Journal of Autonomous Intelligence (2022) Volume 5 Issue 2.
doi: 10.32629/jai.v5i2.550

Original Research Article

Managing Humanitarian Challenges of Disaster Responses and Pandemic Crises: Interface of 4IR Ecosystem

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ABSTRACT

The human civilization has witnessed myriads of road-block and crossroads at every facet of its journey. Many a time, it becomes untenable to sustain its existence. The series of health hazards, critical epidemics and even the catastrophic pandemic diseases have been challenging our vivid foundation and perpetuity. The disasters both natural and man-made have attempted massively to destroy, devastate, and ruin our glorious leadership on earth. In all such cases, the society has responded through rendering relief and rescue operations and offering emergency health services to mitigate these humanitarian crises. It is imperative to understand, the response time for such emergencies varies with the nature and intensity of the hazards. It is still difficult to reach the epicenter or the point of occurrence even though services have begun to function towards the outer periphery region. The deployment of medical and non-medical personnel at the critical point in the early hours becomes unsuitable and unwise decision. There are issues of the inadequacy of resources for deployment strategy. In the era of 4IR (4th Industrial Revolution or Industry 4.0), it is emergent to improvise AI induced guided or auto guided devices that can perform various tasks at such unprecedented humanitarian crisis. The introduction of the Internet of Robotic Things (IoRT) protocol embedded with medical based AI i.e. Internet of Medical Robotic Things (IoMRT) would be able to deliver superior performance to minimize loss of life and property. This paper has attempted to explore how the IoMRT system can contribute to society with excellence.

Keywords: *Humanitarian Crisis; 4IR Ecosystem; Disaster Responses; Pandemic Diseases*

ARTICLE INFO
Received: Feb 13, 2023
Accepted: Apr 5, 2023
Available online: Apr 18, 2023

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CITATION
Chakrabarty A, Das US, Kushwaha S, Churi P. Managing Humanitarian Challenges of Disaster Responses and Pandemic Crises: Interface of 4IR Ecosystem. Journal of Autonomous Intelligence 2022; 5(2): 56–75.
doi: 10.32629/jai.v5i2.550

1. Introduction

1.1 Wonders of 4^{th} IR

The materialistic desires of a human being paired with inquisitiveness, innovativeness, and sheer will have been pushing the frontiers of knowledge, technological advancements and societal changes. Ever since the dawn of the industrial revolution, mankind had figured how to mass-produce goods of daily needs and this transition continued with improvements in the technology, computing power, and connectivity. Human society is at the pinnacle of technological advancement where digital physics and biological systems can intertwine amongst themselves giving a fundamental twist to what is generally perceived as work. The obligatory imaginative question of "what is work" or "future of work", is making inequality distinctly visible and unacceptable in free and open societies; enforcing political will to solve problems that were otherwise ignored in the past as destiny.

The Fourth Industrial Revolution is a convergence of digital, biological, and cyber physics, allowing us to fundamentally alter the very building blocks of life itself[1]. Artificial intelligence, high-speed mobile Internet, big data, big data analytics, cloud computing, blockchain, bioengineering, Internet of Things, nanotechnology, sharing circular economy, etc., are some of the main driving components of the Fourth Industrial Revolution. Although these technologies don't fundamentally change what we do, it changes what is "us", integrating digital physics into the very fabric of our life, ranging from high-speed mobile data, AI-enabled wearable devices, self-driving cars, home automation, etc., and creating a seamlessly connected ecosphere. The breakthrough in the frontier of artificial intelligence and biotechnology is redefining the meaning of being a human, expanding life expectancy, health, and cognition capabilities, and pushing the ethical boundaries of the ever-growing convoluted spiral of morals[2]. The progressive government of Japan has conceived the idea of Society 5.0 based on the pillars of Industry 4.0 pushing the boundaries of human comfort and enhancing human values. Society 5.0 is a perceptually superior and super-smart society where big data analytics, IoT, and AI will power the comfort and convenience of individuals by mobilizing resources for convenience, comfort, and sustainability. Japan has the prerequisite for mobilizing Society 5.0 like a plethora of raw health data from the universal health care system coupled with advanced technology and basic research referred to as "*monozukuri*". 4IR promises the miracles of human comfort, enabled with the wonders of technological development[3].

This paper aims to provide a comprehensive overview of managing humanitarian challenges during disaster responses and pandemic crises by integrating the 4th Industrial Revolution (4IR) ecosystem. Despite the efforts of relief and rescue operations and emergency health services, responding to these crises remains a challenge due to the nature and intensity of the hazards. Therefore, it is imperative to explore innovative solutions that can enhance the response time and minimize loss of life and property. To this end, this paper will summarize the existing methodological framework and elicit research issues, which will be addressed specifically in this article. In particular, we will focus on the potential of AI-induced guided or auto-guided devices and the Internet of Medical Robotic Things (IoMRT) to improve the response system. We will also discuss the challenges and opportunities of implementing such technologies in the context of disaster responses and pandemic crises. By doing so, we hope to contribute to the ongoing discussion on leveraging 4IR technologies for humanitarian purposes.

1.2 Innovations in robotics, healthcare robots & IoRT

Greek Mythology refers to an incident of *Pygmalion and Galatea*, the latter is a statue of the ideal feminine figure and how he falls for her. This may be considered as the earliest reference of human fascination over an inanimate human form[4]. The term robot was introduced in the year 1920 with the hit playwright of the Czech novelist & journalist Karel Čapek called R.U.R., or Rossum's Universal Robots where emotionless human-like machines achieve global domination, only to realize the mistake once humanity goes extent[5]. Robots have been in the forefront of science fiction movies; R2D2 and C3PO for Star Wars or Rosie of "The Jetsons" are some of the popular human-like machines. However, the term "robotics" was coined by a writer Isaac Asimov in his short story "Runabout" in 1942; his opinion was more positive than the previous versions. He also proposed the "Laws of Robotics" for his sci-fi characters. They are as follows:

- A robot shall not injure or harm a human being in any way through their actions.
- Robots are supposed to follow orders of humans expect when it involves harming other humans.
- Robots shall also protect themselves except when it comes to conflict with rules one and two.

First modem robots started appearing around in the year 1950's when an inventor George C. Devol designed a reprogrammable manipulator called it "Unimate", derived from "Universal Automation". He failed to capitalize on his product until the next decade but it was acquired by Joseph Engleberger a businessman with an engineering background. Joseph modified this design and capitalized on it. Later he also came to be known as a "the Father of Robotics". Charles Rosen from Stanford Research Institute in the year 1958 created a robot called "Shakey" which was far more advanced and could observe and respond to its environment[6]. The use of robot and robotics remained confined to factories and academic labs doing mundane industrial works or experiments. Honda in the year 1980 started a humanoid program which later developed into "ASIMO". The advances in LIDAR technologies, actuators, electric motors, and sensors changed the game of robotics which was visible in the DARPA Grand Challenge of 2004, where competing teams tussled with their robots in the middle of the desert. Newer combination of technology is being experimented in this field daily, for example, a robot named "Kengoro" uses oil pouch with electrodes and actuators to make movement identical to muscle[7].

Minimally invasive surgery for neurology, orthopedics, and laparoscopic procedures has driven the demand for robotics in the health care space. However, health robotics are not limited to the use of surgery only. These can broadly categorize under the following types:

- Tele-presence physicians
- Surgical assistants
- Rehabilitation robots
- Medical transportation robots
- Sanitation and disinfection robots
- Robotic prescription dispensing systems

Tele-presence physicians use robotics to examine and treat patients through tele-presence, even specialists can be consulted for guidance and therapy for patients in rural and otherwise inaccessible areas. The robot itself may comprise of ER capability and advanced camera technology for physical examinations. Surgical assistant robots can be remotely controlled assisting surgeons perfume minimally invasive surgeries. The robotic arms are highly sophisticated and use 3DHD technology. The surgeon gets the three-dimensional reference, natural stereo visualization of the augmented reality for performing highly complex surgery. Rehabilitation robots are designed for helping and healing the recovery process of individuals with a disability, brain trauma, spinal injuries, multiple sclerosis, etc., assisting in mobility, strength, and motor functions by adapting to the patients' behavior. Sanitation and disinfection robots are used in scenarios of outbreaks and epidemics where the human presence can prove fatal to the person. These robots use UV lights, Vaporizers (disperse hydrogen peroxide vapor) to disinfect areas in case of outbreaks like Ebola, SARS, COVID, etc. They can also be used for the removal and disposal of corpses in such scenarios. Robotic prescription dispensing systems use the speed and accuracy in dispensing pharmaceutical procedures, with much ease and precision for highly viscous material[8].

The advent of AI and rising labor prices have paved the way for intelligent robots to take over mundane repetitive tasks replacing humans or at times coexisting with human workers to boost productivity. Now IoT paired with robotics better known as IoRT is moving in to completely or partially remove human beings. Approximately sixty percent of Global 2,000 manufactures will incorporate automation technologies like robotics, AI and 3D printing with an upward cost of around 13 billion dollars by 2025. The IoRT market is expected to grow to 21 billion dollars by 2022 disrupting global economies[9].

1.3 The collapse of basic health infrastructure during emergency situations

The Global Climate Risk Index 2020 that tracks losses suffered by countries due to weather-related events ranks Japan, Philippines, Germany as the top three, followed by Madagascar, India, and Sri Lanka[10]. An estimate suggests that India suffered from 371 occasions of natural disaster from 1970 to 2009 which resulted in the death of approximately 151,000 persons and affected 1.86 billion. The most recurring disaster is flood (52%), cyclone (30%), landslide (10%), earthquake (5%), and drought (2%). Accidental Deaths & Suicides Report of India from 1967 and 2016 informed that around 261,779 people died due to natural disasters with annual death of 5,236 people, as shown in **Table 1**.

Table 1. Percentage of casualty occurring from various natural disasters

Natural disaster	Resulting casualty of humans	Approximate percentage
Lightning	92,224	35.23
Cold waves	44,923	17.16
Heat strokes	36,631	13.99
Landslides	32,213	12.30
Floods	29,897	11.42
Cyclones	25,891	9.89

Most of the states in India are susceptible to flood. The main reasons for that are rainfall distributions, inadequate infrastructure across the country[11]. Disaster killed 1.3 million, 4.4 billion displaced, homeless, or injured in dire need of emergency assistance. Around 91% of casualties were from extreme weather events like earthquakes, tsunamis, floods, storms, and drought. Countries hit with disaster reported losses of US$ 2,908 billion out of which US$ 2,245 billion was due to extreme climate between 1998–2017[12,13]. In the year 2016 a forest fire in the Canadian city of Fort McMurray, Alberta showed that there are immediate and long term impact on healthcare systems which is further enhanced if there is an evacuation scenario comprising of both the city and hospital in a moment's notice[14]. The Chernobyl Nuclear disaster of 26 April 1986 needs no introduction that released tons of radioactive materials into the atmosphere the material were deposited mostly over Eastern Europe province of Belarus and Ukraine. Around 600,000 clean-up workers were exposed to different levels of radiation. A total of 346,000 people were evacuated from the area to other non-contaminated zones. The consequential burden on health care after such a nuclear event was also learned from the previous atomic explosion of Hiroshima is that large numbers of people are born with birth defects, leukemia, other forms of cancer, etc. The immediate death due to acute radiation sickness (ARS) was 28 out of 134 personals[15]. The nuclear disaster (Level 7) of Fukushima Daiichi power plant owned and operated by TEPCO after the earthquake and tsunami killed 15,899 and 2,529 untraceable. This event forced an immediate evacuation of over 100,000 from a 20 km radius. This naturally left existing health infrastructure damaged and useless instantaneously. Only 47% of health workers reported to work after a month from the disaster, 38% clerks, and 48% of nurses reported to work. The staff shortage continued until the 18th month after the disaster[16]. Several psychological impacts were also seen amongst the evacuated population like post-traumatic stress responses, chronic anxiety and guilt, ambiguous loss experience, separated families/communities, and self-stigma[17,18].

The rapid expansion of cities towards the forest has increased the number of man-animal conflicts resulting in a new type of health emergency. Around 1,000 people in India get killed during such conflict[19]. Rapid deployment of emergency service can reduce the mortality.

1.4 Outbreaks, epidemics, and pandemic scenarios

Globalization and interconnected transportation have made it easier for diseases to jump from one geographic location to another. This also invites a study of detailed comparison in the emergence of novel pathogens and past epidemics history. Lesson from the 2003 SARS pandemic which resulted in the highest mortality rates of hospital workers highlighted the complexity of understanding novel diseases for clinically recognizing the involved risks[20]. Surprisingly, modern medicine is not that old; it dates back to the late 1860–1870s attributed to the formative works of Louis Pasteur (a French biologist) and Robert Koch (a German physician and microbiologist). These pioneers helped understand the building blocks of pathogen based diseases like smallpox and anthrax. Pathogens jump from one species to another given the congenital conditions or proximity. For example, cow-pox jumped from bovine into humans during the evolutionary process somewhere in the agrarian communities of Asia before killing thousands in the Europe and Americas in the late 15th century. Similarly, measles jumped from domesticated chickens to humans somewhere in Asia before traveling the world to create a catastrophe in the chicken less part of the world[21].

The idea of quarantine emerges during the pandemic of Black Death that later forced cities and principalities to restrain the movement of persons or goods from land or sea because of a contagious disease. In 1377, Dubrovnik on Croatia's Dalmatian Coast was the first to introduce quarantine where a

Table 2. Indicative list of past and present epidemic/pandemic[24–27]

Indicative period	Epidemic/pandemic*	Origin/affected area
3000 B.C.	The prehistoric epidemic of Hamin Mangha, Miaozigou	China
430 B.C.	Plague of Athens	Athens and Sparta
165–180 A.D.	Antonine Plague	Roman Empire
250–271 A.D.	Plague of Cyprian	Tunisia
541–542 A.D.	Plague of Justinian	Byzantine Empire
1346–1353	Black Death	Asia to Europe
1545–1548	Cocoliztli epidemic	Mexico and Central America
16th century	American Plagues	Americas
1665–1666	Great Plague of London	Britain
1720–1723	Great Plague of Marseille	Marseille, France
1770–1772	Russian plague	Moscow
1793	Yellow Fever	Philadelphia, USA
1846-1863	Asiatic Cholera*	India
1889–1890	Flu*	Europe & Rest of the world
1916	American Polio*	USA
1918–1920	Spanish Flu*	South Seas to the North Pole
1957–1958	Asian Flu*	China
1968	Hong Kong Flu* (H3N2 virus)	Asia
1981–Now	AIDS*	West Africa in the 1920s
2002–2003	SARS*	Asia
2009–2010	H1N1 Swine Flu*	Mexico
2012	MERS	Saudi Arabia
2014–2016	Ebola	West African (Guinea)
2015–Now	Zika Virus	South and Central America
2019–Now	COVID-19*	Wuhan, China (First recorded case)

plague named lazaretto was opened for the first time by the Republic of Venice at an island of Santa Maria di Nazareth[22].

Non-pharmaceutical interventions like "social distancing" find its trace back to the biblical times when people maintained considerable distance around lepers, merchant Jews, and maritime travelers known for travel history to countries with contagious diseases.

World Health Organization maintains an R&D blueprint focused on finding a cure for high risk and contagious pathogens for a public health emergency. Currently, the non-exhaustive list comprises of the following diseases: COVID-19, Crimean-Congo hemorrhagic fever, Ebola virus disease, and Marburg virus disease, Lassa fever, Middle East respiratory syndrome coronavirus (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS), Nipah and henipa viral diseases, Rift Valley fever, and Zika. It also lists "Disease X" a novel disease that may pose a serious international epidemic caused by an unknown pathogen and the preparedness required to tackle or intervene in the spread[23].

2. Literature review

2.1 Internet of Things in healthcare

Embedded Internet adapted the nomenclature "Internet of Things" in the year 1999 after a presentation for P&G's Supply Chain aimed at utilizing internet services, ever since it has become the buzz word of the tech world. This may be referred as the birth of the term IoT in general terms[28].

IoT was applied in several areas. One of the prominent areas of application became the health care sector. IoT coupled with u-Healthcare can play an important role in managing, monitoring and preventing chronic diseases (e.g. diabetes mellitus, blood pressure) as well as provide emergency intervention through Wearable Body Sensor Network and Intelligent Medical Server systems for performing the health analytics function thorough underlying technologies like wireless tech, and cloud computing[29]. BSN devices are either of in-body and on-body types while the first one is body implants, the other one is a wearable device. The use of BSN devices to monitor individual health powered by light and low power wireless sensor nodes bought in focus the question data privacy of individual's data. BSN research project of Harvard Sensor Network Lab named "CodeBlue" lacked security protocols in medical devices leaving it as a future scope. BSN-Care was later proposed as a means to secure the IoT health system using BSN, focusing on the specific security requirements[30]. To ease the problems of the elderly in a smart city environment, a smart IoT healthcare system was proposed, which is capable of monitoring, diagnostics, or even performing surgeries remotely. The system connects all paradigms of healthcare like hospitals, doctors, nurses, ambulances, and all other assistive devices with the patient monitored by a centralized server. IoT based health care systems are now part of the commercial market like Nike fuel band and Google Health providing doctors with an edge to monitor patient rehabilitations. IoT healthcare devices still face tremendous challenges like self-improvement, standardization along with security[31].

2.2 The Internet of Medical Things (IoMT)

The penetration of IoT into the health care systems cemented its fate as an integrated healthcare framework that came to be known as the Internet of Medical Things (IoMT) or Internet of Health Things (IoHT). Several avenues of elder care like to overcome the void of doctors by health information management tracking the patients' health as well as the medication process. One of the common morbidity for the elderly is a cardiac arrest that can be intervened using phonocardiogram (PCG) signal monitoring with IoMT devices over emerging wireless networks[32]. Similarly, medical care, in general, can immensely benefit from the full implementation of the IoMT framework and achieve the quality of experience from the user perspective. IoMT is now accepted into healthcare and if used sustainably, it can also overcome the location or demographic challenges faced by the medical sector[33]. However, the challenge is ever-growing as the number of Medical Things (MT) or the Internet of Medical Things (IoMT) especially as the data generated by these devices are sensitive and critical. This will not only put the patients at risk, but also create immense threats endangering life itself. A 5 layered IoT model demonstrated the potential vulnerability and risk for such devices with an unsettling question on how to secure such critical device infrastructure from external attacks[34]. A review of IoMT devices and IoMT-based systems from a multi-layer angle showed that the CPS approach can be the answer for enhancing security while improving the reliability and control over the devices[35].

2.3 The Internet of Robotic Things (IoRT)

In a perfectly utopian interconnected, fully automated world robotics could perhaps do miracles or maybe take care of our indoor plants. Such proof of concept was highlighted at the Ericsson office in Chennai where a robot armed with a mere mechanical arm, sensors, actuator, monitored the temperature, soil moisture humidity for indoor plants using the Ericsson's APPIoT platform for the decision making process[36].

From saving indoor plants to saving human lives, IoRT devices bridges the imagination between science fiction and human reality. One such novel design is an industrial firefighting robot aimed at decreasing the risk of human life and also saving human life by early actions while reducing or minimizing damage and losses to the property. The system is multitasking and is capable of alerting the nearby fire station, mobilizing firefighting robots for timely intervention, etc. The machine learning algorithm will also ensure that it can identify potential fire hazards even before they occur[37]. The mind-boggling question that if humanity is ready to let machines intervene, intercept and invade the very public spaces that one holds near and dear to the rights of personal freedom is probably the hardest one to answer. As robots become more context-aware able to handle human tasks with ease and agility, the secondary question of regulation of the cyber-institutions is invincible. Perhaps we are already stepping towards a future where resources are shared with our non-human counterparts. This may be viewed in a three-part answer: 1) co-exist with non-human robotic forms; 2) proposed good behavior patterns; 3) cyber-institutions for non-human counterparts[38].

Ever since ABI Research introduced the concept Internet of Robotic Things (IoRT), researchers have been puzzled with the question to find how to best manage the devices to achieve optimal performance and achieve the desired level of Quality-of-Service (QoS), the answer to which perhaps lies in effectively using ANN control scheme to achieve global connectively among the IoRT devices. BCI or brain-computer interface that uses an electroencephalogram is another proposed effective mechanism that can efficiently deploy the Internet of Robotics Things using human computer-based control. This interface can be utilized for controlling both the local bots and bots located in some remote locations. The experimental scenario also presented some groundbreaking results despite latency in control to power innovation and cooperative learning and perhaps the use of ICT technology. Although in an ideal scenario a bot would automatically perform the assigned action, a remote control over such things only using the human brain can prove to be miraculous in critical and dangerous situations[39].

A new and a dynamic approach of incorporating the existing robotics technology like Li-Fi and information web married with robotics as "things" applied to the field of healthcare has invented a new framework called as the Internet of Medical Robotics Things also known as IoMRT[40].

3. Methodology

This is a conceptual paper that has attempted to derive a framework or a model to integrate the "Internet of Robotic Things" in the sophisticated medical operations primarily in exigency or extraordinary emergencies. The body of the paper and the central idea has been constructed based on relevant literature, research works, and real-time application protocols across the globe. The paper has been developed based on secondary information embedded with logical, intuitive, and cognitive understanding so that the model of IoMRT protocol can be manifested and implemented in disaster responses and pandemic crises.

4. Objectives

- To study the overview of disasters and emergency health-related crises experienced in India.
- To study the prudence and scope of IoRT intervention in the emergency health care system.
- To explore innovative models of IoMRT protocol in the emergency health care system along with the capabilities of multitasking operations.

5. Analysis and interpretation

5.1 Analysis I

5.1.1 Analysis 1.1

India is the seventh-largest country in the world and is spread over a large geographic location consisting of mountains, flood plains, deserts, etc., and several cultural/ linguistic communities, tribes, and sub-tribes live here with several conflicts, pending resolutions; this makes the region vulnerable both in terms of natural disasters, and man-made disasters. **Table 3** lists the types of disasters faced by India.

Table 3. Various types of disasters experienced in India[41]

Type of disasters				
Water and climate	**Geological**	**Chemical and nuclear**	**Accident**	**Biological**
Floods	Landslides	Industrial and chemical	Forest fires	Biological disasters
Cyclones	Earthquakes	Nuclear disasters	Urban fires	Epidemics
Tornadoes and hurricanes	Dam failures/dam bursts		Mine flooding	Pest attacks
Hailstorm	Minor fires		Oil spills	Cattle epidemics
Cloud burst			Building collapse	
Heat and cold wave			Serial bomb blasts	
Snow avalanches			Festival related disasters	
Droughts			Electrical disasters and fires	
Sea erosion			Air, road and rail accidents	
Thunder and lightening			Boat capsizing	
Tsunami			Village fire	

5.1.2 Analysis 1.2

A significant amount of damages are caused by both natural, and man-made disasters, resulting in death, displacement, and damages. The types of natural disasters in **Table 4** were faced by India in the last decade, which shows the total deaths, total affected number of people along with the cost of damages incurred.

Table 5 shows the list of man-made disasters in India, total death, number of injured, and the total number of affected people in the last decade.

5.1.3 Analysis 1.3

Significant numbers of people also die from recurring endemic diseases in India. **Table 6** shows the number of death as the latest statistics published by the Ministry of Health and Family Welfare Govt. of India.

5.2 Analysis II

Health is considered the greatest wealth of mankind which is apparently claimed that it can be perceived visually. However, the health conditions are always turbulent in nature, i.e., which is not predictable unless appropriate clinical procedures

Table 4. Total death and damages arising from natural disasters[42–44]

Year	Disaster type	Total deaths	Total affected	Total damages ('000 US$)
2010	Storm	287	507,080	-
	Landslide	17	-	-
	Extreme temperature	250	-	-
	Flood	690	3,772,408	2,149,000
2011	Extreme temperature	212	-	-
	Flood	608	12,004,069	1,657,000
	Storm	106	250,050	-
	Earthquake	112	575,200	-
2012	Storm	40	70,000	-
	Flood	279	4,210,860	244,000
	Mass movement (dry)	16	-	-
	Extreme temperature	264	-	-
2013	Storm	106	13,230,004	895,471
	Earthquake	3	59,350	120,000
	Flood	6,453	3,419,473	1,362,000
	Extreme temperature	557	-	-
2014	Extreme temperature	180	-	-
	Landslide	151	200	-
	Storm	119	931,564	-
	Flood	622	5,222,500	16,465,000
2015	Flood	839	16,413,459	2,880,000
	Storm	212	135,100	1,069,000
	Landslide	3	9,000	-
	Extreme temperature	2,248		-
	Drought	-	330,000,000	3,000,000
	Earthquake	98	135,670	-
2016	Storm	128		1,000,000
	Earthquake	8	10,808	75,000
	Landslide	20	5	-
	Extreme temperature	300	-	-
	Wildfire	7	-	-
	Flood	666	3,806,000	1,499,000
2017	Storm	940	123,252	-
	Flood	1,046	22,271,843	2,117,000
	Landslide	96	100	
	Extreme temperature	264	-	-
2018	Storm	625	853,650	2,144,000
	Wildfire	17	-	-
	Drought	-	8,200,000	1,100,000
	Flood	710	23,307,698	2,864,980
	Extreme temperature	44	-	-
2019	Storm	172	20,130,000	1,810,000
	Extreme temperature	112	450	-
	Epidemic	121	1,318	-
	Flood	2,023	3,070,060	10,000,000
2020	Cyclone*	85*	150,000,000*	-

Table 5. Total death and damages arising from man-made disasters[44]

Year	Disaster type	Total deaths	No. of injured	Total affected
2010	Air	158	8	8
	Road	358	133	173
	Water	164	-	17
	Rail	93	252	252
	Collapse	180	230	-
	Other	10	15	15
	Fire	12	8	8
2011	Air	28	5	5
	Road	85	58	68
	Rail	78	152	152
	Fire	118	50	140
	Collapse	32	-	-
	Other	116	121	121
2012	Road	155	113	113
	Water	205	-	150
	Rail	14	30	30
	Fire	38	40	40
	Other	15	-	-
2013	Road	171	43	43
	Water	45	-	-
	Rail	63	36	36
	Collapse	133	101	101
	Other	109	133	133
	Fire	19	19	19
2014	Road	90	20	20
	Rail	76	243	243
	Collapse	103	41	41
	Other	86	145	145
	Explosion	19	17	17
2015	Fire	2	11	3011
	Air	10	-	-
	Road	44	47	47
	Rail	71	198	198
	Gas leak	6	213	213
	Explosion	104	60	60
	Other	38	84	84
2016	Air	29	-	-
	Road	120	111	111
	Rail	150	260	260
	Explosion	17	19	19
	Collapse	67	100	100
	Fire	136	383	383
	Other	59	20	20
2017	Explosion	68	136	110
	Road	170	46	46
	Water	69	-	-
	Rail	63	324	324
	Fire	27	-	-
	Collapse	76	56	56
	Other	108	-	-
2018	Fire	37	150	150

Table 5. (*Continued*)

Year	Disaster type	Total deaths	No. of injured	Total affected
	Road	196	62	62
	Rail	59	90	90
	Explosion	18	5	5
2019	Road	75	35	35
	Water	57	-	-
	Explosion	10	-	-
	Fire	55	-	-
	Others	43	16	16
2020	Road	26	32	32
	Rail	14	-	-
	Gas leak	11	316	316

Table 6. Total death due to endemic diseases in India[45]

Death due to endemic diseases in India (2018)*							
		Male		**Female**		**Total**	
Disease name	**ICD-10**	**Cases**	**Deaths**	**Cases**	**Deaths**	**Cases**	**Deaths**
Cholera	Code A00	359	4	292	2	651	6
Acute diarrhoeal diseases	Code A09	6,891,133	826	6,303,642	624	13,194,775	1,450
Typhoid	Code A01	1,239,310	230	1,069,227	169	2,308,537	399
Acute respiratory infection	Code J00-J06, J10, J11 and J20-J22	21,771,377	2,358	20,224,883	1,382	41,996,260	3,740
Tetanus neonatal	Code A33	73	2	108	2	181	4
Tetanus (others)	Code A35	5,804	43	3,300	26	9,104	69
Diphtheria	Code A36	7,838	96	3,882	84	11,720	180
Whooping cough	Code A37	10,545	3	7,461	5	18,006	8
Measles	Code B05	11,773	20	9,122	14	20,895	34
Hepatitis	Code B15-B19	84,096	405	59,878	179	143,974	584
Rabies	Code A82		83		27		110
Pneumonia	Code J12-J18	511,686	2,594	416,799	1,619	928,485	4,213
Meningococcal meningitis	Code A39.0 + (G 01*)	1,971	86	1,411	66	3,382	152
Syphilis	Code A50-A53	6,126	0	9,869	0	15,995	0
Gonococcal	Code A54	15,836	5	39,634	0	55,470	5
Chicken pox	Code B01	36,422	40	30,541	10	66,963	50
Encephalitis	Code G04.9	6,344	309	3,701	221	10,045	530
Viral meningitis	Code A 87	7,317	80	5,793	58	13,110	138

followed by correlations are adopted. It makes a massive challenge for a society or a state to accomplish and maintain desired health standards among the population efficiently and effectively. The health-related issues become vulnerable or detrimental in case of emergency uncontrollable situations. Indicative health emergencies may include an outbreak of epidemic/pandemic diseases, natural calamities, war-fare, man-made disasters that comprises of ill sustainability, pollution, etc. The biggest challenges of health professionals and health workers to handle such emergency health situations are as follows.

1) **Inadequacy of reachability.** Emergency is considered as instantaneous or sporadic demolition of the system which creates a massive adverse impact on the societal living beings particularly in case of abrupt failure of health services. Circumstances cannot be predicted most of the time and the most challenging tasks are to ensure quick response and reachability deployed appropriate resources with a short time to address mitigate or quarantine the problem as early as possible so that the losses of life and resources can be minimized. Also, the total number of health care centers including primary, community, and sub centers is 1,98,436 out of which 756 are district hospitals catering to an elephantine population of 135 crores[45].
2) **Lack of prompt supply chain of health care resources (medicines, equipment, diagnostic kits, etc.).** There is no such structured and comprehensive strategic planning for an appropriate inventory management system for mainlining optimum stockpile for combating outbreaks, pandemic and other mitigating other emergency health crisis. However, the USA has a dedicated strategic national stockpiling[46] mechanism system for maintaining an optimal inventory of health-related products consistent with the time series prediction. Despite such preemptive measures, the USA couldn't address the COVID19 issue as it does not emerge in through predictive analysis and thereby no appropriate medicine/vaccine is available to date except preventative measures. Till December 2018, there are only 3,108 licensed blood banks and 469 eye banks in India[47].
3) **Deployment of resources in time.** It is imperative that in case disaster resources are deployed immediately so that the affected population is provided with the necessary help and heath. Early warring agencies and systems can play a vital role in an impending disaster, for instance in case of tsunami response agencies may have a time of 10 minutes to few hours before it hits an affected population. Similarly, in case of cyclone hourly monitoring can help mitigate the risks of disaster or evacuate to be affected populations. In India NDRF is the primary response agency for any kind of disasters and early warning agencies for natural disasters are listed in **Table 7**.

Table 7. List of early disaster warning agencies in India

Disasters	Early warning agencies
Cyclone	Indian Meteorological Department
Tsunami	Indian National Centre for Oceanic Information Services
Floods	Central Water Commission
Landslides	Geological Survey of India
Avalanches	Snow and Avalanche Study Establishment
Heat and cold waves	Indian Meteorological Department

A risk assessment may be done using 30 years of data and vulnerability for profile may be created for planning disaster response[41].

4) **Threat from collateral damage.** Occupational deaths of healthcare workers dealing with infectious diseases[48,49] or in situations of war/conflict.
5) **Lack of adequate manpower for deploying in various regions simultaneously.** There is approximately 1 doctor per 1,445 people, against the 1:1,000 ratio as prescribed by WHO while the nurse: patient ratio is 1:483 in India[50,51].

Due to the growing dominance of superior technological environment, it is inevitable that the future emergency crisis management shall be governed by the 4IR ecosystem as mentioned in **Figure 1**. Management of such humanitarian crises will be manifested by e.g., AI, ML, Big Data, IoRT, IoMRT systems that would ensure instant emergency response, higher precisions and coverage of rescue, relief, and recovery; 3R operations, non-human emergency health support, etc. The disaster alarm system will be built upon a dedicated real-life database and data analytics.

Table 8. Challenges of traditional health management and scope of IoMRT protocol in emergency situation

Challenges of traditional health management in case of emergency situation	Scope of IoMRT protocol to address such a humanitarian crisis
Inadequacy of reachability	To offset and overcome emergency health care challenges, IoMRT protocol can be adapted and implanted. For instance, in war situation, deployment of health professionals and workers at the bordering areas are not prescribed which can be served by these IoMRT devices. Their activity may be controlled by using a GPS/GIS-based knowledge ecosystem run by qualified health professionals from a safe range.
Lack of prompt supply chain	The IoMRT protocol can function as an embedded refrigerated system that can preserve lifesaving drugs antibiotics, anti-coagulant, etc. that can be used in exigency or SOS as deemed fit by the central knowledge hub.
Deployment of resources in time	The IoMRT system can be deployed instantly by airdrop and par shooting or using drone technology as the case may be.
Threat from collateral damage	IoMRT is a specialized IoT protocol with feeder AI that can follow instructions of human per excellence on a specific domain. Hence, there is no possibility of self-infection and the same device can be sanitized as per the preventive norms. So a lesser number of PPE and other protective measures shall not forbid the efficiency and effectiveness of IoMRT to let the emergency health management ecosystem.
Lack of adequate manpower for deploying in various regions simultaneously	IoMRT devices or drones can be manufactured in a good number and can be deployed without any physical presence of human being in an emergency health management scenario. These IoMRT drone devices can be controlled, monitored by the centrally established health expert's team through a GPS/GIS network.

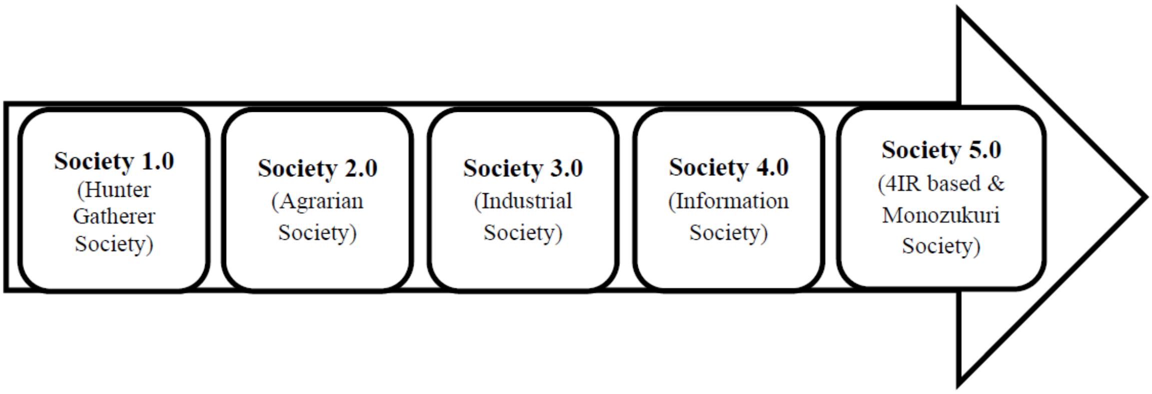

Figure 1. Progression of society from Society 1.0 to Society 5.0[3].

5.3 Analysis III

Figure 2 exhibits the transformation of Industrial Revolutions 1.0 to 4.0 with respect to the indicative timeline. The progression of the industrial revolution moved towards Industry 4.0 where human par intelligence has been embedded in the devices guided by the control stations through a human interface. The accelerated developmental vector of technology has pioneered to reduce, minimize, and even replace total human intervention so that the dedicated devices can perform in a self-guided contingency mode. However, there are issues of the ethical protocol to completely wipe out human intervention for the service of its kingdom.

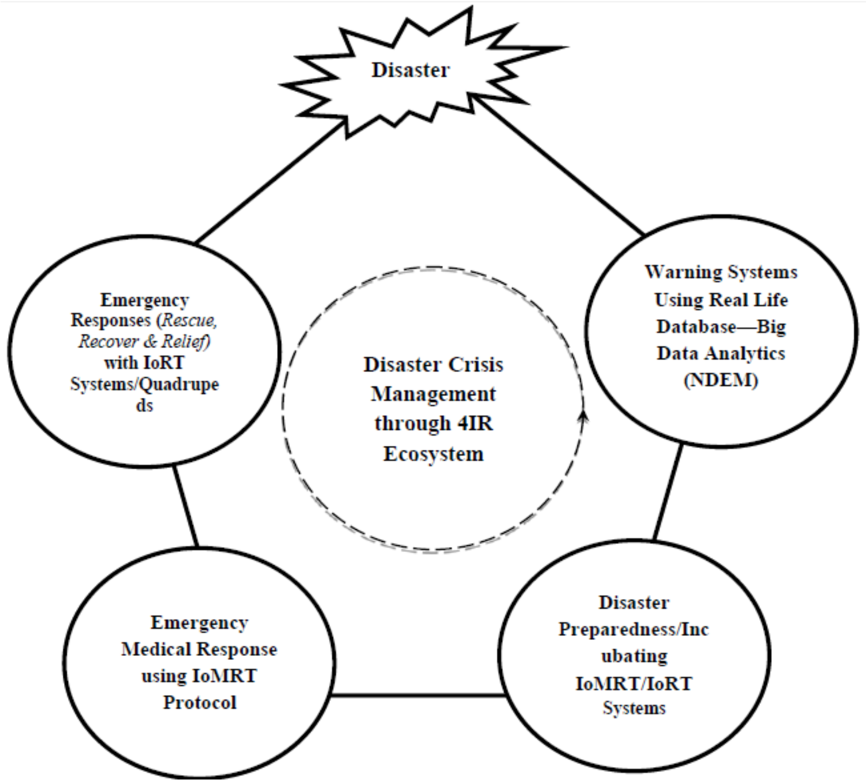

Figure 2. Disaster crisis management in 4IR ecosystem.

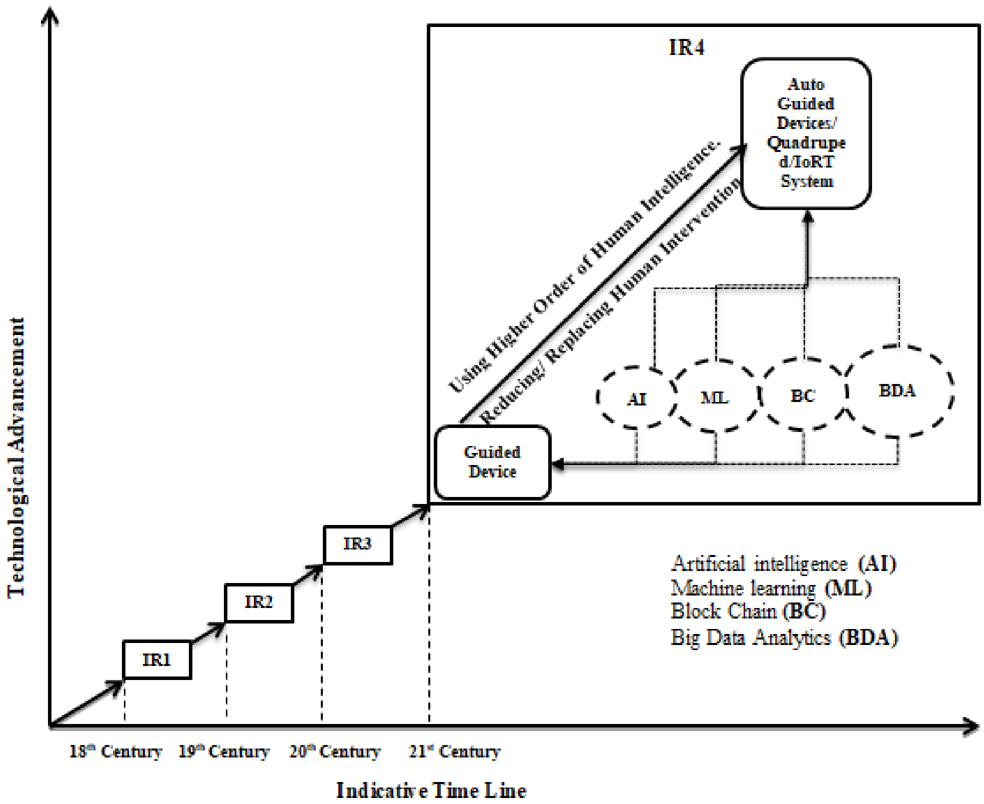

Figure 3. Progression of IR as adapted and modified from previous studies[52–54].

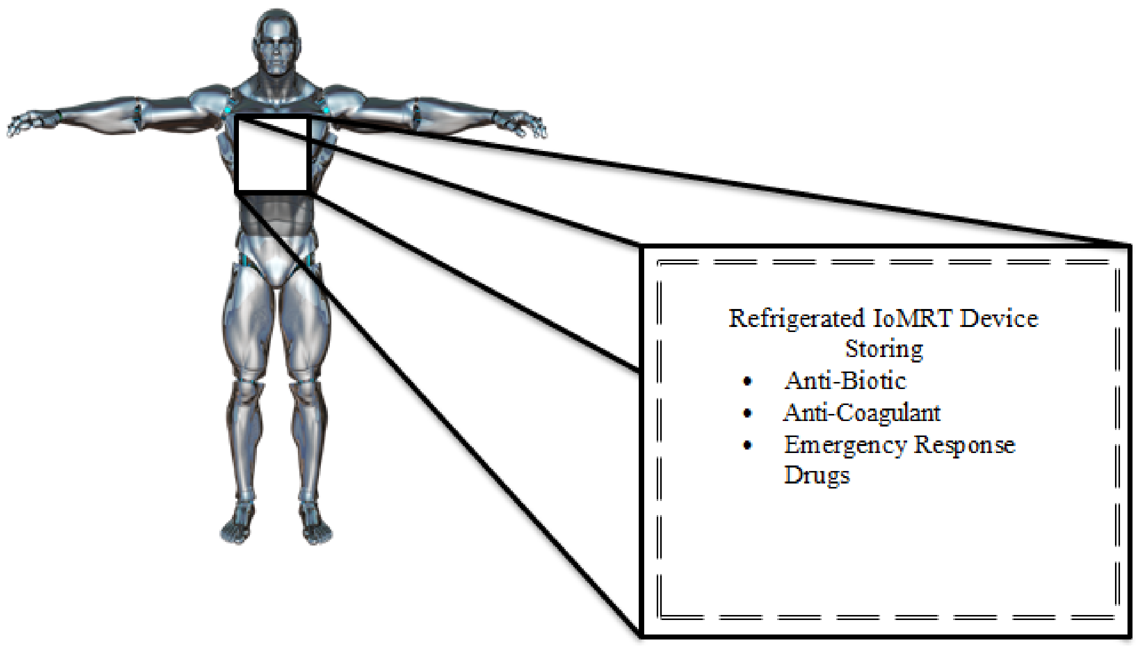

Figure 4. Indicative humanoid with an IoMRT device carrying emergency drugs.

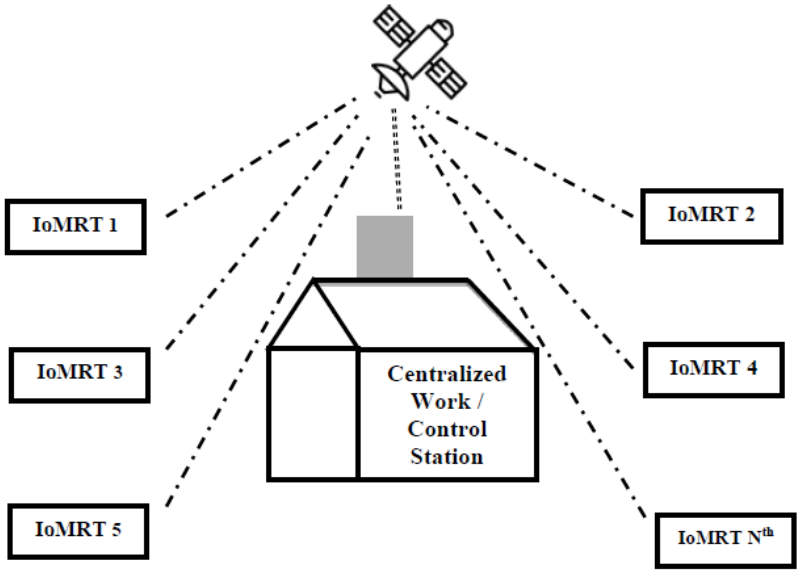

Figure 5. Indicative diagram of an IoMRT device swarm monitored by a centralized work station/control station.

Table 9. Indicative list of full functional bipedal robots/quadrupeds[55–57]

Manufacturer	Device name	Abilities
Boston Dynamics	Atlas	Maneuver and mimic complex human actions
	Spot	Maneuver, mimic, and replicate complex quadruped actions
	Handle	Able to transport load in a complex warehouse-like environment
Toyota	T-HR3	Maneuver and mimic complex human actions; controllable using an exoskeleton to extremely complex human actions
Roscosmos Space Agency	F-850	Mimic complex human actions tested in the ISS module

Fully functional bipedal robots/quadrupeds can be repurposed to act as the IoMRT system in order to prepare and mitigate the disaster scenarios including addressing the pandemic crisis.

5.3.1 Algorithmic steps of iomrt devices guided by a centralized work station/control station

Step 1: There would be control stations at various strategic locations of the country based on vulnerability assessment and risk analysis. Zonation and micro-zonation can be created based on risk mapping for prevention or mitigation of disaster, using panel data and big data analytics. This device can be deployed for immediate diagnosis and treatment of victims during pandemic situations that minimize the ease of contact of health professionals and workers in order to prevent the spread of contagious diseases.

Step 2: Quadruped or humanoids shall be provided adequate inputs using AI and equipped with emergency IoMRT tools so that it can perform the desired action on the target as per the direction, superintendence, guidance, and monitoring of the control station.

Step 3: A special purpose dedicated vehicle shall be used to deploy the humanoids and IoMRT protocol to the target strategic location.

Step 4: Each robots device shall be enabled with multiple sensors like LiDAR for imagery, speech recognition, thermo-graphic camera to recognize and identify the nature and specifications of the victim and assess the nature and magnitude of damage including property.

Step 5: Each IoMRT shall be assigned a dedicated catchment area where the target shall be fixed which would be directed by the respective control station based on appropriate long-lat configuration received from the deployed robot signals and geospatial technology so that conflict of assignment can be nullified with zero error. Route plan and assignment of the dedicated target shall be decided and directed by the control stations and shall be instructed to the respective IoMRT system for immediate successful implementation using the combinatorial assignment optimization model of operation research.

Explanation: IoMRT 1 shall be assigned to five targets, i.e., T1 to T5. Similarly, IoMRT 2 shall be assigned to another five targets, i.e., T6 to T10. The assignment mechanism shall be strictly governed by the respective control station based on various parameters like distance matrix, ease of instant reachability, and ease of the ability to discharge the desired performance at the present capacity.

Step 6: The IoMRT system shall be well equipped with all the essential and emergency medical kit that shall include anti-coagulant, antibiotics, ORS, IV saline drip, sanitizer, anti-septic, Nerve Block Injections, and anti-venom, like an emergency cart maintaining medial SOP. The IoMRT system shall act as an intermediary between the target victim and doctors in the control station using live imagery transmission and voice transcription. The IoMRT system would execute an appropriate assignment as directed by an expert doctor in the control station through codified algorithmic protocol so that the health condition of the victim can be improved and in extreme cases, the target victim may be recovered as per the directive of the control station.

Step 7: In case of executing the recovery assignment, the control system would facilitate a special-purpose dedicated vehicle to mobilize the victim and even the IoMRT system to the rehabilitation center or other strategic deployment purpose.

The IoMRT systems can be administered in a pandemic crisis that would minimize the ease of contact between the patient and the health professionals. This may reduce the chances of spreading contagious diseases particularly among the workforce associated with health services. The modus operandi of the IoMRT system for rendering diagnostic and treatment supports to the victims of the pandemic crisis are quite similar except the response assignments including 3R, i.e. rescue, recovery, and relief due to the extraordinary disaster emergency.

5.3.2 Ease of economic value added multi-tasking operations of humanoids

IoMRT devices can be incorporated/augmented by various function-specific protocols. Each of the configurations of the protocol can be singularly activated, trained, programmed, and deployed for target assignment. The same device can be further deactivated from the existing protocol and activated for some other function-specific protocols. In this ways, the IoMRT device can be used optimally with the help of functionally specific multi-tasking jobs one at a time in a mutually exclusive manner inconsistency with the nature of assignment on a priority basis, with reliability testing before deployment. The ability of multitasking of these humanoids would create an economic value-added model for society.

6. Discussions

The Internet of Robotic Things (IoRT) has been proposed as a solution to improve the response time and effectiveness of relief and rescue operations during humanitarian crises. The deployment of AI-guided or auto-guided devices, embedded with medical-based AI, can significantly contribute to minimizing the loss of life and property during such crises[58]. The integration of these technologies can result in the development of the Internet of Medical Robotic Things (IoMRT), which has the potential to deliver superior performance in disaster management[59].

The IoMRT system can offer a range of capabilities, including remote monitoring and diagnosis, automated emergency response, and the delivery of critical medical supplies to affected areas[60]. For example, the use of drones and unmanned aerial vehicles (UAVs) equipped with medical AI can facilitate the transportation of medical supplies and emergency equipment to inaccessible areas[61]. The IoMRT system can also enable remote diagnosis and treatment of patients by healthcare professionals located in different parts of the world, utilizing telemedicine technologies[62]. This can be especially useful in situations where access to medical personnel is limited, such as in the case of a pandemic or in remote areas.

Furthermore, the IoMRT system can improve the efficiency and accuracy of medical procedures by assisting healthcare professionals in tasks such as surgery and rehabilitation. The use of robots and other automated devices can significantly reduce the risk of human error and enhance the precision of medical procedures, thereby improving patient outcomes.

In conclusion, the integration of AI and robotics in the form of the IoMRT system has the potential to revolutionize the field of disaster management and emergency response. The development and deployment of such systems can significantly improve the response time and effectiveness of relief and rescue operations during humanitarian crises, minimizing the loss of life and property. Future research should focus on exploring the potential applications of the IoMRT system in various disaster scenarios and developing strategies to overcome the challenges associated with the deployment of such technologies in the field.

7. Conclusion

The revolutionary 4IR has empowered the digital ecosystems which can be augmented by artificial intelligence (AI), machine learning (ML), platforms for big data analytics, etc. Due to the outbreak of an epidemic, pandemic, or disaster-related health hazards, the deployment of human par excellence intelligent IoMRT protocol would be leading the key role in addressing the emergency humanitarian and health crisis for mitigating the present and the upcoming civilizational challenges. The protocol would help to deliver all the important assignments including 3R, i.e. rescue, recovery, and relief in extraordinary emergencies. This model is highly effective in a federal system of government where approval from the provincial governments is essential before the deployment of the disaster team for rescue operations as the protocol for emergency response. The IoMRT systems would offset such legal complications and enhance the scope for an instant as well as the quality of disaster response. The ongoing COVID-19 issues may have had different outcomes if the IoMRT ecosystem would have been administered instantly and widely across the globe since there is no threat of infections to be developed in the humanoids to treat the victims of massive contagious diseases.

Conflict of interest

The authors declared no conflict of interest.

References

1. Schwab K. The Fourth Industrial Revolution [Internet]. Chicago, IL: Encyclopædia Britannica; 2018. Available from: https://www.britannica.com/topic/The-Fourth-Industrial-Revolution-2119734.
2. Schwab K. The Fourth Industrial Revolution: What it means, how to respond [Internet]. Geneva: World Economic Forum; 2016. Available from: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.
3. Government of Japan. Realizing Society 5.0 [Internet]. Tokyo: Government of Japan; 2017. Available from: https://www.japan.go.jp/abenomics/_userdata/abenomics/pdf/society_5.0.pdf.
4. Britannica TEoE. Pygmalion [Internet]. Chicago, IL: Encyclopædia Britannica; 2019. Available from: https://www.britannica.com/topic/Pygmalion.
5. Capek K. RUR (Rossum's universal robots). New York: Penguin; 2004.
6. Stanford. Robotics: A brief history [Internet]. Stanford, CA: Stanford | Computer Science; 1998. Available from: https://cs.stanford.edu/people/eroberts/courses/soco/projects/1998-99/robotics/history.html.
7. Simon M. The WIRED Guide to Robots [Internet]. Boone, IA: WIRED; 2020. Available from: https://www.wired.com/story/wired-guide-to-robots/.
8. Crawford M. Top 6 robotic applications in medicine [Internet]. New York: ASME.org; 2016. Available from: https://www.asme.org/topics-resources/content/top-6-robotic-applications-in-medicine.
9. Matthews K. The Internet of Robotic Things: How IoT and robotics tech are evolving together [Internet]. IoT Times; 2019 Jun 19. Available from: https://iot.eetimes.com/the-internet-of-robotic-things-how-iot-and-robotics-tech-are-evolving-together/.
10. Eckstein D, Künzel V, Schäfer L, Winges M. Global climate risk index 2020 [Internet]. Berlin: Germanwatch e.V.; 2019. Available from: https://germanwatch.org/sites/default/files/20-2-01e%20Global%20Climate%20Risk%20Index%202020_15.pdf.
11. Parida Y, Goel PA. India is not prepared for natural disasters [Internet]. Chennai: The Hindu Business-Line; 2020. Available from: https://www.thehindubusinessline.com/opinion/india-is-not-prepared-for-natural-disasters/article30463153.ece#.
12. Mizutori M, Guha-Sapir D. Economic losses, poverty and disasters: 1998–2017. Geneva: United Nations Office for Disaster Risk Reduction; 2017.
13. Patel A. India lost $80 bn due to disasters in last 20 years: UN report [Internet]. Noida: India Today; 2018. Available from: https://www.indiatoday.in/india/story/india-lost-80-bn-due-to-disasters-in-last-20-years-un-report-1366521-2018-10-11.
14. Francescutti LH, Sauve M, Prasad AS. Natural disasters and healthcare: Lessons to be learned. Healthcare Management Forum 2017; 30(1): 53–55. doi: 10.1177/0840470416679338.
15. Dallas CE. Medical lessons learned from Chernobyl relative to nuclear detonations and failed nuclear reactors disaster medicine and public health preparedness. Disaster Medicine and Public Health Preparedness 2012; 6: 330–334. doi: 10.1001/dmp.2012.72.
16. Ochi S, Tsubokura M, Kato S, *et al.* Hospital staff shortage after the 2011 triple disaster in Fukushima, Japan-An earthquake, tsunamis, and nuclear power plant accident: A case of the Soso District. PloS ONE 2016; 11(10): e0164952. doi: 10.1371/journal.pone.0164952.
17. Hasegawa A, Ohira T, Maeda M, *et al.* Emergency responses and health consequences after the Fukushima accident; Evacuation and relocation. Clinical Oncology 2016; 28(4): 237–244. doi: 10.1016/j.clon.2016.01.002.
18. Associated Press in New Delhi. More than 1,000 people killed in India as human and wildlife habitats collide [Internet]. New York: The Guardian; 2017. Available from: https://www.theguardian.com/environment/2017/aug/01/over-1000-people-killed-india-humans-wildlife-territories-meet.
19. Hoek G, Brunekreef B, Fischer P, van Wijnen J. The association between air pollution and heart failure, arrhythmia, embolism, thrombosis, and other cardiovascular causes of death in a time series study. Epidemiology 2001; 12(3): 355–357.
20. Watts SJ. Disease and medicine in world history. London: Psychology Press; 2003.
21. Tognotti E. Lessons from the history of quarantine, from plague to influenza A. Emerging Infectious Diseases 2013; 19(2): 254–259. doi: 10.3201/eid1902.120312.
22. WHO. Prioritizing diseases for research and development in emergency contexts [Internet]. Geneva, Switzerland: World Health Organization; 2020. Available from: https://www.who.int/activities/prioritizing-diseases-for-research-and-development-in-emergency-contexts.
23. Jarus O. 20 of the worst epidemics and pandemics in history [Internet]. New York: Live Science; [Updated 2023 Jan 31]. Available from: https://www.livescience.com/worst-epidemics-and-pandemics-in-history.html.
24. Ashton K. That 'Internet of Things' thing. RFID Journal 2019; 22: 97–114.
25. CDC. 1968 Pandemic (H3N2 virus) [Internet]. Atlanta, GA: Centers for Disease Control and Prevention, (NCIRD); 2019. Available from:

https://www.cdc.gov/flu/pandemic-resources/1968-pandemic.html.
26. National Institute of Allergy and Infectious Diseases (NIH). COVID-19, MERS & SARS [Internet]. Bethesda: National Institute of Allergy and Infectious Diseases (NIH); 2020. Available from: https://www.niaid.nih.gov/diseases-conditions/covid-19.
27. Kohn GC (editor). Encyclopedia of plague and pestilence: from ancient times to the present. New York: Infobase Publishing; 2007.
28. Gelogo YE, Hwang HJ, Kim HK. Internet of Things (IoT) framework for u-healthcare system. International Journal of Smart Home 2015; 9(11): 323–330. doi: 10.14257/ijsh.2015.9.11.31.
29. Gope P, Hwang T. BSN-Care: A secure IoT-based modern healthcare system using body sensor network. IEEE Sensors Journal 2015; 16(5): 1368–1376. doi: 10.1109/JSEN.2015.2502401.
30. Yin Y, Zeng Y, Chen X, Fan Y. The Internet of Things in healthcare: An overview. Journal of Industrial Information Integration 2016; 1: 3–13.
31. Jusak J, Pratikno H, Putra VH. Internet of Medical Things for cardiac monitoring: Paving the way to 5G mobile networks. In: 2016 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT); 2016 Dec 8–10; Surabaya, Indonesia. New York: IEEE; 2017. p. 75–79. doi: 10.1109/COMNETSAT.2016.7907420.
32. Shin D, Hwang Y. Integrated acceptance and sustainability evaluation of Internet of Medical Things. Internet Research 2017; 27(5): 1227–1254. doi: 10.1108/IntR-07-2016-0200.
33. Alsubaei F, Abuhussein A, Shiva S. Security and privacy in the internet of medical things: taxonomy and risk assessment. In: 2017 IEEE 42nd Conference on Local Computer Networks Workshops (LCN Workshops); 2017 Oct 9; Singapore. New York: IEEE; 2017. p. 112–120. doi: 10.1109/LCN.Workshops.2017.72.
34. Gatouillat A, Badr Y, Massot B, Sejdić E. Internet of Medical Things: A review of recent contributions dealing with cyber-physical systems in medicine. IEEE Internet of Things Journal 2018; 5(5): 3810–3822. doi: 10.1109/JIOT.2018.2849014.
35. Saravanan M, Perepu SK, Sharma A. Exploring collective behavior of Internet of Robotic Things for indoor plant health monitoring. In: 2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS); 2018 Nov 1–3; Bali, Indonesia. New York: IEEE; 2018. p. 148–154. doi: 10.1109/IOTAIS.2018.8600865.
36. Raj PA, Srivani M. Internet of Robotic Things based autonomous fire fighting mobile robot. In: 2018 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC); 2018 Dec 13–15; Madurai, India. New York: IEEE; 2019. p. 1–4. doi: 10.1109/ICCIC.2018.8782369.
37. Loke SW. Are we ready for the Internet of Robotic Things in public spaces? In: Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers; 2018 Oct 8–12; Singapore. New York: Association for Computing Machinery; 2018. p. 891–900. doi: 10.1145/3267305.3274150.
38. Razafimandimby C, Loscri V, Vegni AM. Towards efficient deployment in Internet of Robotic Things. In: Gravina R, Palau C, Manso M, *et al.* (editors). Integration, Interconnection, And Interoperability of IoT systems. Cham: Springer; 2018. p. 21–37. doi: 10.1007/978-3-319-61300-0_2.
39. Katona J, Ujbanyi T, Sziladi G, Kovari A. Electroencephalogram-based brain-computer interface for internet of robotic things. In: Klempous R, Nikodem J, Baranyi P (editors). Cognitive Infocommunications, Theory and Applications. Topics in Intelligent Engineering and Informatics, vol 13. Cham: Springer; 2019. p. 253–275.
40. Guntur SR, Gorrepati RR, Dirisala VR. Robotics in healthcare: An Internet of Medical Robotic Things (IoMRT) perspective. Machine Learning in Bio-Signal Analysis and Diagnostic Imaging 2019: 293–318.
41. UNDP. Disaster management in India [Internet]. New York: United Nations Development Programme; 2012. Available from: https://www.undp.org/india/publications/disaster-management-india-0.
42. Bag S. Amphan: Kolkata devastated as cyclone kills scores in India and Bangladesh [Internet]. London: BBC.com; 2020. Available from: https://www.bbc.com/news/world-asia-india-52749935.
43. Slater J. Cyclone Amphan kills more than 85 in India and Bangladesh [Internet]. Washington, D.C.: The Washington Post; 2020. Available from: https://www.washingtonpost.com/world/asia_pacific/cyclone-amphan-india-bangladesh-death-toll/2020/05/21/ddc506c6-9ad6-11ea-ad79-eef7cd734641_story.html.
44. EM-DAT. CRED/UC Louvain, Brussels, Belgium [Internet]. Brussels: Centre for Research on the Epidemiology of Disasters (CRED); 2020. Available from: https://public.emdat.be/data.
45. MoHFW. National health profile 2019 14th Issue. Delhi: Central Bureau of Health Intelligence; 2019.
46. HSS.gov. About the strategic national stockpile [Internet]. Washington, D.C.: U.S. Department of Health and Human Services; 2020. Available from: https://www.phe.gov/about/sns/Pages/about.aspx.
47. Press Information Bureau. Hospitals in the country [Internet]. Delhi: PIB Delhi; 2018. Available from: https://pib.gov.in/PressReleasePage.aspx?PRID=1539877.
48. Pingle S. Helping our healthcare workers [Internet]. Chennai: New Indian Express; 2020. Available from: https://www.newindianexpress.com/opinions/2020/apr/13/helping-our-healthcare-workers-2129255.html.
49. Sepkowitz KA, Eisenberg L. Occupational deaths among healthcare workers. Emerging Infectious Diseases 2005; 11(7): 1003.

doi: 10.3201/eid1107.041038.

50. PTI. Doctor-patient ratio in India less than WHO-prescribed norm of 1:1000: Govt [Internet]. Noida: ETHealthWorld.com; 2019. Available from: https://health.economictimes.indiatimes.com/news/industry/doctor-patient-ratio-in-india-less-than-who-prescribed-norm-of-11000-govt/72135237.
51. PTI. India facing shortage of 600,000 doctors, 2 million nurses: Study [Internet]. New Delhi: The Economic Times; 2019. Available from: https://economictimes.indiatimes.com/industry/healthcare/biotech/healthcare/for-third-day-in-a-row-daily-new-covid-infections-remain-below-50000-mark/articleshow/79146945.cms.
52. Chakrabarty A, Norbu T, Mall M. Fourth Industrial Revolution: Progression, scope and preparedness in India—Intervention of MSMEs. In: Solanki V, Hoang M, Lu Z, Pattnaik P (editors). Intelligent Computing in Engineering. Advances in Intelligent Systems and Computing, vol 1125. Singapore: Springer; 2020. p. 221–228. doi: 10.1007/978-981-15-2780-7_26.
53. Adhikary T, Jana AD, Chakrabarty A, Jana SK. The Internet of Things (IoT) augmentation in healthcare: An application analytics. In: Gunjan V, Garcia Diaz V, Cardona M, *et al.* (editors). ICICCT 2019 – System reliability, quality control, safety, maintenance and management. ICICCT 2019. Singapore: Springer. p. 576–583. doi: 10.1007/978-981-13-8461-5_66.
54. Chakrabarty A, Das US. Dynamics of knowledge management in 4IR through HR interventions: Conceptual framework. In: Peng SL, Son LH, Suseendran G, Balaganesh D (editors). Intelligent Computing and Innovation on Data Science. Lecture Notes in Networks and Systems, vol 118. Singapore: Springer; 2020. p. 695–704. doi: 10.1007/978-981-15-3284-9_75.
55. BostonDynamics. ROBOTS [Internet]. BostonDynamics; 2020. Available from: https://www.bostondynamics.com/robots.
56. Ackerman E. Russian humanoid robot to Pilot Soyuz Capsule to ISS this week: Skybot F-850 will spend a week on the ISS charming astronauts with its sense of humor [Internet]. New York: IEEE; 2019. Available from: https://spectrum.ieee.org/automaton/robotics/space-robots/russian-humanoid-robot-to-pilot-soyuz-capsule-to-iss-this-week.
57. Toyota. Toyota unveils third generation humanoid robot T-HR3 [Internet]. Plano, TX: Toyota; 2017. Available from: https://global.toyota/en/detail/19666346.
58. Gao L, Li J, Wang Y, Li Y. IoT and artificial intelligence based emergency management system in epidemic. Journal of Medical Systems 2021; 45(10): 1–12.
59. Erturk VB, Celebioglu E, Yuksel ME. Development of an intelligent disaster management system based on the Internet of Medical Robotic Things. Disaster Medicine and Public Health Preparedness 2021; 15(3): e9–e13.
60. Chen K, Huang S, Wu Q. An intelligent hospital logistics system based on the Internet of Medical Robotic Things. Journal of Medical Systems 2021; 45(9): 1–10.
61. Kaul M, Murthy YLN, Bhattacharya S. Internet of Robotic Things: A study on IoT and robotics for remote healthcare monitoring. Journal of Ambient Intelligence and Humanized Computing 2021; 12(5): 5295–5311.
62. Khan MR, Hossain MS, Rahman MA, Chowdhury MMH. Telemedicine using IoT and artificial intelligence in rural areas of developing countries: A review. Journal of Ambient Intelligence and Humanized Computing 2021; 12(11): 138.