Ref. Ares(2024)6631495 - 19/09/2024

TEMA

TRUSTED
EXTREMELY PRECISE
MAPPING AND PREDICTION
FOR EMERGENCY
MANAGEMENT

Deliverable D5.1: Report on algorithms for precise Digital Twin construction

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Project Information

Project acronym:	TEMA
Project full title:	Trusted Extremely Precise Mapping and Prediction for Emergency Management
Call identifier:	HORIZON-CL4-2022-DATA-01
Type of action:	HORIZON Research and Innovation Actions
Start date:	1 December 2022
End date:	30 November 2026
Grant agreement no:	101093003

D5.1 – First report on algorithms for generating a precise Digital Twin	
Executive Summary:	**In this report the results regarding the solutions for generating a precise Digital Twin in the TEMA project are presented. Thereby the focus of the reported results lays on solutions regarding generating precise Digital Twins for the TEMA use cases and their specific requirements (e.g. poor visibility, poor data quality). In relation to this, results are reported on solutions for image preprocessing (e.g. colour correction, denoising), speeding up the generation of the Digital Twin by using sorting mechanisms and integration of other data sources than image data in the Digital Twin using TEMA use case data. In addition, based on an analysis of historical natural disaster data, requirements regarding the data material and best practice statements regarding data formats and data acquisition were formulated. The aim of the ongoing**

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	work is to enable the construction of the best possible Digital Twins for the TEMA use cases and trials to provide one critical component for the TEMA platform.		
WP:	5 (T5.1)		
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Version:	2	Status:	Final
Deliverable Type:	R — Document, report	Dissemination Level:	PU – Public
Official Submission Date:	31 May 2024	Actual Submission Date:	4 June 2024
Resubmission Date as requested by EC: 18 September 2024	19 September 2024		

This project has received funding from the European Union – European Commission under grant agreement No 101093003

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The TEMA consortium consists of the following partners:

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Document Revision History

Version	Description	Contributions
0.1	First Draft	ND
0.2	Final Report after Review by Editor	DLR, ND
0.3	Revised Report	ND
0.4	Revised Version of the Report after Review by Editor	DLR, ND

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List of Figures

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List of Tables

List of Terms and Abbreviations

***Table 1**: List of Terms and Abbreviations*

Abbreviation	Description
CLAHE	Contrast Limited Adaptive Histogram Equalization
CRS	Coordinate Reference System
HLOD	Hierarchical Level of Detail
KML	Keyhole Markup Language
NDM	Natural Disaster Management
POI	Point of Interest
SSE	Screen-Space Error
SotA	State of the Art
WP	Work package
TEMA	Trusted extremely precise mapping and prediction for emergency management

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Executive Summary

Natural disasters with the potential to cause enormous damage and losses to infrastructure as well as fatalities have increased considerably in recent decades. This places enormous demands on emergency services with regard to the management of natural disasters. Therefore, the aim of the TEMA project is to improve Natural Disaster Management (NDM) by automating precise semantic 3D mapping and disaster evolution prediction to achieve NDM goals for wildfires and floods in near-real-time.

One technical component of the TEMA platform is the Digital Twin of the afflicted areas. Digital Twins are digital representations of the situation and can provide an overview of the natural disaster. This helps improving NDM by displaying the operational situation in the best case visually as well as georeferenced. However, natural disasters (in TEMA the use cases are forest fires and floods) pose challenges in the construction of Digital Twins (e.g. low visibility during disasters due to, for instance, smoke or no sunshine, bad data quality). Therefore, one focus of the work to date has been on developing solutions for addressing the challenges posed by natural disasters with floods and forest fire by experimenting with various processes for generating a Digital Twin.

This document (Deliverable D5.1. "Report on algorithms for precise Digital Twin construction") encapsulates the work and research achievements of Tasks T5.1 (M7-M30) over the months M7 to M18 for the project and represents the first deliverable of Work Package 5 (WP5) within the TEMA project. The task in T5.1 focuses on addressing the challenges in the generation of Digital Twins. These include the component 3D models, low image data quality due to bad weather conditions, poor visibility as well as contrast and noise problems that can obscure critical features in regions affected by natural disasters. Another focus of the TEMA project is to be able to update the Digital Twin, which was created before the natural disaster, at least partially (e.g. with disaster information layers) during the event. As this information is time-critical, it is important to speed up the generation of the Digital Twin particularly by techniques and processes specific to the image data from TEMA use cases of forest fires and floods.

In relation to this, results are reported on solutions for image preprocessing (e.g. colour correction, denoising), speeding up the generation of the Digital Twin by sorting

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mechanisms and integration of other data sources in the Digital Twin than image data (e.g. results of Task T3.2). These results of the technical implementation will be presented using TEMA use case data. Part of the work to date has also focused on reviewing and analysing historical data on natural disasters from TEMA end users and technical partners. Based on this analysis, requirements regarding the data material and best practice guidelines regarding data formats and data acquisition were formulated, which can be helpful for the pilot trials in Task T6.4, among other things. The processes and techniques devised in Task T5.1 will be further refined and then used across other TEMA tasks. With sorting mechanisms and image preprocessing the work to date specifically will be fed into Task T5.3 focused on augmented reality and rapid visualization.

This deliverable acts as documentation of the work on the Digital Twins to date and includes also a section, which links the present work with the following project tasks. Furthermore, these findings will provide the initial and concrete input for the next work packages.

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1 Introduction

1.1 Purpose and scope of the document

Natural disasters do not only pose great challenges to the disaster prevention and mitigation capacity of infrastructure but also present major demands for the response of rescue and recovery (Novelo-Casanova et al. 2021). In a post-disaster situation, timely response by allocating resources to the most affected areas is one of the most critical aspects to reduce human suffering and number of casualties (Doğan, Şahin & Karaarslan, 2021). In this context, gathering current information becomes the most crucial thing. Digital Twins capturing the afflicted area are one of the most promising technologies for better management of complex environment and facilitates the connectivity between data and rescue teams required through many self-operative functionalities (Fuller et al. 2020; Yu & He, 2022).

In most frameworks for NDMs, however, the possibilities of Digital Twins are not fully exploited. Thus, Digital Twins cannot only be constructed to visually represent the afflicted area but also data from different sources such as sensors or geovisual analyses and predictions can be integrated. However, up to now systematic and holistic approaches were still lacking. TEMA, on the other hand, implements a systematic approach to NDM in which various helpful technical components work together in one solution. As part of TEMA's systematic approach, Digital Twins are integrated into an overall TEMA platform with the aim to improve NDM (e.g., for wildfires, floods) by automating precise semantic 3D mapping and disaster evolution prediction to achieve NDM goals in near-real-time. However, natural disasters (here: the two TEMA use cases fires and floods) pose particular challenges in the construction of Digital Twins such as low visibility during disasters due to, for example, smoke as well as no sunshine compared to typical cases of dry weather and sunlight, and low robustness, when exploiting different data sources of varying image quality. These challenges can be addressed, for example, with photogrammetry solutions. Solutions regarding the construction of precise Digital Twins in the TEMA project are presented in the following report.

1.2 Structure of the document

The remainder of this deliverable is structured as follows. Section 2 gives a brief theoretical and empirical overview about definitions of Digital Twins, their role in NDM,

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their construction and challenges thereof. Starting from this foundation, in Section 3 the focus lays on the role of Digital Twins in the TEMA project. In this Section we outline our definition and the specific requirements of precise Digital Twins in TEMA Furthermore, we also explain how Digital Twins are integrated in the TEMA solution and their interaction with other technical TEMA components. In Section 4 we present the advances beyond SotA during M7-M18 period and the results of the ongoing Task T5.1. In particular, we focus on our work of optimizing the precision of the Digital Twins for the specific requirement of NDM. Finally, Section 5 concludes this deliverable.

2 Digital Twins

2.1 General definition Digital Twin

Common understanding of a Digital Twin is that they are a virtual equivalent or a dynamic digital representation of a real system (Boschert, Heinrich & Rosen, 2018; Grieves, 2014; Tao et al., 2022). In the research literature, however, the definition of a Digital Twin is much more complex. Many authors distinguish between different dimensions in which a Digital Twin model can be expressed: geometry, physics, behavior, and rule (Tao et al., 2019). Thereby, the geometric model describes the geometric shape and assembly relationships of the physical entity. The physical model reflects the physical properties, characteristics and constraints of the physical entity. The behavioral model represents the dynamic behavior of the physical entity in response to the internal and external mechanisms. The rule model incorporates historical data and can exploit tacit knowledge, making the Digital Twin model smarter. In practice, however, not all of these four dimensions are fulfilled when we talk about a Digital Twin. In this project too, the work to date (Task T5.1) has focused on the dimensions of geometry and physics. It is only through integration of other data sources or technologies such as prediction models, for example, that the rule dimensions of Digital Twins are fulfilled in the TEMA project (see **Section 3.3**) Integration of Digital Twins in TEMA for more information on the integration of Digital Twins in the TEMA platform).

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2.2 Challenges in creating a Digital Twin

Regarding creating a Digital Twin, there are different challenges. A central challenge is the data needed for generating a Digital Twin (Fuller et al., 2020). The key here is to have useful data which means quality data that is noise-free with a constant, uninterrupted data stream. Poor and inconsistent data represents a challenge in creating a Digital Twin and can risk the Digital Twin underperforming as it is acting on poor and missing data. Another challenge in creating Digital Twins lies in combining multiple data sources. Here, today's technical innovations offer the possibility to describe the complex nature of, for instance, natural disaster situations not only based on information from a single data source, but multiple modalities make it possible to obtain a comprehensive overview about disaster situations and phenomena (Lahat, Jutten, Lahat, Lahat, & Jutten, 2015). However, the increased availability of multimodal data raises challenges in efficiently and accurately creating Digital Twins due to data integration and analytics (Nweke et al., 2019). The primary issues related to dealing with heterogeneous data in disasters are twofold: First, data generated from various sources such as sensors and other sources are stored in multiple different data structures (von Lubitz, Beakley, & Patricelli, 2008). Second, different types of data exist in a single modality, which increases the complexity of data characterization (Lahat et al., 2015). For example, social media as an emerging modality includes texts, images, videos, geolocations, and hyperlinks describing their emotions, activities or built environment disruptions during disasters (Alam, Imran, & Ofli, 2017; Alam, Ofli, & Imran, 2018). The heterogeneity of data formats, timeframes, and semantics makes it very challenging to efficiently and accurately understand the spatiotemporal fluctuations in disasters and humanitarian actions in the Digital Twin paradigm (Fan et al., 2021).

3 Digital Twins in TEMA

3.1 Our definition of a precise Digital Twin in TEMA

In the context of the TEMA project a precise Digital Twin means a georeferenced Digital Twin. The term georeferencing thereby refers to an environment with locations in physical space and is commonly used in the geographic information systems field to describe the process of associating a physical map or raster image of a map with spatial locations. When it comes to locating objects on a planet, one must choose a Coordinate

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Reference System (CRS) to express the location. Each CRS defines locations using the ellipsoid model it is based on. There are different ellipsoid models (called datums). As the georeferenced system in TEMA must be completely uniform, we use the CRS EPSG to create a precise georeferenced Digital Twin. This gives the possibility that once the Digital Twin has been georeferenced, it can express actual geographic coordinates. However, the georeferenced Digital Twin is not primarily about reading coordinates. Moreover, in the TEMA project georeferencing is the key requirement for matching data from all different technologies respectively data sources. Thereby data can stem from images, maps (GIS), analytics as well as prediction models (e.g. in TEMA: SV-tech-01 (Drone-based images), data from SV-tech-04 (Geovisual analytics) and prediction (PDM-tech-01 (WFA-FireSim); PDM-tech-02 (3Di Hydrodynamic modelling)). If this data is not georeferenced, the data is worthless in the TEMA project as it cannot be properly integrated and therefore used in the overall TEMA platform solution. As TEMA works with many different technologies and data sources one of the main critical issues the project partners have to tackle in the future, is that different data have to be based on the georeferences to be integrated in the georeferenced Digital Twin/ 3D-modell of the afflicted area. This is particularly important if, for example, visualizations of the predictions (PDM-tech-01 (WFA-FireSim); PDM-tech-02 (3Di Hydrodynamic modelling)) over time are to be displayed later in the Smart Desk Software (SV-tech-07). We have informed the TEMA consortium that georeferenced data is a requirement.

Working with georeferenced data also makes it possible, for example, to meet the wishes of end users in the TEMA project, which were expressed in the workshop on Digital Twins, to look at different data from the same perspective (without changing the position (viewing angle/orientation) on the 3D-model-map of an afflicted area when changing masks (e.g. Digital Twin of the afflicted area, Digital Twin with integrated prediction modelling).

3.2 Requirements of a Digital Twin in TEMA

Natural disasters pose specific challenges when generating Digital Twins. In contrast to Digital Twins of large buildings, for example, where data acquisition (e.g. image data) would be carried out without extreme time pressure under the best possible conditions such as dry weather and a certain amount of sunlight. This avoids reflections, excessive shadows and noise. This is not always possible with natural disasters because NDM has to work quickly. Depending on the disaster, poor visibility (e.g. due to smoke and/ or

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insufficient sunshine) and reflection (e.g. reflection of water during floods) pose difficulties in generating a Digital Twin of the afflicted area. This is where best-practice training of drone pilots and automatic flight route planning (e.g. SV-tech-01 (Drone-based image and data acquisition)) can help. If this is not successful, there are often also problems with regard to robustness, when exploiting different data sources of varying image quality. These issues are made worse by the near-real-time constraints. Existing solutions have difficulties here. This requires the development of new solutions for the use case of generating Digital Twins in NDM. Image enhancement solutions tested during M7-M18 period are quite promising and partially solve the problem. They are presented in their application in **Section 4**.

3.3 Integration of Digital Twins in TEMA

The Digital Twin is firmly integrated in the TEMA platform. Since TEMA has two use cases from NDM (flood and forest fire) and different technologies are used for them, there are two different computation flows of the TEMA platform. One focuses on flood cases and the other on forest fire cases. Both are presented here, and the integration of the Digital Twin is explained in each case.

The integration of the Digital Twin (SV-tech-03) in the TEMA platform solution for the fire monitoring mission is depicted in **Figure 1**. The TEMA platform consists of various technical components that have to integrate with each other. These technologies include, for instance:

- PDM-tech-01 (WFA-FireSim)
- PDM-tech-03 (Smoke and wind modeling engine)
- PDM-tech-05 (Information Fusion)
- SV-tech-01 (Drone-based image and data acquisition)
- SV-tech-04 (Geovisual analytics)
- TFA-tech-05 (Flood segmentation)
- TFA-tech-06 (Object detection) (This is optional, because these technologies provide input to PDM-tech-05)
- TFA-tech-07 (Person re-identification)

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- TFA-tech-09 (Satellite-based burnt area detection)
- TFA-tech-11 (Geosocial media analysis)

Data from the respective technologies is pushed to the Context Broker (CB) of SV-tech-02 (Digital Enabler). As one part of the TEMA Digital Twin (SV-tech-03) drone image data is processed. The drone image data has to be received via pull- or push-request. Data is processed and a 3D model in a Cesium tile format (Cesium, 2024) is delivered through the TEMA API gateway to the Digital Enabler (SV-tech-02). The data communication is done via SV-tech-02 (Digital Enabler). TEMA Digital Twin (SV-tech-03) is then displayed in either Smartdesk Software (SV-tech-07) or XR Viewer (SV-tech-06). Both Smartdesk Software and XR Viewer obtain their data from the Context Broker SV-tech-02 (Digital Enabler) via the TEMA API Gateway.

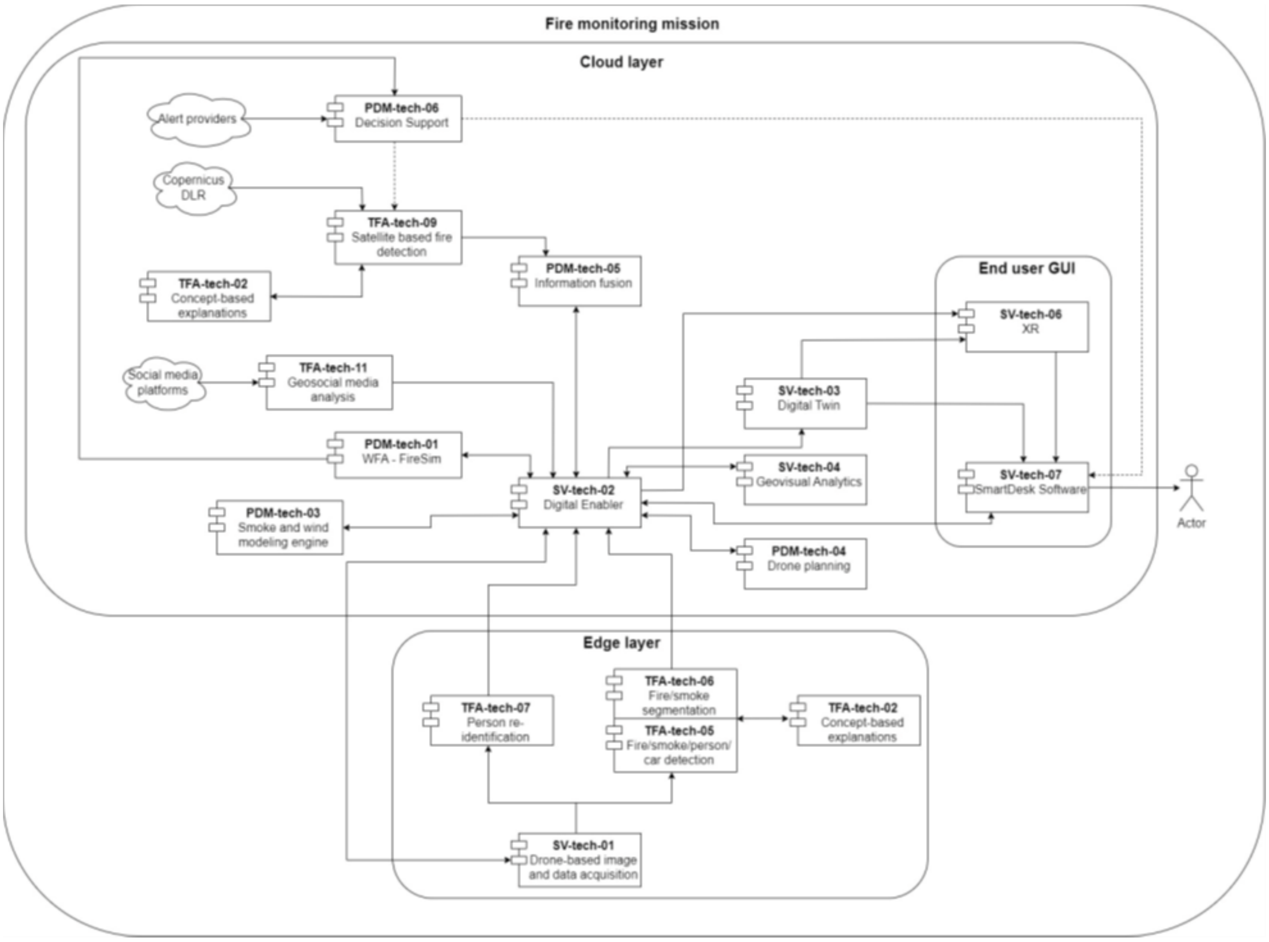

***Figure 1**: Computational flow of TEMA platform during fire monitoring mission.*

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The TEMA platform also runs equivalently for flood monitoring missions. However, some technologies that deliver data differ here as they are specific for the Fire monitoring mission (PDM-tech-01 (WFA-FireSim); PDM-tech-03 (Smoke and wind modeling engine)) respectively Flood monitoring mission (PDM-tech-02 (3Di Hydrodynamic modelling)). The integration of the Digital Twin (SV-tech-03) in the TEMA platform solution for the flood monitoring mission is depicted in **Figure 2**. The TEMA platform consists of various technical components that have to integrate with each other. These technologies include, for instance:

- PDM-tech-02 (3Di Hydrodynamic modelling)
- PDM-tech-05 (Information Fusion)
- SV-tech-01 (Drone-based image and data acquisition)
- SV-tech-04 (Geovisual analytics)
- TFA-tech-05 (Flood segmentation)
- TFA-tech-07 (Person re-identification)
- TFA-tech-08 (Satellite-based flood detection)
- TFA-tech-11 (Geosocial media analysis)

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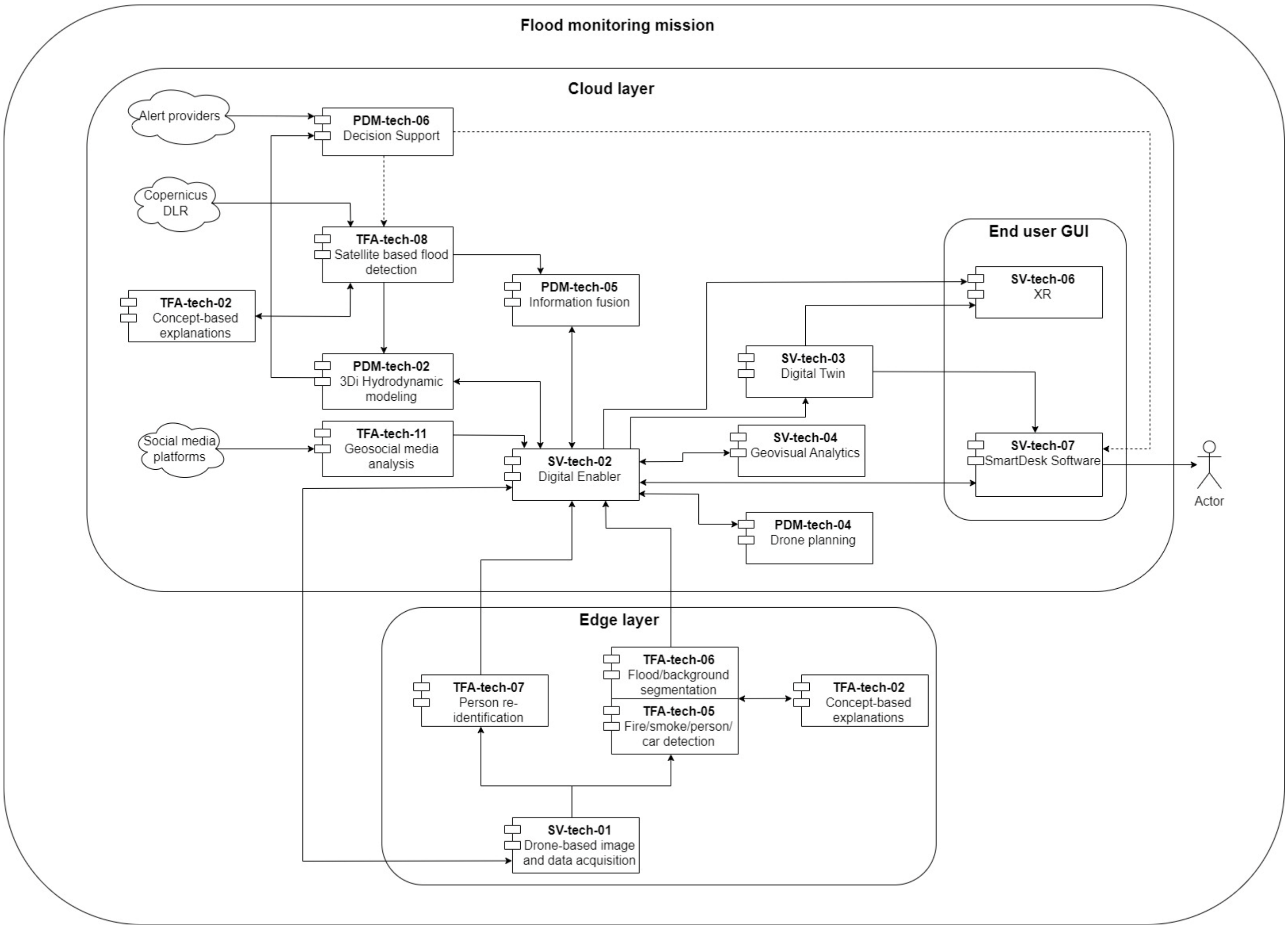

***Figure 2:** Computational flow of TEMA platform during flood monitoring mission.*

During the flood monitoring mission data from the respective technologies is pushed to the Context Broker (CB) of SV-tech-02 (Digital Enabler). As one part of the TEMA Digital Twin (SV-tech-03) drone image data is processed. The drone image data has to be received via pull- or push-request. Data is processed and a 3D model in a Cesium tile format is delivered through the TEMA API gateway to the Digital Enabler (SV-tech-02). The data communication is done via SV-tech-02 (Digital Enabler). TEMA Digital Twin (SV-tech-03) is then displayed in either Smartdesk Software (SV-tech-07) or XR Viewer (SV-tech-06). Both Smartdesk Software and XR Viewer obtain their data from the Context Broker of SV-tech-02 (Digital Enabler) via the TEMA API Gateway.

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4 Work on Digital Twins in TEMA

In this section, the State of the Art (SotA) of Digital Twins in the NDM context, TEMA advances in relation to the SotA and results of M7-M18 period for the ongoing Task T5.1 (M7-M30) are presented. As natural disasters such as forest fires and floods pose particular challenges in the construction of Digital Twins regarding the image quality, especially in the generation of the 3D model, part of the work to date has focused on reviewing and analysing historical data on natural disasters from TEMA end users and technical partners. On the one hand, this helps to gain empirically supported knowledge of the specific challenges of data quality in forest fires and floods, which enables ND to develop customized solutions for image enhancement. On the other hand, it provides ND an insight into the quality of input drone image data and the way in which end users collect dat. As this data can at least partially form the basis of the Digital Twin of a natural disaster (in the TEMA trials), it is helpful to be able to address potential challenges in data collection. Based on this analysis, requirements regarding the data material and a best practice guideline regarding data formats were formulated (see **Section 4.1**), which can be helpful for the pilot trials (Task T6.4), among other things. In addition, the output format of the 3D model or Digital Twin was specified, and the choice of output format was justified (see **Section 4.2**). The focus of the work to date has been on developing solutions for addressing the challenges posed by flood and forest fire disasters (e.g. bad visibility, bad data quality) by experimenting with various processes and techniques for generating enhanced 3D models and Digital Twins for the use cases. ND proposes a combination of different processes and techniques as a new approach to image enhancement. For example, in image pre-processing, techniques and professes for the optimization of contrast and denoising were combined with each other and supplemented by colour correction and super resolution algorithms. The TEMA algorithms were developed, trained and calibrated using the analysed historical data provided by TEMA end users and technical partners on natural disasters in Italy, Greece, Germany and Finland. The processes relate, for example, to image enhancement by using processes and techniques for optimizing the contrast, denoising and correcting colours.

As one focus of the TEMA project is to enable the (at least) partial updating of the Digital Twin (e.g. with disaster information layers time-critical for NDM) during the event, it is important to speed up the generation of the Digital Twin by techniques and processes specific to the image data from TEMA use cases of forest fires and floods. This is particularly important as many technologies in the TEMA project work with large amount

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of image data (e.g. 3D modelling, prediction models). To speed up the generation of the Digital Twin in TEMA, this process must be accelerated (see **Section 4.2**). Therefore, ND has developed sorting mechanisms that sort out images of poor quality directly before image pre-processing to increase the speed for generating the 3D model. Thereby, specific development work had to be carried out by ND for each of the two hazard types. As time is a critical factor in NDM, the work by ND on sorting mechanisms to speed up the generation of Digital Twin lays a good foundation for the work in T5.3, where the focus is on the development of an interactive XR-viewer and rapid visualization of the Digital Twin.

Another focus of T5.1 was testing various processes for the integration of other TEMA technologies in the Digital Twin. Therefore, ND specified the input data format for this purpose (see **Section 4.4**). Furthermore, ND investigated whether the technologies of the other TEMA partners fulfil the requirements (e.g. through referencing) for the integration of the data. ND also referred to work results from other work packages (e.g. link to work of AUTH team members on water masks (Task T3.2)) by conducting experiments on integrating different technologies in the 3D model (see **Section 4.3**). Further TEMA technologies used in the integration experiments by ND were the fire spread simulation (PDM-tech-01) (see Deliverable 4.1) and data from social media analytics. In addition, experiments with layering historical data, for instance, before and after a natural disaster were conducted by ND. These experiments were all carried out successfully. Regarding future work in WP5 on the integration of other data sources, in T5.3 it is planned that Smart Desk and XR viewer can access public information (e.g. google tiles open street map etc.). It is planned that this information can be displayed in the viewers. If there are other publicly accessible data sources for critical infrastructure, then they can probably be displayed by adequate links.

In the following, the SotA and the advances of the TEMA project are presented based on the various results of the work in M7-M18 period. Section 4.1 presents the results of the analysis of the historical data and the resulting requirements for input image data and guidelines for data collection. In Section 4.2 the solutions for optimising the generation of the 3D model and Digital Twin are described. Thereby, the focus is on speeding up the generation of 3D model and image enhancement by different pre-processing processes and techniques. Section 4.3 presents examples of the realised integration of other data sources and TEMA technologies. In Section 4.4 the output data format is specified, and the choice of the format is justified.

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4.1 Analysis of historical data on natural disasters and requirements for drone image data collection

In TEMA the Digital Twin for NDM is created based on the results of all tasks. For instance, this includes data from technologies and data sources such as hydrodynamic modeling, fire simulation, geovisual analytics and drone images (for more detailed information see section 3.3 Integration of Digital Twins in TEMA). Consequently, for integration purposes each TEMA partner is in their corresponding tasks responsible for ensuring that their data is georeferenced and in the correct data format. Focus of the work presented in this deliverable is the generation of 3D models based on enhanced image data from TEMA use cases of forest fires and floods. To understand which aspects of the images of forest fires and floods should be improved and from which quality of data the 3D model must be created in case of a natural disaster, ND has analysed historical data from forest fires and floods and derived requirements that are relevant for this task as well as the data collection in TEMA trials.

SotA on NDM context

Digital Twins are gaining popularity in NDM (e.g. Doğan et al, 2021; Lagap & Ghaffarian, 2024; Li et al., 2016). However, so far, little attention has been paid in research to one potential component of Digital Twins: the 3D models. In particular, there is a lack of knowledge about the quality of input image data on which the 3D models and thus also the Digital Twin are generated. It can be assumed that there are significant limitations in image data quality for the specific use cases of forest fires and floods, e.g. due to smoke or reflections, as initial studies indicate that the data quality sometimes makes it necessary to carry out edits, for example to improve the accuracy of flood mapping (Li et al., 2016). Little is also known about possible variations in data quality due to data collection by professionals or end users. Overall, there is a lack of information on the quality of the input image data. Thereby, it is also interesting to investigate whether existing auto functions of drones, that ensure the collection of high-quality data, are used in data collection in practice.

Advances in TEMA

In the TEMA project on research focus is the quality of input image data. In addition to the holistic image enhancement specific to the use cases of forest fires and floods (see **Section 4.2**), one advance is that data collected with drones by end users can be used for the generation of the 3D model and Digital Twin. This makes sense because in most cases

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the end users are quickly at the site of the disaster and can easily collect image input data. The basis for the generation of the 3D model and the Digital Twin based on end user data is knowledge about the specific problems of this data (e.g. quality and completeness). Therefore, in the TEMA project, ND has analysed the available historical data with this in mind during M7-M18 period (criteria used in the analysis were, for example, blurriness, strength of contrast, georeferencing). Based on the results of the analysis, ND has also formulated requirements respectively best practice guidelines to standardize data collection with drones by end user to ensure that the data collection processes already enable the best possible input data quality.

Results

Requirements for input data

To understand from which data the 3D model and Digital Twin must be created in case of a natural disaster, we have analysed historical data and derived requirements that are relevant for this task. The analysis of the historical data on natural disasters provided by TEMA end users and technical partners has revealed various issues with the material available for the Digital Twin that can be addressed and can, for example, facilitate the pilot trial (Task T6.4) processes. It should of course be noted that the data was not generated for the purpose of generating Digital Twins of the natural disasters. However, this data was still used for the work in this task, as it is data from real events that cannot and should not be generated for the purpose of TEMA. During the analysis of historical data, the following issue was repeatedly observed: The drone operators captured mostly videos. Consequently, for generating a 3D-model of the natural disaster images were taken from videos and were not or not properly georeferenced. This is because videos only have one georeference and even if different images are taken from videos, each image has the same georeference. This means that it is not possible to generate a Digital Twin based on this data. If, on the other hand, individual images are captured, each image has its own georeference. This enables the generation of a Digital Twin. The difference between the two procedures is shown in **Figure 3**.

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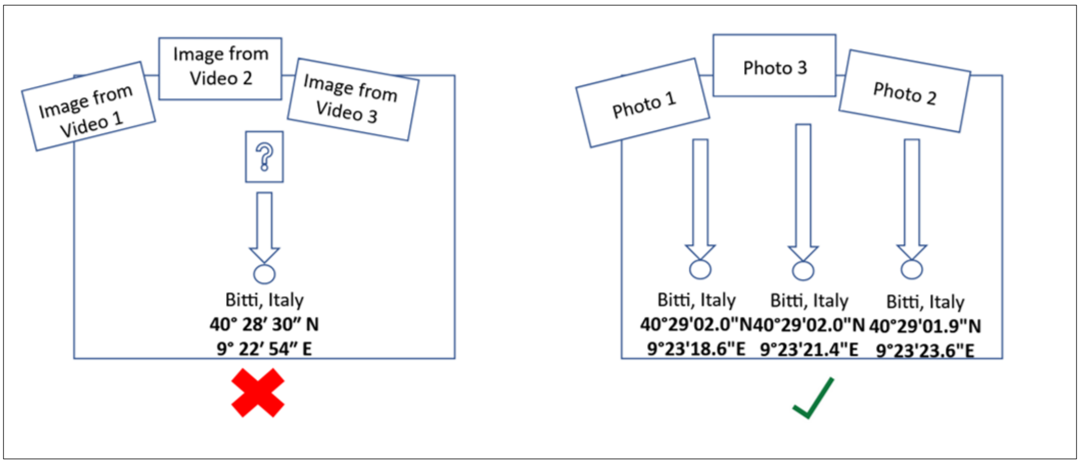

***Figure 3**: Visualization of the differences between images taken from videos and photos containing georeferences.*

Therefore, in this task requirements for the material, on which the Digital Twin respectively the 3D model is based, were formulated. This results in the following essential requirement regarding data (e.g. images of a natural disaster) for the construction of the Digital Twin which are the georeferences of the data: Only one georeference or even a few georeferences for a bunch of photos or even a whole video will automatically cause problems in the construction of the Digital Twin as there is uncertainty as to which data belongs to the georeference(s). In consequence, only photos should be taken instead of videos as a georeference can be assigned to each individual photo and thus each photo can be clearly assigned to a location. It is therefore a recommendation for pilot trials and the work of end users to enable the drone's option to save georeferenced coordinates in the metadata of each image. Most drones then store georeferenced coordinates in the metadata of each image automatically. The image meta data taken by most drones also includes camera settings and optics parameters that can help to build a better 3D model. One example for the meta data of images is shown in **Figure 4**.

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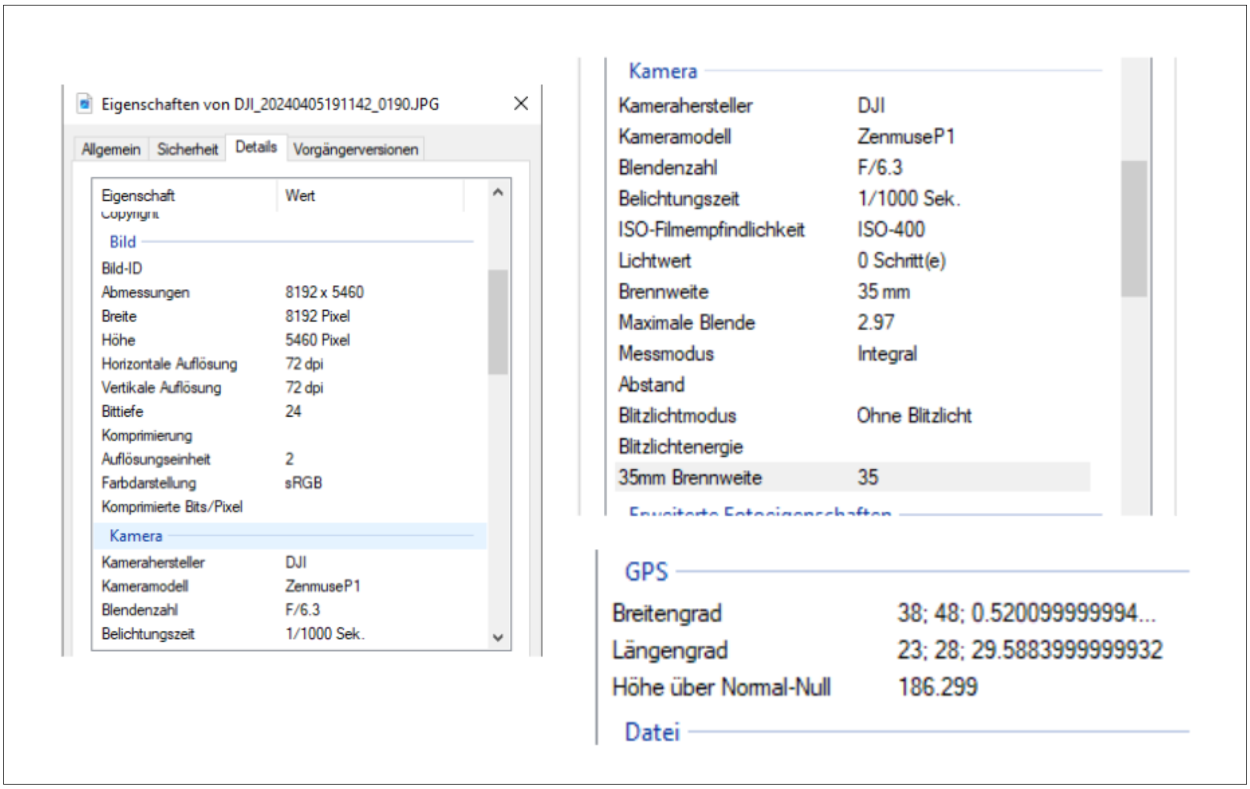

***Figure 4**: Meta data from images.*

Still images are taken not only for georeferencing reasons but also for artifacting video formats and video compression algorithms which can interfere with 3D reconstruction. An example for video artifacts is displayed in **Figure 5** below (use case: flood in Larissa (Greece)).

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Figure 5: Video artifacts shown in the example of the flood use case in Larissa (Greece).

Guidelines for data acquisition using drones

Regarding data acquisition, we formulated a best-practice statement, which could be helpful for the trials in WP6. For drone flights, there are various aspects to consider for data acquisition. These include flight pattern regiments. There are different flight pattern regiments for acquiring data with a drone. The most common flight pattern regiments are the circle pattern and type grid pattern. Pattern type circles are used for smaller areas with a small point of interest (POI) like a small fire in the middle or destroyed houses by a flood, which is illustrated using the example of Larissa (see **Figure 6**). This pattern can be accomplished by an experienced drone pilot or automatically.

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Figure 6: *Circle pattern flown by drone visualized by the example of Larissa.*

When using a circle pattern, the POI should be in the center of the image and should not be larger than 50% of the image. This is illustrated in **Figure 7**.

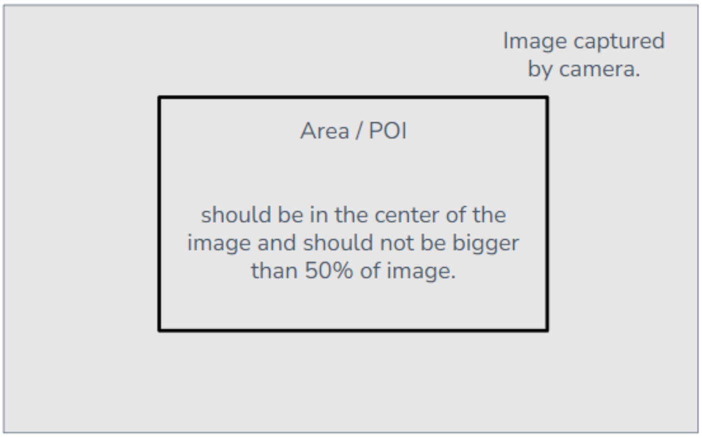

Figure 7: *POI when flying a circle pattern.*

For larger areas of interest, such as disasters that occupy a larger region or multiple smaller ones that are next to each other, the pattern type grid is used as a flight pattern regiment. The pattern type grid is illustrated in **Figure 8**. While theoretically possible this pattern is usually achieved by a type of autopilot function that controls the drone via GPS.

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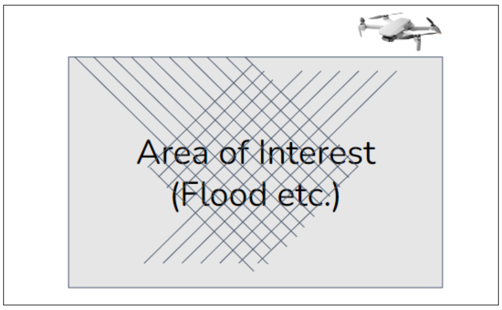

***Figure 8**: Illustration of a pattern type grid.*

Here, the best practice would be to fly at least 100m above ground and using a 20 mpx camera with a 24mm (35mm equivalent) focal length. Example settings for a grid setup for a DJI Mavic3E, a widely used drone, are shown in **Figure 9**. The drone flights the grid on its own and no special knowledge about Digital Twins is needed by the drone operator. In this case, we used the Larissa flood region as an example. While this is an example mission, the drone and flight routing management are performed by SV-Tech01.

***Figure 9**: Example settings for a grid setup for Larissa flood region.*

Regarding data quality of drone images best results are achieved if the drone captures a nadir image and four oblique images in every direction. Nadir images are images that are taken with the camera facing straight down. Oblique images are taken at an angle

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usually between 10-20°. **Figure 10** illustrates the differences between Nadir and Oblique images and **Figure 11** represents a real-world example.

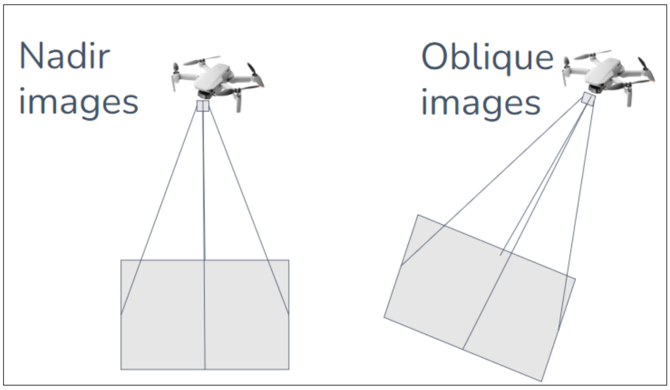

***Figure 10**: Illustration of Nadir vs. Oblique images.*

***Figure 11**: Real-world example of Nadir and Oblique Images.*

To generate a 3D Model from images via stucture from motion (sfm) type algorithms a certain amount of overlap between the images taken must be achieved. To deliver a good result the overlap should be above 70% in each image axis. **Figure 12** shows a real-world example displaying a red roof captured by different drone images.

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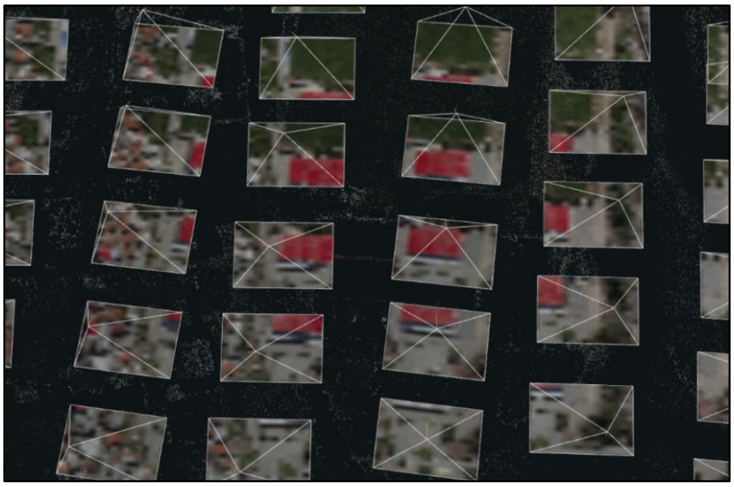

Figure 12*: Illustration of real-world example of image overlap.*

To test our best practice guidelines, we created with TEMA partner KEMEA a 3D-model of a 1,5 km² region near Mantoudi (Greece). It is shown in **Figure 13**.

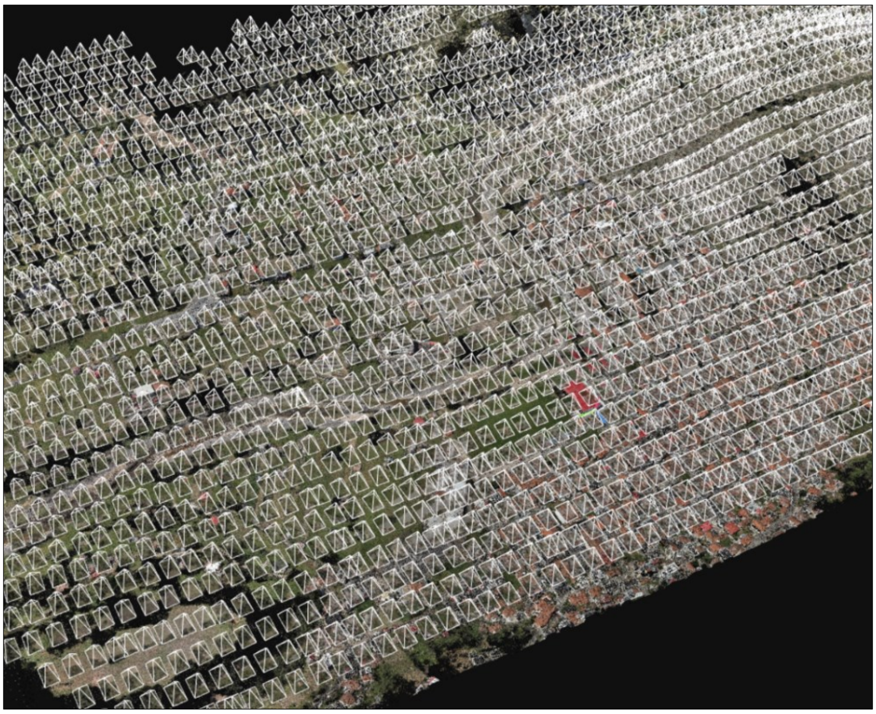

Figure 13*: Picture of data acquisition for the Mantoudi region.*

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4.2 Solutions for optimizing the generation of Digital Twins in TEMA

Digital Twin modeling speed up in NDM context

In on-event disaster situations, the time with which a Digital Twin can be created or updated is a critical component of NDM. Due to the large amount of data, the generation of the 3D model of the afflicted region plays a particularly important role here to be able to respond quickly. The SotA and the advances with regard to the generation of the 3D model in TEMA are presented below.

SotA on modeling speed up in NDM context

Work on Digital Twins in NDM that work with 3D modeling focuses to a large extent on early warning or monitoring systems (e.g. Huang et al., 2015; Li et al., 2016: Wang et al., 2017; Pawana et al., 2023), which could indicate that the 3D model was probably generated before the disaster onset under the best conditions (e.g. data collected by professional drone pilots, good weather conditions) and the data of the 3D model is updated at best on-event. So far, few Digital Twins have probably included data from spontaneously occurring natural disaster situations. A recent review supports the assumption by showing that the data used for the generation of Digital Twins in the NDM context is secondary data (Lagap & Ghaffarian, 2024). One exception, for example, is the European Space Imaging service: This service offers to generate a 3D model of affected regions within 24 hours using satellite data. However, there is no information available on the quality of these 3D models and it can be assumed that details relevant to the NDM are less easy to recognise than if the data were collected with drones closer to the disaster.

So far, however, there has been little research in the NDM context on how the processing of the Digital Twin or in T5.1 of the 3D model can be increased. However, processes and techniques such as sorting mechanisms are used in the NDM context (e.g. Islam et al., 2023) that are suitable for speeding up the processing of the 3D model and thus the Digital Twin. Though in the research literature, sorting mechanisms are sometimes used or proposed to process images in the context of NDM (e.g. Islam et al., 2023; Munawar et al., 2021). However, these do not necessarily focus on sorting images to improve the image data input or increase the speed for generating a 3D model but are rather used for image categorisation based on specific characteristics (e.g. to classify

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images and determine the severity of the flood by weighting the pictures by the intensity of the flood (Islam et al., 2023)).

Advances in TEMA

In the course of the TEMA project one aim is to increase the speed of processing the 3D model. For this purpose, during M7-M18 ND developed sorting mechanisms specific for input image quality in TEMA used cases of forest fires and floods. These sorting mechanisms assess the overall quality regarding clarity and visibility and include or exclude images accordingly when generating the 3D model. This saves time when processing the 3D model. At the same time, this approach ensures that only the images with the highest possible quality are included in the generation of the 3D model.

In many other projects, the 3D model and Digital Twin for NDM are generated before the disaster. The TEMA approach advances SotA by generating the Digital Twin before the event and updating it during the event (e.g. with disaster information layers). Another advance in the TEMA project is that there is a research focus in WP5 on on-event 3D modelling. This can support end users during a specific natural disaster situation. The preparatory work started in M7-M18 period and is continued during M18-M30. The work on-event modelling will be evaluated using smaller and less complex trials of the TEMA project in WP6, in which, for example, 3D models are created for burnt areas after a forest fire.

Results

One focus of the work to date was experimenting with sorting mechanisms for speeding up the generation of the 3D model and image pre-processing. This work is a focus of future work and will be further deepened in connection with the work of T5.3 (Augmented Reality and rapid visualization (M19-M36)). In the work to date, blurred or unsharp images are removed during image pre-processing. Based on the opencv library we further developed a sorting algorithm that sorts images by sharpness. With this algorithm the median distribution of sharpness across the images is calculated. In addition, it also automatically provides a threshold value that is used to cut off images that are unsharp or distorted in another way. The GUI of the software for removing images is shown in **Figure 14**.

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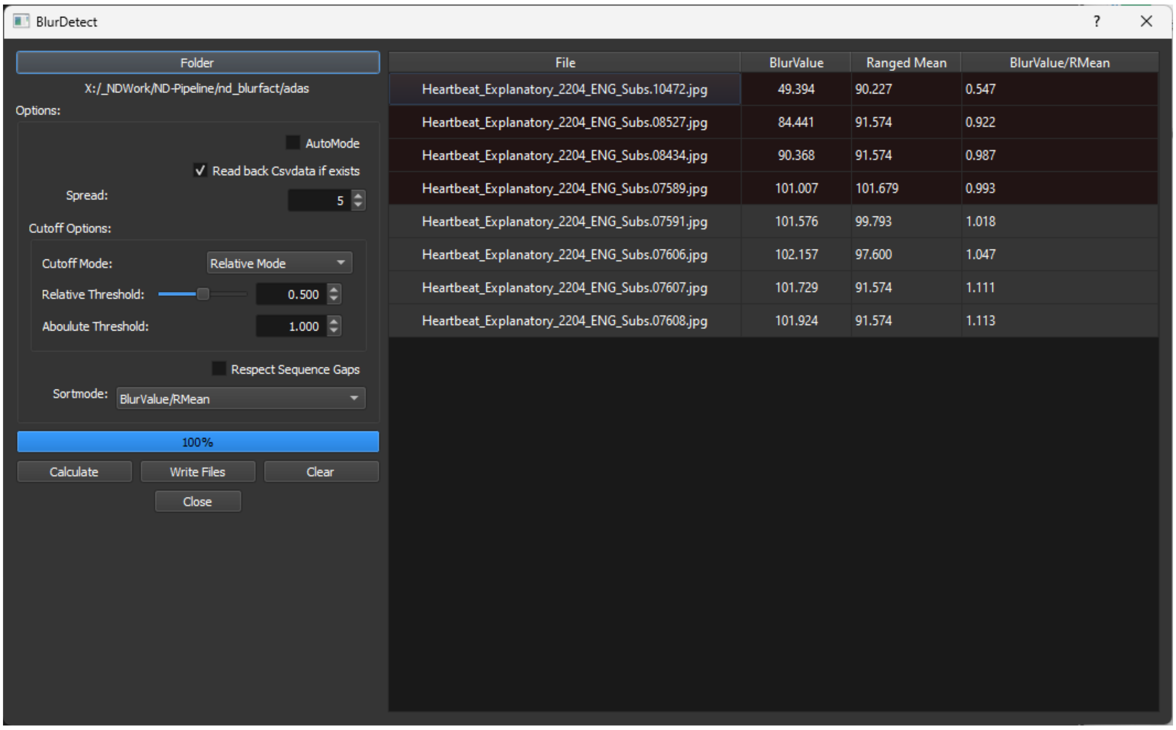

***Figure 14**: Screenshot of the GUI of the software for removing images.*

Image enhancement in NDM context

The quality of input data plays an important role for generating a precise high-quality Digital Twin. Therefore, ensuring a high image quality is vital for conducting geovisual analysis, generating 3D models and carrying out predictions in the NDM context. As processes and techniques play an important role for image enhancement, their current status in the context of NDM and advances in TEMA are described below.

SotA on image enhancement in NDM context

In the initial phase of the TEMA project, there has been little research in the context of NDM regarding techniques and processes for image enhancement. This could be because Digital Twins in NDM are often created as early warning systems or monitoring systems before the disaster based on existing (secondary) data (Lagap & Ghaffarian, 2024) and not on-event. In other contexts, different processes and techniques are used to achieve improvements. A common approach for optimizing images is image pre-processing. Thereby in general techniques and processes such as colour correction, denoising and the optimization of contrasts are used. They show positive results for image enhancement. However, they are not specific to the requirements of NDM as data in this context often

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suffers from contrast and noise problems that can obscure critical features in regions affected by natural disasters.

Recent research from the area of NDM suggests that Contrast Limited Adaptive Histogram Equalization (CLAHE) could be a potential technique for improving image quality of a shoreline monitoring system (Pawana et al., 2023). This technique appears to be particularly effective in combination with denoising (Pawana et al., 2023). However, this does not mean that this specific combination of techniques can also be successfully applied to TEMA use cases of forest fires and floods, as the conditions for the quality of the image data are different here, for example due to smoke. At the very least, research into the transfer of techniques must be carried out and presumably major adjustments need to be made towards the specific TEMA use cases of forest fires and floods.

Advances in TEMA

The main advance beyond the SotA in the TEMA project is that processes and techniques for image enhancement will be developed and adapted specific to the TEMA forest fire and flood use cases. Thereby, in contrast to previous work, the focus in TEMA T5.1 is not on improving image enhancement regarding specific aspects or features (e.g. accuracy of flood mapping), but on increasing the visual quality of the 3D model of the disaster by using processes and techniques such as image pre-processing. To address the challenges of image enhancement in this particular context, ND proposes a combination of contrast, denoising and colour correction specific to forest fires and floods for image pre-processing instead of using isolated or no techniques for image enhancement. This combination also addresses problems caused by individual processes and techniques and could improve, for instance, inherent noise in raw data.

The reported developed processes and techniques proposed by ND combine different techniques: For enhancing the local contrast of the images and improving visibility, ND used conventional CLAHE as proposed by Pawana et al. (2023) for contrast enhancement purposes. CLAHE computes several histograms while simultaneously redistributing the brightness of the image. To mitigate the impact of inherent noise in raw data denoising processes and techniques were used. In addition, experiments with super resolution processes and techniques were conducted by ND to enhance, increase and upsample the resolution of input images. Furthermore, ND also used colour correction through colour constancy, which aims to perceive the colours of objects correctly regardless of differences in light intensity, for example. For developing processes and techniques for image enhancement for forest fires and floods data from end users and technical partners was used. The development of these processes and techniques was initially based on an

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analysis of the quality of this historical data. Based on the results of the analysis and the data, algorithms were developed and calibrated. For example, the data sets on the floods in the Ahrtal and in Larissa and forest fires in Finland were used for this purpose. Exemplary results of the work to date are presented in the next section.

Results

One solution tested during M7-M18 period besides removing image material is to enrich source material by applying image enhancement algorithms or denoising. One example of the work on image preprocessing is the colour correction of the historical use case of the flood in Larissa (Greece)), which is shown in **Figure 15**. Here the source material was optimized through colour correction. The aim of the colour correction was to remove all shadows to get a consistent viewing experience and allow humans and the algorithms an equalized hue range.

Figure 15: Denoising applied to the flood use case in Larissa (Greece).

In low light conditions denoising can help to make the 3D reconstruction more stable. It also removes information in the image without value. An example using TEMA data is shown in **Figure 16**.

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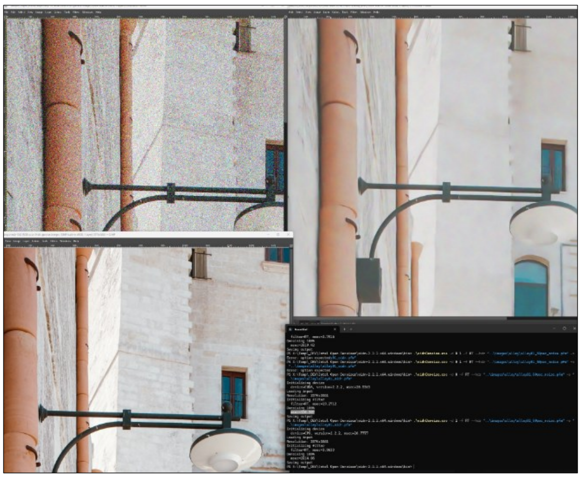

Figure 16: Example for denoising.

Likewise, optimization processes were carried out for the fire use case. As the data situation for the flood case was better, the focus was on this work. However, progress was also made for the fire case. Here experiments with historical data were carried out to map the progression of fire spread. An example of the experiments is a fire case in Finland. Here, the course of the fire and its spread were mapped using image data from various points in time. **Figure 17**, **Figure 18** and **Figure 19** show the clear progress of the fire over time.

Figure 17: Initial situation before the start of the fire.

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***Figure 18**: Start of fire spread.*

***Figure 19**: Spread of the fire as it progresses.*

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Also, during the on-going work in Task T5.1, we experimented with AI generated masks provided by AUTH (Task T3.2). Those experiments included working with upstream image optimization by AI (applying AI directly to drone images), downstream image optimization by AI (applying AI to generated textures), applying AI-generated masks to source images or creating meshes and changes to the mesh by AI generated masks.

One application example is water surfaces. Due to the reflection large flat-water surfaces are a problem for 3D reconstruction algorithms. With AI, water masks can be created to filter out the water surfaces. Object detection from Task T3.2 was used for this. Using the TEMA use case of the Ahrtal flood as an example (see **Figure 20**), it is shown how the water surface can be identified and filtered out.

Figure 20: Pictures of water mask applied to the Ahrtal flood use case.

Furthermore, experiments with layering historical data, for example, before and after a natural disaster were conducted. Changes of the (afflicted) area due to a natural disaster can only be detected accurately here if both Digital Twins lie exactly on top of each other. This is where georeferencing plays a special role. An example of the experiments with mixing historical data in conjunction with current data (e.g. layering of Digital Twins before and after a natural disaster) is the flood in the Ahrtal valley (Germany). The results are shown in **Figure 21**.

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Figure 21: Example of mixing historical data using the flood data from the Ahrtal (Germany).

With regard to KPIs, during our work with historical data we successfully improved the quality of the precise 3D model as visualized in **Figure 19** to **Figure 22**, showing the comparison of SotA algorithms and our optimized process. For this purpose, data of a flood in the Larissa region (Greece) was used. The first example depicts a close-up of a group of houses in the flood region. **Figure 22** shows a screenshot of the 3D model generated with SotA algorithms. In comparison **Figure 23** displays a screenshot of the 3D model that was created with the optimized processes.

Figure 22: Screenshot of the 3D model of a flood in the Larissa region using SotA algorithms.

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Figure 23: Screenshot of the 3D model of a flood in the Larissa region (Greece) generated using our optimized processes.

The second example shows a larger overview of the flood in the Larissa region. Here, too, the 3D models using SotA algorithms (see **Figure 24**) and our optimized processes (see **Figure 25**) are compared with each other.

Figure 24: Screenshot of the 3D model of a flood in the Larissa region using SotA algorithms.

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Figure 25: Screenshot of the 3D model of a flood in the Larissa region using our optimized processes.

The calculations for the percentage improvement achieved are carried out after the trials, as measurement data will be available during the trials and therefore precise geo-reference data are available for comparison.

4.3 Examples for integrating other data in the Digital Twin

In addition to the 3D model generation, we have been working on the preparation of further data for the Digital Twin. In a first example, we have layered the fire simulation (PDM-tech-01 (WFA-FireSim)) onto Copernicus satellite data and information (funded by the European Union - EU-DEM layers) of Montiferru region (Italy). Data such as the simulation of the spread of fire can be loaded in real time and then displayed. As part of the TEMA project, the data is displayed for visualization in the XR viewer (SV-tech-06) (see **Section 3.3** for the TEMA computational flow for TEMA fire use cases), which will be developed in Task T5.3. The data should be imported via KMZ file format. KMZ is an animated version of Keyhole Markup Language (KML), which is an XML notation can be used for expressing graphic annotation. At the same time, two-dimensional maps and three-dimensional Earth browsers such as Google Earth can also be used. Since no video of the fire spread simulation can be inserted due to the reports' format, screenshots of the fire spread are presented to visualize the results (see **Figure 26** and **Figure 27**). The screenshots were taken from an eight-hour simulation. For more information on the fire simulation (PDM-tech-01), see Deliverable D4.1.

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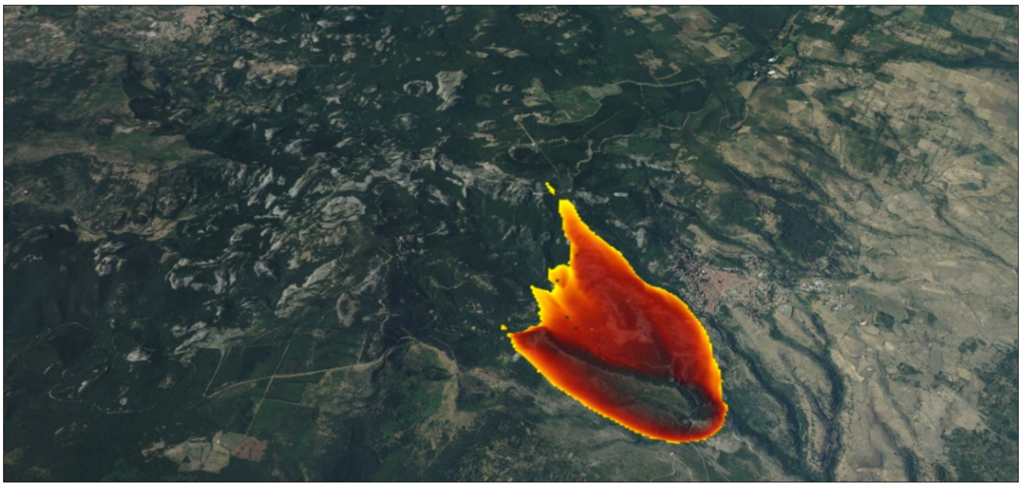

***Figure 26**: Screenshot of the fire spread simulation.*

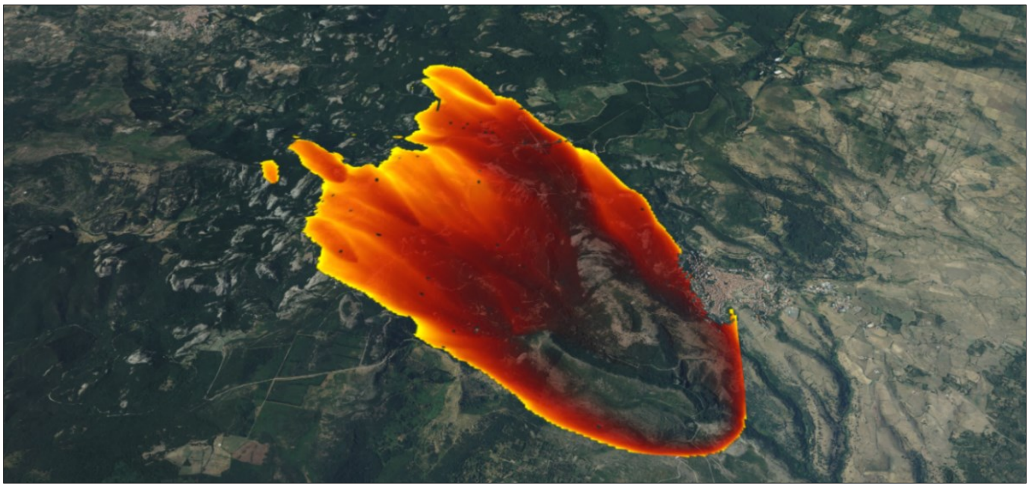

***Figure 27**: Screenshot of the fire spread simulation.*

Another example of how partners can be integrated into the Digital Twin, we looked at the data from Task T3.3 partners. We integrated social media analytics data (Task T3.3) for this purpose. The tweet data was delivered by Task T3.3 partners. The .geojson-format was selected as the exchange format (see **Figure 28**). The format is also used for all other data from TEMA partners.

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Figure 28: Illustration of the exchange format used.

Information from XR-Viewer and Smartdesk stored in this .geojson-format is visualized and displayed accordingly. An example of the data prepared for the XR-Viewer component is shown in **Figure 29**. The example shows the integrated social media analytics of the Ahrtal region. The predefined rating of the relevance of the social media posts for NDM (different colours from green to red) was adopted and integrated into the Digital Twin. The option to read the social media posts is also available.

Figure 29: Social media analytics of the Ahrtal flood integrated in the Digital Twin.

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4.4 Output format chosen for 3D models in TEMA

In addition to the already defined. geojson-exchange-format, an output format for the 3D model was specified. Various aspects were considered when selecting the output format for the 3D model in the project. Importance was attached to the following aspects when selecting the output format:

- Properties of the format: The format should deliver results quickly with little computation. At the same time the format should ensure that still high accuracies of output quality could be delivered.
- The output format should also support a high level of detail approach in which the complexity of a 3D representation according to metrics such as object importance or distance from the tile to the observation point or camera position decreases.
- The output format should support a type of intrinsic georeferencing.
- The output format should also enable details to be loaded on-demand, because the overall model is very large and the exact detail levels are only defined in the area to be viewed by the user.

Due to the aspects that were considered important, we decided on the 3D Tiles format (Cesium), which is an open specification for sharing, visualizing, interacting with and analyzing massive heterogenous 3D geospatial content. Core element of 3D Tiles are tilesets, which are described in JSON. A tileset consists of a set of tiles organized in a hierarchical data structure, also known as tree. The tileset itself contains the root tile and a tile may have child tiles. The tileset properties and tile properties are presented in table 1 (Cesium, 2020).

***Table 2**: Tileset and Tile Properties.*

Tileset Properties	
Root tile:	The root property of a tileset is a tile that represents the root of the tile hierarchy.
Geometric error:	The geometricError property is used to quantify the visual error that would occur if the tileset was not rendered. When the visual error exceeds a certain threshold, then the tileset and the tiles that it contains are considered for rendering.
Property Summaries	The renderable content of tiles may have associated properties. For example, when the tiles contain buildings, then the height of each building can be stored in the tile. The properties object of a tileset contains the minimum and the maximum of select property values for all tiles in the tileset.

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Metadata	Information about the 3D Tiles version and application-specific version information can be stored in the asset property of a tileset.
Tile Properties	
Content	The actual renderable content that is associated with a tile is referred to via a URI in the content property.
Children	The hierarchical structure of tiles is modeled as a tree: each tile may have children, which are tiles in an array named children.
Bounding Volume	Each tile has an associated bounding volume, and different types of bounding volumes may be stored in the boundingVolume property. Each bounding volume encloses the content of the tile and the content of all children, yielding a spatially coherent hierarchy of bounding volumes.
Geometric error	The renderable content of tiles may have different levels of detail. For tiles, the geometricError property quantifies the degree of simplification of the content in the tile compared to the highest level of detail.
Refinement strategy	When the visual error of a tile with a certain level of detail exceeds a threshold, then the child tiles are considered for rendering. The way the additional detail from the child tiles is incorporated into the rendering process is determined by the refine property.

One of the main reasons for using 3D tiles as an output format is that that it is possible to consider refinement strategies. So, on the one hand it can efficiently stream massive datasets to runtime engines and at the other hand still allows the runtime to render this content efficiently. Therefore, this format considers hierarchical structure of tiles in a tileset and integrates the concept of a Hierarchical Level of Detail (HLOD), where tiles at the top of the hierarchy contain representations of the renderable content with a low level of detail. In contrast to the tileset, child tiles contain content with higher level of detail. In terms of the rendering runtime, this offers the possibility of a dynamic approach to rendering, as the level of detail can be selected dynamically. This enables a choice of the level of detail that offers the best trade-off between performance and rendering quality. Thereby the level of detail to be rendered is determined by the geometricError of each tileset and each tile. The geometricError property quantifies the error of the simplified geometry compared to the actual geometry. The runtime translates this geometric error into a screen-space error (SSE), which indicates how much of the geometric error will be visible in terms of pixels on the screen. When the SSE exceeds a certain threshold, the runtime will render a higher level of detail. For a tileset, the geometric error is used to

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determine whether the root tile should be rendered. For a tile, the geometric error is used to determine whether the children of the tile should be rendered as the child tiles that contain renderable content have a higher level of detail and a smaller screen space error.

3D Tiles also allows optimized rendering. For this, the hierarchical structure of tilesets and tiles, the associated bounding volumes, the concept of the geometric error, and the different refinement strategies are relevant. During rendering, the runtime maintains a view frustum, which is defined by the camera position, orientation and the field-of-view angle. The view frustum can be tested for intersections with the bounding volumes of tilesets and tiles. However, regarding rendering, it is not only about the quality of the rendering performance of the displaying device, but also about the available bandwidth to the TEMA cloud.

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5 Conclusion and outlook

In the following two sections the presented results of the work on generating a precise Digital Twin in the TEMA context (Task T5.1) are summarized and initial conclusions are drawn with regard to the work to date. In addition, an outlook is formulated in which the further work in this task and subsequent work packages of the project, which are based on the Digital Twin, is presented.

5.1 Summary and conclusion

Natural disasters place enormous demands on emergency services. Therefore, the aim of the TEMA project is to improve NDM by automating precise semantic 3D mapping and disaster evolution prediction to achieve NDM goals in near-real-time. The 3D model of a disaster is a technical sub-component of this. When generating Digital Twins in the context of natural disasters, as the TEMA project is based on, problems arise in the generation of Digital Twins that are not the case under optimal conditions. To be able to work with this in the context of NDM, various measures were taken to optimize 3D models.

The results regarding the optimization of the algorithms were reported in this deliverable. Regarding image enhancement solutions in NDM context ND proposed a new approach which combines different processes and techniques. For instance, for the optimization of contrast and denoising were combined and supplemented by colour correction and super resolution algorithms. During M7-M18 period these algorithms were developed, trained and calibrated specifically for the use cases of forest fire and floods. For the development data from natural disasters in Italy, Greece, Germany and Finland provided by TEMA end users and technical partners was used. For this deliverable, the algorithms were applied to TEMA use cases after research and work with smaller experiments. The floods in Ahrtal (Germany) and Larissa (Greece) were used for this. The results show improvement in the quality of the 3D model in comparison to the SotA. In the future, the work to date on mage pre-processing specifically will be fed into Task T5.3 focused on augmented reality and rapid visualization.

Regarding the TEMA advance of speeding up the generation of the Digital Twin in M7-M18 period sorting mechanisms were developed for assessing input image quality in TEMA uses cases of forest fires and floods. These sorting mechanisms include or exclude images accordingly when generating the 3D model. Not processing images that are not of high-quality leads to a reduction in the number of images during processing and therefore

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also in the time required to generate the 3D model. These algorithms are being further developed during M18-M30 with a larger amount of data and tested in the TEMA trials. Other advances of the TEMA project are also tested in these trials: The TEMA project is working on being able to at least partially update the Digital Twins and the 3D models during the disaster. For this research and preparatory work was carried out in M7-M18 period. In addition, a research focus of the previous work in M7-M18 was also on-event 3D modelling. This work will be continued in the further course of the project.

Since, in addition to algorithms for optimizing image data in the context of natural disasters, the best way to achieve good image data quality and thus a high-quality Digital Twin is good data acquisition, ND analysed historical data of disasters from end users and technical partners. Based on the analysis, best practice guidelines for the standardised procedure of data collection with drones were formulated. This statement on best-practices for drone pilots can be used in the TEMA pilot trials in WP6. Beyond that it also enables end users, for example, who are usually fastest in the region of the disaster, to contribute data for the generation of 3D models and digital twins for NDM.

Work to date has also focussed on integrating other data and technologies from TEMA into the 3D model. Therefore, ND investigated whether the technologies of the other TEMA partners fulfil the requirements (e.g. through referencing) for the integration of the data. ND also conducted experiments on integrating different technologies in the 3D model (see **Section 4.3**). For instance, the TEMA fire spread simulation (PDM-tech-01) was successfully integrated into the 3D model and a Digital Twin was created. Successful experiments were also carried out to integrate the data from social media analytics. In addition, also the experiments with layering historical data before and after a natural disaster were successful.

The previous work in the ongoing Task T5.1 forms the basis for future work and work on the TEMA platform. Further work steps are presented in the **Outlook Section**.

5.2 Outlook

Future work steps in this task will focus primarily on ensuring data consistency inside the TEMA Digital Twin and further optimize our processes for construction of the 3D model in the TEMA context. With regard to this task, there are the following concrete further work steps:

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The next steps in this ask will focus on establishing the communication with other TEMA components. For this to work, the 3D model generation must be packaged as a docker container. ND already started working on packing the 3D model creation component in a docker container.

Part of this task is also the integration of data from real-time semantic visual analyses and remote sensing (Task T3.2). The first examples of this have already been shown in this deliverable. However, this was done via direct data delivery from the technical partner AUTH. In terms of the computational flow of the TEMA platform, it is envisaged that this data will be delivered via the Context Broker of Digital Enabler (SV-tech-02). Therefore, ATOS, a technical partner working on Task T3.2, will establish the link between TFA-tech-05 (Fire/smoke/person/car detection), TFA-tech-06 (Flood/background segmentation) as well as TFA-tech-07 (Person re-identification) and Digital Enabler (SV-tech-02) in the future.

With regard to the further work on other TEMA work packages, the work on the Digital Twin is, among other things, significantly linked to other work in the project:

The output of the work on Task T5.1 is mainly used for the work on Task T5.3 (starting in M19). In Task T5.3 Augmented Reality and rapid visualization the aim is to develop an operational prototype of an Extended Reality (XR)-based interactive visualization system. This XR-based interactive visualization system will aid the end user/ actor in manually assessing the current situation itself and the best response options as well as the dependability of the AI predictions. If needed data is provided by the responsible TEMA partners, the aim is that the end user will be able to on-the-fly select alternative views, depicting the current situation (in the form of geospatial annotations automatically derived by analytics), near-future predictions, automated decision support recommendations/proposals, original sensor footage/measurements and/or explanations about AI-derived predictions/results.

The work on the 3D model will also play a role in WP6 Integration and validation. In addition to the integration work, the 3D model will be a significant component of the TEMA platform in the pilot trials (Task T6.4), where the TEMA platform prototype will be validated at a proof-of-concept level through two pilot trials for each of the key end users.

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