This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 899739

CROWD DNA

H2020 EU Fet-Open Project

Technologies for computer-assisted crowd management

www.crowddna.eu

Call: H2020-FETOPEN-2018-2019-2020-01

Type of action: RIA

Grant agreement: 899739

WP N°1:	**Datasets**
Deliverable N°1.3:	**Field dataset**
Task lead:	**INRIA**
WP lead:	**FJZ**
Version N°:	**1.3**
Date:	**31/10/2023**

Document information	
Deliverable Nº and title:	**D1.3 Field datasets**
Version Nº:	**1.3**
Task lead:	**INRIA**
WP lead:	**FJZ**
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Reviewers:	**Juliane Adrian (FZJ)**
Submission date:	**31/10/2023**
Due date:	**31/10/2023**
Type:	**Other**
Dissemination level:	**Public**

Document history			
Date	**Version**	**Author(s)**	**Comments**
28/09/2023	**0.1**	**Goc O'Callaghan, Paul Townsend, Alexander Elms**	**Draft Version – Submitted for Review**
6/10/2023	**0.1**	**Solenne Fortun**	**First review**
09/10/2023	**0.1**	**Juliane Adrian**	**Second review**
23/10/23	**0.2**	**Julien Pettre**	**Draft version 2**
24/10/2023	**0.1**	**Goc O'Callaghan/Paul Townsend**	**Third review**
26/10/2023	**1.3**	**Juliane Adrian**	**Fourth review**

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Acronyms and Abbreviations

CDI	Crowd Dynamics International Limited
INRIA	Institut National De Recherche En Informatique Et Automatique
ONH	Onhys
WP	Work-package
MoCap	Motion Capture

1. Introduction

This report details the work completed to achieve deliverable D1.3 Field Data and outlines the data captured, analysis and sharing of data and the interrelation of this deliverable with other consortium partners and deliverables. Key contributing partners to D1.3 are CDI who conducted data capture at multiple observatories, INRIA who conducted video and motion data capture at Hellfest and ONHYS who explored IoT data capture at Hellfest.

In this document, we start with an overview of how data was captured at a range of crowd observatories. This information is complementary to D4.1 which also discusses crowd observatories, enabling the reader to have a comprehensive understanding of the data recording process to create field datasets.

We then provide more information about datasets themselves. More specifically we describe the data processing stages in respect of the ethical and legal framework the project fits in.

2. Methodologies for Crowd Observatories

2.1. Objectives

The objectives at these observatories was to capture data for crowd movement in real-life environments. From the video data captured, the intention was for the videos to be analysed and learnings compared to the experiments within controlled environments. The intention is to use the video data sets to extract information regarding crowd behaviours, trajectories of movement and self-organisation.

Another objective was to explore the creation of new kinds of datasets. This objective has mainly be the focus of Hellfest datasets, where, together with videos we have proceeded to the recording of multimodal datasets, mixing video, motion capture data as well as IoT data.

2.2. Methodology and considerations for data capture

2.2.1. Video data

In our initial conception of data capture, the consortium was interested in capturing video data, the quality and content of which would make it possible to extract certain information about crowd activity, density, movement and even the types of interaction between individuals. To do this, we first identified areas of interest in the places selected as crowd observatories, and decided on the placement of fixed cameras continuously recording crowd activity. This was done for the Hellfest observatory, mainly organised by partner INRIA.

The CDI partner was responsible for the UK observatories, took a different approach to video capture. Due to the varying nature of the observatories, it was important for CDI to use a method of data capture that allowed flexibility in position and dynamic movement around the sites to capture interesting crowd movement as and when it occurred.

Initially it was intended that cameras would be put into fixed positions with a constant power supply and the content uploading to cloud storage in real-time. This was determined as a prohibitive way of data capture due to limitations including:

- The requirement for a rigger as part of the data capture team.
- The complications of integrating the rigging with the production of the observatory.
- The cost in sourcing suitable cables for long distance power.
- The risk of the cameras being unplugged by people not involved in the project.
- The requirement for multiple sets of equipment to cover various areas of the observatory.
- Unreliable Wi-Fi/4G networks meaning data would be lost due to failure to upload.
- The huge amount of video content that would need editing into usable clips.
- The cost of storing significant amounts of data.

The equipment that was used for data capture also needed to be complimentary to the equipment being used by INRIA at Hellfest. The reason is to allow for videos across all observatories to be analysed using the same technique. It was decided that GoPro Hero 8 cameras mounted on tripods that extend around 3.5m would be the most appropriate solution. Extra batteries, charging packs and additional SD cards enabled the data capture team to have flexibility and longevity on site without being too reliant on charge points. Four sets of equipment were purchased to allow the flexibility in the team to capture data in different locations at the same time or for bigger areas capture from multiple angles to assist with triangulation and trajectory mapping in the analysis process.

2.2.2. Mocap and IoT data

Where fixed cameras were able to be used, we have combined them with other modalities. We exposed views of colleagues wearing motion capture suits to the cameras. This gives us a synchronised joint tracking of someone's body motion (thanks to motion capture), as well as the activity of the crowd around her/him.

To get an understanding of the activity around cameras, out of the view field, we also disposed IoT sensors that can detect and track emitting mobile devices in given places (with very little accuracy, but capability to track large areas). Mocap and IoT data was done only at Hellfest, given the complexity of this multimodal capture.

2.3. Detailed description of data capture

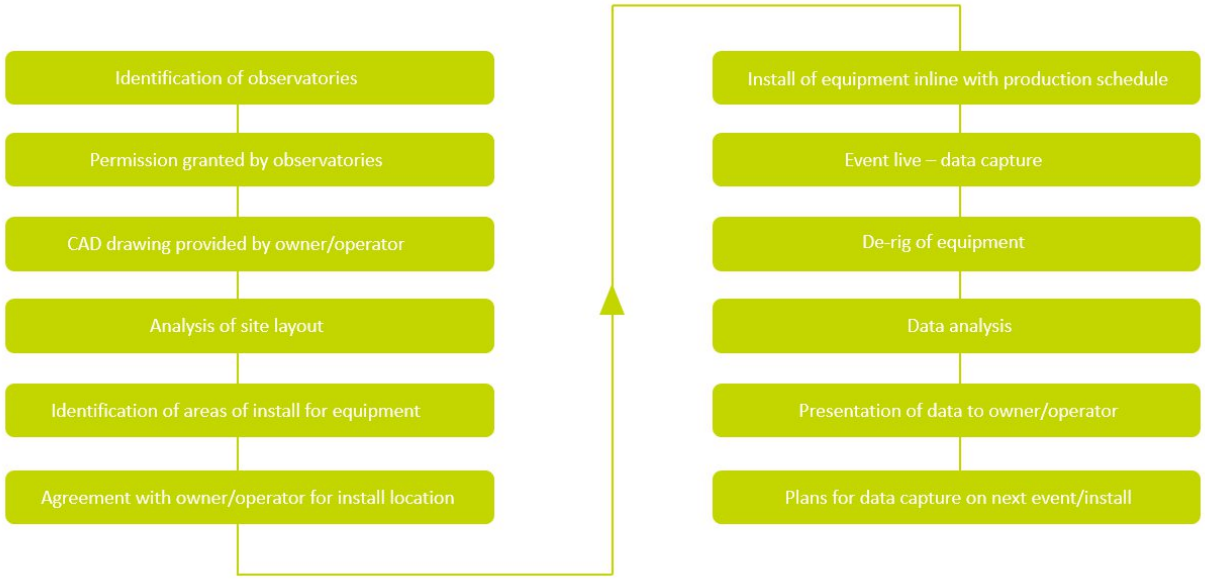

Figure 1. Crowd observatories methodology.

Prior to attending observatories, CrowdDNA partners involved in the installation of crowd observatories went through the following steps:

- Identification of observatory.
- Permission granted by the observatory.
- Analysis of site CAD plans.
- Identification of areas for equipment install.
- Agreement with owner/operator for locations for data capture.
- Obtaining suitable accreditation to attend.
- Equipment testing.

A detailed team briefing was given for each observatory including location overview, filming angles in each respective location, kit list, a risk assessment per observatory, health and safety protocol.

Types of data captured.

The data captured varied depending on the nature of the observatory. Observatories and locations were identified to enable the capture interesting data regarding crowd movements in real-life environments (see Table 1).

Table 1. Locations and events of interest for data capture

Entrance queues and accreditation	The queues that form as a result of the entry requirements to the observatory such as ticket checks, security checks, wristband accreditation.
Merchandise Areas	The self-organisation and queuing of the crowd in merchandise areas.
Bottlenecks	High concentration crowds filtering through a narrow space.
Pinch points	Areas where the crowds are forced to condense causing congestion.
T-junctions/Crossroads	The convergence of multiple routes in which people cross paths and avoid head-on collisions.
Pit areas/Mosh Pits	High concentration of volatile crowd movement involving pushing, circling, jumping and surges.
Stage structure ingress	Growth of the crowd within a stage structure, often before a performance starts.
Stage structure egress	Shrinking of the crowd within a stage structure, often before a performance starts.
Onsite queues	Queues that gather within the observatory.
People Counting	Counting people in the crowd.
Body Motion capture	The way the body moves within a crowd

The table 2 shows the data sets captured in each respective observatory.

Table 2. Type of data captured with respect to capture location

Observatory Type	**Greenfield Festival**	**Greenfield Festival**	**Greenfield Festival**	**Greenfield Festival**	**Indoor Festival**	**Night Club**	**Christmas Market**
Type of data captured	ArcTanGent	Bloodstock	Tramlines	Hellfest	Damnation	Mayfield Depot	Winter Wonderland
Entrance Queues and Accreditation	x	x	x		x	x	x

Merchandise Area	x	x	x	x			
Bottlenecks	x		x	x		x	x
Pinchpoints	x	x	x			x	x
T-junction or crossroads	x	x	x		x	x	x
Pit areas or mosh pits	x	x	x	x			
Stage structure ingress	x	x	x		x		
Stage structure egress	x	x	x		x		
Onsite queues					x	x	x

2.4. Data privacy and ethical approval

A main priority during the data capture process was to ensure data privacy and ethical approval as well as GDPR compliance. In order for access to be ethically granted for data capture at the observatories complied with and the following steps:

- Information about CrowdDNA and the observatories participation included in the privacy policy on the observatories website.
- Terms and conditions of entry to the festival was referenced the privacy policy and therefore information regarding the observatory's participation in CrowdDNA.
- Displaying signage at key locations on site stating that the observatory is participating in CrowdDNA with a QR and/or URL linking to the CrowdDNA website.

CDI and INRIA checked that all of the observatories had complied with the above prior to capturing videos and other data.

During the data capture process every effort was made to ensure the cameras were positioned to film in such a way that individuals could not be identified. In some situation this was not possible due to the limitation of the height of the tripod and the angle of view required to capture the data, for example.

For a video to be released as open source, the video will need to go through some anonymisation to ensure that people are not identifiable. The video, once anonymised, will need to be approved by INRIA, the lead partner in the consortium to ensure ethical approval is received and all data privacy is adhered to.

2.5. Data storage

During filming at Hellfest data was stored on a dedicated NAS, on encrypted disks. During filming at the UK observatories the data was stored on multiple SD cards. This was for two reasons:

1) There was an SD card required per camera.

2) Splitting the videos across multiple SD cards split the risk in case one or more of the SD cards corrupted.

Once filming at the observatories had been completed, the video content from the SD cards were then transferred onto an iStorage secure hard drive. This hard drive is the world's first and only FIPS 140-2 Level

2/3, NCSC CPA, NLNCSA BSPA and NATO Restricted certified hardware encrypted desktop drive. To access the data on the hard-drive a passcode is required and any attempt to access the data without it would cause the hard-drive to wipe the data. This assists with GDPR compliance.

3. Video Data Capture

3.1. Observatories Attended

Multiple observatories were attended in the UK by CDI. These consisted of independent greenfield festivals with varying capacities, an indoor festival, a night club and large-scale Christmas market.

Greenfield Festivals
Tramlines – Sheffield, UK (July 2022)
Bloodstock – Derbyshire, UK (August 2022)
ArcTanGent - Somerset, UK (August 2022 and August 2023)

Indoor Festival
Damnation – Manchester, UK (November 2022)

Night Club
Hacienda at the Mayfield Depot – Manchester, UK (November 2022)

Christmas Market
Winter Wonderland – London, UK (December 2022)

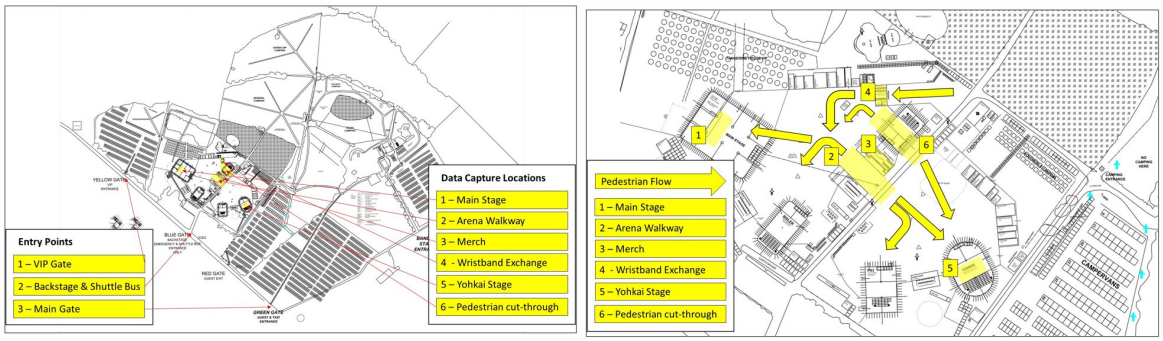

Figure 2. Example CAD maps from ArcTanGent Festival.

Onsite the CDI team had freedom of movement throughout the observatories. A suggested schedule was provided for each observatory caveated with the requirement for flexibility should the crowds be demonstrating some interesting movements or behaviours.

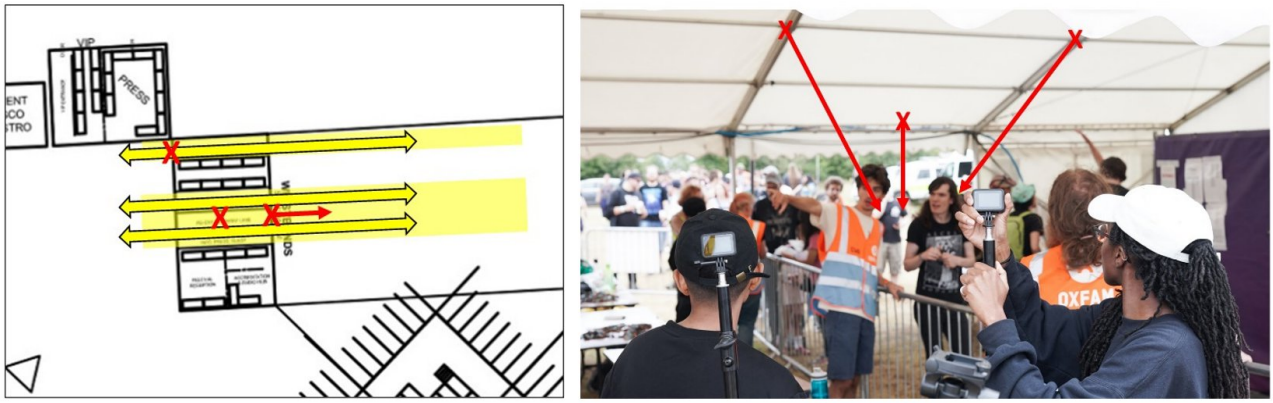

Figure 3. Example of site map analysis and data capture at the observatory. Red crosses show the location of cameras and red arrows the direction in which they are pointing.

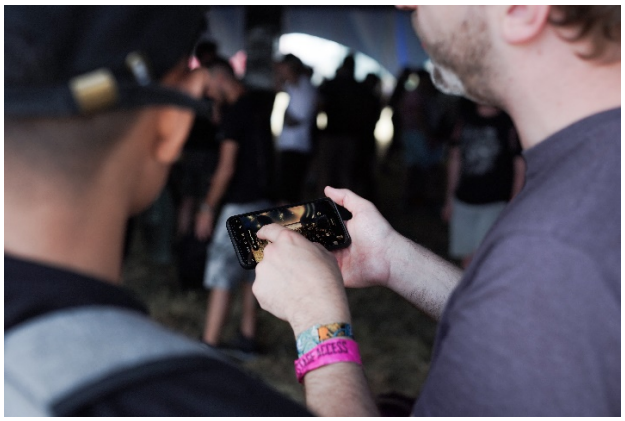


Figure 4. The team in situ at ArcTanGent festival.

The GoPros and tripods were set up in positions to best allow them to capture crowd movement and behaviours from an overhead position. This was intended to help with the anonymisation of people. Where the filming locations allowed, tripods were set up in a triangular formation to assist with triangulation and trajectory mapping of the crowds. This was not always possible due to the infrastructure and movement of the crowds.

The GoPros could be operated using the GoPro app on mobile phones. This meant that cameras could be put into position and checked whilst filming by watching the content being filmed on the app. Before extensive filming sessions, new batteries would be put into the cameras and depleted batteries put on charge.

3.2. Data processing

The consortium has reviewed the videos captured at the observatories and provided feedback on them, enabling CDI to make changes to the filming techniques to ensure the videos are easier to process. Processing of the videos has proved challenging due to the unavailability of time amongst the consortium members to process the videos. There is requirement for a professional video analyst that has an in-depth knowledge of crowds to process the videos.

The videos have been logged per observatory stating file name, date, time, length and location. The video log files are stored with the videos to help with ease of identifications of videos for data processing.

Video Name	Date	Time	Length	Location
Tramlines_Friday_Bag_Check_Gate1	22/07/2022	12:17	00:10:00	GATE 1
Tramlines_Fri_Ingress_Gate1_1	22/07/2022	12:30	00:00:55	GATE 1
Tramlines_Fri_Ingress_Gate1_2	22/07/2022	12:31	00:06:40	GATE 1
Tramlines_Fri_Ingress_Gate1_3	22/07/2022	12:39	00:09:00	GATE 1
Tramlines_Fri_Adj_Pinchpoint_Afternoon_1	22/07/2022	14:05	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_2	22/07/2022	14:16	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_3	22/07/2022	14:28	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_4	22/07/2022	14:40	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_5	22/07/2022	14:52	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_6	22/07/2022	15:03	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_7	22/07/2022	15:15	00:03:00	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_8	22/07/2022	15:22	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_9	22/07/2022	15:34	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_10	22/07/2022	15:46	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_11	22/07/2022	15:58	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_12	22/07/2022	16:10	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_13	22/07/2022	16:21	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_14	22/07/2022	16:33	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_15	22/07/2022	16:45	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_16	22/07/2022	16:57	00:11:47	Pinchpoint
Tramlines_Fri_Adj_Pinchpoint_Afternoon_17	22/07/2022	17:09	00:11:47	Pinchpoint

Figure 5. Example video log.

In line with data privacy and ethical approvals (addressed in the next section) the data captured at the observatories and the respective data sets that are extracted from them could be made open source benefiting crowd management companies, event managers, computer vision for analysing numbers in crowds and human behavioural studies.

4. Multi-Modal Data Capture

4.1. Observatory Attended

Hellfest in France was attended for two successive years. Field data was obtained during the following events:

Hellfest XV edition

17 - 26 June 2022, Clisson, France

Hellfest XVI edition

15 - 18 June 2023, Clisson France

Figure 6 provides a general view of the site of the festival as well as an aerial view of the Warzone stage, that was selected to perform crowd experiments.

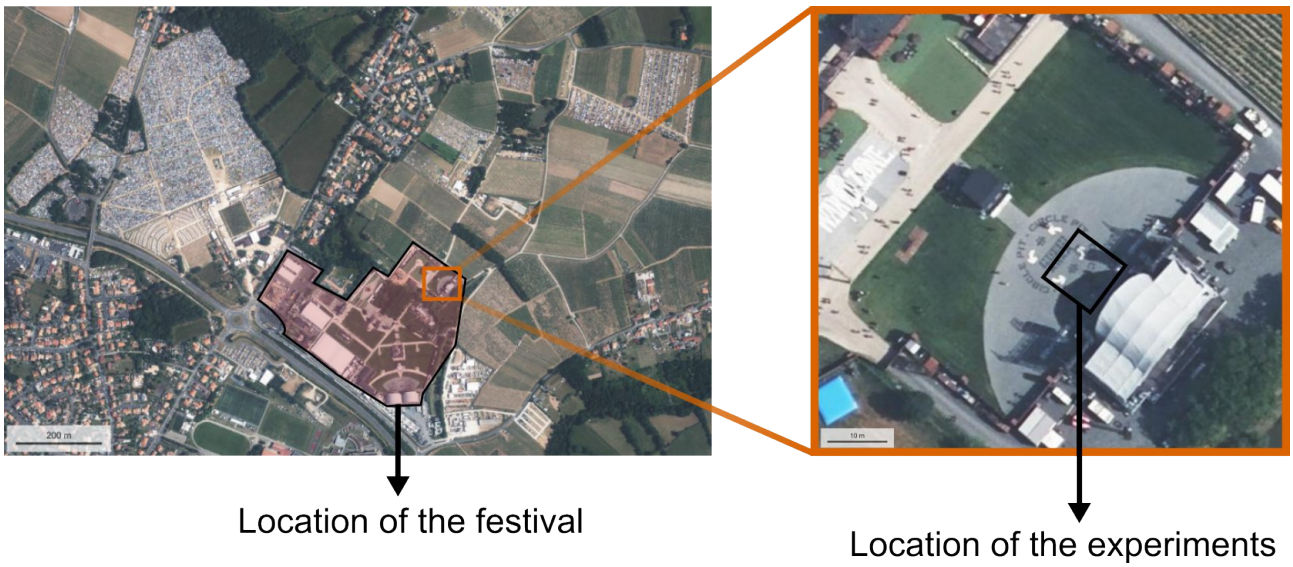

Figure 6. Aerial view of the location of the festival (left), and location of the Warzone stage where mocap experiments took place

4.2. Types of data captured

The aim of the measurements carried out at Hellfest was mainly to establish a link between the image of a crowd as a whole, captured on video, and the movement of individuals' bodies within it. To do this, we chose the Warzone stage as the main measurement site. This stage is home to music groups affiliated with the punk movement, and allows us to observe the dances associated with it (mosh pits, circle pits, pogos), where there is a great deal of physical interaction.

For capturing these relations, two types of data were recorded: full body motion, using motion capture vests (XSENS), as well as videos of the crowd.

The data capturing conditions are illustrated in Figures 7 and 8. Figure 7 shows how the motion capture looked when worn by participants. The equipment was adjusted to the body and contained a number of IMU units. The combination allows each of the control units to be associated with one of the subject's limbs: head, arms,

forearms, legs, thighs, etc. Participants are also wearing coloured caps or hat, so that they can be easily spotted on cameras filming the crowd at the event.

Figure 7 - Illustrations of the XSens suits capturing system. Left: two partners of CrowdDNA are wearing the capture suites. Right: calibration of the motion capture system on site (Warzone).

Figure 8 illustrates conditions for the video capture. We placed 2 cameras (GiGA cameras, able to stream images over the ethernet) with elevated viewpoints pointing at the audience of the Warzone stage. On the right image, one can spot one of the subjects wearing the XSens suit, wearing the orange color caps.

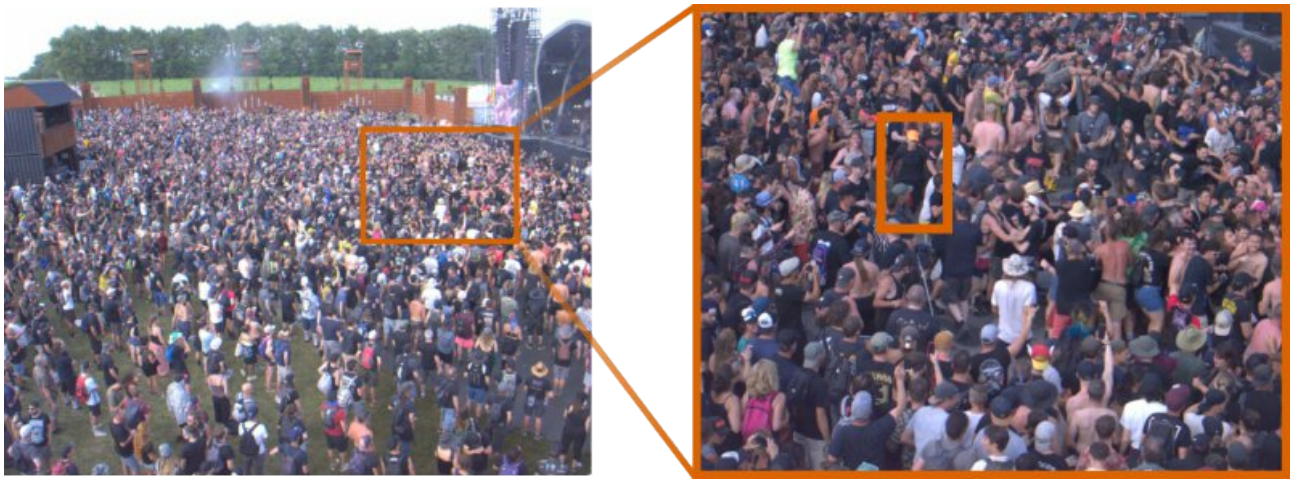

Figure 8 – illustrations of the camera viewpoint on the crowd at Warzone, with 2 focal distances, respectively 6mm (left) and 24 mm (right).

To have an understanding of the circulation of the crowd in places not seen by the cameras, we also tested a system to capture flows of attendees during the festival, which is based on IoT data. The sensing system captured traces of emitting portable devices (phones, or others) used by people at the festival. Multiple detections throughout the festival enabled us to have an estimate of the attendance at different locations, and also about the flows between them.

The IoT datasets are lists of detected devices associated with IoT sensors.

4.3. Video dataset Analysis

The video dataset has been recorded and is internally available to the CrowdDNA consortium. Given the sensitive nature of the video data, we have recruited an engineer to carry out detailed manual processing of the

videos to ensure that they are anonymised and comply with CrowdDNA's legal and ethical framework. At the time of writing, this task has not yet been completed and we are therefore delaying the public release of the video dataset.

4.4. IoT Analysis

IoT data has been captured at the Hellfest twice (in 2022 and 2023). Pending a full analysis by INRIA, a preliminary one has been conducted by ONHYS on the data collected in 2022.

For this kind of data, the main idea is, thanks to sensors deployed throughout the infrastructure, to scan for the presence of devices using Bluetooth and Wi-Fi connectivity. In this way, it is possible to detect a wide range of connected devices, such as smartphones, smartwatches, as well as various wireless headsets and earphones (in the general case, although headsets and earphones would be less likely at a music festival).

The collected data then takes the form of successive timestamped detections associating a device's MAC address (anonymized through hashing at the level of the sensor itself) to a Bluetooth or Wi-Fi signal strength. Although, there are many complicating factors, such as (1) interference, (2) certain people having multiple or no devices (on or off), or (3) the tendency of devices to periodically cycle through randomly generated MAC addresses. It remains possible to use detection counts and simultaneous detections by multiple sensors to roughly estimate the number of people in an area, as well as possible movements from one area to another thanks to correlated detections.

Beyond the usefulness of this data to inform posterior reconstructions of events through simulation, it is also invaluable to inform a hypothetical system capable of estimating the current state of the crowd in an infrastructure, with the goal of adapting said environment to respond to situations that could develop in dangerous ways. As this is exactly the aim of tasks T4.2 through T4.4, this data thus represents the first step in their execution.

We give below some examples of what can be recovered from this kind of data. First, Figure 9 shows the map of the Hellfest as well as the positions of the IoT sensors, which are as follows: 5 sensors at the Hell City Square (which connects the outside entrance, camping grounds entrance, a merchandising area, and the entrance to the music area), 5 sensors at the entrance of the music area (the entrance where tickets are needed), 5 more sensors at the Warzone area (extreme music area with active crowds: walls of death, mosh pits, etc.), and 1 last sensor along the main passage from the Warzone to the two main stages. Figure 10 then shows one of these sensors onsite (EKO012).

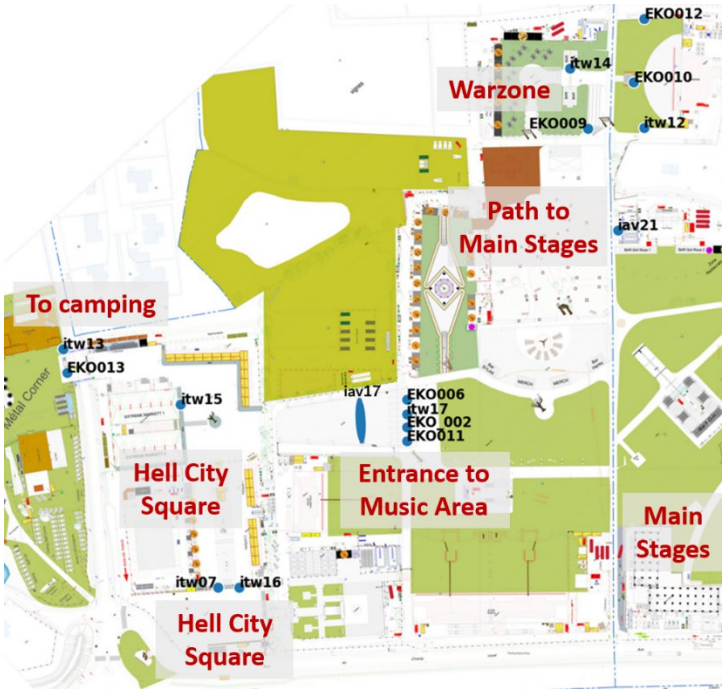

Figure 9. Map of IoT sensor locations (blue dots) at the Hellfest.

Figure 10. An IoT sensor (EKO012, at the very top on the map) onsite.

The first example of collected data shows how, even though individual attendants cannot be counted, it is still possible to compare proportions of people on certain paths. Figure 11 shows two flows of devices on Sunday June 24th: the first one concerns devices moving from the camping grounds to the entrance of the music area, and the second one concerns those whose origin was the outside entrance, as depicted by the two red arrows. Although the same flows of devices can be observed at the beginning of the day, much fewer attendees entered from the outside as the day progressed, while attendees who had a tent onsite could continue to come and go throughout the day.

Figure 11. Flows of IoT devices over time for two paths: camping to music area (top arrow) and outside to music area (bottom arrow).

An additional interesting fact that can be observed, if we focus more on the flow of devices from the camping grounds (top graph on Figure 3), is the large peak towards 21:30 which corresponds to the imminent

performances of the day's two heavy hitters, "Sabaton" and "Metallica" who were set to perform starting at 21:45.

Following this last observation, the second example shows how it is possible to correlate movements of people between two consecutive performances at two different locations.

This example uses the sensors located at the Warzone, as well as the lone sensor located along the path connecting the Warzone to the Main Stages. Figure 12 then depicts the flows of devices that have been detected in one area and that had previously been detected in the other. As can be observed, there is a large peak at around 17:20 on Sunday June 24th (which corresponds to the end of "Terror" at the Warzone and the beginning of "Bullet for My Valentine" at Main Stage 2).

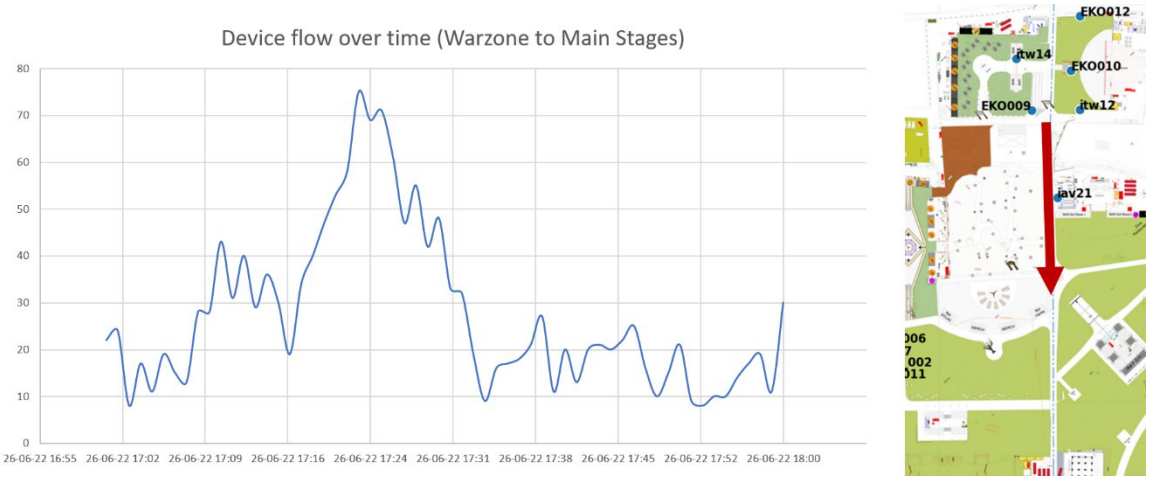

Figure 12. Large device flow peak around 17:20, during the end of "Terror" at the Warzone and the beginning of "Bullet for My Valentine" at Main Stage 2. Arrow on right indicates the direction of the crowd's movement.

We were, in fact, able to observe the corresponding flow of people at that time, as shown by stills extracted from videos recorded along the way (Figures 13 to 16). As can be seen on the third still, this flow was so large that many people chose to traverse the "little forest" instead of going along the main path. Some element of luck was present in being able to observe this in person, as it is one of the largest such peaks in the data for that day. This shows how it might be possible to exploit such data in order to infer the magnitude of the flows and possibly intervene on the infrastructure itself (e.g. in other more constrained venues: open additional pathways for people moving from one spot to another).

Figure 13. View of the crowd starting to move at the Warzone. Over time most of the crowd transitioned to the Main Stage area. Red label on right shows camera orientation.

Figure 14. View of the crowd at the start of the path connecting the Warzone and the Main Stages, note that for this performance transition, the crowd was particularly large, saturating the path. Red label on right shows camera orientation.

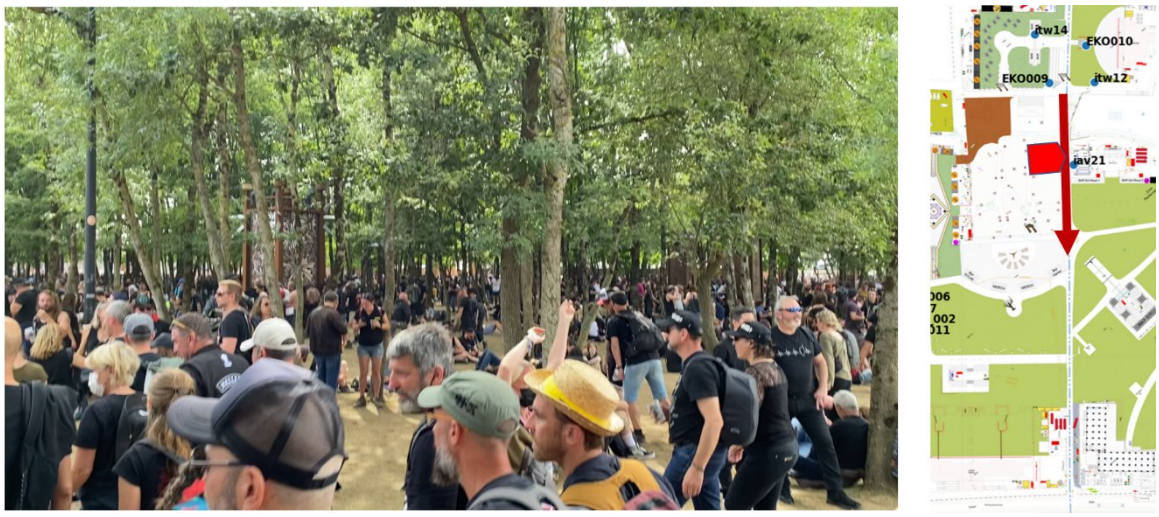

Figure 15. View of the crowd crossing through the forest due to a lack of space on the path. Red label on right shows camera orientation.

Figure 16. View of the crowd after arriving to the (already heavily populated) Main Stage area. Red label on right shows camera orientation.

This last example shows two things. The first one is an occurrence of a crowd movement which can be detected through IoT (which includes its magnitude, thus motivating tasks T4.2-T4.4), and which correlates well with the festivals performance time schedule (in general, we can observe such device flow peaks each time a performance ends, and another starts). The second thing is how crowds are expected to move between stages over time, which poses the question of how to configure them in simulation, thus motivating the work described in WP2.

5. Open-Source Data Sets and Videos

Using a third-party company video data can be anonymised and made open source once vetted for data privacy and ethical approval. The intention is to make a short video clip open source and displayed on the CrowdDNA website (hosted on the CrowdDNA YouTube channel). In the description of the video hosted on YouTube instructions on how people can request access to longer versions of the video will be made available. It is intended that the requests will go through a vetting process to ensure that those in receipt of the longer video will be using it for ethical reasons for the purposes of further understanding and improving crowd movement.

6. Project Legacy

The open-source data sets are the legacy of the project. Therefore, the main focus of datasets for the remainder of the project is to seek ways to provide suitable data sets from observatories and lab experiments that meet data privacy and ethical approval for release. If there is a suitably identified opportunity to innovate a new project from CrowdDNA, some of the data captured so far could be utilised.

The legacy of the project can be achieved through:

- Computer vision (Ml, AI and Neural Network training and validation of datasets)
- Further research into crowd behaviour
- Extension of CrowdDNA project and different scale of crowd modelling

7. Conclusion

At the time of publication of this report for deliverable D1.3 multiple observatories had been successfully attended, a couple of which were attended in both 2022 and 2023 (ArcTanGent and Hellfest). The data captured has been significant and holds potential worth in better understanding crowd movement and behaviours. However, there are some notable limitations in the field data regarding the processing of the information. This is due to a lack of resource/time to be able to process the data and also due to the requirement for a professional video analyst with an indepth knowledge of crowds. The recent recruitment of an engineer fully dedicated to this task will enable us reaching the targeted objective for this datatset within the duration of the project. Overcoming these resource-based hurdles is now addressed which lower the project is at risk at not releasing any open-source information for others to exploit.

It is intended that this deliverable will be updated once the video analyst has started at INRIA. An update will be made to this report in due course.