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Robotics In the Gamut of Indian Science

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Abstract

The use of robotics in science and industry has changed technology and innovation worldwide. Robotics is becoming a key scientific and technical sector in India. This study examines robotics in India, its use in healthcare, agriculture, industrial, and space exploration, and its impact on research and development. Indian scientists and engineers have hurdles in developing indigenous robotic technologies, including cost, infrastructure, and talent deficiencies. The report also highlights government and academic institution efforts to stimulate innovation in this field. The study also discusses Indian robotics' global contests, collaborative research, and local advancements like economic healthcare and automated farming systems. The findings show that robots are becoming more important for social and economic development in India's scientific ecosystem.

Keywords: Robotics, Indian science ecosystem, innovation, automation, indigenous technologies

INTRODUCTION

India has promoted responsible artificial intelligence (AI) deployment and public trust in this technology for years, with 'AI for All' at its core. The breadth and scope of government actions to democratize AI's advantages demonstrate India's holistic and ambitious approach to AI. The Indian government's INDIAai umbrella program harmonizes existing AI initiatives, from building language models (Digital India Bhashini) to increase digital accessibility for citizens to skilling programs Youth for Unnati & Vikas with AI (YUVAi) to demystify AI for school students, to achieve the goal of 'making AI in India and making AI work for India.'

India has also made substantial advances in robotics, focusing on creating and utilizing cutting-edge technologies to support innovation and sustainable and inclusive economic growth. Indian robotics installations rose by 54% to 4,945 units in 2021, ranking 10th in the world for industrial robot installations. However, the coronavirus epidemic and geopolitical instability continue to disrupt global supply chains, extending key component shortages and increasing India's need for robotic self-reliance.

The Bureau of Indian Standards (BIS) defines robotics as the science and practice of creating, manufacturing, and applying robots. Robotic technologies include robot design, building, operation, and use. Robots sense their surroundings, compute decisions, and act accordingly. Robot sensors transmit measurements to a controller or computer that processes them and delivers control signals to motors and actuators to interact with the environment. More advanced robots can perform skills traditionally assumed to be human-only, such as visual perception, speech recognition, and decision-making, owing to improvements in AI and machine learning [1].

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ROBOTICS

In 1921, Czechoslovakian playwright Karel Čapek invented the term 'robot' in his play R.U.R. (Rossum's Universal Robots). The drama investigates how technological development can create machines with desires and robots that rebel against humans. Isaac Asimov's 1940s short fiction

introduced ‘robotics’. A biochemistry professor and visionary invented the word robotics to study robots. Robots are machines or mechanical devices that replace or enhance human or animal effort in businesses that require basic repetitive tasks.

India and other developing nations can use International Association for Scientific Spiritualism (IASS) and related technologies to solve social issues. Policymakers must establish data collection, standardized hardware, skilled labor, finance, and startup culture policies to create a sustainable ecosystem for IAS development and national AI policy. Ecosystem functioning requires clear regulation. Any technology that works in India has a stronger chance of working globally owing to its large population [2].

Robotics involves the design, building, and use of robots, as well as their studies. The programmed robots are artificially intelligent. Motors and sensors enable physical systems to interact with and control the external environment. Humans are becoming increasingly interested in intelligent and autonomous devices to assist in daily life. Modern technologies have greatly influenced robot ecosystems. In recent years, there has been a global shift in robotics research and development. Worldwide, robot systems are utilized in research laboratories for education and entertainment, as well as in non-industrial fields such as assisted living, public relations, domestic services, and commercial entertainment. This introduction focuses on the widely cited benefits of robotics for future life and society’s future well-being, and examines its use in Indian society, considering the potential benefits and challenges of robotics in India and future directions for using robotics in the Indian economy.

Definition and Scope

The robot comes from the Czechoslovak word “*robota*” for forced labor. A robot is a reprogrammable and versatile manipulator that moves materials, parts, tools, or special devices using varying motions to complete various tasks. Robots began as programmable manipulators for grasping, transferring, and releasing objects in 1954. Robotics was initially used in a book. Robotic research has emerged as a new discipline. Satellite and missile communication were added to robotics in 1866. It is also utilized in sensor design. Currently, competitive technologies require endless robots. Technology is progressing rapidly worldwide, resulting in unnecessary misery. Robots can easily execute heroic feats. No life is at risk of casualties.

Robots can help warriors avoid dangerous and brutal duties on the battlefield. Present robots using logic based on the present technology, but what would the robotics sector be like if significant personalities lived in the era of *nano-*, *bio-*, *infro-*, *cogno-*, and quantum technologies? The $10 billion robotics sector is rising rapidly, as robots need to grow. Approximately 1,300 robotics businesses existed in the year 2000. Technology is expanding and improving quickly. Companies provide global services. Applications will move from factories to houses. Many business models have been developed. Robots initially carried and produced drugs for use in humans. Users should eventually engage with each other and become omnipresent personas, thus enabling proper technologies. Their leisure activities included task performance, imitation, and enjoyment.

Robotics is a combination of mechanical engineering, electrical engineering, and computer science. It has evolved significantly over the last decade and is near its peak. Many new avenues have opened in this field. The potential of robotics is easy to express but difficult to grasp. Robots can perform jobs automatically or with instructions, usually via remote controls. Most robots are electromechanical machines that are controlled by computers and electronics. Robots can move and modify materials, such as computer programs. Thus, the robotics and automation research awareness gap remains significant. Robotics and automation have eventually permeated human life. Robots have become ubiquitous as technology advances. They will soon infiltrate the devices, clothing, and bodies. The engineering community must spread knowledge regarding the future scope and applications [3].

Abdilla and Fitch (2017) [4] wrote that in November 2014, the lead researcher’s interest in digital technology conceptual development and her cultural connection to Indigenous Knowledge Systems

created the Indigenous Robotics Prototype Workshop to explore digital technology's cultural relevance to urban indigenous youth. The event fostered cultural pride and confidence in indigenous traditional knowledge while encouraging youth to continue coding and programming by making robots. However, the prototype workshop suggested that Indigenous Knowledge Systems, particularly Pattern Thinking, may suggest a paradigm shift in ethical and innovative technology design. To analyze the ramifications of such a possible transition in autonomous systems in robotics and AI, this study uses an Indigenous Robotics Prototype Workshop as a case study and springboard.

HISTORICAL ROBOTICS DEVELOPMENT

Robots have a history in science, engineering, and fantasy. The past is fascinating, but it also affects present and future robot designs. Ancient Chinese masterpieces foreshadow robots. Chinese astronomy, engineering, and technology flourished during these times. A famous inventor and mathematician created the first robot, which was a mechanical lady that could distribute refreshments. The mechanical concepts described in the design could represent a robot's modern anatomical and physiological systems, implemented on a computer for smooth performance.

Using strange technologies, puppets were animated during the Middle Ages. Hickworth's design and German golden opera performers are examples. European intellectuals were fascinated by the most amazing automaton of the eighteenth century. The box contained a mannequin dressed as a Turkish "sorcerer," who could play chess. A cunningly calculated chess-playing automaton was discovered in the 20th century. The Turk was convincing as a robot that could think that people did not realize that it was human.

In recent years, robots in India have expanded beyond industrial uses, atomic energy, etc., to include education, rehabilitation, entertainment, and even residences. In research labs, education, business, atomic energy, and more, Indian robotics researchers have increased from a handful to over 100. After the workshop on Haptics and Virtual Reality, the Robotics Society of India was founded on July 10, 2011, at the Indian Institution of Technology Delhi to improve robotics activities and foster close cooperation among its members. The society aims to act as an academic center of robotics in India and collaborate with academic societies in related fields in India and abroad. Fully autonomous robots appeared in the second part of the 20th century. Unimate, the first digitally controlled and programmable robot, was lifted and stacked with hot metal from a die-casting machine in 1961. Currently, commercial and industrial robots execute jobs cheaper, more correctly, and more reliably than people. These tasks are too dirty, dangerous, or boring for humans. Robots are employed in the manufacturing, assembling, packing, transport, earth and space exploration, surgery, weaponry, laboratory research, safety, and mass production of consumer and industrial goods [5].

Robotics Highlights

A defense research and development organization-sponsored mobile robot navigation project at the Indian Institute of Technology Kanpur launched robotics in India in the 1980s. The navigation system was built using a mobile robot. Range sensors, laser range scanners, and stereo pan-tilt cameras are installed on the robot. The microcomputer merged and planned the data. After setting up the interior navigation tasks and payload robot navigator design tasks, the project ended in 1994. A team from the Indian Institute of Technology Mumbai simultaneously used computer vision at about the same time. Mumbai's control system coordinates the mobile robot.

Industrial robotics has reached a significant milestone in recent years. George Devol designed Unimate, the first programmable robotic arm in 1954. GM utilized it in 1961. The Stanford Research Institute created Shakey, a mobile robotics milestone, in 1966. Scheinman created the first electric-powered robot, the Stanford Arm, in 1973. The addition of computational capability to mechatronic systems in the 1980s made automation smarter. Notable accomplishments include the 1969 invention of miniature electrically powered robots and the 1972 introduction of the first robot with artificial intelligence [6].

The manipulation robot project began at the Tata Institute of Fundamental Research in 1986. A six-degree-of-freedom robot is used. Computer numerical control robot programming was performed using a microcomputer. Mathematical processors have been extensively used. The fingertips of the robot controlled the force using force and tactile sensors. Software-supported force and visual sensors. The robot assembled parts, paginated, and collated newspapers, folded papers into an aircraft, and explored discretely computed mazes. The study of the team and robot destruction ended this endeavor.

The 21st century saw considerable robotics breakthroughs, including the integration of mobile robots and AI. Factory processes have been transformed by using mobile robots with improved sensors and navigation systems. These robots can deliver materials, maintain inventories, and fulfill orders independently on the production floor. Their mobility makes industrial procedures more dynamic and efficient (2024) [6].

AI has advanced industrial robotics by allowing robots to gain environmental awareness, optimize operations, and anticipate maintenance requirements. Machine learning techniques allow robots to find patterns in massive datasets and make efficient decisions. AI-powered robots may change their actions depending on real-time feedback, thereby improving precision, and reducing errors. They can also predict equipment breakdowns and schedule maintenance, reducing downtime, and increasing machinery life.

APPLICATIONS OF ROBOTICS IN INDIAN SCIENCE

Space robotics, surgery, etc. have demonstrated the scientific use of robotics. Many Indian research and business companies have improved in these areas. Indian science and robotics are the focus of this study. The selected science topics and their robotics applications are explained. We briefly discuss improvements in Indian robotics research and commercialization. Robotics is important in scientific research. The integration of robots adds dimensions to established subjects and allows for the research of others. Research and commercial companies in India are strengthening robotics in various domains. There is a lack of research on robotics in both science and research. This paper discusses Indian science.

Over the past decade, India has strengthened its industrial base by adopting modern manufacturing technologies such as robotics, which boost productivity. Within five years (2016–2021), the number of operational industrial robots has doubled. India ranks 10th internationally for annual industrial installations according to the 2022 World Robotics Report. India has seen slower progress in its robotics ecosystem compared to other wealthy nations.

Government Initiatives

The Indian government has established the following robotics research centers. Artificial Intelligence and Robotics Technology Park (ARTPARK), a Technology Innovation Hub within the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), focuses on AI and robotics. CAMRAS was founded to limit robotics and autonomous system imports.

Indian Institute of Technology Delhi's I-HUB Foundation for Cobotics (IHFC) initiated eight major projects in medical simulators, healthcare robotics, rehabilitation robotics, and drone applications. The draft National Strategy for Robotics aims to make India a global leader in robotics by 2030, realizing its revolutionary potential.

Indian Space Research Organisation (ISRO) and robotics: ISRO is developing humanoid robots for manned missions intended to assist and eventually replace humans. India plans to launch the female astronaut Vyommitra into orbit in 2024 as part of the Gaganyaan project.

Defense Research and Development Organization

Research and Development Establishment (Engineers) develop robotic platforms for defense purposes. The Combat Vehicles Research and Development Establishment (CVRDE) and the Vehicle

Research and Development Establishment (VRDE) develop unmanned tracked and wheeled vehicles. The Centre for Artificial Intelligence and Robotics (CAIR) focuses on autonomous navigation, computer vision-processing, and AI to develop robotic and unmanned systems.

Projects to Build Capacity

Under FutureSkills Prime (Ministry of Electronics and Information Technology (MeitY)), a powerful online platform provides subsidized access to certified courses in AI, Blockchain, Robotics, Cybersecurity, etc.

Atal innovation mission: Atal Tinkering Labs (ATL) feature Do it Yourself (DIY) kits for upcoming technologies such as robotics and Internet of Things (IoT) in specialized innovation workplaces. The Ministry of Education funds e-YANTRA, a robotics outreach program that utilizes young engineers to solve challenges in agriculture, manufacturing, and defense.

Robots Made in India

DAKSHA is an automated mobility platform for various payloads. It can climb stairs and handle IEDs. ISRO is developing a humanoid robot called Vyommitra for use aboard the Gaganyaan spacecraft. MANAV is India's first 3D-printed humanoid robot with vision-processing and sound-processing capabilities that respond to human orders to walk, talk, and dance.

Robotics Uses

Robotics' adaptability makes it useful in many areas. Robots are commonly employed in automotive assembly lines for welding, painting, pick-and-place, and quality-checking activities. In healthcare, robots assist surgeons in promoting faster recuperation. Robotic exoskeletons aid post-injury rehabilitation and mobility. Remote consultations using telemedicine robots are vital in locations with limited medical access. Toyota's healthcare helpers are an example of robots assisting in walking rehabilitation.

Logistics: Warehouse robots optimize efficiency by managing inventories, sorting, and packaging. Autonomous Mobile Robots (AMRs) improve warehouse productivity through autonomous navigation.

In agriculture, robots aid in the planting, harvesting, and monitoring of crops, thereby increasing precision farming. Autonomous tractors plant and harvest, whereas drones check crop health.

In retail and hospitality, robotics improves the customer experience by automating inventory processes, wayfinding, and baggage/parking valet services.

In Science, Technology, Engineering, and Mathematics (STEM) education, robots enhance hands-on learning and engage pupils. For instance, Softbank Robotics created the Nao model for the L2TOR European research project, teaching young children a second language.

Robotic technology is crucial for exploring spaces, including asteroids, moons, and planets. Rovers like NASA's Curiosity acquire data and samples from planetary surfaces.

Defense and security: Bomb disposal robots, surveillance drones, and autonomous vehicles for hazardous-zone reconnaissance have military and security uses.

Robotics improve urban safety and efficiency in smart cities. Humanoid robots provide navigation and information services. Autonomous Mobile Robots (AMRs) transport products and patrol. Site surveys and building modeling data collected by robotics have accelerated building construction [7].

Agriculture

Low yields and rising production costs affect two-thirds of Indian farmers. However, growth in agricultural productivity has been inconsistent. Field workers are scarce owing to mechanization and urbanization, which has driven people from villages to cities. Current productivity practices have depleted water and soil levels, making them unsustainable. Therefore, new agricultural practices are required to address these issues. Robotics is important in many agricultural fields.

Higher-quality seeds, more water and fertilizer, and more machinery have increased farming productivity but have reduced traditional farming employment. High yields of seeds, fertilizers, pesticides, herbicides, and fungicides reduce fieldwork. Horses and bullocks reduced tilling effort but did not reduce fieldwork. It increased employment and spawned new activities that created many jobs. This applies to all agricultural areas. Mechanization did not reduce employment. The introduction of heavy machinery and industrial-scale farming has reduced the number of field workers. Farmers' migration to cities may worsen this issue. Current concerns include labor shortages in the field. This workforce shortage may seriously reduce the Indian food output.

Health and Medicine

Robots in health care are popular worldwide. Many startups and large companies are developing robotics in this field. Telesurgery and remote healthcare will change medicine in the future. Healthcare and medical robots can improve surgery, increase hospital care and treatment, conduct jobs without human interaction, including diagnostics, and provide long-term high-quality care. Healthcare robots have shown promise for telesurgery, robot-assisted surgeries for teleconsultations or telementor ships, medical imaging, health monitoring, hospital medical care, and nursing support.

Innovative technological advances have inspired new ideas, concepts, and technical tactics for healthcare and medical robotics. In addition, robot innovation is fresh with diverse medical diseases, raising several safety and ethical challenges associated with robot and robot-machine cooperation. The medical field has seen exponential growth in robotics, with novel applications and the use of distinct robotic sectors. Medical advances and human-robot assistance improvements are significant. Because most medical robots use cutting-edge technology, this field is fascinating to study. Medical robotics is a vital research topic that enhances the life sciences.

CHALLENGES AND PROSPECTS

Robots must pass through various barriers to become crucial to our lives. Startups can help increase the use of robotics and automation in industry by expanding their use, reducing their size, improving their dexterity, autonomy, and decision-making, and making them more affordable. Over the past five years, the government has prioritized the startup ecosystem through Digital India, Make in India, Skill India, Innovation, and Entrepreneurship. Many academic and R&D institutes that have avoided industry are interested in R&D.

Research that may assist automation and robotics in overcoming these difficulties is now appropriate. This leads me to highlight robotics. AI is the first issue. Autonomous robots require the development and integration of AI. AI is rapidly transforming picture, text, speech interpretation, and logical decision-making. India is lucky to have contributed to early AI tools. Some of us are even more excited if we take pride in the recent success of a talented computer scientist who made our country affluent by contributing to computational and communication ideas. After AI bottlenecks have been eliminated, there are many good AI-based robots. Putting them into the general environment is difficult at this time, as many other bottlenecks must be overcome to keep them running for a long time. This involves improving the reliability, fault tolerance, reproducibility, power consumption, and final assembly costs.

Despite advances in robotics, several hurdles remain in ensuring safe and dependable robot deployment in real-world applications.

Safety concerns: Industrial robot mishaps can be fatal. Improved safety protocols and human-robot collaboration are essential. In 2015, Volkswagen factory robots allegedly killed workers. AI-powered robots cause ethical problems, including autonomous weaponry and algorithmic prejudice. Important healthcare and law enforcement ethics issues. Robots are more susceptible to cyberattacks owing to their increased connections. The "WannaCry" ransomware assault reached a US robot manufacturing factory in 2017.

Data and algorithm bias: Large datasets of trained robots may reinforce societal biases. Amazon's facial recognition algorithms exhibit prejudice.

Job loss: Automation in industries causes job losses. Robots have eliminated manufacturing jobs, resulting in socioeconomic problems. According to Goldman Sachs, this fast-growing technology might eliminate 300 million jobs. Robotic accessibility is limited by high development costs, particularly in smaller companies or developing nations. The absence of standardized regulations presents safety, liability, and ethical concerns. Robotic system development and deployment require clear guidelines [7].

Robotics Ethics

Recent advances in AI and robotics have shown that these systems can perform activities previously assumed to be human-only. Robotics and AI can replace or supplement human jobs. Given these capabilities, robot and AI ethics must be considered. Autonomous robotic systems, particularly those with advanced AI, pose significant ethical challenges. These concerns have led robotics and AI experts to demand international cooperation and research and development guidelines to help humanity exploit technologies.

Out-of-control robotics and AI systems pose major threats to 'ordinary' people. When these systems injure humans, they can act aggressively and uncaringly. The public discusses these cases and fears them. Due to ignorance and lack of funding, these aggressions may not be intentional. Robots are produced items and, therefore, their creators' obligations are likely legal. When accidents and transgressions indicate that intelligent systems detect them as illegal, these difficulties escalate. These explanations suggest that violent conduct may stem from a mechanical drive to complete tasks, a lack of moral judgment, or a lack of training and awareness correction. Thus, we may eventually see highly proficient social robots that can interact in many ways and communicate advanced content, but cannot stop or recognize when they are out of control.

POLICY IMPLICATIONS FOR INDIA

Islam (2018) [8] argues that this study analyzes the Indian experience in light of international evidence on automation and employment. It claims that the apocalyptic idea of global or Indian technological unemployment is overblown. However, the romantic idea that new technology—especially online work—will usher in a new era of affluence in India driven by digitally enabled micro-entrepreneurs is unlikely to happen. However, this does not mean that digital platforms should not produce jobs. Novel regulatory frameworks should nurture a rising population of Indian Internet workers to boost their pay and working conditions. This requires substantial digital infrastructure investment.

Recently, several Indian startups have arisen. Zinnov said that an estimated 170 AI-related firms in India had received $36 million in investment (India-base, 2018). 64 are in Bengaluru. These work in healthcare, e-commerce, finance, and so on. Clients may view the data while making decisions using Tuplejump, a company. The company was bought from Apple. ClearTax creates document-based e-fillings. AIndra developed computer vision equipment for facial recognition and cervical cancer diagnosis.

IT giants, such as TCS and Infosys, are also exploring AI-based solutions. A TCS Virtual Assistant may talk to customers about insurance products (Tata Consultancy Services, 2012). Natural linguistic

interactions were also possible. Using AI, Infosys has automated various IT support operations. IBM's Watson for Oncology solution is used in hospitals to treat cancer patients (Manipal Hospitals, 2018). Cyril Amarchand Mangaldas, a reputable law practice, partnered with Kira, a Canadian AI-based law firm solution provider.

Government AI R&D has been ongoing for several years. MeitY (formerly DOE) began a knowledge-based computer Systems Project in 1986 with United Nations Development Programme (UNDP) funding. This initiative included several development activities. Project-built infrastructure in C-DAC and other academic/R&D centers. The Ministry later launched the National Perception Engineering Program. Robotic arms and other prototypes have been produced under this initiative. Technology Development for Indian Languages Programme programs were also run by the Ministry. Machine translation, text-to-speech, and speech-to-text systems have received the most funding [9].

The Centre for Artificial Intelligence and Robotics (CAIR) defense and civil AI programs are funded by Defence Research and Development Organisation (DRDO). Industry funds R&D for a few enterprises. This scenario is currently shifting. Infosys provided Indraprastha Institute of Information Technology Delhi INR 50 million for AI research.

India currently enjoys a rare opportunity. This can replicate the success of the IT industry with domestic talent. However, if essential procedures are not performed in time, this opportunity will be missed. Major government programs can benefit from AI [10]. India's Digital, Make in India, and Skill India initiatives. Applications and infrastructure development, policy and regulations, research and development, and human resource development are required to accelerate AI technology and its application, as per the Government of India's strategy.

CONCLUSION

India has the potential to use technology to solve major challenges, such as healthcare shortages and poor education. Conventional techniques cannot provide quality healthcare or education. Good health care requires a large number of doctors, which cannot be attained in several years. Thus, AI offers an alternative approach.

This report examines international and national AI adoption. Technology can boost economic growth but also hurts job opportunities. Any nation must maximize opportunities while addressing employment loss. This study investigated other countries to determine their actions.

It proposes infrastructure, policy, research, and human resource development for India based on this. All stakeholders must engage in discussion on these topics. Infrastructure development, public sector applications, policies and regulations, technological development, and Human Resource Development are government responsibilities. This is possible through industrial support.

The report highlighted the main concerns, but further research is necessary to address infrastructure development, policies and regulations, and technological advancements. To formulate a suitable policy, an assessment of the predicted employment losses in various sectors is required. Such studies can inform government policy. It may be too early to create new regulations; however, the Government of India must evaluate and modify existing regulations.

The development of economic power cannot ignore governance investments. Scientific ideas need not conflict with improving people's well-being or the economy. Science and technology can be linked constructively to economic and social objectives. Robotics may be the best catalyst for scientific and technological advancement. Emerging nations must invest in robots or fall behind in robotic growth. Indian scientists will either leverage developing sciences and technologies to develop indigenous robotics technologies or acquire incredibly helpful technology. In conclusion, we have a unique

opportunity in the nation, with an incredible academic program and entrepreneurial spirit, to repair and extend our well-documented leadership in the future as we continue to draw support from faculty, the public and private sectors, and the public at large. Robotics is a science that has constantly advanced. Robotics is a fascinating and cutting-edge field because of this characteristic. Indian scientists and researchers can contribute to robotics technology and redefine the world and the future.

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