

A SYSTEMATIC ANALYSIS OF FLOOD ONTOLOGIES: A PARAMETRIC APPROACH

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Abstract

The article identifies the core literature available on Flood Ontologies and presents a review on these ontologies from various perspectives like its purpose, type, design methodologies, ontologies (re)used and also their focus on specific flood disaster phases. The study was conducted in two stages (i) literature identification, where the systematic literature review methodology was employed; (ii) ontological review, where the parametric approach was applied. The study resulted in a set of 14 papers discussing the flood ontology (FO). The ontological review revealed that most of the flood ontology were task ontologies, formal, modular and used Web Ontology Language (OWL) for their representation. The most (re)used ontologies were SWEET, SSN, Time, and Space. METHONTOLOGY was the preferred design methodology and for evaluation, application-based or data-based approaches were preferred. The majority of the ontologies were built around the response phase of the disaster. The unavailability of the full ontologies somewhat restricted the current study as the structural ontology metrics are missing. But the scientific community, the developers, of flood disaster management system can refer this work for their research to see what is available in the literature on flood ontology and the other major domains essential in building the FO.

1.0 Introduction

A natural disaster like a flood is a serious and recurring event. It results in loss of life, destruction of infrastructure, economic losses, disruption of normal life, food, water scarcity, loss of physical communication, traffic congestions, spreading of physical diseases, etc. New, available technologies need to be adopted and applied to flood disaster management operations to cope with the flood. The pertaining question is, even though knowledge about flood exists, for instance, the vulnerability of the place, major emergencies but even then why consequences are not minimized. According to Xu and Zlatanova (2007) when a flood hits a place, immediate resource allocation is required to minimize the damage and get the situation under control. And it depends on how the different departments, organizations- government or non-government, teams, individuals co-operate among themselves leading to the use of different types of tools, technologies involved in collecting and recording the data resulting in the problem of interoperability of communication between them. The problem of

interoperability of communication between different organizations and data integration from different systems, tools have been highlighted by Othman and Beydoun (2010). From the discussion, it can be understood that though there exists knowledge regarding the flood but its organization, processing, dissemination, and communication swiftly is essential to prompt proper flood disaster management (FDM). The lack of structured and organized knowledge results in delayed decision making which concretes the need for knowledge organization in the domain. In this context, a very recent work by Yang and Wu (2019) may be mentioned. They developed a taxonomy of earthquake response and recovery for organizing and sharing earthquake-related online information resources. However, the work is limited in scope as the taxonomy is useful in classifying and organizing the objects but it cannot support automatic information processing and reasoning, in decision making by the software tools. This can be achieved with the help of the most progressive form of knowledge organization i.e. 'Ontology' ("a formal and explicit specification of a shared conceptualization" (Gruber (1992))). The closes of the relationship between ontology and knowledge organization have been explored by Marcondes (2013) and Herre (2013) whereas the increasing significance of ontologies in knowledge organization has also been argued in Turner (2017) and Ribeiro and Silva (2018). The Ontology allows structuring and logical representation of the knowledge, expressing the explicit relationships between the concepts, relationships between the entities and their properties, which enables the knowledge to be machine-processable for better information retrieval. Ontology-driven systems have gained popularity as they enable semantic interoperability, flexibility, and reasoning support (Schulz and Martínez-Costa 2013). The general notion is ontology acts as the backbone of structured knowledge models. It can help in mapping and merging information from different domains for developing a model with semantic integrity. There have been works where ontologies have been utilized for semantic knowledge management, as the work by Richard et al. 1998 on implementation of ontologies for knowledge management for the people in an organization, so that knowledge access becomes smarter. López de Vergara et al. 2002 proposed an approach where an ontology-based management information meta-model was used to map between different Network Management models (Internet network management model also known as SNMP and OSI network management model also known as CMIP). Bodenreider (2008) examined a few of the existent biomedical ontologies to elucidate the roles played by them in knowledge management, data integration, exchange and semantic interoperability, and decision support and reasoning. In a similar fashion, ontologies play important roles in designing smart and intelligent FDM systems as illustrated in Section 2.0.

The objective of this work is to identify the core literature in the area of flood ontologies (FO) that have been

built for supporting the flood disaster management system (FDMS) or have conceptualized the domain of flood. It also aimed to investigate the current state of the available FO and describe them at a granular level from various perspectives (e.g., purpose, design methodology, knowledge representation formalism, disaster phase aimed at). The primary implications of this work are: it can act as a one-stop point for the available FO and to know whether they can be (re)used or the ontologies need to be built from scratch to suffice the objective. The scientific community and the developers of FDMS can refer this work for their research to not only see what's available in the literature regarding FO but also to find the other related domains essential in building FO. The work allowed us to explore the various aspects of flood disaster which has been dealt with, the help of ontologies like forecasting flood or monitoring the flood phases and also the lacunas like unavailability of resource ontologies for supporting the disaster situation. The major contributions of this work are:

- Provides a general methodology for identifying the core literature and the review of ontologies, which can be applied with the same objectives in other domains like food, medicine, etc.
- Identifies the core literature in ontology supported FDMS.
- Provides a list of parameters that can be used to describe the ontologies concisely.
- Description and summarization of the available FO at one place.
- Identifies the basic ontologies which have been extended to suit the domain of flood.
- Identifies the research gap in flood domain where more ontologies are required.

The rest of the paper has been organized as follows. Section 2 "Flood Ontology and Ontology-based Systems" briefly discusses the FO and its uses in an FDM system. Section 3 provides "State of the art" discussing the similar works conducted in disaster and other domains. Section 4 "Methodology of Systematic Literature Review (SLR)" provides the methodology followed in conducting the current study. Section 5 "Results and Discussion" explains the results and findings of the study. Section 6 "Conclusion and future works" concludes the paper with observations providing the future research directions.

2.0 Flood Ontology and Ontology-based Systems

FO can be referred to as a knowledge artefact used to represent the concepts, relations, attributes related to flood obtained by studying various sources such as experts, manuals, articles etc. As stated above, these ontologies can be used for processing flood-related information and designing the smart and intelligent information systems. The study through the literature revealed that there have been few works that have developed FO

comprising of various classes, subclasses, and properties to fulfill the specific purposes (detailed in section 5.0).

Here, we provide the glimpses of a FO. Also, discuss the usages of FO in a FDM system.

Figure 1, produced from Almagrabi et al. 2014, depicts a Mona-ont flood emergency ontology which includes the concepts to identify contextual information within a flood situation, for example, *Disaster_management_unit* (the component responsible for looking after and tracking emergency situations), *Emergency_situation* (an event that comprises of danger information), *Region* (the whole affected area that can be a city, state or country), *Point_of_Interest* (the geographical features that can be man-made or natural and are part of the region that may influence the rescue operation), *Actors* (the people within the region inside or outside the affected area(s) including the survivor, rescuer, and the user). The ontology also includes the relations, such as *danger_relation* (connect *Emergency_situation* and *Region* to elucidate the *danger_situation* such as "closing in", "finished", "stopped" etc.), *position_relation* (present geographic information to provide relative position information within the ontology, such as "near", "far" etc.). The ontology has been employed by a system that generates alert messaging services to actors within a disaster area to carry out the rescue operations.

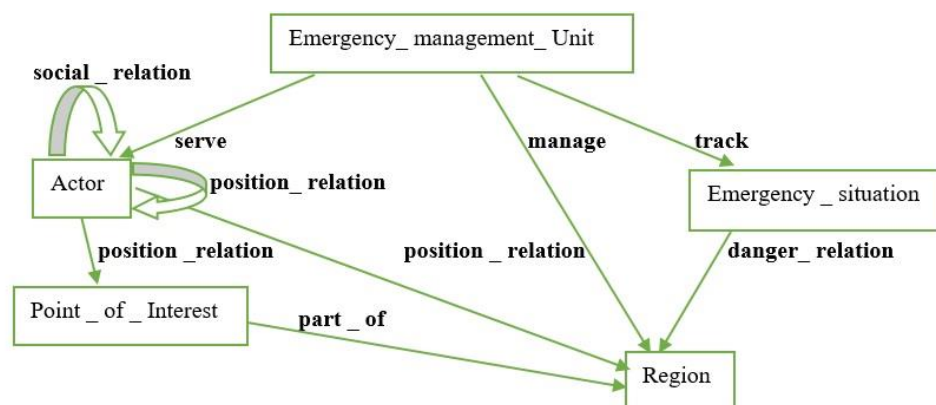


Figure 1. Mona-ont Flood Emergency Ontology (Almagrabi et al. 2014)

The FO are being used in various systems like flood artificial intelligence (Sermet and Demir 2018), emergency decision support system (Shan and Yan, 2017), web-based support system (Katuk et al. 2009), component of conceptual models (Mohd Arsi et al. 2016), hydrological monitoring systems (Wang et al. 2017) for capturing, structuring and organizing the flood knowledge. The systems or framework or conceptual models are then being used for making decisions during flood response, supporting communications between various agents, describing flood emergency situations, flood forecasting, analyzing various phases of the flood, etc. For example, figure 2 furnishes an architecture of flood artificial intelligence system for facilitating the generation

of knowledge and support the communication of flood data and information. In this system, the flood ontology is being used by a knowledge engine to connect user input to relevant knowledge discovery outputs on flooding.

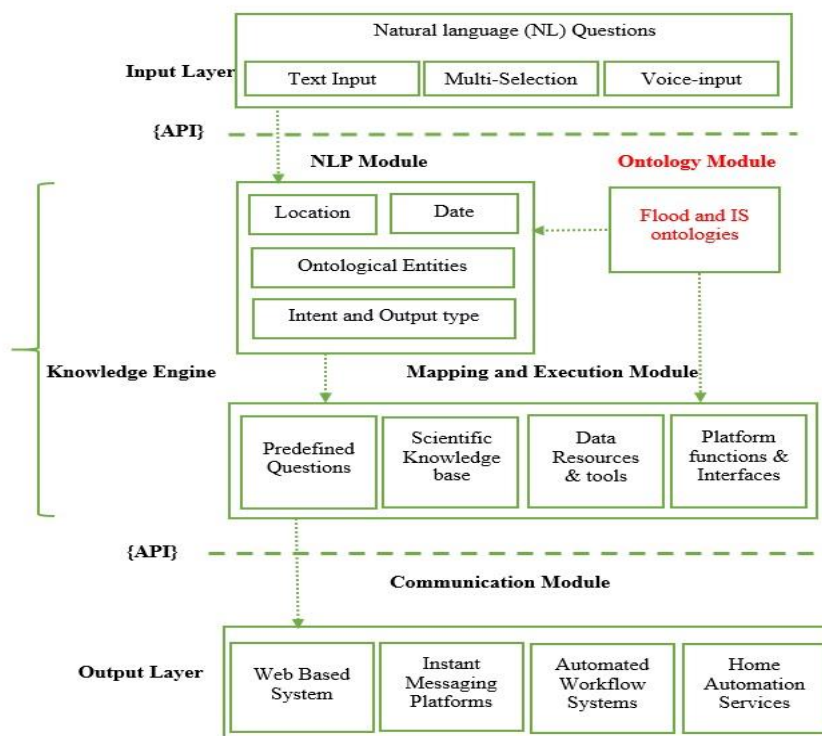


Figure 2. Architecture of Flood AI system (Sermet and Demir 2018)

3.0 State of the art

Ontologies are the supporting structure for any Semantic Web (SW) infrastructure. In the field of disaster, ontologies have been built in order to model the knowledge better and to provide a solid organizational structure to the domain. Ontology building is a complex and time-consuming process thus their existence in any domain allows researchers to decide whether to use or discard them. There have been attempts where researchers tried to summarize the available ontologies in a domain to give a fair idea about them as provided here.

Liu et al. (2013) presented a systematic review of the vocabularies (e.g., ontologies, taxonomies) available in the domain of crisis management. They identified various subject areas, such as processes, organisations, infrastructure, people, and resources. The identified vocabularies were analyzed in terms of their coverage, design, and usability. These reviewed vocabularies are very generic in nature and not specifically designed for any particular disaster like fire, flood, tsunami, etc. Though some of the concepts from these vocabularies may be used but different disasters have different requirements and may not be beneficial if someone is working on a pinpointed topic. The work neither said nor compared the ontologies on the basis of parameters like the

methodology used, ontologies reused or evaluation techniques used to validate the ontologies, which are very important as they act as a platform for the researcher to understand the ontologies in-depth. Similarly, in other domains also the researchers have summarized the existing ontologies to know what is available, like Dong et al. (2008) who were working in multi-agent systems made a general survey on the negotiation ontology research and presented them into two major categories – negotiation protocol ontologies and negotiation disambiguation ontologies which were then compared from the perspective of domain, functions, implementation techniques, evaluation method, and result. Kim et al. (2008) compared various tagging ontologies from various perspectives like concepts, attributes, format of availability. Prantner et al. (2007) described various openly available formal tourism ontologies and their current efforts. These works basically first selected a broader, mature domain, categorized the ontologies and then compared the ontologies with the basic parameters again lacking the parameters like the methodology used, design pattern, ontology re-used and evaluation performed. Mascardi et al. (2007) described seven upper-level ontologies, from various perspectives such as homepage, developers, dimensions, language(s), modularity, applications, alignment with WordNet, licensing. They described some of the ontologies which have been created by merging upper ontologies. Now, since these are top-level ontologies they can be studied upon or compared as they are easier to find as compared to very pin-pointed and immature ontologies that are difficult to access. Similarly, Giunchiglia et al. (2014) described two broader categories of ontologies: classification ontologies (used to describe, classify and search for documents) and descriptive ontologies (used for describing and reasoning about real-world entities).

4.0 Methodology of systematic literature review

A systematic literature review (SLR) in any domain results in enhancing the quality of research. The method is composed of an inquisitive methodology to pinpoint, choose, assess and harmonize the major scientific research outputs, allowing a holistic review of the existing publications. Our methodology of systematic review has been inspired by Camacho and Alves-Souza (2018). Though the skeletal of the methodology has been kept the same, we have tweaked it to suit our study. The proposed methodology is divided into two stages: stage1- literature identification, stage 2- ontological review. Stage 1 deals with finding the core literature and stage 2 deals with reviewing the existing FO from various perspectives. These two stages consisted of eight steps in total as depicted in Figure 3. They have been further described as follows.

Step 1: Query Formulation

The process of SLR started with the formulation of queries keeping in mind the objective of this paper. Various

search terms such as 'flood', 'ontology', 'flood ontology', 'knowledge management', 'disaster management', 'flood management', 'disaster ontology', 'semantic model' were used in different combinations on the selected databases, to retrieve the publications in the area of FO.

Step 2: Selection of databases

After the formulation of query, the databases were selected to search the literature. The selection of databases was dependent on the availability of the databases through the institute and also some of them were used because they are freely accessible on the web. The selected databases are Library and information science abstracts (LISA) (<https://search.proquest.com/lisa/products-services/lisa-set-c.html>), Library, Information Science and Technology Abstracts (LISTA) (<https://www.ebsco.com/products/research-databases/library-information-science-and-technology-abstracts>), Scopus (<https://www.scopus.com/home.uri>), and ScienceDirect (<https://www.sciencedirect.com/>), IEEE (<https://ieeexplore.ieee.org>), GoogleScholar (<https://scholar.google.co.in/>).

Step 3: Formulation of inclusion and exclusion criteria

To suffice the objective of the study, inclusion and exclusion criteria were devised as provided below. These criterions were used to select the papers for complete reading and analysis.

Inclusion criteria (IC)

- Papers published in Journals and Conferences.
- Papers dealt with representation of flood using the semantic techniques.
- Papers dealt with systems including an ontology in the backend which supports the flood disaster.
- Papers dealt with ontologies and/or focused on a particular stage of the flood.
- Papers dealt with FO and have provided the ontologies (expressed in Web Ontology Language (OWL), Resource Description Framework Schema (RDFS), or in any other languages) and/or have at least presented the ontology classes and properties in the paper.

Exclusion criteria (EC)

- Papers published not in English.
- Papers that spoke about FO but have not given any information on ontology, ontology classes, properties, for example in Zuhaili Mohd et. al 2016.

Step 4: Search

In this step, the queries that were formulated with different combinations search terms, such as "flood management" AND "ontology", "flood ontology" AND "knowledge management", "ontology" AND "disaster management", "flood" AND "semantic model" were utilized to search through the databases selected in step 2. When the search through the databases was performed using the query, a lot of redundant results appeared which were discarded using the Excel workbook. Thus, a dataset of papers was prepared with unique results for each database. The databases were of different types, but all of them allowed the search strings with the provisions of Boolean operators like 'AND'/'OR' to be specifically used in it. For example, in ScienceDirect, "flood ontology" AND "knowledge management" was used as a query in the search box labelled 'Find articles with these terms' which searched through the full text of all available articles. Various other filters could also be applied, for instance, content type (journal, conference), publication year, etc. Similar provisions were available for the databases, like Google scholar, LISA and were utilized.

Step 5: Pre-selection and Downloading

While searching through the databases to retrieve the papers, the abstract and title of the papers were read carefully to identify the core set of relevant papers and accordingly, their full text was obtained. But sometimes, this process was found to be insufficient to identify the relevant papers, thus we downloaded the full-text papers and read through them. The papers which talked about ontology and flood together were considered as relevant, whereas the others were deemed as irrelevant.

Step 6: Overview and Final Selection

One of the important inclusion criteria to perform the later part of the study that is a review of the ontologies, was the availability of ontologies in the paper, or in any format just to get a glimpse of them. Hence, a thorough study of the full-text of the obtained papers revealed that only a few of them had spoken about FO specifically, or had explained the ontology-based flood management system. Even among these papers, a set of papers neither presented the FO nor made it available following any of the ontological file format (e.g., .owl, .rdfs) anywhere on the Web, and thus were discarded from the study.

Step 7: Complete reading of the papers

The selected papers were read through in order to perform the study. Complete reading through the papers elucidated the various facts about the FO already built in the domain, like their purpose, type, the methodology used to develop them, formality level, etc.

Step 8: Review of FO

The major aim of this work was to locate the availability of FO in the literature, which disaster phase have they focused on, their creation, scope, objective, uses, and so forth (detailed in section 4). For this purpose, a review of the existing ontologies subject to availability was done. Previous steps helped to identify the core set of literature on FO whereas this step was performed to explore the ontologies from different aspects. This is the second stage of the study, as stated, "ontology review". It constituted three parts, namely, identification, description, and analysis, as described below.

Identification of ontologies: The first step of reviewing the FO deals with identifying the ontologies with some basic information, such as whether ontology was developed under a project, who sponsored, design pattern, number of classes, etc. It has been performed by reading through the core literature plus searching through the ontology libraries, for example, OBO(<http://www.obofoundry.org/>), DAML(<http://www.daml.org/ontologies/>), ONKI(<http://onki.fi/>), Protégé(http://protegewiki.stanford.edu/wiki/Protege_Ontology_Library). Ontology library is a kind of organizational network easily accessible remotely offers relevant or admissible ontologies in a well-organized manner and with a competent approach, which is based on different well-established ontology representation languages, such as RDFS, OWL, etc. (Noy et al. 2008; Naskar and Dutta 2016).

Description of ontologies: It basically deals with the elucidation of the FO at a granular level. It aimed at bringing out the various facts like the design methodology, knowledge formalism, tools used to design, etc. for the holistic view of FO.

Analysis of Ontologies: It was about analyzing the existing FO after their description from various perspectives to draw the inferences on them.

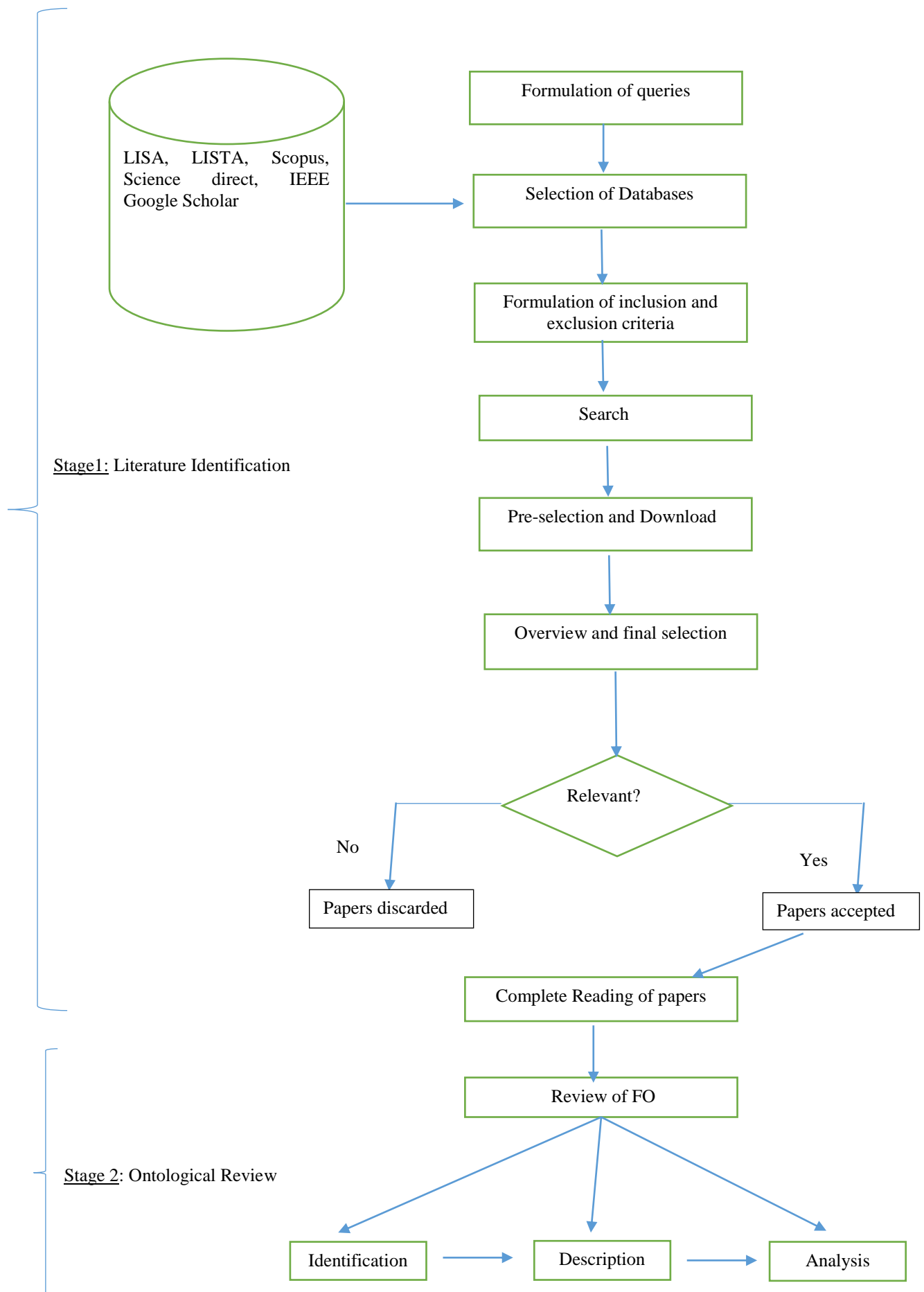


Figure 3. Workflow for systematic literature review

5.0 Result and discussion

Here, we detail our study and analysis of FO following the above discussed two stages approach of SLR.

5.1 Stage 1: Literature Identification

The first stage of SLR was "literature identification" where through rigorous search, the core literature in the area of FO was identified. The selected topic of study was pinpointed i.e. "Flood Ontology", thus to perform a literature review on such a topic was tedious. The concept of ontology development in itself is not very old, thus it was expected when performing a literature review on such topics the number of relevant papers would be less than a prolific topic. But here only lies the opportunity of identifying the untouched areas of research. All the search terms were used with different combinations on the seven databases one by one that were available, to perform the study as depicted in the previous section. Total unique results yielded per database at the initial level has been depicted in Table 1. One of the main reasons for having so many results was the phrase "ontology". Though there exists a whole lot of literature on ontologies but since the topic was very specific, the number of relevant results ultimately obtained was very less.

Sr.No.	Research Databases	Number of papers retrieved
1	LISA	53
2	LISTA	8
3	Scopus	1461
4	Science Direct	646
5	IEEE	85
6	Google Scholar	391

Table 1: Number of unique results yielded using the queries

LISA, LISTA, Scopus, Science Direct, and IEEE were used to search through as these are subscribed by our institute these gave substantial results. The results obtained out of these databases were looked upon, and if the same papers or irrelevant papers were obtained, they were discarded. Google Scholar was also consulted since it's freely available. The study investigated the presence of research material on a much-pinpointed topic hence though initial screening resulted in 36 papers to be downloaded for the study, the final dataset consisted of only 14 papers to be read completely. The results of the selection have been given below in Table 2.

Research Databases	Papers retrieved after queries	Papers pre-selected and downloaded	Papers Overview and Final Selection
LISA	53	1	0
LISTA	8	0	0
Scopus	1461	16	6*
Science Direct	646	3	1*

IEEE	88	5	4*
Google Scholar	391	11	3*
Total	2647	36	14

Table 2: Number of papers obtained during different stages of SLR

Note: The * for Scopus, Science Direct, IEEE, and Google Scholar indicates that papers from these databases were obtained for final selection because rest did not provide ontology in any form.

Considering 14 papers that were selected for complete reading, nine were Journal papers and five were Conference papers. The majority of the papers were published after the year 2010 except one which was published in 2002 and another one was in 2009. These facts clearly indicate that the idea of FO development is fairly new and in budding stages allowing more working opportunities. The results of SLR answered one part of the objective i.e. though 36 publications preached about FO, only 14 of them discussed fairly about the FO while presenting them in some format(.owl, .rdf, .xmi). Hence, these 14 publications (as depicted in the 1st column of Table 3) can be considered as core literature in the field of FO. The next sub-section deals with the review of these FO, intended to reveal detailed information about them.

5.2 Ontological review

This section dealt to achieve the remaining objectives of the study i.e. fine-grained study of the FO. To perform the study, a core set of parameters were defined for both identifying and describing the ontologies. For selecting the parameters, the existing literature by Dutta et al. (2017) and Dutta et al. (2015) were studied. The referred works provided the metadata for ontology description and publication. Besides selecting the parameters from the stated work, a few more additional parameters were identified (e.g., ontology design pattern, the operation used, evaluation approaches) while studying the literature about ontologies. These are essential enough from the point of view of ontology identification and description. The domain of flood is complex and the ontologies are not serving one purpose only, these parameters could bring out more illustrative ideas about the available ontologies. The ontological review process is further detailed in the following.

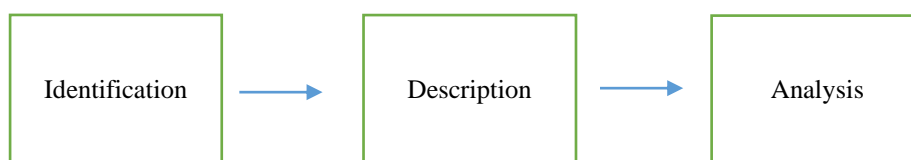


Figure 4. Workflow for Ontological review

5.2.1 Identification of Ontologies:

This step intended to bring out the versatility of FO, increasing interest in the area of developing FO and the concepts, relationships the different FO possess. The ontologies have been identified with the basic information such as sponsored agencies, project name, ontology design pattern, operations used, example classes, properties, etc. as defined below. The summary of the study has been provided in Table 3.

Sponsored Agencies: The development of ontology is a tedious process and is generally sponsored by various agencies for their development. This information allows to understand the kind of people, organization are showing interest in the development of FO and providing support. It encourages the researchers in the field to work and contribute more.

Project Name: Project name narrows down the information about the ontologies which were funded by any agency giving a greater picture of the ontology. The project name allows us to pinpoint the purpose of the ontology and identifies them as individual work or part of a work that has a bigger objective to achieve.

Ontology design pattern: A creative process related more to the structural framework of ontologies. Though there is no appropriate way to design an ontology, thus it is dependent on the understanding, the use and ontology's future development. Still, loosely two terms are used to explain the ontology design, namely modular ontology design and non-modular ontology design. Modular ontologies are the ones that use the concept of inheritance (<https://www.obitko.com/tutorials/ontologies-semantic-web/ontologies.html>) whereas non-modular ones do not.

Operation used: Refers to the process which has been performed to build the desired ontology. These operations are of different types such as Integration, Extension, Pruning (<https://www.obitko.com/tutorials/ontologies-semantic-web/ontologies.html>). Ontologies can be developed from scratch or by reusing the existing ontologies, thus these operations come into the light. Most of the ontologies are developed by using the existing related ontologies as it saves time, labor and confides to the best practices of ontology development.

Example Classes and properties: Refers to the building blocks around which the ontology revolves. A class is a collection of things sharing common attributes whereas properties are the ones that represent the kind of relationships exist between two things. The properties can be of two types: object property (which connects two entities belonging to two different, or same classes), data property (which connects an entity to a literal). These classes and properties directly convey the scope, purpose, and function of the ontologies.

Approximate Classes and subclasses: Gives a glimpse of the ontology structural metrics that contains particular information, like the number of classes, subclasses, data property, object property, axioms, etc. Since full ontologies were not available and only a snapshot of the ontologies was provided in the published papers, we counted the number of classes; and subclasses from them as presented in Table 3. Only one of the works (García-Castro et al. 2012) provided us with the OWL file, so ontology structural metrics is available for it.

As from Table 3, it can be seen that most of the identified FO are modular in nature and have been developed using the extension operation and only very few of the ontologies, non-modular in nature, have used other operations like integration or pruning. There are quite a few of sponsoring agencies, though it is an amalgamation of government agencies and academic institutes (e.g., Andalusian Regional Government, German Ministry for Education and Research, University of Iowa.), most of the ontologies have been funded by government agencies. Few of the existing ontologies are developed as part of the project, for instance, SmartCities/AQUASYSTEM, SemSorGrid4Env, Flood AI Knowledge Engine, etc. We have also given a few example classes and the properties of the FO. The number of classes and subclasses of the ontologies has also been mentioned but since the full ontologies were not available, as stated above, the ontology structural metrics are not provided here.

Name of ontology	Creators	Sponsored agencies	Project Name	Ontology Design pattern	Operations used	Example Classes and properties	Approximate Classes and subclasses
FloodOntology	Agresta et al. 2014	National Operational Program for Research and Competitiveness(PON R&C 2007-2013)	SmartCities/AQUAS YSTEM Project	Modular	Integration	Drainage_Component, Motion_Related_Quantity, Sensing_Device, is_measured, is_quantity_of	55*
Flood Ontology _a	Norwawi et al. 2002	NA	NA	Non modular	Integration	Flood Analysis, EmergencyCommittee, ContactPerson,	8*
Crisis Management Ontology	Roller et al. 2015	NA	NA	Non modular	NA	WaterLevel, ElectricityComponent, ElectricalAsset, ElectricalSupply, WaterSupplyArea, WaterResistanceThreshold, isResponsibleFor, isLocatedIn	11*
Flood Risk Assessment Ontology	Scheuer et al. 2013	German Ministry for Education and Research (BMBF), Contract 02WH1038	Era-Net CRUE project RISK MAP	Modular	Extension	Flood,EventIntensity, RecurrenceInterval, SusceptibilityFunction, ElementAtRisk, DamageRatio, Stakeholder, Authority, intensityOf, hasSusceptibility	24
Flood Risk Ontology	Yi and Sun 2013	NSFC	NA	Modular	Extension	WaterSystem, Watershed flood , Watershed drought Waterquality, Climate, Precipitation	10*
Flood Ontology _b	Wang et al. 2017	NSFC , National Key Research and Development Program of China, China Scholarship Council (CSC) Foundation, National Institute of General Medical Sciences	NA	Modular	Extension	WaterLevel, WeatherStation, HydrologcalStation,RainGuage, WaterLevelGauge, Waterbody,HydrologicalMonitorPoint, isHostedBy, isObservedBy	10*
Freshwater Flood Ontology	Garrido et al. 2012	Andalusian Regional Government	Projects (CICE) P07-TIC-02913 and P08-RNM-03584,	Modular	Pruning	Rainfall, WaterDischarge, Flood,Management, hasCharacterizingindicator, dischargeProducedby	91

Flood Domain Ontology	García-Castro et al. 2012	NA	SemSorGrid4Env European project (FP7-223913) and by the Spanish project myBigData (TIN2010- 17060)	Modular	Integration, extension	OceanRegion, OceanRegionProperties, FloodPlain, FloodZone, FloodDefencePol, Duties, Organizations, Roles, locatedInRegion, appliesTo	47
Dynamic Flood Ontology	Kurte et al. 2017	NA	NA	Modular	Extension, integration	GeoSpatialRegionTimeSlice, timeSlice, GeoSpatialRegion, Timeinterval, ImageSegment, hasFloodFiliation	8*
Flood Ontology _c	Ding et al. 2014	NHTRD, NSFC	NA	Modular	Extension	FloodEvent, DynamicObservation, Sensor, FloodProperties, UrbanFlood, isSpecifiedFor, Observes	21*
Flood Scene Ontology	Potnis et al. 2018	NA	NA	Modular	Extension	FloodWater, Road Vehicle, hasVehicle	4*
Flood Ontology _d	Katuk et al. 2009	NA	NA	Non-Modular	NA	FloodDisasterManagement Committee, FloodOperation CommandCenter, On Scene Control Post, Victim, Supply, Health, EvacuationCenter,	13*
Flood Ontology _e	Sun et al. 2016	French Auvergne-Rhône-Alpes, European Regional Development Fund (ERDF).	NA	Modular	Extension	FeatureOfInterest, Sensor, Property, Observation, flood, waterflow, rainfallamount, PrecipitationNode, WaterCourseNode, sensorID, newFrequency	9*
Flood Ontology _f	Sermet and Demir 2019	Iowa Flood Center and University of Iowa.	Flood AI Knowledge Engine software	Modular	Extension, integration	NaturalHazard, Instrument, EnvironmentalPhenomena, RiverineFlood, flowDirection, flowRate, hasWaterSource, measuredBy	42*

Table 3: Identification of ontologies

Note: (i) The number of classes/subclasses marked with an asterisk (*) indicates that the respective ontologies were only partially available to us and hence we do not know the exact number of classes/subclasses in them. (ii) Example classes (started with Capital letter) and properties (started with small letter) are provided here in the style they were originally found.

Abbreviations used: NA-Not Applicable, NSFC- National Natural Science Foundation of China, NHTRD - National High Technology Research and Development.

5.2.2 Description of Ontologies:

The obtained fourteen ontologies are briefly described here. The description of the ontologies is provided in Table 4 for an easy understanding. A total of twelve parameters have been identified as discussed below to study the ontologies at a granular level.

Purpose of Ontology

It elucidates the use of ontology or function it will perform if included in a system for flood management. It acts as a compass to the scope of an ontology. The purpose of each ontology was different because the ultimate goal of these works differ from one another, for example, FloodOntology developed by Agresta et al. (2014) has concepts to gather information about water parameters in watersheds and sewers for forecasting flood, whereas, the top-level flood ontology_d by Katuk et al. (2009) was developed to classify the flood management activities into categories in accordance to the responsibilities of the agencies and so on.

Type of ontology

It enables to understand the kind of ontologies developed in the domain of flood, giving an idea about the general-purpose, scope of the ontologies and also about the available, missing ontological resources. The ontologies are generally of various types; upper ontology (aka generic, top-level- aims at capturing general knowledge about the world, providing basic notions and concepts for things, e.g. time, space), domain ontology (captures the knowledge valid for a particular type of domain e.g. chemical, electronics), task Ontology (provide terms specific for particular tasks), method ontology (provides terms specific to particular Problem-Solving Methods, e.g. assembling parts of a computer). Application ontology (contains all the necessary knowledge for modelling a particular domain. Usually, it's a combination of domain and method ontologies). Metadata ontology (describes the content of on-line information sources like Dublin Core), Representational ontology (it does not refer to any particular domain but provide representational entities without stating what should be represented), Terminological ontology (a lexicon specifying the terms that are used to represent knowledge in the domain of discourse, e.g. Unified Medical Language System), Information ontology (specifies the record structure of the databases, e.g. Level 1 of the PEN & PAD model, a framework for modeling medical records of patients). Knowledge modeling ontology (specifies conceptualizations of a knowledge area, e.g. Level 2 description of the PEN & PAD model) (Kaewboonma et al. 2014)

Focussed Phases

It relates to the disaster management phase (DMP) in which the FO are concentrated. The disaster management

model (DMM) by Nojvan et al. 2018 was referred to as it was the most recent model available in the literature to identify the phases. It covered most of the aspects of DM. The model has divided the whole DM into three major phases: hazard assessment, risk management, and disaster management actions through thematic analysis. The DM actions were further divided into four major actions i.e. preparedness, mitigation, response, and recovery. So, for this study, we considered the six phases of DM. They are hazard assessment (a process of recognizing the potential hazards to eliminate or control them), risk management (methodical use of management protocols, methods, and practices for understanding, assessing, restricting and even communicating about risk issues), preparedness (actions framed to curtail the effect of disaster when forecasted), mitigation (actions framed to reduce the consequences of upcoming probable disasters), response (the immediate actions were taken during disaster which is short term after a disaster, to save human lives and supply aids), and recovery (to repair the damage, restore services, and reconstruction of facilities after a disaster has struck) (Manitoba-Health-Disaster-Management 2002; Hidayat and Egbu 2010; Alexander 2002). To understand which disaster phases the ontology has concentrated we compared the objectives of the work to the DMP. It may be the case that one ontology had concepts that concentrated on more than one phase of disaster but we generally considered the phase which had maximum attention. According to Table 4, it's clear that the majority of the FOs have been built for response phase of the disaster, few of them have been built for risk management, some of them have been built for contributing towards the preparedness and hazard assessment phases, few of the study was spread around more than one phase like the Flood Ontology_b developed by Wang et al. 2017.

Ontology re-used

One of the most important parameters for the study was ontology re-use, refereeing to the ontologies which support in the construction of FO. This parameter served two purposes, one, it gave an idea of whether the FO was made from scratch or used some concepts from previously available ontologies. Second, it revealed the kind of ontologies that were used to build the FO like top-level ontologies, domain ontologies etc. Some of the most favored ontologies used for creating the FO were Semantic Web of Earth and Environment Technology Ontology (<https://bioportal.bioontology.org/ontologies/SWEET>), Semantic Sensor Network, (<https://www.w3.org/2005/Incubator/ssn/ssnx/ssn>), Time ontology (<https://www.w3.org/TR/owl-time/>) and Hydraulic ontologies. Some of the other ontologies which were used to develop FO are MONITOR (Ontological basis for Risk assessment, <http://www.monitor-cadses.org>), Environment Impact Assessment Ontology (Garrido and Requena 2011), DOLCE (<http://www.loa.istc.cnr.it/dolce/overview.html>), A Geographic Query Language for RDF Data (GeoSPARQL, <http://www.geosparql.org/>), Spatial Image Information Mining (SIIM), Basic

Formal Ontology (<http://basic-formal-ontology.org/>) etc. Of these ontologies DOLCE, SWEET, BFO are the top-level ontologies, whereas MONITOR is a domain ontology for risk management.

Contributing domains

It means while gathering the concepts for the construction of FO, which are the other domain concepts were used. The other domain concepts contribute to the FO as it is generally created for ad-hoc applications. This surfaced the domains frequently used in the creation of FO. Some of the most used domains for the construction of FO are Sensor Network, Hydraulic, Hydrological, Time, and Space. Some ontologies developed for flood risk management also had concepts from risk domains.

Design Methodology

It refers to the systematic steps followed for the construction of ontologies, for instance, METHONTOLOGY (Fernández-López et al. 1997), UPON (De Nicola et al. 2009), etc. An appropriate methodology used to build the ontology will ensure the quality of the ontology and the researchers shall have ready to use methodology at their disposal. Such solutions are difficult to obtain precisely but having a pool off methodologies for the construction of FO will reduce the effort and time for researchers. Though there is no standard methodology (Sermet and Demir 2019) which should be followed in creating an ontology but following anyone of the existing methodologies makes the ontologies more scientific. The interesting fact is that out of the fourteen ontologies developed only five of them have mentioned the methodologies followed. Two of the works followed METHONTOLOGY, whereas others followed, Uschold and Gruinger method, Brief Ontology (Delgado et al. 2005), Ontology Development 101(Noy and McGuinness 2001) etc. as depicted in Table 4.

Class hierarchy development

To develop the class hierarchy, there are generally three approaches used namely, top-down, bottom-up and middle out, which have been explained in the literature with their pros and cons. All of these approaches can be used to create the class hierarchy for the ontology. The top-down approach identifies the root concept first and then slowly narrows down to more specific concepts, so it goes from the abstract level to the concrete level. The bottom-up approach investigates and studies the features of base concepts, then groups them according to their similarities to form a larger aggregate. The process is continued iteratively until the root concept is obtained. So, the bottom-up approach proceeds from the concrete ground and reaches to abstract level (Dutta et al. 2015). A middle-out approach, by contrast, strikes a balance in terms of the level detail. Detail arises only as necessary by specializing the basic concepts, so some effort is avoided. By starting with the most important concepts first and

defining higher-level concepts in terms of these the higher-level categories naturally arise and thus are more likely to be stable. This in turn leads to less re-work and less overall effort (Uschold and Gruninger 1996).

Representation language

Refers to the language in which the concepts and relations are represented for example OWL, RDFS (McGuinness and Van Harmelen 2004). Again there are various ontology representation language available but choosing appropriate ontology representation language amidst various feasible options is difficult. This parameter will allow researchers to see which language has been used mostly for the FO representation. In our study, it is found that almost all of the ontologies were developed used OWL, whereas few of them used UML to represent their ontologies as shown in Table 4.

Level of formality

It is directly proportional to the language and language expressivity used to construct the ontology. The level of formality can be of three types namely; informal, formal and semiformal ontology. Informal ontologies are the ones which have been built like a taxonomy like Yahoo! Directory, DMOZ, formal ontologies are the ones using a formal ontology language (e.g., OWL) like DOLCE, semiformal ontology has a more schema like structure and is built using a language like RDFS (Uschold and Gruninger 1996). Almost all of the ontologies developed here are formal except three, two of them being informal (Roller et al. 2015; Katuk et.al 2009) and one of them was semiformal (Ding et al. 2014). Thus making most of the ontologies machine-processable.

Ontology Editor

It refers to the software that facilitates the ontology development, allowing visualization, modification, maintenance, updating, and syntactic evaluation of the ontology (Altarish 2012) for example Protégé (Stanford University School of Medicine), WebVOWL (Lohmann et al. 2014), etc. Generally, ontologies are developed to solve a specific problem at hand, hence choosing the right ontology editor amidst various feasible options for the ontology development is difficult. Hence, this parameter will help to save the time of the user by supplementing the information of popular ontology editors for FO development. The study revealed very few of the works mentioned about the ontology editors used by them but even among them protégé was popular choice except few, where, one used Java Agent Development Framework (<https://jade.tilab.com/>) and another one used GenMyModel (<https://www.genmymodel.com/>).

Evaluation

It refers to the evaluation done of the FO. It is very much essential that the FO are evaluated and the results are explained to build the trust of the users. Evaluation acts as a platform for designing new FO, analyze whether the ontology is suitable enough for certain applications, domains and also helps in updating the ontology. To evaluate the ontologies various approaches exist like golden standard (based on comparing the ontology with an existing one), application-based (based on using the ontology in an application and evaluating the results), data-based (based on involving comparisons with a source of data, e.g. a collection of documents about the domain to be covered by the ontology), human evaluation (by humans who try to assess how well the ontology meets a set of predefined criteria, standards, requirements), task-based (evaluating an ontology-based on the competency of the ontology in completing tasks), Criteria-based (evaluation based on proposed criteria) (Brank et al. 2005; Yu et al. 2007). Depending upon the availability of the standard ontology, expert, data, application, criteria's any one of the evaluations must be performed. As we see from Table 4, a few of the ontologies (seven) were evaluated and some (five) were not. There is a mixture of methods which have been majorly used like application methods or data-based methods whereas some of them used two or three methods to evaluate the ontology, for example, Flood Domain Ontology (García-Castro et al. 2012) and Flood Ontology_f (Sermet and Demir 2019).

Availability in Ontology Library

Ontology libraries can serve as a link in enabling diverse users and applications to discover, evaluate, use, and publish ontologies (d'Aquin and Noy 2012). The availability of ontologies allows researchers to analyze the ontologies from various perspectives making it more usable. Some of the ontology libraries that were searched are Open Biological and Biomedical Ontology (<http://www.obofoundry.org/>), DAML ontology library (<http://www.daml.org/ontologies/>), ONKI (<http://onki.fi/>), Protégé Ontology Library (http://protegewiki.stanford.edu/wiki/Protege_Ontology_Library). Unfortunately, no FO could be found in them.

IEEE1074-1995 Compliance

The IEEE 1074-1995 standard elucidates the process and activities which may be followed for developing software. These processes and activities can also be followed while developing an ontology leading to a sustainable and quality ontology that can be used, studied, further developed in the future and can be researched on. These activities provide a platform for the developers of ontology to have a clear idea about the activities

they need to perform while developing ontologies. The standard defines three kinds of processes (De Nicola et al. 2009):

a) Project management processes (PMS): refers to the development of a project management framework for the entire ontology lifecycle, comprising of project initiation, monitoring and control and quality management of ontology.

b) Ontology development processes (ODP): refers to the whole creation process of an ontology. The process is divided into three sub-process:

- Pre-development process: is concerned with an environment study and a feasibility study.
- Development process (DP): is concerned with requirements, design, and implementation of ontologies.
- Post-development process: is concerned with installation, operation, support, maintenance, and retirement of an ontology.

c) Integral processes (IP): refers to knowledge acquisition, evaluation, configuration management, documentation, and training of the ontology.

From Table 4, it is evident that when we apply the ISO 1074-1995 to the evaluated FO, a very few of the ontologies are compliant to the processes and even if they are compliant, they are partial i.e. the three processes mentioned above are composed of sub-process for example PMS comprises of project initiation, monitoring and control and quality management of ontology. All the sub-process were not applicable for the ontologies, hence deemed as partial, for instance, ontologies by Agresta et al. 2014, Norwawi et al. 2002, and Sermet and Demir 2019 support project management and integral process partially as the project initiation, evaluation is applicable but rest of the sub-process are not applicable but the sub-process DP was applicable fully as the requirements, design, and implementation of ontologies were applicable hence, they were deemed as full support for DP. For some of the ontologies only sub-process were applicable like DP but that also partially, for example, Flood Risk Ontology (Yi and Sun 2013), Dynamic Flood Ontology (Kurte et al. 2017), hence deemed as partial support for DP.

Name of ontology	Purpose	Type of Ontology	Focused phases	Ontologies re-used	Contributing domains	Design Methodology	Class hierarchy development	Representation language	Level of formality	Ontology Editor	Evaluation	Availability in Ontology Libraries	IEEE1074-1995 Compliance
FloodOntology	Provide a consolidated, structured knowledge base for flood prediction.	Application	HA	SWEET,SSN	Sensor, Hydraulic, Hydrological	Uschold and Gruinger	MO	OWL	Formal	Protege	NA	No	PMS,IS (Partial) DP(Full)
Flood Ontology _a	Organizing knowledge about flood occurring event, deriving data from hydrology ontology and supply a report to response team for action.	Task	Response	NA	Hydrological, Emergency Management Team	Methontology	MO	OWL	Formal	Protege	NA	No	PMS,IS (Partial) DP(Full)
Crisis Management Ontology	Capturing knowledge of a scenario where electrical asset is down due to flood that can be used to develop a data sharing solution, provided through the linked data available between various stakeholders involved.	Task	Response	NA	Hydrology, Electrical, Stakeholders	NA	NA	NA	Informal	NA	Application and data based	No	DP,IS (Partial)
Flood Risk Assessment Ontology	Capture knowledge relevant to the flood risk assessment with the stake holders involved for overcoming the situation.	Application and domain	RM	SWEET, MONITOR	Risk Domain, Hydrology domain, stakeholders	Modified Methontology and UPON	MO	OWL	Formal	NA	Application based	No	PMS,IS (Partial) DP(Full)
Flood Risk Ontology	Developing a flood risk assessment workflow.	Task	RM	SWEET, Watershed Ontology, Water resource risk ontology	Watershed science	NA	TD	OWL	Formal	NA	NA	No	DP(Partial)

Flood Ontology _b	Managing the flood related knowledge so that various stages of flood can be recognized based on the existing knowledge.	Task	Preparedness, Mitigation, Response and Recovery	SSN, Time, OGC GeoSPARQL	Sensor Network, Time, Hydrology.	NA	TD	OWL	Formal	Protege	Data based	No	DP,IS (Partial)
Freshwater Flood ontology	Simplify and optimize use of the ontology for flood information. Also describe the semantic modeling of floods and flood-related concepts.	Domain	RM	EIA, DOLCE	Hydrology, Hydraulic, management	Brief Ontology	TD	OWL	Formal	NA	Manual	No	DP,IS (Partial)
Flood Domain Ontology	Act as supporting ontology to semantic sensor web infrastructures representing infrastructural and coastal flood data.	Task	Preparedness	Role, Additional region, Coastal Flood defence	Sensor domain, Hydraulic	NA	NA	OWL	Formal	Protege	Static approach, data and application, manual	No	DP,IS (Partial)
Dynamic Flood Ontology	Model the spatio-temporal changes in flood disaster situation.	Task	Response	Time, SIIM	Image Domain, Time, Space	NA	NA	OWL	Formal	NA	NA	No	DP (Partial)
Flood Ontology _c	Developed as a unifying semantic description model to map relations between geo-models and geo-observational data.	Application	All Phases	SWEET	Hydraulic, hydrology, meteorological, Geoscience	NA	NA	NA	Semi-Formal	NA	Data based	No	DP,IS (Partial)
Flood Scene Ontology	Mine the topological and directional knowledge in context to the flood disaster phenomenon.	Task	Response	BFO	Image Domain, Time, Space	Ontology Development 101	NA	OWL	Formal	NA	NA	No	DP(Full)
Flood Ontology _d	Modelling the flood management activities that needs to be carried out by different agencies according to their responsibilities.	Task	Response	NA	Flood Management Committee, Hydraulic, hydrology,	NA	TD	NA	Informal	NA	NA	No	DP (Partial)

Flood Ontology _e	Act as a central ontology to which other ontologies can be connected, helping to develop a full context data model.	Task	All Phases	Climate and Forecast ontology and Irstea Hydro Ontology	Sensor, Hydraulic, hydrology, meteorological	NA	NA	UML	Formal	JADE	Data based	No	DP,IS (Partial)
Flood Ontology _r	Developed for comprehending and resolving complex environmental queries to support the Flood AI intelligent system.	Information	Preparedness, monitoring, Response, and recovery	NA	Natural Hazard, Instrument, and Environmental Phenomena	NA	TD	UML	Formal	GenMy Model	Data driven ,application approach and partially manual	No(Present in GitHub)	PMS,IS (Partial) DP(Full)

Table 4: Describing ontologies

Ontologies extended: Semantic Web of Earth and Environment Technology Ontology(SWEET), Descriptive Ontology for Linguistic and Cognitive Terminology(DOLCE), Environmental Impact Assessment(EIA), Semantic Sensor Network(SSN), Time Ontology , Sensor web Ontology, MONITOR (Ontological basis for Risk management), A Geographic Query Language for RDF Data ,(GeoSPARQL), Spatial Image Information Mining (SIIM), Basic Formal Ontology(BFO)

Abbreviations used: RM- Risk Management, HA- Hazard Assessment, MO- Middle Out, TD- Top Down , NA-Not Applicable JADE-Java Agent Development Framework, UML-Unified Modelling Language

5.2.3 Analysis:

This step of ontological review is about analyzing the existing FO based on the descriptions provided in the previous section. This enables in bringing out the inferences to achieve the objective of the granular study of ontologies.

The purpose of ontology acts as the compass to define the scope, concepts required, and domains to be reused leading to its development. As depicted in Table 4, though all the ontologies were related to flood but had a different purpose, so different concepts from various domains were used to construct them. Some of the major domains are hydrology, hydraulic, sensor, time, space. Each of these domains has concepts either related to natural phenomena, captures information about the natural phenomena or captures the temporal, spatial components which are required for building the FO. But since purpose differs, they are required in different combinations. Ontologies that carry knowledge about natural phenomena are favored because flood is a natural phenomenon and thus it's bound to have concepts that can be reused. Similarly, if the purpose is to capture flood flow information, ontologies having concepts about such devices will be favored. Thus we see that the majority of the ontologies are task or application ontologies.

Focused phases deal with the fact that the developed ontologies majorly support which phase of the disaster out of the six phases considered. In the study, it was discovered that there were no ontologies that were built to support the phases like recovery, and mitigation specifically. All of the ontologies were built for different purposes but the majority of the ontologies were built around the response phases and had a common link. All these ontologies were built assuming a certain scenario, which may take place during a flood, like Flood Ontology_b (Wang et al. 2017) was developed to monitor the various stages of flood of Yangtze River. For the experimental purpose observational data of two months from 22 sensors were obtained. Then with the help of semantic querying and knowledge acquisition the workability and operation of the developed ontology was shown. Although, a few of the ontologies took into consideration the various actors involved during the flood when such a situation comes these actors require different kinds of resources and need to communicate between them. Hence, there is a need for ontologies for the flood which could organize the different resources that could be used by the various agencies and individuals to support the response phase of an FDM system.

Building ontology from scratch requires a lot of time, effort and cost (Dutta et al. 2015). It's always suggested to reuse the existing ontologies. This work investigated which of the existing ontologies were used predominantly for FO development. Table 4 clearly depicts that the flood-related ontologies have been built mainly using

SWEET ontology as it is holistic, unified, and application-independent (Ding et al. 2014). It has both integrative and faceted structure, with terms from various domains, such as environmental and earth system sciences, physics, chemistry or maths to describe human activities and natural phenomena. SWEET has been used in FO because it defines a hierarchy of many flood risk-relevant terms, e.g. flood/inundation and different infrastructure facilities (Scheuer et al. 2013) making it a versatile ontology to support the semantic systems built for flood management systems. Similarly, SSN ontology has been used a lot to create FO because the data required to monitor flood situations can be collected through the installed sensors, thus making this ontology a very essential component of FO. There are few other ontologies, like Environment Impact Assessment ontology (Garrido and Requena 2011) has concepts already available to directly model the flooding domain and those which are not directly included can be generalized in the representations of other concepts. MONITOR (Kollarits et al. 2009) models the concept of risk and describes the relations between natural, social and built environments. It also describes potentially hazardous events, associated risks, risk assessment, and risk management terms in-depth stacking an important component of flood risk ontologies. There are other ontologies like; Time ontology which are used to ensure the temporal component, so that the dynamic information about flood can be collected. Other top-level ontologies like DOLCE, BFO are also used as base ontologies for building the flood domain knowledge and other relationships.

The design methodologies for ontology describes everything about the developmental steps of ontologies with their motives, weaknesses, and strengths. There exist few principles, recommendations for developing ontologies when these are followed it leads to more comprehensive and acceptable ontology. In this study, it was found that very few works have explicitly stated the methodologies used, so it was difficult to point out a particular methodology, which is popular or appropriate but among them, it was seen that METHONTOLOGY is the preferred one as it is a structured, generic, application-independent approach method for building ontologies from scratch. In one of the works authors used a mixture of two methodologies METHONTOLOGY and UPON where the later methodology introduces use cases and competency questions to help define the scope and purpose of the ontology. Some of the works used very recent methodologies, like Brief Ontology; formally defined by Garrido & Requena (2012) as an extraction algorithm and a tool for creating ontologies. In essence, it produces a reduced version of the ontology with relevant knowledge, with limitation of requiring an ontology. Using this, we cannot build ontologies from scratch whereas one of the works used Ontology Development 101, for a declarative frame-based system that was free of this limitation. So though there is no single correct design methodology for ontology development in any domain but it's the scope, purpose and envisioned application

that drives the choice.

Majority of the ontologies were developed using OWL language and Protégé as the ontology editor. The primary reasons for them to be preferred are their popularity and varieties of functions they provide. For instance, OWL is a W3C recommended formal language for representing the information making it ready for machine processing since the purpose of developing ontology is making it usable rather than coding the information for the sake of it. OWL also provides different species with various levels of expressivity making it a powerful tool for representing concepts and their relationships. Similarly, Protégé is a knowledge-based editor, open-source, easy to use, allowing the user to create, edit, update and visualize the ontology very easily. However, Sermet and Demir argue that most of the ontology editors do not support the simultaneously accessed workplace and online development. Though the Protégé desktop supports illustrations and visualizations but visual editing is limited, whereas Web Protégé facilitates online and collaborative environment but does not offer any visual editing capabilities. Thus they used GenMyModel, an online modelling platform.

Ontology evaluation is an important part of the ontology life cycle adopted in the SW and other semantics-aware applications. Trust and confidence in the ontologies for its immediate usage comes from the fact whether the ontologies have been evaluated or not. In this study of the FO, it was observed that some of them have been evaluated using application-based or data-based approaches whereas two of them have been done by manual method but many of them were not evaluated, hence there is no guarantee that these ontologies are trustworthy. The domain of flood does not possess as such any standard ontology that can be used to compare. Thus, it becomes difficult to evaluate the ontologies by own self. There are few ontologies that were developed as a part of the research and development program of major organizations, hence, for them, it was easier to get data but for independent scholars, it's difficult to get the data. So, this may be another reason why few of the ontologies were evaluated.

From this study, it is observed that most of the FO support sub-process of ODP, i.e. DP if not fully but at least partially meaning some of the activities are applicable. The activities related to DP are requirements, design, and implementation of ontologies these mainly deal with the purpose, scope, usage, and designing of ontologies and ontologies at least needs to go through these processes for its development. Hence most of them support the DP. But the processes, like installation, operation, support, maintenance of ontology are not applicable because it may not fall under the purview of their scope. Some ontologies support the IP partially, especially the evaluation and documentation activities as these increase the trust in the ontologies and give a fair idea about the ontology, whereas configuration management and training of the ontology are generally absent. Very few of the studied

ontologies support the PMS but partially as it treats ontology development as a project management framework that deals with project initiation, monitoring and control, and quality management of ontology and some of these activities are not applicable for studied ontologies.

Discussion:

It was observed that most of the FOs studied were built around small tasks performed during a flood. Among these very few tried to conceptualize the whole flood disaster together. Ontologies are considered computational artifact like software programs. So as programs, ontologies can become big and complex, thus using the modular approach makes it easier to process, update, assess and reuse. The choice of evaluation approach may be based on the matured ontologies available in the domain. As this domain can be considered fairly new thus majorly application or data-based approaches are used. In most of the ontologies, top-down approach has been chosen for hierarchy development. If a flood disaster strikes there are some general resources required, for example, boats, food, and medical aid to provide an immediate response. Information about them has not been captured in these FO which is essential to carry out the rescue, relief operations. A very few papers, for instance, Shan and Yan 2019 discussed that the strategic and tactical features of flood emergency response include the resources required for rescue comprises of emergency equipment, relief supplies, and materials for daily living. Thus, we need more ontologies, modelling the resources and connecting it to phases like the response phase, recovery phase. Although, as claimed in the literature, most of the ontologies are in OWL, the access to them is tough as very few (only two) of them were available. The research focus should be on developing the FO systematically for various other DMP by adopting available methodologies. Also, making the ontology available should be emphasized to make it reusable.

6.0 Conclusion and Future Works

The work was built on two primary objectives: one identifying the core literature in the area of FO and another exploring the existing ontologies at a granular level from various perspectives. The first objective was achieved through the process of SLR yielding a set of core literature i.e., 14 papers discussing the developed FO presenting their core concepts in the paper or as OWL file. These works were published in various conferences, journals of different subjects proving it as an interdisciplinary area of work. Both subject experts and ontology experts collaborated for these works, which can be easily observed from the affiliations of the authors. But since the concentration of the work was not on bibliometric studies (Pritchard 1969), so this was not mentioned specifically. Next, the ontological review was performed using the parametric approach. The existing literature was studied to identify and select the parameters. These parameters were then defined and applied for the

granular study. This stage of the study was done to review the ontologies and to understand the current state of the FO from various perspectives like its purpose, scope, design methodology used, tools used, the kind of ontology be it functional wise or structure-wise, etc. rather than their critical point of view. This review also laid the foundation of studying ontologies from the parametric approach where they can be used to identify and describe the ontologies in any other domain concisely and even the whole methodology used can act as a general methodology for similar kinds of studies. The study revealed that there is no standard FO available in the field. The major constraint of this study was the unavailability of the full FO, even though the developers were contacted for making the ontology available, but very few of them replied. So, with limited resources, maximum information is provided here. Structural ontology metrics for all the ontologies could not be made because of the aforementioned reason. Ontologies reviewed here were mostly scenario/task-specific and only a few of the ontologies were intended to organize the knowledge in flood domain. Though it's true that flood in the village and in urban area will pose a different kind of problems but the minimal resources required to tackle the situation remains almost the same, just its type may vary for example; boats will be required for both the places but the type of boat required for urban area to village area may vary. Hence, a resource ontology that organizes these kinds of resources will be helpful to tackle the situation during a flood. In the future, we would like to build an ontological model for resources.

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