State-of-the-Art Robotic Technologies in Fighting the COVID-19 Pandemic

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Article

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Abstract: The COVID-19 pandemic has posed unprecedented challenges to global healthcare systems, necessitating rapid innovation in healthcare delivery methods. State-of-the-art robotic technologies have emerged as vital tools in combating the spread of the virus and mitigating its impact on healthcare systems. This paper explores the role of advanced robotics in pandemic response, focusing on key areas such as disinfection, telemedicine, delivery systems, and patient care. Robots equipped with ultraviolet (UV) light, autonomous vehicles, and drones have demonstrated significant effectiveness in sanitizing high-traffic areas, delivering essential supplies, and reducing human contact, thereby minimizing virus transmission. Additionally, robotic systems have facilitated remote healthcare services through telepresence robots, enabling healthcare providers to monitor patients and offer consultation without physical interaction. The integration of artificial intelligence and machine learning in robotic systems has further enhanced their adaptability, enabling real-time decision-making and personalized care. This study provides an overview of the advancements in robotic technologies, their application in healthcare settings, and their potential for long-term benefits in pandemic preparedness and response. Challenges in implementation, ethical considerations, and future directions are also discussed to highlight the evolving role of robotics in healthcare innovation.

Keywords: robotic technologies; COVID-19 pandemic; healthcare robotics; disinfection robots; delivery robots; telepresence robots; robotic surgery; autonomous navigation

1. Introduction

A. Overview of the COVID-19 Pandemic

The COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, has rapidly spread across the globe, leading to severe public health and economic disruptions. Initially detected in Wuhan, China in late 2019, the virus quickly became a global health emergency, overwhelming healthcare systems, straining resources, and leading to widespread social and economic consequences. The pandemic's rapid escalation highlighted the critical need for innovative solutions to contain the virus, protect frontline healthcare workers, and support patients during treatment.

B. The Role of Technology in Pandemic Response

In response to the pandemic, technology played an essential role in mitigating the effects of COVID-19. From contact tracing apps to telehealth platforms, technology was leveraged to support both the containment of the virus and the management of public health systems. Automation, artificial intelligence, and robotics emerged as central technologies in addressing various pandemic-related challenges, from diagnosing and monitoring patients to reducing human-to-human contact and ensuring the continuous delivery of essential services.

C. Importance of Robotics in Healthcare

Robotics, a field encompassing automated machines designed to perform tasks traditionally carried out by humans, has proven indispensable in pandemic response. Robotic technologies help mitigate the risks associated with direct human contact, enhance healthcare efficiency, and enable the performance of tasks in environments where human intervention may not be feasible or safe. In the

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context of COVID-19, robots have been utilized in areas such as disinfection, supply delivery, patient monitoring, and telemedicine. Their ability to operate autonomously or remotely has made them invaluable in maintaining essential services while reducing the risk of virus transmission.

D. Scope of the Paper

This paper aims to explore the state-of-the-art robotic technologies that have been employed in the fight against the COVID-19 pandemic. It will review the various applications of robotics in healthcare, emphasizing their role in patient care, disinfection, delivery, and telemedicine. Additionally, the paper will address the technological innovations, challenges in adoption, and future implications for the continued use of robotics in healthcare settings. By focusing on the intersection of robotics and pandemic response, this paper seeks to provide insights into how robotic technologies can enhance preparedness for future global health crises.

2. Robotic Applications in Healthcare During COVID-19

A. Disinfection Robots

Disinfection robots have become critical in healthcare settings during the COVID-19 pandemic, where sanitation and cleanliness are paramount in preventing the spread of the virus. These robots are equipped with ultraviolet (UV) light or other advanced disinfecting mechanisms to sanitize surfaces, equipment, and environments. UV-C light, known for its germicidal properties, has been widely used by autonomous robots to disinfect high-traffic areas in hospitals, clinics, and public spaces. The advantage of robotic disinfection is its ability to perform cleaning tasks without human intervention, minimizing the risk of exposure to the virus for healthcare workers and patients. Studies have shown that UV-based robotic systems can effectively reduce the viral load on surfaces, contributing to a safer environment for both staff and patients.

B. Delivery Robots

Delivery robots have been increasingly utilized in healthcare facilities and hospitals to transport medications, food, and medical supplies. These autonomous robots are designed to navigate through hospitals and other public spaces, delivering critical items while reducing the need for human contact. By automating these delivery tasks, these robots help minimize the risk of COVID-19 transmission between patients and healthcare providers, ensuring that essential items are delivered efficiently and safely. Delivery robots also help alleviate the burden on hospital staff by taking over routine logistical tasks, allowing them to focus on direct patient care. Drones, as an extension of this technology, have been used in certain regions to deliver medicines and supplies to remote areas, further expanding the reach of robotic delivery solutions.

C. Telepresence Robots

Telepresence robots have gained significant attention as tools for enabling remote communication and healthcare monitoring. These robots, equipped with video conferencing systems, allow healthcare providers to interact with patients and colleagues from a distance, reducing the need for in-person consultations and minimizing exposure to the virus. In COVID-19 wards, where minimizing human contact is critical, telepresence robots have facilitated remote doctor-patient interactions, enabling real-time consultations and check-ups without compromising the safety of healthcare workers. These robots also support virtual rounds and interdisciplinary team meetings, allowing healthcare providers to collaborate effectively while maintaining social distancing guidelines. The adoption of telepresence robots during the pandemic has highlighted their potential for reshaping the future of healthcare delivery, offering patients and providers greater flexibility in managing care.

D. Robotic Surgery and Diagnostics

Robotic surgery systems have become instrumental in ensuring that non-COVID-19 medical procedures continue without delays during the pandemic. By enabling remote control of surgical tools, these systems allow for precise, minimally invasive procedures that reduce patient recovery times and limit the exposure of medical staff to potentially infectious environments. The ability to perform surgeries remotely also reduces the need for medical teams to be physically present in high-

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risk areas, further decreasing their potential exposure to the virus. In addition to surgery, robotic systems have supported diagnostics by automating tests and data collection, streamlining processes, and minimizing human error. These innovations not only helped manage COVID-19 cases more efficiently but also ensured the continuation of essential medical services during a period of increased healthcare demand.

E. Social Monitoring and Surveillance Robots

Social monitoring and surveillance robots have been deployed in public spaces to help monitor and enforce social distancing measures, a critical aspect of controlling the spread of COVID-19. These robots use sensors and cameras to detect and monitor crowd sizes, individual movement patterns, and compliance with public health guidelines. In hospitals and other healthcare settings, robots equipped with thermal imaging systems have been used to detect fever in individuals, an early symptom of COVID-19. Surveillance robots are also used in public areas such as airports, train stations, and shopping malls to assist in monitoring compliance with mask-wearing and other safety protocols. By automating the surveillance process, these robots help reduce the need for human oversight, thereby limiting potential exposure to the virus and ensuring public health measures are followed effectively. Additionally, their integration with AI systems allows for real-time analysis, providing actionable insights to healthcare officials and policymakers.

These robotic applications have not only played a crucial role in the immediate response to the COVID-19 pandemic but have also shown potential for long-term transformation in healthcare delivery. The rapid development and deployment of these technologies underscore the significant role that robotics can play in enhancing healthcare systems' resilience and efficiency.

3. Key Technologies Behind COVID-19 Robotic Solutions

A. Artificial Intelligence and Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) have been foundational in enhancing the capabilities of robots deployed during the COVID-19 pandemic. AI algorithms enable robots to process vast amounts of data, make decisions in real-time, and adapt to dynamic environments. In healthcare robotics, AI has been used to improve task automation, such as recognizing patterns in medical imaging, detecting anomalies, and making predictions based on patient data. Machine learning further refines these capabilities by enabling robots to learn from their experiences, continuously improving their performance and decision-making. For example, AI-powered diagnostic robots can assist healthcare providers in interpreting medical scans or monitoring patient conditions based on real-time data inputs. In disinfection and delivery robots, AI allows for object recognition, obstacle avoidance, and navigation, ensuring smooth and safe operation in complex environments like hospitals.

B. Autonomous Navigation and Mapping

Autonomous navigation and mapping technologies have been crucial in allowing robots to perform their tasks independently in environments such as hospitals, public spaces, and remote areas. These technologies rely on a combination of sensors (such as LIDAR, ultrasonic sensors, and cameras) and algorithms to allow robots to map their surroundings, identify obstacles, and navigate efficiently without human intervention. In the case of delivery robots, for instance, they autonomously navigate through hospital corridors to transport medications or medical supplies to specific locations, avoiding people, walls, and furniture along the way. These robots can update their maps dynamically in response to changes in the environment, ensuring that they remain adaptable and capable of operating in ever-changing situations. The ability to autonomously map and navigate spaces is vital for the efficient and safe deployment of robots in healthcare settings, minimizing risks and improving operational efficiency.

C. Internet of Things (IoT) Integration

The integration of the Internet of Things (IoT) with robotics has revolutionized healthcare delivery during the COVID-19 pandemic. IoT-enabled robots can communicate with other devices and systems, creating a networked ecosystem that enhances their functionality and performance. For

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example, IoT sensors embedded in robots can collect real-time data on environmental conditions (such as air quality or temperature), patient health metrics, or the status of medical equipment. This data can be analyzed in real time, enabling healthcare providers to make informed decisions remotely. IoT integration also allows robots to interface with other hospital systems, such as patient management software, inventory systems, or remote monitoring platforms, ensuring that all stakeholders are informed and can respond promptly to emerging needs. In addition, IoT-enabled robots can be remotely monitored and updated, allowing for proactive maintenance and ensuring continuous operation without downtime.

D. Robotic Process Automation (RPA)

Robotic Process Automation (RPA) involves the use of software robots or "bots" to automate routine tasks that are typically performed by humans. During the COVID-19 pandemic, RPA has been applied to automate administrative, logistical, and repetitive processes, which helped alleviate the strain on healthcare professionals and other essential workers. For example, RPA has been used in hospitals to automate the processing of patient data, scheduling, and billing, freeing up human staff to focus on more complex tasks. In the context of robotic solutions, RPA can also be applied to automate processes such as the deployment of disinfection robots, monitoring robots, or telepresence systems, allowing them to operate without the need for manual intervention. RPA's efficiency in performing repetitive and rule-based tasks makes it an ideal solution for managing high-volume workloads and ensuring consistency and accuracy in operations, especially during times of crisis like the COVID-19 pandemic.

These key technologies, when combined, enable robots to perform complex tasks autonomously, adapt to changing circumstances, and interact seamlessly with other systems and devices. The integration of AI, IoT, autonomous navigation, and RPA in COVID-19 robotic solutions has not only proven vital during the pandemic but also paves the way for continued innovation and transformation in healthcare robotics for future global health challenges.

4. Impact of Robotic Technologies in Pandemic Management

A. Reduction of Human Exposure to Infection

One of the most significant impacts of robotic technologies in pandemic management is the reduction of human exposure to infection. During the COVID-19 pandemic, minimizing human-to-human contact became a central strategy in reducing virus transmission. Robots were deployed in various roles to mitigate the risk of healthcare workers and patients encountering the virus. For example, disinfection robots equipped with UV-C light or chemical sprayers autonomously sanitized hospital rooms, hallways, and high-contact surfaces, eliminating the need for human staff to be exposed to potentially contaminated environments. Similarly, delivery robots transported food, medications, and medical supplies to patients, avoiding unnecessary interactions between healthcare providers and infected individuals. Telepresence robots further reduced exposure by allowing healthcare providers to remotely monitor and interact with patients, ensuring that medical consultations could continue without physical proximity. In public spaces, social distancing and surveillance robots helped enforce health protocols, reducing the risk of community transmission. Overall, robotic technologies played a crucial role in protecting healthcare workers and the general public from unnecessary exposure to COVID-19.

B. Enhancement of Healthcare System Efficiency

Robotic technologies have significantly enhanced the efficiency of healthcare systems during the pandemic. By automating routine, repetitive, and high-risk tasks, robots freed up valuable human resources to focus on critical patient care. For instance, robots performing disinfection tasks minimized the time healthcare workers needed to spend in potentially hazardous areas, allowing them to dedicate more time to direct patient care. Delivery robots efficiently transported medical supplies and medications, reducing the burden on human staff and enabling faster service. The use of robotic systems in diagnostics, surgery, and patient monitoring streamlined medical workflows, reducing delays and ensuring timely interventions. Moreover, robots, particularly telepresence

 doi:10.20944/preprints202501.1211.v1

robots, enabled remote consultations, helping healthcare systems manage patient loads without requiring physical presence in crowded medical facilities. This enhanced operational efficiency, allowing healthcare systems to maintain a higher capacity for critical care and reducing the strain on overburdened hospitals. In a time when healthcare infrastructure was stretched thin, the adoption of robotic technologies was crucial in maintaining continuity of care and optimizing available resources.

C. Public Health and Safety

Robotics has also had a profound impact on public health and safety during the pandemic. By automating essential services such as disinfection, supply delivery, and social monitoring, robots helped ensure that critical public health measures were adhered to while minimizing the risk of infection. In crowded public spaces like airports, shopping centers, and hospitals, robots equipped with thermal imaging sensors could detect individuals with fever, one of the early symptoms of COVID-19, and flag them for further screening. Social distancing robots also helped enforce safety guidelines by monitoring crowd density and directing people to maintain appropriate distances. Furthermore, the use of robots in high-risk areas allowed healthcare providers and public health officials to focus on critical decision-making and resource allocation without being directly exposed to potential carriers of the virus. These technologies were instrumental in managing public health measures, ensuring the continued functioning of essential services, and maintaining safety protocols in both healthcare and public spaces. Robotics' role in safeguarding public health during the pandemic has demonstrated its potential as an invaluable tool in managing future health crises and emergencies.

Overall, the integration of robotic technologies in pandemic management has provided tangible benefits in reducing human exposure to infection, enhancing healthcare system efficiency, and ensuring public health and safety. These impacts underscore the potential for continued innovation in robotics to address future public health challenges and enhance preparedness for global health emergencies.

5. Challenges and Limitations

A. Technical Challenges

Despite the numerous benefits of robotic technologies in pandemic management, several technical challenges persist that hinder their widespread implementation. One significant challenge is ensuring the reliability and precision of robots in dynamic, real-world environments, particularly in healthcare settings. Autonomous robots need to navigate complex and often crowded spaces, such as hospitals, where their ability to avoid obstacles, adapt to changing layouts, and perform tasks accurately can be compromised. The integration of sensors, AI, and machine learning algorithms requires constant calibration and refinement to ensure optimal performance. Furthermore, ensuring the seamless communication between robots and existing healthcare infrastructure, such as patient management systems and hospital networks, can be technically complex and requires extensive software development. Another challenge lies in maintaining robots' operational efficiency, particularly when it comes to battery life, charging infrastructure, and performance under varying environmental conditions, such as temperature fluctuations or physical wear and tear. Overcoming these technical hurdles is essential for ensuring that robotic solutions can consistently operate at scale and integrate smoothly into healthcare and public spaces.

B. Ethical Concerns

The rapid deployment of robotic technologies during the COVID-19 pandemic has also raised various ethical concerns. One of the primary issues is the potential for job displacement. As robots take over routine and logistical tasks, there is a risk that some healthcare workers or support staff could face job losses, particularly in roles that involve manual labor or administrative tasks. This concern is especially relevant in developing regions where the healthcare workforce may already be limited. Moreover, there are privacy and data security concerns surrounding the use of robots, especially those that collect and process sensitive health data. The integration of AI and IoT systems in healthcare robots raises questions about who has access to this data and how it is safeguarded.

 doi:10.20944/preprints202501.1211.v1

Additionally, there are ethical questions regarding the reliance on autonomous systems for decision-making in critical situations, such as patient care or diagnostics. While robots can enhance efficiency, there are concerns about their ability to fully replace human judgment, particularly in complex or emotionally sensitive medical scenarios. Addressing these ethical issues requires a careful balance between technological advancement and the safeguarding of human rights, privacy, and employment.

C. Costs and Accessibility

The high costs associated with developing and deploying robotic technologies pose significant barriers to widespread adoption, particularly in resource-constrained settings. The initial investment required for robotic systems—ranging from disinfection robots to telepresence and diagnostic robots—can be prohibitive for many healthcare providers, especially in low- and middle-income countries. While the long-term benefits of automation and efficiency are clear, the upfront capital cost, as well as ongoing maintenance and software updates, can place a strain on healthcare budgets. This cost barrier also impacts accessibility, as many healthcare facilities, particularly in underserved regions, may not have the financial capacity to integrate these technologies into their operations. Furthermore, the need for specialized training to operate and maintain these systems adds to the overall expense. For robotics to reach their full potential in global pandemic response, efforts must be made to reduce costs, improve scalability, and ensure that healthcare systems in all regions can benefit from these innovations. Public-private partnerships, government funding, and open-source robotics initiatives could play a crucial role in addressing these accessibility and affordability challenges.

Overall, while the use of robotic technologies in pandemic management has proven transformative, it is essential to address these technical, ethical, and financial challenges to fully realize their potential. Innovations that focus on improving the affordability, accessibility, and adaptability of robotic solutions will be crucial in ensuring that these technologies can be effectively deployed to manage future health crises globally.

6. Future Directions in Robotic Technologies for Healthcare

A. Advancements in AI and Robotics

The future of robotic technologies in healthcare is closely tied to advancements in Artificial Intelligence (AI), machine learning, and robotics. AI will continue to play a crucial role in enhancing the autonomy, efficiency, and adaptability of robots. As AI algorithms become more sophisticated, robots will be able to perform increasingly complex tasks with greater precision and minimal human intervention. For example, AI-driven robots could develop improved decision-making abilities in areas like diagnostics, patient care, and surgical assistance. Machine learning will also enable robots to learn from vast datasets and improve their performance over time, allowing them to adapt to new healthcare environments and patient needs. In addition, advancements in robotics, such as improved mobility, dexterity, and human-robot interaction, will make robots more versatile and capable of handling a broader range of healthcare tasks, from simple administrative duties to complex surgeries. The integration of advanced AI with robotics has the potential to revolutionize healthcare delivery by providing real-time data analysis, enhancing decision-making, and ultimately improving patient outcomes.

B. Global Distribution of Robotic Systems

The future of healthcare robotics also involves expanding access to robotic systems on a global scale, particularly in underserved and low-resource regions. As technology becomes more affordable and scalable, efforts will focus on ensuring that robotic solutions can be deployed universally, improving healthcare outcomes worldwide. Public-private partnerships and international collaborations will be key to driving the global distribution of healthcare robots. The cost of robotics needs to be reduced through innovations in design, manufacturing, and distribution to make them accessible to healthcare facilities with limited budgets. Moreover, training healthcare professionals to operate and maintain these systems is vital to ensuring their effective integration into diverse

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healthcare settings. Remote and rural areas, which often face challenges in accessing specialized healthcare services, can particularly benefit from robotic technologies, such as telepresence systems, robotic surgery, and delivery robots. By democratizing access to robotics, healthcare systems worldwide can benefit from the efficiencies and enhanced capabilities that these technologies offer, bridging the gap between resource-rich and resource-poor regions.

C. Post-Pandemic Applications

While robotic technologies were crucial in managing the COVID-19 pandemic, their potential extends far beyond crisis response. Post-pandemic, these technologies will continue to play an important role in improving healthcare efficiency, patient care, and overall system resilience. Robotics will find applications in routine healthcare operations, such as hospital logistics, elderly care, and chronic disease management. For instance, robots could assist in the aging population by providing companionship, monitoring health metrics, and delivering medications. In hospitals, robots will continue to assist in disinfection and environmental cleaning, ensuring ongoing sanitation while reducing the workload of healthcare workers. Telepresence robots will remain integral in enabling remote consultations, reducing the need for travel and in-person visits, thus improving healthcare accessibility. Moreover, advancements in robotic surgery will allow for more precise, minimally invasive procedures, improving patient recovery times and reducing healthcare costs. Post-pandemic, the focus will also shift toward the use of robots in preventative healthcare, such as early diagnosis of diseases, health monitoring, and public health surveillance. Additionally, robots will continue to assist in research and clinical trials, supporting healthcare innovations and accelerating the development of new treatments.

The long-term impact of robotics on healthcare will be profound, with continuous innovation driving improvements in patient care, healthcare workforce efficiency, and system sustainability. Future developments in AI, global distribution, and post-pandemic applications will ensure that robotic technologies remain a vital tool in shaping the future of healthcare delivery worldwide. By embracing these advancements, healthcare systems will be better equipped to handle not only pandemics but also the ongoing demands of routine and specialized care.

7. Conclusions

A. Summary of Key Contributions

Robotic technologies have proven to be a critical asset in managing the COVID-19 pandemic, offering solutions that reduce human exposure to infection, enhance healthcare system efficiency, and promote public health and safety. Through applications such as disinfection robots, delivery robots, telepresence systems, and robotic surgery, these technologies have transformed how healthcare services are provided, enabling healthcare workers to focus on critical care while minimizing their exposure to the virus. The integration of advanced technologies, such as Artificial Intelligence (AI), autonomous navigation, and Internet of Things (IoT) capabilities, has further elevated the effectiveness of these robotic systems. Despite the challenges related to technical limitations, ethical concerns, and costs, the impact of robotics on pandemic management has underscored their potential in healthcare and crisis response.

B. Robotic Technologies as a Game-Changer in Pandemic Management

Robotic technologies have undeniably served as game-changers in pandemic management. They have revolutionized not only how healthcare tasks are performed but also how healthcare systems respond to sudden crises. By automating critical functions, robots have alleviated the pressure on healthcare facilities, ensuring that essential services continued to operate during peak pandemic periods. Robots have helped preserve limited human resources, while their ability to operate autonomously in hazardous environments has minimized the risk of virus transmission. The success of these technologies during the COVID-19 pandemic highlights their transformative potential in future health crises, making robotics an indispensable tool in healthcare.

C. Recommendations for Policy Makers and Healthcare Providers

 doi:10.20944/preprints202501.1211.v1

For policymakers and healthcare providers, it is crucial to prioritize investments in robotics and automation technologies as part of healthcare infrastructure modernization. To foster innovation and ensure equitable access to these technologies, governments should consider providing financial incentives, grants, and subsidies for healthcare systems, particularly in low- and middle-income countries, to facilitate the adoption of robotics. Furthermore, healthcare providers should invest in training programs for staff to effectively operate and maintain robotic systems, ensuring seamless integration into their workflows. Ethical considerations, including data privacy and job displacement concerns, must also be addressed through clear regulations and guidelines that balance technological advancement with societal needs. Collaboration between healthcare institutions, technology developers, and policymakers will be essential in driving the widespread adoption and deployment of robotics in healthcare.

D. The Ongoing Evolution of Robotics in Crisis Response

The COVID-19 pandemic has accelerated the evolution of robotic technologies, but this is only the beginning. As advancements in AI, machine learning, and robotics continue, we can expect robots to become even more intelligent, adaptable, and capable of performing a wider range of tasks in healthcare and beyond. Post-pandemic, these technologies will continue to play an essential role in routine healthcare operations, elderly care, disease management, and even the prevention of future pandemics. The ongoing evolution of robotics will likely redefine the healthcare landscape, making it more resilient, efficient, and accessible. The lessons learned during the pandemic will guide the development of robotic systems for future crisis responses, ensuring that healthcare systems worldwide are better prepared for the challenges of tomorrow.

In conclusion, robotic technologies have proven to be indispensable in managing the COVID-19 pandemic, with their continued evolution offering vast potential for improving healthcare systems globally. The ongoing integration of robotics in healthcare will not only reshape pandemic response strategies but will also usher in a new era of healthcare delivery that is more efficient, equitable, and adaptable to future challenges.

References

1. Asif, J. Chilela, D. Benhaddou and J. Chen, "Vertical Network Slicing and its Impact on 5G Data Traffic and Performance," *2024 International Wireless Communications and Mobile Computing (IWCMC)*, Ayia Napa, Cyprus, 2024, pp. 1094-1099, doi: 10.1109/IWCMC61514.2024.10592312.
2. Asif, M., Chilela, J., Benhaddou, D., & Chen, J. (2024, May). Vertical Network Slicing and its Impact on 5G Data Traffic and Performance. In *2024 International Wireless Communications and Mobile Computing (IWCMC)* (pp. 1094-1099). IEEE.
3. Ibrar, M., Asif, M., Kashif, M., Imran, N., Hameed, S., & Ali, M. (2021). State of the Art Robotics for Combating with COVID-19 Pandemic. *International Journal*, *10*(3).
4. Ibrar, Muhammad, Muhammad Asif, Muhammad Kashif, Naveed Imran, Sana Hameed, and Mubashir Ali. "State of the Art Robotics for Combating with COVID-19 Pandemic." *International Journal* 10, no. 3 (2021).
5. Asif, M., Ibrar, M., Ahmad, S., Farooq, M. A., Ullah, H., Abbasi, M. K., & Afzal, Z. Detection of COVID-19 from CX-Ray Scans Empowered by Machine Learning.
6. Asif, Muhammad, Muhammad Ibrar, Shahbaz Ahmad, Muhammad Arslan Farooq, Hamid Ullah, Muhammad Kashif Abbasi, and Zeshan Afzal. "Detection of COVID-19 from CX-Ray Scans Empowered by Machine Learning."