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WaterOnto: Ontology of Context-Aware Grid-Based Riverine Water Management System

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Abstract

The management of riverine water always remains a big challenge, because the volatility of water flow creates hurdles to determine the exact time and quantity of water flowing in rivers and available for daily use. The volatile water caused by various water sources and irregular flow pattern generates different kinds of challenges for management. Distribution of flow of water in irrigation network affects the relevant community in either way. In the monsoon seasons, river belt community high risk of flood, while far living community suffering drought. Contemplating this situation, we have developed an ontology for context-aware information representation of riverine water management system abetting the visualization and proactive planning for the complex real-time situation. The purpose of this WaterOnto is to improve river water management and enable for efficient use of this precious natural resource. This would also be helpful to save the extra water being discharged in sea & non-irrigational areas, and magnitude and location of water leakage. We conceptualized stakeholder and relevant entities. We developed a taxonomy of irrigation system concepts in machine process able structure. Being woven these hierarchies together we developed a detailed conceptualization of river flow that helps us to manage the flow of water and enable to extract danger situation.

Keywords: Irrigation water, Diversion, Reservoir, Web 3.0, Management, Ontology, Wireless Sensor Network, Semantic Modelling, software agents, Disaster

1. Introduction

In nature, water is the essential fluid from which all lives are created. All living things need water for survival. Water resources are sources of water that are useful or potentially useful to humans. Many uses of water include agricultural, industrial, household, recreational and environmental activities. Virtually all of these human uses require fresh water. Only 2.5% of water on the Earth is fresh water, and over two-thirds of this are frozen in glaciers and polarize caps. Water demand already exceeds supply in many parts of the world, and many more areas are expected to experience this imbalance in the near future. Estimation theory claims that 70% of worldwide water use is for irrigation in agriculture. Climate change asserts significant impacts on water resources around the world owing to the close connections between the climate and hydrologic cycle. Due to the expanding human population competition for water is growing such that many of the world's major aquifers are becoming depleted. Rivers are of immense importance geologically, biologically, historically and culturally. Although they contain only about 0.0001% of the total amount of water in the world at any given time. The rivers are vital carriers of water for irrigation and other nutrients provision source to the human body.

A grid-based wireless sensor assisted system was proposed in [1] and water monitoring Ontology [2] is the science of relationships how the things are related to each other. It seems as a complex stuff around but with the terms recognize globally and explicit implications streamline the contextual understanding standardization. We can achieve a well-established model of any phenomenon. Which helps us to relate objects and infer knowledge from given domain. Studer [3] Defines Ontology as an explicit representation of information that can be effected from temporal and spatial variations.

Rivers flow information changed spatially and temporally that need to be closely monitored pre-planning required for possible reactions to a disaster situation. Ontological represents semi-structured data in an efficient way along with contextual knowledge, particularly where stockholders having variation in major technical veracity and diversity. Sharing of information in a variety of formats is challenging task that is manageable by developing an ontology for information sharing. Ontology support interoperability and context information flow representation transitively assisting towards managing the provenance [4] of the system and decision can be retraced and evaluated for authenticity and efficacy of the information. The fundamental constructs of ontology include Classes, Relations, Axioms and Instances depict the domain knowledge in more comprehensive and natural semantic style with core concepts and their correlations. Semantic model [5] enables towards the design of automated system real-time monitoring. The classes represent concepts, which are taken in a broad sense [6] for all stakeholder in contextual computing environments. Collaborative interaction among concepts of similar and different domains are illustrated by to *Relations* [6]. Ontologies usually contain binary relations but increasing cardinality of association push towards course grain ontologies. Binary relation represents an association between the *domain* of the relation and *range*.

Axioms are used to associate class and property IDs with either partial or complete specification of their characteristics, and to give other logical information about classes and properties [7, 8]. A class axiom contains a collection of descriptions, which can be more general classes, restrictions, sets of individuals, and boolean combinations of descriptions. Ontology is exported in XMLs and regenerated in java like code. According to [9], *formal axioms* serve to model sentences that are always true. They are normally used to represent knowledge that cannot be formally defined by the other components. In addition, formal axioms are used to verify the consistency of the ontology itself or the consistency of the knowledge stored in a knowledge base. Formal axioms are very useful for inferring new knowledge. An axiom in the WaterGrid can infer list the causes of that variation flow using possibility theory [10].

Instances are used to represent elements or individuals in an ontology [6]. An example of an instance of the concept water low volume in Merab canal measured by Sensor WSN6321 on February 8, 2016, was 200 cubic meter per minute.

The effects of climate change are insidious and chronic that cannot be brought under control quickly, especially with the inadequate measures and unpredictable. Climate change and desertification should be considered globally as well as locally. Specific floods can also be caused by ice accumulation, a landslide in riverbeds and ice melting due to high temperature, breach of embankments, drainage congestion etc. In this paper, we will discuss the ontology of Context-Aware Grid Based Riverine Water Management System through which we overcome following information issues:

- Time and quantity of water flowing in rivers and available for use of daily routine use in irrigation, household, industry, and sea to fulfill fresh water need for sea.
- Identification of major water level alteration trends, and sharing current situation information to relevant authorities for possible proactive measures through smart intelligent web 2.0 bases application [11].
- Reducing information format ambiguity and contextual statics for mitigation strategies through interoperable information sharing enables heterogeneous machine capable to process Ontology web language.

Developing domain knowledge for water management systems and interconnected disciplines for spatial- temporal situational variation.

2. Related Work

There is a few cite-worthy literature that reflects the sound knowledge of water management system and building a knowledge-base for river flow management and quality of water. They aim towards the management of water for irrigation purposes and disaster management responses. In general, all of them proposes the model-based management of water with geographical and climate concerns. In [12] authors discussed the methodology for the fusion of different geographic domain ontologies with top-level ontology, in order to provide a solid base for information exchange. Semantic factoring and concept lattices prove to be powerful tools in the formation and integration of geographic context. More specifically, the proposed methodology allows the detection of possible implicit relations between concepts what are not pre-defined, for example, the detection of hierarchical concept lattice includes new classes derived from the fusion or division of originally overlapping ones, which increase its semantic completeness. Thus, lattices [13], in contrast to trees and partially ordered sets, are richer structures, which conform the fundamentals characteristics of geographic categories, such as multidimensionality and the existence of overlapping relationships between them. Thus, it incorporates different, complementary conceptualizations of geographic space, each of which being suitable for some context and level of detail.

The architecture and implementation of a prototype ontology-based KM system [14] are developed for flow and water quality modeling. It adopts a three-stage life cycle for the ontology design and a Java/XML-based scheme for automatically generating knowledge search components. It is shown to be able to simulate human expertise during the problem solving by incorporating artificial intelligence and coupling various descriptive knowledge, procedural knowledge and reasoning knowledge involved in the coastal hydraulic and transport processes. Through the development of this prototype system, it has been demonstrated that the KM system can be integrated into the numerical flow and water quality modeling by incorporating AI technology to provide assistance on the selection of model and its pertinent parameters. The integration renders a more intelligent and user-friendly system in the problem domain, which can narrow significantly the gap between the numerical modelers and the application users. The prototype system demonstrates its capability in both the component reusability and the facilitation of knowledge acquisition and search.

The fundamental issue in the design of interoperable GIS for urban applications, the development and use of ontologies to support semantic interoperability [15]. The extensive ongoing research on interoperation of information has demonstrated the importance of allowing multiple information systems to share and exchange data across system boundaries [16]. Each layer constructs ontologies by first defining a generic functional model described by abstract data types, then domain ontologies are derived from the functional model by specializing its components and properties. We have presented several examples to illustrate how ontologies can be used in an application domain such as urban (traffic, electric, water, etc.) networks. The development of ontology is still hampered by the complexity. The isolating complex system by layers reduced a number of inherent properties from a large number of terms.

Ontologies based proposed solution are triggered by increasing complex natured numbers of natural and man-made disasters, such as earthquakes, tsunamis, floods, air crashes [7]. Post disasters recreation, rehabilitation, and restoration cost are ten times higher than pre-disaster mitigation strategies. This finding posed a challenge to the public and demonstrated the importance of disaster management authorities for proactive mitigation embedded solution of mechanically effort support by emerging technologically for context-awareness. The success of disaster management, amongst all, largely depends on finding and successfully integrating related information to make decisions during not only in response phase but equally in contingency planning. This information ranges from existing data to operational data. Most of this information is geographically related and therefore when discussing the integration of information for disaster management response, we often refer to the integration of geo-tempo information. Current efforts to integrate geo-temporal information have been restricted to keyword-based matching on Spatial Information Infrastructure (SII, may also know as Spatial Data Infrastructure). However, the semantic interoperability challenge is still underestimated. One possible way to deal with the problem is the use of ontology to reveal the implicit and hidden knowledge. This paper presents an approach for ontology development and ontology architecture, which can be used for emergency response and contingency planning.

3. Domain & Methodology

The domain of our project covers the management of water that is produced through melted glaciers and rainfall. Management contains the storage of water along with its distribution and overspill of water that causes damage to the irrigation land. The community affected by flood or drought disaster and irrigation fields productivity is another important stakeholder. We focused on main concepts includes:

1) Water diversion mechanism

2) Water reservation mechanism

3) Fusion of reservation and diversion mechanism for water flow control

4) Provision of the information into interoperable representation

5) Defining concepts for developing uniform domain understating

The layered architecture from data acquisition to decision level includes Data acquisition layer, Analysis layer, and Decision/Recommendation Layer [14]. In the Data Acquisition phase, the data generated from Wireless Water Sensor Network (WWSN) is aggregated local, sub-divisional, and divisional nodes then forwarded to the divisional server system for analysis. The analysis is performed based on a set of axioms defined over that subset of WWSN determines local contextual condition for current flow and identify the patterns. Then predefined policies and decision along with recommended mitigation strategies are adopted. In absence of available mitigation strategy pattern, current information forwarded to responsible authorities. WaterOnto, an ontology-based knowledge management representation system enables the software agent [17-19] to react on the analysis information. The decision layer supports agents for decision connected for mitigation of flood disaster and efficient management of water-flow. The WaterOnto merges and enhances sub-ontologies of irrigation, water sources, consumption, and flow as shown in Fig.1. Processed and structured Statistical data assists the River flow management authorities for past pattern and current mitigation strategies. Interactive interface assists management authorities such as irrigation, disaster management and for sharing and using their relevant information WaterGrid would provide lives streams of river flow data that would be aggregated and validated at local and division levels before sharing to top management authorities.

3.1. Ontological conceptualization of River Management

The classes or terms we considered in our project are discussed gradually with descending order of contribution towards knowledge management. The two most

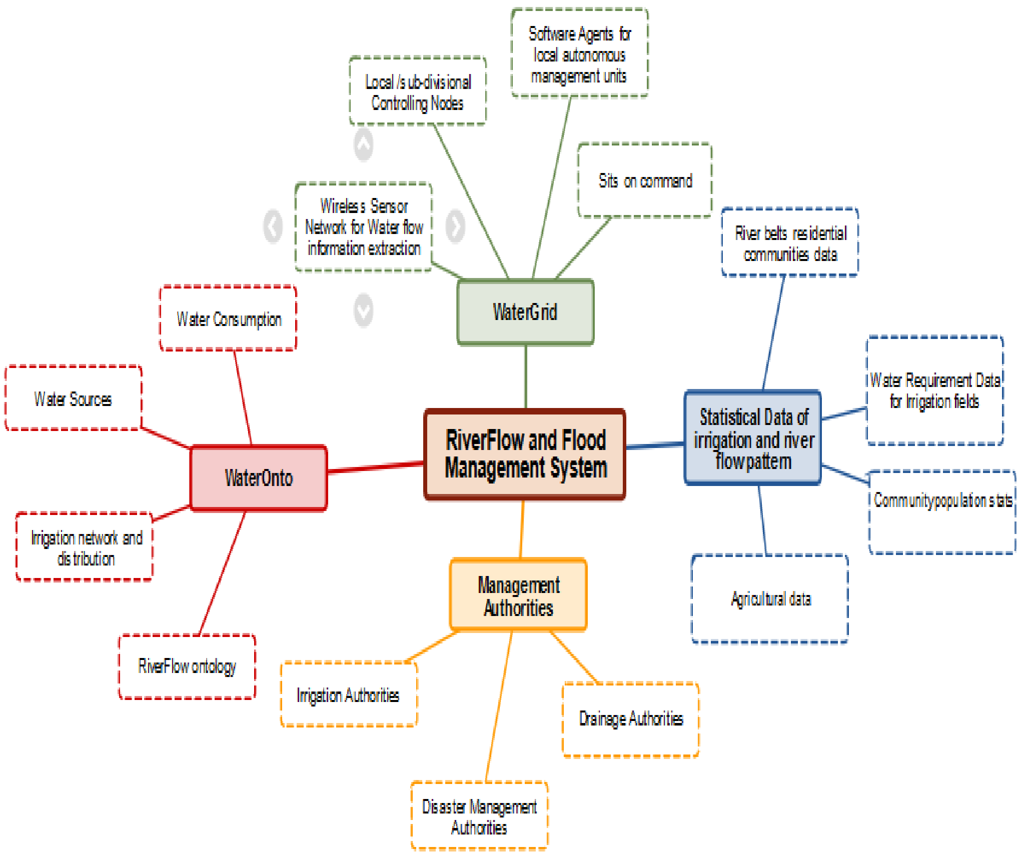

Figure. 1: Context diagram of Riverflow and Flood Management System

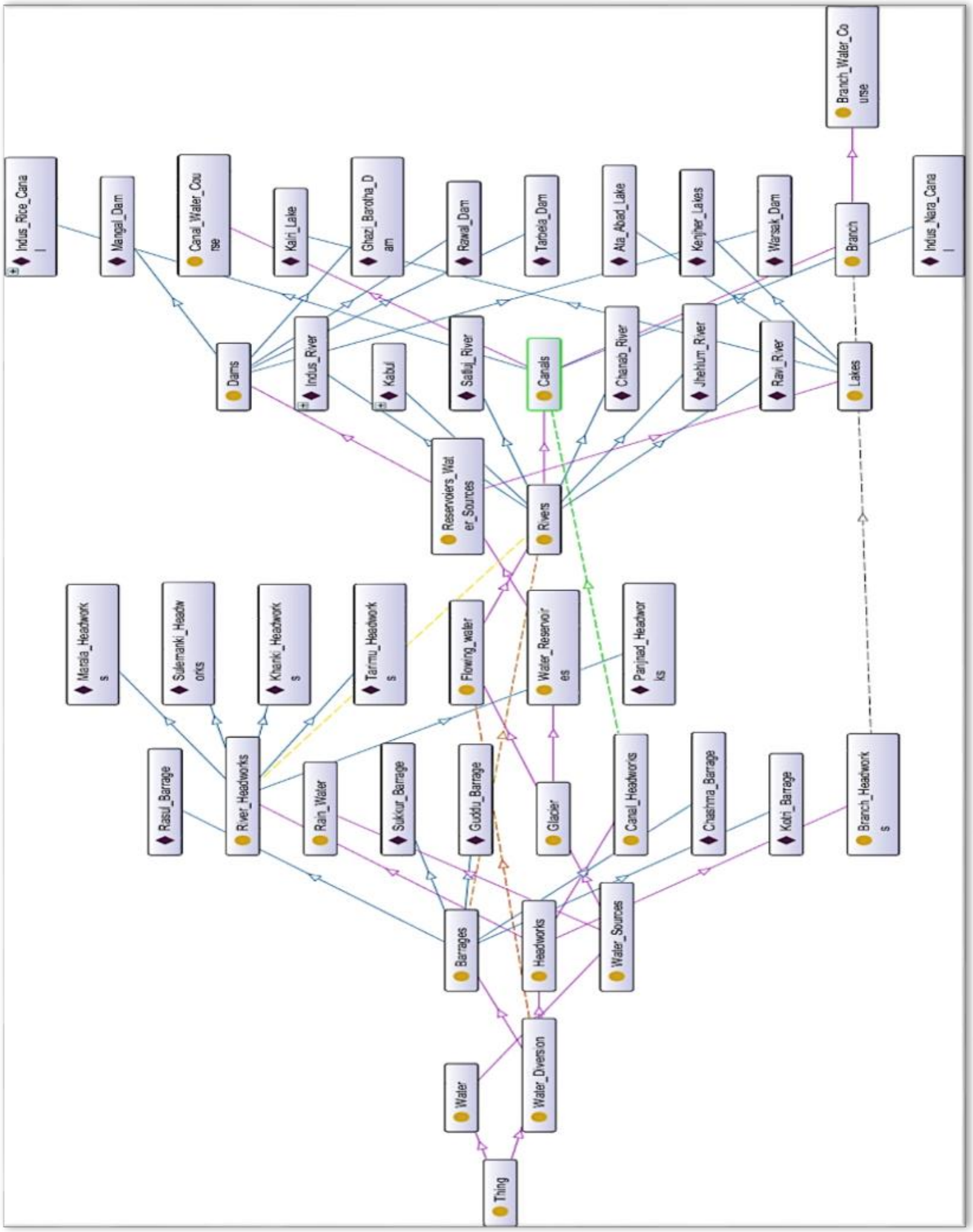

Figure. 2: A sub set of the ontology is show for representation

important concepts are water resource and management entities. The concept of river domain and their relation with other concepts is defined and represented in WaterOnto ontology. Water [20](a colorless, transparent, odorless liquid, which forms the seas, lakes, rivers, rain and is the basis of the fluids of living organisms) is melted and flowed from Glaciers [20] (a slowly moving mass or river of ice formed by the accumulation and compaction of snow on mountains or near the poles). These solid glaciers are melted through warming factors such as sunlight and global warming elements and transformed into flowing water [20]. The Flow acceleration depends on the inclination angle of surface and viscosity of fluid. Due to the geographical oddness of planet this flowing water is then transformed into rivers [20] (A large natural stream of water flowing in a channel to the sea, a lake, or another river [20]) after merging through different spans of rocky area and mountain ranges. This geographical oddness also plays role in splitting rivers in short natural streams (a small, narrow river) and merging several streams together to form water reservoirs: Lake [20] (a large area of water surrounded by land). Lake is the natural means of storing water; in parallel, human-developed means to store water named Dams (a barrier constructed to hold back water and raise its level. Forming a reservoir used to generate electricity or as a water supply).

Moreover, we have many other water diversion mechanisms [20] which are applied on rivers such as Barrages (an artificial barrier across a river or estuary to prevent flooding, aid irrigation or navigation, or to generate electricity by tidal power). Barrages help us to divert and control the follow of the river of water. In most cases, barrages divert the flow of rivers towards dams and dams store the water and branch-outs different canals (an artificial waterway constructed to allow the passage of boats or ships inland or to convey water for irrigation). Further, we have diversion mechanism on canals called headwork [20] (apparatus for controlling the flow of water in a river or canal). These headworks manage the flow of water in different watercourses (a brook, stream, or artificially constructed water channel). These watercourses are used in irrigation lands and supplied to different tanks that supply water for the irrigation of fields, fish ponds, and domestic water supply purposes.

To conformance of the grid-based approach in our project, we have used object properties such as two different hierarchies i.e. flowing water and water diversions mechanisms, we have knit them, as they become grid in conceptual terms. Main object properties or relations in our project domain are merges_into_river, merges_into_dam, shoots canal, shoots watercourse, and diverts towards. The domains and ranges in ontology development are defined in WaterOnto. Thus, we define domain for merges_into_dam is flowing water (rivers and streams) and range is (dam), domain for merges_into_river is flowing water and range is rivers, domain for shoots canal is dam and range is canal, similarly domain for shoots watercourse is headwork's and range is watercourse and domain for diverts towards is barrage and range is dam. By using it we can weave the water flowing mechanism into water storage and water diversion mechanisms. A subset of the ontology is represented in Fig.2.

The data properties possess by the classes in our project are discussed in this section. Rivers hold information about WaterInFlow (measured in cusecs), WaterOutFlow (measured in cusecs), and Length (measured in feet). These properties manage and calculate the illegal usage of water like stealth and accidental breach of the river bank in between source and target of water flow mechanisms. Depth (measured in feet), Width (measured in feet) and name Canals and Watercourse holds same data properties as river provided. The other information includes location, which is measured by values of latitude and longitude and WaterInFlowTime and WaterOutFlowTime. Location helps us to determine the current outflow values which dam shoots out towards a particular canal along with diversion. Similarly headwork shoots, which watercourse with its location and magnitudes. WaterInFlowTime and WaterOutFlowTime are captured to manage the flow of water (measured in cusec).This information is relatively important in order to calculate the deviation in flow with respect to normal flow and unpredictable situation calculation such as global warmings scale at glaciers. In the case of danger, prior information assists for mitigation strategies.

The proactive mitigation strategies include to alarm and prepare for a flood. The non-uniform melting problem results in variation of flow intensity. Concrete classes are rivers, dams, barrages, canals, headworks and watercourses. Individuals or objects are created from the hierarchy of the class and contextual semantic information will be based on the data generated from wireless sensor network proposed in WaterGird [1]. Low power WSN for calculating the flow of water discharge in canal and watercourse is developed [21]. A. Ontological conceptualization of Disaster Management, Rehabilitation, and other Supporting authorities.

The stakeholder authorities related to river management, Disaster Management, irrigation management, agricultural bodies, and communities. We encapsulated these authorities and defined their interaction relationship with each other in normal and danger situation. Irrigation authorities handle the flow of rivers, canals, and watercourse etc. Besides irrigation department, other departments also interested such as disaster management authorities, rehabilitation department, volunteers, NGO's.

The Indus basin the one major river covering 75% irrigation area [22] of Pakistan supported with others river joined into Indus after covering other upper regions commonly known as Indus River System. WWSN proposed WaterGrid would spread across the river belt and canals networks to provide real-time data to the aggregation sub-server nodes. The sparse matrix of sensor grid work in the normal situation and increase the on demand number WWSN and based on the criticality of danger situation. WaterGrid [1] is scalable and energy efficient computational model. To provide interoperability of the information and compatibility for Web 3.0, semantic representation of conceptualization of the domain knowledge facilitate the human and machine equally. The data extracted from WWSN the noise filtration applied to minimize the BER (Bit Rate Error). The filtered information further processed and transformed into ontology Web Language. WWSN IDs are coded with location and temporal context to increase the confidence level of decision support system. Functional and relational properties of corresponding authorities along their mandate of work are defined in WaterOnto. The decision support system extracts the data from contributing nodes and applies knowledge engine for decision support. A subset of classes, the individual provides data in waterOnto are shown in fig 3.

3.2. Location aware response strategies

To response real time situation, awareness about the location, current constraint imposed by local context, capacity of local authorities, accessibility routes to targeted location, capability of existing resources at particular location breach point of river, canals along with its effects on the community, irrigation fields can be determined by support of geographic information system [23]. We defined the GIS (Geographic Information System) concepts to supporting ontology of WaterOnto. The location is monitored from by GIS coordinates of the location and measure to respond the disaster situation, breach level, a nearby community, and attributes are calculated for effective response strategy. Depending on the magnitudes of danger the relevant authorities receives alerts, and early response can be provided with immediate availability of information. Semantic web and data with

RDF/XML, Ontology/XML enables the software agents to generate Early warning system from real contextual information. response strategy. A mobile application is designed extracts the information from volunteers, alter them on need by victim based

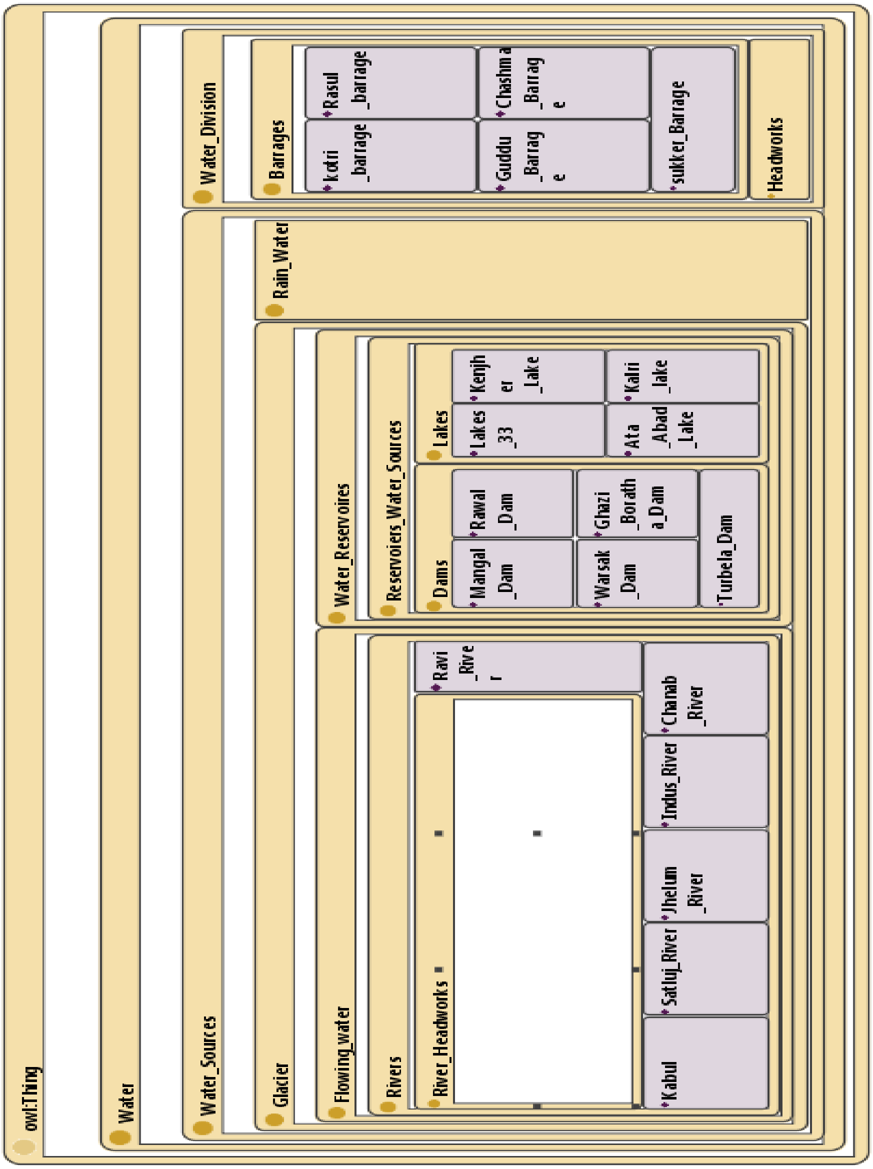

Figure. 3: A Subs Set of Classes and Individual in WaterOnto

Provide accurate and timely information for prompt and feasible response strategy. Complete coordination mechanism for on the services they can offer, their location, time to approach the victim. Further, application propagates the information about

NGOs and volunteer approached to victim community to other relevant NGOs and rehabilitation authorities registered through this app for efficient coordination [24]. This app used the structured processed data about flood and drought condition for broadcasting to volunteer and NGOs. This information will not only reduce the gap of missing affected community subset but also prove to strong real-time coordination tool to eliminate duplication of assistance. The systems updates database based on disaster information

4. Modularization Corresponding Ontologies

The modular approach resolves the complex domain problems to aspect-oriented [25] problem for simplicity and manageability. Development of a module for disaster management, rehabilitation department, volunteer organization, rural communities, irrigation, and agricultural, are defined in ontological conceptualization for representing interaction mechanism. For representing the relation we cite two relevant

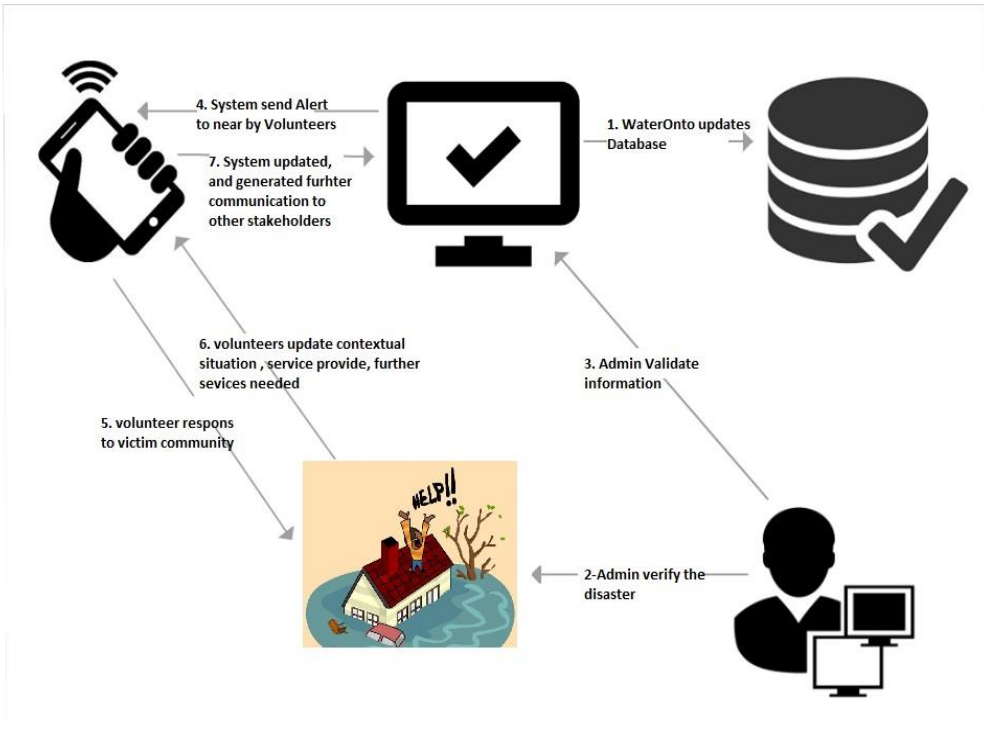

Figure. 4: Mobile Application for Response Strategies

provided by WaterOnto. Admin validates the disaster information, after confirmation by admin. The system will notify volunteers for their service to support victim community by guiding access path, community needs, and possible time to approach location. The software architecture for the app is shown in

domain with positive and negative consequence. Agricultural improvement portal was designed to improve the water utilization and improving the agricultural product. One of the main stakeholders of WaterOnto is a farmer that is interested in river water flow, dry season, availability of water from river and rainforest casting for plan irrigation for cultivated their crops etc.

The concept of the representing a volunteer system is the modular approach towards the design of disaster management. The corresponding entities are conceptualized in the ontology for better understanding and contingency planning.

5. Conclusion

In this paper, we presented a simple approach for knitting the hierarchies of water producing sources and water distribution and diversion mechanisms such that it raise the phenomenon of context awareness in terms of water over flow form one node to another. Precisely it helps us in the optimal distribution of water to the irrigation land and will reduce the wastage of fresh water by sinking into the sea. We represented modular ontology development to simply the complexity of large scale system. We discussed the efficient water utilization and avoidance and response mechanism for the flood. The cross anthologies are developed for integrated system [5]. We proposed the integration of technology through semantic modeling. Machine process-able Data assist in improving the economy through better provision of irrigation to agricultural lands as well as household and industrial use. We also proposed integrated the disaster management authorities, response and rehabilitation authorities for automation on information processing and coordination.

6. Future Work

We would explore the details of the self-alarming system by utilizing machine learning approaches and climate and geographical factors that contribute to the damage and pollution of water supply. For example sedimentation and overflow that places a severe impact on water storage and wastage. The autonomous system needs to develop that recommend and automate based on information processed by WaterOnto after acquisition from WaterGird and then applying heuristic bases on combined human and machine intelligence for the optimal solution and proactive response strategies. Our future work will focus on: (1) a formal definition of the concepts used to create a multi- layered ontology, using different inter-related layers to reduce the number of terms that must be considered at each level; and (2) the design of tools to allow users to collaborate in the ontology generation process.

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