Mixing social media analysis and physical models to monitor invasive species

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***Abstract*—Invasive species, such as jellyfish, cause economic losses in millions annually. Therefore, being able to accurately monitor and predict jellyfish is vital to several stakeholders (e.g. tourism, fishery, government). A potential tool to help these communities could be by combining a biophysical drift model with a processing chain for soft information fusion which would predict jellyfish occurrences. To guarantee accuracy, the model needs to be validated by actual data. This data can be gathered from citizens who reported jellyfish sightings on social media or a dedicated citizen science mobile app. As the information provided by citizens is spread among numerous atomic reports, we use a platform for soft information fusion to aggregate and fuse these reports into a single information network. The soft information fusion platform relies on the use of domain knowledge, provided through an ontology. The information network can then be queried to extract relevant features to validate the jellyfish drift model. Future work includes the initialisation of the model with soft information, as well as making use of the different levels of quality of the reports provided by citizens, in order to assess the quality of the fused information.**

***Index Terms*—Ontologies, Hard-Soft Fusion, Natural Language Processing**

I. Introduction

Coastal tourism is an important source of wealth in Europe and generates a total of C 183 billion in gross value added. This represents over one third of the maritime economy while employing over 3.2 million people[1]. During the past years, anomalies in jellyfish populations have led to undesirable consequences. Jellyfish blooms have become very common and several sectors, such as coastal tourism and fisheries are majorly affected by their presence. For example, jellyfish blooms repel thousands of beachgoers and the fishing industry encounters clogged fishnets and stings. However, predicting and monitoring jellyfish blooms is challenging. Unlike other disastrous events, such as oil spills, they cannot be spotted through satellite imagery before they reach the beaches.

Within the H2020 ODYSSEA project, a biophysical drift model was developed, which predicts jellyfish blooms and their location of appearance. The model encompasses a large number of parameters, and among them, the different stages of development of the jellyfish. In order to collect data for model validation, we relied on information gathered from social networks, namely Twitter, and citizens reports collected through dedicated applications. With the aim to acquire and use information provided by citizens, we developed a soft information processing chain. The soft data processing chain relies on the use of InSyTo combined with access to the Twitter API and the use of Google translate service.

The remaining of the paper is organised as follows. Section 2 presents the context of our work including the Odyssea project and the societal impacts of jellyfish blooms on different sectors of the economy. Section 3 briefly describes the biophysical drift model. In section 4, we present the soft information acquisition processing chain. We detail how we deal with information items expressed in natural language associated with metadata up to its transformation and aggregation into a semantic information network. Finally, section 5 presents tracks for future work, regarding the initialization of the model with soft information and the management of the heterogeneous quality in the numerous soft information items.

II. Context and Related Work

A. The ODYSSEA Project

ODYSSEA (http://odysseaplatform.eu/) is an EU H2020-funded project aiming to develop, operate and demonstrate an interoperable and cost-effective platform that fully integrates networks of observing and forecasting systems across the Mediterranean basin, addressing both the open sea and the coastal zone. The project involves 28 partners (universities, research centres, international organizations, NGOs and private companies).

Within the ODYSSEA project, a biophysical approach for invasive species monitoring was proposed. If complex models are developed to model the drift and expansion of invasive species, it is often difficult to validate and initialize these models with information concerning the actual presence of such species. Jellyfish, for instance, are very difficult to spot with currently deployed physical and biological sensors. However, when a beach is invaded by jellyfish, a lot of people share the information on social media or dedicated citizen science apps. Our idea is to use information gathered on social media and dedicated apps to support the monitoring of invasive species, the same way as social media is used to support crisis management [1]. The role played by social media in crisis and emergency events take action from the situation assessment phase, with new sources of information about the ongoing

[1] https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/docs/body/study-maritime-and-coastal-tourism_en.pdf

(potentially remote) situation, to the dispatch of response efforts. Therefore, the use and management of social media during a crisis is an emerging and rapidly growing trend in the crisis management and IT research communities (examples of such work are described in references [2] to [11]). Similarly to what has been done in the crisis management domain we would like to use the information provided by citizens through social media and mobile apps to improve invasive species monitoring.

B. Jellyfish Invasion Monitoring Use Case

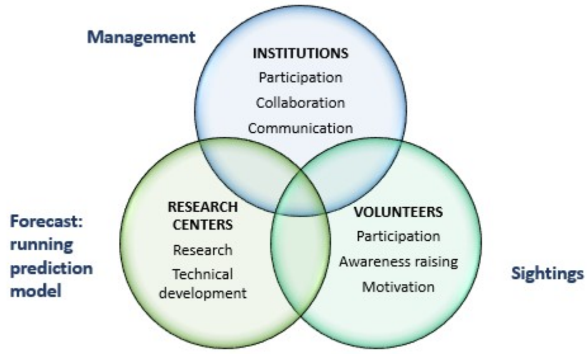
Although an essential part of a healthy marine ecosystem, anomalies in jellyfish populations have led to undesirable consequences for societies dependent on marine resources. When favourable conditions are present, jellyfish population quickly expand resulting in jellyfish blooms. These blooms consist of large numbers of jellyfish and can be problematic through their direct interference with human activities (e.g. tourism, fishing, etc.).

Unfortunately, jellyfish blooms have been very common globally in recent years and could be linked to climate change, overfishing and eutrophication. According to the latest report on World Fisheries and Aquaculture, more than 30 of major commercial marine species are being fished to unsustainable levels, creating an imbalance in the species distribution of the marine environment. Jellyfish are preys of many Mediterranean top predators, however, since the numbers of predators gradually decline, jellyfish populations are flourishing. In addition to that, an increasing trend in chlorophyll-a concentration in the Mediterranean Sea shows phytoplankton growth, which creates a suitable environment with high food availability for jellyfish.

The most affected by jellyfish blooms is the tourism sector which suffers losses in millions of euros when blooms block beaches and sting bathers. While the stings can be painful and last up to two weeks, it is not the only effect as the inconvenience the mauve stinger causes repels thousands of potential beachgoers. Second to tourism comes the fishing industry and aquaculture. The fishing industry suffers because of clogged fishing nets, painful stings and a reduced economic revenue. Moreover, in the aquaculture sector mainly salmon and sea bream species are impacted as jellyfish swarms may damage whole fish farms in case they are floating by and therefore causing economic losses in millions. The consequences of episodes of jellyfish blooms are detrimental to all three sectors. In order to solve this problem, the first and most important step is to report sightings and issue early warnings on jellyfish occurrence to the relevant end-users in the affected sectors.

For dealing with this problem, the ODYSSEA project aims to create an integrated system for the sighting, prediction and research of jellyfish on the Mediterranean coast.

The jellyfish prediction system runs thanks to the close cooperation between Administration, Research Centers and Volunteers. Deltares has been responsible of developing a forecast drifts model of jellyfish, which is obtained by a combination of hydrodynamic and meteorological models. The shift of a jellyfish shoal was estimated by a drift model (Lagrangian type), in which particles are assimilated to the jellyfish shoal.



The initial offshore position of the jellyfish shoal is determined by sightings. The forecast model is feed by the data provided by a huge number of volunteers (fishing vessels, pleasure crafts, etc), who collect the information on the presence of jellyfish at sea. The information is collected in two different ways: the first consists of filling in an excel sheet with the information related to the species sighted (if known), the approximate number of jellyfish in the shoal and their position taken from the GPS data of the boat. The information is sent by e-mail to be processed. The second option for initial data collection is based on the use of an app that directly feeds the prediction system. Both data collection systems allow to attach photos for supporting the identification of the jellyfish species listed.

On the one hand, the prediction system is used to send warnings of the arrival of jellyfish on the beaches in order to limit bathing. On the other hand, the system itself is a source of data that allows universities and research centers to continue their studies on the proliferation of jellyfish.

In Spain, there are several prediction systems running thanks to the close cooperation between Administration, Research Centers and Volunteers. The forecast drift model of jellyfish is obtained by a combination of hydrodynamic and meteorological models. Based on the currents (Regional Ocean Modeling System (ROMS) model) and wind (Aemet meteorological model), a drift model was applied (Lagrangian type), in which particles are assimilated to the organisms (jellyfish) sighted.

The sighting system is based on the participation of volunteers (fishing vessels, pleasure crafts, etc.) in the collection of information on the presence of jellyfish at sea. To ensure that the sightings meet quality criteria, the Administration and Research Centers elaborated guidelines for the identification of the most common jellyfish species in the Spanish Mediterranean coast, which were distributed among numerous agents (fishermen's associations, recreational fishermen's associations, conservationist associations, diving clubs, surf collectives, research entities, etc.).

III. Modelling jellyfish drift

Using numerical modelling tools the behaviour of jellyfish can be simulated and their horizontal and vertical migration can be predicted. These predictions may include the likelihood of jellyfish spatial and temporal distributions and potential stranding locations before they reach the coast in touristic areas. Within the ODYSSEA project an individual-based model (IBM) was developed to simulate the life cycle of mauve stinger (Pelagia noctiluca) from fertilized egg stage to the adult stage [17]. This IBM combines available biological and behavioral knowledge on the mauve stinger with freely available hydrodynamic fields from the Copernicus Marine Environment Monitoring Service (CMEMS). It should be noted that current developments focus only on the mauve stinger but the model can be adapted to other species.

More specifically, the jellyfish drift model is a biophysical model which describes both the lifecycle and the horizontal transport of the jellyfish. The lifecycle modelling includes spawning (release of fertilized eggs), stage development (growth), and behavioural processes such as diurnal vertical migration and temperature-induced behaviour (motility adjusted for the effect if temperature).

The model is driven by the hydrodynamic field input from CMEMS models and is built in the general Lagrangian particle tracking framework OpenDrift [16]. By combining hydrodynamics, particle tracking and life cycle, the spatial and temporal variations in distributions of jellyfish can be simulated (see Figure 1).

Initial validation of this biophysical model was performed with the aim to compare it with other more simplistic jellyfish prediction approaches, which only included simple drifting, or fixed diurnal behaviour. This general qualitative analysis was conducted by comparing the predicted and observed stranding locations per month and per administrative units (NUTS2016). For the given model period (May to December 2018), the biophysical model performed the best in predicting jellyfish sightings, followed by the simple drift model and the fixed diurnal behavior model. Nevertheless, it should be noted that the spatial and temporal coverage of the currently available citizen sourced data is insufficient to conduct comprehensive model validation. This motivates our study to investigate the effectiveness of soft information fusion techniques in order to enrich the validation dataset. In the future, after comprehensive validation, this jellyfish drift modelling tool could be used to issue early warnings to inform local authorities and industries for suspending bathing on affected areas or take other response measures to limit damages to their operations.

IV. Obtaining information from citizens

In order to obtain information from citizens, we developed a processing chain that gathers information from Twitter as well as from a dedicated mobile app. The processing chain relies on the use of an ontology and the conceptual graphs formalism, to provide a pivot representation framework. Thus, information items, coming from both sources can be merged.

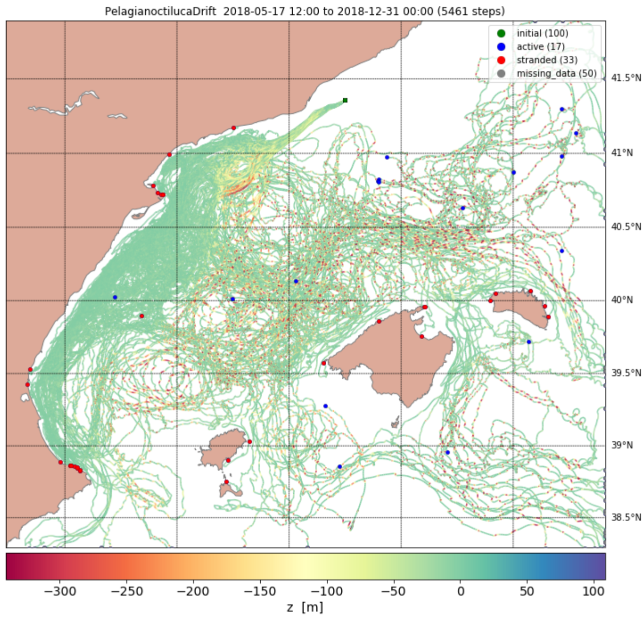


Fig. 1. Illustrative example output of jellyfish drift model, developed within the H2020 ODYSSEA project, indicating trajectories together with initial locations, active particle positions, and stranded jellyfish in the Balearic Sea.

We first describe the use of a domain ontology to parameterize generic semantic information fusion algorithms. We then describe the theoretical approach of conceptual graphs fusion that is used in the semantic information fusion platform and finally explain how this platform (namely InSyTo, [14]) is specialized and used within our use case.

A. Domain Ontology

Within the jellyfish monitoring use case, an ontology was designed to model the application domain. It is used to specify the usage of the data and the end-users needs. The ontology is the conceptual model, describing the application. It represents the different actors of the domain and the relations over these actors. Furthermore, it is used to parameterize the generic algorithms, that manage the soft data (i.e. actual observations of jellyfish reported by citizens).

Figure 2 depicts the ontology used in our use case. It specifies different events of interest regarding marine environment management, and for which the ODYSSEA project aims at providing citizen sourced information.

B. Conceptual Graphs Representation

Graph-based structures seem to be key structures for situation understanding and soft information representation. Graph-based formalisms are easily readable and understandable by humans and graphs are a natural way to represent several ideas or objects interacting with each other. Our approach relies on the use of bipartite graphs, more specifically a subset of the conceptual graphs ([12], [13]) to represent soft data and knowledge. The conceptual graphs formalism is a model that encompasses a basic ontology (called *vocabulary*),

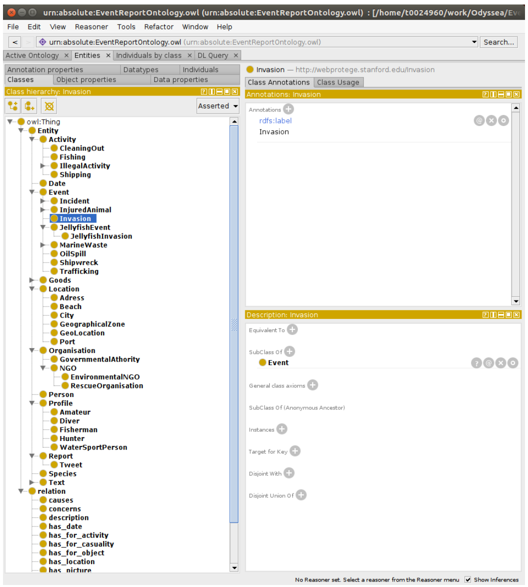


Fig. 2. Odyssea ontology for jellyfish invasion monitoring

graph structures and operations on the graphs. The vocabulary defines the different types of concepts and relations that exist in the modelled application domain, while the graphs provide a representation of the observations which are provided by the information sources.

Basic **conceptual graphs** are bipartite graphs containing concept and relation nodes. Figure 3 gives an example of a conceptual graph. The rectangular boxes represent concept nodes and the ovals represent relation nodes.

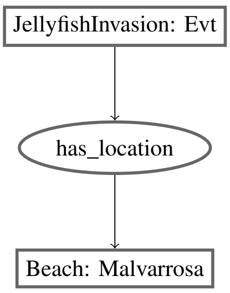


Fig. 3. An example of conceptual graph

The term **concept** is used to refer to a concept node. The concepts represent the "things" or entities that exist. A concept is labeled with two components: the conceptual type and the individual marker.

The **conceptual type** defines the category to which the entity belongs. For instance, in Figure 3 the concept `[Beach::Malvarrosa]` is an instance of the category `Beach`, i.e., its conceptual type is `Country`.

The **individual marker** relates a concept to a specific object of the world. The object represented by `[Beach::Malvarrosa]` has the name (or value) `Malvarrosa`. The individual markers may also be undefined. An undefined or generic individual marker is either blank or noted with a star $*$, if the individual object referred to is unknown.

The term **relation** is used to refer to a relation node. The relation nodes of a conceptual graph indicate the relations that hold between the different entities of the situation that is represented. Each relation node is labeled with a relation type that points out the kind of relation that is represented.

The notion of **vocabulary** is defined in [13]. The concept types and the conceptual relation types, which are used to label the concept and relation nodes, are organized in hierarchies.

Formally, we denote the set of concept types as T_C, the set of relation types as T_R and the set of individual markers that are used to labeled the concept nodes as markers, which defines a vocabulary $\mathcal{V} = (T_C, T_R, \text{markers})$. A basic conceptual graph G is then defined by a 4-uple $G = (C_G, R_G, E_G, l_G)$, where

- (C_G, R_G, E_G) is a finite undirected and bipartite multi-graph. C_G is the set of concept nodes. R_G is the set of relation nodes, and E_G is the set of edges.
- l_G is a naming function of the nodes and edges of the graph G which satisfies:
  1) A concept node c is labeled with a pair $l_G(c) = (type(c), marker(c))$, where $type(c) \in T_C$ and $marker(c) \in \text{markers} \cup \{*\}$.
  2) A relation node r is labeled by $l_G(r) \in T_R$. $l_G(r)$ is also called the type of r.

Within our case study, the *vocabulary* defined to support the conceptual graphs is the domain ontology described in IV-A. This basic domain ontology contains the T-box part of the ontology, that is used as a support for the types of concepts and relations used in the nodes of the conceptual graphs.

The facts themselves, corresponding to the A-box of the ontology, are not defined in the basic ontology, as one of the the purposes of our work is to acquire them through the automatic extraction of information from the citizens reports. These facts will be stored as conceptual graphs, arranged in a big information network.

C. InSyTo : a platform for semantic information management

The InSyTo Synthesis platform encompasses a generic graph-based fusion algorithm made of two interrelated components. The first component is a generic sub-graph matching algorithm, which itself relies on the use of fusion strategies. The graph matching component takes care of the overall structures of the initial and fused observations. It is in charge of the structural consistency of the fused information, regarding the structures of the initial observations, within the fusion process.

The fusion strategy part is made of similarity, compatibility and functions over elements of the graphs to be fused. They enable the customization of the generic fusion algorithm according to the context in which it is used. According to the fusion strategies that are used, the InSyTo graph fusion algorithm provides three different operations. These operations are depicted in figure 4 and described hereafter.

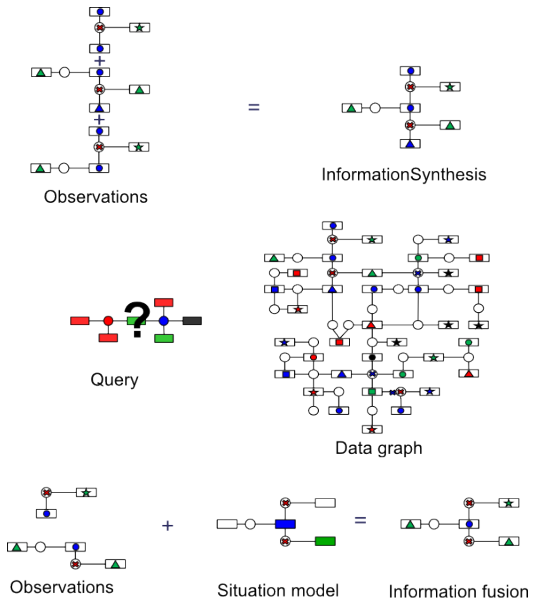


Fig. 4. Example of a conceptual graph

1) Information Synthesis: **Information synthesis** enables one to collect and organize information about a specific subject. Through information synthesis, all the gathered information items are organized into a network. The redundant part of the information items are detected and eliminated.

The fusion strategies are used within information synthesis, in order to enable the fusion of information items that are slightly different but describe the same situation of the real life. These discrepancies may appear when different sources of information with potentially different levels of precision for instance, are used to draw a picture of an on-going situation (see [14]).

2) Information Query: All the instances of information corresponding to a specified graph pattern may be found within a network of information, through the **information query** function.

The specialization relationship between the query and the data graphs imply that the structure of the query graph must be entirely found in the data graph. The query function relies on the search for injective homomorphism between the query graph and the data graph.

3) Information Fusion: When a model of a situation of interest (e.g. an activity involving a specific person at a specific date) is available, one may want to monitor the situation and trigger further processes if an instance of such a situation is happening. Therefore, different observations, potentially coming from different sources, are filtered out in order to keep observations of interest only. They are then assembled through **information fusion** in order to provide a representation of the ongoing situation of interest, as precise as possible.

The model of situation is, within information fusion, more generic than the observation graphs. Further more, fusion strategies may be used, as for the Information Synthesis function. The use of the model constraints the structure of the fused observation.

D. Tweet analysis using InSyTo

We describe how these three functions are combined and used to acquire citizen sourced information through specific apps and social media. Within the jellyfish monitoring use case, we first made an inventory of the existing media commonly used by citizens in order to report about events that may have an impact on touristic activities, such as jellyfish blooms. It appears that two classes of media are nowadays commonly used. The first one is composed of the many existing social networks through which citizens share with their connected fellows reports about what they encounter. These reports may include textual descriptions of events and opinions, images and/or videos. The reports are sometimes geo-localised.

The second class of media is the one related to dedicated mobile applications. Through these applications, users receive higher guidance for reporting events. The reports are generally geo-localised and quality controlled. This result in structured databases, potentially including free text fields.

In both media, the language used to fill free comments depend on the users. Therefore, the set of soft information items that we can gather through citizens are multilingual.

For our use case, we selected Twitter as a representative of the first class of media: social networks. As no dataset of tweets exist, to our knowledge, containing information and observations about jellyfish blooms, we acquired tweets using several hashtags and keywords (jellyfish invasion, beach, ...) in three languages (English, French and Spanish). The dataset obtained shows both the strength and weaknesses of using social media as an information source. The tweets cover a geographically wide area, but the contents are very poor, often not delivering factual report on the situation and no information is available on the quantity and species for instance. Furthermore, the quantity of Tweets acquire in this way is very small. The experiments conducted on Twitter illustrated that it is possible to make use of such media when and where no other sources of information are available, but we need to have other sources of information, more reliable, detailed and widely used by citizens.

This analysis lead us to consider adding information from the second class of media: dedicated apps. Regarding this second class, and although the specific ODYSSEA Project App is unavailable yet, there are apps that enable citizen to provide information on jellyfish bloom sightings, marine litters and other information of interest, such as the JellyWatch App (jellywatch.org). These organisations are better known and their application is more widely used. The citizens reporting the events are trained and provide quantitative and qualitative information. The data acquired through these kinds of apps have the opposite characteristics from the one acquired through Twitter. Reports are factual and well completed. The geo-localisation of the event reported is always given, but reports cover only a very small geographical area, linking to the actions of NGOs for promoting the use of the app.

In order to use our approach on a worldwide basis, we will need to work together with NGOs and app providers implanted in all the communities and areas of interest around the seas. The work presented here is a preliminary proof of concept, taking into account a few information sources.

The InSyTo platform described above is used to analyse and aggregate information collected from both sources. Figure 5 describes the overall information processing chain. The first step of information acquisition is specific to each source of information and is detailed hereafter. Once the data acquisition step is performed however, the processing of the information items is shared for any information source.

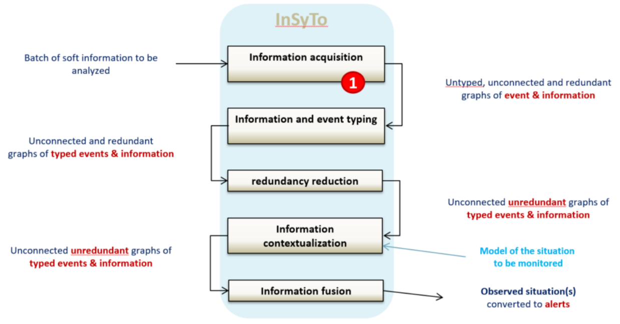


Fig. 5. Analysis of a batch of Soft information items with InSyTo

The information acquisition step is made of parts, as depicted on Figure 6. First, the metadata of the information items are extracted. As the format of the information items and their metadata are specific to each source of information, this operation is ad-hoc. Then, to analyze the natural language parts of the information items (texts of the tweets and comments or descriptions boxes of the mobile app), we rely on the Named Entity recognition (NER) function of Spacy [15]. Therefore, for information items containing text in a language for which Spacy has no model, we first translate them using Google Translate API [19].

Regarding the transformation of input soft information into graphs, named entities are extracted by Spacy and used to build the concept nodes of the information graph. Other concept nodes and relations, such as the author of the report, the date of the report, keywords etc. are extracted form the metadata. As many relations among entities may be expressed in the text of the tweet but not extracted automatically, the information graph is unconnected and some of the concepts have generic types, with values corresponding to the keywords.

Once this information acquisition phase is performed, the main analysis is applied equally on graphs coming from any source of information.

A second step depicted on Figure 5. It consists in interpreting the keywords into types of events that are being reported in the tweet. For this step, we rely on a keyword-type of event correspondence table. For instance, the use of the keyword #jellyfish will imply that the tweet reports about a “JellyfishEvent”. The use of #invasion will imply that the

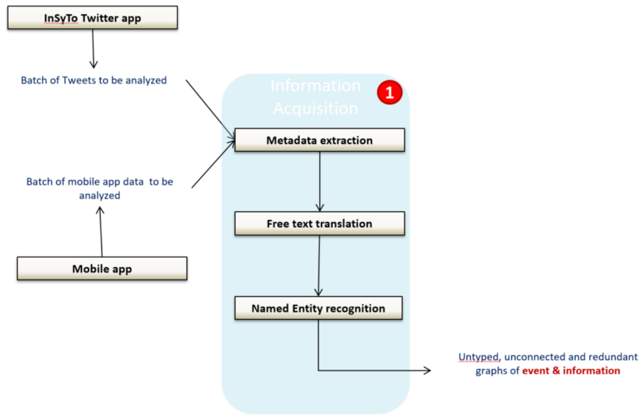


Fig. 6. Analysis of a batch of Soft information items with InSyTo

tweet reports about an “InvasionEvent”. If both keywords are used, a sub-type of JellyFishEvent and InvasionEvent will be search for in the Ontology and we will deduce that the twee reports about a “JellyfishInvasionEvent”.

Once the typing step has occurred, concepts nodes may be redundant in the information graph and the graph is still unconnected as some relations were not retrieved from the text, as said before. Thus a step of internal fusion, using the synthesis function occurs. It enables removing redundant information.

Then each information graph, representing an event being reported, is fused (using the fusion function) with a model of event. This model is a graph representing the minimal ideal event report and containing not instanciated nodes. For instance, knowing that an event takes place somewhere, at a specific date, the model of event will include an “Event” node, connected to a “Location” and “Date” node through ”has_for_location” and “has_for_date” relations.

Once all this steps have been achieved, each tweet graph is added to the situational information network using the synthesis function. Cues indicating the presence of jellyfish can be searched for. To do so, the query function of InSyTo is used. A graph (depicted on Figure 7) representing the following question is queried over the semantic information network :

- What = Jellyfish
- Where ?
- When ?
- How (many) ?

The graphs answering this query represents the occurrences of jellyfish invasion that have been reported by citizens. The information collected can be used to validate the drift model. It should be noted, however, that due to the temporal and spatial discontinuity the extracted features (’Location’ and ’Date’) need to be further aggregated into monthly averages and spatial zones according, for example according to administrative units (NUTS2016), see figure 8. By comparing the number of reported and predicted individuals within a geographic region

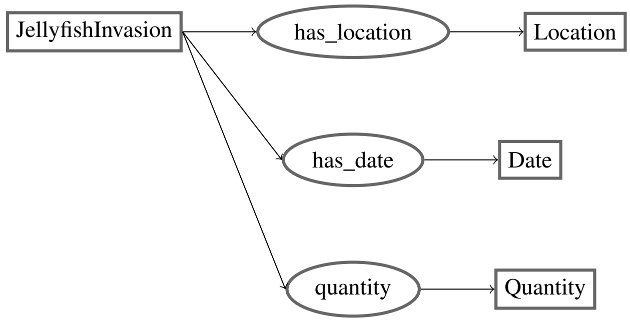


Fig. 7. Query graph for jellyfish reports

for a specific month allows us to perform qualitative validation. Nevertheless, differences between the temporal coverage of observed and predicted jellyfish stranding remain as the biophysical model provides predictions for the full calendar year while observations are mainly available during summer period (peak season).

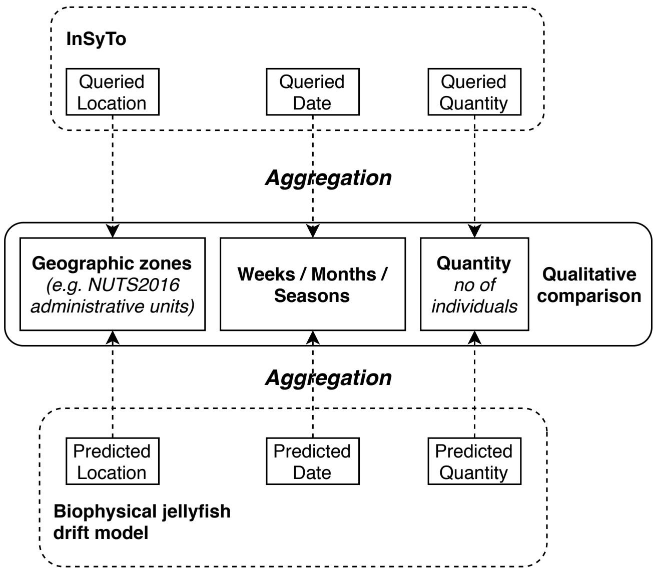


Fig. 8. Validation process using the output of InSyTo and biophysical jellyfish drift models

V. Conclusion and Future work

In this paper we presented a work that aims at using both biophysical modelling and fusion of soft information for jellyfish invasion monitoring. We first presented the jellyfish drift model that is used for jellyfish invasion forecasting. We explained how the information of the actual presence of jellyfish reported by citizens can be used in order to validate the drift model. The presented methodology aimed at enriching existing citizen sources datasets since the lack of coherent in-situ observations do not permit for comprehensive quantitative assessment.

To gather and aggregate all the reports of jellyfish from citizens, we use the InSyTo platform, that provide soft information fusion services. The fusion services are organised together with tweet acquisition and google translation means, in order to get as much information as possible from the different available sources and applications.

As a first step of mixing the use of biophysical drift model and soft information for jellyfish, we limited our approach to the validation of the drift model with the citizen data reports. However, our aim, regarding future work is to go beyond the validation of the model with citizen reports and initialize the drift model thanks to inputs gathered from citizens. This is a complex task as only jellyfish having reached their full-grown stage are usually spotted by citizens on beaches. Therefore, we will have to disable the other stages of jellyfish development in the drift model if it is initialized by sightings. Consequently, validating this new parameterisation of the drift model will be essential, and the loss or gain in prediction quality between the use of the full model and the use of the model reduced to full-grown state jellyfish should be quantified.

A second track for future work, is taking advantage of the uncertain information management feature provided by InSyTo [21]. As seen before, citizens may provide data from different means. Specialized applications, ensure that the citizen reporting information is well-intentioned and willing to provide as efficient as possible information. However, these apps are not sufficiently widely used nowadays and we still lack of input data from most of the regions of the world. On the contrary, a lot of people use their favourite social media in order to share information with their connections. They don't aim at providing sound and complete observations, from a scientific perspective. However, in places where we lack of input information, their inputs may be valuable. As we are fully aware of the different levels of quality of input information acquired through these two means, we aim at defining quality parameters and use them in order to provide jellyfish observers with quoted information regarding the confidence we have on its quality.

Acknowledgment

The research leading to these results received funding from the European Union's Horizon 2020 Research and Innovation Program (H2020-BG-12-2016-2) under grant agreement No. 727277 - ODYSSEA (Towards an integrated Mediterranean Sea Observing System). The article reflects only authors' view and that the Commission is not responsible for any use that may be made of the information it contains.

References

[1] C. Laudy, Marcin PRZYBYSZEWSKI, Anna STACHOWICZ, Fabio RUINI, Alessandro ZANASI. Fusion 2017 Using Social Media in Crisis Management - SOTERIA Fusion Center for Managing Information Gaps, FUSION 2017, July 2017, Xi'an, China

[2] Mukherjee, S. The Use of Twitter, Facebook, LinkedIn etc. as Strategic Tools for Crisis Communication. International Journal of Management and International Business Studies, 4(2), 175–180, 2014.

[3] Mergel, I. Social Media Practices in Local Emergency Management. Results from Central New York. Retrieved from http://sotechem.syr.edu/wp-content/uploads/2014/11/SoTechEM_Executive_Report-mwedit111914.pdf [sotechem.syr.edu], (2014).

[4] Yin, J., Lampert, A., Cameron, M., Robinson, B., Power, R. Using Social Media to Enhance Emergency Situation Awareness. IEEE Intelligent Systems, 27(6), 52–59, 2012.

[5] Kryvasheyeu, Y., Chen, H., Obradovich, N., Moro, E., Hentenryck, P. Van, Fowler, J., Cebrian, M. (2016). Rapid assessment of disaster damage using social media activity. Science Advances, 2(3), 2016.

[6] Jin, Y., Liu, B. F., Austin, L. L. Examining the Role of Social Media in Effective Crisis Management: The Effects of Crisis Origin, Information Form, and Source on Publics' Crisis Responses. Communication Research, 41(1), 74–94, (2014).

[7] Abbasi, M.-A., Kumar, S., Filho, J. A. A., Liu, H. Lessons Learned in Using Social Media for Disaster Relief - ASU Crisis Response Game. In Proceedings of SBP12, the International Conference on Social Computing, Behavioral-Cultural Modeling, and Prediction (pp. 282–289), (2012).

[8] Cresci, S., Cimino, A., Dell'Orletta, F., Tesconi, M. Crisis Mapping During Natural Disasters via Text Analysis of Social Media Messages. In Proceedings of WISE 2015, the International Conference on Web Information Systems Engineering. http://doi.org/10.1007/978-3-319-26190-4 [doi.org], (2015).

[9] McClendon, S., Robinson, A. C. Leveraging Geospatially-Oriented Social Media Communications in Disaster Response. In Proceedings of the 9th International ISCRAM Conference (pp. 2–11), (2012).

[10] Chen, R., Sakamoto, Y. Perspective Matters: Sharing of Crisis Information in Social Media. In Proceedings of the 2003 46th Hawaii International Conference on System Sciences (pp. 2033–2041). Ieee. http://doi.org/10.1109/HICSS.2013.447 [doi.org], (2013)

[11] Olteanu, A., Vieweg, S., Castillo, C. What to Expect When the Unexpected Happens: Social Media Communications Across Crises. In Proceedings of CSCW '15, the 18th ACM Conference on Computer-Supported Cooperative Work and Social Computing, (2015).

[12] Sowa, J-F. Conceptual Structures. Information Processing in Mind and Machine. Addison-Wesley, Reading, MA. 1984.

[13] Chein, M., Mugnier, M.-L. Graph-based Knowledge Representation: Computational Foundations of Conceptual Graphs. Springer. 2008.

[14] Laudy C. Semantic Knowledge Representations for Soft Data Fusion — Efficient Decision Support Systems - Practice and Challenges From Current to Future. Chiang Jao Publisher. 2011.

[15] Honnibal, M., Montani, I. spaCy 2: Natural language understanding with Bloom embeddings, convolutional neural networks and incremental parsing. To appear.

[16] Dagestad, K.-F., Röhrs, J., Breivik, Ø., Ådlandsvik, B. (2018). OpenDrift v1.0: a generic framework for trajectory modelling. Geosci. Model Dev, 11, 1405–1420. https://doi.org/10.5194/gmd-11-1405-2018

[17] El Rahi, J., Jellyfish Modelling in the Spanish Coastal Waters: Life Cycle, Transport and Stranding of Pelagia noctiluca. Master Thesis, Deltares, Delft. 2019.

[18] C. Laudy, Rumors detection on Social Media during Crisis Management, ISCRAM 2017, May 2017, Albi, France

[19] https://cloud.google.com/translate/docs/apis

[20] https://github.com/explosion/spaCy/releases/tag/v2.2.4

[21] S. Fossier, C. Laudy, F. Pichon. Managing uncertainty in conceptual graph-based soft information fusion. FUSION 2013: 930-937