

MULTIMODAL DATA FUSION OF SOCIAL MEDIA AND SATELLITE IMAGES FOR EMERGENCY RESPONSE AND DECISION-MAKING

Ilias Gialampoukidis, Stelios Andreadis, Stefanos Vrochidis and Ioannis Kompatsiaris

Information Technologies Institute
Centre for Research and Technology Hellas
6th Km Charilaou-Thermi road, 57001, Thessaloniki, Greece

ABSTRACT

Artificial Intelligence (AI) is already part of our lives and is extensively entering the space sector to offer value-added Earth Observation (EO) products and services. The Copernicus programme provides data on a free, full and open basis, while the recently launched Data and Information Access Service (DIAS) providers index, store and exchange tremendous amounts of data and cloud infrastructure computational resources. Copernicus data and other georeferenced data sources are often highly heterogeneous, distributed and semantically fragmented. One example is the massively generated social media data from citizen observations, including visual, textual and spatiotemporal information. Social media information offers reliable, timely and very prescriptive information about a crisis event. In this work we present the multimodal fusion aspects for combining satellite images and social media for emergency response, such as flood monitoring and extreme weather conditions in polar regions.

Index Terms— Multimodal data fusion, Social Media, Emergency response, Decision-making, Deep Learning

1. INTRODUCTION

During the past decades, emergency response was based mainly on phone calls and other methods to respond during a crisis event, lacking real-time and multimodal information about the affected area. Nowadays, the monitoring of a crisis event takes into account the ubiquitous visual content that becomes available to civil protection agencies and authorities from social media, static cameras or cameras on board of a drone, and satellite images.

Satellite images are often used for rapid mapping and recovery, but the available streams of social media posts are a valuable data source that can enhance the existing estimations, such as the estimated snow depth in a near-urban area [1]. The mapping services from satellite imagery may also be

enhanced with geotagged images, relevant text messages and temporal information for multimodal event detection [2, 3].

The revisit time of a satellite defines the temporal availability of the first mapping of an area after a disaster occurs. The ground segments of space systems receive the satellite image from the area of interest, while additional layers of geospatial information is already available from other distributed sources of data, such as citizen observations from social media. The main challenge is to fuse these multimedia data with satellite images for a more effective mechanism that may assist first responders in their daily operations.

2. DATA MINING IN SOCIAL MEDIA

Social media are collected and filtered in terms of relevancy to a target event (e.g. Twitter posts referring to a specific flood incident) using both visual and textual information with deep vector representations from deep neural networks [4] in a binary classification problem to filter out irrelevant tweets.

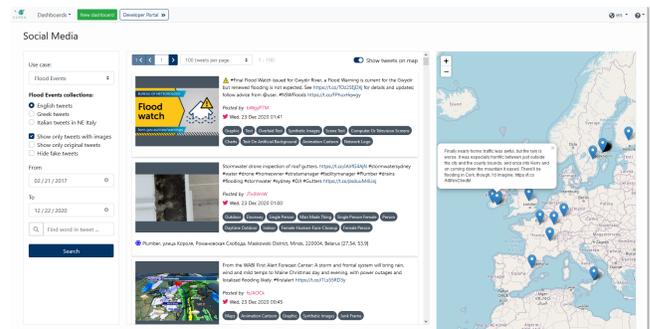


Fig. 1. A social media dashboard with locations and filtering options.

The temporal dimension of a tweet is available, allowing for burst analysis to identify extreme events in the time series of relevant tweets, based on the extracted contextual information. However, the spatial dimension is rarely available and the geographical location needs to be estimated for positioning georeferenced tweets (images, text) on a map, offer-

This work has been supported by the projects H2020-EOPEN and H2020-CALLISTO with grant agreements 776019 and 101004152 respectively.

ing situational awareness through social media analytics. The tweet localization uses first Named Entity Recognition to extract locations in raw text, which are then linked to external Knowledge Bases (e.g. OpenStreetMap) to get the latitude and longitude of each mentioned location. These social media analytics are demonstrated in Figure 1.

Temporal and spatial information together are correlated with the outcomes of the analysis of a satellite image, such as Sentinel 1 for snow depth estimation or water body detection.

Searching in large amounts of Earth Observation data with respect to a multimodal query can be also triggered by a social media search with respect to a multimodal text-image query [5]. The multimodal character of satellite images results from the various number of channels and associated metadata (date, time, geographical location, mission, etc.). Each satellite image can be considered as a collection of satellite image patches with semantic information about each one of them, as concepts correspond to each patch (e.g. urban area, rock, water, snow, etc.). These concepts also appear in social media streams, where a concept extraction algorithm is applied, and allow for semantically correlating social media posts or events with satellite images that contain the same concepts in their patches [6].

3. MULTIMODAL DATA FUSION WITH SENTINEL IMAGES

Multimodal fusion combines several and heterogenous data sources or information extracted to provide meaningful decisions or enhanced and accurate estimations for operational purposes. Fusion can take place also at a semantic layer where web technologies offer the tools to link data and consider the available policy-driven rules for decision-making [7].

At the feature level the technologies combine the vector representations per modality in an early fusion manner. However, a late or hybrid fusion approach effectively combines the decisions per modality [8].

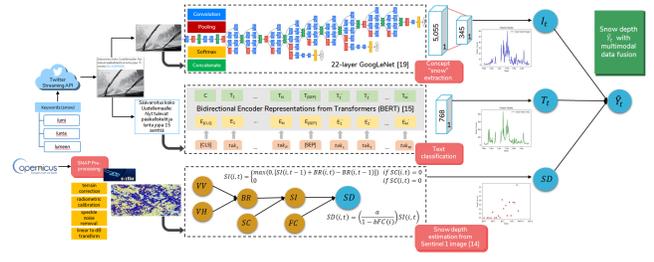


Fig. 2. A multimodal fusion framework for snow depth estimation using social media and Sentinel 1 images [1].

The multimodal fusion framework for snow depth estimation using Earth Observation and social media data, as it is proposed in [1], is shown in Figure 2. The visual concept *snow* is extracted, the relevance of the Twitter text to the ac-

tual meaning of *snow* is estimated using Natural Language Processing and the snow depth is estimated from Sentinel 1 images. All these highly-heterogeneous data and knowledge extracted are combined towards a novel snow depth estimation with multimodal data fusion.

Earth Observation and social multimodal data fusion offers a plethora of visual analytics tools for natural hazard monitoring and water safety, security, and management [3]. Satellite image analysis for water mask extraction in flooded areas already fuses satellite image channels with Digital Elevation Model (DEM) measurements [9]. Traffic management during the first hours of a crisis event is also supported by a road passability service [10] to infer whether a road segment from point A to point B is passable or not due to flooding. Annotated datasets have been provided in the context of Multimedia Evaluation Benchmark tasks, such as the Multimedia Satellite Task and its successors¹. The problem of fusing social media and satellite images has also been tackled in the EOPEN² project, as shown in Figure 3.

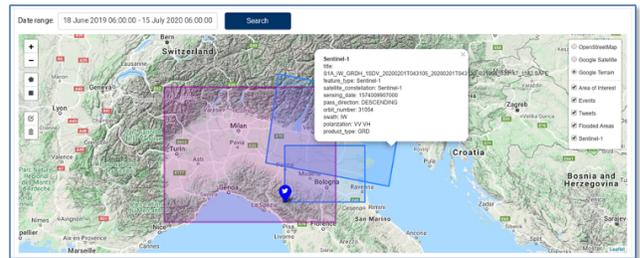


Fig. 3. Retrieval of sentinel images and social media from the same crisis event.

4. CONCLUSION AND FUTURE RESEARCH

The gap between the DIAS providers and the application end users can be bridged through dedicated AI solutions that will add value to the large volumes of satellite data (images and associated metadata) which are frequently coming to Earth from Sentinel constellation. AI is a collection of technologies that combine data, algorithms and computing power.

The generation of effective information for the users relies on the fusion of heterogeneous sources of data (Earth Observation, drone navigation and video analysis, social media stream monitoring, in-situ sensor data). The creation of value on EO data goes beyond the space sector and needs to foster the development of geolocation-based services for both the public and the private sector, in applications relative to policymaking, water management, security and journalism.

Complementary data sources such as citizen observations through dedicated mobile apps and social media platforms

¹<https://multimediaeval.github.io/editions/2020/tasks/floodmultimedia/>
²<https://eopen-project.eu/>

need to be linked to EO data when spatial information is available or can be automatically estimated. Galileo-enabled mobile devices with authenticated and precise geo-reference need to be involved in the design of fully automated processes in decision support systems. These challenges are expected to be addressed in the context of the CALLISTO project³, recently presented in the EO Big Data online workshop⁴, which has started in January 2021 and has a duration of three years.

CALLISTO combines Earth Observation with crowd-sourced data, videos from Unmanned Aerial Vehicles and in-situ data, through machine learning and data fusion technologies; the outcomes are semantically-enriched and served to humans in interactive interfaces and mobile apps. The interfaces enable virtual presence and situational awareness, through Virtual, Augmented and Mixed Reality, creating a novel and innovative immersive environment for the Copernicus market and, in particular, for emergency response and security applications.

5. REFERENCES

- [1] Damianos Florin Mantsis, Marios Bakratsas, Stelios Andreadis, Petteri Karsisto, Anastasia Moutmzidou, Ilias Gialampoukidis, Ari Karppinen, Stefanos Vrochidis, and Ioannis Kompatsiaris, “Multimodal fusion of sentinel 1 images and social media data for snow depth estimation,” *IEEE Geoscience and Remote Sensing Letters*, 2020.
- [2] Guido Vingione, Laurence Marzell, Enrico Cadau, Ilias Gialampoukidis, Stefanos Vrochidis, Ioannis Kompatsiaris, Bernard Valentin, Matthieu Melcot, Leslie Gale, Woo-Kyun Lee, et al., “The h2020-eo open project,” in *ESA Conference on Big Data from Space*, 2017, pp. 28–30.
- [3] Stelios Andreadis, Marios Bakratsas, Panagiotis Giannakeris, Anastasia Moutmzidou, Ilias Gialampoukidis, Stefanos Vrochidis, and Ioannis Kompatsiaris, “Multimedia analysis techniques for flood detection using images, articles and satellite imagery,” in *Working Notes Proceedings of the MediaEval 2019 Workshop, Sophia Antipolis, France*, 2019, pp. 27–30.
- [4] Anastasia Moutmzidou, Stelios Andreadis, Ilias Gialampoukidis, Anastasios Karakostas, Stefanos Vrochidis, and Ioannis Kompatsiaris, “Flood relevance estimation from visual and textual content in social media streams,” in *Companion Proceedings of the The Web Conference 2018*, 2018, pp. 1621–1627.
- [5] Wei Yao, Anastasia Moutmzidou, Octavian Dumitru, Stelios Andreadis, Ilias Gialampoukidis, Stefanos Vrochidis, Mihai Datcu, and Ioannis Kompatsiaris, “Early and late fusion of multiple modalities in sentinel image retrieval,” in *11th IAPR International Workshop on Pattern Recognition in Remote Sensing (PRRS 2020/2021)*, 2021.
- [6] Ilias Gialampoukidis, Anastasia Moutmzidou, Marios Bakratsas, Stefanos Vrochidis, and Ioannis Kompatsiaris, “A multimodal tensor-based late fusion approach for satellite image search in sentinel 2 images,” in *27th International Conference on Multimedia Modeling (MMM 2021)*. 2021, June 2021, Prague, Czech Republic (accepted).
- [7] Maria Rousi, Vasileios Sitokonstantinou, Georgios Meditskos, Ioannis Papoutsis, Ilias Gialampoukidis, Alkiviadis Koukos, Vassilia Karathanassi, Thanassis Drivas, Stefanos Vrochidis, Charalampos Kontoes, et al., “Semantically enriched crop type classification and linked earth observation data to support the common agricultural policy monitoring,” *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 2020.
- [8] Ilias Gialampoukidis, Elisavet Chatzilari, Spiros Nikolopoulos, Stefanos Vrochidis, and Ioannis Kompatsiaris, “Multimodal fusion of big multimedia data,” *Big Data Analytics for Large-Scale Multimedia Search*, p. 121, 2019.
- [9] Marios Mpakratsas, Anastasia Moutmzidou, Ilias Gialampoukidis, Stefanos Vrochidis, and Ioannis Kompatsiaris, “A deep neural network slope reduction model on sentinel-1 images for water mask extraction,” in *40th Asian Conference on Remote Sensing, Daejeon, Korea*, 2019.
- [10] Anastasia Moutmzidou, Marios Bakratsas, Stelios Andreadis, Ilias Gialampoukidis, Stefanos Vrochidis, and Ioannis Kompatsiaris, “Road passability estimation using deep neural networks and satellite image patches,” *ESA Conference on Big Data from Space*, pp. 1–4, 2019.

³<https://cordis.europa.eu/project/id/101004152>

⁴https://ec.europa.eu/info/events/workshop-big-data-and-artificial-intelligence-earth-observation-2020-nov-19_en