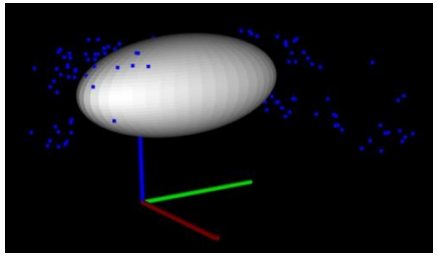
[Mohcine Chraibi]

Body Motion Capturing

Shoulder orientation by

- **Single IMU** [Jette Schumann]
- **Shoulder marker** [Ann Katrin Boomers]
- **3D cameras**
- **ML** like **YOLO*pose**





[Deniz Kilic]

[Alaa Khater]

Full body motion capture (mocap) system setup: (optical systems are not usable in crowds due to the missing line of sight to markers)

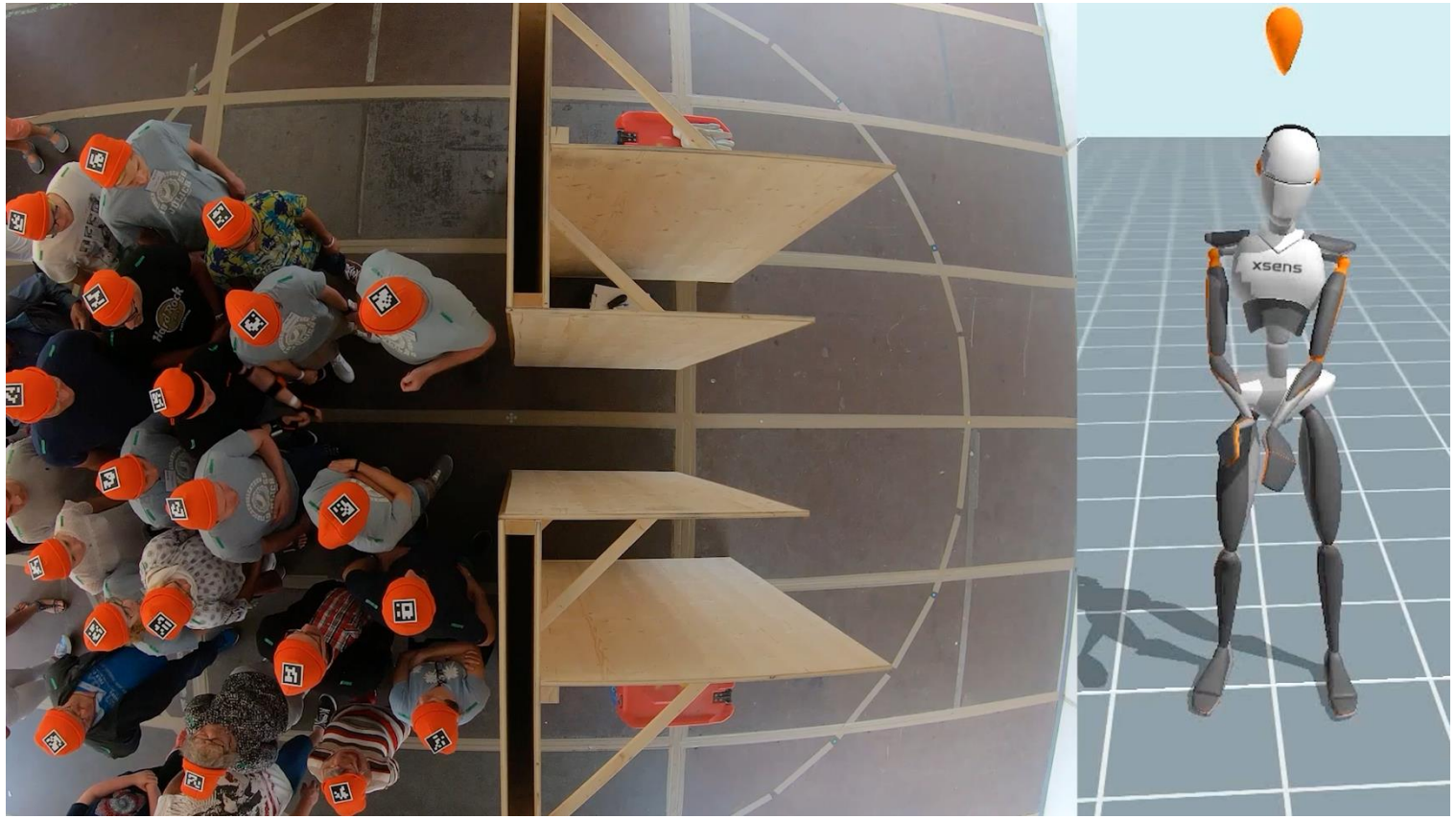
- **Inertial measurement units (IMU)** at differentiable segments (measuring): Accelerometer (acceleration), Gyroscope (angular rate), Magnetometer (magnetic field)
- **Biomechanical model** of human skeleton incl. sensor fusion

[Xsens]

3D Full Body Motion Capturing Systems

Capturing body motion in crowds for e.g. shoulder orientation, arm and foot position, gait, bobbing:

- **Describe/Understand effects** like integration into bottlenecks, physical interaction, passing or overtaking, body posture inside dense crowds
- **Enable reliable 3D models** e.g. bipedal models or models considering body orientation and expansion

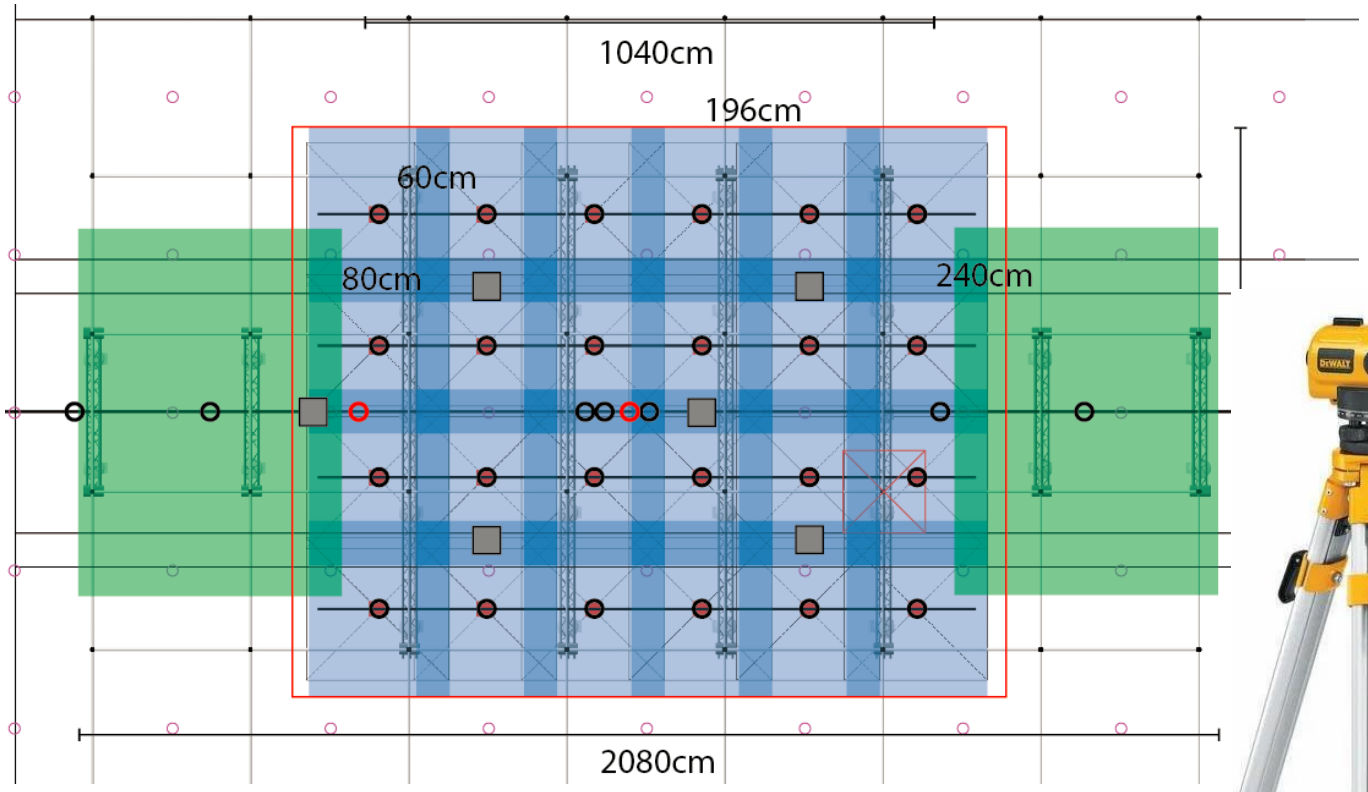


Sensor Fusion

Calibration and Synchronisation

Fusion of data from different sensors needs

1. **Spatial calibration** by a shared world coordinate system of extrinsic calib., e.g. for camera grid



Sensor Fusion

Calibration and Synchronisation

Fusion of data from different sensors needs

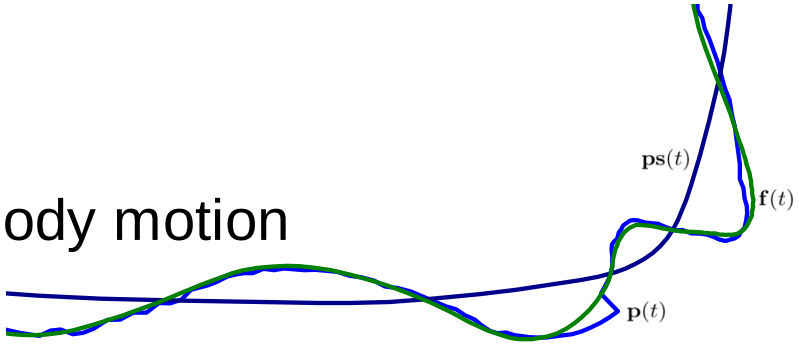
2. **Time synchronization:**
   - **Manually:** abrupt motion, switched light,
     best: audio like clapping, record global absolute time
     (together with internal time or within video recording)
     (no frame accurate sync possible)
   - **Automatically:** for industrial cameras:
     shared bus (Firewire), computer software (e.g. PointGrey);
     for camcorder: Tentacle, Sony Camera Control Box for RX0

3. **Person mapping**

Sensor Fusion

Hybrid tracking system

Fused trajectory places 3D full body motion into camera coordinate system

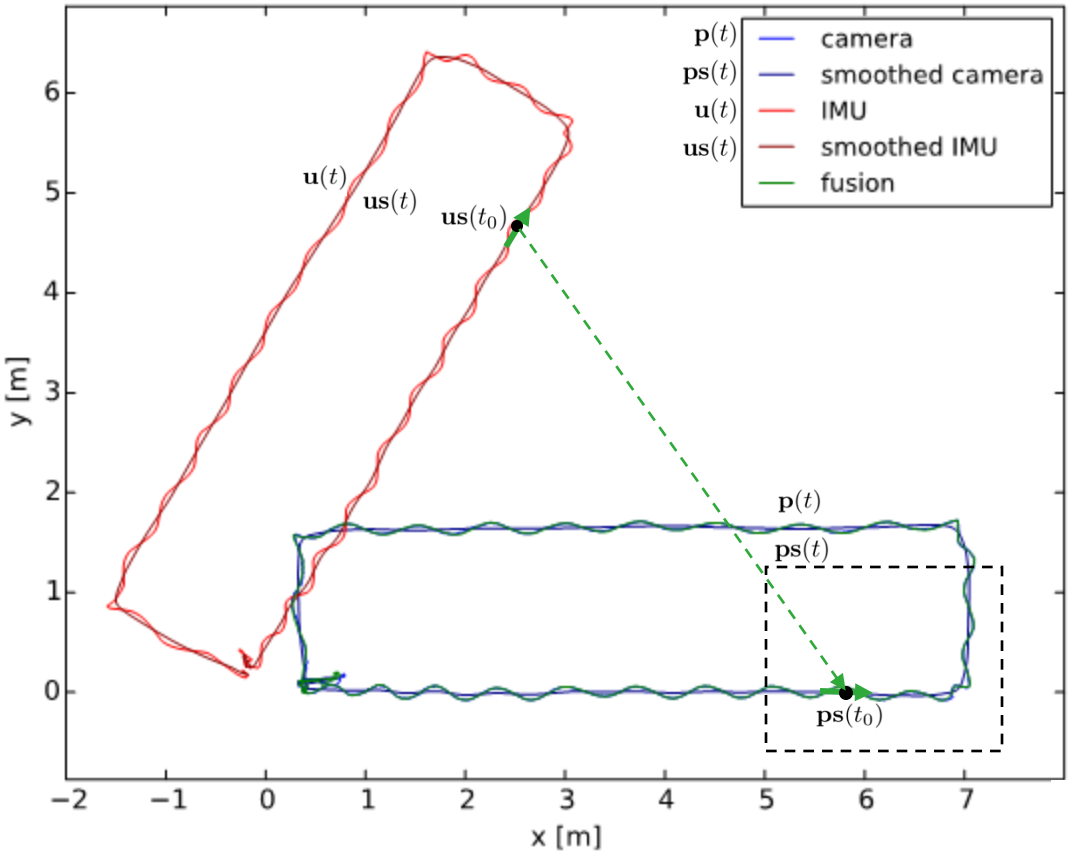


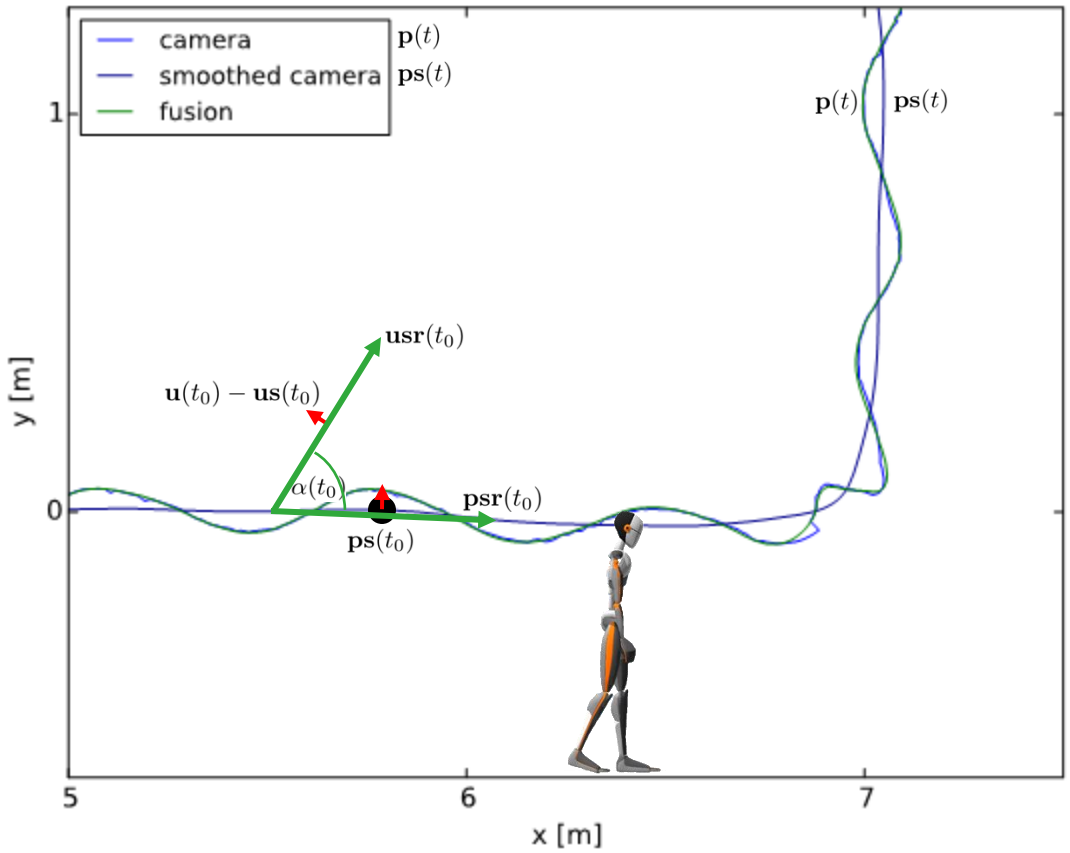
$$\mathbf{psr}(t) = \mathbf{ps}(t + \Delta t) - \mathbf{ps}(t - \Delta t)$$

$$\mathbf{usr}(t) = \mathbf{us}(t + \Delta t) - \mathbf{us}(t - \Delta t)$$

$$\alpha(t) = \frac{\langle \mathbf{psr}(t), \mathbf{usr}(t) \rangle}{\|\mathbf{psr}(t)\| \|\mathbf{usr}(t)\|}$$

$$\mathbf{f}(t) = \mathbf{ps}(t) + \mathbf{R}(\alpha(t))(\mathbf{u}(t) - \mathbf{us}(t))$$

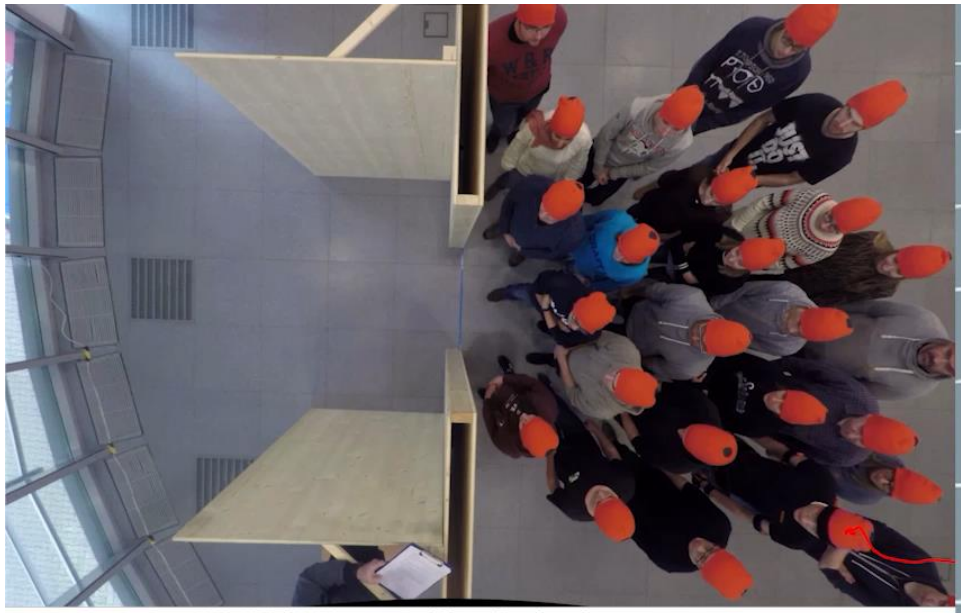


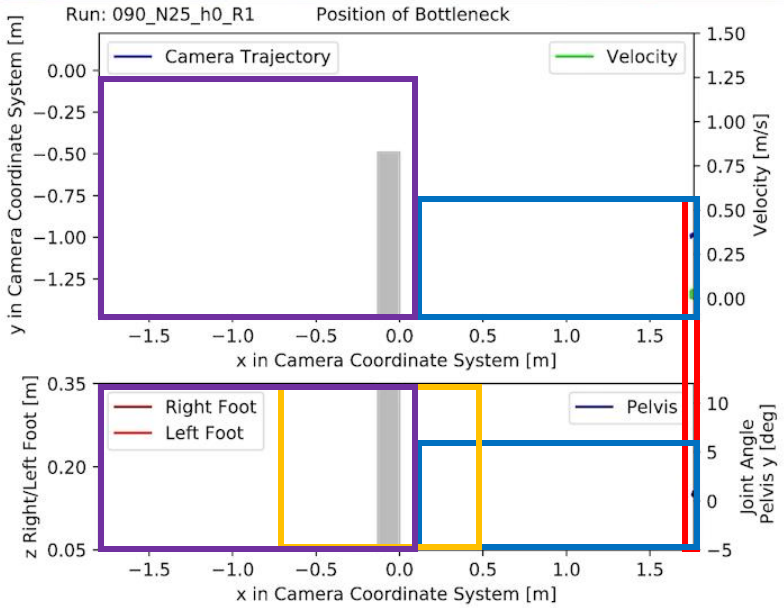


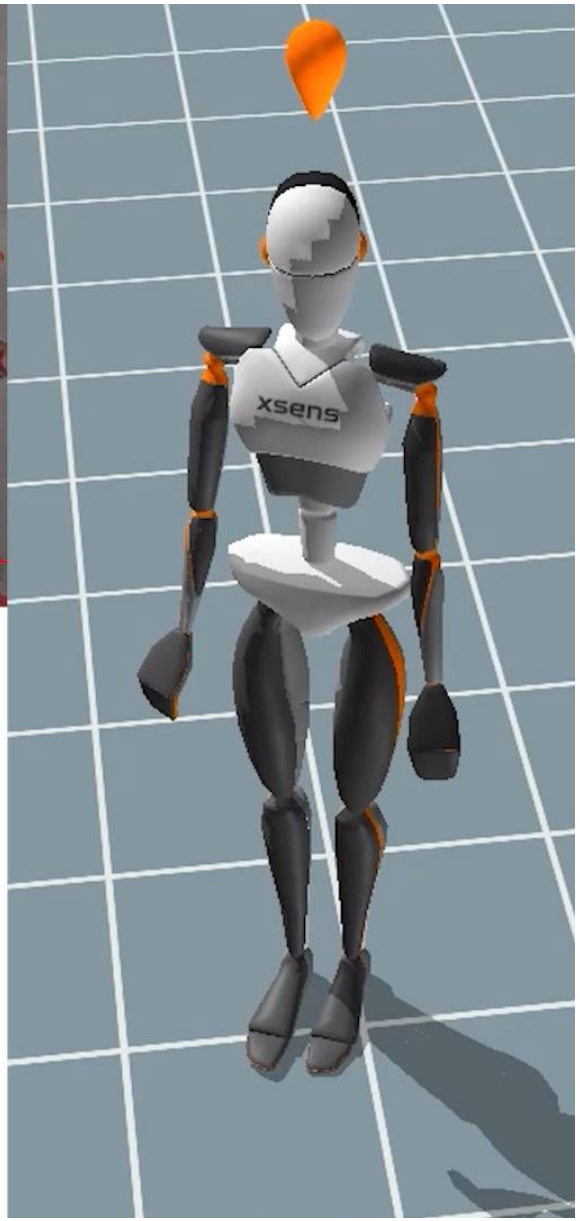
[Boltes et al.: A Hybrid Tracking System of Full-Body Motion Inside Crowds, Sensors 21(6), 2108 (2021), DOI: 10.3390/s21062108]

Passing Bottleneck

Width: 0.9 m
Motivation: high



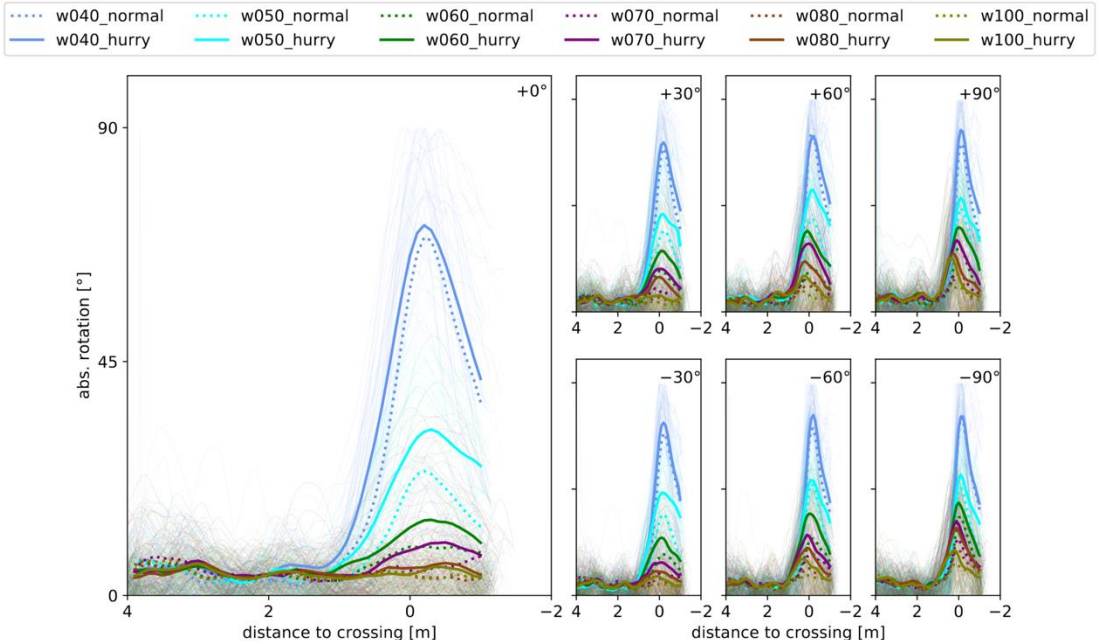


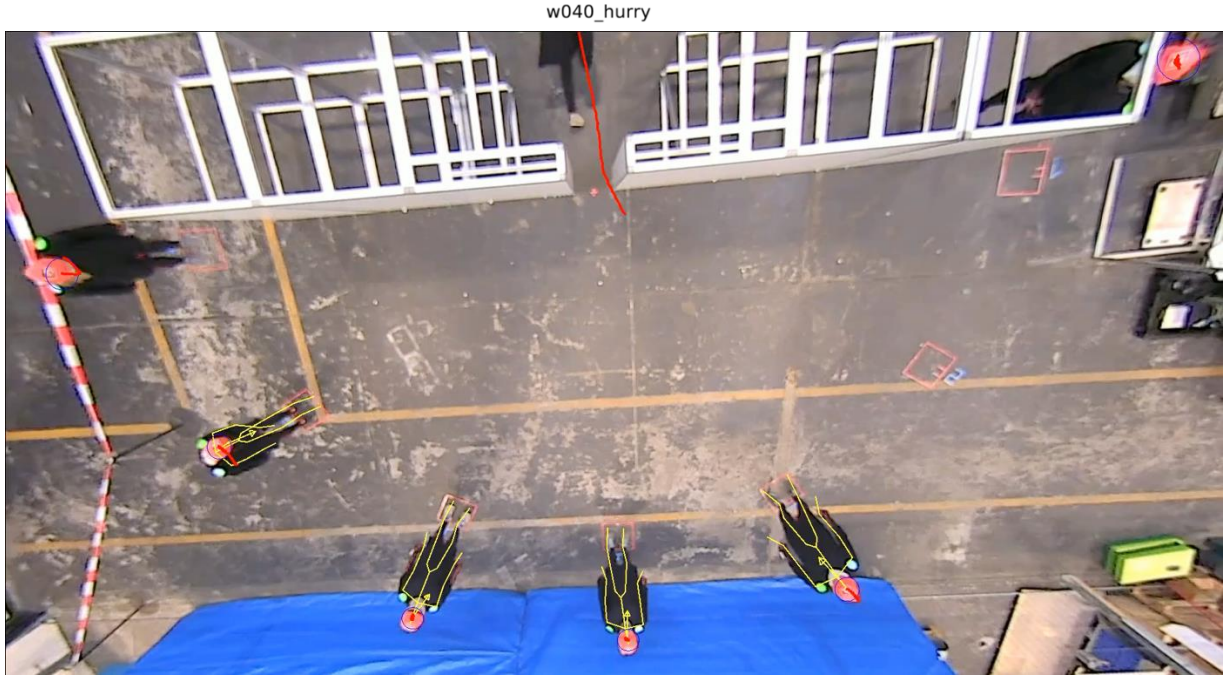


- Stand still
- Small steps (low velocity) before passing bottleneck
- Rotation of pelvis
- Large steps (higher velocity) through bottleneck and beyond

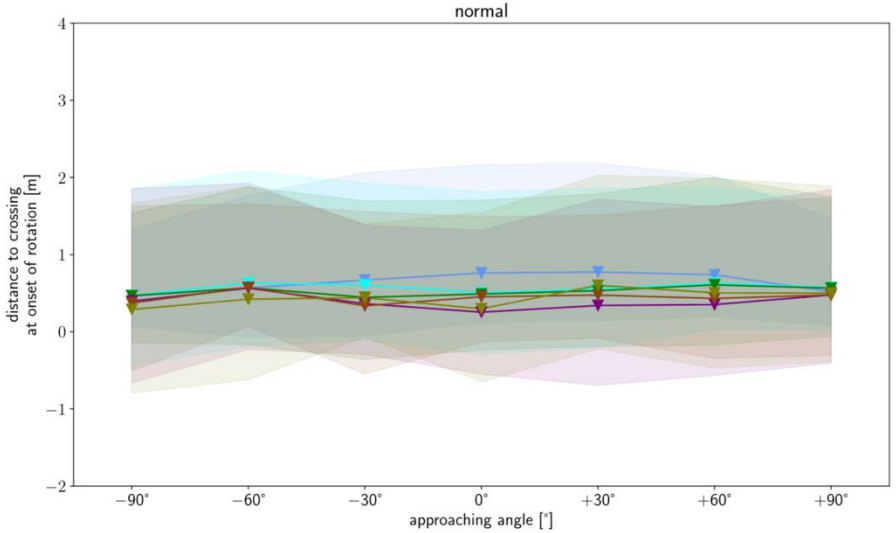
[Boltes et al.: A Hybrid Tracking System of Full-Body Motion Inside Crowds, Sensors 21(6), 2108 (2021), DOI: 10.3390/s21062108]

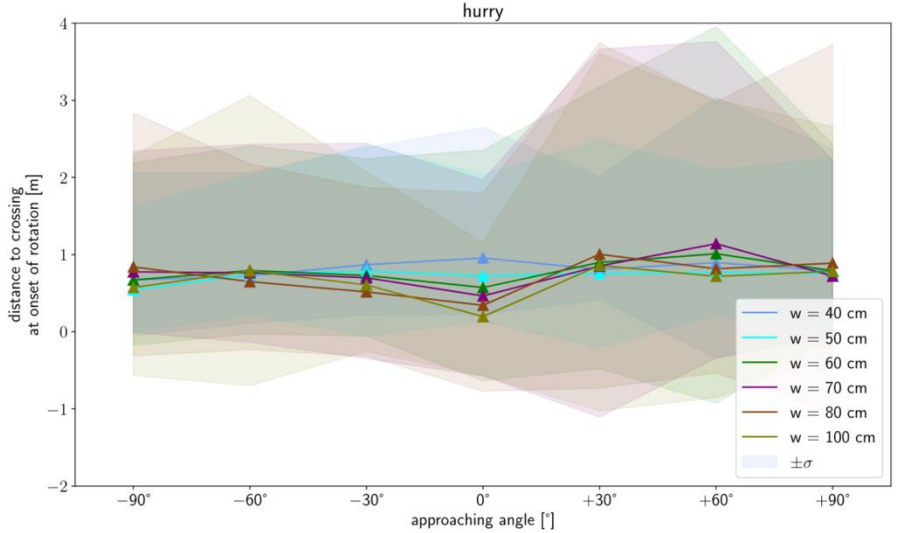
Passing Bottleneck





avg.
0.49 m

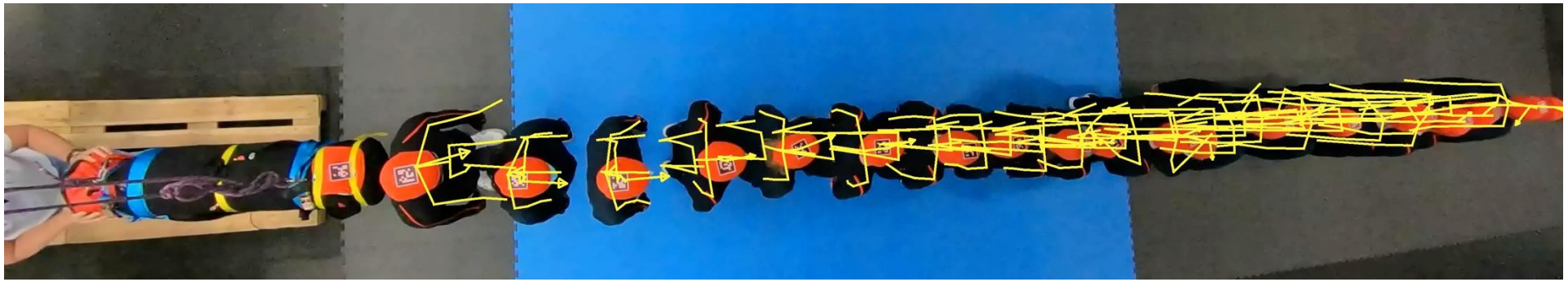




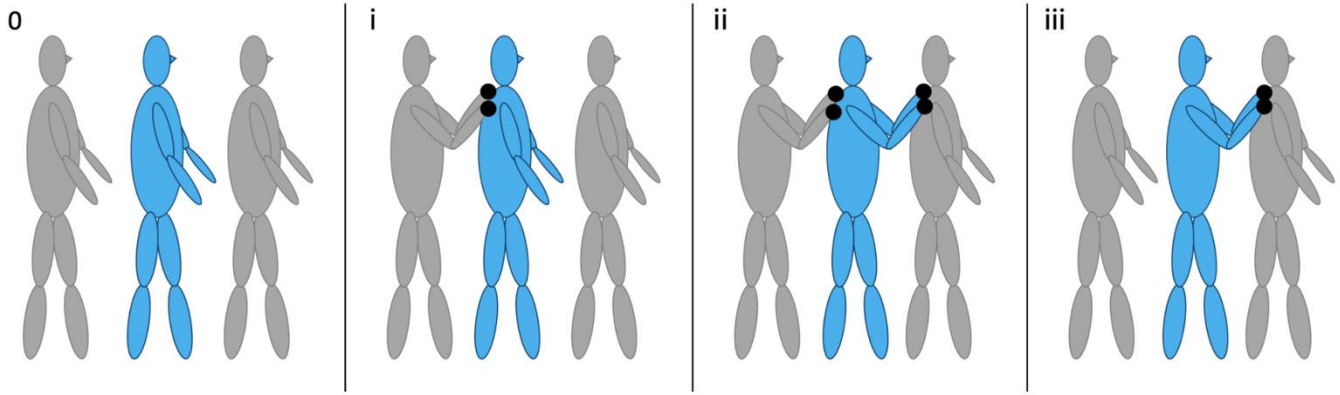
avg.
0.75 m

[Boomers et al.: How Approaching Angle, Bottleneck Width and Walking Speed Affect the Use of a Bottleneck by Individuals, Sensors (2024), DOI: 10.3390/s24061720]

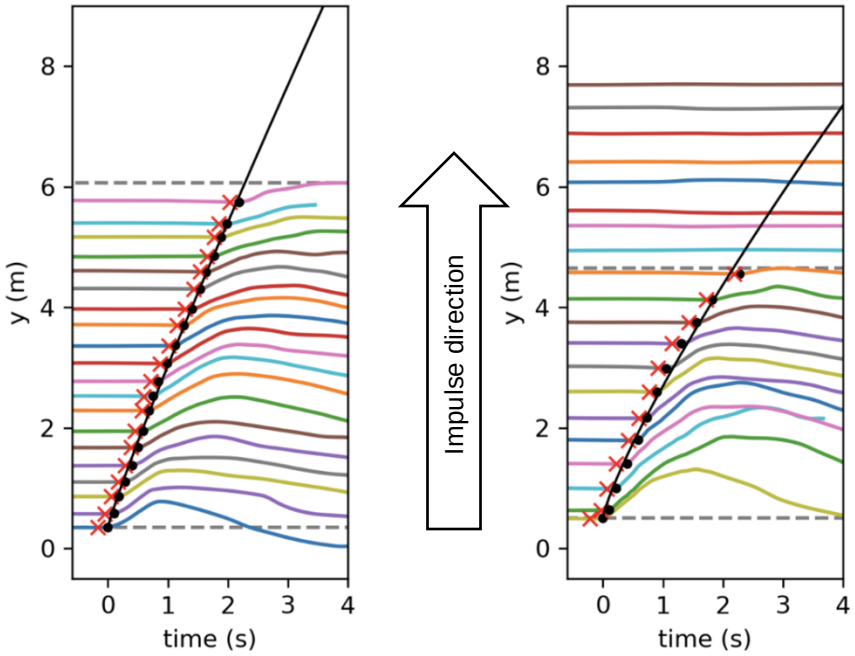
Impulse Propagation



Medium impulse, elbow distance, prepared



Phases of impulse propagation (0) no external impact (i) receiving,
(ii) receiving and passing, (iii) passing on an impulse



no distance elbow distance

[Feldmann et al.: Propagation of Controlled Frontward Impulses Through Standing Crowds, Collective Dynamics 9 (2024), DOI: 10.17815/CD.2024.148]

LoStInCrowds - Locomotion Strategies and Injury potential in dense pedestrian Crowds

Partner:
Institute of Biomechanics and Orthopaedics
German Sport University Cologne

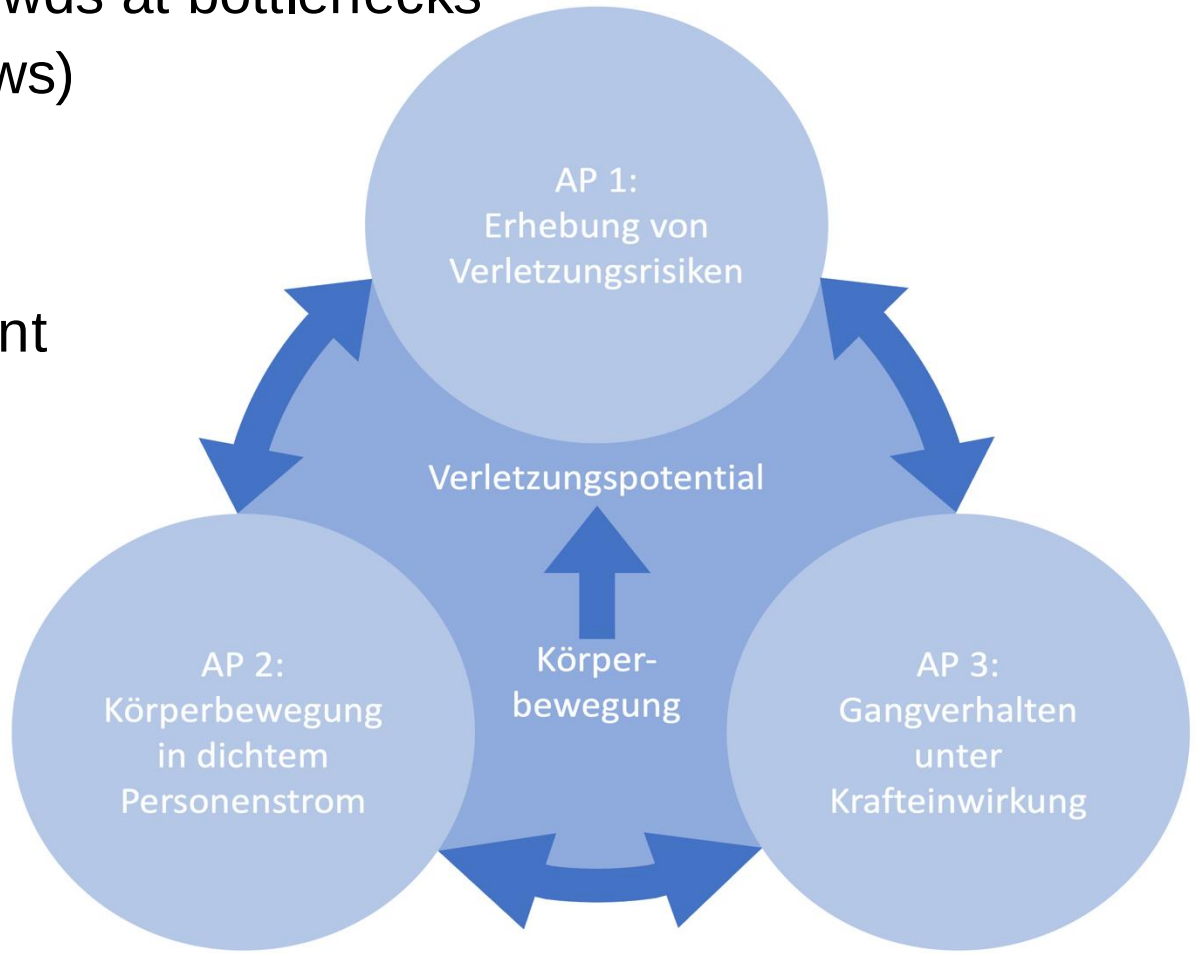
Duration: 01.01.25 – 31.12.27

PhD student: Carina Wings

LoStInCrowds - Locomotion Strategies and Injury potential in dense pedestrian Crowds

Goals:

1. **Identifying risk factors** for injuries in crowds at bottlenecks (paper review, data/video review, interviews)
2. Investigating **influencing variables** (e.g. density, motivation, gender, height, age and fitness) on overall body movement and thus the risk of injuries within condensing pedestrian streams
3. Small-scale experiments analyzing **individual factors** that modulate the risk of injury potentials



Densedynamics - Pulse propagation in dense crowds - decoding the origin of dangerous dynamics

Partner:

School of Architecture and Civil Engineering

University of Wuppertal

Duration: 3 years, starting in summer 2025

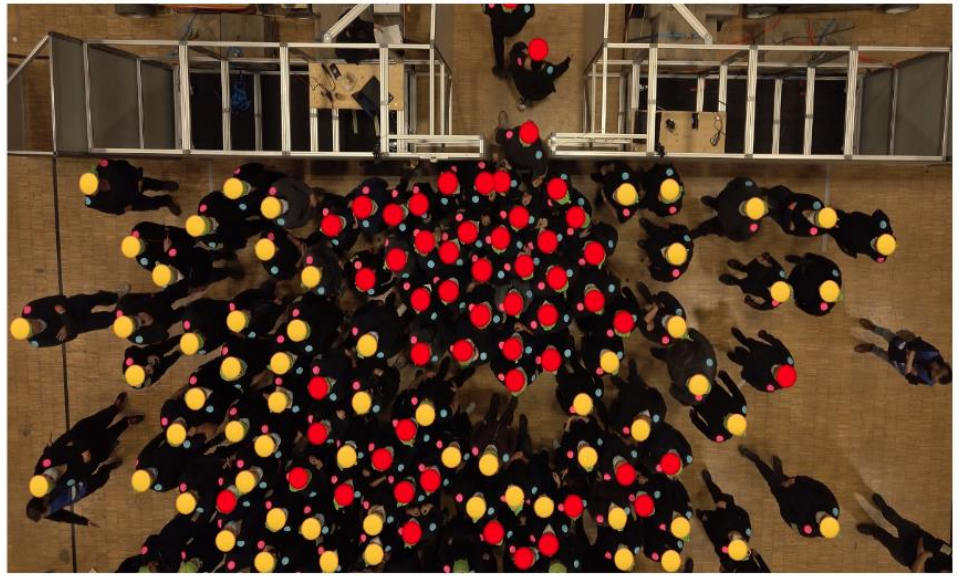
Densedynamics - Pulse propagation in dense crowds - decoding the origin of dangerous dynamics

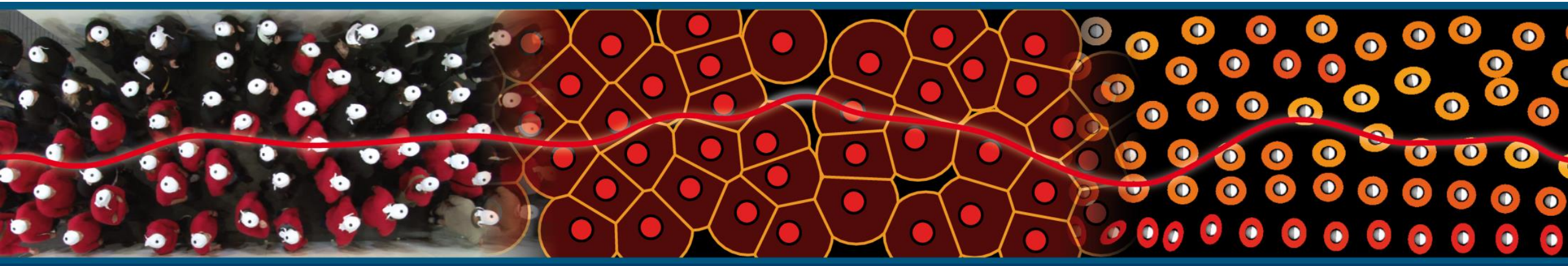
A: Waiting behaviour and collective dynamics

- Active and passive people in experiments
- Under which circumstances do people “wait“?
- How do pedestrians switch between waiting and moving forward?
- How is the dynamic within the crowd affected?
- Different space usage of crowd

B: Connection between impulses and body movements

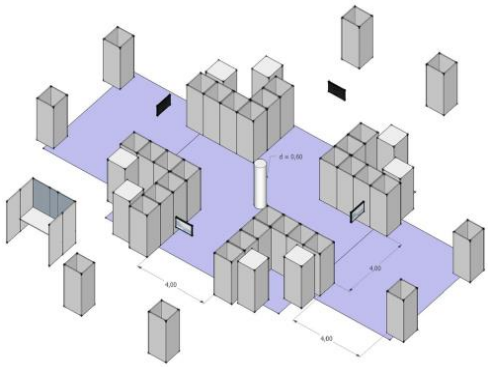
- Movement strategies to recover from external impulses
- Identification using MoCap Data
- Analyse strategies in “2D crowds“





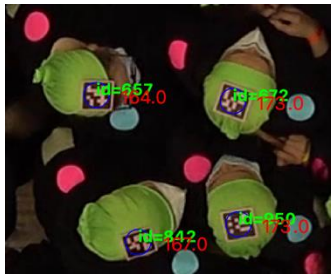
FAIR Data

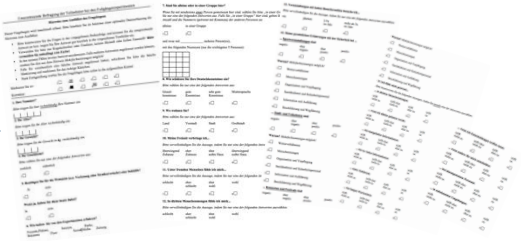
Controlled Experiments

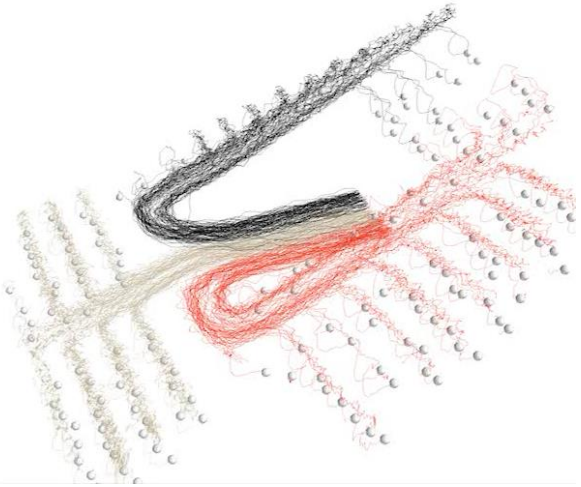


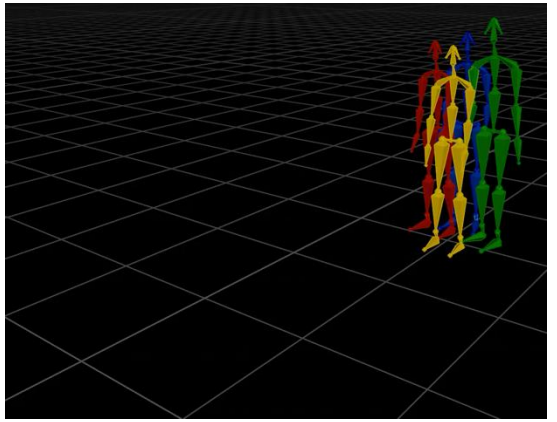
Data: large variety of influencing aspects to dynamic of person, group or crowd

- **Global static information:** e.g.
  surrounding: facility design, lighting/wall/floor condition, temperature, humidity, acoustics;
  people: instruction/motivation, distribution of age/gender
- **Personal static information:** e.g.
  age, gender, disability, body size, weight,
  culture affiliation, togetherness, clothes, luggage
- **Personal dynamic information**: e.g.
  physical: (3D) trajectories, motion of body parts
  (head, shoulder, gait, eye movement);
  mental: physiological response, behaviour









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Logged in as: Maik Boltes (su) Update Profile Admin Log Out

Pedestrian Dynamics Data Archive

Search

Recent Changes Media Manager Sitemap

Trace: · impulse_crowd · start

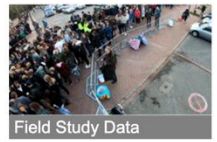
start

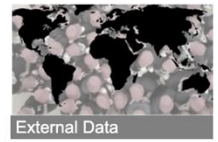
Data archive of studies about pedestrian dynamics

This data archive (DOI: 10.34735/ped.da, re3data: 10.17616/R31NJMT6) of experiments studying the dynamics of pedestrians is build up by the Institute for Advanced Simulation 7: Civil Safety Research of Forschungszentrum Jülich with support of projects and partners.


Experimental Data


Machine Learning Data


Field Study Data

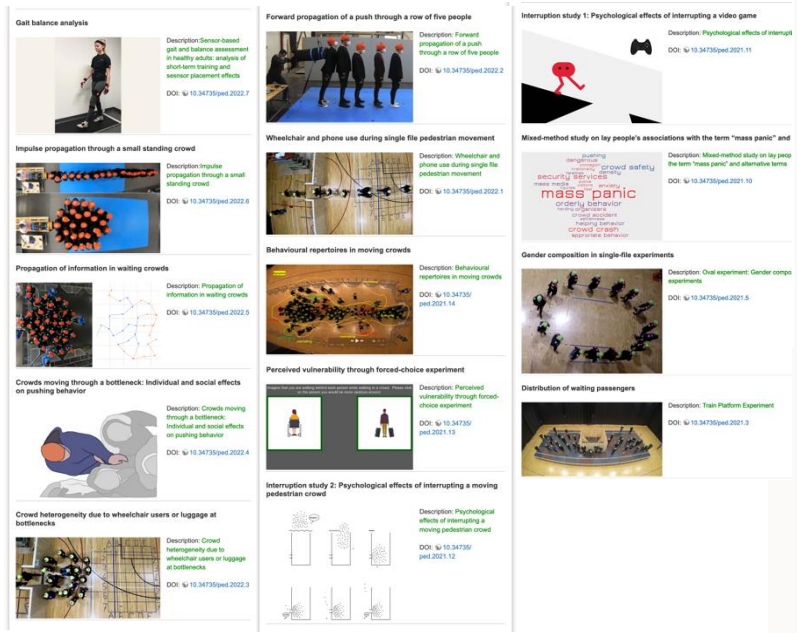

External Data

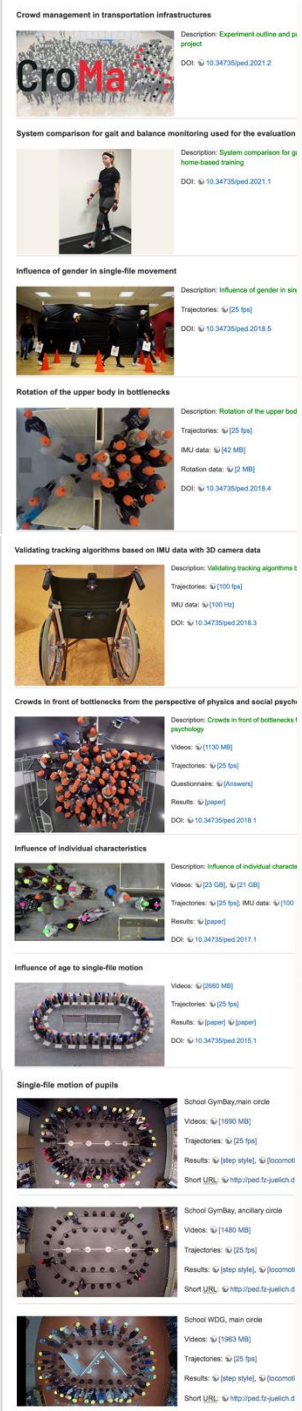
For most experiments, video recordings and trajectory data can be found. Furthermore, other data types e.g. motion capturing, pressure, heart rate or questionnaire data can be found. The automatic extraction of pedestrian trajectories from video recordings was done mostly with our own pedestrian tracking software PeTrack. The experiments are listed in chronological order from new to old.

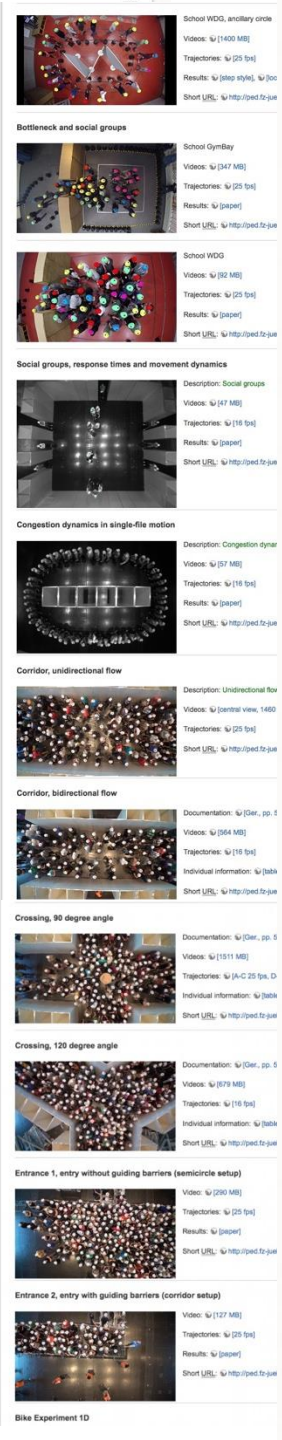
You are very welcome to use our data for further research, as long as you name the source of the data.
If you have further questions feel free to contact ped-data-archive@fz-juelich.de.

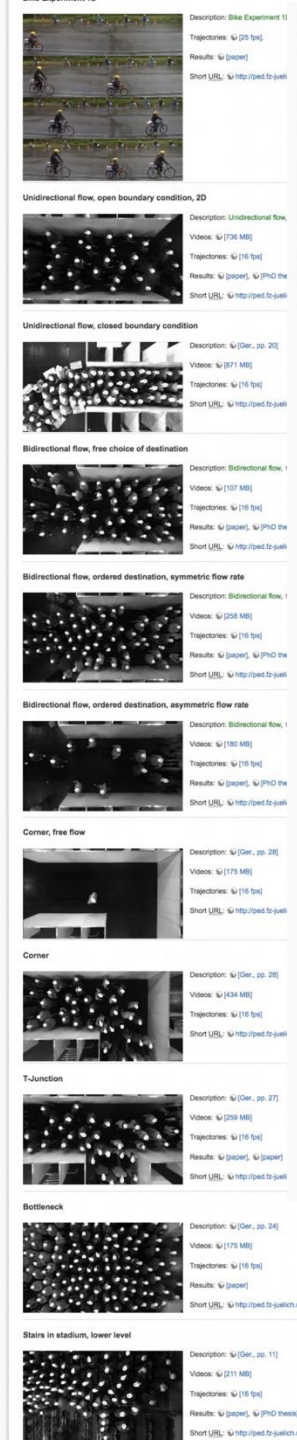
FAIR Data Approach

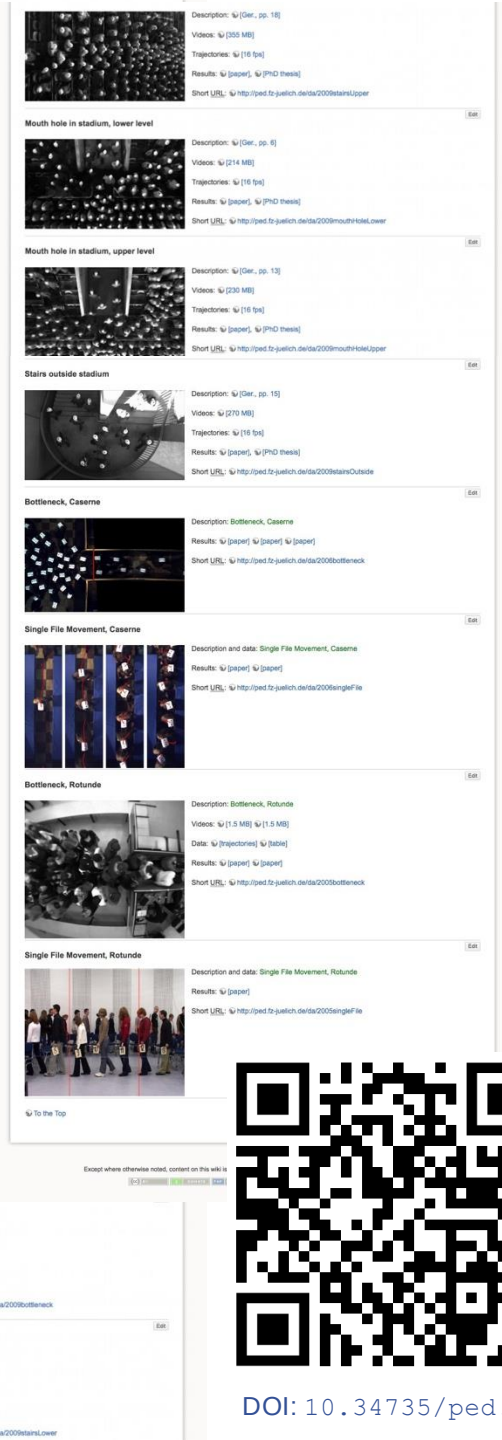
In order to be able to efficiently use and reuse legacy datasets, we are focusing on adhering to the FAIR data principles. Learn more about FAIR data and making your own datasets more FAIR. Standardised and uniform data formats help with the subsequent reuse and are also described here.











→ ~60 visits/day

DOI: 10.34735/ped.da

Be FAIR to Pedestrian Dynamics Data

Findable: Detailed description by metadata in a searchable environment

Accessible: Easy access to data and saved in a long-term storage

Interoperable: Use of exchangeable formats functioning across different systems

Reusable: Metadata includes process of data creation for easy reproduction of data

DataCite

Jülich DATA

WIKIDATA

HELMHOLTZKG

- 45 experiments
- 1787 runs
- 5942 data objects

Open Access

PED Metadata Schema

jupyterhub

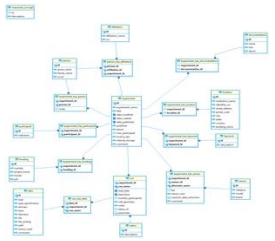
PedPy

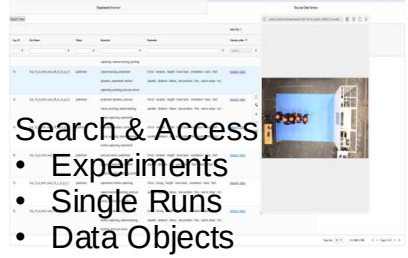
Fileserver with all Experiments

Pedestrian Dynamics Data Archive

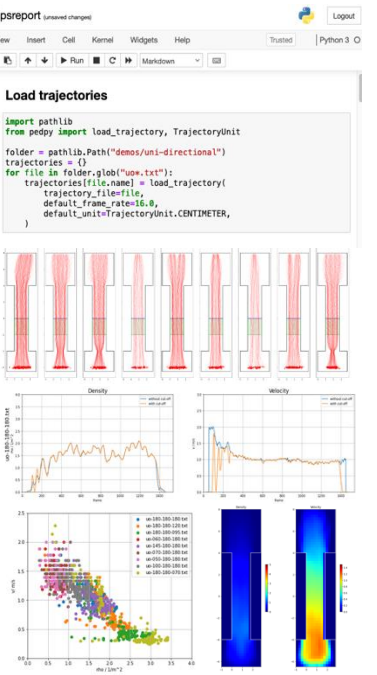
Pedestrian Dynamics Database

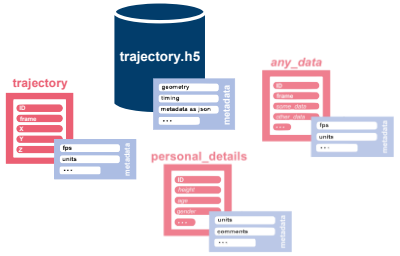
Dashboard

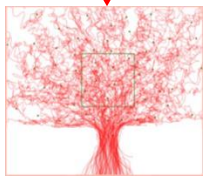




Search & Access
- Experiments
- Single Runs
- Data Objects







Trajectory Structure

Setup Structure

```
POLYGON (
(-4 -4, -4 5, 4 5, 4 -4, -4 -4),
(-3.5 -3.5, -3.5 0, -0.45 0, -0.45
4, -0.5 4, -0.5 0.05, -3.55 0.05,
-3.55 -3.5, -3.5 -3.5),
(3.5 -3.5, 3.5 0, 0.45 0, 0.45 4,
0.5 4, 0.5 0.05, 3.55 0.05, 3.55 -
3.5, 3.5 -3.5))
```

Standardized metadate and data formats

[Boltes et al.: Be FAIR to Pedestrian Dynamics Data, Collective Dynamics 9 (2024), DOI: 10.17815/CD.2024.163]

Open Science

Open source, open data and open access journal

- *Open source* framework **JuPedSim** for pedestrian dynamics simulations: http://www.jupedsim.org
- *Open source* software **PeTrack** for automatic trajectory extraction: http://ped.fz-juelich.de/petrack
- *Open source* library **PedPy** for pedestrian movement analysis: http://ped.fz-juelich.de/pedpy
- After finishing thesis about experiments the **data** published publicly available in the *open data archive*: http://ped.fz-juelich.de/da, .../extda
- Support of *diamond open access journal* **Collective Dynamics**: http://www.collective-dynamics.eu/

DOI: 10.5281/zenodo.6144559

DOI: 10.5281/zenodo.6320753

DOI: 10.5281/zenodo.7386931

DOI: 10.34735/ped.da

ISSN: 2366-8539

Open Science

Ease collaborations

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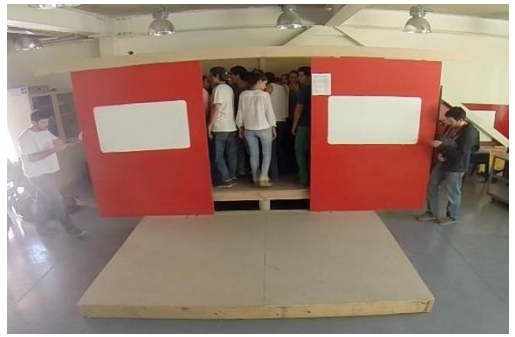
[University Tokio, Japan]

[University of Science and Technology of China, China]

[University of New South Wales, Sydney, Australia]



[Pontificia Universidad Catolica de Valparaiso, Chile]

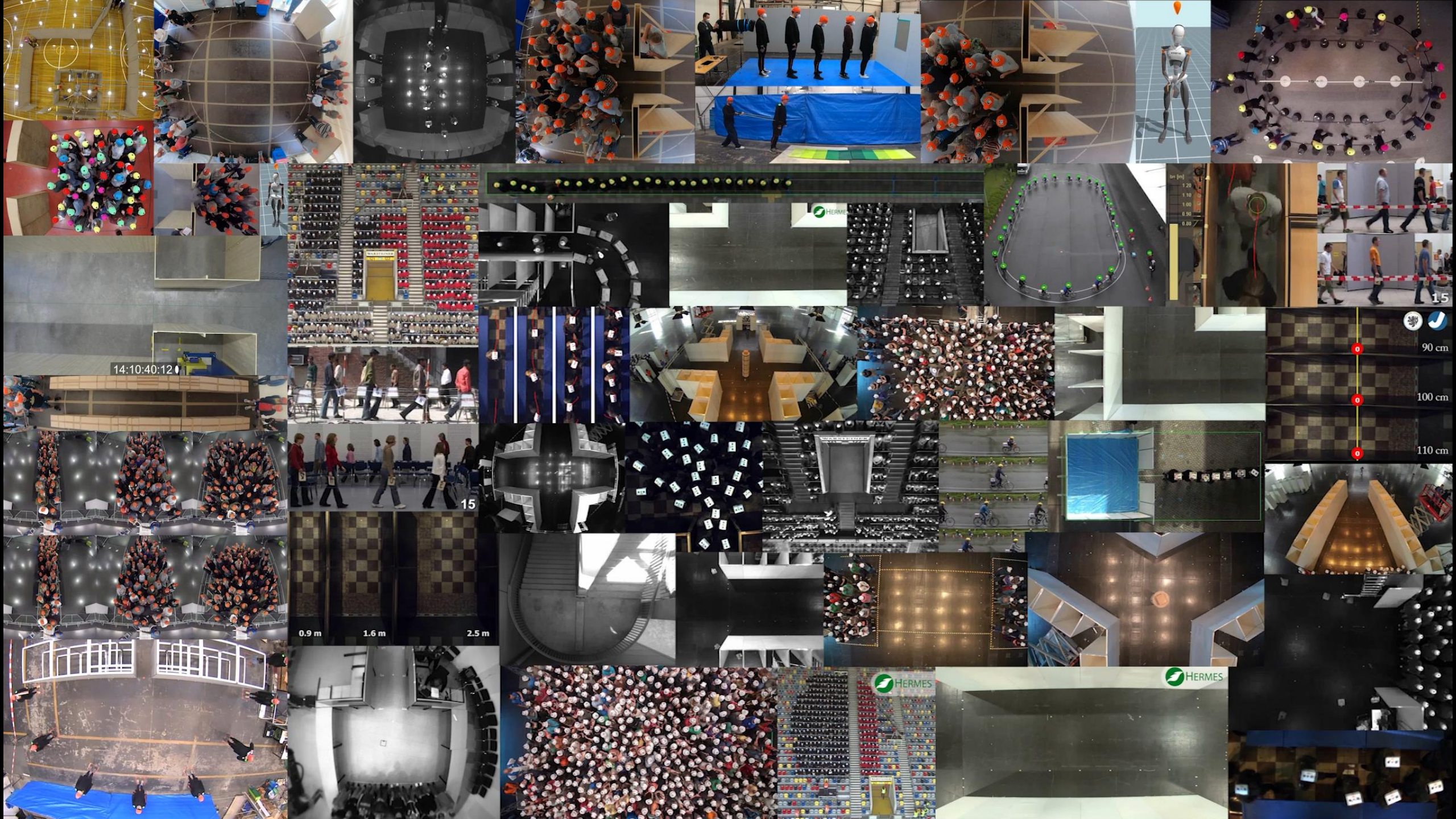
[Universidad de los Andes, Santiago, Chile]

[Monash + Melbourne University, Melbourne, Australia]

[National Research Council Canada, Ottawa, Canada]

[Carleton University, Ottawa, Canada]

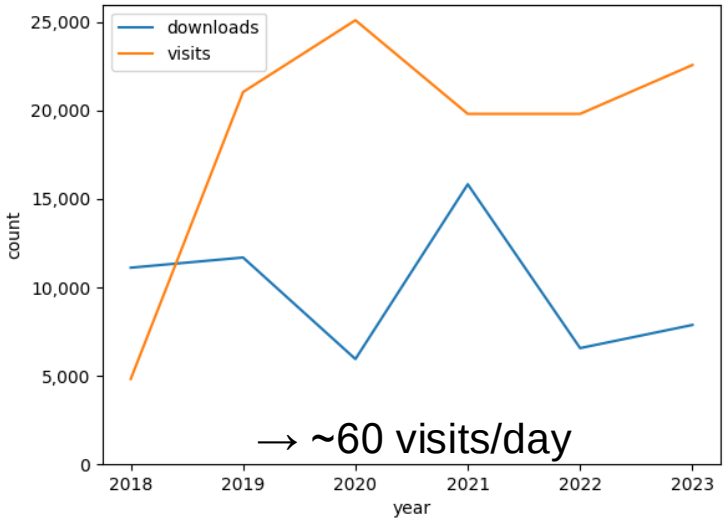
[PAMELA & PEARL, University College London, United Kingdom]

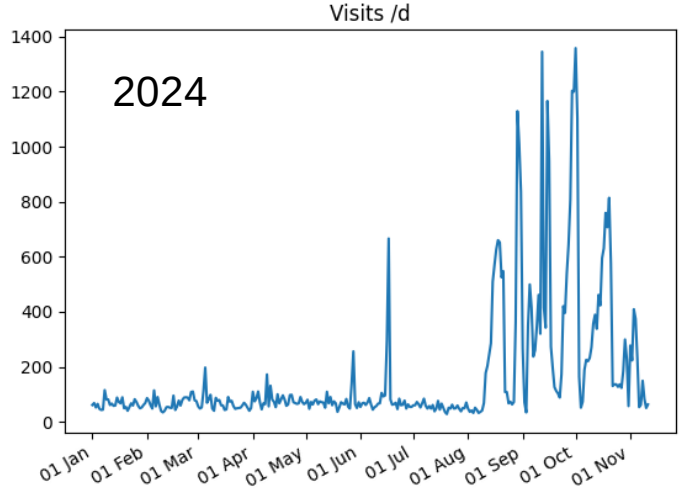

14:10:40:12
15
0.9 m
1.6 m
2.5 m
90 cm
100 cm
110 cm
HERMES
HERMES

QUESTIONS FOR DISCUSSION

- How much control is needed in experiments?
- Are experiments with people reproducible and thus worth to perform?
- Is open science always the right way to work?
- What is needed next to improve pedestrian models?

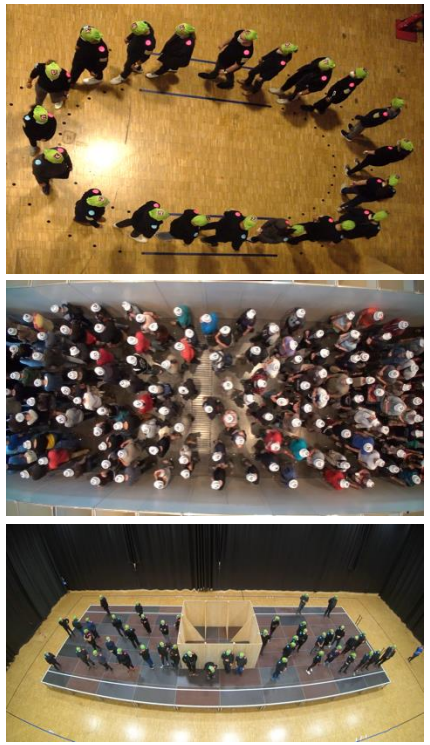
Data Archive: Access History, Top 3

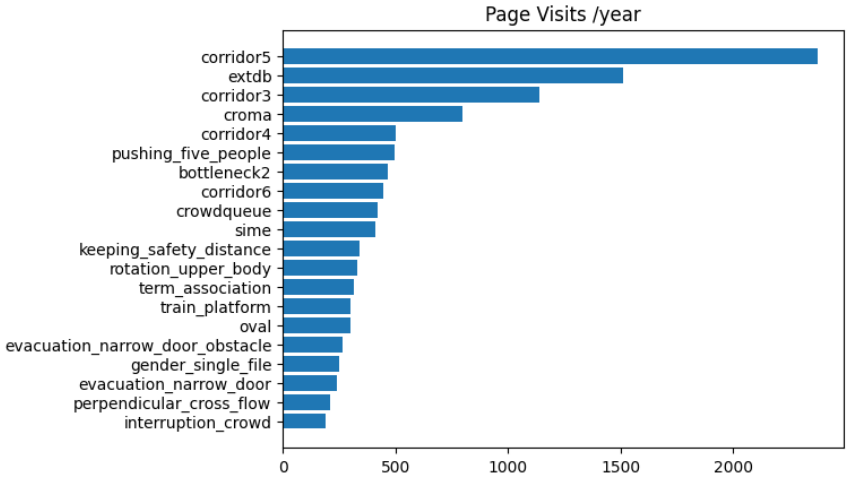


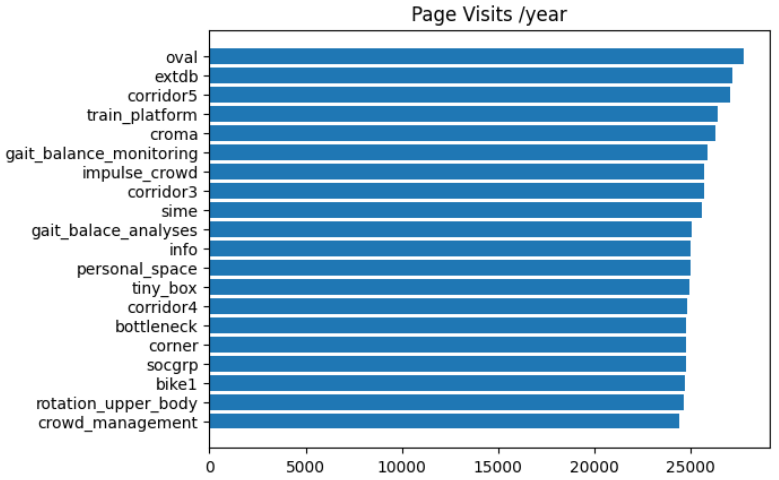


2023

2024 (until 12.11., without FZJ, BUW, robots)





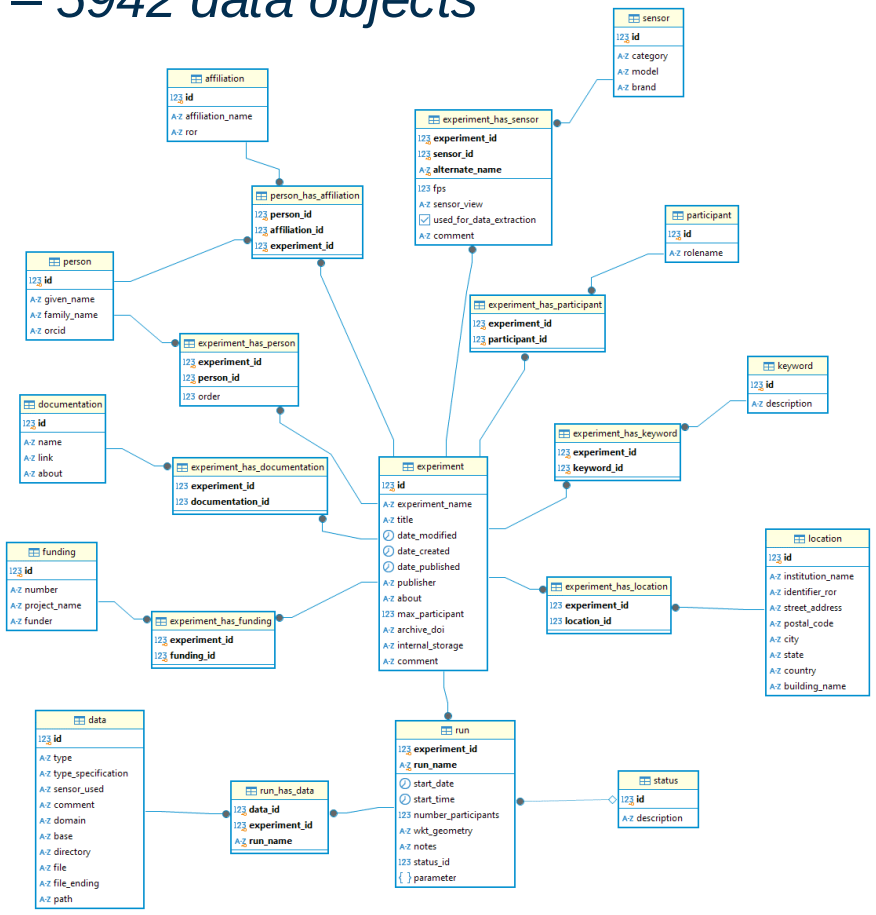


Fair2Ped+ and Fair2Ped (RDM Challenges)

- Experiments database for pedestrian dynamics data

  direct connection of single data objects (e.g. video, trajectories)

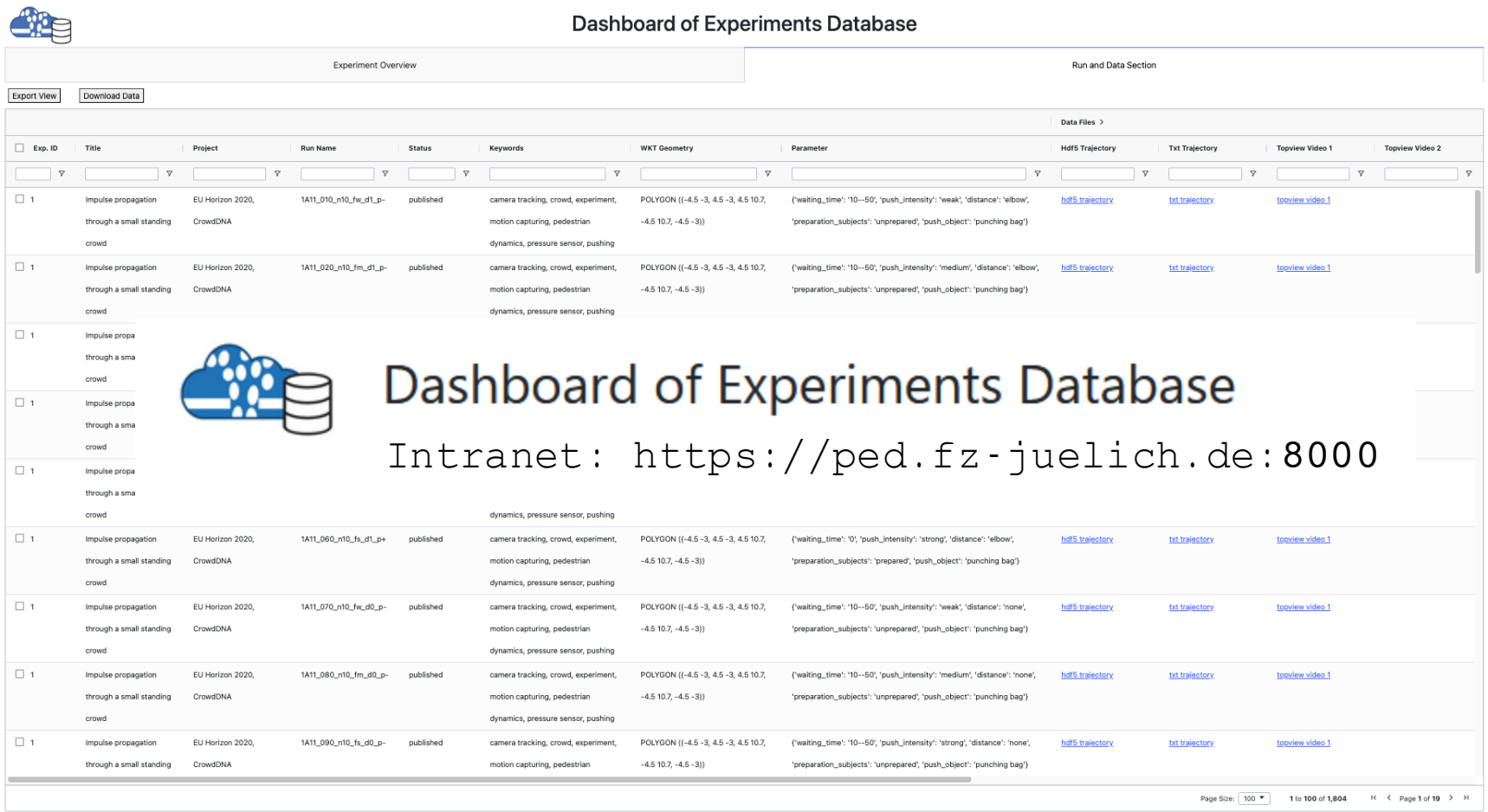
  → *45 experiments – 1787 runs – 5942 data objects*



Fair2Ped+ and Fair2Ped (RDM Challenges)

- Dashboard as user friendly database front-end

  → *Search – download*



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Fair2Ped+ and Fair2Ped (RDM Challenges)

- Connection to other metadata repositories

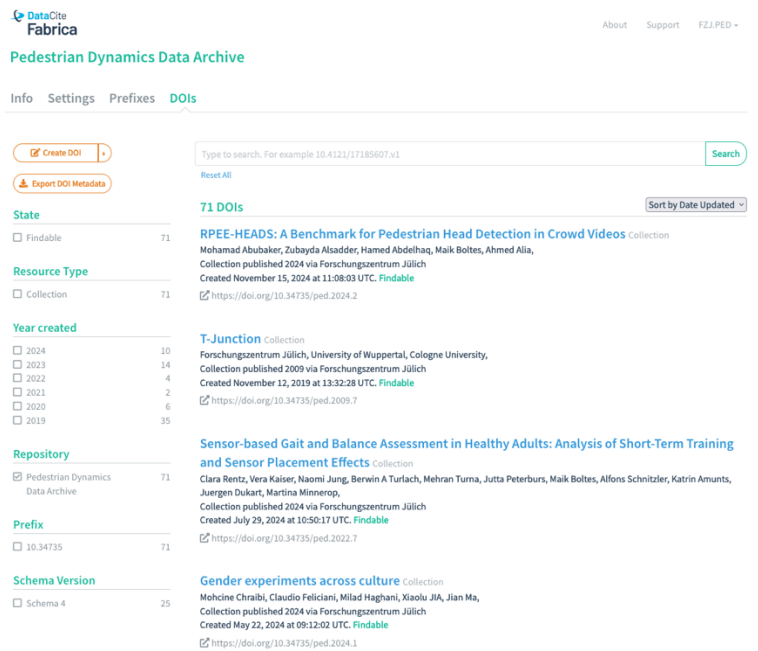
  → *Enhance visibility – enhance findability*

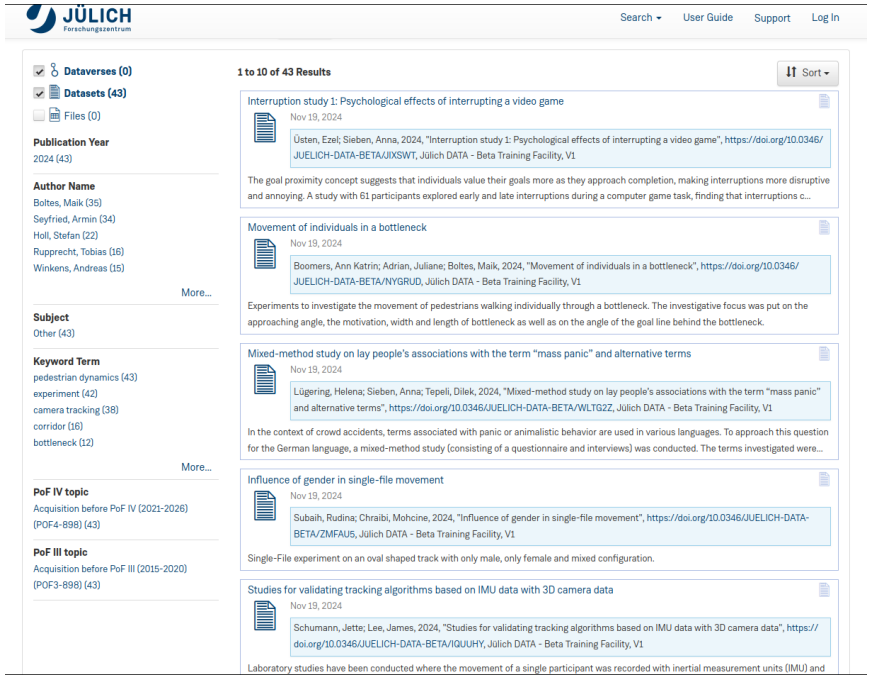
DataCite

Jülich DATA

WIKIDATA

HELMHOLTZKG





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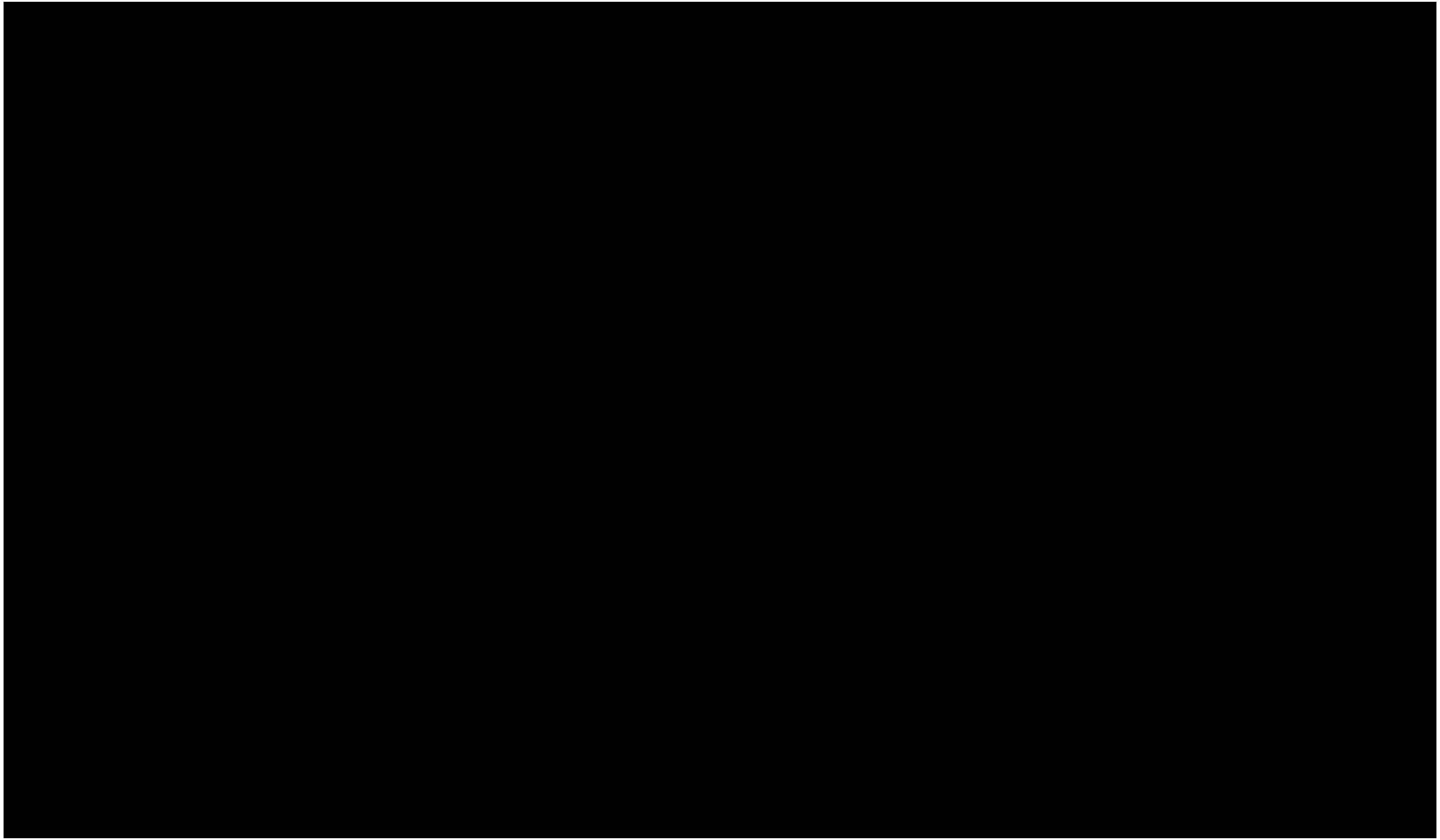

Fair2Ped+ and Fair2Ped (RDM Challenges)

- Database relies on information collected by us ☺
  - → *Document legacy datasets / experiments*
  - → *Document new datasets from the beginning on*
- This was created to facilitate your daily work
  - → *Small hands-on tutorial planned (January / February 2025)*
  - → *Rocketchat Channel for errors caught, questions and feedback*
  - → *USE IT* ☺

Dashboard of Experiments Database

`Intranet: https://ped.fz-juelich.de:8000`

WHERE WE LEFT OFF… (AFTER 2ND RDM CHALLENGE)

- **Metadata** schema for database
  - Filled with experimental metadata (30 experiments / 1482 runs)
  - Only metadata without connection to data
  - Only accessible through database
  - Gathered user feedback
- **Standardized** and coherent and trajectory and geometry **structure**
  - Only sample datasets transformed

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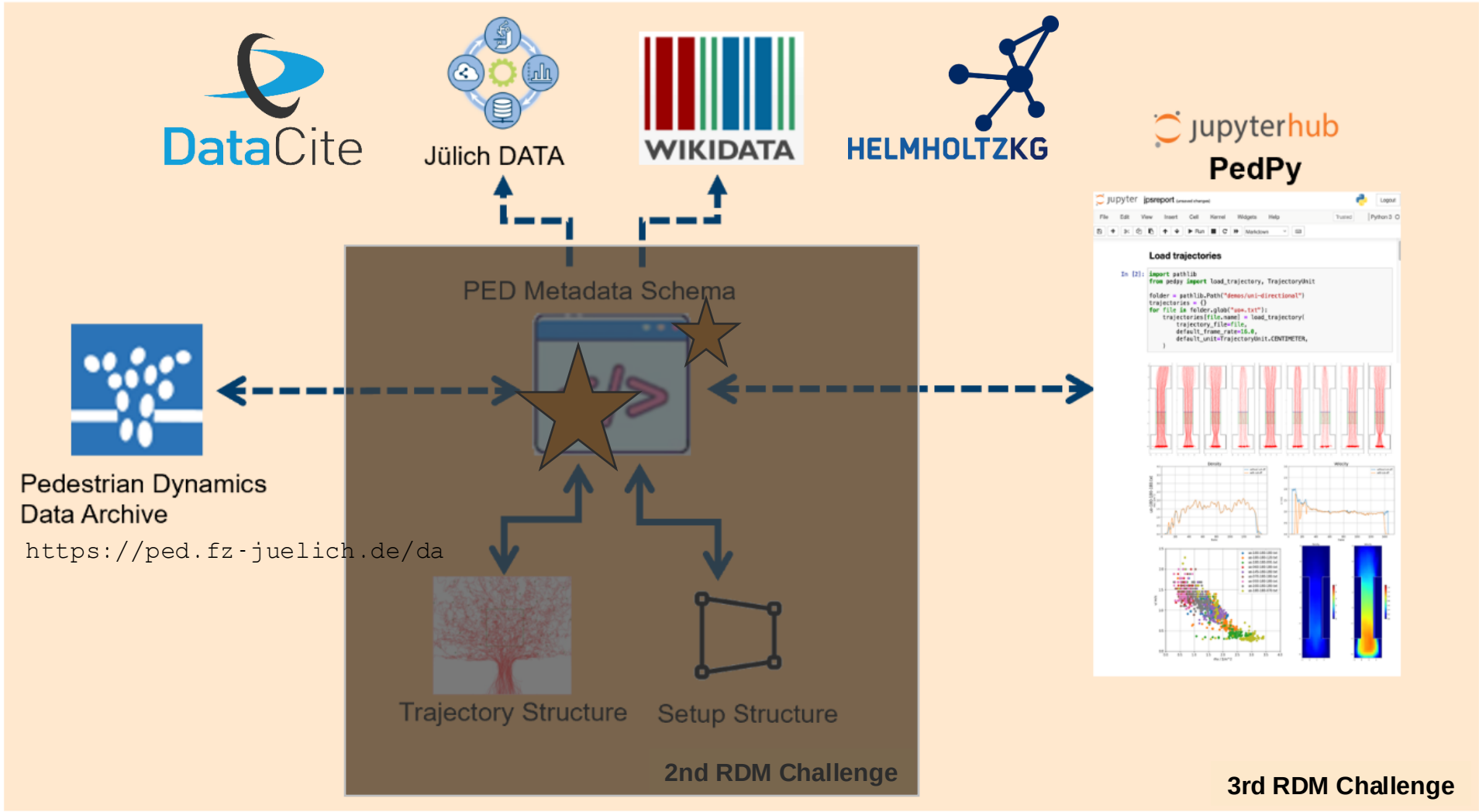
WORKING FIELDS FOR ROUND 3



DATA ACCESS

- Connect single **data objects** to the database

  → *5942 data objects are now accessible (trajectories, mocap, geometries, videos, questionnaires, pressure, mood)*

- Facilitate search and access through a **web front-end**

  → *Dashboard has been built with search functions through experiments, runs and data types*

- Enabling **direct access** to each data object

  → *Direct data access possible by URL or through dashboard export (data or table)*

Dashboard of Experiments Database

`Intranet: https://ped.fz-juelich.de:8000`

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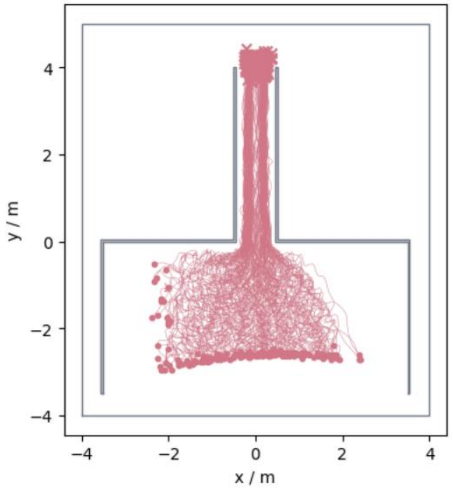
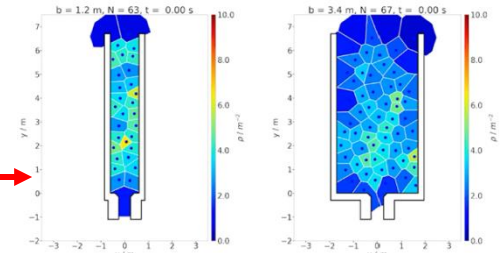
DATA ANALYSIS CONNECTION

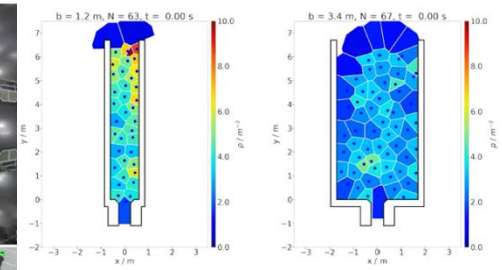
Direct access to analysis tools (e.g. PedPy)

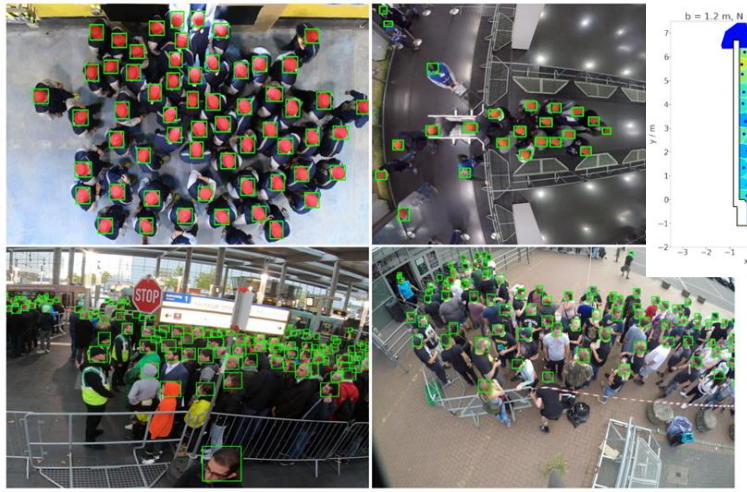
→ *Search, visualize & analyze*

→ *Possibility to process large amounts of prefiltered data for i.a. machine learning applications*









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2B071	2021-10-09	11:59:00	145	POLYGON ((3.57 19.5, 3.57 -0.51, 1.49 -0.5, 1.43 -0.97, -1	[NULL]	3	{"group_color":"green","setup_on_platform":"empty","stairs_on_platform
bi_corr_400_b_07	2023-06-22	13:24:00	926	POLYGON ((-13 -2, -13 6, 13 6, 13 -2, -13 -2), (5 5, -5 5, -	[NULL]	4	{"participant information":"choose your exit based on your wristband col
Tue_04_p_noW_SF_05_s_s_b_p	2022-04-26	10:41:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"strong","height":"shoulder","orientation":"back","feet":"parallel
bi_corr_400_b_08	2023-06-22	13:29:00	926	POLYGON ((-13 -2, -13 6, 13 6, 13 -2, -13 -2), (-5 4, 5 4,	[NULL]	4	{"participant information":"choose your exit based on your wristband col
bi_corr_400_b_09	2023-06-22	13:48:00	926	POLYGON ((-13 -2, -13 6, 13 6, 13 -2, -13 -2), (5 5, -5 5, -	[NULL]	4	{"participant information":"choose your exit based on your wristband col
bi_corr_400_b_10	2023-06-22	13:51:00	926	POLYGON ((-13 -2, -13 6, 13 6, 13 -2, -13 -2), (5 5, -5 5, -	[NULL]	4	{"participant information":"choose your exit based on your wristband col
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Tue_05_m_noW_ME_01_w_s_b_p	2022-04-26	10:49:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	1	{"force":"weak?","height":"shoulder","orientation":"back","feet":"parallel
Tue_05_m_noW_ME_02_w_s_b_p	2022-04-26	10:50:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	1	{"force":"weak?","height":"shoulder","orientation":"back","feet":"parallel
Tue_05_m_noW_ME_03_w_s_b_p	2022-04-26	10:53:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	1	{"force":"weak?","height":"shoulder","orientation":"back","feet":"parallel
Tue_05_m_noW_ME_04_w_s_b_p	2022-04-26	10:53:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	1	{"force":"weak?","height":"shoulder","orientation":"back","feet":"parallel
Tue_05_m_noW_ME_05_s_s_b_p	2022-04-26	10:53:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	1	{"force":"medium?","height":"shoulder","orientation":"back","feet":"paral
Tue_05_m_noW_ME_06_m_s_b_p	2022-04-26	10:53:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	1	{"force":"medium?","height":"shoulder","orientation":"back","feet":"paral
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Tue_06_m_noW_AS_02_w_s_b_p	2022-04-26	10:57:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"weak","height":"shoulder","orientation":"back","feet":"parallel",
Tue_06_m_noW_AS_03_m_s_b_p	2022-04-26	10:57:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"medium","height":"shoulder","orientation":"back","feet":"parall
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Tue_07_m_noW_A7_01_w_s_b_p	2022-04-26	10:59:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"weak","height":"shoulder","orientation":"back","feet":"parallel",
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Tue_07_m_noW_A7_03_s_s_b_p	2022-04-26	11:00:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"strong","height":"shoulder","orientation":"back","feet":"parallel
Tue_08_m_noW_ME_01_w_s_b_p	2022-04-26	11:04:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"weak","height":"shoulder","orientation":"back","feet":"parallel",
Tue_08_m_noW_ME_02_w_s_b_p	2022-04-26	11:04:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"weak","height":"shoulder","orientation":"back","feet":"parallel",
1_00_main	2015-04-30	09:00:00	1	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	individual w	4	{"walking_direction":"counterclockwise"}
1_01_main	2015-04-30	09:05:00	16	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	[NULL]	4	{"walking_direction":"counterclockwise"}
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1_04_main	2015-04-30	09:15:00	6	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	[NULL]	4	{"walking_direction":"clockwise"}
1_05_main	2015-04-30	09:18:00	25	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	[NULL]	4	{"walking_direction":"counterclockwise"}
1_06_main	2015-04-30	09:21:00	11	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	[NULL]	4	{"walking_direction":"counterclockwise"}
Tue_08_m_noW_ME_03_w_s_b_p	2022-04-26	11:05:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"weak","height":"shoulder","orientation":"back","feet":"parallel",
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Tue_08_m_noW_ME_05_s_s_b_p	2022-04-26	11:05:00	1	POLYGON ((-1 -0.89, 3 -0.89, 3 4, -1 4, -1 -0.89))	[NULL]	2	{"force":"strong","height":"shoulder","orientation":"back","feet":"parallel
1_07_main	2015-04-30	09:26:00	39	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	same step r	4	{"walking_direction":"counterclockwise"}
1_08_main	2015-04-30	09:29:00	39	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	[NULL]	4	{"walking_direction":"counterclockwise"}
1_09_main	2015-04-30	09:33:00	32	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	[NULL]	4	{"walking_direction":"counterclockwise"}
1_10_main	2015-04-30	09:37:00	16	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	[NULL]	4	{"walking_direction":"counterclockwise"}
1_11_main	2015-04-30	09:44:00	1	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	individual w	4	{"walking_direction":"counterclockwise"}
2_00_main	2015-04-30	10:19:00	1	POLYGON ((1.04 -2.25, -0.9 -2.25, -1.38 -2.25, -1.6 -2.23	individual w	4	{"walking_direction":"counterclockwise"}
entrance_2	2023-06-19	15:17:00	319	POLYGON ((7 5, 7 -2, -3 -2, -3 5, 7 5), (-0.22 -1.44, -0.17	experiment	4	{"participant_information":"your favorite artist is playing at the concert a
2B090	2021-10-09	12:45:00	40	POLYGON ((3.57 -0.51, 1.49 -0.5, 1.43 -0.97, -1.345 -0.97,	[NULL]	4	{"group_color":"blue","setup_on_platform":"wall","stairs_on_platform_at

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REPOSITORY CONNECTION

Mirror our metadata to other repositories & enhance findability of our data and metadata

→ *APIs applied to transfer metadata from database to JülichData and DataCite*

DataCite

Jülich DATA

WIKIDATA

HELMHOLTZKG

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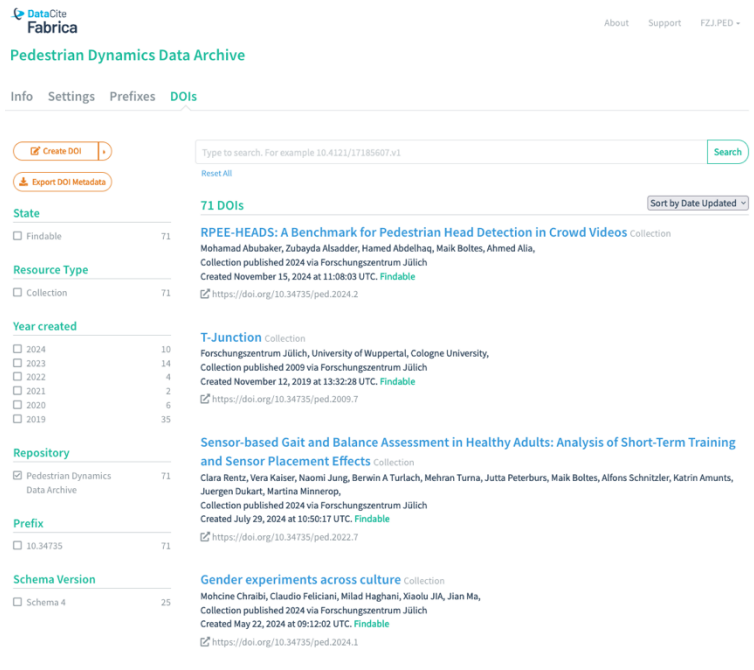

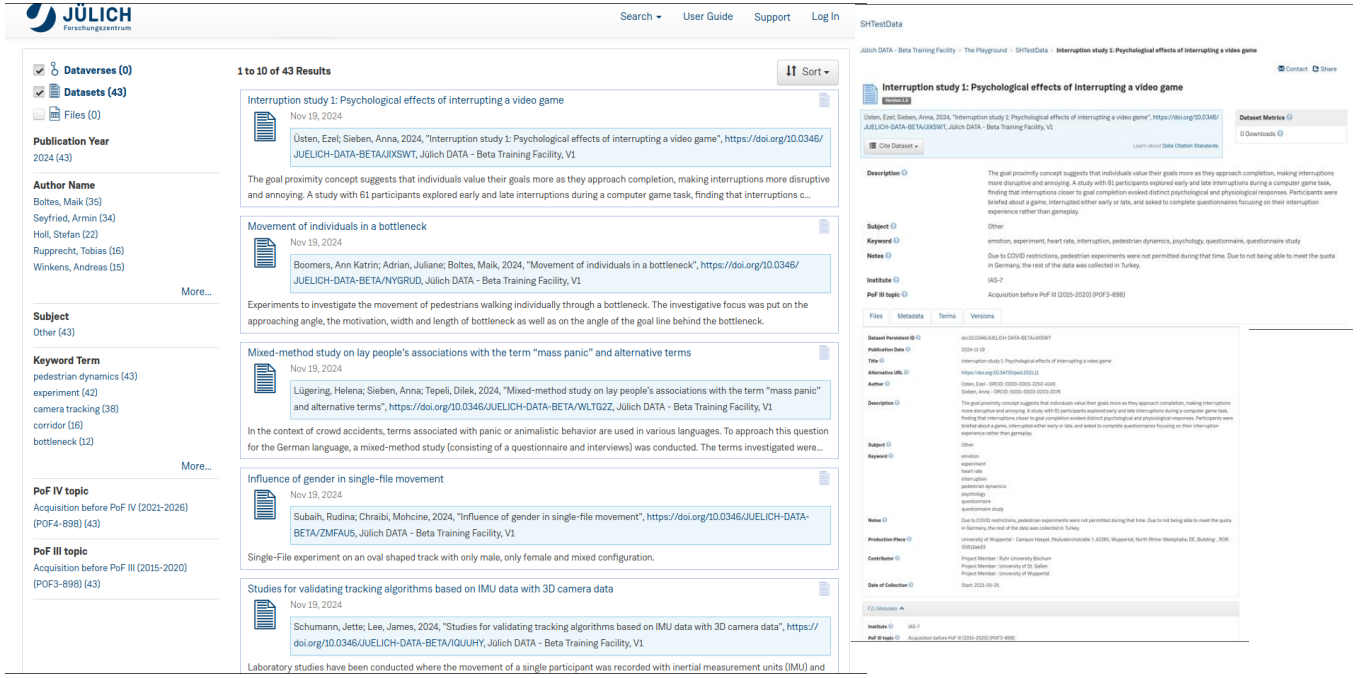

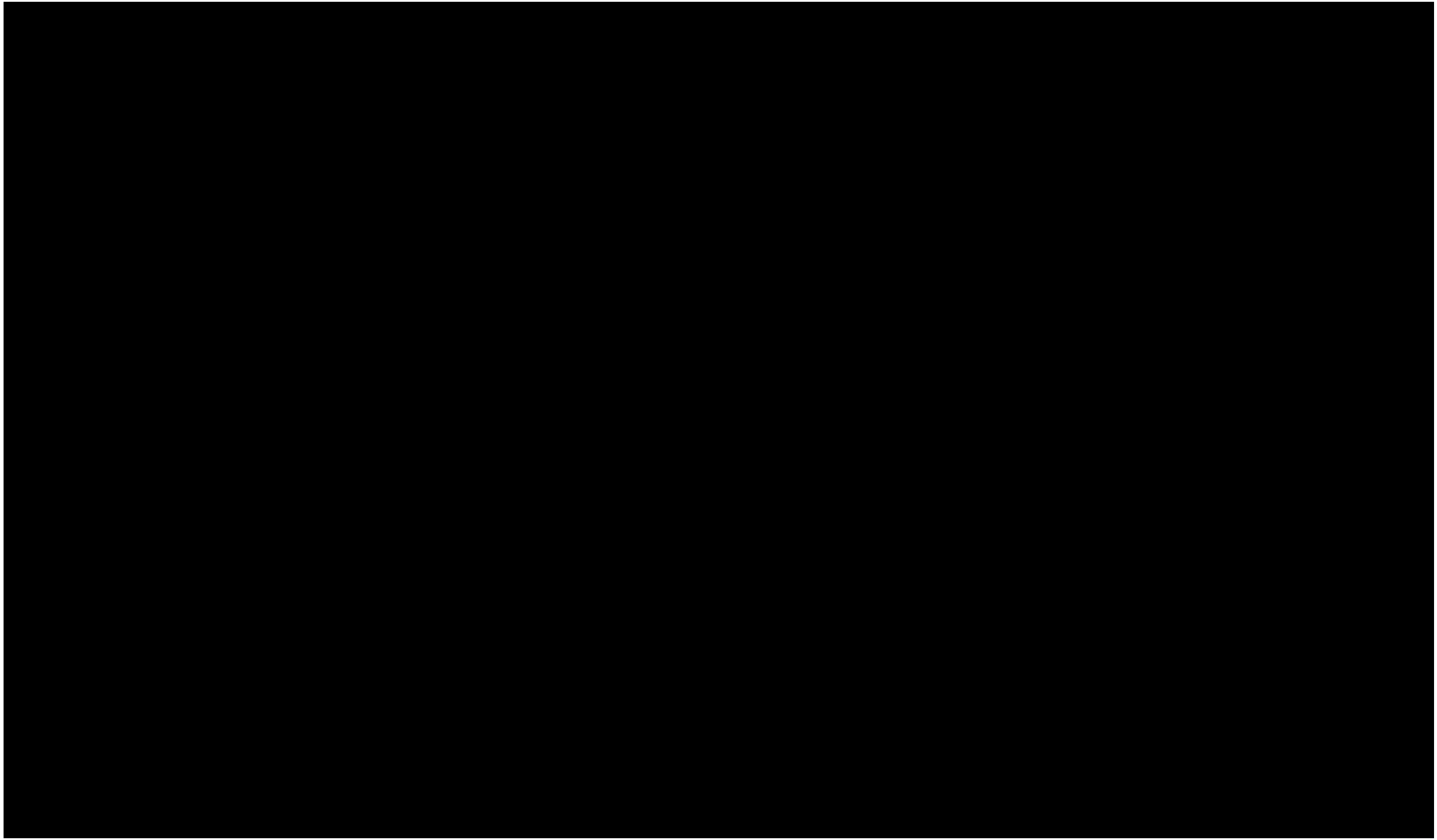

SUMMARY

- Enlarge and extend experiments **database** for pedestrian dynamics data

  45 experiments – 1787 runs – 5942 data objects

- **Dashboard** as user friendly database front-end

  Search – download – process – analyze

- Connection to other metadata **repositories**

  Enhance visibility – enhance findability

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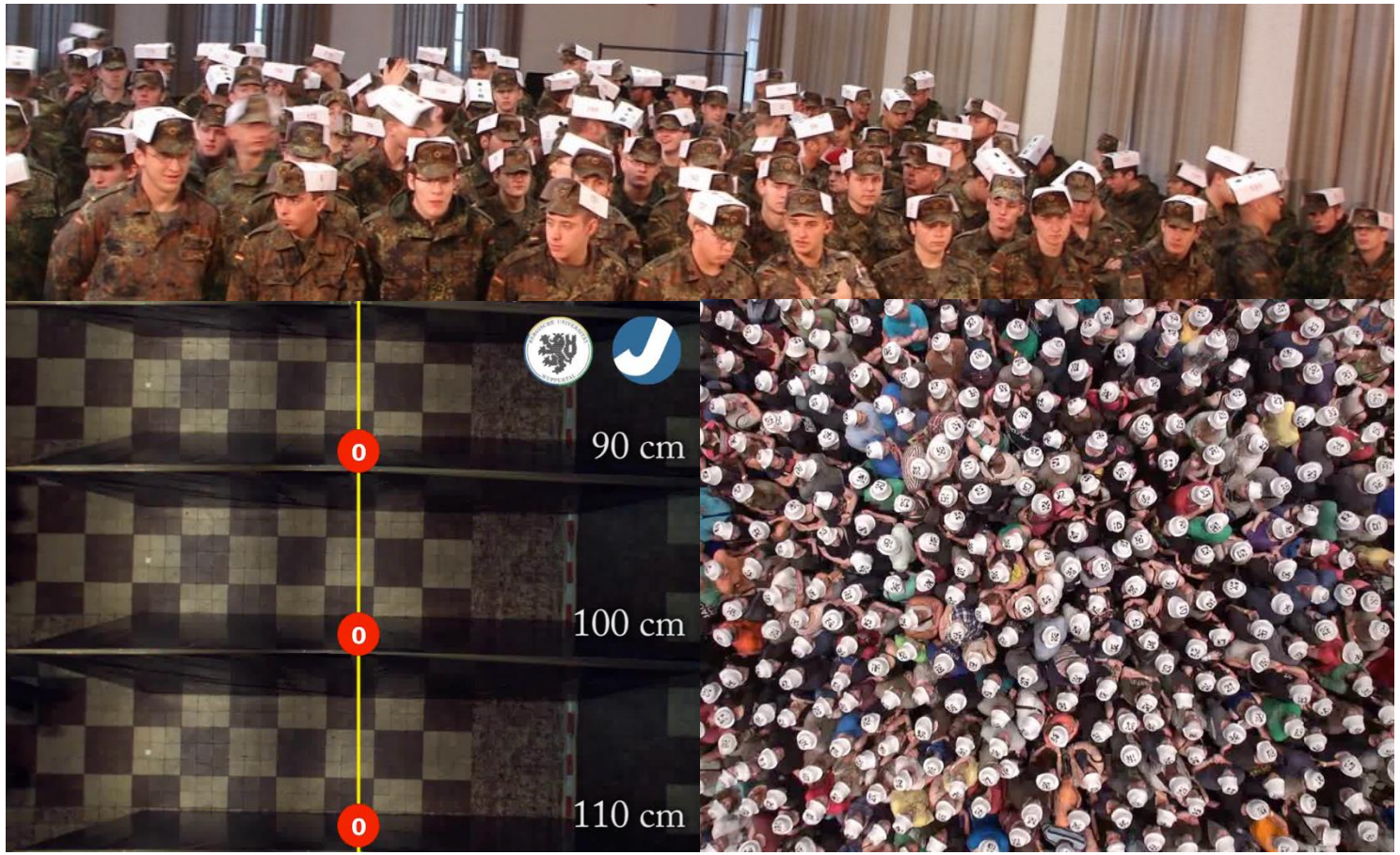
Advantages

Controlled experiments

- **Selective analysis** of parameters **without undesired influences**
- **Variability** of the experimental procedure
- **Generation of desired situation** like **high densities** seldom seen in field studies
- Possibility to extract **requested data** like **microscopic trajectories at high quality** in space and time
- **Privacy issues manageable** by declaration of consent



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Disadvantages (in comparison to field studies)

Controlled experiments

Collecting the data is **expensive**
(fee for participants, build structure)

Situation is **artificial** so that transferability to real life has to be justified

Some **parameters** influencing pedestrian dynamics are difficult to set up artificially

For microscopic data the **space and time is limited** to the experimental area

[Getty Images]

But: extraction of **meaningful general findings** is much harder for field studies

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3D full body motion capturing systems

Advantages (depending on system):

self-contained (e.g. local storage)

light weighted

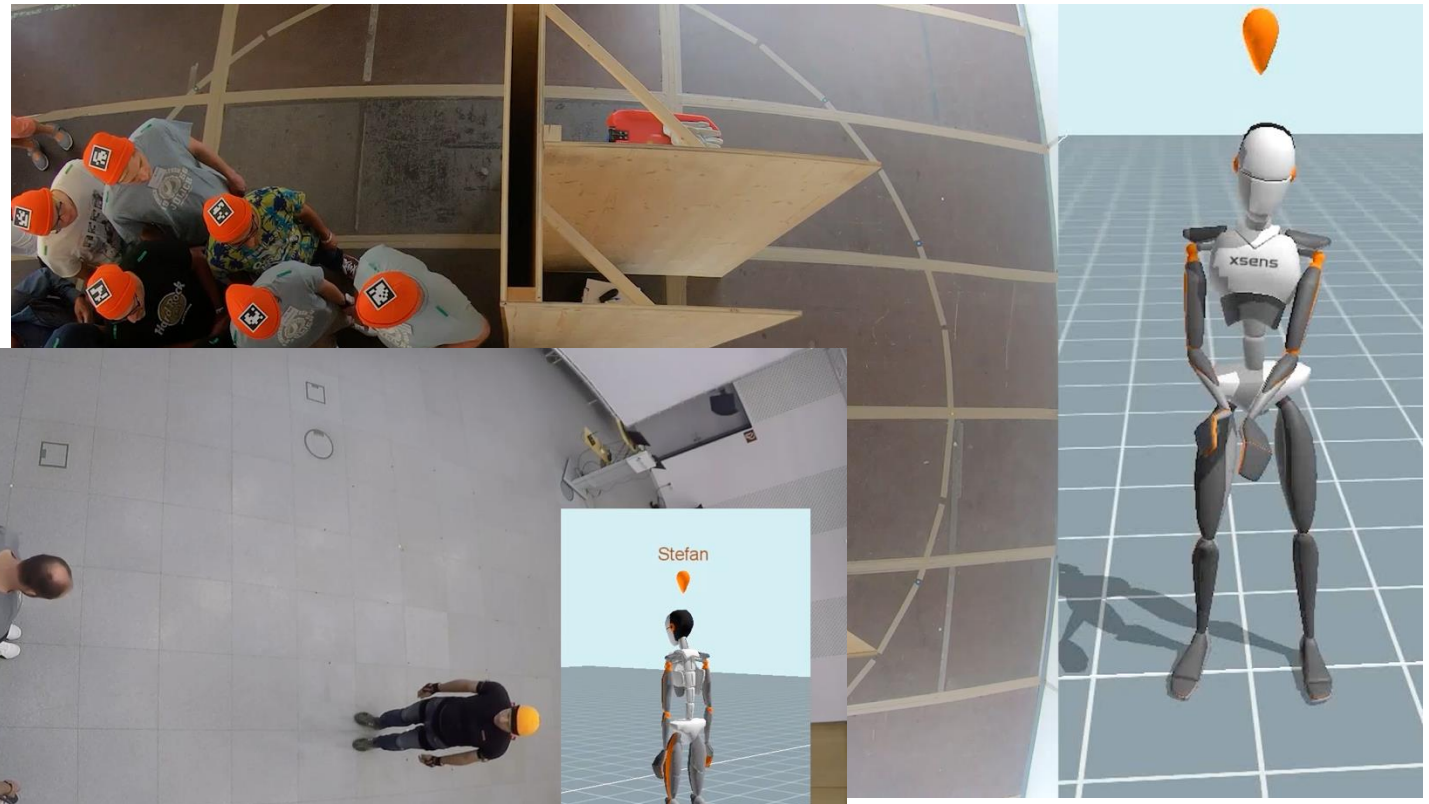
wireless control

→ no visibility from outside needed

→ usable inside crowd

Disadvantages (IMU

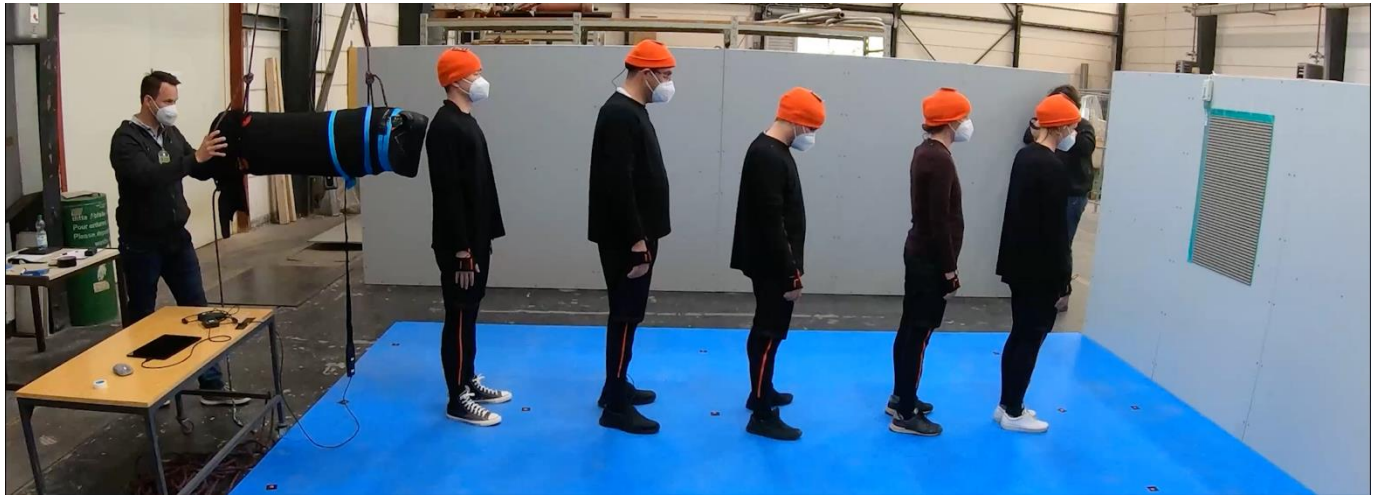
Capturing only
relative movement
→ drift in space

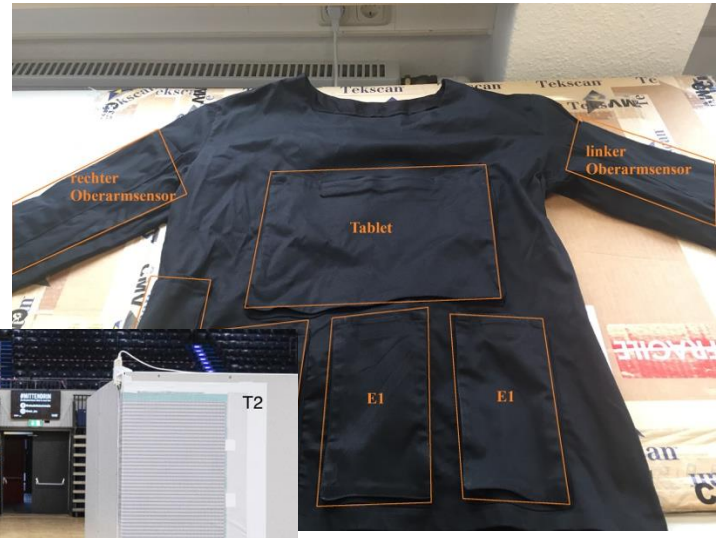


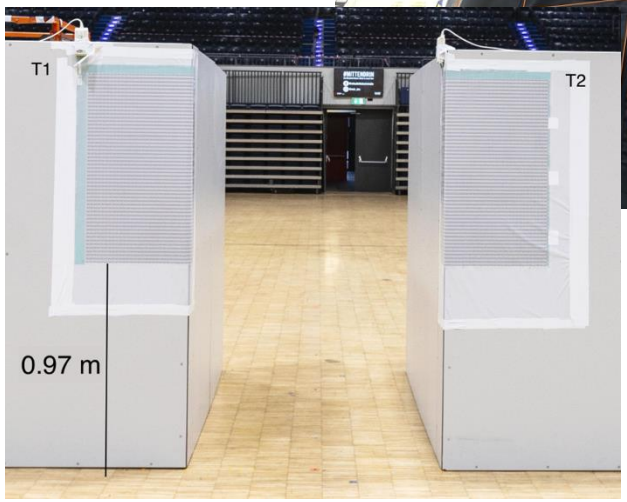
System

Pressure pads

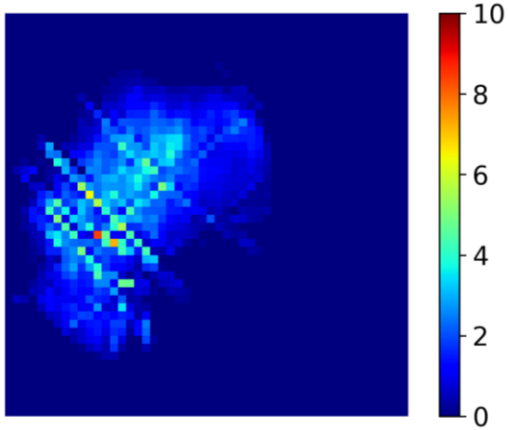
[Feldmann et al.: Forward propagation of a push through a row of people, Safety Science 164, 106173 (2023), DOI: 10.1016/j.ssci.2023.106173]



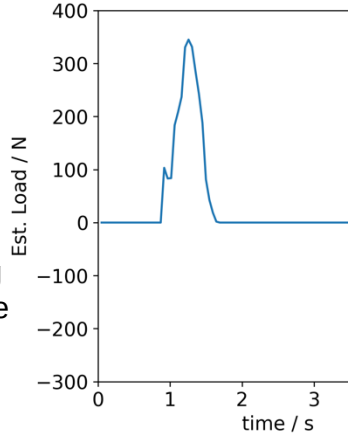




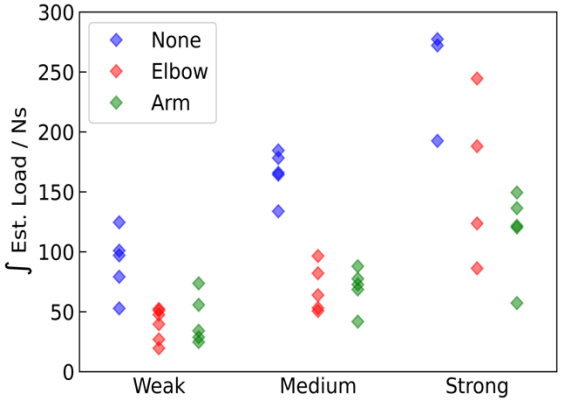
recording



integrating over space



integrating over time



Other systems

Heart rate variability sensors

Electrodermal activity sensors

Emotional response systems

Happy-or-not terminals

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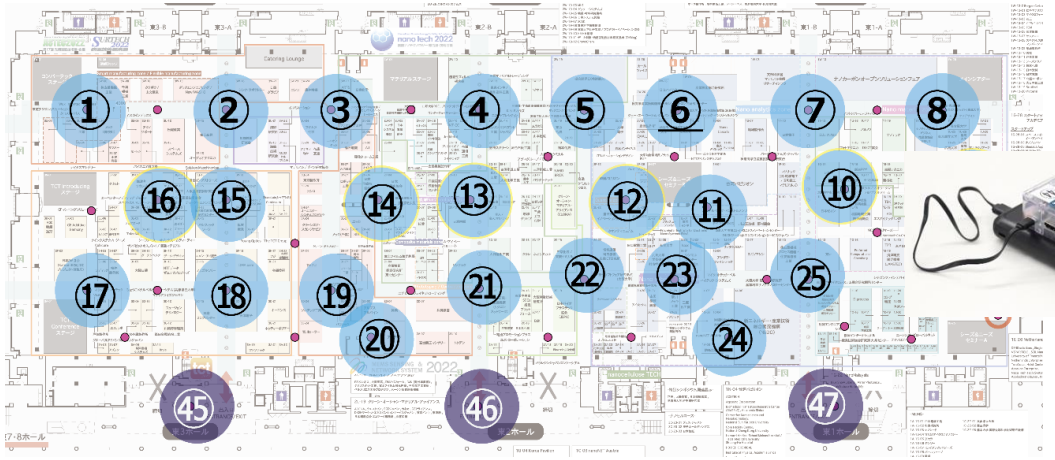
System example

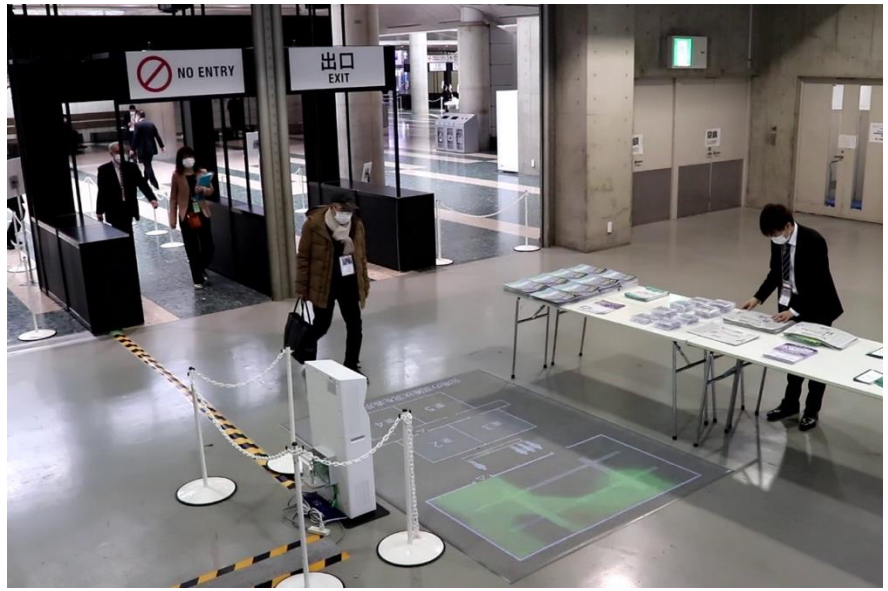
Bluetooth Low Energy (BLE) Scanner

Grid of Raspberry Pi's scanning for BLE devices

1. Pedestrian **density estimation** scanning **all** BLE devices (e.g. smartphones)
2. **Large-scale tracking** and **measurement of dwell time** scanning **specific** BLE devices (e.g. beacons handed out to people)

[Claudio Feliciani & Tobias Arens:
Github: Open-Source Python code Blescan
https://github.com/Crowd-Management-Japan]



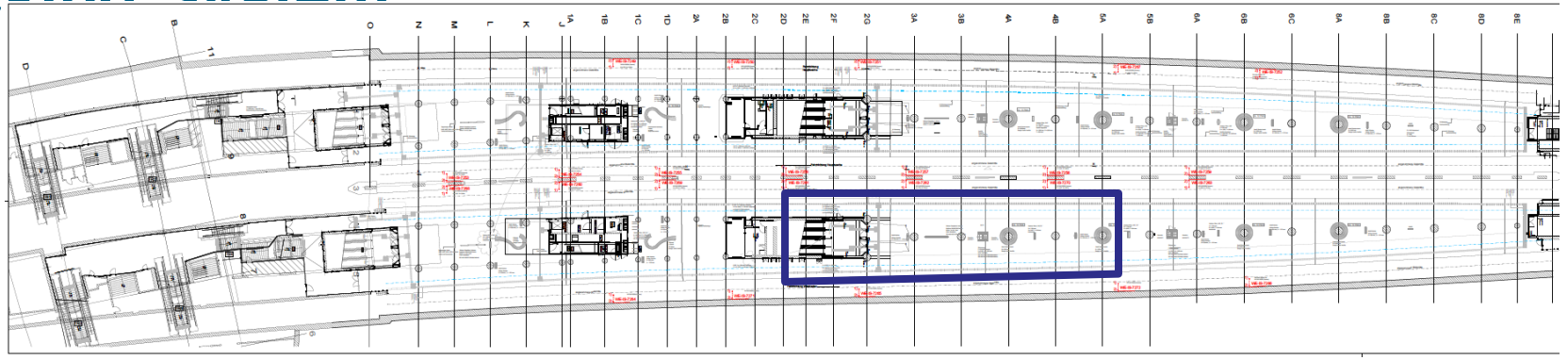


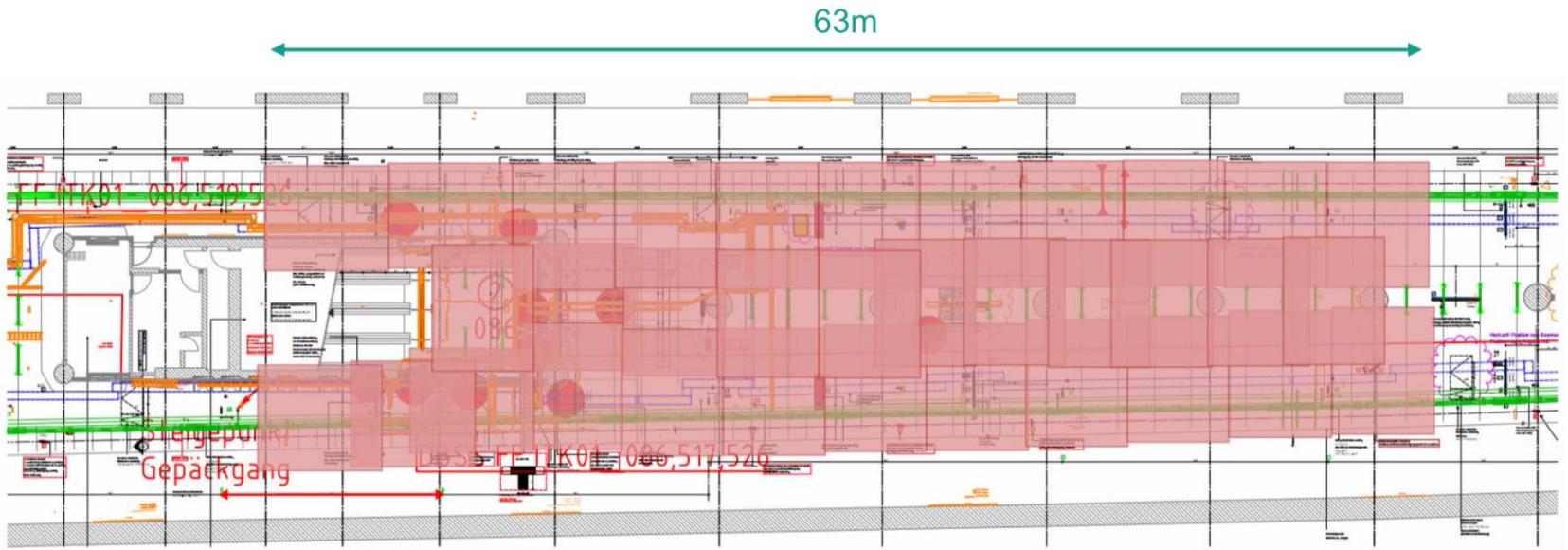
Live relative density heatmap at entrance of business fair

Trajectories (2D, 3D)

Embedded Field tracking System

Tracking system from ASE
consisting of overlapping grid
of 33 stereo cameras
covering 1000 m²
at city train (S-Bahn) platform
of Frankfurt central station





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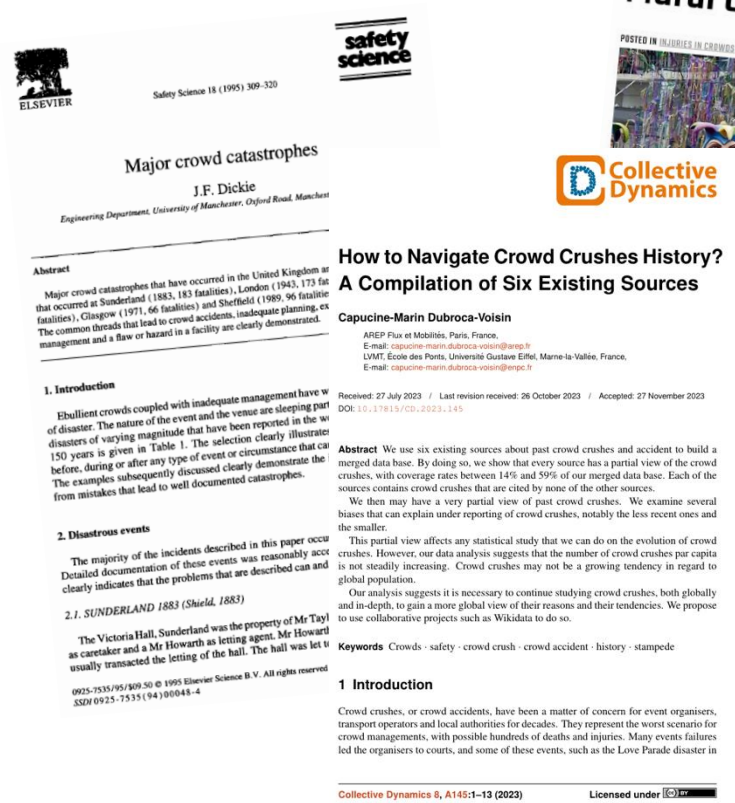
LoStInCrowds - Locomotion Strategies and Injury potential in dense pedestrian Crowds

1. Identifying risk factors for injuries in crowds at bottlenecks (paper review, data/video review, interviews)

Malteser
…weil Nähe zählt.

Deutsches Rotes Kreuz



ELSEVIER

Safety Science 18 (1995) 309-320

safety science

Major crowd catastrophes

J.F. Dickie

Engineering Department, University of Manchester, Oxford Road, Manchest

Abstract

Major crowd catastrophes that have occurred in the United Kingdom ar
that occurred at Sunderland (1883, 183 fatalities), London (1943, 173 fat
fatalities), Glasgow (1971, 66 fatalities) and Sheffield (1989, 96 fatalitie
The common threads that lead to crowd accidents, inadequate planning, ex
management and a flaw or hazard in a facility are clearly demonstrated.

1. Introduction

Ebullient crowds coupled with inadequate management have w
of disaster. The nature of the event and the venue are sleeping part
disasters of varying magnitude that have been reported in the w
150 years is given in Table 1. The selection clearly illustrate
before, during or after any type of event or circumstance that ca
The examples subsequently discussed clearly demonstrate the
from mistakes that lead to well documented catastrophes.

2. Disastrous events

The majority of the incidents described in this paper occu
Detailed documentation of these events was reasonably acc
clearly indicates that the problems that are described can and

2.1. SUNDERLAND 1883 (Shield, 1883)

The Victoria Hall, Sunderland was the property of Mr Tayl
as caretaker and a Mr Howarth as letting agent. Mr Howarth
usually transacted the letting of the hall. The hall was let t

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Collective Dynamics

How to Navigate Crowd Crushes History?
A Compilation of Six Existing Sources

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Received: 27 July 2023 / Last revision received: 26 October 2023 / Accepted: 27 November 2023
DOI: 10.17815/CD.2023.145

Abstract We use six existing sources about past crowd crushes and accident to build a merged data base. By doing so, we show that every source has a partial view of the crowd crushes, with coverage rates between 14% and 59% of our merged data base. Each of the sources contains crowd crushes that are cited by none of the other sources.

We then may have a very partial view of past crowd crushes. We examine several biases that can explain under reporting of crowd crushes, notably the less recent ones and the smaller.

This partial view affects any statistical study that we can do on the evolution of crowd crushes. However, our data analysis suggests that the number of crowd crushes par capita is not steadily increasing. Crowd crushes may not be a growing tendency in regard to global population.

Our analysis suggests it is necessary to continue studying crowd crushes, both globally and in-depth, to gain a more global view of their reasons and their tendencies. We propose to use collaborative projects such as Wikidata to do so.

Keywords Crowds · safety · crowd crush · crowd accident · history · stampede

1 Introduction

Crowd crushes, or crowd accidents, have been a matter of concern for event organisers, transport operators and local authorities for decades. They represent the worst scenario for crowd managements, with possible hundreds of deaths and injuries. Many events failures led the organisers to courts, and some of these events, such as the Love Parade disaster in

Common Injuries in Crowds: Mardi Gras Edition

POSTED IN INJURIES IN CROWDS ON JANUARY 13, 2020

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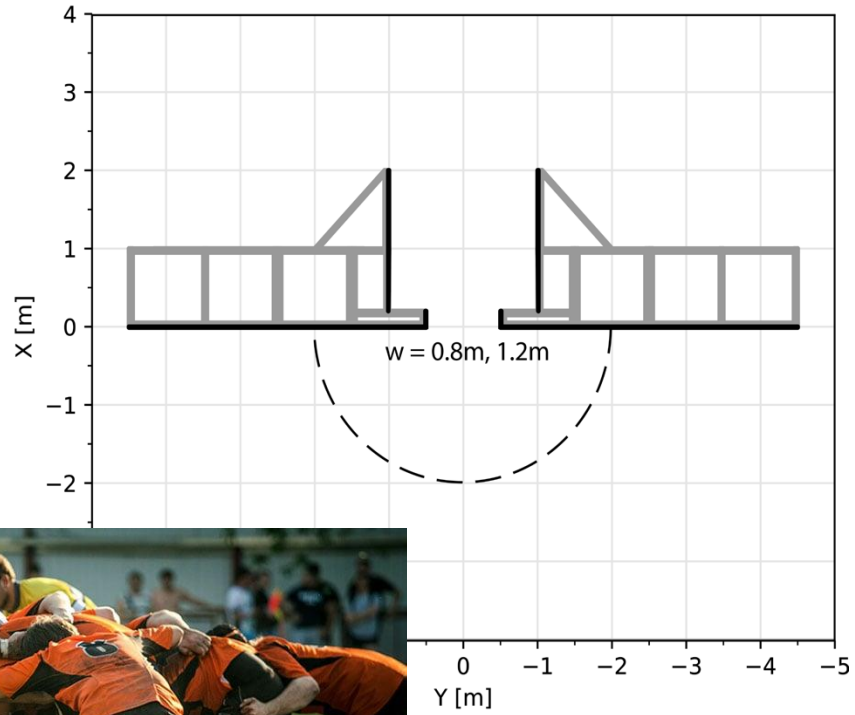
LoStInCrowds - Locomotion Strategies and Injury potential in dense pedestrian Crowds

2. Investigating influencing variables (e.g. density, motivation, age and fitness) on overall body movement and thus the risk of injuries within condensing pedestrian streams

Variation: density, motivation, age composition

Study: influence of individual characteristics: physical fitness, age, gender, height on locomotion strategies

Capturing: head trajectories, MoCap data from 20 neighbouring persons inside crowd of 50 people, force between people (force suit)



[pixabay]

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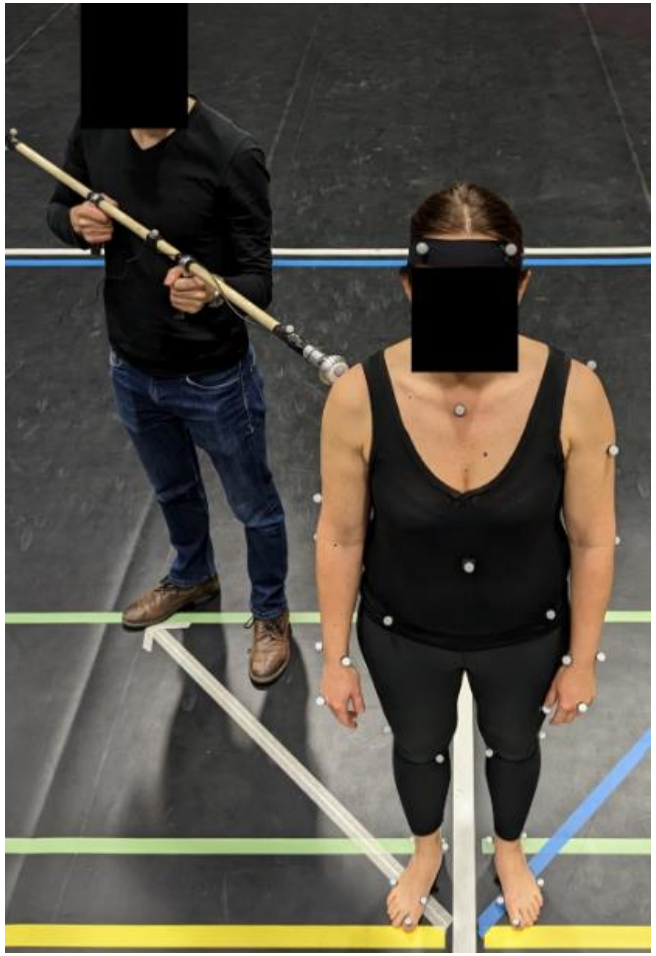
LoStInCrowds - Locomotion Strategies and Injury potential in dense pedestrian Crowds

3. Small-scale experiments (max. 5 people) analyzing individual factors that modulate the risk of injury potentials

Variation: force (location, direction, temporal characteristic)

Study: movement patterns provoked and reconstructed by externally applied contact forces (with respect to physical fitness, age, gender, height)

Capturing: MoCap data, force to people, ground reaction forces (force plates)



[Thomas Chatagnon]

Densedynamics

- A: Bottleneck

Parameter	Variationen
Engstellenbauweise	Wand (ca. 2 m hoch), Schleuse (ca. 1,2 m hoch)
Engstellenbreite	Wand: 0,4 m - 1,2 m, Schleuse: fix 0,5 m
Motivationslevel	niedrig, mittel, hoch
Öffnen der Engstelle	permanent, regelmäßig (1x pro s), unregelmäßig (alle 1-5 s)
Störung	keine, einzelne Personen gehen durch Menge (nach links, rechts, hinten), Anweisungen: z.B. Langsam gehen
Anzahl Engstellen	wenn Schleuse: ein oder zwei Schleusen nebeneinander

- B: Impulspropagation

Tabelle 3: *Mögliche Variationen des Experiments zu Impulsausbreitung.*

Parameter	Variationen
Aufstellformation	verschiedene 2D Formationen
Richtung des Stoßes	von rechts, links, vorne, (hinten)
Stärke des Stoßes	schwach, mittel, stark
Abstand zwischen Probanden	kein Abstand, Ellenbogenabstand, regelmäßig, unregelmäßig
Vorbereitung der Probanden	vorbereitet (sofort), unvorbereitet (nach Wartezeit)
Durchmischung der Probanden	nur Männer, nur Frauen, gemischt Größe / Gewicht ähnlich, gemischt

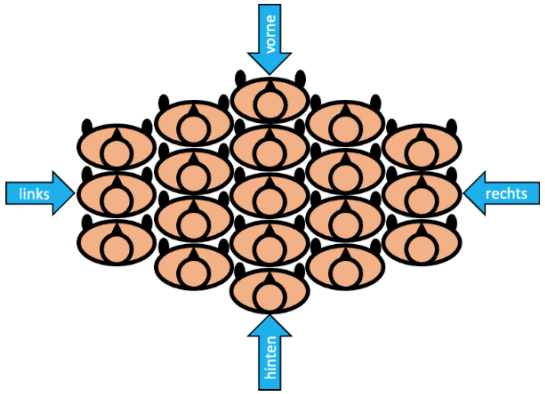


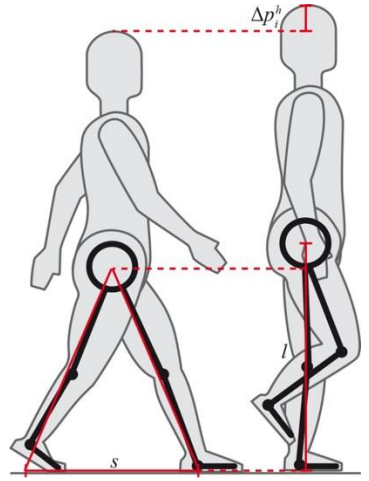
Abbildung 12: *Sketch einer Aufstellformation des Experiments zur Impulsausbreitung mit Andeutung der möglichen Stoßrichtungen.*

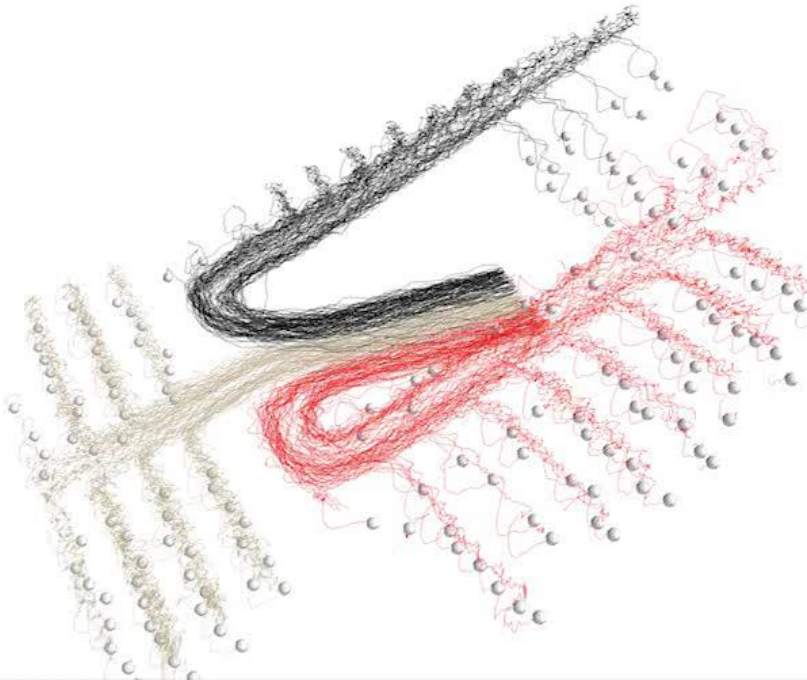
Camera system

[Boltes et al.: Collecting pedestrian trajectories, Neurocomputing 100, 127 - 133 (2013), DOI: 10.1016/j.neucom.2012.01.036]

Camera recordings allow the extraction of **trajectories** of head (and shoulders) and a **qualitative validation**

3D devices like stereo cameras enable **3D tracking** (e.g. stairs, height variation like bobbing)



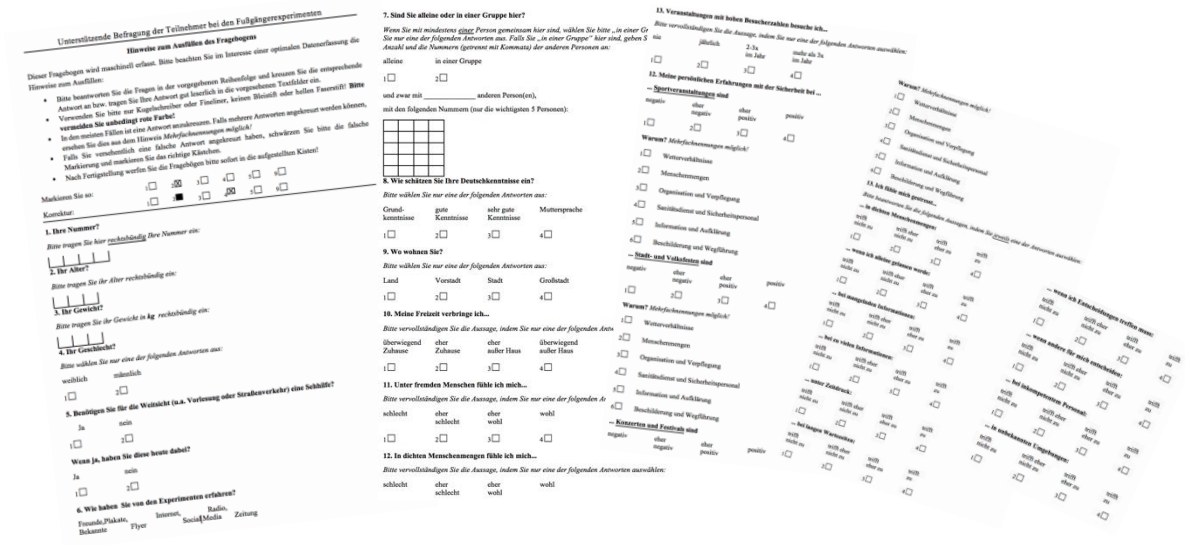


Camera system

Persons‘ height needed for calculating trajectories in real world:
Coding options:

Color code mapping to height range

ID and questionnaires



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VR-Driven Visual Ana. Framework to A

Using social virtual reality for

1. **Immersive analysis** of empirical data derived from pedestrian experiments to perceive the situation as **part of the crowd** by adopting the perspective of an individuum:
   - *e.g. experiencing visual restrictions or*
   - *proximity*
2. Performing **VR-based studies** with authentic populated immersive environment and social reactions of surrounding people

[Project BaSiGo, bidirectional corridor, DOI: 10.34735/ped.2013.5]

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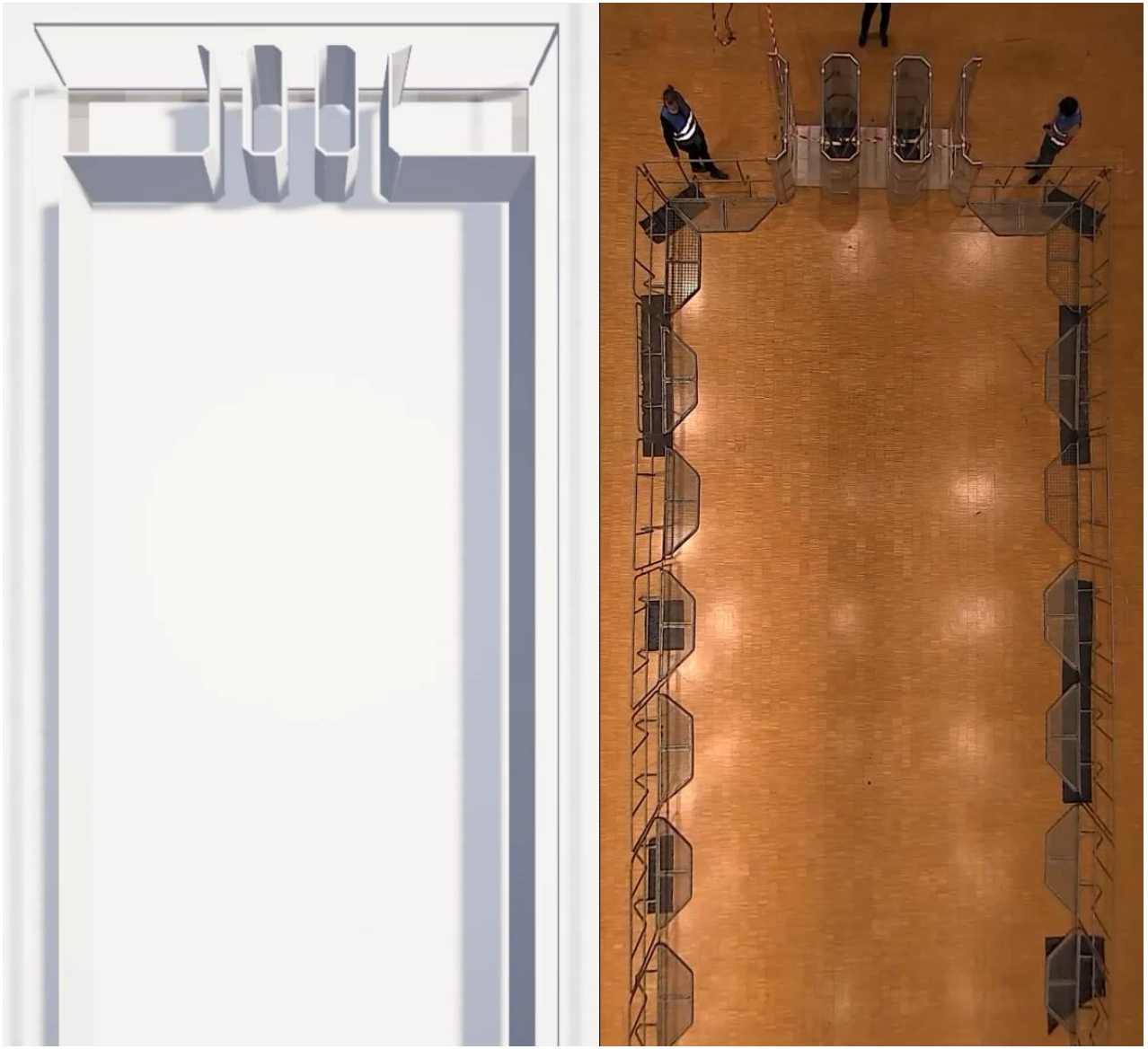
VR-Driven Visual Ana. Framework to Advance PD Research

Visualization library: **Unreal Engine**
(deployable to HMD or room-sized VR)

Input data:
Geometry
Head trajectory (no shoulder orientation)
Individual information:
height, weight, shoulder width,
gender, age

Dataset used for test and expert review:
Crowd Management Experiment within
CroMa exp. (DOI: 10.17815/CD.2023.141)



VR-Driven Visual Ana. Framework to Advance PD Research

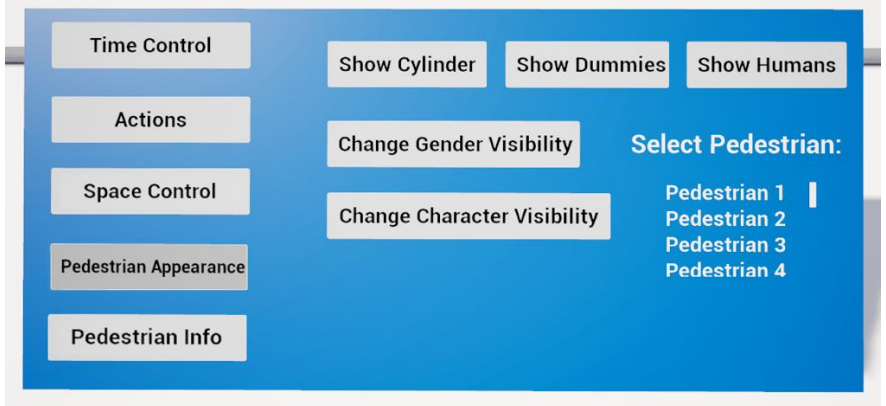
Character representations for virtual agents:

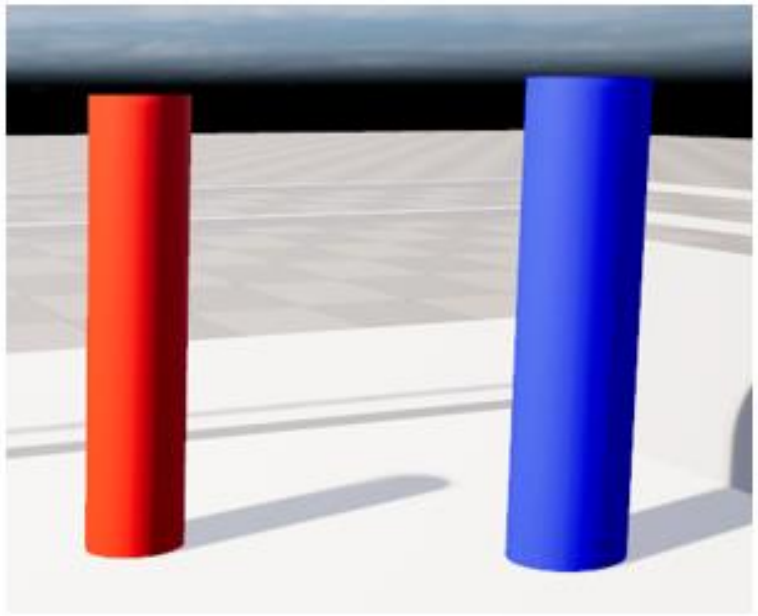
Cylinders (most abstract only showing measured data)

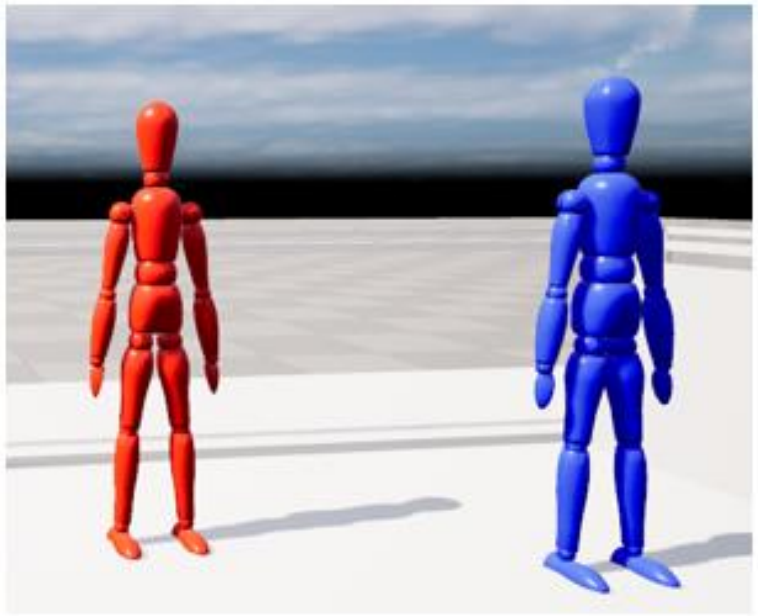
Mannequins (abstract but human like extension)

Human characters (highest perceived presence)

Color: **gender** (red: female, blue: male)







VR-Driven Visual Ana. Framework to Advance PD Research

Perspective:

Exocentric view

(free fly or

balcony with(out) railing)

Egocentric view

(free movement or point of view from another person)