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Machine learning techniques and Big Data analysis for flood risk management, assessment of droughts and other extreme climate events: different approaches

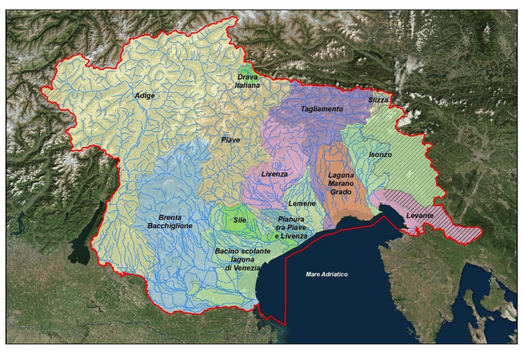
Michele Ferri[1], Francesca Lombardo[1], Daniele Norbiato[1], Roberto Fiorin[1], Martina Monego[1], Lisa Napolitano[1]

(1)Autorità di Bacino distrettuale delle Alpi Orientali, Venice, Italy. Michele.ferri@distrettoalpiorientali.it

CONTEXT – The Oriental Alps River District & The Flood Risk Management Plan

Considering the challenges presented by the climate and global changes, the Basin District Authority of the Oriental Alps River District (AAWA), as the competent authority appointed for implementing The EU Directives 2007/60/EC and 2000/60/EC in the Oriental Alps River District, is exploring innovative methodologies for water management, assessing the flood risk, droughts and the status of water bodies.

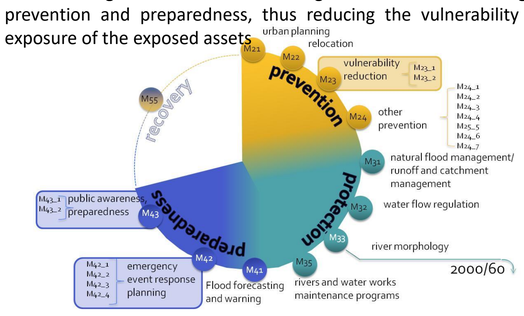
https://sigma.disrettoalpiorientali.it/portal/

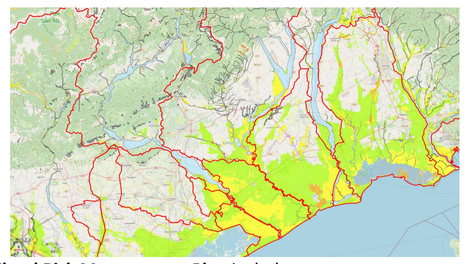


The Oriental Alpes River Districtct

- ✓14 basins with different hydrological and morphological aspects
- ✓2 lagoon environments of particular interest
- ✓2 autonomous provinces
- ✓3 Regions

In the Oriental Alps River District (DAO), North East of Italy, the **flood risk management plan** (FRMP - in actuation of the 2007/60/EC directive) is prioritizing new **innovative non - structural measures** for water management and for assessing the flood risk focusing on prevention and preparedness, thus reducing the vulnerability and exposure of the exposed assets





The **Flood Risk Management Plan** includes:

- flood hazard and risk maps or the whole district
- objectives for the purpose of managing the flood risk
- the conclusions drawn from the flood hazard and risk maps
- proposed measures for achieving those objectives, falling in the categories of prevention (M2), Protection (M3), Preparedness (M4) and other (m5)

APPROACH: H2020 research projects for flood risk management in the District

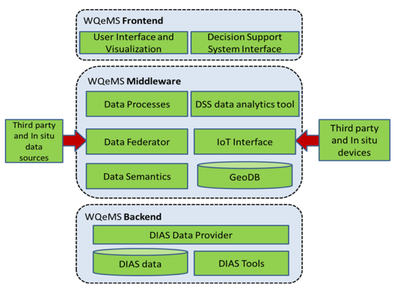
Past experiences (Ferri et al. 2018) prove that particular effective approaches for an integrate water and extreme climate event management rely in the aggregation of **hybrid datasets from various sources**, including both **'artificial sensors'** (e.g. traditional environmental monitoring and detection sensors, remote sensing, surveillance cameras etc.) and '**social sensors**'. However, heterogeneous data collection, aggregation and visualization alone may not be enough to achieve an efficient water management. In fact, one of the most critical challenge faced by authorities during the managing of a water-related crisis is the overwhelming flow of heterogeneous information coming from humans and sensors, which has to be processed in order to filter meaningful items and provide **crisis decision support** (Kontopoulos et. al 2018). Examples of such technologies are the one being developed inside **various Horizon 2020 European projects followed by AAWA**:

XR4DRAMA (Extended Reality For DisasteR management And Media planning - Call: H2020-ICT-2018-20, G.A. 952133, https://xr4drama.eu/);

The **XR4DRAMA approach** is about facilitating the sourcing of all relevant (digital) information (satellite images, AV content from social media and drones, sensor data) needed to deal with a specific, potentially dangerous or challenging scenario faced by natural disaster managers. creating immersive representations of the environment via XR technology to anticipate the event as accurate as possible and to understand and re-assess consequences of specific actions/decisions.

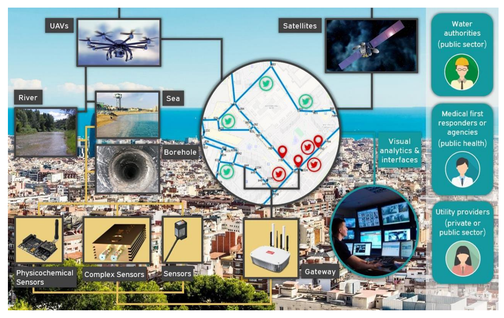
WQeMS project (Copernicus Assisted Lake Water Quality Emergency Monitoring Service - Call: H2020-SPACE-2020, G.A. 101004157, https://wqems.eu/);

WQeMS approach aims to provide an operational water emergency monitoring service in order to support and complement existing decision support systems, including both **quantitative (**in alignment to 2007/60/EC) **qualitative aspects** (in alignment to 2000/60/EC). The target is the optimization of the use of resources by gaining access to frequently acquired, wide covering and locally accurate water-status information.



WQeMS starts from the latest developments and advances in the Copernicus EMS, identifying the adaptation needs of existing products and services, as well as suggesting n**ew ones to be added in the existing portfolio.**

aqua3S project (Enhancing Standardisation strategies to integrate innovative technologies for Safety and Security in existing water networks – call: H2020-SU-SEC-2018, G.A. 832876, https://aqua3s.eu/)

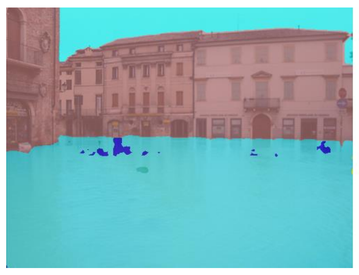


The aqua3S approach consists in combing novel technologies in water safety and security, aiming to standardise existing sensor technologies complemented by state-of-the-art detection mechanisms. The aim is to reach an integrate water and extreme climate event management, with a focus also on **water distribution and supply networks**, through incorporation of existing sensor networks with videos from UAVs satellite images and social media observations.

Dedicated components are developed for heterogeneous data collection, harmonization trough a dedicate ontology and storage. Semantic representation and data fusion provides intelligent decision support systems, alerts and messages to the public. Finally, the user interface offers the most suitable visualization for each type of data

THE ALGORITHMS: some examples of the developed technologies and their application in the District

Big data fusion & Machine learning techniques for Managing the emergencial phase of an extreme climate related emergency



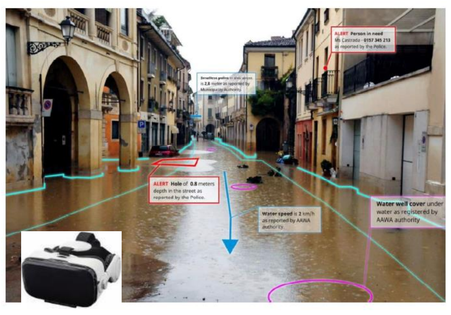
```
Objects localised:
water (48.86%)
building (41.48%)
sky (9.11%)
sea (0.045%)
river (0.008%)
```

The xR4DRAMA Visual Analysis service uses modern **image classification and segmentation techniques** to identify the type of scene, recognize if there is a flood, extract information about people and vehicles in danger, as well as to localize surrounding infrastructure.

The Visual Analysis service also detects river overtopping through the **analysis of videos from static cameras and videos sent by citizens and first responders** through dedicated apps.

Similarly, the text analysis service **extracts relevant information from audio messages sent by citizens and tweets**, to detect and tag emergency-related situations (such as people in danger, blocked or flooded roads, etc.).

```
scene: canal_urban (confidence level: 83.83%)
is_outdoor: True
emergency: flood (confidence level: 99.12%)
people_in_danger: 0
vehicles_in_danger: 0
```



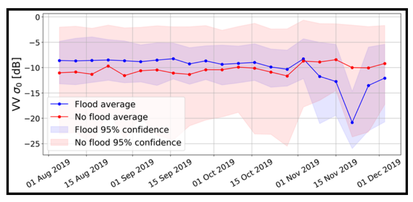
The **XR4DRAMA Decision Support System** extracts knowledge from the textual and visual analysis modules in order to automatically provide a severity score (a degree of emergency) to the point of interest (POI) identified in the context of flood risk management.

The **physiological data acquisition** module uses a wearable system (smart vest) for monitoring physiological parameters, movements of the trunk and posture of the first responders in the field and integrates the data in the XR4DRAMA platform, where the signals are analysed to extract **stress levels predictions using machine learning techniques.**

All the information are presented to the end users creating **immersive representations of the environment via XR/VR technology**. The approach has been tested in a Pilot Use case based in the **city of Vicenza.**

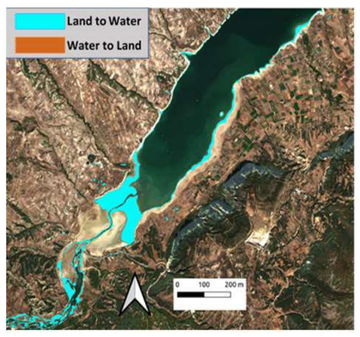
Big data fusion & Machine learning techniques for Qualitative and Quantitative assessment of water bodies

WQeMS is developing extreme events services to offering extended and frequent coverage in monitoring water bodies both form a quantitative and qualitative perspective, as well as site specific elaboration and analysis. The service is developed in utilize Copernicus satellite products (Sentinel-1 and Sentinel-2) to identify occurrence extreme events in water bodies which can also degrade water quality. The focus is on mapping floods and hydrocarbon formations and muddy water which is usually owed to extreme rainfall/flood events. This is achieved by utilizing ONDA DIAS infrastructure and data provision, and developing advance deep learning models which are capable of discovering patterns in such data



For flood detection, time series of Sentinel-1 data are used. are used as input to a custom deep neural network model. The model inherently exploits temporal information in order to learn temporal patterns that are mostly characteristic under the presence of an extreme flood event. As a result, extreme flood maps can be generated every time Sentinel-1 passes over the interested area. At the same time several statistics that are indicative of the magnitude of a flood event are calculated and will be available to the user. Since produced flood products are based on Synthetic Aperture Radar data, which are not prone to weather and sun illumination conditions.

The **land-water transition zone changes detection service element** performs inundation mapping at areas of interest, detect possible changes that took place between dates or seasons and calculate the inundation regime of the land-water transition zones



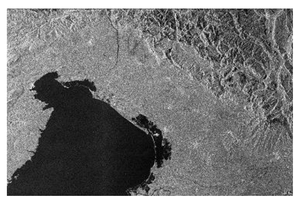
For Hydrocarbon formation detection, WQeMS develops an oil spill detection module that identifies hydrocarbon formations in inland waters based on Copernicus Sentinel-2 high resolution data derived from ONDA DIAS. A novel deep learning algorithm targets small-scale oil spill events observed for the first time in inland waters, which is more challenging compared to coastal and open sea waters.

These services are complemented with the development of a **mobile app and an alerting module,** where end users are able to post text, photo, and location of an occurring water related event. A social media crawler that collects public Twitter posts, which refer to water-related incidents, is utilized to search for emerging instances at the water bodies

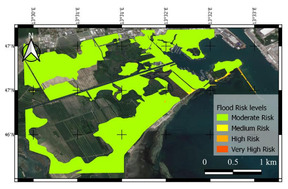
The Overall approach is current tested in the context Oriental Alpes River District, in particular for the monitoring of the **Giaretta Lake** (also known as Camazzole) located in the Province of Padova, Municipality of Carmignano di Brenta.

Big data fusion & Machine learning techniques for managing the water distribution and supply system during extreme event

In the context of aqua3s, dedicated algorithms have been deployed to extract from heterogeneous data sources only information that are most useful for an effective water management and to provide assessment of potential crisis situation, which can also impact water distribution and supply network

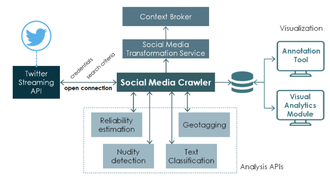


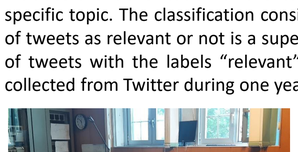
Identification of the extension of water bodies and/or of flooded areas from Satellite (Sentinel-1) images and estimation of water depth. Firstly, a Visual Content Acquisition Module (Moumtzidou et al. 2020) extracts data from the Copernicus Open Access Hub . The approach for the extension detection consists in pixel-based classification on thresholds over the processed VH band. In order to limit the background noise, the algorithm is being validated by AAWA experts which annotated the data processed by a set of satellite images of the District from 2019, including the ones capturing the flood event of November 2019. In some specific areas of interest (Muggia, Trieste and the Isonzo River Plain) the water level of the detected areas is also estimated trough a high resolution Digital Elevation Model (DEM)

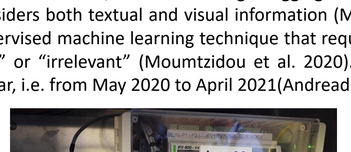


Automatic flood risk and hazard mapping from satellite images, applied to the areas detected by the previous algorithm. The mapping criteria are derived from flood risk and hazard maps in the update of the FRMP -II Cycle (AAWA 2021). Hazard classification involves an estimation of water depth, which requires in turn the elaboration of data from the DEM, for calculating slope, and from the Corine landcover for estimating the roughness. Risk classification instead, as the combination of the probability of an event and its negative consequences (EC, 2007), requires a set of socio - economic and demographic datasets for assessing vulnerability and exposure (AAWA 2021). The GIS layers used are the same of the FRMP of DAO.

Social Media Monitoring. This feature aims to collect and analyze social media data, specifically posts from Twitter. A dedicated crawler tool has been implemented to receive in almost real-time tweets that satisfy a query, based onto a set of keywords (in Italian and English) related to a specific topic (such as natural disaster or water contamination related terminology). For every received tweet, the procedure includes the identification of eventual fake news; the automatic geotagging and the classification of a tweet as relevant or not to the specific topic. The classification considers both textual and visual information (Moumtzidou et al 2018). The automatic text classification of tweets as relevant or not is a supervised machine learning technique that requires to be trained with manual annotation to mark a set of tweets with the labels "relevant" or "irrelevant" (Moumtzidou et al. 2020). The annotation dataset consists in social media posts collected from Twitter during one year, i.e. from May 2020 to April 2021(Andreadis et al. 2021).







Anomaly detection based on almost real time data acquisition from monitoring sensors and numeric simulation models. The system allow associating to qualitative and quantitative variables a set of threshold values, defined by user as representative of an anomaly situation (i.e. drought, a flood, a contamination etc.). In case of data acquisition out of the range, automatic warning is provided. Possible operational scenario are also available according to the specific anomaly event triggered

The aqua3S approach is currently under development and prototypes of the system are planned to be tested in seven operational scenarios chosen across different EU countries to represent a wide spectrum of situations in water management, each one with its unique features, challenges and goals. The Oriental Alpese River District, and in particular the **area of Trieste, Muggia and the Isonzo River Plain** will be one of those "testing grounds".

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