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Risk and Disaster Management: From Planning and Expertise to Smart, Intelligent, and Adaptive Systems

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Abstract. "Disaster" means some surprising and misfortunate event. Its definition is broad and relates to complex environments. Medical Informatics approaches, methodologies and systems are used as a part of Disaster and Emergency Management systems. At the Holon Institute of Technology – HIT, Israel, in 2016 a National R&D Center: AFRAN was established to study the disaster's reduction aspects. The Center's designation is to investigate and produce new approaches, methodologies and to offer recommendations in the fields of disaster mitigation, preparedness, response and recovery and to disseminate disaster's knowledge. Adjoint to the Center a "Smart, Intelligent, and Adaptive Systems" laboratory (SIAS) was established with the goal to study the applications of Information and Communication Technologies (ICT) and Artificial Intelligence (AI) to Risk and Disaster Management (RDM). In this paper, we are redefining the concept of Disaster, pointing-out how ICT, AI, in the Big Data era, are central players in the RDM game. In addition we show the merit of the Center and lab combination to the benefit of the performed research projects.

Keywords. Disaster Management, Risk Management, Knowledge Management, Research Infrastructure, Public Health

1. Introduction

"Disaster" means some surprising and misfortunate event. Its definition is broad and relates to complex environments. It is seen that Informatics and more particularly Medical Informatics is used in Disaster and Emergency Management [1].

In order to study the disasters implications an Israeli National Research Center for Disaster Reduction, the AFRAN Center, was established in 2016 at the Holon Institute of Technology (HIT). This is a multidisciplinary research center committed to investigate and produce new approaches, methodologies and recommendations in the fields of disaster mitigation, preparedness, response and recovery. In addition, there are the designations to disseminate disaster's knowledge and to involve information and communication technologies (ICT) and Artificial Intelligence (AI) in Risk and Disaster Management (RDM). For this purpose a "Smart, Intelligent, and Adaptive Systems" laboratory (SIAS Lab) was established.

In this paper, we redefine the concept of Disaster and point out how ICT, AI, in the Big Data era, are central players in the RDM game. We also present the advantage of AFRAN and SAIS combination to the research projects.

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2. Background: Disasters and their management

2.1. Different kinds of disasters

Risk is the fruit of uncertainty, of actions or inactions, which can engender wasteful outcomes of out-of-order and unusual events such as disasters.

Disasters are disruptive and have large and heterogeneous impacts and consequences on human activities, from an individual level (Nano-disaster, i.e. a medical emergency) to a large national or multi-national level affecting a large population (Large Scale and Sudden Disasters or "Mega-disasters").

We classify the disaster events in 3 main different types: (1) **Natural disasters** due to: (1a) Nature forces such as weather phenomenon like hurricanes, floods, extreme heats, (1b) Seismological events such as: earthquakes, volcanic eruptions, landslides; (1c) Pandemic such as pandemic influenza, (2) **Man-Made disasters** which result from negligence or hostile and malice activities. This type relates to: (2a) Residential or industrial causalities such as fires, explosions, and "Nuclear, Radiological, Biological or Chemical" hazards, (2b) Transport calamities -Air, Maritime, Road, Railway-,(2c) Cyber-attacks of any kind of infrastructures, (2d) Societal events which must be conflicts or acts of terrorism; (3) Combinations of : (3a) Natural and Man-Made disasters called ***Natech disasters*** for "Natural Hazard Triggering Technological Disasters", (3b) Man-Made disaster with hostile activities called ***Hostech disasters*** for "Hostile Hazard Triggering Technological Disasters" [2].

Disasters are inducing losses of human life, property, economic and to the environment. The Mega events usually exceed the involved community's abilities and capabilities to cope its upshots by using its own remaining resources. Number of scales were defined and implemented over the time for quantifying and categorizing the severity, the complexity, and the impacts of disasters [3,4].

Moreover, a disaster comprises a chain of disasters, and so being a system of systems. For example, the Tōhoku earthquake on March 11, 2011, of a magnitude of 9.0, induced fire destruction of towns and the tsunami which induced a major nuclear incident at Fukushima, *a NaTech* [5].

2.2. RDM as a framework for handling any kind of disaster

A disaster is a dynamic and complex environment and reduction its risks, impacts and consequences relate to RDM. This field has a large and heterogeneous number of sub-areas, such as Disaster Risk Reduction (DRR), Disaster Risk Policy (DRP), Information and Communication Technologies (ICTs), Medicine with focuses on RDM and Public Health, and Humanitarian Logistics. RDM sub-specialties deals with: (1) **Preparation** stage which deals with planning and reducing impact of disaster before it hits; (2) **Response** stage to the event by providing emergency response over time from initiation which already include the first recovery stage; (3) **Recovery** stage handling new planning and restoration of community's; services and infrastructures reconstruction and rehabilitation, and (4) **Mitigation** stage involved in the previous stage for increasing abilities and reduction of damages before the next disaster.

While no one can infallibly predict the future, one of the main component of RDM is the development of a "Disaster Preparedness Program" (DPP) [6]. Obviously, the DPP will result from a thought process in which an assumed predictable sort of disaster is expected and the following sequences of events, which in normal (or guessed)

circumstances will occur. However, events will happen which are not in the line of thinking. Thinking about surprising and unexpected events is a key-issue of preparedness programs. Accordingly, the DPP involves RDM and more particularly "what-if" scenarios. Once they happen, communities are ready to the best possible.

From Public Health and Medical Informatics perspectives, risks to healthcare customers and providers (practitioners and organizations) are prevalent in daily practice and more when a disaster occurs. From medical and humanitarian perspectives saving lives is of major importance followed by reducing damage to infrastructures and property.

3. Challenge: RDM in the Big Data and AI Era

From an ICT point-of-view, during the last decay, "Data, Information and Knowledge" (DIK) became a central capital with a critical *Value*. ICTs introduced huge changes in Knowledge Management (KM) and AI applications, more particularly when it relates to RDM by providing tools supporting DIK integration and *Visualization*.

The *Volume* and the *Velocity* of data related to disasters is enormous and highly dynamic due to the large *Variety* of sources comprising: (a) professional and scientific data centers collecting continually responses of sensors (b) wide audience media like Social Networks (SN) where everyone can alert or discuss on a hazardous event [7]. *Veracity*, *Variability* and *Volatility* of DIK from this kind of last sources is a key-issue for DM; combining a large variety of DIK sources is expected to improve DIK *Validity*. However, open media Social Networks has a strong *Vulnerability* to inaccurate and/or fake reports. Globally, Big Data in RDM helps to reduce DIK silos existing. In other words, disasters-related data is huge and there is a need to dynamically discover valuable knowledge in all domains and more particularly in Public Health and Healthcare Planning and Policy. Data Mining, Process Mining [8], Machine Learning, and more globally AI provide tools supporting these goals achievement.

In order to explore and study the disaster's aspects, development of DPP, new methodologies and systems generating DIK, AFRAN Center and the SIAS Lab were established. The designation of this combination is also to offer recommendations in the fields of disaster mitigation, preparedness, response and recovery and to disseminate disaster's knowledge by adding the perspectives of ICT and AI to RDM.

4. Conceptualizing and implementing a multidisciplinary approach

AFRAN is an expertise and multidisciplinary infrastructure mainly dealing with RDM from different perspectives on "Governance, Strategy, and Policy" (GSP), "Quality, Health, Safety, Security and Environment" (QHSSE), "ICT and AI". Its main aims are to implement and to match the Quality Management Principles to the DM field. The studies designations are (1) improvement of Disasters Knowledge Management, and (2) solving the complex problems of disasters.

To achieve that, the center enhances cooperation with municipalities, governmental offices, industrial and academic organizations, and more globally decision-makers, at the local, and international levels. Moreover, the emphasis is to create public understanding of the risks posed by natural, hostile and industrial hazards, and improve by development of local and national DPP, and enhancement of disaster-resilience and performance of multi-safe-fail-systems.

SIAS interacts with AFRAN from an "ICT & AI" perspective and by strongly integrating the QHSSE and GSP aspects. SIAS is action-oriented and real-world focused, supporting the different steps of RDM.

SIAS mainly concentrates on improving methodologies and developing innovative Decision Support Systems, Automated and Autonomous systems, Social and Collaborative environments, Uncertainty and Risk Management tools, Quality Engineering and Resources Optimization methodologies.

It primarily employs and extends theories, techniques and technologies from AI, and more particularly (1) Data Science, Big Data and Internet of Things -IoT-; (2) Knowledge Representation, Information Visualization, and HMI; (3) Social and Community Intelligence, and Open-Source Intelligence; (4) Automation, Robotics, and drone abilities.

SIAS lab research runs in parallel with Medical Informatics and Systemic point-of-views in order to look at the disaster field before, during, and after the event by taking into account impact on infrastructures and their management. Having a holistic view, requires understanding, implementation, and the development of the most relevant tools to use for emergency and disaster preparedness including mitigation, response operations and, recovery program.

A particular focus is paid to Cyber-Physical Systems and Informatics issues [9], Disabilities and Elderly specific issues in DRM [10], Ethics [11] and Innovation Management.

Some of SIAS research projects deal with sudden barged events and Social Networks (SNs) which are the primary data report sources. SNs serve as early warning platforms reflecting citizen's worries. Contain and accuracy, of each report, depend on a large number of parameters related to the event (e.g. 5W2H), its first announcer (institutional or individual), the specific SN used for reporting or reacting to a report. SIAS works on (1) a historian framework implementation, (2) influence and reliability evaluations of announcers and commentators message by using for examples, Sentiment Analysis and Social Networks Analysis. The current RDM application fields, at SIAS, are mainly related to natural disasters and epidemiology. Moreover, other research projects of the laboratory focus on (1) improving EMS dispatch user experience, and (2) understanding and evaluating the use of the IoT for supporting individuals with communicational limitations and Search-And-Rescue teams [12].

5. Conclusions and perspectives

Disaster can affect social, economic, technological, ecological and healthcare environments at the short and long terms. In order to readiness at the decision makers and citizen's levels, the AFRAN Center for Disaster Reduction has been established at HIT – Holon Institute of Technology (Israel), two years ago, and then focused on providing consultation on disaster-resilience and recovery enhancement from the mitigation, preventive and response points of view.

Last year, the SIAS Lab adjoin the AFRAN for providing it with the ICT, AI, from a Medical informatics perspective in the Big Data and IoT era. The current common projects are focusing on designing and developing a smart and intelligent platform to serve during disaster preparation, response, recovery, mitigation, and in later studies of it. This platform will provide information on (1) tools allowing supporting identification of no dead people but with limited communication capabilities (e.g. children, deaf-dumb

persons, people with neurodegenerative disease young such as Alzheimer, tourists) in the context of emergency or disaster [13], (2) emergency and disaster events by (a) monitoring groups on Social Networks for detecting outstanding events or their precursor signs (b) archiving DIK from various sources on emergency and disasters events [14].

A major achievement, of AFRAN and SAIS activities, is the involvement, more specifically, the collaboration of students from the different faculties in the different projects. It gives the opportunity to train next engineers' generation to RDM and the related technologies. At large part of them come from or will be involved in Industry and Government's departments and agencies.

Preparedness to- and mitigation of disasters start by evaluating the risks. Domain-expert inputs are crucial at this step such as the right use of the huge amount of available data related to prior events. Response and Recovery are using on-filed acquired DIK. AFRAN and SIAS are building workflows consisting in handling exceptional events, and more particularly disaster from one end to the other by considering the overall RDM quality is based by continuously integrating domain-expert knowledge and smart, intelligent, and adaptive systems which are evaluated from past and present DIK and can be used for guiding future actions.

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