XR4DRAMA Knowledge Graph: A Knowledge Graph for Disaster Management

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***Abstract*—The evolution of Knowledge Graphs (KGs), during the last two decades, has encouraged developers to create more and more context related KGs. This advance is extremely important because Artificial Intelligence (AI) applications can access open domain specific information in a semantically rich, machine understandable format. In this paper, we present the XR4DRAMA KG which can represent information for disaster management. More specifically, the XR4DRAMA KG can represent information about: (a) Observations and Events (e.g., data collection of biometric sensors, information in photos and text messages), (b) Spatio-temporal (e.g., highlighted locations and timestamps), (c) Mitigation and response plans in crisis (e.g., first responder teams). Moreover, we offer a mechanism that can create or update Points-Of-Interest (POIs), based on a visual or textual messages received from users.**

***Index Terms*—Knowledge Graphs, Disaster Management, Points of Interest, POI Management Mechanism**

I. Introduction

The creation of context related Knowledge Graphs (KGs), i.e., KGs that can be used only in specific environments, seems to be the next step for allowing KGs to become the main knowledge representation format for the Web [1]. Our focus in this work is on representing information for disaster management, more specifically, information about: (a) Observations and Events (e.g., data collection of biometric sensors, information in photos and text messages), (b) Spatio-temporal features (e.g., highlighted locations and timestamps), (c) Mitigation and response plans in crisis situations (e.g., for the first responder teams). 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. For this reason, we provide a mechanism that creates or updates Points-of-Interest (POIs)[1]. We will refer throughout the paper to the POI creation/update mechanism as *POI management mechanism*. The formal definition of a POI is a specific place or location point inside a map that someone may find useful or interesting. In our case, POIs also include geospatial data which contain either textual or visual information about the state of a location which has suffered a destruction.

The XR4DRAMA KG was developed in order to work as the knowledge representation of the XR4DRAMA project[2]. XR4DRAMA is dedicated to improving situation awareness via extended reality (XR) and a number of other technologies. One of the main use cases of the XR4DRAMA project focuses on disaster management. Therefore, the XR4DRAMA KG can represent the structures and integrate the results coming from multiple advanced analysis components that process multimodal data (in this project we integrate visual, textual, and stress level analysis messages). Additionally, the XR4DRAMA KG through its POI management mechanism offers an innovative mechanism that can create or update POIs, which contain crucial geospatial information that is needed in a case of emergency.

Our contribution in this paper, is on one hand the XR4DRAMA KG which can represent multi-modal measurements, by mapping textual, visual, and stress level messages/measurements, which in turn can aid citizens and first

[1] https://xr4drama.eu/2022/07/07/xr4drama-pois-virtual-whiteboards/
[2] https://xr4drama.eu/

responders, in order to avoid crisis or tackle with the best possible outcome a disaster that has already occurred. On the other hand, the paper presents the POI management mechanism for the XR4DRAMA KG, which could be helpful in real-life scenarios by creating (or updating) POIs that will further ease the work of first responders and notify the citizens.

The rest of this paper is organized as follows. Section II, contains the related work. Next, in Section III we present the XR4DRAMA KG, the POI management mechanism which creates or updates POIs and the data upon which we constructed the KG. Section IV, contains the evaluation of the KG and the POI management mechanism. We conclude our paper with Section V.

II. Related Work

The area of KGs for disaster management is rich to present a handfull of studies, some papers that present a blueprint of what a KG for disaster management should contain are presented in [2] and [3], [4]. In the last two the focus is mostly on geospatial information about a disaster, while the first one is more general. The difference between these studies and XR4DRAMA KG, is that they remain at a theoretical level while we offer a complete KG with a POI management mechanism.

In [5], [6], the authors present a deep learning model that can generate a KG for disaster management, but as most data-driven models it is restricted upon the data that is trained. This means that if a new case needs to be inferred, for instance a different type of disaster, new classifiers need to be trained. Comparing this to the XR4DRAMA KG which is not restricted to the information existing in some datasets, shows that our KG might be more general than these models. Close to our study is [7], where the authors present a KG for disaster management, but they do not include a POI management mechanism, for accessing the information in the KG. Similar is the case of [8], as there is no POI management mechanism.

One can take a more detailed view for the KGs about disasters and disaster management by reading the survey of Mazimwe et al. [9].

III. XR4DRAMA Knowledge Graph

The XR4DRAMA KG is part of the back-end of the project's platform. For this reason, the multimodal mapping mechanism which receives messages from the visual, textual, and stress-level analysis components and passes their containt into the XR4DRAMA KG will not be analyzed in detail. But one can find a blueprint of these messages here[3]. Moreover, the source code of the multimodal mapping mechanism can be found here[4]. The idea of the pipeline is that after the multimodal mapping mechanism has received the message from a component, it will map the information into the KG. Then, when the message arrives from the textual or visual analysis component the POI management mechanism of the XR4DRAMA KG, will create a new POI or update an existing one, based on the information in the message and information from the KG. In the second case, the idea is that the state of a created POI changed, for example a flood has affected more buildings, thus the information in the initially created POI needs update. Figure 1, shows an outline of the pipeline, where each number in the circles shows the order of steps.

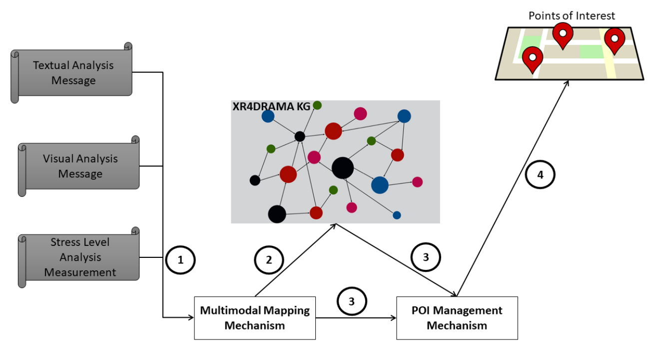

Fig. 1. Pipeline of the XR4DRAMA KG

A. Nature of Data

The multi-modality and variety of data flowing in the system and the necessity of homogenization and fusion mandated the adoption of a semantic knowledge graph to address the requirements of the project. The XR4DRAMA KG is not responsible for archiving and storing raw data files, since there is an underlying data storage facility for that purpose. Instead, the XR4DRAMA KG hosts metadata of raw data, analyses results and miscellaneous information with semantic value among other candidates, for being mapped and fused into the knowledge base.

The main categories of data needed to be captured in the XR4DRAMA KG were: physiological analysis, visual analysis, and textual analysis results and general information about virtual reality experiments, but due to lack of space further analysis can be found here[4].

B. A Knowledge Graph for Disaster Management

In this subsection, we describe the structure of the KG schema (i.e., the XR4DRAMA ontology) and the philosophy of each class at a high level. The KG along with the codes developed to populate it can be found here[4]. Figure 2 illustrates a high level overview of the core XR4DRAMA ontology classes.

- **InformationOfInterest:** The basic entities of interest to facilitate the decision support.
- **Location:** This class represent the geographical area where something happens. It can be presented with coordinates or with the name of the location (e.g., Vicenza).
- **Metadata:** All the secondary information that comes with the analysis results and can be used in the decision-making process.

[3]https://xr4drama.eu/wp-content/uploads/2021/12/d3.5_xr4drama_semanticrepresentationfusiondss_20211201_v1.2.pdf

[4]https://github.com/valexande/xr4drama-icsc-paper

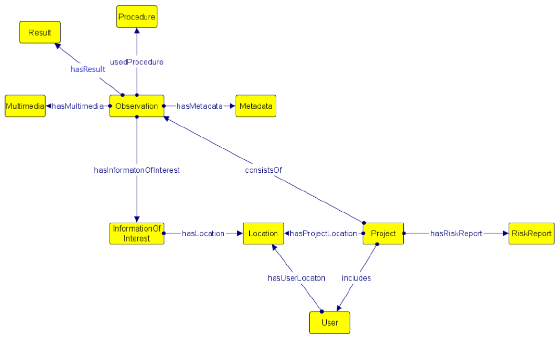

Fig. 2. XR4DRAMA KG high level illustration

- **MultimediaObject:** The type of the mean of transmission that is used to transform information, it can be either Audio, Textual, or Video.
- **Procedure:** This class describes the process of analyzing the date, and is used by each respective component.
- **Project:** This class describes each operation and some data regarding them.
- **RiskReport:** This class describes the aggregated result of all the risk levels that derive from the different components.
- **Sensor:** Some information about the sensors that are used during a project.
- **User:** A user can be a responder or a citizen. Each one of them has different inputs of data to feed the knowledge base.

C. Point of Interest Creation and Update

The idea behind POIs is to create some points in an area (i.e., pins on a map) that contain crucial geospatial information, that could ease the work of first responders, and help citizens to avoid the emergency. The creation of a POI is easily understandable, as if no POIs exist in the area a new one needs to be created, if an emergency occurred. On the other hand, the update of POIs is performed when other POI(s) already exist in the area, and some information in them needs to be updated, as the state of the emergency has changed. For instance, a flood affected more buildings. Below we analyze the information from a visual message that is passed to a POI when is created or updated (see Table I).

One can notice that when a POI is created the information passed from the visual analysis messages are: (i) how many people are in danger, (ii) how many vehicles are in danger, (iii) how many animals are in danger, (iv) what infrastructure was affected, (v) what objects are affected, (vi) the type of emergency, and if the emergency is a flood (vii) if a river has overflown. The aforementioned data can be dynamic, meaning that even if some are missing the POI will still be created. Moreover, the *current_user* is the name of the user who sends the message, the *category* and *subcategory* characterize the area which was affected. The necessary data is the current_user, the category, the subcategory, and the coordinates. On the other hand, if a POI already exists only some information can be updated. The data which can be updated are: (i-vii), blue colored lines in Table I.

TABLE I
INFORMATION PASSED FROM A VISUAL MESSAGE TO A POI WHEN CREATED

Label	Value	Example
category	string	Education
subcategory	string	Universities
current_user	string	citizen
peopleInDanger	integer	0
vehiclesInDanger	integer	0
animalsInDanger	integer	0
riverOvertop	boolean	false
emergencyType	string	flood
objectsInDanger	list of strings	[car,bench]
infraInDanger	list of strings	[building]
type	string	Point
coordinates	list of floats	[11.5504,45.5499]

We also analyze the information from a textual message that is passed to a POI when is created or updated (see Table II). Similarly, when a POI is created the information passed from the textual analysis messages are: (i) which are the affected objects, (ii) an auxiliary label that characterizes the location, and (iii) the source text of the textual message. The aforementioned data can be dynamic, meaning that even if some are missing the POI will still be created. The necessary data is the current_user, the category, the subcategory, and the coordinates. On the other hand, if a POI already exists only some information can be updated. The data which can be updated are: (i-iii), blue colored lines in Table II.

TABLE II
INFORMATION PASSED FROM A TEXTUAL MESSAGE TO A POI WHEN CREATED

Label	Value	Example
category	string	Education
subcategory	string	Universities
current_user	string	citizen
sourceText	string	a university was affected by the flood
affected_objects	list of strings	[car, man]
label	string	harbor
type	string	Point
coordinates	list of floats	[11.5504,45.5499]

IV. EVALUATION

The evaluation of the XR4DRAMA KG was twofold. On the one hand, we evaluated the consistency and completeness of the XR4DRAMA KG; we did this with two different evaluation methods. Firstly, we evaluated the completeness and consistency of the XR4DRAMA KG (subsection IV-A. Secondly, the evaluation of the POI management mechanism was performed by computing the precision-recall-F1 scores used for information extraction systems (subsection IV-B).

A. Completeness and Consistency of Knowledge Graph

The completeness of the XR4DRAMA KG was evaluated through a set of Competency Questions (CQs) assembled during the formation of the official ontology requirements specification document (ORSD) [10]. For this reason, before constructing the XR4DRAMA KG, we asked from users to define a set of questions that they would like to be answered by the XR4DRAMA KG. The users were authority workers from *Autorita' di bacino distrettuale delle alpi orientali*[5] and journalists from *Deutsche Welle*[6]. In total a number of 32 CQs was collected; which can be found here[4]. The completeness of the XR4DRAMA KG was found adequate, as each CQ when translated into a SPARQL counterpart returned the desired information.

The consistency of the XR4DRAMA KG was found adequate, as out of 56 SHACL rules, from which 21 referred to object type properties and 35 to data type properties, none of them returned any invalidation of the rule. Moreover, we checked if there exist instances which belong to intersection of classes, as we did not desire such a case, and there were not any.

B. POI Management Mechanism Evaluation

The evaluation of the POI management mechanism was performed using the usual precision, recall and F1-score used for information extraction systems (Equations 1, 2 and 3), for the creation or update of POIs from visual and textual messages.

$$precision = \frac{|\{RelevantInstance\} \cap \{RetrievedInstance\}|}{|\{RetrievedInstance\}|} \quad (1)$$

$$recall = \frac{|\{RelevantInstance\} \cap \{RetrievedInstance\}|}{|\{RelevantInstance\}|} \quad (2)$$

$$F1 = 2 * \frac{recall * precision}{recall + precision} \quad (3)$$

Retrieved Instances are considered all the visual (or textual) messages for which the POI management mechanism, *did not* return an error when we casted a message in order to create or update a POI.

Relevant Instances are considered all the the visual (or textual) messages for which the POI management mechanism, managed to create or update a POI, when we casted a message with them.

The dataset on which we evaluated our POI management mechanism contains a set of 1201 textual messages and 600 visual messages, and can be found here[4]. Notice that in order to tackle potential biases, the value of each label in each message was randomly collected from a gold standard dataset created from domain experts. The precision, recall and F1-scores for both textual and visual messages can be found in Table III. Notice, the results are rounded to four decimals.

[5]http://www.alpiorientali.it/

[6]https://www.dw.com/en/news/s-30701

TABLE III
PRECISION, RECALL AND F1-SCORES FOR TEXTUAL AND VISUAL MESSAGES

	Precision	Recall	F1
Textual Messages	0.88	1.0	0.9361
Visual Messages	0.89	1.0	0.9417

V. CONCLUSION

In this paper we presented the XR4DRAMA KG, a KG that can represent knowledge for disaster management, for example, information such as: (a) Observations and Events, (b) Spatio-temporal data, (c) Mitigation and response plans in crisis. Additionally, the XR4DRAMA KG through its POI management mechanism offers an innovative mechanism that can create or update POIs.

For future work, we plan to develop a mechanism that will make the POIs more helpful in decision making. More specifically, we will add a severity score computed by a decision support system in the POI, in order for the POI to indicate the severity of the destruction. Additionally, we will equip POIs with a sequence of tasks that need to be performed when a disaster has occurred.

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