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Challenges and Advancement in Autonomous Robotics: A Comprehensive Review

Rajat Jayantilal Rathod[1], Dr. H. K. Patel[2], Priyank Jayantilal Rathod[3]

[1]Individual Researcher
Email: *irajatrathod[at]gmail.com*

[2]Institute of Technology, Nirma University, India
Email: *hkpatel[at]nirmauni.ac.in*

[3]Individual/Academic Advisor
Email: *rathodpriyank[at]gmail.com*

Abstract: ***Robotics and Automation are integral parts of the industries that backbone many challenging engineering applications with easy and affordable solutions. In this cutting - edge technological development, these applications require an autonomous system that can replicate all human interventions with robotics. Recent industry developments provide and suggest various robotic solutions in welding, packaging, and transportation technologies. Still, many applications require autonomous robotic solutions to perform their routine operations, and recent developments in artificial intelligence and engineering provide unified robotic solutions to many industrial applications. Autonomous robotics is a revolutionary integration of the current utilization of robotics and automation in various manufacturing industries. Certain limitations of autonomous robotics can be identified and addressed by different researchers and engineers to develop rigid autonomous robotic solutions. This research describes recent robotic solutions and comprehensively reviews the autonomous robotics challenges and advancements for various industrial applications. The paper suggests new advancements and future aspects of autonomous robotics to manufacture multiple industrial domains like Military, Medical, Space, Nuclear, Transportation, and other Manufacturing Processes.***

Keywords: Advancement, Challenges, Artificial Intelligence, Autonomous, and Robotics

1. Introduction

Autonomous robotics is the developing field of robotics engineering that provides developments of robotic systems that are self - reliant and operative machines without human intervention. Robotic systems are modified to perform the desired tasks depending on the need. There are wide probable industrial applications of autonomous robotics that can make a difference in their routine operations. Some domestic applications of autonomous robotics can also be helpful in traditional work environments. Autonomous robotics with combinations of various sensors, manipulator designs, actuators, and Artificial intelligence (AI) based control systems to perform the given task without any limitations [1]. Autonomous robotics have followed key affecting factors.

- Logical Integration: Logical learning and performing are integral parts of an Autonomous robotic system that are always integrated with various types of sensors to know and understand the surrounding objects, environment, and obstacles. Autonomous robotic systems are equipped with a supportive control system in which most logical developments are coded to make the system learn and act like a human. Logical developments can know the objects, environment, and obstacles from the sensors and make decisions to fulfill the process requirement.
- Sensors, Actuators, and Control System: For precise operations from the autonomous robotic system, various types of available sensors like an ultrasonic, camera (Image processing), mechanical and electrical switches, photo - electric, and other electrical detecting sensors are integrated with the precise motorized mechanism into the robotic arm or manipulator system with advanced controllers and processing system to achieve the targeted operations
- Production and Scalability: A system must be designed and developed to fulfill the domestic and industrial applications that can perform like a human and perform faster, safer, more precise, reliable, and consistent operations. Autonomous robotic systems have multi - tasking facilities that increase work efficiency and boost production capacity. Also, the industry can rely on Autonomous robotic systems for their production scalability. These systems can be used daily throughout the week without any intermediate pause in the operations to meet the targeted requirements.
- Cost and Safety: By adding an autonomous robotic system, specific hazardous applications can be addressed to de - risk probable human damages. This can be a cost - effective solution that can optimize the high associated cost in traditional applications in various industries. These systems have multiple actuators for precise, reliable, and efficient operations with lower operation costs and an increased safe work environment.
- Innovation and Challenges: There are specific ongoing research and innovations in various fields like space, nuclear, and other unknown environments. All such industrial applications require high costs to make a prototype to learn and train the system for precise, reliable, and efficient operations. Moreover, recent developments in medical and military applications use partial autonomous systems to suggest and support their traditional work environments. The autonomous robotic systems will require additional clearance from various local and international agencies that comply with regulations to work autonomous robotic systems with

humans. Replacing humans with an autonomous robotic system can lead to unemployment, a primary societal concern that delays research in this field.

Autonomous Robotics has an enormous scope of applications in various industries that promise faster, safer, more reliable, consistent, and cost - effective operations. These applications open vast research opportunities and shape the future of autonomous robotic systems for calm, healthy, and wealthy societies [1].

2. Challenges

Many technical and non - technical issues have been observed in earlier developments and will remain identical in recent developments [2].

Technical Challenges:

- Logical Integration: Autonomous robotic systems are always associated with the key and real - time decisions from associated object identification, defining the path to complete the operations in the unknown environment. Providing data and algorithms to the system is a frequent challenge that one system should address and learn to perform the given task with the right decision for safety, reliability, and efficiency [3].
- Sensors, Actuators, and Control System: For precise results and outputs, sensors and actuators are integrated into the system, which mainly navigates the entire operation with complex algorithms. The challenge is to deal with the external dynamic process parameters and environment that can lead to distortions in the sensing part and provide fluctuating results to make an autonomous robotic system with precise decision capacity [4].
- Layout and Systems: Autonomous robotic systems require precise path planning and control systems that can provide a logical minimal path and load for an operation. Path Layouts are fabricated with the data to navigate systems in unknown object obstacles and load to avoid uncertain circumstances for a precise and efficient robotic system.
- Safety and Reliability: The safety of humans, systems, and human collaborative operations is the prime focus that has always been a challenge in system malfunction. Various applications with dynamic environments and continuous processes require accurate and efficient operations with the robotic system. Reliability issues to perform all such consistency tasks are often raised when the system has minor modifications in the product to protect the high associated cost and time. These autonomous robots' Analysis and verification are essential for precise, reliable, and efficient operations [5].

Non - Technical Challenges:

- Moral & Ethics: Autonomous operations raise situations of privacy and decision capability of a system and its developer. The assigned worker's moral and ethical responsibility is to address the relevant person's concerns. If human - intensive tasks are replaced with an autonomous robotic system, then training for the autonomous system should be added to mitigate the associated unemployment challenges [5].
- Regulation & Standards: Autonomous Robotic systems require local and international licenses and permissions to operate these systems within appropriate legal frameworks. Potential threats and changes must be considered in the research and development of the autonomous robotic system for a safe domestic and industrial environment. Incorporation of dis - similar robotic systems and accessories must be uniform to standardize autonomous robotic systems. This will develop and emphasize using autonomous robotic systems and platforms to reduce costs and scale this field for various industrial applications.
- Environmental Capability: These autonomous robotic systems are frequently placed in a dynamic environment, which creates a challenge to provide a rigid robotic structure that can last in these conditions. This also requires modifying and upgrading the recent designs to an adequate futuristic rigid robotic system structure to withstand the dynamic load in the dynamic environment.

3. Advancements

Autonomous robotics is the key development area in engineering as it demands cutting - edge solutions for various applications. Recent developments have been utilized for decades. However, recent research has been a step forward in developing autonomous robotic systems and associated technologies that enable them to push the demands of various domestic and industrial applications. Artificial intelligence and its sub - set machine learning and data mining create boundless solutions with advanced sensor technology and servo system - based robotic structures to do challenging tasks. Continuously evolving technological developments will require ongoing research that allows advancement in the associated technological developments for various tedious, human - intensive, and traditional applications [6].

- Logical Integration and Control Systems: An autonomous robotic system needs to learn how to read data and build algorithms to minimize its efforts like humans. Once it learns to understand the data, it can realize nearby objects, obstacles, and environments to create a similar work environment to do the assigned task. Most advanced controller and processing techniques are used to simulate the given data to train the systems to perform desired functions with human - like decisions [7].
- Sensors and System: Recent developments in sensing technology created a breakthrough in building autonomous robotic systems. Sensors like LiDAR, radar, sonar, computer - based vision, and mapping systems are integrated into artificial intelligence and machine learning systems to learn and develop relevant logic better to understand objects, obstacles, and the environment. LiDAR is a small and cheap photoelectric sensor technology that enables autonomous robotic systems to create similar object identification. Radar and Sonar sensors transmit and receive data to identify objects in the detection range, mainly in underwater environments. The integrations to the computer - based vision system to analyze the surrounding environment through the image processing techniques with the help of deep machine learning of data with more reliability. The last and most useful technology in recent developments to make an autonomous car utilize advanced simultaneous localization and mapping solutions integrated with the

recent sensing technology to create a robust and efficient system for autonomous operations [7].

- Path Planning and Multitask Adaption: System algorithms are trained with the available data to make the precise path so robotic systems can navigate and avoid objects and obstacles in dynamic environments to perform precise operations. Also, associated sensing technology and actuators are integrated into the robotic systems to simultaneously enable multi - joint operations and multi - tasking, such as everyday parallel operations. In this system development that performs multi - tasking operations, recent machine learning algorithms and artificial intelligence models with data mining play a vital part in experiencing and learning new situations [8].
- Data Learning and Feedback: Several data learning methods exist for training control systems to address challenging, complex systems in a dynamic environment. Control systems can learn and be trained using a real - time learning approach or transfer all data and libraries to allow robotic systems to understand the hierarchy of the system and its aim to perform the tasks. Sometimes, systems can be applied to a feedback system to learn and train the system based on the given feedback and adjust the error for the precise mechanism [8].
- Human - robot collaboration: Recent developments have critical applications like the natural tone of various natural languages, societal feedback, and other human - inspired works that require human and robot cooperation. These collaborations can mitigate societal issues of becoming unemployed by providing safe, attentive, and research - based solutions [9].

Technological Advancement:

- Artificial Intelligence (AI): AI is an algorithm that learns from data to make a robotic system autonomous. It is an integral part of the autonomous robotic system, enabling human - like decision tasks in complex work scenarios in a dynamic environment. The recent development of vision systems and error resolutions makes an artificially intelligent robotic system safer and more accurate in various applications [10].
- Machine Learning (ML): Machine Learning is a subset of artificial intelligence with prompt learning methods that enable robotic systems to learn and perform like humans. Continuous learning methods in machine learning enhance device performance and efficiency by allowing corrective system actions for more reliability in dynamic and complex scenarios [10].
- Computing and Robot Operating Systems (ROS): All autonomous robotic systems work on real - time data collection and learning methods that require high computing power. The recent developments in processors enable autonomous robotic systems to provide high computing processing power for real - time data collection, processing, and analysis to reduce the time for precise and faster system response. Moreover, the robotic operating system has also been developed to make the robotic system think and work with lower processing power and enhanced work capacity. ROS provides adjustable algorithms to control autonomous robotic systems. It also has integrated solutions with multiple libraries and tools for standardizing the autonomous process [11].

Overall, Recent technological developments in autonomous robotic systems provide a broad scope of research and development, using artificial intelligence, machine learning, data mining, and data analysis to offer cutting - edge autonomous robotic solutions for many domestic and Industrial applications [11].

4. Applications

Autonomous robotic systems offer a wide range of solutions for current development.

- Automated Guided Vehicles (AGV): Automated guided vehicles are the preliminary development of Self - driving vehicles used in remote exploration and work in military, hazardous, and unknown environmental works. Recent developments in transportation and mobility have provided a notable autonomous robotic system application in cars, trucks, and drones for faster, more reliable, and more efficient solutions.
- Exploration and Surveillance: Earlier, these systems were used to explore unknown environments like space, seismic zones, sea, and other non - seen disasters to reduce human intervention in such dynamic conditions. AI - integrated systems identify the surrounding environments and can navigate systems to assist others in following the path of dynamic environmental conditions. These systems are capable and proven in exploring and surveilling spaofr technology, which plays a pivotal role in the absen, cwhichans [12].
- Robotic System as a Service: Current Industrial developments in medicine, agriculture, and other applications use service robots to perform traditional human - like tasks. Some applications also involve robotic - human collaboration to perform heavy tasks like agriculture production (using drones), weight lifting, fabrication, manufacturing, and other applications with humans to improve reliability and efficiency [12].
- Autonomous robotic systems offer various applications with enhanced safety, precision, efficiency, and performance across various industrial applications to derail human and associated costs [13].

5. Limitations

There are certain Limitations to the widespread applications of autonomous robotic systems. Autonomous robotic systems have several challenges and advantages, but they also have certain limitations to their potential use.

- Cost: Autonomous Robotic Systems require high initial costs to train the system to learn like humans.
- Maintenance: Routine system maintenance is required to ensure its functions. Some autonomous robotic systems require regular updates to standardize the associated operations.
- Technical Expertise: Incremental use of autonomous robotic systems requires technical expertise to operate and maintain this system, which requires additional training.
- Regulations and Safety: Local and International licenses and standards must be followed to ensure safe environmental operations. Safety and security concerns must also be addressed to match the integrity of the autonomous systems [14].

6. Future Scope

Many recent developments in autonomous robotic systems can be enhanced with various system integrations [15].

- Improvement and enhancement in the logic and algorithms of Artificial Intelligence and Machine learning
- Standardize the robotic system and research that can be unique and integrated with available robotic systems.
- Sensing and control systems need to be capable of powering this autonomous robotic system technology to grow further with lower power consumption and lower processing time.
- Interdisciplinary collaborations are required to exchange the available domain knowledge to perform various application - based research to increase system usage.
- Local and international regulation changes should be made to expand autonomous robotic systems and promote their application among industries.

Looking forward to these developments, applications of autonomous robotic systems seem promising to do further research and innovation to expand their domestic and industrial applications. Future developments can be biological - inspired robots or robotic systems as a service to perform various tasks in a dynamic environment [16].

7. Conclusion

This research describes autonomous robotic system challenges, advancements, limitations, and future scope to provide more information about the systems. Technological and non - technological difficulties are identified in this research, which proposes advancements in autonomous robotic systems. Some key challenges and advancements are highlighted for further research and innovation in autonomous robotic systems.

This widespread application field is evolving rapidly to follow all relevant aspects, including safety, reliability, and efficiency. With the rigid stone foundation in technology, these challenges can be addressed, and the potential of autonomous robotic system capabilities can be overcome to open new opportunities in developing futuristic autonomous robotic systems.

This paper describes current research and understanding of autonomous robotic systems, including their challenges, advancements, and potential future applications. This research will encourage all researchers, engineers, and key persons to promote existing autonomous robotic systems and pursue further study in various domestic and industrial applications.

References

[1] Frost, C., A. Butt, and D. Silva. "Challenges and opportunities for autonomous systems in space. " In Frontiers of Engineering: Reports on Leading - Edge Engineering from the 2010 Symposium.2010.

[2] Ohradzansky, Michael T., Eugene R. Rush, Danny G. Riley, Andrew B. Mills, Shakeeb Ahmad, Steve McGuire, Harel Biggie et al. "Multi - agent autonomy: Advancements and challenges in subterranean exploration. " arXiv preprint arXiv: 2110.04390 (2021).

[3] Alatise, Mary B., and Gerhard P. Hancke. "A review on challenges of autonomous mobile robot and sensor fusion methods. " IEEE Access 8 (2020): 39830 - 39846.

[4] Connelly, James, W. S. Hong, R. B. Mahoney Jr, and D. A. Sparrow. "Current challenges in autonomous vehicle development. " In Unmanned Systems Technology VIII, vol.6230, pp.115 - 125. SPIE, 2006.

[5] Carreno, Jose, George Galdorisi, Steven Koepenick, and Rachel Volner. "Autonomous systems: Challenges and opportunities. " DTIC Document, Tech. Rep. (2010).

[6] Mistry, Michael, Aleš Leonardis, Mark Witkowski, and Chris Melhuish. Advances in Autonomous Robotics Systems. Springer International Publishing, 2014.

[7] Liu, Boni. "Recent advancements in autonomous robots and their technical analysis. " Mathematical Problems in Engineering 2021 (2021): 1 - 12.

[8] Satterfield, Brian, Heeten Choxi, Adam Salamon, and Peter Drewes. "Advancing robotics: the urban challenge effect. " Journal of Aerospace Computing, Information, and Communication 5, no.12 (2008): 530 - 542.

[9] Heyer, Clint. "Human - robot interaction and future industrial robotics applications. " In 2010 ieee/rsj international conference on intelligent robots and systems, pp.4749 - 4754. IEEE, 2010.

[10] Martin, Bradley, Danielle C. Tarraf, Thomas C. Whitmore, Jacob DeWeese, Cedric Kenney, Jon Schmid, and Paul DeLuca. "Advancing Autonomous Systems. " Rand Corporation (2019): 9 - 11.

[11] Ndlovu, Thando, David Root, and Paulin Wembe. "A review of the advantages and disadvantages of the use of automation and robotics in the construction industry. " The Construction Industry in the Fourth Industrial Revolution (2020): 197.

[12] Zghair, Noor Abdul Khaleq, and Ahmed S. Al - Araji. "A one decade survey of autonomous mobile robot systems. " International Journal of Electrical and Computer Engineering 11, no.6 (2021): 4891.

[13] Wortham, Robert H. Transparency for Robots and Autonomous Systems: Fundamentals, technologies and applications. Institution of Engineering and Technology, 2020.

[14] Chatterjee, Amitava, Anjan Rakshit, and N. Nirmal Singh. Vision based autonomous robot navigation: algorithms and implementations. Vol.455. Springer, 2012.

[15] Bekey, George A., Robert Ambrose, Vijay Kumar, Arthur C. Sanderson, Brian Wilcox, Yuan F. Zheng, Jun - ku Yuh, and David Lavery. "Robotics: state of the art and future challenges. " (2008).

[16] Wong, Cuebong, Erfu Yang, Xiu - Tian Yan, and Dongbing Gu. "An overview of robotics and autonomous systems for harsh environments. " In 2017 23rd International Conference on Automation and Computing (ICAC), pp.1 - 6. IEEE, 2017.