xR4DRAMA

Extended Reality For DisasteR management And Media planning

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D1.3

Public final activity report and final self-assessment

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Abstract

This deliverable comprises the final public activity report and self-assessment of the xR4DRAMA project, containing: (i) the consortium presentation and the objectives of xR4DRAMA; (ii) a summary of the project results; (iii) the management of the data

generated in xR4DRAMA; (iv) the assessment against performance indicators; (v) the impact achieved by the project.
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Executive Summary

This deliverable report is compiled to describe the end results and the impact of the xR4DRAMA project. The primary goal of this public document is to aggregate general information about xR4DRAMA along with the key details about all the project’s activities – and make everything accessible in a single place. The document discusses the project's accomplishments and outcomes for each work package.

The document begins with an introduction describing the purpose of xR4DRAMA as well as some important project information. A presentation of the consortium members, an overview of the objectives, and a summary of the key results are among them.

Following that, data management is outlined as it is essential in order to monitor the data in terms of privacy and confidentiality, ensure that the legal (including copyright) and potential ethical standards for data generation, use, storage and sharing are observed and followed throughout the project, guarantee that technical standards are applied for data representation, and determine which data can be shared in the open data initiative.

Afterwards, it presents the final self-assessment of each task, an integration operation to provide concrete evidence of the project's success. The assessment is based on performance indicators that were initially defined in a previous report delivered at the beginning of the project and then slightly revised in this report for evaluation purposes.

Finally, it discusses the impact of xR4DRAMA, in other words the positive impact of this project's research on many different factors that were deemed important to investigate. The report ends with a conclusion that contains a synopsis of its content.

Abbreviations and Acronyms

AdaIN	Adaptive Instance Normalisation
AR	Augmented Reality
ASR	Automatic Speech Recognition
AT	Authoring Tool
BOL	Building and Object Localisation
DMP	Data Management Plan
DoA	Description of Action
DSS	Decision Support System
DT	Decision Tree
EmC	Emergency Classification
FC	Fully Connected
FRs	First Responders
GIS	Geographic Information System
GPS	Global Positioning System
HRV	Heart Rate Variability
IO	Innovation Objective
KB	Knowledge Base
KG	Knowledge Graph
ML	Machine Learning
NLG	Natural Language Generation
POI	Point of Interest
PST	Photorealistic Style Transfer
PUC	Pilot Use Case
ROI	Regions-of-Interest
SA	Situation Awareness
SAP	Self-Assessment Plan
SD	Shot Detection
SME	Small and Medium Sized Enterprises
SR	Scene Recognition
SVM	Support Vector Machines
UAV	Unmanned Aerial Vehicles
UI	User Interface
UX	User Experience
VR	Virtual Reality
XR	eXtended Reality

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1. INTRODUCTION

In our daily lives, decision-making is an essential process that we engage in to evaluate various alternative solutions or actions. This process occurs almost instantaneously, within seconds. However, it can become complicated if we are unable to fully anticipate or comprehend the potential outcomes of our decisions. This presents a significant challenge, particularly for professionals in high-stakes positions, such as first responders, whose decisions can greatly impact society.

Situation Awareness (SA) is highly correlated to decision-making capabilities. The concept of SA has its roots in the work of human factors practitioners who study the behaviour of professionals in high-pressure situations, such as aviation, air traffic control, and large system operations. In these contexts, SA is crucial for ensuring the quality of human decision-making and performance. Nevertheless, the definition of SA is subject to debate, and there is no universally accepted understanding of the term. The xR4DRAMA project adopts the definition of SA as presented by M.R. Endsley in 1995 (Endsley, 1995): "*situation awareness is the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*". In other words, SA is a cognitive process that entails gathering information, interpreting its meaning, and anticipating future events to enable effective decision-making in complex and dynamic environments.

Novel technologies can increase situation awareness if applied the right way. The guiding challenge in xR4DRAMA is how SA can be created, enhanced, and maintained in disaster management and media production planning missions. A high level of SA will enable professionals and other people involved in these scenarios to make more informed decisions and take effective actions. The xR4DRAMA project aims to develop an interactive system that improves situation awareness by leveraging extended reality (XR) technologies to:

· facilitate the retrieval of all relevant information needed to organise necessary actions.

· generate a realistic digital representation of an environment, helping decision-makers to anticipate potential challenges and plan accordingly.

· improve communication and collaboration between team members by creating a shared projection of the environment, allowing for real-time updates and adjustments.

· enable continuous updates of the representation to keep up with the dynamic changes of the situation, allowing for better decision-making and adaptation in constantly evolving environments.

xR4DRAMA focuses on collecting and representing streaming data from outdoors environments where crisis events are happening as well as offline assets from the authorities, media production teams and from the web, in interoperable, collaborative, state-of-the-art augmented reality (AR), virtual reality (VR) and mobile environments, where end-users will be able to connect, operate and interact on different situation awareness scenarios. The project is bringing together different technologies, such as multimodal analysis, semantic web, XR, and smart wearables. Its concept is depicted Figure 1: xR4DRAMA concept.

Figure 1: xR4DRAMA concept

This report describes in detail the outcome of the xR4DRAMA activities and is structured as follows:

- The remainder of Section 1 introduces each consortium member, describes the revised project objectives, and summarises the key results and achievements.

- Section 2 briefly outlines the data management plan in the xR4DRAMA project in order to satisfy guidelines specified by the EC (e.g., with respect to the rights or ethics).

- Section 3 provides a self-assessment of each task of the project based on a revised version of the key performance indicators defined in "D1.2: Data management and self-assessment plan ".

- Section 4 explains the positive impact of xR4DRAMA in different aspects. The types of impact that are demonstrated are the industrial, the societal, the scientific and the technical ones.

The document concludes with Section 5, which provides a summary of the key topics covered throughout.

1.1 Consortium

1.1.1 Centre for Research and Technology – Hellas (CERTH)

The Centre for Research and Technology-Hellas (CERTH), founded in 2000, is the only research centre in Northern Greece and one of the largest in the country. CERTH has important scientific and technological achievements in many areas including Energy, Environment, Industry, Mechatronics, Information & Communication, Transportation & Sustainable Mobility, Health, Agro-biotechnology, Smart farming, Safety & Security, as well as several cross-disciplinary scientific areas. The Information Technologies Institute (ITI) of CERTH was founded in 1998 as a non-profit organisation under the auspices of the General Secretariat for Research and Technology (GSRT), with its head office located in Thessaloniki, Greece.

The participating team of CERTH-ITI in xR4DRAMA is the Multimodal Data Fusion and Analytics Group (M4D) of the Multimedia Knowledge and Social Media Analytics Lab (MKLab). The team has significant experience and scientific expertise on Social Media Monitoring and Social Network Analysis, Web Multimedia Mining, Image and Video Analysis, Multimedia Understanding, Interactive Multimedia Search and Knowledge Retrieval, Virtual and Augmented Reality, Artificial Intelligence (including Machine Learning and Deep Learning), Semantic Technologies and Integration of heterogeneous resources, Knowledge Representation, Reasoning and Management, Computer Vision, Visual analytics as well as Big Data Analytics. Through the years, the team has participated in 79 European and national projects. It has acted as coordinator in 15 European and 4 national projects, as a technical manager in 13 European projects and as a scientific manager in 13 European projects.

CERTH coordinates the xR4DRAMA project as well as assures the overall management of the project (WP1). Moreover, CERTH takes responsibility for the mediation, on behalf of the consortium, with the European Commission (EC), and for assuring all the related administrative duties, through its in-place management structure.

During the project, CERTH also led WP3 dealing with analysis and fusion of multi-modal data and WP8 dealing with the ethics requirements. Furthermore, they led T2.1, which involved crawling, searching, and retrieving textual and multimedia data, T5.4, which focused on developing a mobile application for citizens' awareness, and T7.2, which encompassed forming user groups and carrying out collaboration and standardisation activities.

1.1.2 Deutsche Welle (DW)

Deutsche Welle (DW) is Germany's international broadcaster, dedicated to fostering global freedom of opinion with unbiased news and information. It offers services in 30 languages across a multitude of platforms and reaches an audience of about 200 million people every week. DW also runs DW Akademie, an organisation that trains journalists worldwide and supports the development of free media. Via DW Innovation, the broadcaster participates in national and international R&D projects. The team is always eager to explore emerging technologies – and their impact on media, journalism, and audiences. Both data-driven-journalism (DDJ) and extended reality (XR) have been focal topics for several years now. DW Innovation specialises in media innovation concepts, use case development, user requirements and user testing, prototyping, and documentation/communication of project results. The team frequently contributes to the development and launch of software tools for journalists and media producers.

In xR4DRAMA, DW was involved in all work packages – with a strong focus on WP6 (use cases and system evaluation) as well WP7 (dissemination and exploitation, the latter of which was also led by DW. In particular, DW was in charge of D 6.1 (Pilot use cases and initial user requirements), D 6.2 (Final user requirements), D 7.1. (Dissemination and communication strategy), and D 7.3 (reports on dissemination, collaboration, and standardisation activities). Furthermore, DW supported the writing and editing of D 6.3 (Evaluation of the 1st prototype and updated user requirements) as well as D6.4 (Final system evaluation).

1.1.3 Nurogames (NURO)

Nurogames is an independent game development and software engineering company founded in 2006 in Cologne/Germany. Nurogames develops gaming and serious games solutions for consumers and for the industry. Nurogames covers the entire value chain of game development - from the initial idea to the final product - for all major mobile, web, PC, console, VR, AR and XR platforms with a track record of more than 14 years.

In xR4DRAMA, Nurogames developed the authoring tool, the VR Collaborative platform and the backend infrastructure to support the entire platform. The authoring tool acts as an entry point for the user to the xR4DRAMA platform. The authoring tool allows creation and management of projects and users. The VR Collaborative platform, although connected to the authoring tool, acts as a separate tool which works to allow users to access the location in virtual reality. This allows multiple users to be present either using VR headsets or through their desktops in the same environment and interact. The backend developed by Nurogames acts as a middleware platform.

1.1.4 up2metric (U2M)

up2metric is an SME established in Athens, Greece, which develops innovative B2B software solutions to “make cameras see and understand”. One of the company's main goals is to transfer state-of-the-art knowledge from the academic fields of Computer Vision, Photogrammetry, Remote Sensing and Metrology to the market. up2metric exploits key enabling technologies such as 3D computer vision, deep learning, and Augmented Reality to build solutions in commercial and research projects. Since 2017, up2metric has developed solutions on Infrastructure Inspection, Industrial Automation, Cultural Heritage Recording, and Precision Agriculture. The company has developed novel algorithms that are part of a core in-house software modules portfolio, which is adapted to fit each clients' specific needs. U2M assists clients and partners from the first step in the AI world to solve problems, design innovative products, gather the necessary image data, develop the applications, and deploy them to hardware.

up2metric is part of the Attica Technology & Science Park “Lefkippos”[1], member of the Hellenic Photonics Cluster[2], the Greek Startup Ecosystem[3], and the Federation of Hellenic Information Technology & Communications, Enterprises[4].

In the xR4DRAMA project, up2metric developed an online service for the image-based 3D reconstruction of objects and outdoor spaces using data from drones, mobile phones, handheld cameras, and online satellite services (T2.2, T2.3, T4.4). The reconstructed 3D models are optimised for their use in the VR environment. Furthermore, up2metric developed the location-based Augmented Reality application (WP4) which serves as a field task management application for the first responders in flood management situations and

[1] https://lefkippos.demokritos.gr/

[2] http://hphos.gr/

[3] https://elevategreece.gov.gr/

[4] http://sepe.gr

the media production planning experts. The AR application is based on a geospatial server (T5.3).

1.1.5 Universitat Pompeu Fabra (UPF)

Universitat Pompeu Fabra (UPF) was established in 1990 as a public university with a strong dedication to excellence in research and teaching. It is one of the few Spanish universities in the world Top 200 (Times Higher Education ranking - THE – 2022), and among the first 15 under 50 years (THE 2022).

In xR4DRAMA, UPF participates through the Natural Language Processing Group (UPF-TALN) of the Department of Information and Communication Technologies (DTIC). DTIC has an important track record of active participation and in EU projects, including coordination (a total of 66 FP7 projects and 10 other projects in non-FP7 program such as CIP, Ambient Assisted Living and the Lifelong Learning Program, and, up to now 50 H2020 projects). DTIC is the Spanish university department with the largest number of ERC grants (39), also forming part of the FET Flagship initiative “The Human Brain Project”. It is the only Spanish ICT department that has been awarded the “Maria de Maeztu” excellence by the Spanish government for the quality and relevance of its pioneering scientific research. UPF-TALN (http://www.taln.upf.edu/) was founded in 2005 by its current director Prof. Leo Wanner. During the 17 years of its existence, it has gained widely acknowledged expertise in a number of areas in Natural Language Processing, including text analysis, content (concept and concept relation) extraction from multilingual material, multilingual text generation and summarisation, and natural language interaction. UPF-TALN has also a solid record of coordination of and participation in large scale European and national RTD projects.

During the project, UPF has been involved mainly in WP3, leading tasks T3.3, T3.4, and T3.6.

1.1.6 Autorità di Bacino Distrettuale delle Alpi Orientali (AAWA)

The Water Authority of the Eastern Alps (AAWA) is a Public Body responsible for the management of the rivers in the Eastern Alps River basin district, which covers the north-east regions of Italy and the transboundary river basins between Austria, Slovenia, and Switzerland.

AAWA is responsible for catchment planning, including remedial measures to reduce hydraulic and geological risks, as well as for the protection and the sustainable use of water resources. It coordinates the activities to be implemented on a basin scale such as safeguarding the quality and quantity of water resources, studying the schemes necessary to prevent, in particular, disastrous events (droughts and floods). According to the Water Framework Directive 2000/60/EC and the Floods Directive 2007/60/EC, AAWA promotes Basin Plans which indicate the objectives of water resources and flood risk management and the measures aimed to achieve these objectives. AAWA has close connections with the main stakeholders of the project, both at local (municipalities, local Civil Protection and Region delegates) and national level and it is continuously engaged in exploitation and dissemination activities, which involve citizens and authorities, sharing the gained experience and the best practices with local communities and professional world.

The AAWA's team is composed of engineers highly qualified in software applications to plan hydrology and hydraulic issues. AAWA provided to the project the results from the EWS AAWA implemented in the Brenta-Bacchiglione River: a modelling platform able to provide, through web-services, flood scenarios (including water depth above ground, water speed, hazard, and risk mapping) and access to hydro-meteorological sensors.

In xR4DRAMA, AAWA undertook the implementation of the disaster management use case, engaging practitioners in the domain of disaster management to include them in the evaluation and testing of xR4DRAMA platform and organised the appropriate pilot use cases. AAWA was involved in all work packages – with a strong focus on WP6 (use cases and system evaluation), which was led by AAWA. In particular, AAWA was in charge of D6.3 (Evaluation of the 1st prototype and updated user requirements) as well as D6.4 (Final system evaluation). Furthermore, AAWA supported the writing and editing of D6.1 (Pilot use cases and initial user requirements) and D6.2 (Final user requirements).

1.1.7 Smartex S.R.L. (STX)

SMARTEX s.r.l is a small, limited liability company founded in 1999 with the aim of developing e-textile or new electronics structures compatible with textile processes and manufactures. Core activity is the implementation of bio sensing apparels (Tshirts, bands, vests, etc.) able to monitor vital signals, such as electrocardiograms, heart rate, respiration signal and rate, index of activity as well as bio-potentials like EMG. Moreover, systems based on piezoresistive textile sensors allow acquiring biomechanical signals for the recognition of gesture and posture.

The team of Smartex is composed of electronic engineers, one textile designer, bioengineers and physicists, and the company is an equal opportunity employer as the current ratio of female/male is 57/43.

The team has a significant experience in the development of safe, comfortable and easy-to-use interfaces between human and devices, focusing on the fabrication of multifunctional interactive fabrics, flexible and conformable to the human body for enabling the delivery of key enabling technologies (services, devices, products) in areas such as:

1. health monitoring: health promotion and disease detection and prevention;
2. rehabilitation: function restoring;
3. health assistance: disability compensation for higher quality of life;
4. sport medicine: function support and body monitoring;
5. quality of life and safety in workers.

In the xR4DRAMA project, the Smartex was involved in the development and production of wearable sensing platform, for real-time monitoring of physiological, environmental parameters and posture/activity of the end-user (WP2) and in stress detection (WP3). Moreover, Smartex led WP2 focused on the collection, management, and harmonisation of heterogeneous data.

1.2 Objectives

Situation awareness is crucial for humans to best execute tasks, plan things and take the appropriate decisions. xR4DRAMA translates the three main elements of SA, i.e., perception, comprehension, and projection into three sequential levels that build on each other. Each level stands for different stages in the management of any given events (e.g., disasters, media productions), but is also characterised by different degrees of immersion. At the first level (Level 1 SA), the focus is on extracting and presenting pre-existing information from various online resources and databases. The visualisation at this level is simplistic and aims to provide an accurate general overview of the situation. At the second level (Level 2 SA), more specific and detailed information from people on location and specialised sensors is integrated and displayed. Lastly, at the third level (Level 3 SA), various XR technologies and advanced visualisation techniques are employed to present an immersive experience that provides a high degree of situation awareness. All levels of SA are designed to be accessible to all stakeholders involved in a given scenario, with varying degrees of access and on different devices. The end goal of the xR4DRAMA platform is to create a shared, distributed, and consistent Situation Awareness that optimises real-world decisions and operations in disaster management and media production planning.

The xR4DRAMA system consists of four software tools that communicate and exchange data with each other to support the interaction requirements of the professionals in a team and the citizens affected by an incident. These tools are categorised according to user type. In particular, the professional groups are the ones who work in the control room and remotely manage a flood response or a media production operation and the ones that carry out their tasks in the field, such as the first responders. The authoring and the collaborative VR tools are designed for the former group, whereas the AR application is designed for the latter group. For situations where citizens are actively involved, an awareness mobile application named as citizen app is conceived as the communication point between them and the professionals. Additionally, the workers in the field are equipped with a smart vest system that tracks their physiological signals and enables continuous monitoring of their status by the entire team.

All the end user software tools are supported by a set of technologies that work in the backend and are accessed through a centralised interface, the backend's application programming interface (API). The backend consists of a multifaceted module set that a) acquires data from various sources, such as the smart vest, the user-generated multimedia, as well as content obtained from social media, the open Web and satellite services, b) analyses the raw data from different modalities (text, audio, image, video) to generate more knowledge and create realistic 3D model representations and c) organises 2D and 3D content in a geospatial database to allow all relevant data to be suitably placed in maps and in 3D space.

In order to realise the project's goals and support the aforementioned functionalities, xR4DRAMA defines a number of innovation (IOs), technological (TOs), user oriented (UOs) and impact making objectives (IMOs). Figure 2: xR4DRAMA concept associated illustrates the way xR4DRAMA's activities are involved and connected, associated with the corresponding objectives.

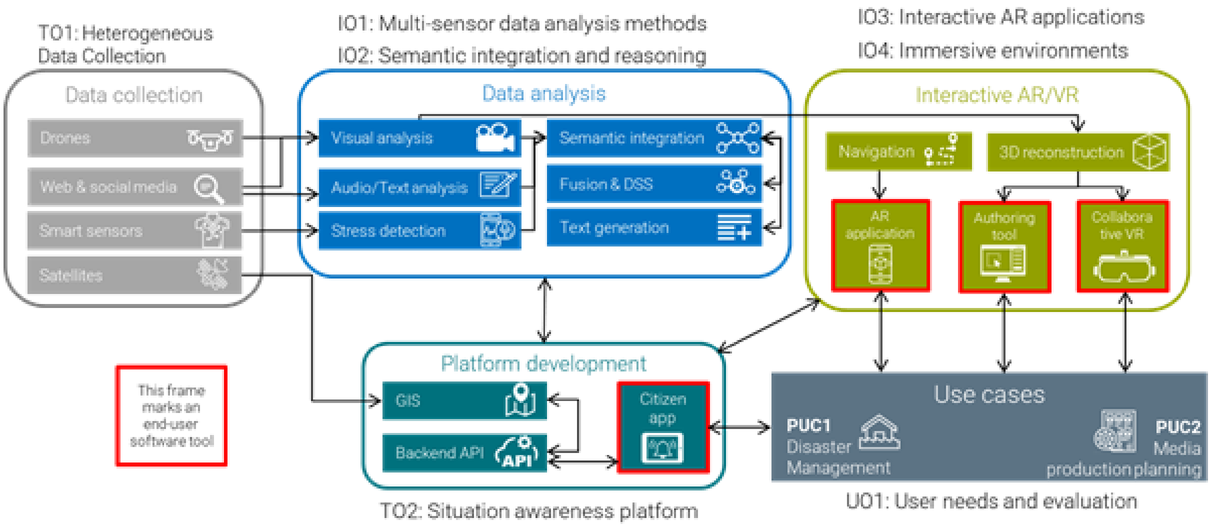

Figure 2: xR4DRAMA concept associated with its objectives

1.2.1 IO1: Develop multi-sensor data analysis methods for situation awareness

The main innovation objective in terms of multi-sensor data analysis methods for situation awareness comprises four sub-activities that focus on different aspects of crisis management.

First, sensor data analysis aims to collect physiological data during crises using smart wearables equipped with sensors. Signal processing and Artificial Intelligence (AI) analyse the data to determine the emotional state of the wearer, and then adjust a Decision Support System (DSS) in real-time. Physiological data like heart rate and respiration rate are gathered, and a time-frequency analysis is used to extract highly correlated parameters that develop an AI model to estimate an individual's stress levels.

Furthermore, localisation of assets in audio-visual content aims to use image and video data from outdoor areas of interest to locate buildings, their surroundings, and other valuable assets required for media production and situation monitoring. Scene recognition algorithms are applied to images and videos provided by Deutsche Welle (DW), as well as to media content sourced from social media and the web, to identify and localise relevant objects and the event environment. This approach involves building a 3D-model of the unknown area, including the identified objects of interest, by extracting subsequences of relevant data.

Moreover, the objective of multilingual audio and written language analysis is to develop technologies to analyse language information from various sources in crisis management, such as communication data from first responders, victims, and local staff, social media messages related to the crisis, and relevant online background information. To achieve this goal, cutting-edge deep neural network-based automatic speech recognition techniques are employed for spoken language analysis, and their performance is improved by tuning them with domain-specific data. In addition, neural semantic parsing and concept extraction techniques are investigated for deep analysis of the obtained transcripts and written language materials in the xR4DRAMA contexts and languages (English, German, and Italian), building on the techniques already available at UPF. The ultimate goal is to enhance the capabilities of language analysis in crisis management.

Finally, the objective of stress level detection is to develop innovative technologies for assessing the stress levels of actors in a given situation. Apart from the aforementioned body sensor-based method, an additional method that operates on the analysis of the acoustic features of the voice of the actors involved is considered. The acoustic feature-based stress detection technique experiments with features such as Mel-frequency cepstrum coefficients, pitch, loudness, and timbre. To account for the fact that stress manifests differently in different individuals, the body sensor-based and voice-based techniques will be treated as an ensemble of techniques whose multiple outputs will be used to determine the final decision.

1.2.2 IO2: Develop semantic integration and reasoning on audiovisual and smart sensor inputs

There are three main activities on this innovation objective that focus on multimodal information fusion and semantic representation, personalised information generation and DSS for situation awareness.

In xR4DRAMA, it is crucial to establish a pipeline for the fusion of signals from various sources, such as smart sensors, remote sensing measurements, and audio captured from the field. Additionally, formal representation models and abstraction technologies must be in place for the consistent and explicit annotation and linking of diverse knowledge sources, including the system's analysis modules. This facilitates intelligent information management. Multimodal data fusion is used to create appropriate semantic data models for low-level information fusion, while content modelling delivers a semantic representation of the derived textual, visual, numerical, and 3D model concepts. These include physiological and visual analysis data, and natural language representations. These models are represented in a network of interconnected ontologies, which also support the representation of uncertainty in the information content.

Moreover, to ensure that important stakeholders are kept up to date on the current state of affairs, personalised multilingual information generation techniques are developed for English, German, and Italian. These techniques operate on the semantically integrated data obtained through the previous activity, selecting the most relevant content for the intended recipient. To achieve this, deep learning-based and graph navigation/transducer-based natural language generation techniques are tested. The techniques cover discourse structure planning, content selection, and verbalisation of the selected content. The experimentation starts with the techniques available at UPF. Additionally, domain-specific schema-based planning mechanisms and grammar-driven graph transducer-based generation are implemented as a baseline.

Finally, the main objective of this research activity is to identify the significant characteristics of a new crisis event and establish effective methods to relate them, recognise similarities and enable predictions. This ultimately guides decision makers by forming the basis of the

DSS. The ontological structures created in multimodal information fusion and semantic representation serve as the foundation for the reasoning mechanisms employed by the DSS. The reasoning process accounts for incomplete and uncertain information, contextual clues derived from cross-modal sources (textual, visual, and audio), as well as geospatial data, and social media analytics. Statistical methods are utilised to resolve conflicting information, and a combination of deductive reasoning and probabilistic inference is employed to prioritise proposed actions and present the most relevant ones.

1.2.3 IO3: Develop enhanced interactive AR applications for outdoor media production and disaster management

The main goal of this innovation objective is the visualisation in Augmented Reality (AR). The AR modules aim to enhance the physical environment by overlaying information layers that cater to the needs of the first responders during field operations. These layers of information are streamed from various data sources available on the xR4DRAMA platform, including stakeholders' archives, data captured during response processes by xR4DRAMA tools, news coverage, social media streams, visual data, prediction models, and DSS analytics results. Using AR sensors, the first responders are able to position their findings in real 3D space, merging the real-world 3D space with virtual data connected to the GIS and the xR4DRAMA platform. The data to superimpose on the real world comprises narrative information such as history and protocols, real-time streamed data, and 3D information such as infrastructure, obstacles, and restricted areas. AR sensors provide a real-time view from the first responder's viewpoint, which can be utilised by stakeholders in the control room to provide support, supervision, and advice to on-site personnel. In the media use case, this interactive walkthrough can improve the planning process.

Furthermore, another objective is to implement the necessary technologies that will aid the navigation of first responders and journalists in the real world through the xR4DRAMA AR module. To achieve this, 3D models of the environment and infrastructures are created and linked to a GIS system. The AR device is equipped with sensors such as GNSS, IMU, Gyro, and WiFi to enable navigation. Since the user experience greatly depends on navigation, it is a crucial aspect of the AR module.

Finally, it is important to develop scene understanding for the AR interaction in order to assist the actors in the field. The main objective of this activity is to offer semantic data for the physical environment that the local media contact and first responders can visualise using the AR device. Such data is essential to ensure a smooth and continuous integration of information from the control room and the DSS with the real-world environment.

1.2.4 IO4: Develop immersive environments for strategic planning of media productions and disaster management

The main innovation objective in terms of development of immersive environments for strategic planning of media productions and disaster management comprises four sub-activities that focus on different aspects of the immersive experience.

First, the aim of 3D reconstruction of outdoor spaces from heterogeneous sources is to create 3D models of the location being investigated by utilising a blend of satellite data, images captured by unmanned aerial vehicles (UAVs), and a mobile mapping platform. These models serve as the basis for the virtual reality (VR) environment, the overlay of information and localisation in AR, as well as the data analytics tools.

Moreover, multi-user interactions in immersive environments plans to implement an environment where multiple users can come in and interact with each other. The users can test and play with the tools to create environments that other users can view and get informed from.

Furthermore, the use of VR environments allows users to visualise the entire scenario of the use case before sending personnel to the scene, thereby enhancing their comprehension of the situation.

Finally, the VR Authoring tool is designed to enable producers or managers to create VR environments to aid in event planning. The tool is compatible with Windows PCs and can export all environments to a VR headset for easy visualisation.

1.2.5 TO1: Heterogeneous Data Collection

There are multiple different data collection types that comprise this technological objective. To begin with, this activity focuses on collecting and managing data from multimedia content retrieval through the field, social media, web, and open repositories. The project utilises existing data-sharing services and develops data wrappers to facilitate content access for consortium data providers and producers, such as DW. These providers grant access to selected parts of their historical images, documentary, and media archives to the xR4DRAMA platform, allowing for the localisation of building structures and outdoor environments and the creation of their 3D models. Advanced retrieval techniques are also employed to gather visual data from public databases, including videos and images from news sources and social media. Textual data, such as summaries and transcriptions related to the aforementioned visual data, are also collected accordingly.

Another objective of this technological activity is to plan and execute data recording for the purpose of 3D-reconstruction. This supports the GIS module and the geolocalisation processes in AR application of the XR tools, while also improving the accuracy of terrain remote sensing on request. To achieve this, vertical and oblique aerial drone imagery are combined with a customised mobile mapping platform, consisting of images and GPS / IMU data. Careful mission planning is essential to ensure the initial data has the necessary spatial and temporal resolution required for scalable 3D models suitable for the online xR4DRAMA platform. For 3D-reconstruction, techniques such as Structure from Motion and SLAM, as well as single image reconstruction are employed. The resulting 3D mesh models are provided in suitable formats for use in Virtual and Augmented Reality apps, creating immersive 3D experiences.

Moreover, this technological objective aims to create a remote sensing service for the xR4DRAMA platform, which supports the visualisation of the immersive VR environment and the GIS module. This service allows for the creation of a rough 2.5D/3D terrain model through satellite data, without the need to deploy in-situ 3D recording devices or agents to the field. The Copernicus open access hub web services and Data and Information Access Services (DIAS) are utilised to serve satellite imagery and data.

Finally, smart fabric and interactive textile platforms allow for the collection of physiological and psychological data in real-life situations without interrupting the activities of the individuals involved. By combining objective data gathered during emergency scenarios with visual, auditory, and virtual inputs, these platforms offer a supportive tool that can be customised and tailored to the user's needs and circumstances. To achieve this, a series of sensing vests are designed and implemented specifically for use in disaster scenarios, providing first responders with imperceptible sensing tools that can supply the Decision Support System with personalised and contextualised data.

1.2.6 TO2: Interactive Situation Awareness Platforms

The main technological objective in terms of development of interactive situation awareness platforms comprises three sub-activities that focus on different platforms.

Initially, the system development, integration, communication, and data management involved creating an infrastructure for constructing, transmitting, and merging the platform's data in a safe and protected manner. Subsequently, efforts were focused on integrating all of the developed services into this architecture. Throughout the project, a comprehensive data management plan was established to ensure that data security and compliance with GDPR regulations are maintained.

Moreover, the objective of 3D GIS for navigation and geo-localisation is to create a Geographic Information System (GIS) that encompasses positioning and spatial scaling details for all assets related to xR4DRAMA that need to be positioned in the physical world through the AR tools. The GIS links the 3D landscape with all the assets requested by field agents and the DSS to be projected in AR. Additionally, it enables spatial queries in the database to select information based on the location of the field agents, such as first responders and journalists, for display in AR.

Finally, the objective of development of a citizen awareness app is to design a mobile application that enhances situational awareness for the general public. The mobile app can recognise the user's context based on various factors, including their location, time, and proximity to hazardous zones. Using input from other technological and innovation objectives, the application presents the user with clear and concise information regarding the current status of the event, any potential hazards or alerts, and displays them seamlessly on a mobile platform.

1.2.7 UO1: User needs and xR4DRAMA evaluation

The initiative of use case creation and end-user requirements definition established two use cases that catered to the demands of (1) disaster management and (2) planning for (remote) media production. These use cases considered typical situations and established work processes in these areas. The xR4DRAMA tool is put into practice in the standard operating environments of disaster management and media production to evaluate and enhance the level of situational awareness. An iterative evaluation methodology was used to uphold a user-centric approach and lead development activities in the project.

1.2.8 IMO1: Dissemination and Exploitation

Disseminating project results, standardisation and collaboration with external bodies involves carrying out dissemination activities to raise awareness about the xR4DRAMA system and engage with collaborative partners, including small and medium-sized enterprises (SMEs) working on comparable solutions for similar or other domains. Finally, market analysis, sustainability and exploitation plan and business model implement a set of tools and a management platform based on best practices in Post-disaster needs assessment (PDNA).

1.3 Summary of results

xR4DRAMA has been a highly productive and fruitful project, with many interesting results emerging from the four evaluation sessions (two for each pilot use case), important lessons learnt and remarkable innovation progress. The management team and the consortium as a whole, took all the necessary corrective and proactively delivered action plans to ensure the smooth operation of the project that has ended up with a successful track.

Below, we present a summary of the key results (KR) achieved throughout the course of the project at all levels (technical, innovation, evaluation, dissemination, and exploitation).

1.3.1 Multi-sensor data analysis methods

Assets localisation in audio-visual content

Task 3.2 involved the development of algorithms designed to extract information from visual content. The xR4DRAMA visual analysis pipeline receives visual input in the form of images or videos from the data collection module, the citizen app, the authoring tool, and static surveillance cameras (particularly for the River Overtopping Detection (ROD) module). More specifically, the xR4DRAMA visual analysis pipeline consists of the following modules:

1. **Shot Detection (SD)** analyses visual data in order to segment the acquired video in shots and extract the most meaningful frames (i.e., keyframes) for further analysis, as, in many cases, videos and documentaries contain shots of multiple scenes. Some scenes may not be directly relevant to the information we would like to extract or useful for 3D reconstruction purposes. It is, therefore, important to pre-process these videos so that we split them in the different scenes that they contain to examine if further processing of them is needed. For this purpose, we have deployed TransNet V2 (Souček & Lokoč, 2020), a deep network that reaches SoA performance on respected benchmarks.

2. **Scene Recognition (SR)** provides a high-level annotation about the type of area or buildings that are depicted in the visual scenes. We used a VGG-16 network (Krizhevsky, 2012), the first 14 layers of which were pre-trained the 365 categories of the Places-2[5] dataset. The remaining layers were trained on a subset of 99 selected classes of Places dataset (presented in the Table 3 of D3.2), in order to adjust the SR model to the xR4DRAMA needs and classify only the relevant scenes. Moreover, the Scene Recognition (SR) model

[5] http://places2.csail.mit.edu/

classifies scenes in two general environmental categories, i.e. indoor or outdoor, and use them so as to differentiate between frames that could be further processed and used for 3D reconstruction of an area (T4.4) (outdoor scenes) or not (indoor scenes).

3. **Emergency Classification (EmC)** detects floods in the analysed images or videos. For the training of the EmC model a VGG-16 architecture pre-trained using the Places-2 dataset was used. The adaptations made were the following: i) the final Fully Connected (FC) layer was removed and replaced with a new FC layer with a width of 3 nodes freezing the weights up to the previous layer and ii) a softmax classifier was deployed to enable multi-class recognition. The train EmC model can recognise two image categories: “Flood” and “Other”.

4. **Photorealistic Style Transfer (PST)** generates new images with the same content and the style of a selected image that can be transferred to make them look like they are in different lighting, time of day or weather. It aims to provide enhanced input images to object detection and localisation algorithms, to get more accurate results. The next paragraph, titled "Photorealistic Style Transfer," provides a more detailed description.

5. **Building and Object Localisation (BOL)** is responsible to detect, recognise and localise buildings and the desired buildings, objects or elements that might exist in the acquired xR4DRAMA image and video samples. It consists of two different deep learning models:

i) An *image semantic segmentation model* that mainly focuses on the localisation of buildings and urban elements. Wanting to focus on the labels that really cover the xR4DRAMA’s needs, we created a custom mixed dataset using images both from CityScapes[6] and the Mapillary Vistas[7] datasets keeping only selected labels.

Figure 3: This figure displays the analysed frame, the extracted masks, and the final masked frame. The labels that were detected include: 'building', 'sky', 'vegetation', 'wall', 'road', rail track, 'sidewalk', terrain'

ii) An *image instance segmentation model* that we use to localise and count the number of people, animals and vehicles, in case the EmC module detects floods in the analysed

[6] https://www.cityscapes-dataset.com/

[7] https://www.mapillary.com/dataset/vistas

image or video. Regarding the model for the detection of people, animals and vehicles, we use the instance semantic segmentation model of the PixelLib[8] framework.

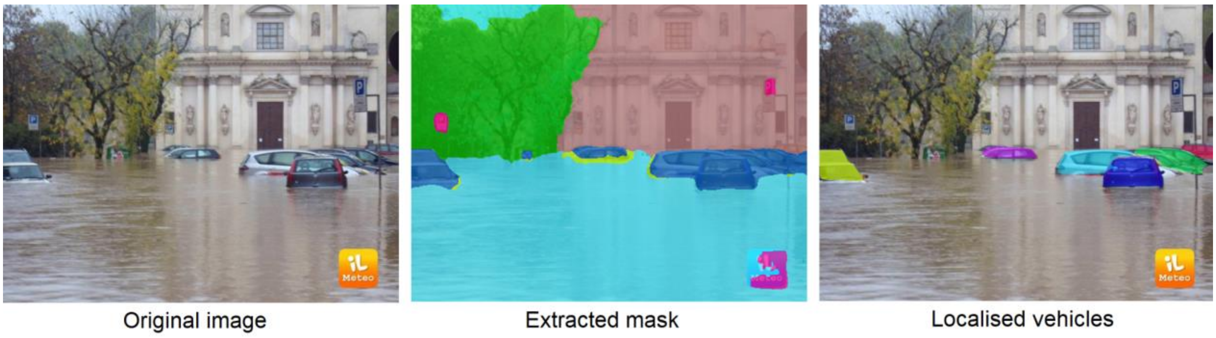

Figure 4: This figure shows the analysed image, the extracted mask, and the localised vehicles

6. **River Overtopping Detection (ROD)** analyses input from a static camera installed at the Angeli bridge at Vicenza, Italy, estimates the water level and provides information about whether there is an overtopping or not. The system uses OpenCV's Canny edge detector[9] to detect a marker (rod) of known length. Canny edge detector uses a multi-stage method to identify different edges in images.

Figure 5: In this figure, we can see the original frame, the cropped rod after applying PST and the rod's edges

Once the marker is detected, the system calculates the distance in pixels between the marker's highest and lowest detected points, which should indicate the surface of the water. This distance corresponds to the length (in pixels) of the visible portion of the marker, which can then be translated into its actual length in metres using calibration data. The length of the visible portion is then used to determine the water level, and if it exceeds a predefined

[8] https://github.com/ayoolaolafenwa/PixelLib
[9] https://docs.opencv.org/3.4/da/d22/tutorial_py_canny.html

threshold, one of three alert types is triggered: "Moderate," "Severe," or "Extreme." For this specific camera, AWAA has defined thresholds of 3.0m, 4.6m, and 5.4m for these alert types.

The information extracted from the above modules is sent to the xR4DRAMA's Knowledge Base (KB) for further use. The masks generated by the semantic segmentation model are exploited to pre-process the video frames before the 3D reconstruction process (T4.4). More information for the visual analysis modules is provided in D3.2 and D3.8.

Photorealistic style transfer

When there is severe noise, poor brightness, low contrast, and a narrow grey range, it can be challenging to improve image collection in low-lighting settings. Maximising the information from the input image on the patterns that are available and extracting the colour information that is concealed behind the low luminance values are the key challenges in low-light image enhancement.

We propose and integrate a novel framework for image enhancement on low-light conditions. To better retain texture regions in image enhancement, a modified U-Net based architecture is developed which employs dense blocks that incorporate dense, convolutional, and wavelet pooling layers. The framework requires low-light and normal-light images as input and improves image quality by encoding with low frequency (LL (low-low)) components and unpooling with high frequency (LH (low-high), HL (high-low), HH (high-high) components.

To achieve photorealism, a model needs to successfully increase the luminance of an image while recovering the structural information of the image. The suggested U-Net-based network is paired with wavelet transforms and Adaptive Instance Normalisation (AdaIN) to overcome this problem. More specifically, wavelet pooling and unpooling are used to recover the images while still maintaining the content's information for the transmission network. To create the enhanced images, the frameworks input both low-light and normal-light images. The quality of feature transferring is thus improved, and connections are skipped during the transferring process, using dense blocks. The associated features of various levels from the encoding process are added to the enhanced features as part of the picture reconstruction process with the goal of creating a natural stylisation effect.

Following a U-Net alteration, the network is composed of the encoder, enhancer, and decoder. In order to maintain the structural integrity of a picture, the encoder and decoder create the symmetric structure of a U-Net. Convolutional and pooling layers in the encoder also require a downsampling mechanism, whereas an equivalent upsampling mechanism is present in the decoder. Encoder and decoder modules are connected via a skip connection in the U-Net architecture. Multi-layer feature aggregation (MFA) and AdaIN blocks are added to the already-existing skip connections in a module called enhancer. A Haar wavelet-based pooling layer, which replaces the traditional max-pooling layer in the enhancer module and encoder, is used to capture smooth surface and texture information. The framework of this network is presented in the following figure.

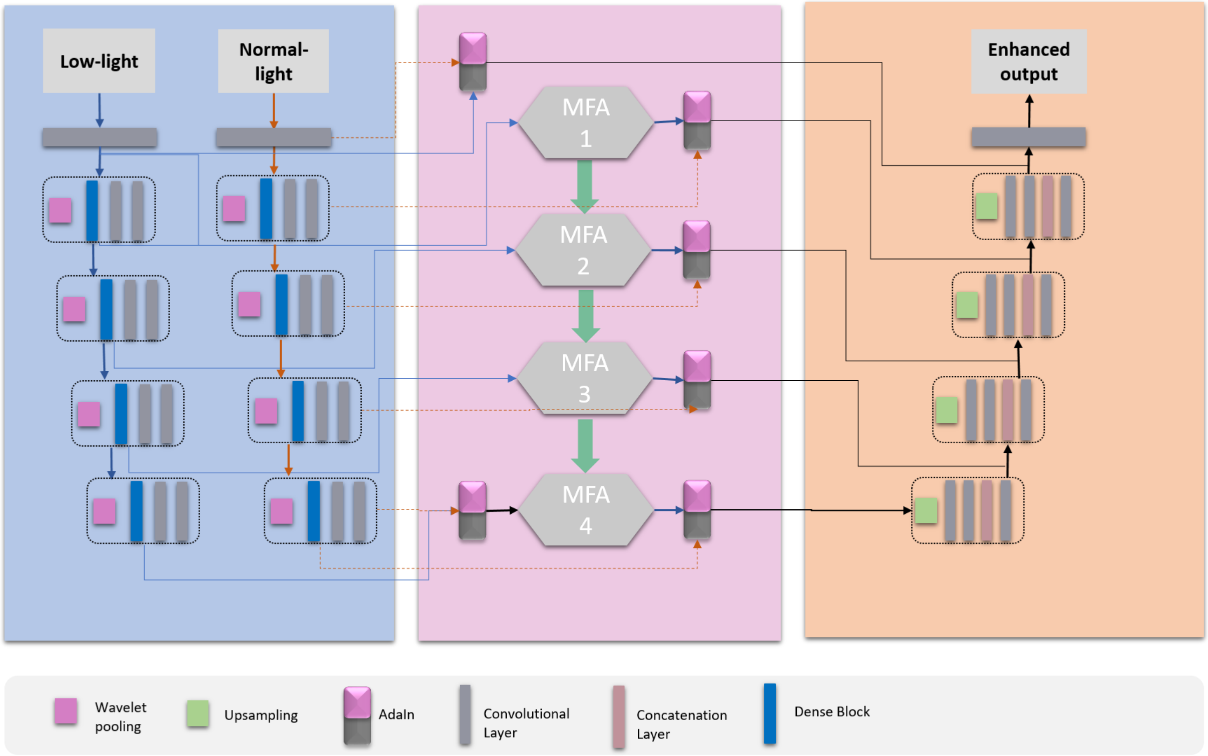

Figure 6: Image enhancement framework based on U-Net architecture and wavepooling layers

The suggested methodology on LOL benchmark low-light dataset delivers state-of-the-art with reduced computational resources, both in training and testing processes, according to experiments comparing it with current research in image enhancement[10].

Multilingual language analysis module

Multilingual audio and written language analysis are integrated in the xR4DRAMA platform to analyse the material acquired in T2.1 or provided by the users from several sources for the derivation of abstract linguistic representations, which can be used by the language generation component that will export information relevant to the needs and requirements of the users.

This component is responsible for (i) the transcription of spoken language into text and (ii) the analysis of textual and spoken (i.e., speech data transcriptions) material obtained from different sources, including communication data from citizens, textual information provided by location scouts, social media messages and online information.

Automatic Speech Recognition (ASR) addresses the task of transcribing natural spoken language into text.

[10] *Batziou, E., Ioannidis, K., Patras, I., Vrochidis, S., Kompatsiaris, I., "Low-light image enhancement based on U-Net and Haar", 2023, In Proceedings of the 29th International Conference on Multimedia Modeling (MMM 2023), 9 - 12 January 2023, Bergen, Norway (accepted for publication)

The ASR functionality is used within the xR4DRAMA project to make audio content in the form of speech recordings accessible to automatic analysis, so that information received in that form can be presented efficiently without the need to have a person listen to each audio message. In the integrated prototype it is used primarily to obtain information from messages sent by citizens or first responders through their corresponding apps, though some work was also done on phone calls to emergency services as a possible application scenario.

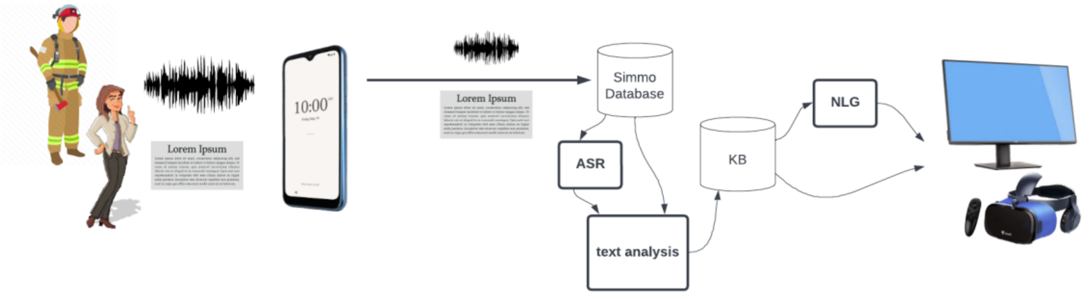

Figure 7: Language Analysis information flow in the xR4DRAMA platform

The text analysis component processes the content received from the crawler by retrieving each document and, depending on the document type, passing it through ASR as needed before analysing the text and storing the extracted information in the KB. The information is then made available to the system's users through geolocated points of interest (POIs) shown on a map, or through reports generated to provide the information of interest, using the Natural Language Generation (NLG) component as required.

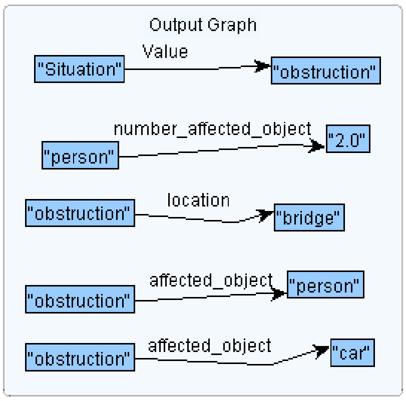

Figure 8: Language Analysis output graph for *"Aiuto, c'è un'auto incastrata sotto ponte degli angeli con due persone dentro"*

Sensor-based stress level detection

When first responders are on the field during disastrous situations, their stress is of key importance for ensuring that their performance will be in top level and for not risking their health condition. By continuously monitoring the physiological signals of the first responders, it is possible to predict and monitor their stress levels in real-time. Task T3.1 was responsible for developing the necessary algorithms for stress detection based on physiological data from the first responders.

The sensor-based stress detection module involves the analysis of data received from the smart vest that is described in task T2.4, while the first responders are on the field wearing it. The sensor data analysis includes three different steps: feature extraction, feature selection and stress detection. When dealing with sensor data, feature extraction identifies the most discriminating characteristics in signals and provides derived values that are more informative regarding the current state. The features extracted from the smart vest sensors include time and frequency domain features for all different modalities of the vest and features regarding the heart rate variability (HRV) extracted from the ECG sensor as well as features regarding respiration rate variability and breath to breath intervals from the respiration (RSP) sensor. The total number of features extracted is 314.

After performing massive feature extraction, the feature set typically consists of large amounts of information, which in many cases is redundant and reduces the overall performance. Feature selection has the role to only maintain the most useful subset of features and eliminate the redundant ones that produce noise for the final classification. The sensor-based stress detection module implements a feature selection step based on a genetic algorithm. Finally, the stress detection is performed by using an extreme gradient boosting machine learning algorithm, trained on the subset retrieved from the feature selection process.

The whole module, including the feature extraction, feature selection and stress detection operates in real-time through the developed API. The API receives data from the smart vest and proceeds to analyse them as described above. The results are forwarded to the fusion module, which is responsible for combining the sensor-based stress level detection results and the audio-based stress level detection results.

Audio-based stress level detection

The stress level detection component of xR4DRAMA, developed in T3.4 of WP3, is responsible for developing body sensor-based (see previous section) and audio signal-based technologies for the assessment of the stress level experienced in an emergency situation.

The audio-based stress detection system is designed to work with voice recordings from different sources, in particular phone calls (from citizens to emergency numbers) and voice messages from first responders (FRs).

Detecting stress using audio-signal based techniques requires two main processes: i) acoustic feature processing and extraction and ii) prediction (or classification) of the estimated level of stress. At a high level, these tasks can be described as audio signal processing, data processing and statistical inference via machine learning algorithms.

An initial version of the stress detection module was developed during the first period of the project and was later replaced by a second version that improved significantly over the initial baseline. This required significant work in collaboration with the user partners to produce and manually annotate in-domain data, using simulated phone dialogues as well as a specially designed stress exercise for first responders.

This data was used to train and evaluate the improved version of the audio-based stress module, as described in detail in D3.10.

1.3.2 Semantic integration and reasoning

Multimodal data fusion

When dealing with multiple data sources multimodal fusion can improve the overall systems performance and offer valuable information by effectively combining each modality into a unified outcome. During the xR4Drama project, two different multimodal fusion modules have been developed; the fusion stress level detection module and the multimodal severity score fusion module. Task T3.5 was responsible for developing the fusion algorithms for both stress levels detection and severity computation.

Fusion of stress level detection: The fusion-based stress detection module is responsible for fusion sensor-based stress detection results and audio-based stress detection results. Through the developed API, the fusion module receives the sensor and audio-based stress level detections and proceeds to fuse them by using a support vector machine learning algorithm. The final fused stress level detections are forwarded to the knowledge base. In cases where there are no audio results, since the audio module operates with voice recordings that are not always present, the fusion module operates normally by considering the sensor-based stress level detections as the final result.

Fusion of severity computations: This module is receiving as input data the final stress detection from the fusion stress level detection module along with visual analysis results to achieve situation awareness. The stress of the first responders on the field is combined with the emergency probability produced from the visual analysis tool, giving a clearer overview of the disaster severity. The received stress levels along with emergency probability of the image received from the same area are fused using a fuzzy inference system to produce a severity score of the area. Then, the module forwards the severity score along with the corresponding danger zone information to the decision support system.

Semantic integration

The most important information during disasters for the people involved, is the situation before the disaster, and is mostly unavailable. Furthermore, first responders are not trained to face those real-life scenarios because mostly they acquired theoretical knowledge on how to act during events. The extended reality environment can replicate the principal features of a general disaster. xR4DRAMA KG can work as the knowledge representation mechanism that will allow participants to be trained in a safe situation also making use of physiological sensors to monitor response and health data.

As part of their day-to-day business journalists and other media houses produce news coverage in various locations. Despite thorough research and preparations, remote production planning very often runs into challenges and difficulties. Many depend on the characteristics of the individual location and the situation on the ground. These challenges can be circumstantial and organisational - like accessibility, noise, the presence of people, the lack of infrastructure (from electricity supply to parking space), the wrong choice of equipment or other filming restrictions. Hence, it is crucial for journalists and media houses to access information about the state of a location, such as the accessibility of the location, among others, to plan their media coverage.

The challenge is to combine all this information into a coherent image to give everyone a precise picture of the location and the situation on the ground in order to prepare themselves for a smooth and safe production. The xR4DRAMA KG can fill the aforementioned gap in distribution of crucial knowledge to journalists, in order for them to be able to plan the news coverage more efficiently. Moreover, using this approach, the status of first responders can be monitored, to better assign tasks during emergencies. Based on the aspects, the xR4DRAMA KG in a real-life scenario can provide first responders important information and can reproduce in real time the actual event inside the control room to allow for well-informed and efficient decision making.

The xR4DRAMA KG was created to serve as the knowledge representation for the xR4DRAMA project. Using many technologies, including eXtended Reality (XR), xR4DRAMA is committed to enhancing situation awareness. The main use cases of the xR4DRAMA project focus on disaster management and media planning. In short, xR4DRAMA project stands in three key-points: (a) Facilitating the gathering of all necessary (digital) information for a particular, difficult or even dangerous situation that a media team faces, (b) Utilizing extended reality technologies to simulate an environment "as if on site" in order to accurately predict an event or incidence, and (c) Establishing a shared understanding of an environment and giving users of the project's platform (first responders in the field/control room, citizens, and journalists) the option to update representations of locations as events change, allowing them to comprehend and re-evaluate the effects of particular actions/decisions.

As a result, the xR4DRAMA KG may incorporate the findings of several advanced analysis components that process multimodal data and depict the structures they produce (in this project, for the media use case, we integrate visual and textual analysis messages).

Additionally, the xR4DRAMA KG provides an innovative method through its Point-Of-Interest (POI) management mechanism that may generate or update POIs, which contain essential geospatial data that can make it easier for journalists to cover the production recordings and information that is needed in a case of emergency.

When covering a recording of a documentary in a remote location, unknown to the media production team, a journalist should have access to geospatial data that gives details on the location they will be visiting. Also, for an individual in a disaster management situation it is also important to access geospatial data that contains information about the location that suffered the destruction. The information will enable him or her to accurately and cost effectively set up the production. For this reason, we offer a tool that allows users to add or update POIs. We use the term POI management mechanism to refer to the process for creating and updating POIs, throughout the paper. A POI, according to the official definition, is a particular place or location point on a map that a user would find useful or interesting. In our situation, POIs also comprise geospatial data that includes details from user provided videos, photos, and text messages on the condition of a location. As a result, POIs contain data that can assist journalists in actual situations involving media preparation.

To make it easier for first responders, journalists and media organisations to complete a remote production mission, POIs aim to create some points in a region (i.e., pins on a map) that convey vital geographical information. Any user can add or modify POIs using the AR app. The user can either provide a picture or video that the visual analysis component analyses, and some of the important data in the image or video is then passed to a new or existing POI (the pipeline for a textual message is similar).

It is simple to comprehend why a POI would need to be formed: if an event had taken place and there were none already present in the region. The updating of POIs, on the other hand, takes place when there are already POIs in the region and part of the information in them needs to be updated since the event’s state has changed.

Multilingual personalised information generation module

The text generation module converts structured information from the various analysis components (textual, visual, stress, etc.) into human-readable reports or messages. It can be used to prepare aggregated documentation as well as status or situation updates or messages.

For the disaster management use case the module can generate a timeline of events throughout the development of an emergency situation. Given a project id and two timestamps, the module receives the information selected by the DSS component and provides a verbal summary in English or Italian of the emergency situations that occurred in that timeframe. The module also serves to generate a title and small description for the POIs created from text and visual analysis information.

Regarding the use case of media production, the module generates a report by organising in a coherent and cohesive way the relevant information coming from the data acquisition and language analysis modules. This report contains a general overview of the location as well as information about the target area such as the usual weather, infrastructure availability (e.g., restaurants, hotels, hospitals, parking, internet, …), etc. As for the disaster management use case, POIs with automatically generated titles and descriptions are created based on the information extracted from textual sources such as review sites (e.g., FourSquare).

UPF’s generator takes as input a selection of contents from the Knowledge Base (KB, T3.5) and produces texts in English and Italian.

Following the methodology previously described in the DoA and D3.6, our approach to text generation divides the task into three subtasks: content selection, discourse planning and linguistic generation. Discourse planning (also referred to as “sentence packaging”, “text planning” or simply “aggregation”) and linguistic generation were tackled by improving UPF’s grammar-based generator FORGe (Mille et al. 2019) to increase its coverage both for English and Italian (although a large part of the rule engine is multilingual), particularly in xR4DRAMA’s domain, by extending our linguistic resources and by experimenting with the implementation of a complementary module using neural networks.

Decision support system

One of the main goals of the Decision Support System (DSS) is to generate the Severity Level (SL) of a POI fusing the information that is available to the KB, either via the Textual or the

Visual Analysis outcomes. The severity score is then used from the KB to create or update the situational picture of a danger zone containing that POI. Two different approaches are used in order to assess the current severity of a situation, depending on the type of the analysis message DSS receives from the KB (Textual or Visual).

For the Textual Analysis messages, a rule-based approach was used. When a textual message is generated, KB communicates that information to DSS in real time. The following message is an example of such a textual message.

For the Visual Analysis messages a Machine Learning (ML) approach was developed in order to assess the weights of every category that was detected from the Visual module with an intelligent way, and thus avoiding the use of heuristic weight values. Using the results produced by the analysis of example frames of videos with flood scenarios by the Visual Analysis module we created an annotated dataset with 96 entries. That dataset was then used to train and test four well-known ML algorithms, namely the Ridge Classifier, the Support Vector Machines (SVM), the Random Forest (RF) Classifier and the Decision Tree (DT) Classifier looking for the best possible accuracy score. Then, the best performing model was integrated into the DSS framework and by its interaction with the KB.

Danger zones are either created or updated from the KB, based on the severity score it receives from the DSS support system. There are three different scenarios, which we will analyse in detail, that the KB considers when it receives a severity score from the DSS. Additionally, the fusion of stress levels of first responders with results from the visual analysis module can offer a better insight into the situation of the severity of the danger zones in real time. The fusion method is based on a fuzzy inference system which combines the stress level of each first responder with results from the visual analysis of the same danger zone in the last one hour. In the current application, the inputs are the stress levels of the first responders and the emergency probability from the visual analysis tool, and the output is the severity score of the current danger zone.

The task creation list is another function which is a result of the communication between the KB and DSS. In this case, the DSS will recommend to the KB to attach a set of tasks to POIs that need to be performed by the first responders for the disaster to be tackled. The use case for this service was based on a flooding scenario, in which external sensors would measure the water level of the river Bacchiglione which passes through Vicenza, and if the water level would overcome a threshold, then the DSS would recommend various tasks that need to be performed on different locations. Therefore, the task would be attached to POIs for the first responders to see and perform them, to have the best possible outcome in a disaster management scenario. We provide a message as it comes from the DSS, which the KB must map in the various POIs existing on the map. Notice that where the task will be mapped is subject to the coordinates it contains.

We also offer a mechanism that assigns the crucial information that accompanies a project. A project is a set of observations, where each observation corresponds to a visual, textual or stress level analysis message. More intuitively, a project is a set of observations which are clustered based on locality. For instance, a project may refer to all the observations for the urban area of Vicenza.

· The general information refers to a general description of the area that the project refers to. In more detail, each time a new project is created the KB will retrieve the collected Wikipedia page, and if it does not find any relevant information from Wikipedia it will search in DBpedia[11], the abstract that refers to the location of the project.

· The emergency data are the emergency numbers that can be used for each project, the emergency numbers are subject to the country, and sometimes region of the country. These numbers are the numbers from which one can call the police, ambulances, and firefighters.

· The legal documents refer to the legislation concerning recording in public places for each country (and region of country in some cases), and legislation about operating drones in public spaces.

1.3.3 Enhanced interactive AR applications

AR module

The Augmented Reality (AR) application is the user interaction interface for the field tasks management for the two Pilot Use Cases, thus it supports the First Responders (FRs) in the Disaster Management scenario (PUC1) and location scouters and journalists in the Media Planning scenario (PUC2). The AR application was developed as a mobile phone application, supporting both major ecosystems Android and iOS, with standard and enhanced AR interaction features that follow the user requirements. The AR application communicates bilaterally with the xR4DRAMA platform so the field actors get the latest information from the platform and at the same time the control room receives updates from the field. Thus, improved situation awareness is ensured for both in-situ and away users.

The xR4DRAMA AR application is a location-based application that, based on the GIS service, exploits data points from OpenStreetMap and other online geodata sources, and aggregates them into various Points-Of-Interest (POIs) and Regions-Of-Interest (ROIs). These POIs and ROIs are organised into thematic categories and hold relevant information about the geographical entity they represent. The user can interact with these entities either in the map view, or the AR view, and alter them to organise one's tasks and keep in par with the control room. Object detection using ML adds to the functionalities of the application providing assistance to actors in the field. The final version of the AR application is connected and integrated with the backend and the GIS Service and is fulfilling a long list of user requirements. Briefly given, the AR application provides project management and user communication, POIs and ROIs management such as viewing, editing, and adding, task management, POIs and ROIs search functionality, and navigation. Furthermore, advanced capabilities are offered via the AR view of the application such as the placement of digital objects and whole scenes in the real world, recording of mixed realities scenes for inspecting

[11] https://www.dbpedia.org/

them in the AT, AR measuring, visualisation of the digital POIs in the real world, and visualising flood forecasts. The accuracy of the outdoor navigation and the pose estimation of the user have been improved in this final version using a hybrid method of SLAM implementation and GPS localisation.

Some of the user-driven capabilities are presented in the following figures. Figure 9:presents some screenshots of the application allowing the user to *Overview* general information, browse *Files* specific to the project, and search for project *Contacts*.

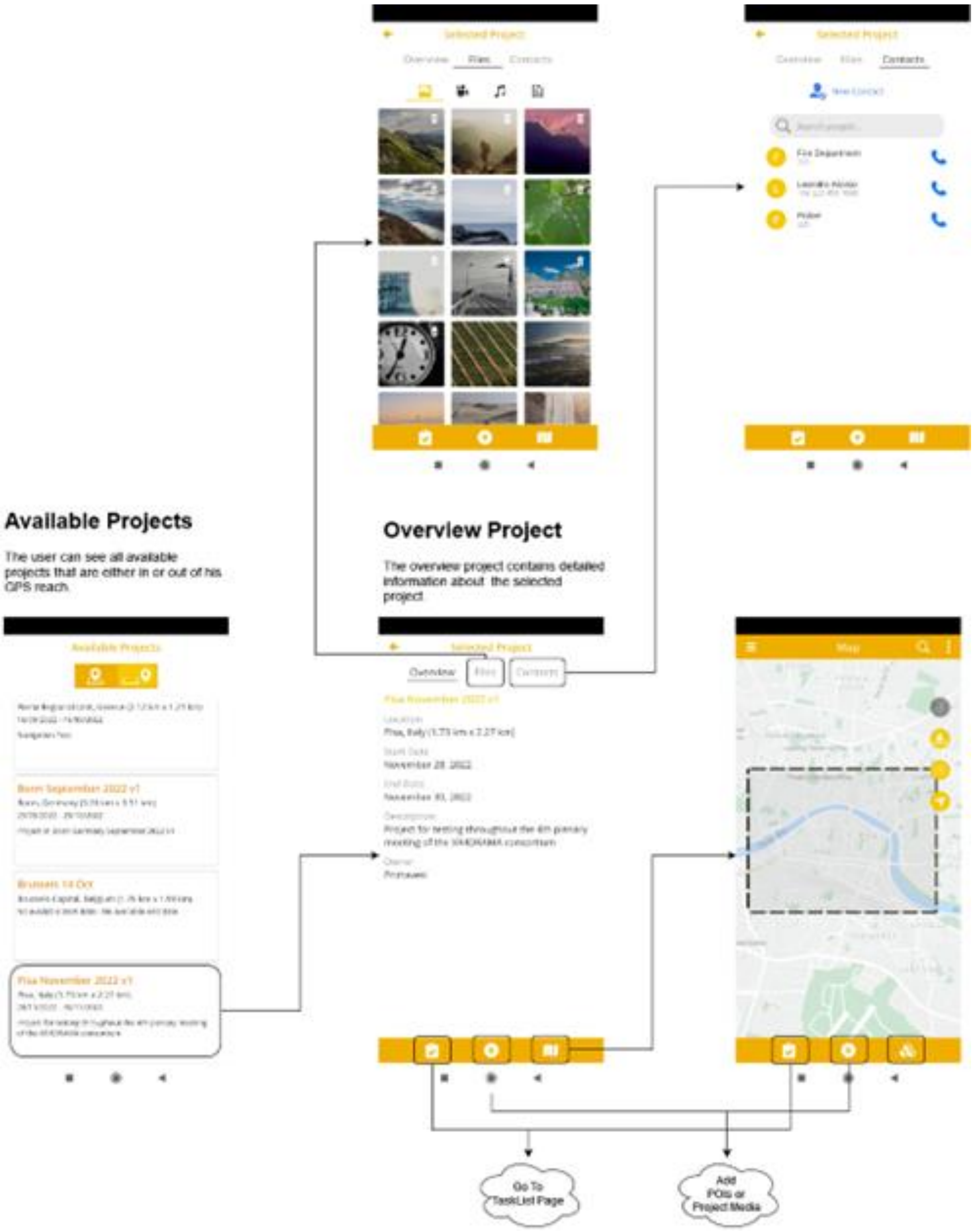

Figure 9: The AR application. Project management screens

Figures Figure 10: and Figure 11: The AR present some indicative screenshots of the application and the management of the geographical information.

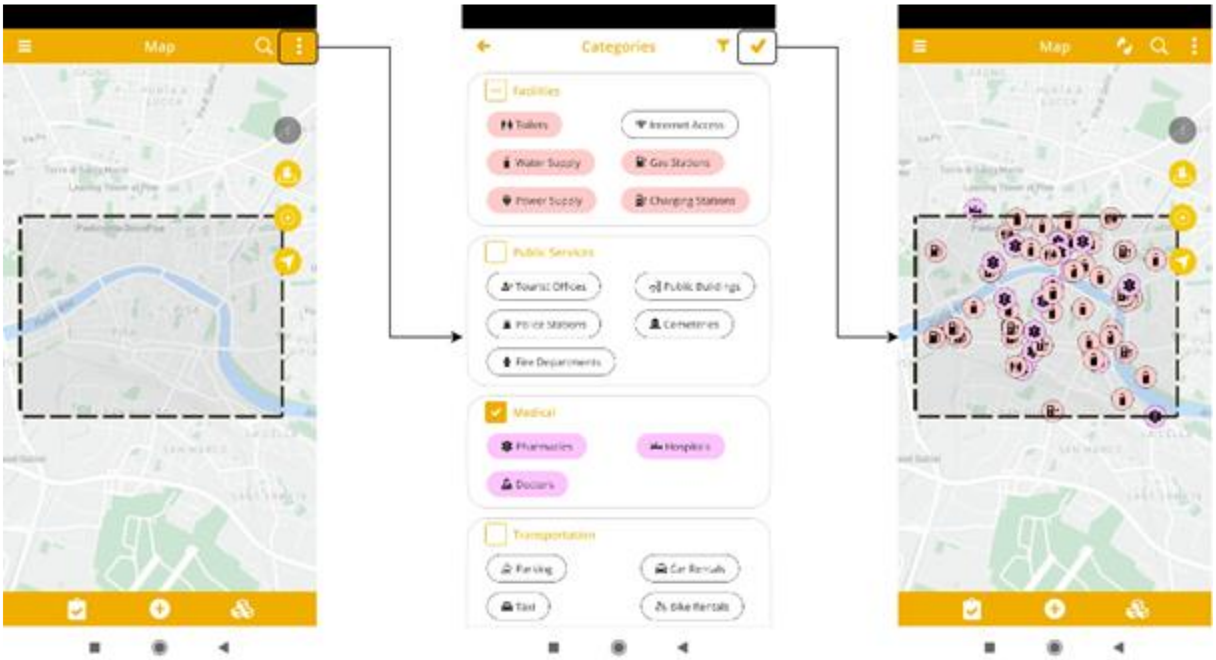

Figure 10: The AR application. POIs and ROIs management. *Left*: the main 2D map view; *middle*: Categories of the geographical entities; *right*: entities belonging to the selected categories are presented on the map

Figure 11: The AR application. POIs management: *a)* the main 2D map view; *b)* information mini panel for a selected geographical entity; *c)* complete information panel; *d*) custom attributes edited by a user or an automated service

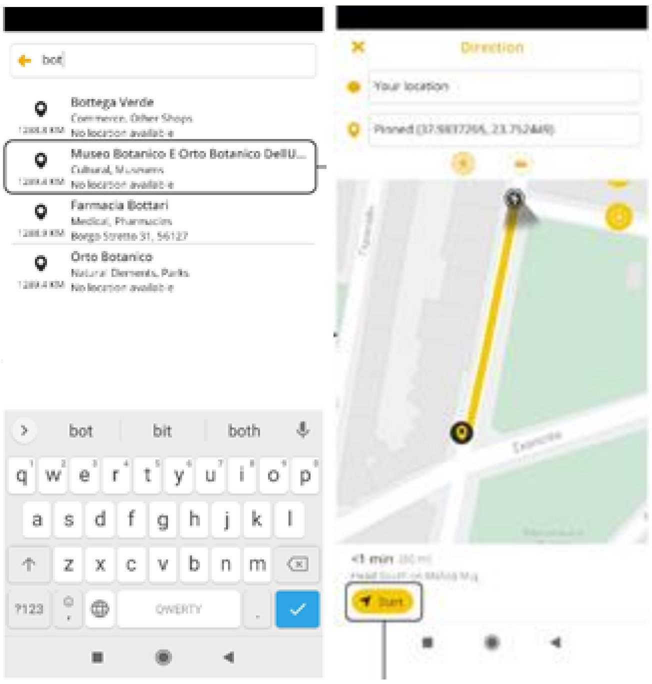

Figure 12: The AR application. *Left*: the search in POIs and streets functionality; *right*: the navigation functionality

FiguresFigure 13, Figure 14, Figure 15: present different AR capabilities of the application. Figure 13 presents the overlaying of digital information on the real physical world starting from a task assignment, whereas Figure 14 and Figure 15: present the virtual scenes placement where the user uploads scenes to the project from the Authoring Tool and then manipulates them in the real world to plan the media production, or disaster management.

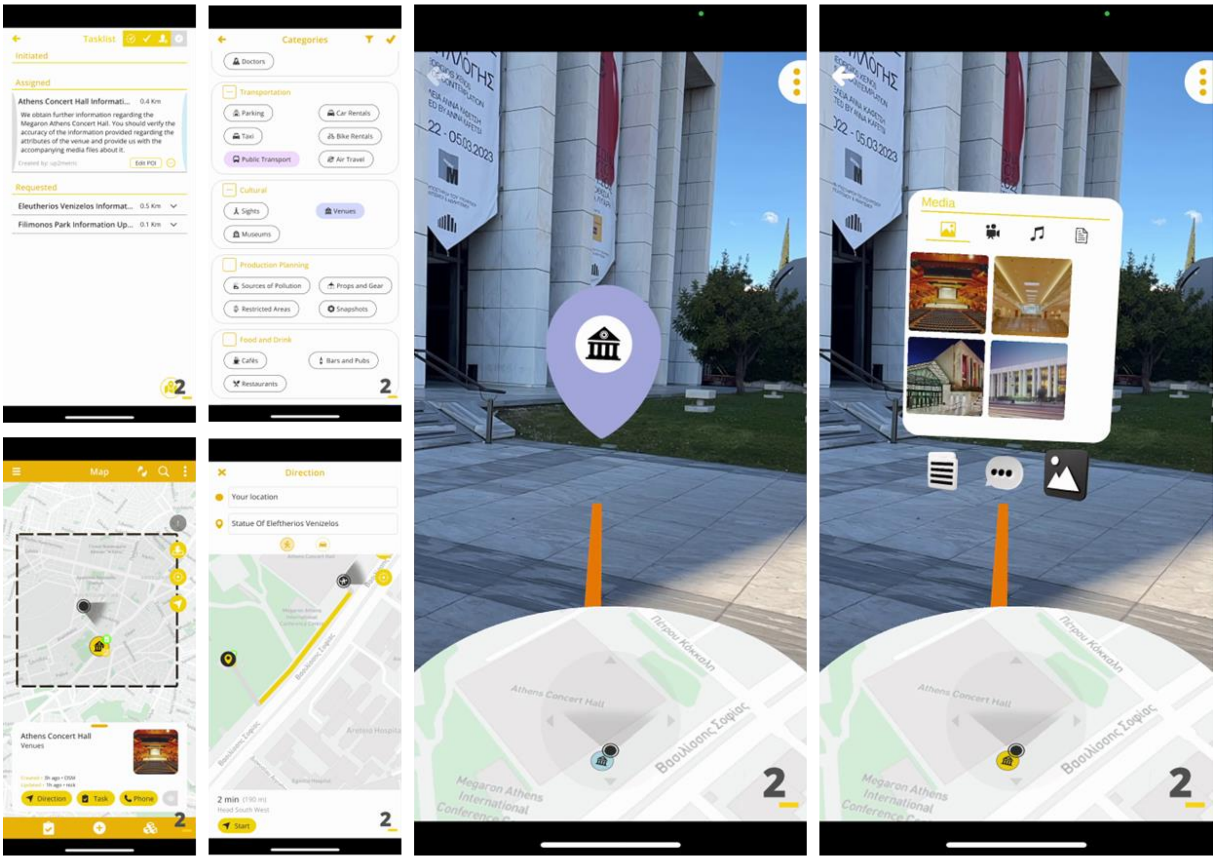

Figure 13: The AR application. *a*) Task management and a POI with its information panel on the 2D map; *b*) POI categories and the navigation feature; *c*) A POI overlaid on the real world and the mini-map navigation map; *d*) A POI info panel and the mini-map navigation map

Figure 14: The AR application. The images present various media planning setups embedded in the real world via the AR application, as retrieved from the xR4DRAMA platform

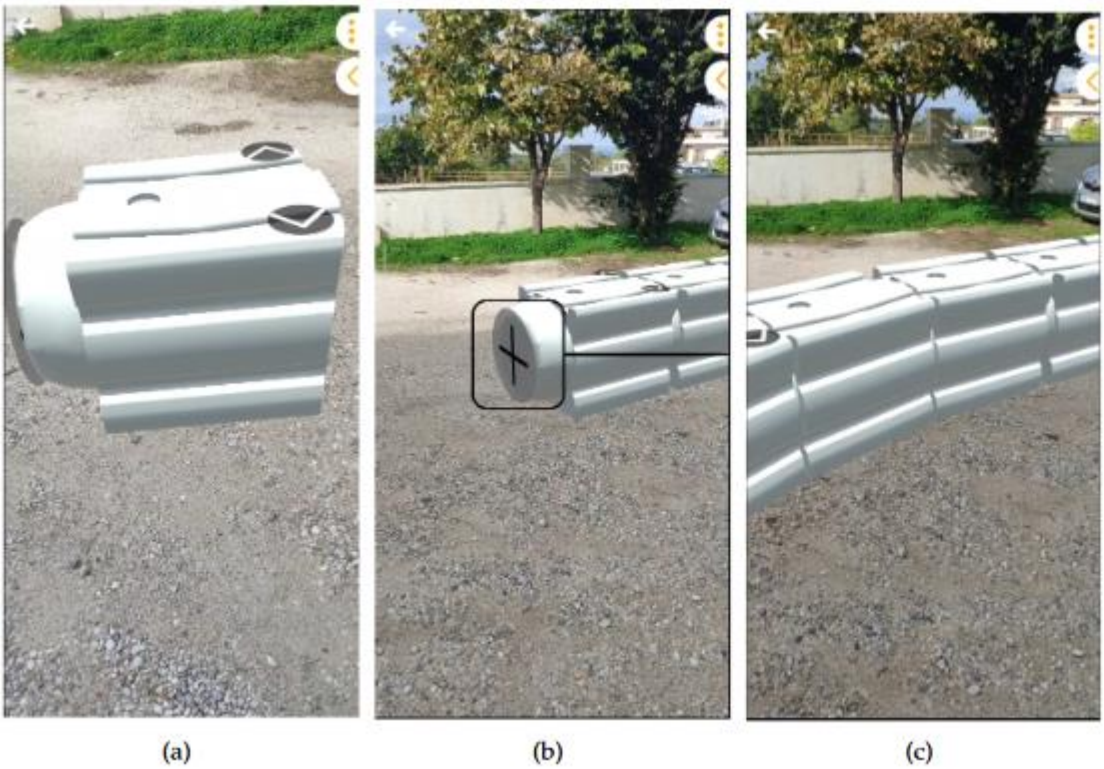

Figure 15: The AR application. Placing aquadikes for the flood management pre-event: *a*) presents the initial aquadike (digital object) placed in the real world; the arrows on the aquadike facilitate the object placement; *b*) shows how the interact-able object can be reproduced (plus sign) in the scene to produce a chain of aquadikes as in picture (*c*)

Scene understanding

The xR4DRAMA AR application supports real-time outdoor scene object detection while using the AR view. Once inside the object detection mode, the user has the option to capture a screenshot or record the screen view via the utility toolbar. A SSD-Lite MobileNetV2 architecture was customised to efficiently run in the Unity framework where the overall AR application is developed and trained to identify classes appropriate for the automation of tasks in the outdoor environment such as humans, motorcycles, bicycles, buses, cars, truck, stop signs, fire hydrant, traffic light, and animals like cats, dogs. The detection results appear as transparent detection boxes on the app screen (Figure 16:).

Figure 16: The AR application. Detection of objects of interest via the AR camera view to assist the field task management

1.3.4 Immersive environments for strategic planning of media productions and disaster management

3D modelling from multimedia, UAV images and satellite data

In the xR4DRAMA project, the online 3D reconstruction service was developed consisting of two separate web services; the first service is responsible for generating georeferenced photorealistic 3D triangular mesh models from a collection of overlapping images, and the second service is responsible for generating a textured mesh model from satellite data (images and DEM). Thus, the 3D reconstruction service can exploit the aerial photographs or videos typically captured by drones and ground level images captured by a handheld camera or a mobile phone, and it can also combine satellite images and elevation data (i.e., DEMs) retrieved by the online satellite data services (e.g., the Copernicus hub) to generate 3D mesh models of large areas.

The image-based 3D reconstruction implements a typical photogrammetric pipeline to obtain the photorealistic 3D mesh models from sets of overlapping images and uses available image metadata to approximate the scale, the position, and orientation of the model, as well as online services providing elevation data for an area. The photogrammetric pipeline encompasses Structure-from-Motion for estimating the camera parameters (external and even internal orientation) and reconstructing a sparse point cloud and dense image matching, i.e., Multi-View Stereo, to create a dense point cloud. The 3D models are simplified via a process borrowed from the computer graphics and games development techniques to and are also processed by an AssetBundle server to increase efficiency in the Unity-based Authoring Tool (AT) and Virtual Reality (VR) application.

The scope of the service is to support 3D reconstruction for objects, outdoors environments, and large landscapes of the xR4DRAMA efficiently tackling the user requirements for handling disaster management and media production planning. The implementation solution follows a modular scalable microservices architecture that on the one hand connects securely to the xR4DRAMA platform and on the other hand can efficiently handle a large amount of data typically exploited for image-based reconstruction in GPU-intensive processes. The user has a seamless access to the service via the Authoring Tool (AT) where one can upload the data and automatically receive the reconstructed 3D model in the Virtual Reality (VR) application. Figure 17: presents the workflow of the image-based 3D reconstruction in the xR4DRAMA platform.

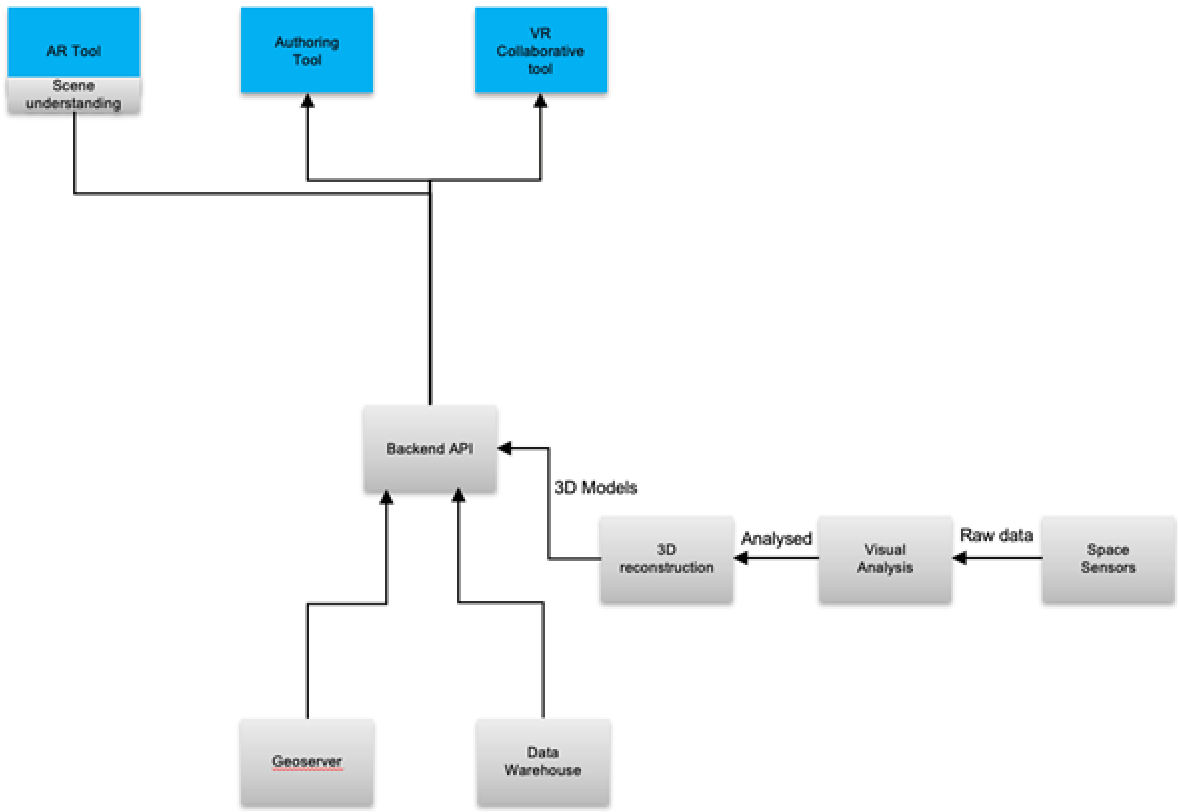

Figure 17: The 3D image-based 3D reconstruction service workflow in the xR4DRAMA platform

In the flood management scenario, the first responders (FRs) are mainly exploiting the 3D reconstruction service in the pre-emergency preparation procedures. The FRs can upload images, or videos, taken by drones via the Authoring Tool and the 3D reconstruction services provides them with a textured georeferenced 3D model of the inspected area which is automatically uploaded in the Authoring Tool and the VR application for further inspection in an immersive environment. Sample results of 3D reconstructed models via drone footage are presented in Figure 18:. In Figure 19:, an indicative DEM and the corresponding RGB from multispectral image are shown, along with the produced 3D mesh model for the AT and the VR front-end tools.

Figure 18: Photogrammetric 3D modelling of the Vicenza city centre in Italy. *Left and middle column*: indicative vertical images of the city centre captured by UAV; *right*: the resulting photo-textured 3D mesh model

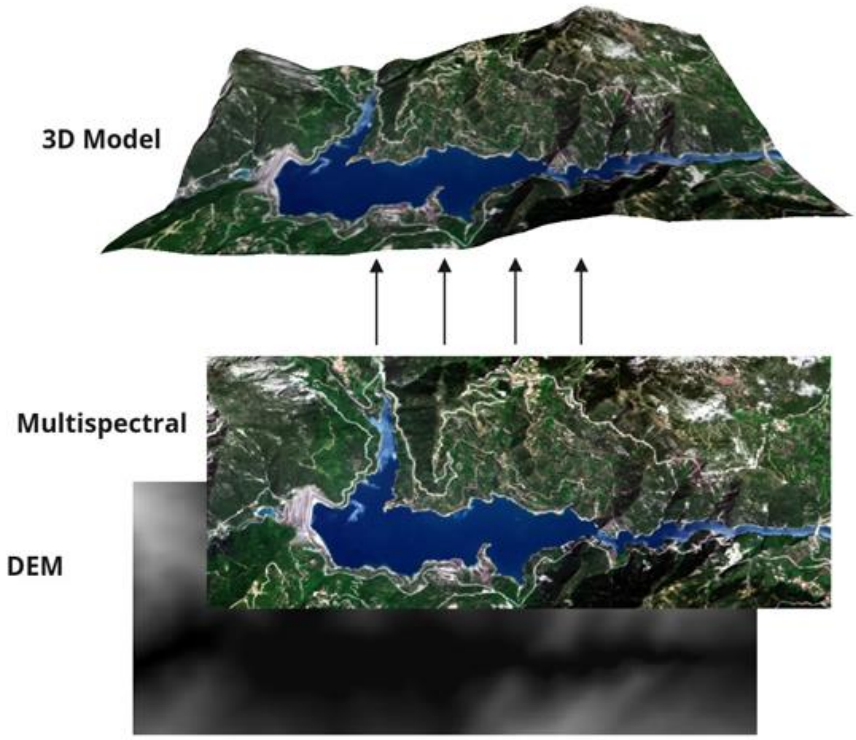

Figure 19: 3D modelling via satellite data. The 3D mesh model is automatically created and inserted into the front-end tools

In media production planning, the 3D reconstruction service is used for the modelling of outdoor areas recorded by drones, or the modelling of objects and building facades by handheld cameras, or mobile phones. Figures Figure 20: and Figure 21 show results from the demos in the media production planning scenario.

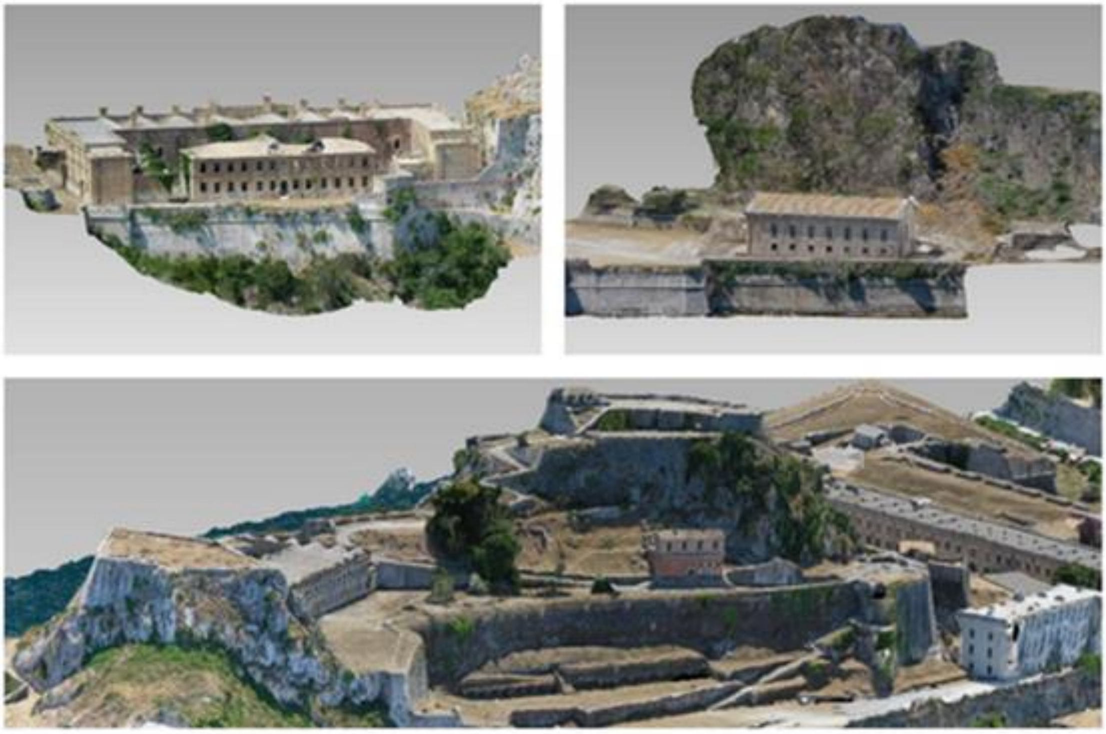

Figure 20: Image-based 3D reconstruction of the Venetian fortress in the city of Corfu

Figure 21: Image-based 3D reconstruction of the War memorial Stralau in Berlin-Friedrichshain. *Left and middle column*: indicative images used for the reconstruction; *right*: a view of the reconstructed 3D mesh model

VR authoring tool

The authoring tool was designed to provide a user-friendly interface for creating and managing projects related to disaster management and media production. The tool allowed users to create projects, add Points of Interest (POIs), and manage data related to these projects. It also included features for 3D visualisation, map services, and data management.

Key updates in the final version include:

- Updated User Interface (UI) and User Experience (UX) for easier navigation.
- Integration of text generation for better situational awareness.
- New user profile personalisation with 2D avatars.
- Integration of satellite data for an additional informational layer.
- Integration of flood maps and data from various sensors for the disaster management use case.
- New file management system handling tags and visual analysis data.
- Integration of 3D model reconstruction pipeline for integrating 3D models into the tool.
- Broadcast messages to citizens for sending messages to the citizen app.
- Integration of stress levels from physiological sensors for the disaster management use case.
- Global search for all the POIs and data stored for a project.

The tool requires a Windows operating system, a minimum of 16 GB RAM, a minimum of 5 GB free HDD space, and a dedicated graphics card to run. To launch the Collaborative VR Tool, a more powerful system is required, including a VR headset like HTC Vive.

Virtual reality environment

The VR tool aims to provide immersive and collaborative solutions for media production and hazard management. The VR tool is designed to be used by producers and first responders' management teams, providing access to the entire system, and enabling the creation of projects related to specific incidents or productions. The first version of the VR tool was tested, and feedback was collected for improvements. The second version of the VR tool, delivered in November 2022, was developed based on this feedback. It introduced several new functionalities and improvements, including:

- Larger Map: The mini map was made larger and more visible by default.
- POIs and Photos Display: Functionality was added to display Points of Interest (POIs) and photos in the VR tool.
- Avatars and Profiles: New avatars were added, and profile pictures were removed.
- Coherent Categories: The same categories were implemented across all tools.
- XR Props and Setups: Integration between the AR and VR app is still in progress, planned for the final version.
- POI Creation: POI creation was added, while task creation requirement was depreciated.
- Improved VR Locomotion: A new fly mode was added, and easier navigation was implemented.
- User Management System: This is planned to be implemented in the final version.
- POI Indicators: Functionality was added to implement icons/visual aids that tell users if a POI is connected to a media file, a comment, and/or a task.
- Locate Users: Functionality was added to allow users to see each other’s locations across all xR4DRAMA applications.
- XR Scale: A 1.75m model was added in the props of VR.
- VR Overview: Functionality was added in the desktop version to allow users to view the entire VR model in a smaller scale to get a better overview.
- VR Drone Flights: Improvements have been made in the screen size and usability.
- 3D Models Inspection: The fly mode will help in solving this issue.

The xR4DRAMA VR tool requires a Windows OS, Intel i7/i9 CPU, minimum 32 GB RAM, minimum 5 GB free HDD, NVIDIA GTX 2080 or above Graphics Card, and an HTC Vive VR Headset to run.

1.3.5 Heterogeneous Data Collection

Web and social media data collection system

The Web and social media data collection module is a fully-fledged solution that was implemented in order to collect free online data from various web and social media resources. The retrieved content is stored in an internal repository and provided to the analysis modules for further processing which formulates the content to be shown in the front-end tools.

Figure 22 depicts the designed architecture, in which we distinguish four different phases, each one incorporating different techniques depending on the use case:

- *Phase 1 - Requirements*: In this phase, the input of the module is defined. The data collection needs can be expressed in the form of *URL addresses* or keywords forming *textual queries*.
- *Phase 2 - Discovery*: In the situations where the exact web resources to be gathered are not known, discovery has to be conducted. Detection of relevant web resources can be made in 3 ways: a) using *web crawling*, when the input is an entry URL, b) using *search*, when the input is a textual query, c) *streaming* in real-time, instead of search, where an existing API (e.g., Twitter) provides such capability. This phase is bypassed when the indicated URL resource in Phase 1 is the only one to be integrated.
- *Phase 3 - Content Extraction*: The procedure is straightforward when data collection is done using existing APIs as it corresponds to a simple *retrieval* action. However, if there is no available API, *web scraping* techniques have to be applied.
- *Phase 4 - Storage & Integration:* As a last step, the retrieved content from the previous phase is parsed and stored using a *unified representation* model able to aggregate various types of multimedia. The base data model is the SIMMO (https://github.com/MKLab-ITI/simmo) one.

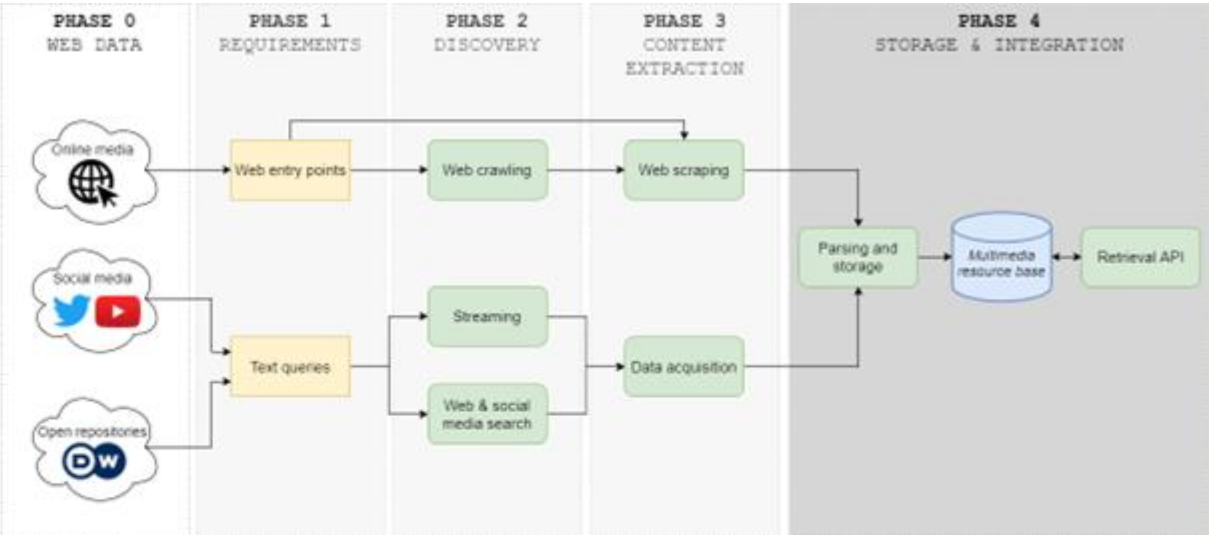

Figure 22: Web and social media data collection module architecture

As it can be noticed by the architecture, different workflows are supported, and several different techniques are applied to accommodate different types of resources. One of these is *web crawling*, in which given a seed URL address, the hyperlinks are iteratively traversed up to some predefined depth to discover new webpages. The implementation of this module is based on the open source crawler4j[12] library.

[12] https://github.com/yasserg/crawler4j

To access the content of a webpage, *web scraping* is applied. This process is employed in a way that only meaningful multimedia is extracted out of the abundant information a webpage contains, by removing noise elements such as navigation bars, footers and on-page advertisements. The boilerpipe[13] algorithm, a solution for boilerplate removal, was chosen due to its efficiency and flexibility for supporting every website without requiring additional human effort. Like web scraping, we also implemented a PDF scraping module to extract text from PDFs using Apache PDFBox[14].

Regarding web and social media search, we developed wrappers on top of existing APIs and executable software to query and retrieve data from Twitter, well-known video websites (Youtube, Vimeo), Flickr, Foursquare, Reddit, Wikipedia, and archives from Deutsche Welle. For Twitter, we also enabled real-time twitter post retrieval using the Twitter Streaming API, which allows for creating a persistent connection to Twitter and continuous monitoring of new tweets for a given set of keywords and/or a given set of profiles.

All the data acquisition results are stored into a MongoDB database with records that follow the SIMMO data model. SIMMO can cover a wide range of data representation requirements, nevertheless, there are a lot of entities and metadata that have to be stored for this project and cannot be mapped using the base SIMMO version. Therefore, adjustments had to be made to the model to keep a unified way of storing and managing the collected information. Updates include introducing new entities, as well as adding and/or changing fields and behaviour in existing entities. A REST API is deployed as the web interface that provides access to the SIMMO database.

Lastly, the web and social media data collection is the module that handles the integration of the reports coming from the citizen app due to the modalities of these reports (text, audio, image, video) matching the ones of the web and social media content. To cater to the need for retaining the citizen reports in the xR4DRAMA platform, the module converts them into SIMMO objects before storing them in the SIMMO database.

Visual sensing of space

For the needs of the xR4DRAMA project, the capturing of visual and survey data from the demo cases was planned and carried out. The data regard outdoor usage scenarios for flood management and media production planning and are captured via drones, handheld cameras, mobile phones, and GPS sensors. The goal was to collect visual data that are subsequently utilised by different xR4DRAMA platform modules for 3D-reconstruction, Visual Analysis, the GIS backend, the AR geo-localisation process, and the VR application.

Vertical and oblique aerial imagery were fused with building facade images from a handheld camera. Optimal mission planning was required to ensure the necessary spatial, temporal, and radiometric resolution of visual data that enabled the reconstruction of scalable 3D models for the needs of the xR4DRAMA platform. Also, simple instructions were created for inexperienced users to take images by mobile phones and upload them to the platform for

[13] https://github.com/kohlschutter/boilerpipe
[14] https://pdfbox.apache.org/

3D reconstructing objects and spaces. The scenarios analysed in the context of xR4DRAMA target the recording of appropriate data for reconstructing: i) an urban – suburban area (small part of a town, historic centre etc.), ii) individual Points-of-Interest (buildings, Cultural Heritage monuments), and iii) individual building facades. In Figure 23, the area covered in a drone campaign in Corfu, where the media production planning demo was carried out, is presented. Figure 24 presents sample oblique images for the reconstruction of a historic building in Corfu.

Figure 23: Data collection for the media production planning use case. The five areas of interest selected in Corfu old city

Figure 24: Data collection for the media production planning use case. Sample oblique images of Saint George Church area

Remote sensing

In recent years, various constellations of satellites, in combination with land, air and marine based sensors, have observed the Earth and generated valuable visual and multispectral satellite data. They differ in spatial resolution (the actual size of each pixel on the ground), in swath, in the frequency they pass from the same area, in the spectral bands they support and the area they can capture each day. In xR4DRAMA, a remote sensing service was implemented as a backend module (i.e., offered as an API) that retrieves data from the Sentinel Hub web service to provide Earth Observation imagery and 3D information and more specifically i) multispectral or true-colour (visible spectral zone) satellite images (at 10m resolution) and ii) Digital Elevation Models (at 15m resolution). Sentinel 1 and Sentinel 2 are two constellations of two polar-orbiting satellites each that support Copernicus, the European Union's Earth observation programme. In particular, Sentinel 1 acquires C-band synthetic aperture radar imagery, regardless of the weather, while Sentinel 2 images land and coastal areas at high spatial resolution in the optical domain. All Sentinel satellite data as well as the Copernicus information services are provided for free and are openly accessible to users.

In the xR4DRAMA service, the user can download satellite data by specifying a bounding box for the area of interest, a time interval (start and end), and a list of raster types (True-Colour or/and Multispectral image and Digital Elevation Model). Moreover, satellite data can be downloaded for multiple timestamps by defining the parameter. All results are stored in the service, so the user makes future search requests. The results are visualised in the Authoring tool and the VR application.

Physiological sensing system

For the *Disaster Management scenario*, a physiological sensing platform was used to acquire physiological signals and to detect the movements of the trunk and the posture. All these data have been processed and correlated to monitor the stress level of first responders (FRs) operating in flood conditions.
The physiological data acquisition module uses a wearable system (smart vest) for monitoring physiological parameters and integrates the data in the xR4DRAMA platform through the Citizen application.
The design of the smart vest has been adapted to be used below the uniform of first responders. Indeed, after the first pilot (PUC1) in Vicenza, a survey on the usability and the comfort of the wearable system has been done. Even if the feedback by users was good enough, they suggested some improvements, such as the use of a lighter and more breathable fabric, complaining that wearing the first prototype version makes them sweat and hot. Consequently, to make the garment more comfortable a selection between new kinds of fabrics with specific technical properties, both for yarns and for fabric construction has been carried out.
Moreover, a new production of data loggers (RUSA device) upgrading the power consumption management and optimizing the signals filtering has been done. The smart vests have been tested in the pilot sessions (PUC1) held in Vicenza to monitor the stress levels of the users involved and consequently validate their characteristics in terms of physiological and activity data collection, and transmission through the xR4DRAMA platform.

Environmental sensing

This section describes the feasibility study of the wearable/portable environmental sensors addressing the use case scenarios according to the end users' requirements.

The *Media Production Planning* use case foresees the possibility to work from a remote position in the control room of the company's headquarter for the management of the production. In this scenario location scouts are in charge to collect data on the field.
Based on the specifications and requirements provided by DW partner, the need to collect data on environmental noise was highlighted in order to improve the quantity and the quality of the collected information on the environmental conditions.

A feasibility study has been carried out by STX partner in order to investigate on the market a device able to measure noise and sounds and to integrate in the xR4DRAMA platform the collected data in post-processing.
The selected device is *the Zoom H3-VR virtual reality audio recorder* identified as a complete solution for capturing and processing spatial audio for VR, AR and mixed-reality content. The device records data on board to a microSD card and they are processed offline and then integrated in the xR4DRAMA platform.

During the first pilot (PUC2) held in Corfu, the portable audio recorder has been tested and it was confirmed that the resulting recordings can be used in the Virtual Reality application of xR4DRAMA. However, the recorder must be aligned in the same direction as the 360° camera used in the field to avoid sound distortion with respect to the 3D map in VR. This aspect was evaluated as too time-consuming to use during scenario exploration by local scouts.

Instead, the *Disaster Management use case* focuses on flood prevention and preparedness by means of innovative solutions. Based on the information on the use case provided from AAWA partner, a proof-of-concept mock-up has been designed and produced by Smartex partner. The wearable pressure device can provide more information in order to evaluate the physical vulnerability associated with people affected by flooding, and in particular their “instability” with respect to remaining in an upright position.

According to the initial requirements reported in D6.1, the physical vulnerability associated with people affected by flooding considers the values of flow velocity (v) and water height (h), and currently these parameters are collected by local environmental agencies from stations detectors installed along rivers. To make the vulnerability curve model more accurate, it is important to detect these parameters *in close proximity* in which first responders operate.
Therefore, a feasibility study has been carried out to design a system able to acquire the <u>local water-flow pressure at the ankles level</u> when first responders operate in flooded areas.
From the measurement of the hydrodynamic pressure, it is possible to obtain the water flow velocity and from the position of the device (once it is worn) the height h from the water pull is acquired.
The proof of concept is based on the use of two small water pressure sensors incorporated in a box in which the electronic board and the Bluetooth module for data transmission and the module for recharging the battery are integrated. The switching on and off of the device is controlled by a waterproof switch inserted in the upper part of the box. Moreover, an android application has been developed in order to collect and to record data (D2.1, D2.4).
Test sessions have been carried out in order to verify the functionality of the device. During the calibration phase of the pressure sensors, an issue with the zero-pressure reading occurred. Each sensor has its own offset, so several measurements in the air and in the water have been carried out with the aim of finding a common calibration curve, then the equation was entered into the firmware to read the pressure values from the sensors.
In the second pilot of PUC1, the wearable pressure system has been tested on the field in order to evaluate its usability and acceptability, and the results were positive.

1.3.6 Interactive Situation Awareness Platforms

System development and integration

The development and integration of the xR4DRAMA system is a multifaceted process, involving a range of technical requirements and architectural considerations. The platform also needs to take data from multiple online sources such as OpenStreetMap. It also connects to the social media sources to acquire knowledge about the discourses associated with the specific concerns.

The following block diagram provides an overview of the various sources and data the platform brings together.

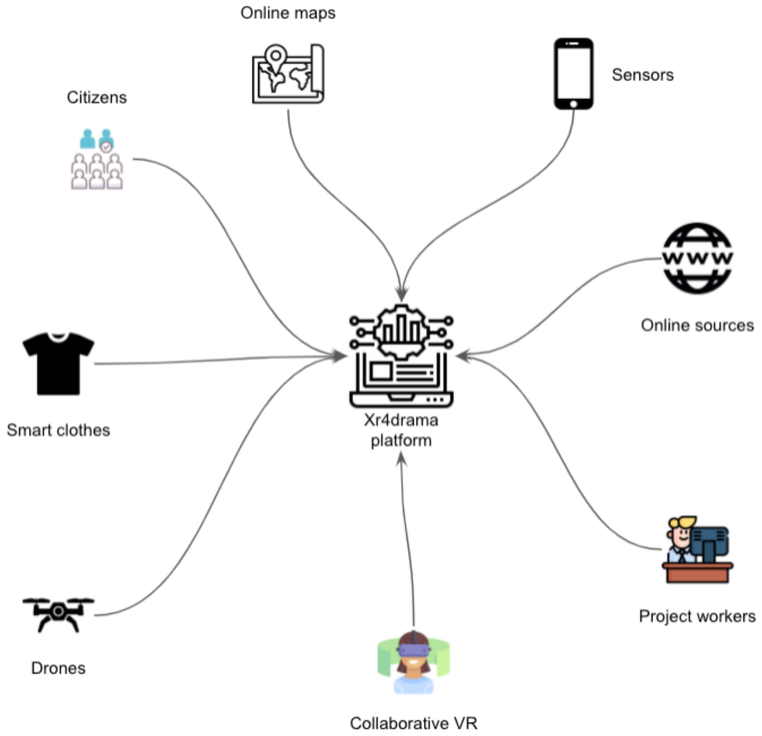

Figure 25: An overview of the various sources and data the platform brings together

The design process began with the collection of technical requirements. This was achieved through various methods such as document analysis, use case studies, interviews, and surveys. These methods helped in understanding the user needs and defining the technical requirements of the xR4DRAMA platform.

Once the technical requirements were defined, the next step was the architectural design of the system. The architecture was designed to address the technical requirements and to ensure efficient data processing flow. The architecture design included the logical design of xR4DRAMA components, the communication model, and the data management policy.

The system was divided into 12 services, each with its own functionalities, system requirements, internal design, and data flow. These services included GIS and Data Storage, among others. Each service was introduced along with the owner responsible for its implementation. This division of services ensured that each component of the system was handled by experts in that area, leading to a more efficient and effective system. The diagram below shows the architecture of the system.

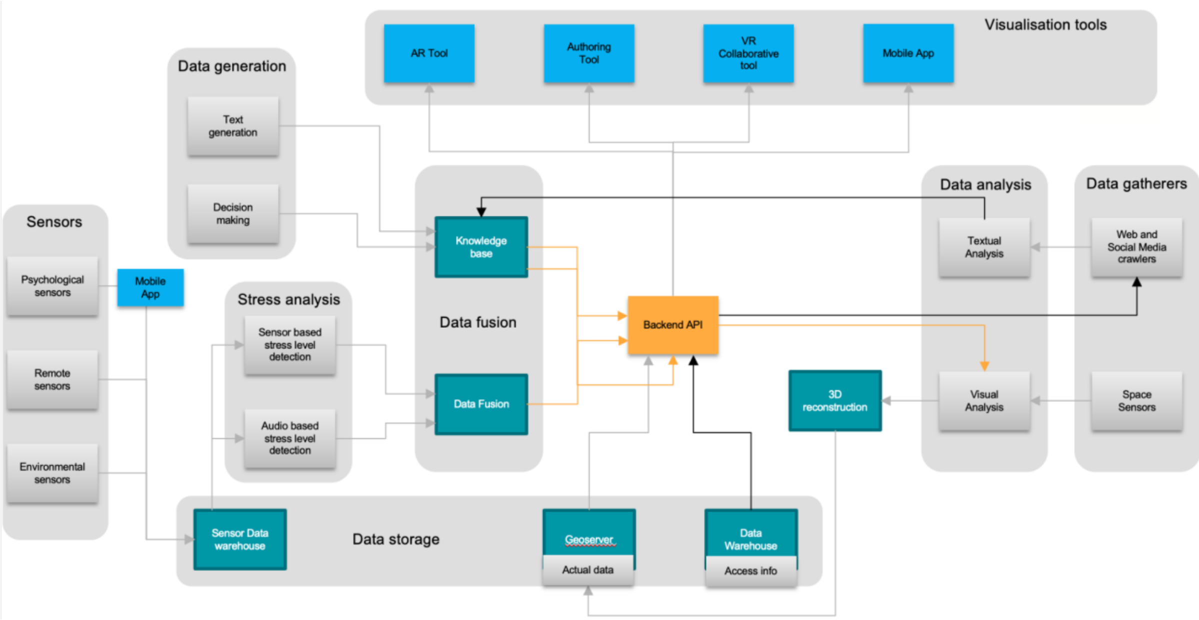

Figure 26: System architecture

In summary, the design and implementation of the xR4DRAMA system was a comprehensive process that involved a deep understanding of technical requirements, a robust architectural design, and a user-centric approach to tool development. This meticulous process resulted in a robust, efficient, and user-friendly system that provides immersive and real-time situational awareness.

GIS system

The xR4DRAMA project was developed as a location-based platform that aggregates georeferenced information from various sources as its knowledge base. The GIS Service describes the backend component that functions as a support to the AR application, the Authoring Tool, and the VR application, by providing a geospatial database with content of different modalities (e.g., 2D and 3D visual content, audio files and generic data such as PDF files). It is also responsible for processing the georeferenced information, enabling various location-dependent functionalities (e.g., point-to-point navigation) to be accessible inside the platform. The *GIS Service* can be viewed as the central component of the *GeoService* network, an architecture logic that encapsulates all georeferenced components into a concrete end-to-end system. The GeoService network is responsible for overseeing the various requests originating from and to the GIS Service. It essentially serves as a wrapping bundle, containing all logic related to geolocation operations. The communication between the various geo-related processes is managed by a deployed Redis server. Figure 27: presents the base architecture of the overall GeoService.

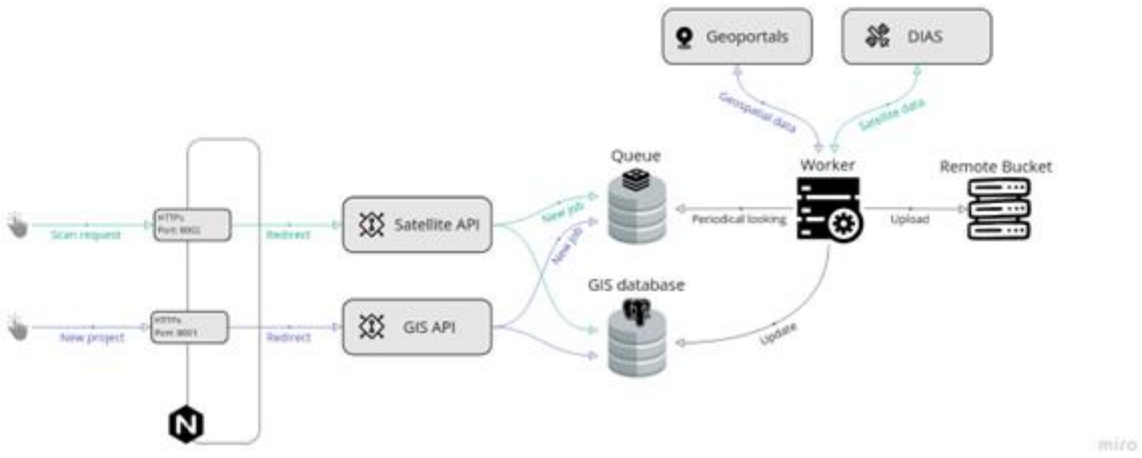

Figure 27: The base architecture of the xR4DRAMA *GeoService*

In a nutshell, the GIS Service provides the end user and the xR4DRAMA multiple services with the following main functionalities:

1. Project management;
2. File storage;
3. Geospatial and other data management in categories;
4. Search engine;
5. POIs management;
6. Task list management;
7. User navigation;
8. Risk reports to mark dangerous areas;
9. Elements at risk estimation.

The above key functionalities are tightly tied to the AR application and to the AT, and the VR collaborative application, since the frontend tools serve as the visualisation and interaction means with the GIS Service. The users can also connect to the GIS Service using typical desktop GIS tools.

Citizen awareness application

The Citizen awareness app is a mobile application designed for the wider public. This application aims to create the habit of a citizen becoming cautious about a possibly harmful situation and facilitate the authorities by acting according to their planning for disaster management. When a catastrophic event takes place, the affected people seek help using traditional means such as calling local emergency numbers or looking for information online from civil protection and TV news. While this approach is standard practice, it can lead to delays and inconsistencies because an emergency request is often approximately described, and critical information such as the exact global positioning system (GPS) location or severity of the situation is missing in the description. A crucial function of the Citizen awareness application enables the user to report an ongoing situation or make an emergency geolocated request via text, audio, image, or video directly to the authorities that handle disaster management. The emergency report is analysed by one of the analysis modules of xR4DRAMA which speeds up the process of decision-making by the authorities managing the disaster. The first Figure from the left below shows what the main screen of the application looks like and the second Figure from the left shows an example of the emergency report using an image. Furthermore, the Citizen awareness application detects the context for the user based on location, time, and proximity to the event, and accordingly informs and alarms the user about likely threats, from location-based ones to evacuation alerts and more. The application map includes information generated by the authorities during the crisis management, such as disaster management-related POIs (e.g., safety areas, flood reports, danger zones, civil protection distribution places, etc.) thus effectively improving the situational awareness of the user. The fourth Figure from the left below shows an example of a text notification created by the authorities and received in the application's device. The third Figure from the left illustrates the application map with the information registered by the authorities such as disaster management POIs and danger zones.

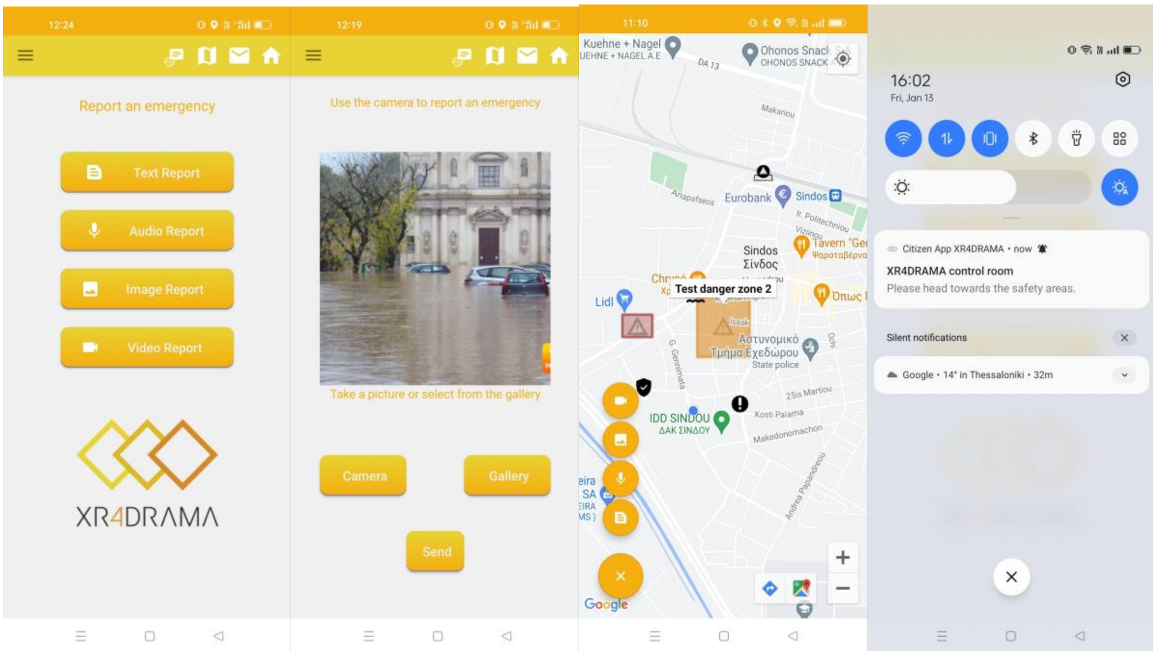

Figure 28: (From left to right) Citizen awareness app main screen. Emergency report using an image. Application map. Text notifications from the authorities

Finally, the Citizen awareness app includes a separate mode for the first responders only, in which the first responder can connect the mobile application with the SMARTEX garment equipped with sensors and share their physiological signals to the xR4DRAMA platform. These signals are used for analysis and prediction of the first responder stress levels by the tools developed in WP3. The first responder mode is integrated in the citizen application as part of T5.4 and is considered a separate mode, which the wider public cannot access due to lack of authentication credentials. In the first Figure from the left below, the first responder login screen is shown. In the second Figure from the left the connection with the RUSA device inside the SMARTEX garment is illustrated and finally in the third Figure the physiological data streaming is presented.

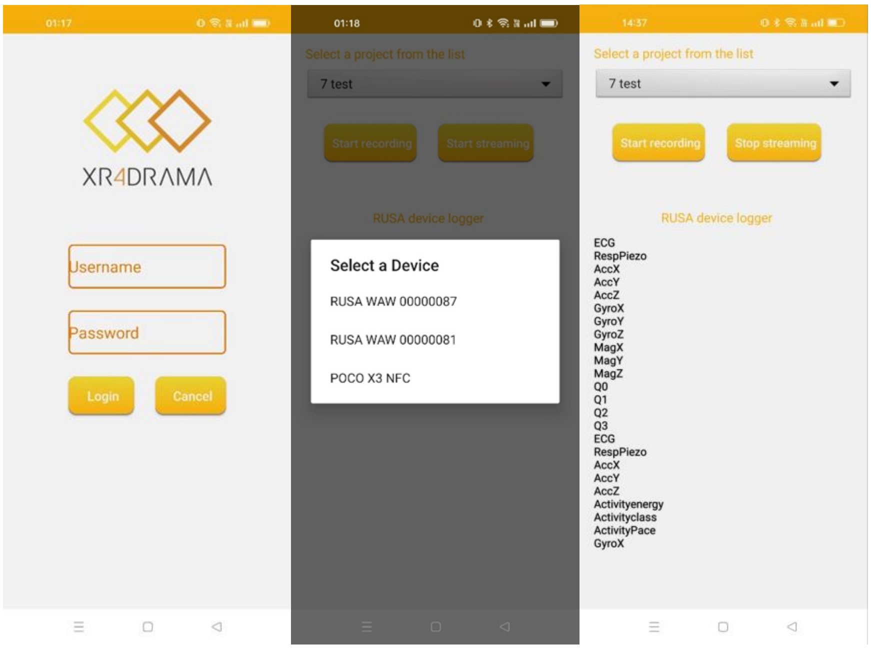

Figure 29: (From left to right) First responder mode login screen. Bluetooth connection with RUSA device panel. Streaming physiological data

1.3.7 User requirements and xR4DRAMA evaluation

Use case creation and end-user requirements definition

As agreed, upon at the beginning of the project, DW quickly started working on the refinement of xR4DRAMA use cases and a comprehensive list of requirements the platform would have to meet. First documents and outlines existed as early as Christmas 2020. The first official deliverable (D 6.1) was published in February 2021 and started with an exploration of the concept of situation awareness (which is key to xR4DRAMA) as well as "state of play" sections regarding XR technology in the field of disaster management and media production planning.

At the core of the deliverable, DW and the consortium discussed what the **two complementary pilots** would look like.

Regarding the disaster management scenario, the text explained how the xR4DRAMA would be used when dealing with flood emergencies, monitoring river breaking/overtopping, assigning specific tasks to specific professionals, and monitoring stress levels of first responders in the field.

Regarding the media scenario, the deliverable showed how producers and reporters would benefit from the platform, namely by first running initial, map-based queries, then updating "grid squares" based on fresh data/content provided by scouts, and eventually discussing the upcoming production as if on site, in a fully immersive mode. Details on both the disaster management and the media production planning use case are explained at length in D 6.1.

D 6.1. also featured **initial requirements** for the xR4DRAMA platform, which were split up in general, overarching needs and those that had to be met for the individual use cases. The text also commented on requirements prioritisation, the iterative methods the consortium would apply, and the plan to recruit small groups of professional, friendly users in order to find out what is really important, what works, and what does not.

After an initial development cycle, a couple of early tests, and lots of fruitful discussion among the xR4DRAMA partners as well as external stakeholders, the consortium followed up with D 6.2, which documented the **final user requirements** and is basically a more exhaustive re-iteration of D 6.1.

User testing and evaluation

AAWA and DW proposed to the consortium the user testing and evaluation methodology, structured in two cycles: the first one evaluating the first prototype involving only internal users and the second one about the final prototype, involving a broader community focusing anyway on small user groups. AAWA and DW defined the pilots' objectives and scenario for both the media production and the disaster management use cases, organising the tests in the field and assigning the roles to be covered to verify the adherence to user requirements of the xR4DRAMA system.

The first pilots took place in Corfu and Vicenza in May 2022, with the participation and collaboration of the whole consortium, providing feedback that were reference points to address the technical development of the platform towards the final prototype. The results of the **1st prototype evaluation** were reported in Deliverable 6.3 and the user feedback was also reported using the GitLab platform. Although the functionalities developed in the first prototype were incomplete and some of them should be fixed or better implemented, the xR4DRAMA platform tested in the first cycle proved to be a solid prototype and the evaluation allowed the consortium to have a final clear vision on the platform.

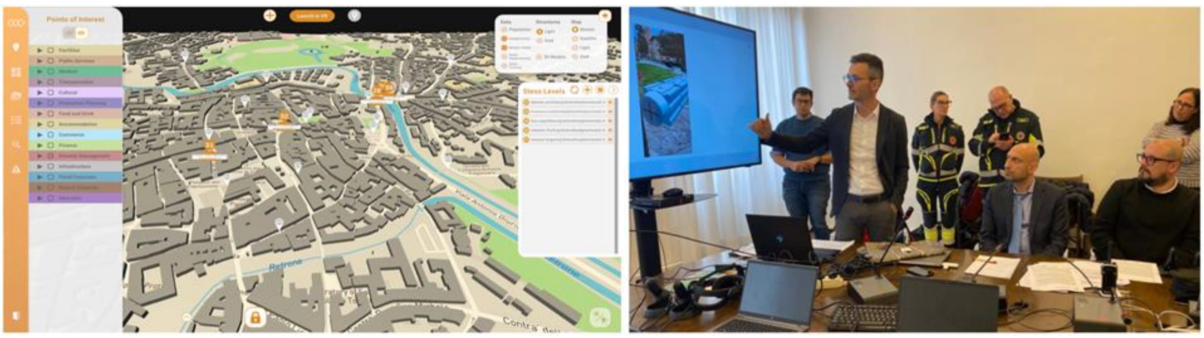

Figure 30: Operators in the Control room monitoring the first responders' stress level and tasks (Vicenza, PUC1 pilot)

After the accomplishments of MS4 (final system implementation), other two pilots, PUC1 in Vicenza and PUC2 in Corfu and Berlin, were organised in March 2023, to test the xR4DRAMA system, gathering precise feedback and indications from the end user's perspective as results of the evaluation. The results of the **final system evaluation** are reported in Deliverable 6.4: the end-users involved in the pilots expressed a high level of satisfaction about the overall xR4DRAMA system, which shown to have progressed a lot from the 1st prototype, to meet the end-users' needs and requirements in both fields (disaster management and media planning). The user requirements were in fact successfully fulfilled by the system, in the management of the different scenarios, and the pilots showcased the effectiveness of the xR4DRAMA system in addressing the challenges faced in the use cases, providing real-time information, and improving the accuracy of decision-making processes.

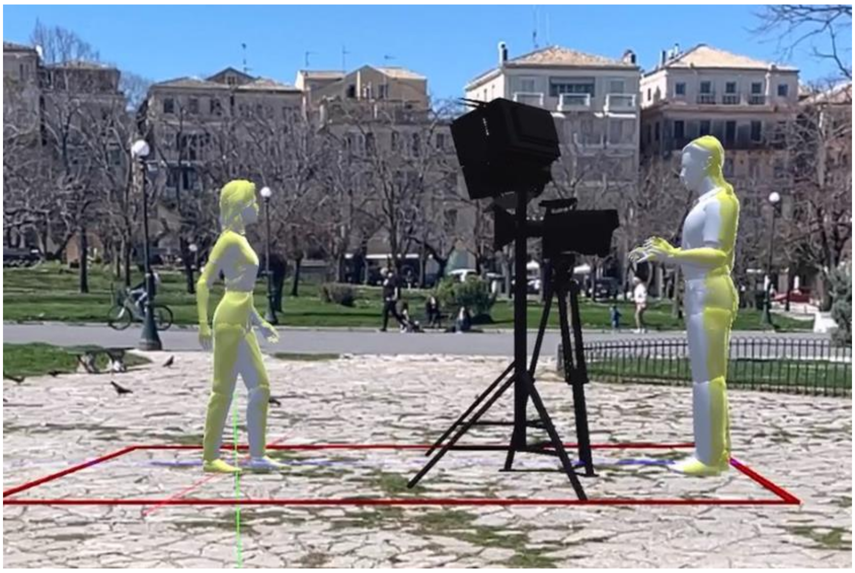

Figure 31: Photo of the predefined production set up placed on Spianada Square, Corfu - PUC2 pilot

1.3.8 Dissemination and Exploitation

Dissemination, standardisation and collaboration

xR4DRAMA crosses the finishing line with a long list of completed dissemination, standardisation, and collaboration activities. Right from the start, the project was visible, connected, open, approachable, and invested in contributing to the R&D community at large.

Dissemination

Let's begin with a short overview, or more precisely: the most important dissemination statistics. xR4DRAMA can look back at:

- 15 academic papers (13 accepted for publication and 2 currently under peer review)
- 25+ blog posts

- 1 documentary film
- 2 post cards
- 2 posters
- 170+ followers on LinkedIn
- 190+ followers on Twitter
- 15 (major) event attendances
- a lot of interest in the community of stakeholders

Website statistics

The xR4DRAMA website, launched in late 2020, refined in early 2021, and equipped with a new tracking instance in early 2022 and constantly updated, shows the following statistics (based on data collected from January 2022 to April 2023):

KPI	Goal (as defined in 7.1. and 7.3)	Project Reality
Page view per month	250 + x	258
Visitors per month	100 + x	123
Average visit duration	1:30 min + x	2:37 min
Countries of origin	20+	44

Table 1: Website statistics

Twitter statistics

The xR4DRAMA Twitter presence, also launched in late 2020 and constantly monitored and maintained, shows the following statistics (based on data collected between November 2022 and April 2023):

KPI	Goal (as defined in 7.1. and 7.3)	Project Reality
Tweets per month	10+	9-10
Final number of followers	125+	187
Impressions per month	3000+	2123
Profile visits per month	1500+	1420
Mentions per month	3+	2+

Table 2: Twitter statistics

A couple of notes regarding the Twitter results: Musk's Twitter take-over in 2022 had negative consequences: Many academics and journalists (actually or potentially interested in xR4DRAMA) left the platform. Furthermore, statistics became partly unavailable and somewhat unreliable. In addition, the aspired "curation rotation" principle (each partner hosts the channel for a month, then hands over to the next) was not always easy to implement. Finally, regarding impressions: xR4DRAMA frequently got past the 3000 mark and even close to 4000 a couple of times, but slow months (holiday season, flu/COVID season etc.) pulled down the average.

LinkedIn stats

Originally set on maintaining a group on LinkedIn, the consortium decided to kill this instance after a couple of months – and set up a Company/Showcase page instead. This turned out to be a prudent decision.

While there are no exact and exhaustive statistics for LinkedIn (the platform can be difficult that way) and they also were not foreseen in the dissemination/communication deliverables at first, there are (very positive) basic numbers:

xR4DRAMA on LinkedIn now has 173 followers. Every post gets a substantial amount of interaction. Many posts get more than 10 positive reactions and at least one share/repost. The best-performing one received more than 20 positive reactions and four shares/reposts.

Publications

Academic publishing was a core xR4DRAMA dissemination feature from the beginning. In total, the partners managed to publish 13 papers, an additional 2 are currently under review. Here is a detailed list.

1. Symeonidis, S., Diplaris, S., Heise, N., Pistola, T., Tsanousa, A., Tzanetis, G., ... & Vrochidis, S. (2021, May). **xR4DRAMA: Enhancing situation awareness using immersive (XR) technologies**. In *2021 IEEE International Conference on Intelligent Reality (ICIR)* (pp. 1-8). IEEE.
2. Pérez-Mayos, L., García, A. T., Mille, S., & Wanner, L. (2021). **Assessing the Syntactic Capabilities of Transformer-based Multilingual Language Models**. In: *Findings of the Association for Computational Linguistics: ACL-IJCNLP 2021*.
3. Kasner, Z., Mille, S., & Dušek, O. (2021, August). **Text-in-context: Token-level error detection for table-to-text generation**. In *Proceedings of the 14th International Conference on Natural Language Generation* (pp. 259-265).
4. Mille, S., Ferreira, T. C., Belz, A., & Davis, B. (2021, August). **Another PASS: A reproduction study of the human evaluation of a football report generation system**. In *Proceedings of the 14th International Conference on Natural Language Generation* (pp. 286-292).
5. Xefteris, V. R., Tsanousa, A., Mavropoulos, T., Meditskos, G., Vrochidis, S., & Kompatsiaris, I. (2022, March). **Human Activity Recognition with IMU and Vital Signs Feature Fusion**. In *MultiMedia Modeling: 28th International Conference, MMM 2022, Phu Quoc, Vietnam, June 6–10, 2022, Proceedings, Part I* (pp. 287-298). Cham: Springer International Publishing.

6. Chatzistavros, K., Pistola, T., Diplaris, S., Ioannidis, K., Vrochidis, S., & Kompatsiaris, I. (2022, September). **Sentiment analysis on 2D images of urban and indoor spaces using deep learning architectures**. In *Proceedings of the 19th International Conference on Content-based Multimedia Indexing* (pp. 43-49).
7. Batziou, E., Ioannidis, K., Patras, I., Vrochidis, S., & Kompatsiaris, I. (2023, March). **Low-Light Image Enhancement Based on U-Net and Haar Wavelet Pooling**. In *MultiMedia Modeling: 29th International Conference, MMM 2023, Bergen, Norway, January 9–12, 2023, Proceedings, Part II* (pp. 510-522). Cham: Springer Nature Switzerland.
8. Xefteris, V. R., Tsanousa, A., Symeonidis, S., Diplaris, S., Zaffanela, F., Monego, M., ... & Kompatsiaris, I. (2023). **Stress detection based on wearable physiological sensors: Laboratory and real-life pilot scenario application**. *SIGNAL 2023 Editors*, 14.
9. Ferri, M., Lombardo, F., Norbiato, D., Fiorin, R., Monego, M., & Napolitano, L. (2022, September). **Machine learning techniques and Big Data analysis for flood risk management, assessment of droughts and other extreme climate events: different approaches.** In *Workshop on Statistical Hydrology* (Vol. 17, p. 20).
10. Vassiliades, A., Symeonidis, S., Diplaris, S., Tzanetis, G., Vrochidis, S., Bassiliades, N., & Kompatsiaris, I. (2023, February). **XR4DRAMA Knowledge Graph: A Knowledge Graph for Disaster Management**. In *2023 IEEE 17th International Conference on Semantic Computing (ICSC)* (pp. 262-265). IEEE.
11. Vassiliades, A., Symeonidis, S., Diplaris, S., Tzanetis, G., Vrochidis, S. & Kompatsiaris, I. (2023). **XR4DRAMA Knowledge Graph: A Knowledge Graph for Media Planning**. In *Proceedings of the 15th International Conference on Agents and Artificial Intelligence - Volume 3: ICAART*
12. Kosti, M. V., Georgakopoulou, N., Diplaris, S., Pistola, T., Chatzistavros, K., Xefteris, V. R., ... & Kompatsiaris, I. (2023). **Assessing Virtual Reality Spaces for Elders Using Image-Based Sentiment Analysis and Stress Level Detection**. *Sensors*, 23(8), 4130.
13. Vassiliades, A., Stathopoulos-Kampilis, G., Antzoulatos, G. , Symeonidis, S., Diplaris, S., Tzanetis, G., Vrochidis, S., Bassiliades, N., & Kompatsiaris, I. (2023, February). **XR4DRAMA a knowledge-based system for disaster management and media planning**., *The Knowledge Engineering Review* (under review)
14. Xefteris, V. R., Dominguez, M., Grivolla, J., Tsanousa, A., ... & Kompatsiaris, I. (2023). **Stress detection based on physiological sensor and audio signals, and a late fusion framework: An experimental study and public dataset**., *Scientific Reports* (under review)
15. Symeonidis, S., Samaras, S., Stentoumis, C., Plaum, A., … & Vrochidis, S. (2023). **An Extended Reality system for situation awareness in flood management and media production planning.**, *Electronics* (accepted for publication)

Events

Due to the pandemic, project promotion at events was a difficult thing well into the second year of xR4DRAMA: Many conferences and meetings were cancelled, some only took place in a stripped-down, virtual form. However, things got better over the course of time and in total, consortium members attended 15 events to spread the word about xR4DRAMA. Here is a list:

1. IEEE International Conference on Intelligent Reality (ICIR) 2021
2. International Conference on Natural Language Generation 2021
3. Thessaloniki Design Week 2022 (first in-person appearance)
4. International Conference on Content-based Multimedia Indexing 2022
5. IEEE International Conference on Intelligent Reality (ICIR) 2022; (up2metric received an award for the xR4DRAMA mobile app here)
6. Stereopsia 2022
7. VR Days 2022 (special invitation by the conference organiser whom the consortium had met at Stereopsia)
8. International Conference on Multimedia Modeling 2023
9. International Conference on Semantic Computing (ICSC) 2023
10. International Conference on Agents and Artificial Intelligence (ICAART) 2023
11. International Conference on Advances in Signal, Image and Video Processing 2023
12. Conference on Advances in Signal, Image and Video Processing (SIGNAL) 2023
13. AAWA Info Day & xR4DRAMA Demo in the Piovese District 2023
14. Open day at CERTH/ITI 2023
15. Beyond Expo Thessaloniki 2023

Standardisation

At project level, xR4DRAMA monitored compliance with the following standardisation bodies:

- AR Framework
- IEEE P2048.3 – Immersive Video File and Stream Formats
- IEEE P2048.5 – Environment Safety
- IEEE P2048.6 – Immersive User Interface
- IEEE P2048.8 – Interoperability Between Virtual Objects and the Real World

At work package level, mainly focusing on WP2, xR4DRAMA adopted and standardised SIMMO, a unified data model for web and social media content. The same data model was also leveraged for storing the reports created by the citizen app (T5.4).

Collaboration

First, four collaborative development events took place between the consortium partners, two in the beginning of the project (user workshops) in order to set up and align on the system’s user requirements, and two during the first pilots (one for each use case) to better understand the evaluation feedback and discuss upon the actions that had to be done in the final development phase. Moreover, we were constantly communicating with testers and potential users (e.g., Cyprus University of Technology, DW video editors and media planners, Euronews, TU Delft, Vragments). Lastly, we collaborated with the following H2020 European projects:

- *CALLISTO*[15]. We established a synergy with CALLISTO where we have identified mutual areas of interest and common goals and we collaborated in two different

[15] https://callisto-h2020.eu/

pillars: a) we exchanged knowledge, methodological steps and ideas about named entity recognition and geolocalisation in textual content and b) both projects provided access to potentially relevant datasets that were either found in the literature or created during the project. Eventually, xR4DRAMA's visual analysis task exploited the Mapillary street level images dataset that is available in CALLISTO's repository[16].

- *INVICTUS*[17]. We shared insights with respect to ethics, both via email and in person during the VR Days event in Rotterdam.

Market analysis, sustainability and exploitation plan and business model

The global disaster management market size was valued at around USD 84.14 billion in 2020 and is expected to grow at a CAGR of 5.4% from 2021 to 2028. Collaborations between governments, NGOs, and private sector organisations are becoming more common in order to optimise resources and streamline disaster response efforts. Developing nations are becoming more aware of the need for disaster management solutions, creating opportunities for market expansion.

The global journalism market size was valued at around USD 34.4 billion in 2021 and is expected to grow at a CAGR of 4.2% from 2022 to 2028. Trends such as Digital transformation, IoT, Satellite Journalism and data-driven journalism is becoming a new standard in journalism. Developing nations are becoming more aware of the need for disaster management solutions, creating opportunities for market expansion.

Based on these numbers, specific business plans for disaster management and journalism have been created.

[16] https://github.com/Agri-Hub/Callisto-Dataset-Collection
[17] https://invictusproject.eu/

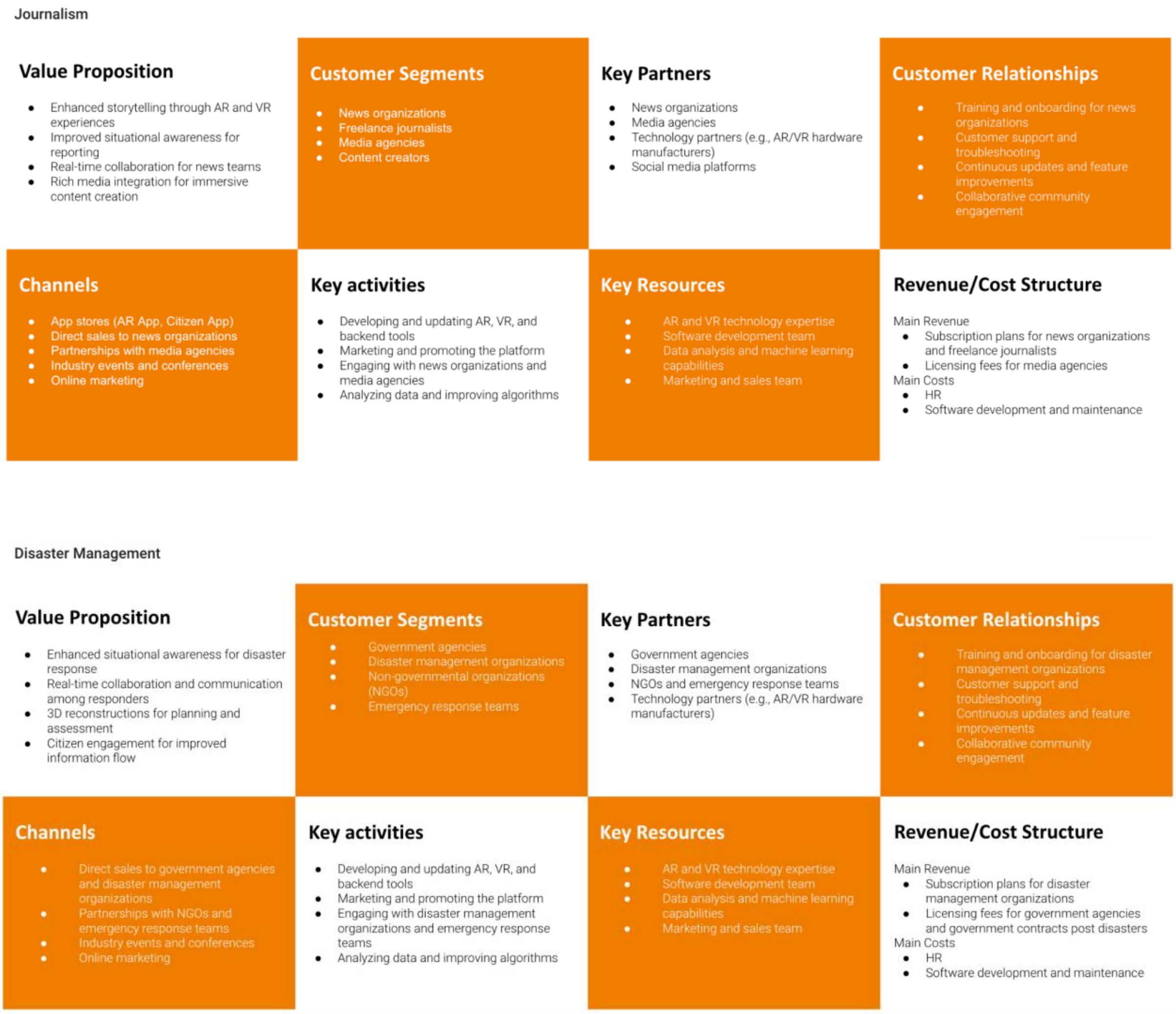

Figure 32: Market Analysis Overview

2 DATA MANAGEMENT

xR4DRAMA has adopted a robust data management plan and methodology to have a general overview of the data used with the project activities, putting in place all the necessary monitoring and mitigation measures. Certain rules and regulations along with technical and organisational security measures have been developed in alignment with the data management as defined in Horizon 2020, as well as with the relevant applicable national, EU and international legislation, especially whenever real data inherent to human participants has been processed. In addition, xR4DRAMA has received feedback and recommendations on data management from the Ethics Advisory Board which was taken into account and therefore took all the necessary actions.

Generally, there are three main categories of data in xR4DRAMA:

(a) **personal data**, which take into consideration mainly the General Data Protection Regulation (Regulation (EU) 2016/679), the Charter of Fundamental Rights of the European Union 2000/C, 36401, with a focus on respect for human dignity, right to the physical and mental integrity of the person and respect for privacy and protection of personal data, the Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector, EU ethics and data protection as well as other national relevant data protection regulations.

(b) **Data protected** by relevant Intellectual Property Regulations

(c) **Open data** which could be used with no specific restrictions.

Since the beginning of the project, the xR4DRAMA consortium had clearly identified and recorded the relevant datasets that would be used during the lifespan of the project, per WP as well as per PUC. Specific templates (Table 3) had been created based on the "Guidelines on FAIR Data Management in Horizon 2020", thus providing a summary of their data and how this would be FAIR (Findable, Accessible, Interoperable and Reusable).

Data set reference and name	The identifier for the dataset: Dataset_<WPno >_<serial number of dataset>_<dataset title>

Data set description	● State the purpose of the data collection/generation ● Explain the relation to the objectives of the project ● Specify the types and formats of data generated/collected ● Specify if existing data is being re-used (if any) ● Specify the origin of the data ● State the expected size of the data (if known) ● Outline the data utility: to whom will it be useful
Standards and metadata	● Outline the discoverability of data (metadata provision) ● Outline the identifiability of data and refer to standard identification mechanisms. Do you make use of persistent and unique identifiers such as Digital Object Identifiers? ● Outline naming conventions used ● Outline the approach towards search keyword ● Outline the approach for clear versioning ● Specify standards for metadata creation (if any). If there are no standards in your discipline describe what type of metadata will be created and how
Data sharing	● Specify which data will be made openly available. If some data is kept closed provide rationale for doing so ● Specify how the data will be made available ● Specify what methods or software tools are needed to access the data. Is documentation about the software needed to access the data included? Is it possible to include the relevant software (e.g., in open source code)? ● Specify where the data and associated metadata, documentation and code are deposited ● Specify how access will be provided in case there are any restrictions
Archiving and preservation (including storage and backup)	● Specify the procedures that will be put in place for long-term preservation of the data (beyond the lifetime of the project) ● Specify how long the data should be preserved and what is its approximate end volume, including a reference to the associated costs (if any) and how these are planned to be covered.

Discoverable	Define further whether the data and associated software produced and/or used in the project are discoverable (and readily located), and identifiable by means of a standard identification mechanism such as the Digital Object Identifier.
Accessible	Define further whether the data and associated software produced and/or used in the project are accessible and in what modalities, scope, and licences.
Assessable and intelligible	Define whether the data and associated software produced and/or used in the project are assessable for and intelligible to third parties in contexts such as scientific scrutiny and peer review.
Useable beyond the original purpose for which it was collected	• Specify how the data will be licensed to permit the widest reuse possible • Specify when the data will be made available for re-use. If applicable, specify why and for what period a data embargo is needed • Specify whether the data produced and/or used in the project is usable by third parties, in particular after the end of the project. If the re-use of some data is restricted, explain why • Describe data quality assurance processes • Specify the length of time for which the data will remain re-usable
Interoperable to specific quality standards	• Assess the interoperability of your data. Specify what data and metadata vocabularies, standards, or methodologies you will follow to facilitate interoperability. • Specify whether you will be using standard vocabulary for all data types present in your data set, to allow inter-disciplinary interoperability. If not, specify whether you will provide mapping to more commonly used ontologies.

Table 3: Data management plan template

This information had been continuously updated, with all new data that might emerge, or with any updates on the existing ones.

Regarding **data sharing**, all data has been accessible only by the xR4DRAMA members. The (partially) public availability of each dataset has been defined after further analysis towards copyright input material and privacy and legal consideration. Any data sharing (e.g., for publication and/or dissemination/communication purposes), has been done with respect to the following data sharing guidelines, respecting personal data protection policy:

- Before the use of any of these data beyond the Consortium members, the Coordinator has requested the approval of the Ethics Board and Ethics Advisor. Upon their approval, the data have undergone an anonymisation and de-identification process (when applicable) to reassure that no personal data were included.
- After this process, the data have been safely shared out of the Consortium for a specific publication or dissemination/communication purpose.

More, certain measures have been adopted for the proper management of personal data throughout the project. After the completion of a mapping of the personal data identified and collected during project activities, xR4DRAMA consortium partners have outlined the WP/task under with which personal data collection/processing is related, the main reason/purpose of the processing, the lawful basis of processing (*mainly consent Art 6,1 (a) GDPR, processing under the performance of a contract for WP1 activities of Art 6,1,(b) GDPR, and the provisions of Art 14 GDPR, where consent cannot be obtained for certain reasons*),adherence to data minimisation principle, the data controller/responsible for each dataset, as well as *general information on the technical and organisational measures in place.* This mapping was updated via the internal inventory created by the coordinator (CERTH) where it was encapsulated with an internal data processing approach which included justifications as to how GDPR requirements translate to the project context and how data protection rules will be applied at project and partner level.

In all activities that required human participation (PUC, dissemination communication etc.) all individuals were adults, able to provide their informed consent and being involved on a voluntary basis, without having to encounter any physical, emotional, social, economic, or legal risk as well as any deceptive activities that would create psychological stress or anxiety under any circumstances. Under no case was the participation obligatory for any of the employees of the xR4DRAMA consortium partners and no negative repercussions followed any withdrawal of the research. There was also no preferential treatment for those agreeing to participate over those who do not.

Certain information sheets and informed consents have been developed and duly updated for each project's activities, while parallel to that, and in line with Art. 14 GDPR, and with its potentially applicable derogations (art. 14 (5) (b) GDPR), a dedicated **Data Protection Notice**[18] has been uploaded on M4D's website (as Data Controller) to inform data subjects about the processing of their personal data, stemming from social media and surface web crawling activities. Particularly for the latter, the collection and the processing have been in line with the terms and conditions as well as the privacy policies of the Twitters' website, as well as with full compliance on the terms of services and the privacy policies of each website, while a detailed analysis on the terms of use in online data stemming from social

[18] https://m4d.iti.gr/wp-content/uploads/2023/04/XR4DRAMA-Data-Protection-Notice.pdf

media in relation to Directive 2019/790 (the lawful access for text and data mining on research) has been conducted on approximately 25 online sources, identifying the ones that could be lawfully used for the xR4DRAMA purposes

Furthermore, xR4DRAMA activities abided by the data minimisation principle, ensuring that only the necessary for the project data had been collected and processed, with the rest to be properly deleted/destructed, following specific protocols. All data have been duly depersonalised, unless permitted by the research participant (through their informed consent). All pseudonymous data have been altered in that way that they cannot be related to certain research participants. A privacy policy[19] has been created and published, concerning all personal data processing activities that the consortium has applied. DPIAs (and DPIA's screening) of all partners have been duly updated including the relevant guarantees to data subjects.

All datasets containing personal data have been stored in secure servers within organisations' premises, accessible only to authorised individuals. Access to files containing personal data has been restricted only to research teams, while certain technical and organisational measures (e.g., encryption in communications, authentication using password) have been in place to mitigate any potential data breach or potential unauthorised access to the data. All partners responsible for processing data have ensured necessary security controls, including weekly backup policies, integrity checks, and access controls within their infrastructure.

The storage of the personal data has been agreed according to the EC's guidelines up to 5 years after the end of the project to be able to fulfil reporting obligations to the European Commission, unless a longer retention period is required by law or for the establishment, exercise, or defence of legal claims.

[19] https://xr4drama.eu/_privacy_/

3 SELF-ASSESSMENT

Within the context of the self-assessment procedures, and in order to apply a high-quality assessment, xR4DRAMA specified adequate methods and instruments. In xR4DRAMA, the assessment covered the following three major categories:

- the extent to which the results of each task or component meet the objectives defined in the Work Plan
- contribution to the state-of-the-art
- end-user satisfaction

In the following, we present the assessment of the xR4DRAMA results against clearly defined performance indicators, which were initially defined early in this project (Month 6) in D1.2 and were slightly adapted in the framework of this report.

3.1 WP1: Project management and coordination

<table>
<tr><th colspan="5">WP task Assessment</th></tr>
<tr><td colspan="2">WP</td><td>1</td><td>Date:</td><td>April 2023</td></tr>
<tr><td colspan="2">resp. Partner</td><td>CERTH</td><td>Responsible QEG member</td><td>Spyridon Symeonidis</td></tr>
<tr><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">1. WP Objectives</td></tr>
<tr><td>#</td><td colspan="2">Objective</td><td>Task</td><td>Milestone</td></tr>
<tr><td>1</td><td colspan="2">Ensure that the project is carried out in accordance with the given time and budget parameters.</td><td>T1.1</td><td>MS1 – MS5</td></tr>
<tr><td>2</td><td colspan="2">Ensure proper administration and reporting to the Commission.</td><td>T1.1</td><td>MS1 – MS5</td></tr>
<tr><td>3</td><td colspan="2">Ensure proper data management monitoring throughout the project.</td><td>T1.2</td><td>MS1 – MS5</td></tr>
<tr><td>4</td><td colspan="2">Ensure the high quality of the research and development in the project.</td><td>T1.3</td><td>MS1 – MS5</td></tr>
<tr><td colspan="5">2. Evaluation strategy</td></tr>
<tr><td>#</td><td colspan="4"></td></tr>
<tr><td>1</td><td colspan="4">Request of internal 6-month periodic activity and expenditure reports from each partner.
● Assessment of the budget figures as reported by the partners in the 6-month internal expenditure reports in the light of overall budget figures of xR4DRAMA and their extrapolation to the total duration of the project.
● Assessment of the completion (in %) of each task/activity by the time</td></tr>
</table>

	foreseen in the Work Plan based on the information obtained from the 6-month internal activity reports.
2	• Assessment of the successful and timely completion of the requests by the partners of the Consortium and the Commission. • Assessment of the timely submission of the deliverables. • Assessment of the successful management of the meetings.
3	• Assessment of the data management plan and activities (as documented in the internal activity reports and the respective deliverables) by an Ethics Advisory Board towards their accordance with the guidelines on data management set in Horizon 2020.
4	• Assessment of the research and the software development progress within each WP according to the indicators and the evaluation goals established (as documented in the internal activity reports and the deliverables and as presented by the scientists in charge of the tasks/activities at teleconferences and plenary meetings).

3. Indicators		
#	*Highest expectation*	*Lowest expectation*
1	(a) Expenditure of funds proportionally to the lifetime of the project. (b) 100% completion of all tasks / activities by the foreseen deadline.	(a) Justified expenditure of funds, in accordance with the EC regulations. (b) 75% completion of all tasks / activities by the foreseen deadline.
2	(a) Completion of the requests received either by the partners of the Consortium or the Commission within 7 working days. (b) Exhaustive treatment of all topics foreseen in the agenda of a meeting.	(a) Completion of the requests received either by the partners of the Consortium or the Commission within 14 working days. (b) Treatment of all topics foreseen in the agenda of a meeting to an extent that allows for the continuation and successful completion of the topics over distance.
3	No objections from the Ethics Advisory Board and thus no need for remedial actions.	Remedial actions required to address the objections of the Ethics Advisory Board.
4	100% fulfilment of the criteria / highest metric figures established for a given task / activity.	Meeting the minimal requirements / performance figures established for a given task / activity.

3.1.1 Final assessment

Objective 1

This objective deals with holding management meetings, monitoring the scientific and technical progress and time schedule of the project, ensuring the production of deliverables, managing the consortium, and mediating in the event of conflicts and disputes.

The only deviation regarding the time of the project is the fact that the consortium requested a 6-month extension to the project to compensate for the delays provoked by the COVID-19 situation, especially the difficulties conducting the pilot sessions due to travel restrictions. Such an extension allowed us to organise alternative plans (to cover the case where the pandemic continues for the whole project period) and complete the development and testing activities, delivering high quality results.

During the project, fourteen meetings took place. Five of them (three plenary and two user meetings) were held in the first half of the project (M1-M12). In the second period of the project (M13-M30), one review meeting, one technical meeting, three plenary meetings, and four pilot test meetings took place.

Scientific and technical progress and the time schedule have been closely monitored. All deliverables foreseen for the reporting period have been submitted. To better monitor the project, we have set up a wiki platform, which is used to report the progress, the meeting minutes and the interaction between the partners. The wiki also included access to common documents and guidelines.

The working atmosphere in the consortium is excellent; no conflicts or disputes were to be mediated. All tasks (100%) have been completed by the foreseen deadline. Funds expenditure funds was proportionally to the lifetime of the project, and thus the highest expectation was reached.

Objective 2

This objective includes monitoring progress of the project in its various administrative aspects (finance, reporting to the Commission, notification, and monitoring of deadlines, initiating management meetings, etc.). All these aspects have been successfully pursued during the project. All requests received either by the partners of the Consortium or the Commission were addressed within 14 working days. All topics foreseen in the agenda of a meeting were successfully completed.

Objective 3

No objections were raised from the Ethics Advisory Board and thus there was no need for remedial actions. More info is provided in the context of WP8.

Objective 4

The first prototype and final system have been delivered and all milestones have been reached. Action Points towards the development of the final prototype had been compiled and closely monitored to ensure project progress and guide the final evaluation. At least the minimal requirements/performance figures established for a given task/activity have been met.

3.2 WP2: Heterogeneous data collection, management and harmonisation

WP task Assessment			
WP	2	Date:	April 2023
resp. Partner	STX	Responsible QEG member	Maria Pacelli

1. WP Objectives			
#	*Objective*	*Task*	*Milestone*
1	Develop data collection tools to extract freely available textual and visual content from open web resources (including Social Media).	T2.1	MS2, MS4
2	Data collection from drone images and available satellite data (images and Digital Elevation Model) with aim to reconstruct the 3D models that will be visualised in the XR modules of the authoring tool (WP4). The collected data will be used for the images analysis (T3.2) and the 3D-reconstruction (T4.4).	T2.2	MS2
3	Setup of the service to acquire the relevant satellite data, pre-process them and build the backend for custom 3D modelling from satellite images as a cloud service.	T2.3	MS2
4	Development and production of a wearable monitoring system capable of acquiring physiological and psychological features of the users in the emergency scenarios.	T2.4	MS2, MS4
5	The feasibility study on the use of wearable or portable environmental sensors according to the use case scenarios requirements and Development of a proof of concept mock-up that will be tested at laboratory level.	T2.5	MS2, MS4

2. Evaluation strategy	
#	
1	• Measurement of the amount of content in the module’s database, in terms of number of multimedia items.

	• Assessment of the capabilities and success rate of the data collection module with respect to the indicated web and social media resources.
2	• The quality assessment for the data captured for the 3D reconstruction will happen in two phases: the on-field assessment and the post-process quality assessment. • The initial quality assessment of the collected data (images and videos) will be semi-automatic and will be conducted in the field, while collecting data. • The image data will be validated visually in the field, to ensure they are clear, sharp etc. • A draft 3D model will be created on very low resolution to ensure the data are enough for 3D model completeness. • The final assessment will be based on the final 3D model which will be reconstructed via SfM and SLAM algorithms.
3	• The quality assessment of the Satellite data (images and DEM) will be semi-automatic and will be conducted during the acquisition from the web services. Both image and 3D data will be validated visually in the GIS environment, to ensure that they are optically clear and sharp and that they are georeferenced correctly. • A rough terrain model will be generated and visualised to ensure the completeness of the data.
4	For the physiological data, quality assessment will be done • on the electronic device verifying that each functionality is on, through the visual analysis of data in streaming and data recorded on the SD card; • on the smart vest, a check will be done on the quality of gathered signals to assure that the size of the garment is appropriate to fit the body of the user.
5	• For the environmental data of the wearable (or portable) systems, the data quality assessment will be evaluated at laboratory level in a first phase and later in the field. Data will be collected and evaluated in post processing.

3. Indicators

#	*Highest expectation*	*Lowest expectation*
1	• Collect 100000 multimedia items • Collect successfully 95% of indicated resources • Dynamic, real time	• Collect 10000 multimedia items • Collect successfully 50% of indicated resources • Periodical data acquisition from social media.

	data acquisition from social media on project creation.	
2	To have a large number of images and data collected with drones around multiple areas of interest that support both crisis management and media production scenarios. The data should be of good quality to allow dense 3D mapping.	To have one scene for crisis management scenario and one scene for media production scenario, recorded via images and videos collected with drones. The data should be of good quality to allow dense 3D mapping.
3	To have satellite images and elevation models for multiple areas of interest that support both the crisis management and the media production scenarios. The data should have the adequate spatial resolution to reconstruct a rough terrain of the area under inspection, in order to support the XR modules and the DSS of the xR4DRAMA authoring platform.	To have satellite images and elevation models for one scene for the crisis management scenario and one scene for the media production scenario. The data should have the adequate spatial resolution to reconstruct a rough terrain of the area under inspection, in order to support the XR modules and the DSS of the xR4DRAMA authoring platform.
4	Identify on the ECG data the R peaks of the QRS complex, the number of false R peaks has to be < 5% of the total number of detected beats. RR interval is used for the estimation of the HRV indexes that are correlated to the stress level.	Movement artefacts could affect the quality of physiological signals, specific processing on ECG signals allow to identify R peaks, HR and RR intervals that are correlated to the level of stress (5% < False R peaks number < 10%)
5	Disaster Management: Data collected provide information on water pressure solicitations in proximity of First Responder in correlation with his posture data collected using the smart vest.	Disaster Management: Data collected provide information on the water pressure solicitations applied on the pressure sensors embedded in the device.
	Media Production Planning: Sophisticated ambisonic sound in a fully immersive	Media Production Planning: Basic quality sound recordings attached to a POI.

	environment.	

3.2.1 Final assessment

Objective 1

CERTH has successfully created advanced data collection modules that bring high value web and social media data to the xR4DRAMA platform. The tools developed for this objective are robust and well-rounded, ensuring sustainable delivery of data after the end of the project.

Specifically, during the project we collected 51319 multimedia items (twitter posts, reddit threads, foursquare POIs, Flickr images, Youtube videos, etc.). We managed to connect to and collect data from 85.7% of indicated social media (only Tripadvisor could not be connected due to their terms of use), which is closer to the highest expectation. Moreover, we obtained content from 100% of the indicated traditional webpages which exceeds even our highest expectation. Finally, we managed to support dynamic and real time data collection from Wikipedia and Foursquare on creation of a new project in the xR4DRAMA authoring tool, whereas we support periodical data collection for the rest social media sources.

Objective 2

The objective was to *collect visual and other data* to reconstruct photo-textured 3D models for the purpose of enhanced situation awareness via the xR4DRAMA VR application. The collected data were to be used in the images analysis (T3.2) and the 3D-reconstruction (T4.4) modules. The quality assessment was based on random visual tests in the field and the generation of a sparse point cloud to ensure the needed coverage per application. The data collection satisfied the highest set expectation, as the images collected in most of the sub-cases for the demo sites, either the PUC sites, or test sites used throughout the project in Greece, Italy, and Germany, allowed the dense 3D mapping in the sense of improving the situation awareness of the final user.

Objective 3

The objective was to *implement a service to retrieve available satellite data*, pre-process them, and build the backend to support a custom online service for 3D modelling from satellite images. The key result, i.e. the xR4DRAMA *satellite service*, satisfies the highest of the expectations which were to retrieve satellite images and elevation models for the platform. This said, the satellite images were mostly used in the flood management use case, as the scale of the media production planning was much larger, thus the drone footage was more appropriate than the satellite imagery.

Objective 4

For the physiological data, quality assessment has been done testing the wearable sensing platform when worn by the user before to start the pilot sessions in order to identify the R peaks on the transmitted data :

- Physiological monitoring sessions lasting a few minutes, were carried out for each user in order to verify that all signals (ECG, respiratory rate and accelerometers and quaternions) were correctly acquired. The control was carried out through the visual analysis of the streaming data;
- Data transmission to the xR4DRAMA platform was verified by checking the data flow of the Citizen app of the signals collected by the wearable sensing platform;

After the pilot sessions, feedback from users was collected to evaluate the usability of the system and the quality of user experience;
A random analysis of the quality of the ECG acquired by the system during the tests was performed and the highest expectation on data quality was achieved.

Objective 5

Disaster Management: the mock-up of the water pressure sensor device has been tested in the laboratory with the aim to verify the coherence of pressure values detected in static condition (hydrostatic test) and in the field (hydrodynamic test) during the second pilot (PUC1).
Media Production Planning: during the first pilot (PUC2) the Zoom H3-VR virtual reality audio recorder has been tested to verify the quality of resulting recordings and their integration in post processing on the xR4DRAMA platform.
For both devices we achieved the lowest expectation.

3.3 WP3: Analysis and fusion of multi-modal data

WP task Assessment			
WP	3	Date:	April 2023
resp. Partner	CERTH	Responsible QEG member	Spyridon Symeonidis, Jens Grivolla

1. WP Objectives			
#	*Objective*	*Task*	*Milestone*
1	Sensor data analysis	T3.1	MS2, MS4
2	Localisation of assets in audio-visual content	T3.2	MS2, MS4
3	Multilingual audio and written language analysis	T3.3	MS2, MS4
4	Stress level detection	T3.4	MS2, MS4
5	Multimodal information fusion and semantic representation	T3.5	MS2, MS4
6	Personalised information generation	T3.6	MS2, MS4
7	Decision Support System for situation awareness	T3.7	MS2, MS4
2. Evaluation strategy			

#	
1	• Sensor data analysis will be evaluated using metrics such as accuracy, sensitivity, specificity, f-score and r-square.
2	• Building and Object Localisation module will be quantitatively evaluated by measuring (i) variable Intersection over Union (IoU) accuracy between the ground truth and detected areas (binary masks) and (ii) qualitatively by superimposing the masks over the original images. A comparison will be carried out between the module's results with or without the usage of Photorealistic Style Transfer techniques. • Photorealistic style transfer will be quantitatively evaluated by measuring (i) Peak signal-to-noise ratio (PSNR) and (ii) structural similarity index measure (SSIM) between ground truth and enhanced outputs.
3	• Word/Sentence Error Rate for ASR; • Precision and recall for parsing and concept/concept relation extraction. • Baseline: Off-the-shelf state-of-the-art ASR technologies Kaldi, CMU Sphinx, and Wav2Letter++ for speech recognition; for semantic parsing and concept (relation) extraction: version of the corresponding techniques developed at UPF at the beginning of the project.
4	• Accuracy/Error (RMSE) for voice-based stress level detection. • Baseline: For voice-based stress level detection, a baseline system developed during the first phase of the project was used as reference.
5	• For the fusion of the results of audio and physiological sensors, we will use the same evaluation metrics as in T3.1: accuracy, sensitivity, specificity, f-score and r-square (in case of regression). • For the semantic integration the validation of the accuracy of the respective annotations will be achieved by answering a set of questions formulated during the task's development.
6	• Manual evaluation of linguistic quality of system reports using questionnaires. • Baseline**:** For text planning a schema-based planner will be realised as baseline. For linguistic generation an extended (in terms of grammatical and lexical resources, in order to cover the grammatical constructions and vocabularies of all languages involved in xR4DRAMA) version of the grammar-based graph transducer generation platform MATE developed at UPF will be used for xR4Drama-specific datasets and for automatic evaluation on benchmark datasets (e.g. WebNLG), and state-of-the art neural approaches will be used as baseline for human evaluation on benchmark datasets (e.g. WebNLG).
7	• The assessment of the accuracy and fullness of the developed decision support system will be functioned by: ○ Result accuracy

	○ Precision ○ Completeness ○ Response Time The response time in our list refers the queries that will be formulated. A concise and efficient solution in order to query all the different data elements it is quite possible to be found.	
3. Indicators		
#	*Highest expectation*	*Lowest expectation*
1	• 100% (classification, regression)	• In case we apply classification algorithms, we expect at least 75% accuracy • In case we apply regression, we will accept a model of at least 85% R-square
2	• 3% improvement in variable IoU accuracy when compared to the baseline; • 10% improvement in PSNR when compared to the baseline; - 5% improvement in SSIM when compared to the baseline;	• 2% improvement in variable IoU accuracy when compared to the baseline; • 2% improvement in variable PSNR and SSIM respectively when compared to the baseline
3	• 10% error reduction with respect to the baseline for all indicators.	• 5% error reduction with respect to the baseline for all indicators.
4	• 10% error reduction with respect to the baseline for all indicators.	• 5% error reduction with respect to the baseline for all indicators.
5	• 100% (classification, regression)	• For classification: at least 80% accuracy • For regression: at least 90% R-square
6	• Manual evaluation: very good ratings (4 to 5 in a 5-value Likert scale).	• Manual evaluation: average/good ratings (3 to 4 in a 5-value Likert scale).
7	• Precision, recall, F-score > 0.9 • Response time to queries: < 1.5 sec	• Precision, recall, F-score > 0.8 • Response time to queries: < 3.5 sec

3.3.1 **Final assessment**

Objective 1

The sensor data analysis module is evaluated on the data that were collected to train the algorithms. Since the stress detection was performed using regression models, the evaluation metric chosen was the R-square metric. Results of the evaluation showed that the sensor-based stress level detection module achieves an R-square value of 85.35% which stands above our lowest expectation.

Objective 2

The image semantic segmentation of the Building and Object Localisation (BOL) module is evaluated in a quantitative way using the mean Intersection Over Union (mIoU) metric. Taking as a baseline the DeepLabV3+ architecture trained on the Mapillary Vistas dataset, we achieved a mIoU of +2.1% using our custom dataset and PST.

The photorealistic style transfer module is evaluated in a quantitative way, where our approach is compared with the baseline namely Zero-DCE (Guo et al., 2020) for LOL benchmark dataset. The Peak Signal-to-Noise Ratio (PSNR) scores correspond to the average value of the complete test set of enhanced images in the LOL dataset. As it is reported in (Batziou et al, 2023) our framework increases the PSNR up to 20%. Concerning the SSIM value of our framework in the LOL dataset, it has increased approximately 50%. PSNR values show that the generated images from our approach obtain higher proximity to the input normal-light images than the image generated by the baseline method. As far as SSIM value is concerned, the output of our framework on the LOL dataset is the higher scores compared with the baseline method.

Objective 3

Speech recognition (ASR) quality was improved significantly using Whisper (used in latest pilot tests but could not be evaluated in time to be included in D3.9), compared to the wav2letter++ models used earlier in the project. The word error rate (WER) is around 80% lower than with the previous system, on the very challenging Italian emergency phone call dataset gathered in the project (noisy recordings and fast speech). The system thus now provides generally excellent transcriptions whereas transcription quality on this dataset was quite poor previously. The transcriptions now also contain near-perfect punctuation and casing in addition to having improved robustness to noise.

There was significant improvement in coverage for information extraction rules, both for "generic" grammatical rules (especially Italian), and domain-specific rules for both use cases, compared to earlier iterations.

The domain-adapted concept extraction system showed a 23% improvement in accuracy over the generic model (and corresponding improvements in both precision and recall), exceeding the highest expectations.

Additionally, results from tweet relevance classification experiments show a very high F1 score of 0.97.

Objective 4

Audio-based stress detection in the final prototype was significantly improved from the baseline developed for the first prototype. The Root Mean Squared Error (RMSE) for audio-based stress level detection was reduced from 0.28 to 0.11 from the initial baseline to the final version on the domain-specific evaluation set, a reduction of the error by over 60% (in line with the highest expectations)

Objective 5

Competency Questions (CQs) compiled during the creation of the official ontology requirements specification document (ORSD) were used to assess the completeness of the xR4DRAMA KG. For this reason, we asked a group of specialists to create a series of questions that they would like the xR4DRAMA KG to answer before we built it. The experts were authority workers from *Autorita' di bacino distrettuale delle alpi orientali* and journalists from *Deutsche Welle*. A total of 32 CQs were gathered, and we have included a sample of 10 of them in Figure 33:The full list of CQs may be accessed here.

1) What is the risk level of the observation?
2) Which is the emergency in the observation?
3) What is the detection/creation time of the observation?
4) Which is the area in the observation?
5) What is the probability of the area in observation?
6) Which is the Stress level of the between time intervals?
7) Which is the objects found in video?
8) Which is the most/least risky observation?
9) What is the multimedia type used in observation?
10) How many people are in danger between time intervals [$t1$]-[$t2$]?

Figure 33: Batch of Competency Questions

The completeness of the 4DRAMA KG was found adequate, as each CQ when translated into a SPARQL counterpart returned the desired information. This translates to a 100% classification.

In addition to the CQs, we carried out a validation process to examine the syntactic and structural quality of the KB's metadata and to verify their consistency. Custom SHACL consistency checking rules and native ontology consistency checking, such OWL DL reasoning, were used to adhere to the closed-world criterion. One can find constraint violations, such as cardinality inconsistencies, incomplete, or missing information, by employing the first method. By employing the latter, the terminological semantics, or TBox, are taken into account as validation, much like in the case of class disjointness. Out of 56 SHACL rules, 21 of which referenced to object type properties and 35 to data type properties, the consistency of the xR4DRAMA KG was deemed sufficient because none of them returned any rule invalidation. We also looked for instances that belong to the intersection of classes because we did not want that to happen, but none were found.

Regarding the population of the xR4DRAMA KG, based on the content of the visual, textual, and stress level analysis messages, the mapping accuracy is at 95%, meaning that almost all messages from the textual, visual, and stress level analysis that were intended to be populated in the KB, it will end up in the KB. The reason for that was because the mapping mechanism that would translate the information from the messages of the multimodal mapping mechanism, was initially semantically aligned with classes and properties of the xR4DRAMA KG.

The fusion-based stress level detection module is also evaluated on the training dataset by again using the R-square metric. Results show that the fusion-based stress level detection module achieves an R-squared value of 95.47% which stands above our lowest expectation.

Objective 6

The quality of text generation results was evaluated manually by end users and technical partners on a 5-value Likert scale. Results for the grammar-based text generation (FORGe) are in line with the highest expectations:

Grammaticality	Readability	Usefulness
4.74	4.34	4.54

Table 4: Evaluation results (maximum rating = 5), both PUCs, for the FORGe-based text generator

Additional experiments on neural rephrasing of FORGe results show considerable improvements in fluency:

Fluency (3-point scale)	FORGe	Text-wise paraphrase	Sentence-wise paraphrase
Good	48.8%	74.38%	87.6%
Average	50.4%	24.79%	10.74%
Bad	0.8%	0.83%	1.65%

Table 5: Fluency ratings of rephrasing using neural networks compared to original FORGe output

Objective 7

Since the Textual Analysis Severity assessment is done by a heuristic rule-based approach, to validate the output of DSS we used the information contained in the annotated dataset from the analysed video frames by the Video Analysis module. After extracting the information from the flooded pictures and considering the input fields of the Textual Analysis messages, we modified the dataset to represent the same information every visual scene carried but in a textual message format. That information then was processed by the Textual Analysis DSS module, and the Severity Level generated was compared to the original severity value of the annotated visual dataset.

Textual Analysis DSS module was able to achieve a 0.766 accuracy score (1) using a total of 30 entries for testing.

To validate the Visual Analysis message severity assessment of DSS standard metrics like precision, recall, F1-score and Accuracy score were used. The annotated dataset was split at 76 entries for training and 20 entries for testing using cross validation. The four different Machine learning algorithms were tested after hyperparameter tuning each one. In the following Table 6 we can see the results for each one of the models according to their best achieved accuracy score.

	Accuracy Score
Linear Regression (Ridge Classifier)	0.65
SVM (SVC)	0.75
Random Forest Classifier	0.75
Decision Tree Classifier	0.85

Table 6: Machine Learning algorithms performance according to Accuracy score

The best performing algorithm is Decision Tree Classifier with max_depth = 5 (the maximum depth of the tree), max_leaf_nodes = 10 (the maximum amount of nodes that can be used when growing a tree in best-first fashion) and random_state = 42 (controls the randomness of the estimator – if integer a deterministic behaviour during fitting is obtained). In the following Table 7 we can see more analytically the validation metrics for DT.

	precision	recall	f1-score	support
Low	1	0.666667	0.8	3
Medium	0.75	1	0.857143	3
High	0.875	0.875	0.875	8

Very High	0.833333	0.833333	0.833333	6
accuracy	0.85	0.85	0.85	0.85
macro avg	0.864583	0.84375	0.841369	20
weighted avg	0.8625	0.85	0.848571	20

Table 7: Precision, Recall, F1-score for DT algorithm

Following there is the confusion matrix of the testing phase of DT algorithm, with the best performing parameters.

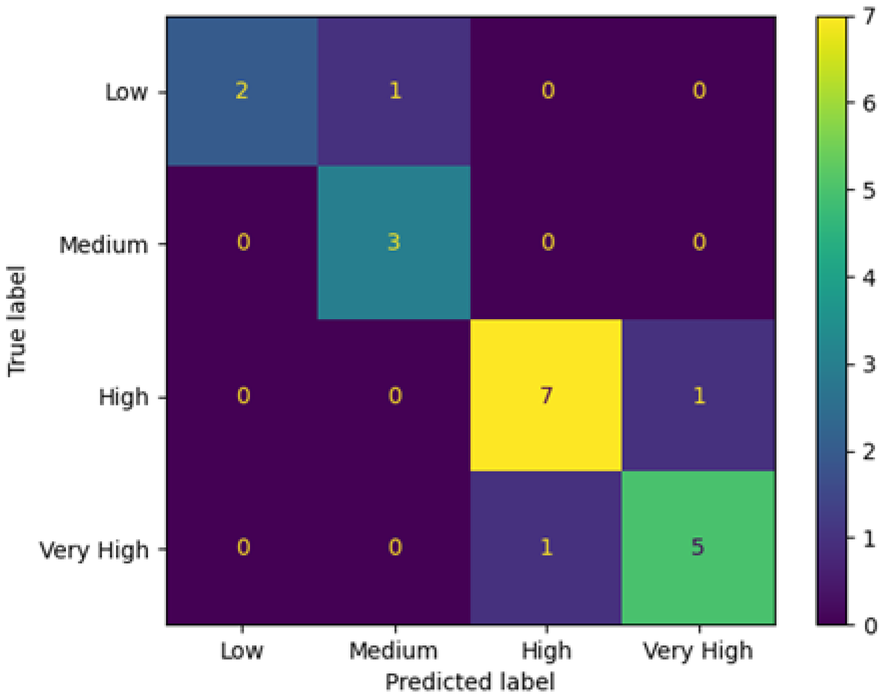

Figure 34: Confusion Matrix of DT algorithm

Also, the time responses for each query were below 1 second as the decision support system would process each query in real time and would provide a response within less than 1 second.

3.4 WP4: Interactive AR/VR solutions for media production and hazard management

WP task Assessment				
WP	4	Date:	April 2023	
resp. Partner	U2M	Responsible QEG member	Christos Stentoumis	
1. WP Objectives				
#	*Objective*		*Task*	*Milestone*
1	Development of a tool for visualisation of Decision Support System results in AR.		T4.1	MS2, MS4
2	Development of visual and GIS-assisted uninterrupted navigation for AR		T4.2	MS2, MS4
3	Development of 3D computer vision, object detection and scene segmentation algorithms on top of devices' commercial APIs, to assist user navigation in the real world and also quickly identify potential threats and dangers for the agents in the field.		T4.3	MS2, MS4
4	Generation of high-fidelity 3D models of urban and country areas by exploiting visual data from UAVs, digital archives and web resources and satellite remote sensing data.		T4.4	MS2, MS4
5	Development of a collaborative VR tool where users can interact together in a VR scenario and create VR environments.		T4.5	MS2, MS4
6	Development of a VR authoring tool to create multiple environments for various situations with different interactions.		T4.6	MS2, MS4
2. Evaluation strategy				
#				
1	• Conduct periodic functional tests to ensure that the tool's functional and technical aspects are within expectations and aligned with the user requirements. Review how the tool meets the defined requirements in T6.2 and obtain feedback on the UI/UX design.			
2	• Evaluate the accuracy in geo-localisation and orientation.			

3	• Quantitative evaluation (Precision, recall, accuracy, F1 score, sample classification time) of extracted concepts against a representative gold standard.	
4	Assessment of geometric and visual resolution and accuracy of the reconstructed 3D models. These need to be: • geometrically accurate and visually precise • serve the requirements of VR presentation The reconstructed models should be able to be used by the VR tools of T4.5 and T4.6 and served via the xR4DRAMA platform.	
5	• Similar to the evaluation strategy of Objective #1, based upon periodic functional tests and user tests.	
6	• Similar to the evaluation strategy of Objective #1, based upon periodic functional tests and user tests. Additional to the alignment with the user and technical requirements, user tests will provide feedback on user friendliness, immersiveness and ease of understanding the VR environment.	
3. Indicators		
#	*Highest expectation*	*Lowest expectation*
1	Meet at least 90% of user requirements. The tool is found highly useful and valuable by users in both the crisis management and media production scenarios.	Meet at least 80% of user requirements. Some exceptions are accommodated for specific services to remedy unforeseen issues during the planning of the integration. Existence of small-scale deviations that do not affect the entire system.
2	Achieve an accuracy of ±30cm in geolocalisation and ±1 degree in orientation.	Achieve an accuracy of ±1m in geolocalisation and ±5 degrees in orientation.
3	Achieve ≃ 80% F1 score in near real time conditions.	Achieve ≃ 70% F1 score in near real time conditions.
4	Achieve geometric and visual resolution and accuracy of ≃10cm	Achieve geometric and visual resolution and accuracy of ≃30cm
5	Meet at least 90% of user requirements. Multiple users able to use a single environment (>2 people) editing a single VR environment.	Meet at least 80% of user requirements. Some exceptions are accommodated for specific services to remedy unforeseen issues during the planning of the integration. Existence of small-scale deviations that do not affect the entire system.
6	Meet at least 90% of user	Meet at least 80% of user requirements.

	requirements. The tool is user friendly, provokes immersiveness and found highly useful and valuable by users in both the crisis management and media production scenarios.	Some exceptions are accommodated for specific services to remedy unforeseen issues during the planning of the integration. Existence of small-scale deviations that do not affect the entire system.

3.4.1 Final assessment

Objective 1

The objective was to develop a tool for the *visualisation of Decision Support System results* in AR; the objective was fully met as the developed AR application fully supports all the data and the results from the xR4DRAMA platform and not only the DSS results. The application was periodically evaluated by the users. In the second development phase, after the first pilot testing, the users were receiving new versions with latest corrections and features every three weeks following the project issue log (i.e., in Gitlab). The highest expectation was to meet at least 90% of user requirements and to find the AR application highly useful and valuable by users in both the crisis management and media production scenarios. These are fully met at 100% based on the D6.2 Final User Requirements and the D6.4 Final system evaluation report.

Objective 2

The objective was to *have AR navigation based on visual cues and GIS information*, which is met using the GPS, compass, and IMU sensors of the mobile phone, as well as the SLAM-based navigation of the AR Foundation framework (exploiting ARkit, ATCore). The lowest expectation was met as the achieved accuracy in repetitive tests is ±1 m in geolocalisation and ±5 degrees in orientation when using the iPhone 13 Pro device.

Objective 3

The objective was to *develop 3D computer vision, object detection, and scene segmentation algorithms* to assist user navigation in the real world and quickly identify potential threats and dangers for the agents in the field. Based on the user requirements (D6.1 - Pilot use cases and initial user requirements) and the final selection of mobile phones as frontend devices, a real-time object detection in outdoor environments feature was developed to detect a predefined set of classes via the phone camera in the AR view of the application to assist automated field task management. The feature runs on mobile phones integrated in the Unity-based application. The evaluation of the final deployed feature is quantitative (i.e., via precision, recall, accuracy, F1 score) on standard evaluation datasets.

The SSDLite neural network architecture was selected for the implementation of the object detection functionality. This neural network architecture is specifically tailored for mobile and resource constrained environments. It takes as an input a low-dimensional compressed representation which is first expanded to high dimension and filtered with a lightweight depth wise convolution. Features are subsequently projected back to a low-dimensional representation with a linear convolution. The training set used for the object detection module of the AR app consists of VOC and BDD100K transformed into VOC format. The results are optimised for precision as, given the real-time feed, there are many appearances of an object, and it is needed to be certain of any detections. The performance is at the lowest expectation (≃70% F1 score in near real time conditions); e.g., humans 0.78, car 0.91, train 0.39, bus 0.76, traffic sign 0.86, truck 0.71, bike 0.68, motor 0.47.

Objective 4

The *generation of high-fidelity 3D models of urban and country areas* by exploiting visual data from UAVs, digital archives and web resources and satellite remote sensing data is implemented via the *3D reconstruction service*. The 3D reconstruction service accepts images uploaded by the user via the AT, or retrieved by the satellite service, or fed by the image analysis service (which retrieves images and videos from the internet) and reconstructs a georeferenced photo-textured 3D model that is post-processed for optimal performance in the Unity-based AT and VR application. The highest expectation is reached given that the user has grabbed the appropriate images, as the visual and geometric accuracy is heavily dependent on the initial raw images. The service is qualitatively evaluated by the users in the Pilots and quantitatively evaluated in suburban environments using drone images and GPS measurements as ground control points. The achieved resolution is 3cm (flight height ~100m) and 5cm accuracy.

Objective 5

The VR tool allows more than 2 users to simultaneously work on the same environment from the VR Device or desktop. More than 90% of the requirements were addressed, the only major requirement which was not implemented was VR Tutorials for the users which were provided live by the development team.

Objective 6

The objective was to develop an Authoring tool which can create projects/scenes and environments that can be used in VR as well as create a high level of situational awareness by importing and visualising data from the various backend components of the xR4DRAMA platform. The tool addresses more than 90% of the requirements laid by the user partners as well as provide additional functionalities which allow better situational awareness.

3.5 WP5: Platform development

WP task Assessment					
WP		5	Date:		April 2023
resp. Partner		NURO	Responsible QEG member		Yash Shekhawat
1. WP Objectives					
#	*Objective*			*Task*	*Milestone*
1	Create technical requirements and a complete			5.1	MS1,

<table>
<tr><td></td><td>system architecture</td><td></td><td>MS2</td></tr>
<tr><td>2</td><td>Develop an integrated system</td><td>5.2</td><td>MS2,
MS4</td></tr>
<tr><td>3</td><td>Develop and integrate a GIS system.</td><td>5.3</td><td>MS2,
MS4</td></tr>
<tr><td>4</td><td>Build a mobile awareness app for end users</td><td>5.4</td><td>MS2,
MS4</td></tr>
<tr><td colspan="4">2. Evaluation strategy</td></tr>
<tr><td>#</td><td colspan="3"></td></tr>
<tr><td>1</td><td colspan="3">• Assess if all the components have an integration plan, data flow and specifications specified.</td></tr>
<tr><td>2</td><td colspan="3">• Assess if all the components are integrated and the entire pipeline of the system can be run without/low manual intervention.</td></tr>
<tr><td>3</td><td colspan="3">• Evaluate the accuracy of the data displayed in the visualisation tool.</td></tr>
<tr><td>4</td><td colspan="3">In order to evaluate the performance of the mobile app we have to consider the following concerns:
• Flexibility: The flexibility of the application’s capabilities and their ability to respond to and perform in different scenarios and situations.
• System Complexity: Important is the role of the simplicity of the application regarding user interaction. Aspects like the effort and the time that is needed for a user to effectively use the app or number of steps needed to fulfil a task, have to be taken into consideration.
Major concerns in the user validation domain will be evaluated:
• Task-driven evaluation: The user of the app has to take a number of actions in different functionalities and measure the performance.
• Self-acting valuation: The user of the app will freely explore the application’s environment with a basic guidance and afterwards comment on the system’s functionality.</td></tr>
<tr><td colspan="4">3. Indicators</td></tr>
<tr><td>#</td><td>Highest expectation</td><td colspan="2">Lowest expectation</td></tr>
<tr><td>1</td><td>The system architecture meets at least 90% of user requirements.</td><td colspan="2">The system architecture meets at least 70% of user requirements.</td></tr>
<tr><td>2</td><td>All the components work without any manual intervention and a user is able to create a project as well as use the xR4DRAMA for situational awareness in any</td><td colspan="2">All the components work with low manual intervention and a user is able to create a project as well as use the xR4DRAMA for situational awareness in specified regions</td></tr>
</table>

<table>
<tr><td></td><td>region</td><td></td></tr>
<tr><td>3</td><td>Any geospatial query can be answered from the GIS Database</td><td>60% of the geospatial queries can be answered from the GIS Database</td></tr>
<tr><td>4</td><td>The application is fully functional in large scale tests:
Flexible in different environments from the required scenarios and use cases
Immediate familiarity from the users and a good use on their part.
Application Load speed <6s
Crash-free session rate >99,5% (during a session the possibility not to have a crash on the app)</td><td>The minimum version of the tasks can be fulfilled:
The predefined use cases and scenarios are fully covered but the app may have flexibility issues to new ones.
Difficulty for the tool to integrate in the users' ecosystem as a result to spend more time within a session.
Application Load speed <12s
Crash-free session rate ~99%</td></tr>
</table>

3.5.1 Final assessment

Objective 1

The objective was to create a robust system architecture and integration plan which addressed all the user requirements. More than 94% of the user requirements were addressed by the final version of the system. 168 issues and new features were reported/requested by the users on gitlab. 164 of those issues were addressed and closed in the development. The remaining issues were either deprecated or the features were deemed not useful by the users.

Objective 2

In most cases, no intervention is required for making the system usable, intervention is only required to create specific visualisations and situational awareness situations. All the components of the system are integrated to perform as intended and provide the functionality requested by the user.

Objective 3

The objective was to *develop and integrate a GIS system* in the xR4DRAMA platform, which is fully met as the developed GIS service is the core of the xR4DRAMA platform and every service and user front end depends on it. The GIS service supports the geographical entities in the project, i.e. POIs and ROIs, which are the essential organisation unit of the information in the platform. The highest expectation is met as the GIS handles all the geospatial vector information and queries requested by the users.

Objective 4

The main objective which is to build a mobile awareness app has been accomplished, the Citizen Awareness App V2.0.8 has been released. The application is fully integrated with the rest of the xR4DRAMA tools.

Regarding the evaluation of the app in terms of **flexibility**, the application is fully functional but was built to work in the predefined PUC1 and was tested in the two large scale pilot tests Vicenza. Flexibility with new ones may be an issue, e.g., built to address the Flood Disaster use case and not different disasters like a wildfire.

In terms of **system complexity**, the Vicenza municipality volunteers and the AAWA personnel had no previous experience with the app during the two pilots that were carried out, yet they were able to use it without any issues. Generally, there was no complaint about the familiarity of the application.

Finally, the loading speed is instant, most certainly less than 6s, and there were no crashes reported during the two Vicenza pilots that the application was tested on.

3.6 WP6: Use cases and system evaluation

WP task Assessment			
WP	6	Date:	April 2023
resp. Partner	AAWA	Responsible QEG member	Francesco Zaffanella
1. WP Objectives			

#	*Objective*	*Task*	*Milestone*
1	Define, design and specify the two pilot use cases	T6.1	MS1
2	Specify and refine the user requirements for both use cases	T6.2	MS1
3	Communicate and explain the user requirements to technical partners	T6.3	MS2
4	Evaluate the xR4DRAMA system and functionalities	T6.4	MS3, MS5
2. Evaluation strategy			
#			
1	Validation with both technology providers and users of the case studies.		
2	Validation of the initial and final requirements with both technology providers		

	and users of the case studies.	
3	The use case set ups have the aim to monitor xR4DRAMA platform's steps of development and to reveal any weaknesses and shortcomings in order to improve them into the next stages of the project and to implement the collaboration between technical partners and end users. Exercises (laboratory and field testing) will be organised to test the xR4DRAMA system by implementing all the use cases scenarios. Verification of the adherence to initial requirements and flawless integration of technology. Verification of the adherence to updated user requirements (after 1st prototype evaluation). Readiness for test in case studies. Indicator comparison will be chosen based on user requirements, but specific indicators will be visibility of system status, match between system and the real world, flexibility and efficiency of use, ability of managing/preventing errors, ability to provide help and documentation, clearness in visualizing the provided information from the system, quality of textual information.	
4	Verification of the adherence of the xR4DRAMA platform integrating all of its modules with case study requirements and the usefulness in in-vivo experiments. A systematic evaluation will be done by the users with the help of questionnaires, interviews, hot debriefs and written feedback. Results in terms of user satisfaction. Indicator comparison will be chosen based on use cases (e.g., platform usability, quality of information, faster information, etc.).	
3. Indicators		
#	*Highest expectation*	*Lowest expectation*
1	Very good correspondence of case studies as a representative showcase of the real world	Good correspondence of case studies as a representative showcase of the real world
2	Development of all requirements according to present-day technological potentials	Development of the necessary requirements for the basic functionality of the system
3	• Very good assessment of case study scenarios in terms of proximity of the test to real world problems • Percentage of fulfilled user requirements > 80%	• Good assessment of case study scenarios in terms of proximity of the test to real world problems • Percentage of fulfilled user requirements: 65-80%
4	• 25 users involved in the evaluation • Balanced user group in terms of gender, age, professional level • Very good results in terms of users‘ satisfaction (identified	• 15 users involved in the evaluation • The user group includes participants of both genders • Good results in terms of users‘ satisfaction (identified by questionnaires)

	by questionnaires)	

3.6.1 Final assessment

Objective 1

The objective here was to (roughly) define, design, and specify xR4DRAMA's pilot use cases. DW did so with great enthusiasm, working towards a comprehensive list of requirements right from the start. First documents and outlines were delivered only a couple of months after the project had been kicked off. DW all work in close collaboration with the technology providers and pilot users. Indicators show that the task was carried out in the best possible way: The two xR4DRAMA pilots were (and continue to be) excellent examples of real-world problems, and everything was conceived with state-of-the-art concepts and technology in mind.

Objective 2

This one was about specifying and refining the user requirements for both use cases. DW went on to develop and sharpen the needs of the project and its pilots in an iterative fashion, with many feedback loops (partners and users). The team kept an eye on the platform development, documented shortcomings, and made sure those were fixed in the next stage of development. Field tests played a particularly important role in the adjustment of requirements. Once again, typical indicators reveal a very good overall track record here: The final set of requirements addressed a wide variety of pain points and/or feature requests by users in the field (disaster management and media), serves as a blueprint for the extension of the platform into other domains, and draws on the latest digital technologies (which in xR4DRAMA also show emergence, i.e. the system is more than the sum of its parts).

Objective 3

The objective was to communicate effectively to technical partners the requirements necessary to develop an xR4DRAMA system useful in real-life situations and set up use-case scenarios to test it.

The use cases set up, recreating scenarios to be faced in disaster management or media production planning, were judged very good in terms of proximity of the test to real world problems, as testified also by the results of the questionnaire compiled by the end users after the 1st PUC1 pilot: 90% of the end-users involved declared that the pilot set up was realistic to reproduce a disaster management scenario, its evolution and cascading effects.

Furthermore, the achievement of a high percentage of satisfied requirements was a clear indicator of the achievement of the objective of communicating and explaining the requirements to the technical partners in a successful way: about 87.1% of the system requirements were fully or partially accomplished (94.7% of the system requirements reported in D6.2 were completely or partially fulfilled and among those not implemented there are requirements that the end-users had given a low level of priority; 9 of the 12 additional requirements, defined following the evaluation relating to the first cycle pilots and in any case with a low priority assigned, have been implemented) and 100% of the general requirements were accomplished.

Regarding PUC1-specific requirements, 96% of the functionalities requested for the Authoring and VR collaborative tools were completely or partially implemented, while 100% of the requirements for the two mobile applications were fulfilled. Regarding PUC2-specific requirements, 100% of the requirements were accomplished.

Objective 4

The objective was to qualitatively evaluate the xR4DRAMA system in terms of user satisfaction.

In the PUC1 pilot the end-users group involved a relatively small number, 16 people (6 AAWA technicians in the role of citizens; 5 Civil protection volunteers of Vicenza; 5 control room operators from AAWA and Vicenza municipality), not including some local reporters who followed the activities. The group was highly qualified in disaster management and in risk management-related technologies, and with a representation of different ages and genders. In the PUC2 pilot the end-users group involved 9 people who represented several important media planning departments (production, news, innovation unit, etc.) and have experience in media productions/journalism and immersive technology. The group was balanced in terms of gender and age.

The overall group of users involved in the second cycle evaluation was of 25 people, who declared a high level of satisfaction about the use of the xR4DRAMA system, defining the system as innovative especially because it combines several individual components and technologies in a unique system which increases situation awareness.

3.7 WP7: Dissemination and exploitation

WP task Assessment					
WP		7	Date:	April 2023	
resp. Partner		DW	Responsible QEG member	Nicolaus Heise	
1. WP Objectives					
#	*Objective*			*Task*	*Milestone*
1	to develop and implement a dissemination strategy			T7.1	MS1
2	to identify and initiate collaboration activity with other projects and contribute to standardisation bodies			T7.2	MS1
3	to develop a business plan based on a market analysis and IPR definitions of the modules			T7.3	MS2

<table>
<tr><td></td><td colspan="2">developed</td><td></td><td></td></tr>
<tr><td>4</td><td colspan="2">to develop an exploitation plan and a sustainability strategy that support each other</td><td>T7.4</td><td>MS5</td></tr>
<tr><td>5</td><td colspan="2">to develop an xR4DRAMA showcase</td><td>T7.5</td><td>MS5</td></tr>
<tr><th colspan="5">2. Evaluation strategy</th></tr>
<tr><th>#</th><th colspan="4"></th></tr>
<tr><td>1</td><td colspan="4">A quantitative evaluation will be used against the measurable dissemination goals quantified in Section 2.2.2.7 of the DoA:
For the xR4DRAMA website, the evaluation will be carried out in terms of:
• the number of site visits
• the number of articles published
For Social Media activities, the evaluation will be carried out in terms of:
• the followers and engagement (likes and comments) in LinkedIn and Twitter
For the number of conferences on which xR4DRAMA is presented, the evaluation will be carried out in relation tothe number of actual conferences (taking into account potential pandemic-related restrictions)</td></tr>
<tr><td>2</td><td colspan="4">For the number of collaborative development events, the evaluation will be carried out in relation tothe number of actual workshops (taking into account potential pandemic-related restrictions)</td></tr>
<tr><td>3</td><td colspan="4">Peer review of the business plan by an internal/external expert.</td></tr>
<tr><td>4</td><td colspan="4">Peer review of the exploitation plan by an internal/external expert.</td></tr>
<tr><td>5</td><td colspan="4">A qualitative evaluation of the public showcase will be made by internal/external experts who will be assigned by the Project Coordinator. The experts will evaluate:
• the video demo in terms of clarity and completeness
• the demonstrator in terms of reliability and timeliness
• the publications in terms of number
• the final project fact sheet in terms of clarity and completeness</td></tr>
<tr><th colspan="5">3. Indicators</th></tr>
<tr><th>#</th><th>Highest expectation</th><th colspan="3">Lowest expectation</th></tr>
<tr><td>1</td><td>100% achievement of the dissemination goals defined in Section 2.2.2.7 of the DoA and refined in D7.1 and D7.3.
• 250+ page views per month
• 100+ visitors per month
• an average visit duration of</td><td colspan="3">66% achievement of the dissemination goals defined in Section 2.2.2.7 of the DoA and refined in D7.1 and D7.3:
• ca. 165+ page views per month
• ca. 66+ visitors per month
• an average visit duration of ca. 1 min + x</td></tr>
</table>

	1:30 min + x • visitors from 20+ countries • 10+ tweets per month • a final number of 125+ Twitter followers • 3000+ tweet impressions per month • 1500+ Twitter profile visits per month • 3+ Twitter mentions per month • 4+ publications per year • 4+ public presentations per year • 4+ events attended per year	• visitors from 12+ countries • ca. 6+ tweets per month • a final number of ca. 80+ Twitter followers • ca. 2000+ tweet impressions per month • ca. 1000+ Twitter profile visits per month • ca. 2+ Twitter mentions per month • 2-3 publications per year • 2-3 public presentations per year • 2-3 events attend per year
2	100% achievement of the dissemination goals defined in Section 2.2.2.7 of the DoA: • 4 co-design and collaborative development events • 15 expert participants per event	66% achievement of the dissemination goals defined in Section 2.2.2.7 of the DoA: • 3 co-design and collaborative development events • 10 expert participants per event
3	No comments regarding the quality and the expected effectiveness of the business plan.	Minor comments regarding the quality and the expected effectiveness of the business plan.
4	No comments regarding the quality and the expected effectiveness of the exploitation plan.	Minor comments regarding the quality and the expected effectiveness of the exploitation plan.
5	No comments regarding the quality and the expected effectiveness of the showcase.	Minor comments regarding the quality and the expected effectiveness of the showcase.

3.7.1 Final assessment

Objective 1

In WP7, was carried out under the general supervision of DW, the main goal was to develop and implement a sophisticated communication and dissemination strategy.

DW went to work right away so that even before the first deliverables were due, the project had a recognizable and active web presence. By the end of the project, xR4DRAMA ran a lot of channels and provided even more background and promotion materials. There were: a website including a frequently updated blog, social media presence with a responsive community, a collection of papers and project materials, press releases, and several appearances at expert conferences and industry meetings.

Dissemination goals (as outlined above) were met at 100% and often exceeded, with the exception of the not too relevant Twitter stats, where impressions turned out to be substantially lower as expected, and profile visits and mentions were slightly lower. As already explained, this may have to do with the platform's massive changes and hiccups since the 2022 takeover.

Objective 2

For this objective we have achieved the highest expectation, 100% of the dissemination goals defined in Section 2.2.2.7 of the DoA. We have organised in total 4 co-design and collaborative development events. Specifically, 2 user workshops in the beginning of the project and 2 co-design and collaborative development sessions during the first pilots took place. There were at least 15 participants in each one of these events.

Objective 3

A business plan was presented to the partners with no significant changes requested or comments received.

Objective 4

An exploitation plan was presented to the partners with no significant changes requested or comments received.

Objective 5

DW produced a 12-minute documentary about xR4DRAMA that features all partners, technologies, and use cases. It was shot over the course of two months in three countries (Germany, Greece, Italy). A rough master cut premiered at the last consortium meeting in Thessaloniki, in late April 2023. All partners were very happy with the film, felt well presented, and thought of the production as an excellent means of project dissemination. There were no negative comments. Upon its official release in June 2023, the xR4DRAMA film not only be featured on several video portals and websites, but also aired on international TV.

3.8 WP8: Ethics requirements

WP task Assessment			
WP	8	Date:	April 2023
resp. Partner	CERTH	Responsible QEG member	Spyridon Symeonidis, Nicolaus Heise
1. WP Objectives			

#	*Objective*		*Milestone*
1	Set out the 'ethics requirements' that the project must comply with.		MS1-MS5
2. Evaluation strategy			
#			
1	Assessment of the 'ethics requirements' plan and guidelines by the Ethics Advisory Board.		
3. Indicators			
#	*Highest expectation*	*Lowest expectation*	
1	No objections from the Ethics Advisory Board and thus no need for remedial actions.	Remedial actions required to address the objections of the Ethics Advisory Board.	

3.8.1 Final assessment

Objective 1

The xR4DRAMA consortium has paid particular attention to the identification and monitoring of the ethics issues raised by the research. Already before the beginning of the project, the xR4DRAMA Consortium set out the project's ethics requirements. During the lifespan of the project, it had to deliver six deliverables dedicated to ethics (five of them already till M10), successfully addressing all potential issues that would arise from human participation to research activities, presenting the adopted safeguards and mitigation measures as well as the project's adherence to EU regulations.

At the beginning of the project, xR4DRAMA consortium established a very efficient Ethics Advisory Board (EAB) which consisted of one representative from the consortium and one external, both experts in ethics and data protection. The Ethics Advisory Board provided its views, comments and suggestions regarding ethical issues related to project's activities, outlining potential risks, and continuously consulting and advising the consortium throughout the project evolution. Since the beginning of the project, EAB members have given their advice, feedback and consultation on issues related to (1) Privacy and data protection, (2) Copyright protection and (3) other ethical and societal implications. Through their participation in selected meetings as well as the review of certain deliverables, they mainly provided their views and initial recommendations especially in activities related to human participation and data protection, in terms of conformity of the project's activities and outcomes with the Horizon 2020 guidelines, National and European regulations and ethics in research.

Their initial recommendations, which have been thoroughly presented in D8.5, had been seriously taken into account by the xR4DRAMA consortium, which addressed all of them, taking concrete corrective actions (as described in D8.6). The final opinion of the EAB (D8.6) on xR4DRAMA activities is positive, indicating that the project approached the accomplishment of the highest expectation, with no need for remedial actions.

4 IMPACT

4.1 xR4DRAMA's contribution towards topic's expected impact

Expected impact	xR4DRAMA contribution towards expected impact
Increase in the use of Interactive Technologies in the industrial and societal domains.	xR4DRAMA introduced the concept of *situation awareness* to improve the anticipation, planning, observation and managing of large-scale events. This refers not only to unexpected or sudden occurrences (e.g., natural disasters or accidents), but also to planned events, such as media productions, demonstrations, sport or cultural events, and the organisation of large-scale gatherings in general. This situation awareness is established and enhanced using AR and VR technologies that can be operated and adapted remotely as well as by personnel on site (such as first responders and location scouts). More specifically, geo-referenced AR applications allow to bring large scale infrastructure information to the eyes of field operators via the GIS backend. The use of such a tool extends far beyond the PUCs of xR4DRAMA; construction works, inspection processes, infrastructure maintenance can adapt comprehensive XR tools to monitor the progress of the tasks and objectively guide the behaviour of their employees for efficiency, cost reduction, and safety reasons. Furthermore, the terrain reconstruction from the Satellite Service is based on the Copernicus satellite service, which is a key service provided freely by the EU and exploited by numerous public services in the EU member countries. The service developed in xR4DRAMA could be of great use in a variety of XR applications that need a 3D model for the immersive experience. More details about industrial and societal impact are provided in sections 4.2 and 4.3.
Increase in the number of European SMEs and start-ups who benefit from technology transfer	Dissemination and communication activities during the project also included reaching out to startups and SMEs – via social media posts/messages and via meetings/talks at events. The consortium followed a content marketing approach in this context. Contacts (and leads) were generated by demonstrating knowledge, asking questions, and explaining how xR4DRAMA as a platform (or components of it) can benefit individual companies and their solutions. In this way, the consortium was able to connect and interact with a significant number of stakeholder companies across Europe, many of which had already been active in the IT and media bubble but were at

	the same time new to the multimodal approach of xR4DRAMA. The consortium successfully promoted the idea to boost situation awareness via an XR-AI-IoT mix, clear contribution to Pan-European R&D communication and technology transfer.
Increase in market opportunities in the Interactive Technologies sector for European SMEs	The consortium's approach integrated user-centricity with challenges inherent to SME operations. It developed use cases and user requirements considering SME and industry partner needs, thereby tailoring solutions to be market oriented. Efforts were strategically channelled into employing accessible or reasonably priced existing technology, consistently prioritising cost-effectiveness to facilitate market entry. Project results, in turn, were presented either as open-source or very affordable, aligning with the commitment to accessibility. xR4DRAMA introduces a pioneering platform combining XR, IoT, AI, data analytics and a number of other technologies, thereby expanding market horizons and establishing the concept a new, immersive concept of situation awareness. The adoption of xR4DRAMA promises European SMEs a competitive advantage, enhancing productivity and fostering innovation. xR4DRAMA's fusion of technologies cultivates a suite of applications with transformative potential across diverse business sectors. Its utilisation enables all kinds of immersive/collaborative planning, scouting, and managing work with regard to remote or had-to-access locations. Within the disaster management sector, a highly fragmented market often resorts to free software solutions. However, xR4DRAMA presents a custom tool conforming to rigorous cybersecurity, data retention, backup, and disaster recovery standards. Its proficiency extends to data interoperability and portability, team management, and localisation. The incorporated VR/AR technologies facilitate a virtual platform, enabling emergency planners to visualise safe paths and potential impediments. This utility serves as an invaluable asset to SMEs dedicated to safety and security management, making xR4DRAMA an instrumental tool in modern business operations. Looking at the media sector, xR4DRAMA and products derived from it have the chance to become powerful, disruptive tools for production planners/content creators and their teams. Instead of using a plethora

	of other, often incompatible apps (as it is still common today), those stakeholders can opt for a "one stop shop" instead: xR4DRAMA offers a detail-rich, customised, immersive, and completely private 3D map with multimedia notebook and task managing functions. This could change the game for countless media workers who need to produce content "in the field" – and it is a great opportunity for SMEs in the interactive tech sector catering to them.

4.2 Industrial impact

The main industries targeted by xR4DRAMA are Disaster Management and Journalism. The following section describes the impact on both industries.

Disaster Management Industry:

The political landscape strongly emphasises disaster management, especially regarding floods, due to increased precipitation levels and rising coastal water levels. Economically, the cost of disasters is significant, with flood damage in Europe potentially rising to €44 billion per year in a 3°C global warming scenario. However, investments in disaster management technologies such as xR4DRAMA could significantly reduce these costs. The social impact of natural disasters, including trauma and community disruption, also underscores the importance of efficient disaster response systems. Technologically, xR4DRAMA ensured it remained up to date with the latest advances to ensure maximum effectiveness. Legal considerations include ensuring compliance with data privacy laws and acquiring necessary permissions for operations like drone flights. Environmentally, effective disaster management can minimise damage to ecosystems and other environmental resources.

Media Production Industry:

Politically, free access to information and open media production is promoted, although the rise of digital and social media has raised concerns about misinformation and cyber harassment. Economically, media plays a significant role in economic development, with the potential for technology optimisation to further boost this impact. Socially, the media has the power to inform public opinion and incite social change, with an increasing emphasis on digital and social media platforms. Technologically, xR4DRAMA can significantly enhance media production planning using VR and AR technologies. Legally, compliance with privacy policies and data protection laws is crucial, particularly considering the vast amounts of information involved in media production. Environmentally, digital tools like xR4DRAMA can reduce the need for on-site personnel and heavy equipment, minimising environmental impact.

In conclusion, both the disaster management and media production industries present significant opportunities for xR4DRAMA. Both industries are heavily impacted by political, economic, social, technological, legal, and environmental factors. To succeed, xR4DRAMA adapted to these dynamic environments, ensuring compliance with relevant laws and regulations, keeping pace with technological advancements, and demonstrating clear value in economic and environmental terms.

4.3 Societal impact

Natural disasters have a huge impact on society. They can cause trauma and grief that can put people, families, and communities under immense pressure. This is usually caused by the loss of jobs, loss of people, loss of homes etc. which can lead to mental health issues, alcohol over usage, drug usage, domestic violence and other crimes that can disrupt and degrade the society as a whole. In general, disasters will lead to physical, psychological, emotional, and economical disruptions in a society. It is also important to note that people and communities with strong social connections (like metropolitan cities) and sufficient resources will be less affected by a disaster as compared to more vulnerable communities (rural settlements near water bodies) with limited resources. Major actions that a society will have to take after a disaster include rebuilding/reconstruction of public and private infrastructure, access to health care, temporary shelter, financial aid etc. Finally, the report from the Australian Business Roundtable for Disaster Resilience & Safer Communities stated that during the 2009 Black Saturday Bushfires in Australia, the costs in terms of social impact were higher ($3.9 billion)[20] compared to costs related to financial impacts which were $3.1 billion in Victoria. These costs of social impact included costs related to mental health issues, high alcohol consumption, chronic diseases, family violence and environmental damage. This importantly points out to the fact that disasters have an equally severe if not greater impact on the society compared to the economic impact[21]. xR4DRAMA aims to increase the preparedness for disasters such as floods and to mitigate the consequences of them by increasing the awareness of all people involved in such situations (professionals dealing with them and the general public). This will lead to better decision making and a more efficient course of action which will as a result significantly reduce any related negative impact from these disasters.

Concerning the media production planning use case, the societal impacts are also noteworthy. Media has the power to affect a society positively as well as negatively. Media plays the role of delivering information to the public which helps them form an opinion and subsequently bring about a social change. These social issues could be public health, infrastructure, crime, marriages, gender discrimination, racism, climate change and so on. The major source of information for people is media which includes newspapers, radio, television, smart phones, and nowadays social media channels. Through these media channels, people gain knowledge, form opinions, and take actions. Nowadays social media has taken over the world and according to Statista there are approximately 4.6 billion users of social media currently[22]. This figure itself shows the reach of media in today's world and how much power it has, to create a social impact. To achieve a positive societal impact, the

[20] https://vcoss.org.au/emergency-management/2016/03/the-social-impact-of-natural-disasters-at-what-cost/
[21] http://australianbusinessroundtable.com.au/assets/documents/Factsheets/Factsheet%20-%20The%20economic%20Cost%20of%20the%20Social%20Impact%20of%20Natural%20Disasters.pdf
[22] https://www.statista.com/topics/1164/social-networks/#dossierKeyfigures

quality of a media production must be increased, and xR4DRAMA supports that goal by increasing the situation awareness of remote locations that are previously unexplored by the media professionals. Designated production sites thus become very tangible, and this enhanced comprehension can be easily communicated to the audience who receives the final product of media production planning.

4.4 Scientific and technical impact

xR4DRAMA delivered a number of high-impact contributions to the technical and scientific fields of relevance. 3D reconstruction and modelling based on multimodal content were improved as large-scale data collection and processing algorithms (assets localisation, space sensing, remote sensing) dealt with challenges of real-world conditions of the pilots and aimed at faster reconstruction times while maintaining precision. Multimodal analysis, from IoT signals to GIS, video, text, and audio went beyond the SoA for the assessment of the current situation in public spaces during crisis incidents and events, such as scene assets, damage assessment and actors' physiological condition, allowing to manage risks, and plan media productions or intervene when appropriate using the xR4DRAMA decision support system. The AR application for first responders featured GIS-aided localisation to allow for uninterrupted navigation of multiple actors in the field and was seamlessly connected with the authoring tool and VR environment in the production offices and control rooms. The resulting environments (3D desktop, VR etc.) enhance training and emergency preparedness of first responders, and provide immediate situation awareness by adapting in real-time, exploring and dealing with different coverage and management scenarios in the virtual world.

The main technical impacts achieved by xR4DRAMA are:

- Dynamically adaptive 3D environments enabling both real time VR representations and offline VR simulations for media production planning, first responder units training and crisis incidents assessment;
- Task management system that enables control room to assign tasks to people in the field and track their status;
- GIS-assisted AR applications for field teams, allowing real-time situation awareness, seamless communication and data exchange with the control room and the office production team;
- Smart vest system for physiological monitoring of the actors in the field;
- The development of awareness application for citizens providing them real-time information about crisis events, thus enabling situation awareness also for the general public;
- Methods for efficient extraction and retrieval of online media and crisis-related content from various sources.

The main scientific impacts are advances in a number of research fields, including:

- SoA approaches for the analysis of physiological signals and users’ stress-levels;
- Development of adaptive, immersive XR environments by measuring and interpreting multi-modal local, environmental and user assets.

- SoA approaches in natural language processing, such as robust multilingual speech recognition, semantic language analysis and projection of the output onto ontological structures; speech-based stress level prediction; and large coverage multilingual language generation;
- Novel methods for 3D reconstruction of outdoor environments based on multimodal input, such as drone recordings, images and videos retrieved from the web and social media, and remote sensing data;
- Innovative computer vision methods for scene recognition, photorealistic style transfer, building and object localisation, emergency classification and river overtopping detection;
- Semantic integration of multimodal data inputs and reasoning for the creation of domain-specific decision support systems.

5 CONCLUSIONS

In this deliverable, we described the final outcomes of the xR4DRAMA project, along with a brief outline of the Data Management Plan (DMP), provided the results of the Self-Assessment Plan (SAP) and showed the project's impact.

The members of the xR4DRAMA consortium were introduced, as well as the main objectives that were explained. Following, the key results that were produced to fulfil these objectives were described.

As regards the DMP, we summarised the main categories of data in xR4DRAMA, the actions we took to identify and record the relevant datasets that would be used during the lifespan of the project, and the measures we applied for the collection, sharing, management and protection of the data, including personal ones. The preparation of the DMP was also driven by the guideline on data management set in Horizon 2020 and the recommendations that were provided by the Ethics Advisory Board in the first year of the project.

Additionally, the SAP was detailed which includes the evaluation results based on the indicated KPIs. The assessment was designed and conducted per work package and tasks to monitor and guarantee the successful outcome of every activity of the project. The measurements show that the expectations have been fulfilled for all the project's tasks.

Lastly, we provided evidence about the positive impact the xR4DRAMA project and its implemented solutions achieved. Several aspects were examined, namely the industrial, the societal, the scientific and the technical ones, in order to prove the significant added value the project generated.

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