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Information diffusion for real time resource planning during crisis leveraging emerging digital technologies

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Abstract. Every day in some corner of this world displacements are happening due to adverse impact of climate change or natural disasters or riots or epidemics and global pandemics. Such displacements could be either internal displacement or cross border displacement. In just last year (2019), nearly 24.9 million people have been displaced due to the above cited reasons as per the report of United Nations Refugee Agency. Warsaw International Mechanism has put forth its effort to address the concern of displacements and support humanity along with United Nations, States, few ad-hoc working groups, civil societies and few supporting countries way back in 2016. On one side while the combined and sincere efforts are being made, on the other side the threats in terms of violence, riots, natural disasters, pandemics keep increasing at an alarming rate. Recent Covid-19 is a classic example which are likely to trigger more displacements to be continued in 2020. This has a spillover effect on demand and supply chain of health care services to the impacted as well as the citizens or locals in a particular region. Our paper aims to bring the combined efficiencies of emerging digital technologies and available data in order to gain insights and use them efficiently at the time of global crisis without causing interruption to health care and humanitarian services to all needy people.

Keywords: Disaster and displacement, semantics for disaster management, humanitarian services for the needy, semantic information system for healthcare, healthcare service for global crisis

1 Introduction

In today's world, humanity is being overlooked by few sects of people causing violent conflicts and riots while most others understand the need for uninterrupted humanitarian services, health care, education and good standard of living for all beings. Several countries, working committees, ad-hoc groups have joined hands together to provide their best for displaced people through refugee camps or ensuring the rehabilitation for them and so on. Despite these sincere efforts, statistics on global displacement still shows an alarming number across the globe from almost 145 countries several millions of people getting displaced and are homeless. The adverse impact is that the major displacements are happening in the top 10 regions where the health risk alert of Covid-19 is high according to UN refugee agency. This is a critical issue that cannot be overlooked for making humanitarian and health care services more efficient at the times of such global crisis. In our study, we aim to bring forth the combined capacities of existing data bases from heterogeneous sources and real time streaming data that could come from any part of the globe and leverage the emerging digital technologies towards dynamic decision making and planning of resources in rescue operations. This proposed system based on the secondary research highlights how the benefits could be taken to various stakeholders such as government authorities, volunteers, media, adhoc working groups, health care professionals and supporting staffs, residents of the impacted areas, new migrants displaced in those areas and the local authorities of those areas. The digital forces such as mobility, cloud computing, analytics, semantics and social media are fast emerging, and the computing resources are available at a much lower costs almost like a commodity (Kalidoss et al., 2016). Therefore, our proposed system is set to bring more efficiency at a reasonable cost for sustenance of such initiatives.

1.1 Compelling needs for semantics-based information system - Need for system from integration to insights:

Most publications and recent articles from leading journals, research articles, media channels, governmental data, press news etc. agree that loads of data are available but in isolated manner. This implies the unavailability of insights, even though information of some sort was made available prior. Even though rapid urbanization poses a common problem facing any developed or developing country, the demographics, climate and environmental factors cannot be undermined. Past disaster damages related data and insights should enable urban sensing and drive the future growth plans. All these factors need to be keyed into decision support system for dynamic decision making.

1.2 Need for system that drives real time actions:

In majority of the countries, the federal or central or state government and various departments maintain their respective databases related to the public, officials in that locality and all stakeholders as appropriate. However, information needs more analytics powered by fast growing technologies to facilitate communication dissemination in real time and in seamless manner. Making the heterogeneous data work together and making the heterogeneous systems communicate with each other are cumbersome tasks unless there is a common language which these information systems can interpret. Semantics is one such technology that serves as a boon to address the interoperability challenge.

This paper is organized as follows. Section 1 gives the context for choosing semantic based system for health care services and disaster management and the perspectives from emerging digital technologies. It also includes the primary causes for severe damages due to disasters and its impact on displacements across the globe. Section 2 includes the literature review related to our study. Section 3 gives the insight into prevailing traditional disaster management system and some of the gaps in the same. Sections 4 and 5 detail out on semantic applications overview and our proposed intelligent communication system that utilizes the available information from various data sources and how they could be aggregated to provide timely alerts to various stakeholders. Section 6 further elaborates on the pilot implementation of the proposed system. It gives insight into various types of databases which handle big data, multiple sources of data flow, and multiple types of data such as text, images, and real-time message streams and so on. Section 7 lists out various potential benefits from the proposed semantic based system. Section 8 provides the summary view of the article and few recommendations for futuristic work to enhance the humanitarian services further.

2. Literature Review

According to UN Refugee agency, in last year alone nearly 2000 disasters have triggered 24.9 million displacements either internally or cross borders put together. The report also indicates that the numbers are expected to increase in 2020 and beyond due to global health crisis prevailing in developed and developing countries. Disaster response and recovery are the most crucial aspects of disaster management whether it is a natural or a man-made disaster. Majority of literature cite the common challenges as lack of coordination, lack of understanding the nature and the impact of disaster, lack of real time inputs, poor urban planning, inadequate infrastructure and resources and so on.

In the research article by Oden et al. 2012, the authors have determined that the four main challenges to be addressed are coordination among groups involved in the response, communication among these groups, timely information exchange, and effective information technology support for emergency responders in the field. Though this study uses information technologies to connect location dependent desktop system to mobile phone, it does not take into account of multiple data types and multiple data sources from multiple locations and interoperability of such diverse platforms. The study by FAO finds the two main pillars of disaster management and global governance are disaster risk reduction (DRR) and climate change adaptation (CCA). However, integrating these pillars is quite challenging as the rules and laws vary from land to land. The governance structure, constituencies and political stability and several other factors determine the outcome and efficiency of integration. The study further indicates the need for smart disaster risk management system, and this is in line with our proposed system leveraging emerging digital technologies for better health care and humanitarian services to the needy.

The international strategy for disaster reduction indicates set of priorities for disaster management such as early warning, coordinated effort making, utilising available information effectively and innovatively, making information available to relevant stakeholders and strengthen the disaster preparedness. This is in line with our proposed semantic based information system that is capable of providing real time inputs based on context to relevant stakeholders as one version of truth and enables planning and mobilising of resources, food and health care packages to the needy without delays.

The literature work on design science invariably talks about the utility of information systems (IS) design (Bisandu 2016 and Hevner et al. 2004). The applications and the benefits to stakeholders is at the central theme of any IS design. The design science research methodologies emphasize the relevance of utility to creative, cognitive and social behaviour of such stakeholders making use of the IS design implementation. The proposed semantic oriented system aims to enable such cognitive and social behaviour from various stakeholders involved

in rescue operations and humanitarian services at the time of crisis by providing contextual inputs in a timely manner. The design science research methodology and framework recommended by Hevner et al provides seven primary guidelines for IS system development and usage. Though our proposed system is aligned to all the seven guidelines, the primary focus is on guideline 2 of problem relevance that is IT and disaster in today's context and in future, guideline 6 of design as a search process with available information from existing data sources and guideline 7 of design for communication of research to stakeholders both technical and managerial in nature.

3. Existing Disaster Management System and Challenges

The National Institute of Disaster Management (NIDM, 2014) report finds that the four main aspects of an early warning system or a disaster management system are knowledge of risk, prediction of the same and monitoring periodically, dissemination of information to all relevant stakeholders and response to the risk in terms of better coordination. It also finds that ICT (Information and Communication Technologies) plays an indispensable role in disaster and risk management. Even though several ICT systems are available, they are either special purpose (like tsunami warning for coastal areas) or lack some enhanced capabilities or suffer from inter system coordination (stand alone and supports only a specific cause).

The United Nations Office for Disaster Risk Reduction (UNISDR) defines warning system as a set of capabilities needed for the timely and meaningful generation and dissemination of alert information to individuals, communities and organizations at risk for optimal preparedness and response and at the appropriate time (UNISDR, 2006). At the same time, the Third International Conference on Early Warning also revealed problems and deficiencies of the warning system (EWC III, 2006). For instance, some information systems work well with certain format and not with all types and formats of data. The existing Early Warning (EW) system and Disaster Management (DM) system cannot be completely explained in all aspects and the challenges are multi fold and is still an ambition to visualize the processes in real time and take dynamic decisions (Konecny et al, 2010).

4. Semantics Applications for Healthcare and Humanitarian Services during Crisis

As a result of the gaps found from existing information systems for disaster management, this study proposes a semantic oriented system which address interoperability issue and supports multiple sources, multiple types and multiple formats of data. Semantic based system inherently uses common vocabulary languages such as web ontology (OWL), resource description framework graphs (RDF) and so on which are known for their support in platform independence. Typically, a semantic web can be used for data integration, knowledge synthesis, knowledge representation and management, semantic web services and data interoperability (Mukherjee et al., 2013). The key objective for semantic application in any domain is to have improved usability, completeness of information and its accuracy through knowledge reasoning (Bitar et al., 2014). In our study we focus on semantic based system that can improvise healthcare and humanitarian services to the needy during crisis by addressing the challenges indicated in earlier section 3.

About 11 themes are identified and broadly classified in the healthcare impact during disaster through a study made by Pourhosseini et al. 2015. These themes are related to human resources management, resources management, victims' management transfer, environmental hygiene monitoring, nutrition management, mental health control, inter-agency coordination, training, technology management, information and communication management, and budget

management. Most studies from literature also converge at these broad categories of healthcare services impact and emphasize the need to improve the coordination, inter personnel collaboration, planning and execution and so on. Our semantic based approach is aiming to address almost all of these broadly classified challenges. The detailed analysis and illustration of how our proposed system works is being addressed in the next section.

5. Proposed Semantic Oriented System for Healthcare and Humanitarian Services during Crisis

The proposed system components and its high-level architecture for information fusion from multiple data sources has been illustrated in figure 1. The working stages of transforming data into actionable insights is shown in the figure 2. To bring in more clarity, a scenario analysis has been assumed and explained in figure 3 and figure 4. The working of semantic information system (SIS) is illustrated in the figure 5 with the help of RDF semantic graph.

Let us assume that some part of the nation is affected by a novel disease and the active cases analysis finds that there is no prior availability of treatment details. In our context sensitive system, we propose that the details of the active cases could be aggregated using the available limited data from various private and government databases (figure 3).

The data thus obtained could be semantically mapped to real time information coming through a global organization like WHO (World Health Organization) or some alert from authentic sources or recommendations on health care comes as a live stream from a research laboratory based in some other part of the world, the information can be loaded in to a system (decision support system) and further processed with business intelligence tools (ETL- Extract Transform and Load) and fed in to semantic based information system (proposed) for action plans that are generated automatically (figure 4) based on the context and live inputs streaming from different corners of the world.

The proposed system is platform independent (OWL based) and hence overrides the interoperability challenges and semantically aggregates visual data (See DB), geo location maps and coordinates inputs (Sci DB) and other heterogenous inputs (NoSQL DB) to provide set of recommendations to various stakeholders as shown in figure 5.

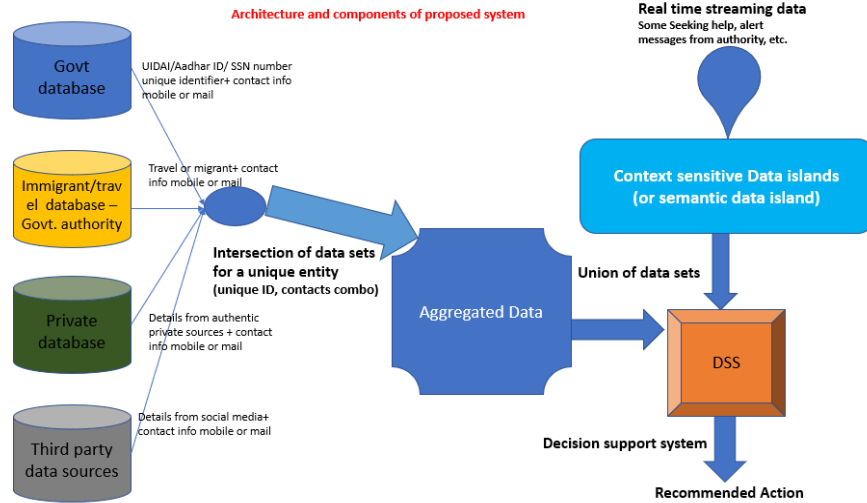


Fig. 1. Architecture and components of our semantic based system

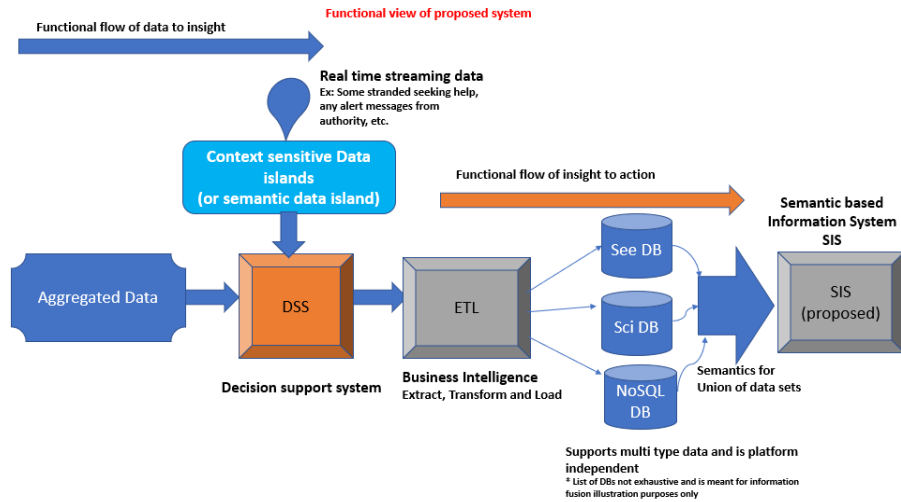


Fig. 2. Functionalities of semantic based system for turning data to insights to actions

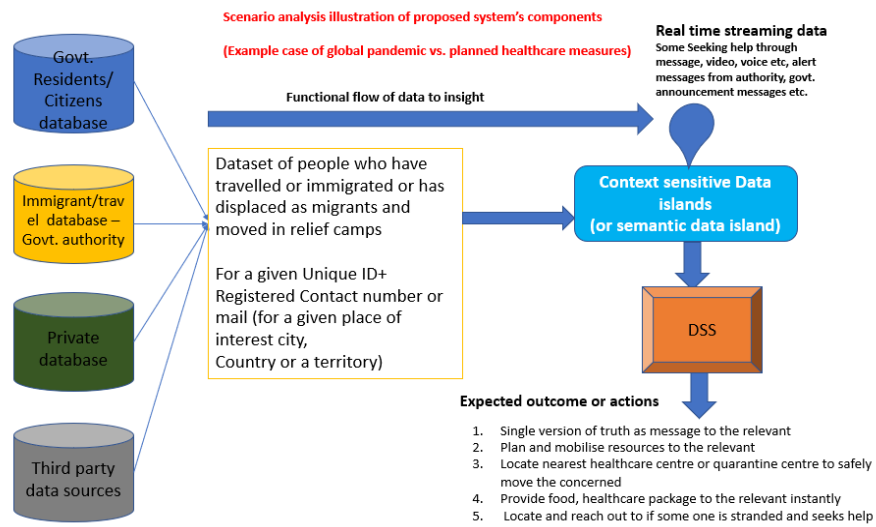
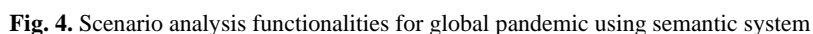


Fig. 3. Scenario analysis architecture for global pandemic using semantic system



A pilot study was conducted to understand the perspectives and challenges from the residents of Chennai during the lockdown period ever since March 2020 owing to Covid-19 global pandemic. The study participants include adults in the age group of 25 to 45 years (50%), senior citizens (30%) and super senior citizens (20%). The study finds that more than 80% of senior

and super senior citizens are pensioners in the locality of our study and have access to basic digital technologies like smart phone, email, online surfing etc. We had conducted pilot survey through online and telephonic calls owing to prevailing situation then. We had planned for 50 responses overall through online emails and calls but however we got close to it about 45 responses. The adults group aged between 25 years to 45 years comprised people with working background from IT, ITES, Banking, Colleges and universities, sales and marketing sectors and are working from home or from respective native locations during the lockdown and unlocking periods.

The overall outcome of the study showed that majority of the participants either agreed or strongly agreed for information as single truth and aggregated one. The pilot study also finds that the information of basic needs such as essentials, medicines, emergency reach out and rescue teams are made available without distortion but with accuracy and reliability. Some participants find other sources of information like special themed apps, information from their peer groups or chat groups are adequate for them to sustain the tough period during crisis.

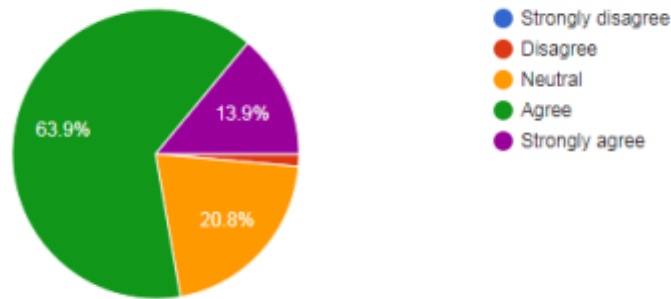


Fig. 6. Participants from pilot study emphasize information integration and diffusion

Based on the pilot study outcome, we propose to use the context sensitive semantic oriented system which takes into the account the scenario-based implementation. For the context of global pandemic and lockdown scenario, the desired outcome from the semantic system would be to provide single version of current situation in the country (as against more distorted inputs from multiple sources and unreliable sources), provide recommendations on dos and don'ts to every resident of the locality and inputs on some of the basic needs for the residents so as to enable them to sustain through the tough times. Our system is designed to accept inputs in the format of XML, Microsoft Excel or spreadsheet and Web Ontology Language files (OWL). The aggregated data from a business intelligence tool (BI tool/ ETL tool) as shown in figure 2 can be fed into our SIS semantic information system in any of the formats listed above.

To explain this, the data could be containing a list of health care centres, medical shops, grocery needs, clinics, private ambulance services etc. based on the current location of the person who seeks information or help. The Excel sheet might be available as aggregated secondary data. For creating OWL and XML files, the ontology has to be defined once at least and revised on need basis thereafter. We used ThingWorx platform by PTC to define the demo ontology as shown in figure 7 below. Every entity a living or non- living is considered a thing which is uniquely identifiable.

As a result from pilot study, if we have to populate the list of covid19 or a specialty healthcare centres for a given geo location, then every such centre would be conceptualised as a thing and its meta properties, geo location properties and attributes can be defined using the Thing Worx platform and the details would be populated in to a result set for users to consume the information service.

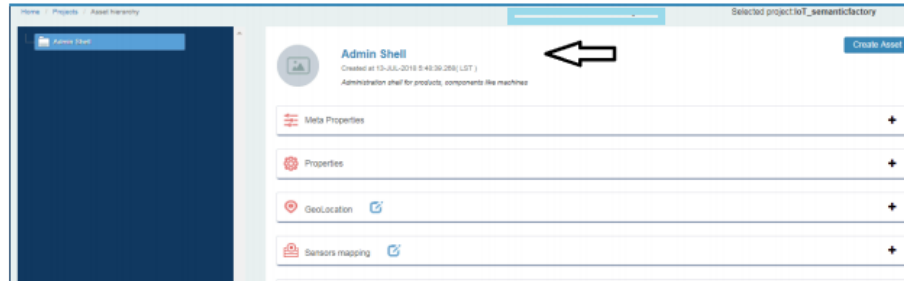


Fig. 7. Creating disaster response ontology using PTC ThingWorx platform

We then designed a simple user interface using an approach called Build Your Own Application (BYOA) as shown in figure 8. The service providers have to subscribe just one time to the master portal of BYOA and they would be provided with unique credentials to login and later customize to build their own application using listed services per se for a specialty clinic or rehabilitation center, it could be the excel upload of patient records, send notifications, dashboard viewing and so on. Thus, having a context driven approach such as semantics is helpful in designing solution which enjoys platform independence and is easy to customize and maintain and is also cost effective and robust.

Another advantage is that neither the citizen nor the service collaborator needs to be aware of underlying technologies or software languages used due to its user friendliness nature in implementation. Even when a person goes offline, technologies like google pins can assist to locate the person at risk through a call or message. The geographic location thus obtained will be pulled by ETL system discussed in figure 3 and aggregated for providing humanitarian aids by our proposed semantic based system. One of the classic examples was the rescue operation undertaken during Kerala floods of 2018. Besides all these, the proposed system can also generate some basic reports for governmental units and other authorities like number of cases treated, other third party and private service providers for healthcare who can be reached out for transferring excess number of patients, providing healthcare kits without delays etc.

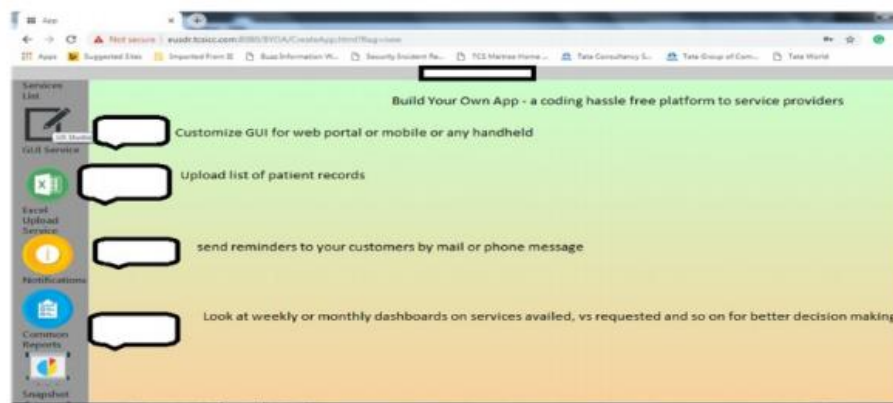


Fig. 8. A simple GUI for viewing of results for a semantic context-oriented search

The system is in very nascent stage and a lot more to be done in both natural and man-made disaster response front. However, the preliminary results are encouraging and shows by using semantics- oriented information system, we can overcome the interoperability challenge and improve service collaboration during any disaster or crisis.

7. Potential Benefits and Practical Implications

The main and foremost advantage of developing a semantic oriented system is to overcome the challenge of interoperability and hassle-free exchange of information at the hour of need across various IT systems handling various varieties and volumes of data. Our proposed system can work with multiple existing and available data bases that store and retrieve details in different ways using different technologies or platforms. As an initial step, we have come up with the pilot implementation taking into consideration the current global crisis of covid19 and the immediate disaster response of health care and humanitarian services. However, we intend to extend it to other types of disaster scenarios as well like tsunami, forest fire breakout, earthquake and so on. The process of building the holistic response system is time consuming though but largely beneficial to the society if we look at the larger sect and longer period in the future. The proposed system output also avoids distortion of information and at the same time provides needed inputs as reports to authorities, to individuals, to service collaborators and to the information systems administrator for customization. The proposed system can also support when the person at risk goes offline but only if the person is reachable or identifiable through any mobile phone calls or messages and is able to provide geo location inputs in some format so that our system can match relevant records from various sources for the given context and provide timely assistance.

8. Summary and Future Directions

The healthcare and humanitarian services are the most sought after any calamity, be it a man-made such as a riot or a natural disaster such as an earthquake. As the growth redefines itself in terms of communication and computing technologies, most of the hardware and software in today's market is commoditized and can be better utilised to improve any services segment. In our study it is healthcare and humanitarian services segment that is said to enhance with more computing capabilities for dynamic decision making in real time reducing delays in response to crisis. Risk reduction and response improvement during crisis are quite challenging and there is lot of scope for improving communication, coordination and collaboration between various stakeholders. Existing literature indicates that the semantic based disaster management is very limited in scope and capacity and does not take into account every stakeholder concerned (Teduh et al., 2020). Our proposed system in the contrary improves these above specified aspects and in addition takes into consideration, multiple level of individuals (residents/ citizens) in the stakeholder chart. The future is set to transform itself with technological advancements for a better world and a safe living for all.

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