Industry 4.0 technologies and their applications in fighting COVID-19 pandemic

Mohd Javaid [a], Abid Haleem [a], Raju Vaishya [b], Shashi Bahl [c, *], Rajiv Suman [d], Abhishek Vaish [e]

[a] Department of Mechanical Engineering, Jamia Millia Islamia, New Delhi, India
[b] Department of Orthopaedics, Indraprastha Apollo Hospital, SaritaVihar Mathura Road, 110076, New Delhi, India
[c] Department of Mechanical Engineering, I. K. Gujral Punjab Technical University Hoshiarpur Campus, Hoshiarpur, Punjab, India
[d] Department of Industrial & Production Engineering, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India
[e] Department of Orthopaedics, Indraprastha Apollo Hospital, SaritaVihar, Mathura Road, 110076, New Delhi, India

ARTICLE INFO

ABSTRACT

Background and aims: COVID 19 (Coronavirus) pandemic has created surge demand for essential healthcare equipment, medicines along with the requirement for advance information technologies applications. Industry 4.0 is known as the fourth industrial revolution, which has the potential to fulfil customised requirement during COVID-19 crisis. This revolution has started with the applications of advance manufacturing and digital information technologies.
Methods: A detailed review of the literature is done on the technologies of Industry 4.0 and their applications in the COVID-19 pandemic, using appropriate search words on the databases of PubMed, SCOPUS, Google Scholar and Research Gate.
Results: We found several useful technologies of Industry 4.0 which help for proper control and management of COVID-19 pandemic and these have been discussed in this paper. The available technologies of Industry 4.0 could also help the detection and diagnosis of COVID-19 and other related problems and symptoms.
Conclusions: Industry 4.0 can fulfil the requirements of customised face masks, gloves, and collect information for healthcare systems for proper controlling and treating of COVID-19 patients. We have discussed ten major technologies of Industry 4.0 which help to solve the problems of this virus. It is useful to provide day to day update of an infected patient, area-wise, age-wise and state-wise with proper surveillance systems. We also believe that the proper implementation of these technologies would help to enhance education and communication regarding public health. These Industry 4.0 technologies could provide a lot of innovative ideas and solution for fighting local and global medical emergencies.

© 2020 Diabetes India. Published by Elsevier Ltd. All rights reserved.

1. Introduction

COVID 19 (Coronavirus) pandemic has affected almost all countries and has made a significant effect on the available healthcare facilities and treatment systems. There is a requirement for the introduction of various advance technologies to tackle various problems related to this viral pandemic. Industry 4.0 is also known as the fourth industrial revolution, which consists of advance manufacturing and information technologies, to fulfil the customised requirement of different areas of the human being in lesser time. These technologies provide wireless connectivity in the manufacturing and service sector to enhance automation. In the

* Corresponding author.
E-mail addresses: mohdjavaid0786@gmail.com (M. Javaid), haleem.abid@gmail.com (A. Haleem), raju.vaishya@gmail.com (R. Vaishya), bahl.ptu2010@gmail.com (S. Bahl), raje.suman@gmail.com (R. Suman), dradhishekvaish@gmail.com (A. Vaish).
URL: https://www.researchgate.net/profile/Abhishek_Vaish5
https://scholar.google.co.in/citations?user=rfyiwvsAAAAJ&hl=en (M. Javaid), https://scholar.google.co.in/citations?user=4047148AAAAJ&hl=en (A. Haleem), https://scholar.google.co.in/citations?user=2Lu3gQ0AAAAJ&hl=en (R. Vaishya), https://scholar.google.co.in/citations?user=A3tEW98AAAAJ&hl=en (R. Suman)

fully implemented scenario of Industry 4.0, we see all these technologies are connected, and medical stakeholders communicate with each other for manufacturing and use of the vaccine, healthcare equipment & logistics, checkup, surveillance, detection and deciding necessary actions with lesser human physical involvement. The proper updates on the gathering of people are provided by the data captured by the advance technologies [1,2].

Industry 4.0 factories have machines which are supported by wireless connectivity and sensors. These sensors are connected to a system that can visualise and monitor the entire production line and can also make its own decisions. Industry 4.0 uses smart manufacturing processes for the manufacturing of essential disposable items to fulfil the shortage of COVID-19 pandemic. It provides a smart supply chain of medical disposables and equipment during this crisis by which the patients can receive the required essential medical items, in time [3,4].

Industry 4.0 is a smart system, used as a flexible production line for almost entire production processes real-time information provided by Artificial intelligence (AI), Internet of Things (IoT) and other digital technologies. Designing and development of any medical part are done rapidly using advance designing software and further used digital manufacturing technologies like 3D printing to print the required parts [5,6].

We have aimed to confirm the utility and applications of Industry 4.0 technologies for the management of COVID-19 pandemic, in this comprehensive review.

2. Significant benefits of Industry 4.0 technologies for COVID-19

Industry 4.0 technologies have the capability of providing better digital solutions for our daily lives during this crisis [7–9]. Various benefits of Industry 4.0 technologies, as being envisaged by us for mitigating effects of COVID-19 pandemic are as under:

- Planning of activities regarding COVID-19
- Providing a better experience without imposing the risks to healthcare and other workers
- Manufacturing of precautionary item related to this virus
- Provide medical part in time using smart supply chain
- Used robotic based treatment of the infected patient to reduce doctors risk
- Used virtual reality for training purpose
- Promote a flexible working environment of treatment
- These digital technologies help people to perform daily life work during the lockdown
- Provides several innovations with the help of advance manufacturing and digital technologies
- Researchers can employ these technologies for social and media platforms to identify unusual information
- Used for better risk assessment and global public health emergency of this virus [10,11].

3. Industry 4.0 technologies for remote areas

Advance digital technologies provide telemedicine service for proper preventive and control of this virus. These technologies detect any abnormality regarding the patient and immediately contact medical staff during an emergency. The remote health monitoring system is done quickly by these technologies [12,13]. Sensors are used to sense physiological data and provide useful information to the patients and doctors. The applications of advance digital technologies are applied to create better exposure and innovative solution for the treatment of COVID-19 patient.

Digital technologies are helpful for distance education, remote and online learning during the emerging of COVID-19 pandemic. These provide available relevant information to share guidance and documentation. During the lockdown, these technologies are helpful for teaching and learning process in remote areas [14,15]. These provide digital and multiple sources for open educational resources.

4. Significant technologies of Industry 4.0 which may help in COVID 19 outbreaks

Industry 4.0 technologies detect the symptoms of COVID-19, which helps to avoid any confusion regarding this disease and can also predict the chances of acquiring the disease. It helps track potential health problems and expected chances of recovery. Table 1 discusses the significant technologies of Industry 4.0, which may help in COVID 19 outbreaks [16–24].

AI-based video surveillance has a high capability to reduce the workload of doctors and hospital managers during this crisis. This is useful to observe the activities of the patient affected by this virus. Industry 4.0 technologies improve the working efficiency of a healthcare professional and provide a better solution. The applications of these technologies are used to learn about COVID-19 [25–31]. Lot of misinformation on COVID-19 is fed to masses through various technological platforms, so there is a requirement to identify misinformation & misinformants and then provide exact information. Digital technologies of industry 4.0 show superior capabilities to detect the misinformation [32–35].

We have analysed, pooled and suggested the capabilities of various Industry 4.0 technologies applications in the management of COVID-19 pandemic. Such consolidated information was not yet available in the literature. This comprehensive review would help the healthcare administrators and researchers to combat such pandemics and epidemics using these technologies effectively, presently and in future also.

5. Future scope

In future, Industry 4.0 technologies will be applicable to store sensitive data of our health care system that can be used for another similar pandemic like COVID-19. This revolution could rapidly be adopted by the professional, doctors, staff which can influence the treatment line of COVID-19 and other similar pandemics or epidemics. It can be used to centralize all medical tools, devices and treatment process. In future, the medical industry would grow and has to adapt to digital technologies to create smart healthcare system and hence there is a need to change the software platform software devices to the latest ones. This revolution provides disruptive innovation to minimise the effect of COVID-19 virus.

6. Conclusion

Industry 4.0 provides an automatic solution to various manufacturing industries and other related areas. This consists of various manufacturing and digital information technologies to collect, transfer, store, analyse and proper monitor information system. Digital technologies provide an innovative method for the proper isolation of the infected patient to reduce the high risk of mortality, speeding up the drug manufacturing, treatment process and care. By the application of these technologies, people are working from home; they are discovering a new office culture, work timings, virtual offices, virtual meetings, and extensive written communications. Industry 4.0 has the capability of remote operation using smart technologies which is helpful for COVID- 19 outbreak. This revolution speeds up the digital transformation with

Table 1
Significant technologies of Industry 4.0 which may help in COVID 19 outbreaks.

S No	Technology	Description of technology	How is it helpful?
1.	Artificial intelligence	Artificial intelligence is a powerful tool which can be very useful against the pandemic of COVID 19 regarding the assessment of risks of infection and screening of population. It is an application similar to machine learning, computer vision and natural language processing which can instruct computers to use models based on big data for recognising, explaining and predicting the pattern. Today, there is restricted use of this technology as there is lack of data. Sometimes the available data is very noisy and outlier.	AI can predict the outbreak and can also minimise or even stall the spread of the virus. The wrong information present on the social platforms related to COVID 19 can be detected and removed subsequently with the application of AI. The clinical trials for drugs and vaccines against this virus can be optimised with the use of AI. It can be used to develop robots, which can help undertake sanitisation jobs and perform an online medical examination of the people. This technology can produce CT scans which are required for detecting pneumonia caused by a virus. The application of this technology is beneficial to manufacture the equipment required for the healthcare system.
2.	Internet of Things	Internet of Things is an automated solution that has resulted in tremendous growth in automated manufacturing, management of assets etc. It comprises of collection, transfer, analytics and storage of data. Collection of data is done with the help of sensors incorporated in mobile phones, robots etc. The data collected is then sent for analytics and decision making to the central cloud server.	IoT is proving to be very helpful in the fight against COVID-19. For instance, drones are in use for surveillance in order to ensure the implementation of quarantine and mask-wearing. This technology can be used for tracing the origin of an outbreak. It can be helpful to the epidemiologists for searching patient zero and also in identifying the persons coming in contact with the patients. The compliance of quarantine by the patients can be ensured. The patients who breach the quarantine can be tracked down. Moreover, this technology can be beneficial in providing relief to the medical staff by remote monitoring of in-home patients.
3.	Big data	Big data is an analytic technique which is very much suitable to track and control the worldwide spread of the disease COVID 19. This technology can store a large amount of patient infected by this virus. This technology provides the basis for a faster and almost real-time evaluation of decision making. It will help save the lives of the people and quickly identifying effective therapies.	Big data can be highly useful for analysing and forecasting the reach and impact of the coronavirus on people. The COVID-19 trackers can collect the almost real-time data from sources around the world and subsequently equip the scientists, doctors, epidemiologists and policymakers with the latest information which can be very helpful to make better decisions in order to fight against the virus.
4.	Virtual reality	Virtual reality (VR) is a digital technology that provides a simulated experience which is almost same or different from the working world. Its applications include video games, 3D games, educational training, medical training, military training etc. The environment provided by this technology presents the benefits of great comfort, creativity and productivity. People can work together in real-time through intuitive whiteboards, the simulations can be visited, and the content can be recorded.	In the times of COVID-19 outbreak, the technology of virtual reality offers a great option to video calls. The most significant benefit of this medium is its ability to make people feel like they are together in the same space without the need for travelling. The extra benefit is that people can entirely focus on the task in hand without any distractions at all. VR improves efficiency, upgrades the working in a group, reduce the travel costs, reduce the absenteeism and lowers the impact of the environment. So, in this time of COVID-19 disease, VR has been an excellent tool for communication and collaboration.
5.	Holography	Holography is 3D photography. It presents 3D views with changing perspectives. It is a contrast to the photography; it records both the phase and the complex amplitude of the wave which comes from the object. The record is called the hologram. It is like a window which has memory. The hologram can reconstruct an accurate 3D image of the original object. It provides corporations with an alternative to virtualise their events without the need for webcasting. With the use of this, The businesses can launch products, add new clients and build their brands.	The digital technology of holography has paved a new way to conduct conferences and live events. It ensures the reduced exposure of the speakers, employees and clients to COVID-19. It feels like speakers are live from their homes or offices virtually on a real event stage regarding COVID-19. Thousands of people can attend this live streaming at the same time. Holography has now the ability to offer ultra-realism. In this time of COVID 19 outbreak, when the workers are bound to stay at home, this technology of streaming holographic events is becoming readily acceptable.
6.	Cloud computing	Cloud computing is a digital technology which involves the delivery of computer system resources over the internet such as servers, storage, databases, networking, intelligence etc. This technology provides faster innovation and resources which are flexible. It results in reduced operating cost and increased efficiency of running the infrastructure.	In the present times of social isolation amid COVID-19 outbreak, people have been able to continue their digital lives with the help of applications like Zoom video, Slack, Netflix through services such as Amazon Web Services, Microsoft Azure and Google Cloud. Cloud computing can be helpful to fight against COVID-19 in several ways. For instance, introduced especially designed Salesforce Care solution for healthcare providers who receive a large number of requests due to COVID-19.
7.	Autonomous robot	An autonomous robot is used to carry out the tasks without the influence of any external agency. It can be employed to collect information about the environment. It can be used for a very long period without help. It is considered as a sub technology of robotics and artificial intelligence. It can ignore the situations which may be dangerous for human beings.	During the present times of lockdown in COVID-19 pandemic, an autonomous police robot can be deployed for patrolling the areas to confirm that the people are following the orders of lockdown. The autonomous police robots may also be deployed in the hospitals in order to help the medical staff to perform their duties without any disruption. It can be very helpful to enhance the performance of the medical staff and in turn, to contain the spread of the COVID-19.
8.	3D Scanning	3D scanning is used to convert the physical part in CAD digital data. This technology is successful for the reverse engineering processes. In medical, this technology is used for scanning the human body and its part as per precise dimension. 3D scanning output is used for the analysis of real-world object for collecting data about its shape and appearance. The 3D model can then be constructed with the use of collected data. This data can be used for a large number of applications. 3D scanners are also useful in developing video games and movies.	3D scanning is a non-contact technique which helps the thoracic chest scanning for COVID-19. Also, a useful tool to detect and quantify COVID 19 virus. Virtual reality, motion capture, robotic mapping and industrial design are some of the other applications of this technology.
9.	3D Printing	3D printing is already emerging in the medical field for the manufacturing of customised part from the input of CAD digital file. This can quickly revise the previous version of the product in lesser time and cost. It helps in the design and development of ventilator parts as per the required shortage. Thus, fulfils the need of the global supply chain by manufacturing required precaution parts.	3D printing technology can be used in some critical applications to contain the spread of COVID-19 disease. A face mask to be produced with the use of this technology is already under development. This face mask can be employed to test a large number of persons for COVID-19 in 30 min. The use of surgical masks and N95 respirators is not suitable for the environment, and it can prove to be detrimental to the ecosystem. On the other side, it is claimed that the newly developed NanoHack 3D-printed mask is recyclable and can be reused.

Table 1 (*continued*)

S No	Technology	Description of technology	How is it helpful?
10	Biosensor	Biosensors are used for the conversion of the biological signal into an electrical signal. Some of the essential types of biosensors are optical, thermal, piezoelectric and electrochemical biosensors. They find applications in a wide variety of fields such as medical science, food industry, marine sector etc. They are stable and sensitive. In the case of biological wars, the biosensors can be employed for the support of the military. This technology of biosensor, which is entirely new to the market used effectively as a wireless device in an environment of the multi-patient hospital.	In the present time of pandemic COVID-19, the biosensors are capable of providing the devices which can be easy to employ, sensitive, cost-saving and can provide high accuracy. Glucose monitor is a perfect example of the biosensor which is used in clinical analysis and diagnosis of the disease. A single-use wireless biosensor patch 1AX is under development. This biosensor patch can be employed for the early detection and then the monitoring of the symptoms of COVD-19. The real-time recording of the temperature, ECG trace, respiration rate etc. will be performed by this patch.

better crowd management, transportation management and safety of the public. These digital technologies create virtual clinic through the application of telemedicine consultations. So, there will be a reduction in physical crowding of the patients in the hospitals and clinics. These technologies track the record of the patient and prevent the patient from unnecessary hospital consultations.

Declaration of competing interest

None.

References

[1] Javaid M, Haleem A. Industry 4.0 applications in medical field: a brief review. Curr. Med. Res. Pract. 2019;9(3):102—9.
[2] Ienca M, Vayena E. On the responsible use of digital data to tackle the COVID-19 pandemic. Nat Med 2020 Mar 27:1—2.
[3] Zeng J, Huang J, Pan L. How to balance acute myocardial infarction and COVID-19: the protocols from Sichuan Provincial People's Hospital. Intensive Care Med 2020 Mar 11:1—3.
[4] Manogaran G, Thota C, Lopez D, Sundarasekar R. Big data security intelligence for healthcare industry 4.0. Cyber security for Industry, 4.0. Cham: Springer; 2017. p. 103—26.
[5] Ruan Q, Yang K, Wang W, Jiang L, Song J. Clinical predictors of mortality due to COVID-19 based on an analysis of data of 150 patients from Wuhan, China. Intensive Care Med 2020 Mar 3:1—3.
[6] Haleem A, Javaid M, Vaishya R. Industry 4.0 and its applications in orthopaedics. J Clin Orthop Trauma 2019;10(3):615—6.
[7] Cheng GJ, Liu LT, Qiang XJ, Liu Y. Industry 4.0 development and application of intelligent manufacturing. In2016 international conference on information system and artificial intelligence (ISAI) 2016 Jun 24 (pp. 407-410). IEEE.
[8] Grasselli G, Pesenti A, Cecconi M. Critical care utilisation for the COVID-19 outbreak in Lombardy, Italy: early experience and forecast during an emergency response. Jama 2020 Mar 13.
[9] Ahmed SF, Quadeer AA, McKay MR. Preliminary identification of potential vaccine targets for the COVID-19 coronavirus (SARS-CoV-2) based on SARS-CoV immunological studies. Viruses 2020 Mar;12(3):254.
[10] Haleem A, Javaid M. Additive manufacturing applications in industry 4.0: a review. J. Ind. Integat. Manag. 2019. https://doi.org/10.1142/S2424862219300011.
[11] Ren JL, Zhang AH, Wang XJ. Traditional Chinese medicine for COVID-19 treatment. Pharmacol Res 2020 Mar 4:104743.
[12] Alloghani M, Al-Jumeily D, Hussain A, Aljaaf AJ, Mustafina J, Petrov E. Healthcare services innovations based on the state of the art technology trend industry 4.0. In2018 11th international conference on developments in eSystems engineering (DeSE). 2018 Sep 2. p. 64—70.
[13] Haleem A, Javaid M, Vaishya. Effects of COVID 19 pandemic in daily life. Curr. Med. Res. Pract. 2020. https://doi.org/10.1016/j.cmrp.2020.03.011.
[14] Fisher D, Wilder-Smith A. The global community needs to swiftly ramp up the response to contain COVID-19. Lancet (London, England) 2020 Apr 4;395(10230):1109.
[15] Li Q, Feng W, Quan YH. Trend and forecasting of the COVID-19 outbreak in China. J Infect 2020 Apr 1;80(4):469—96.
[16] No IZADP, Naudé W. DISCUSSION PAPER SERIES artificial intelligence against COVID-19. An Early REv. 2020:13110.
[17] Petropoulos Georgios. Artificial intelligence in the fight against COVID-19 [Internet]. Available from: https://www.bruegel.org/2020/03/artificial-intelligence-in-the-fight-against-covid-19/.
[18] Bean Randy. Big data in the time of coronavirus (COVID-19). CIO Netw [Internet]. Available from: https://www.forbes.com/sites/ciocentral/2020/03/30/big-data-in-the-time-of-coronavirus-covid-19/#161ff87558fc.
[19] He S. Using the Internet of Things to fight virus outbreaks [Internet]. Available from: https://www.technologynetworks.com/immunology/articles/using-the-internet-of-things-to-fight-virus-outbreaks-331992.
[20] Dialani P. HOW VIRTUAL REALITY IS HELPING TO DEAL WITH COVID-19 [internet]. 2020. Available from: https://www.analyticsinsight.net/virtual-reality-helping-deal-covid-19/.
[21] Microscopy E, Fields M, Micro- E, Beams E, Boone PM. NDT Techniques : laser-based electron holography in phase space. 2001. 1995.
[22] Irvine C. New holographic virtual events will reach millions amid coronavirus (COVID-19) crisis [internet]. DVEholographics. Available from: https://www.prnewswire.com/news-releases/new-holographic-virtual-events-will-reach-millions-amid-coronavirus-covid-19-crisis-301025496.html.
[23] What is cloud computing? [Internet]. Available from: https://azure.microsoft.com/en-in/overview/what-is-cloud-computing/.
[24] Lawrence C. Is cloud computing the superhero of covid-19?. Dev Hub [Internet]. 2020 Mar; Available from: https://www.codemotion.com/magazine/dev-hub/cloud-manager/cloud-computing-covid-19/.
[25] Moeslund TB, Granum E. A survey of computer vision-based human motion capture. Comput Vis Image Understand 2001;81(3):231—68.
[26] Wand M, Adams B, Ovsjanikov M, Berner A, Bokeloh M, Jenke P, et al. Efficient reconstruction of nonrigid shape and motion from real-time 3D scanner data. ACM Trans Graph 2009;28(2).
[27] Sampol C. Covid-19: developing high tech protective masks [Internet]. Medical Expo e-mag. 2020. Available from: http://emag.medicalexpo.com/covid-19-development-of-high-tech-protective-masks/.
[28] Kim P, Chen J, Cho YK. SLAM-driven robotic mapping and registration of 3D point clouds. Autom ConStruct 2018;89(May):38—48.
[29] Pejcic B, De Marco R, Parkinson G. The role of biosensors in the detection of emerging infectious diseases. Analyst [Internet] 2006;131(10):1079—90. https://doi.org/10.1039/B603402K. Available from:.
[30] Patch for detection and monitoring of COVID-19 symptoms fast tracked [internet]. Med-Tech Innovation/News; 2020. Available from: https://www.med-technews.com/news/patch-for-detection-and-monitoring-of-covid-19-testing-fast-/.
[31] Ren JL, Zhang AH, Wang XJ. Traditional Chinese medicine for COVID-19 treatment. Pharmacol Res 2020 Mar 4:104743.
[32] Baldwin R, Tomiura E. Thinking ahead about the trade impact of COVID-19. Economics in the time of COVID-19. 2020. p. 59.
[33] Haleem A, Javaid M, Vaishya R, Deshmukh SG. Areas of academic research with the impact of COVID-19. AJEM (Am J Emerg Med) 2020. https://doi.org/10.1016/j.ajem.2020.04.022.
[34] Gupta R, Misra A. Contentious issues and evolving concepts in the clinical presentation and management of patients with COVID-19 infection with reference to use of therapeutic and other drugs used in Co-morbid diseases (hypertension, diabetes etc.). Diabetes & metabolic syndrome. Clin Res Rev 2020;14(3):251—4.
[35] Gupta R, Ghosh A, Singh AK, Misra A. Clinical considerations for patients with diabetes in times of COVID-19 epidemic. Diabetes & Metabolic Syndrome. Clin Res Rev 2020;14(3):211—2.