Living in Future : Prospects and Applications of Artificial Intelligence in Manufacturing Industries

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Abstract

We may be witnessing major transformational change in this age of computation of manufacturing and processing. The rise in consumer demand has affected major industries throughout the world. Therefore, the need for a catalyst for instigating such hyper changes has been felt by every element involved in such process.

The need for artificial intelligence has seen a boom in last few years with more funds available for research and development of implementable concepts into acceptable and feasible designs. This paper is an effort to understand how artificial intelligence has developed in recent years. Also, the different aspects of manufacturing and allied activities that can be transformed sincerely for innovation, maximizing time-output ratio including quality control.

Keywords: AI, business efficiency, intelligence, neural network

I. INTRODUCTION

In recent times the World Economic Forum [52] has recognized the 4th Industrial Revolution as the most disruptive socio-economic transformation that humanity has ever faced [50]. It includes all of the continuing technology-enabled changes that are touching industries and countries around the world. Among these, we have self-driving cars, connected devices, AI-enabled computer chips, mobile internet technologies and other innovations that indicate this colossal shift to the new era.

As compared to the last industrial revolution, manufacturing is also gaining centre stage of several of these pioneering advancements. In general, manufacturing is considered as being naturally inclined to transform with the intent of making things easily affordable and gaining competitive advantage in the market. Experts all over the world agree that "the next Kanban" will be the AI in manufacturing, more popularly known as smart manufacturing [46]. According to global giant Accenture, major industrial applications of AI have high probability of being the most disruptive due to the high levels of global competition. This fact has also been ascertained by 92% of manufacturing executives, thereby, confirming that AI is surely going to the ultimate drivers of innovation in the space [49].

Recent advances in artificial intelligence (AI) have enthused passionate interest from private sector, and public sector &governments all across the globe as they anticipate higher likelihood of bulk-produced consumer product machinery with super human like intelligence a reality in near times. While AlphaGo deep mind became the first computer program to defeat a professional human Go player capturing headlines all across the globe, there are many other real breakthroughs in artificial intelligence waiting or are in the process of taking place in the near future. There are many impressive developments in artificial intelligence based computer programs that have made such technologies, which can learn and wisely respond including decision making in different ranges of real time areas and applications.

Some of the instances of preliminary growth of AI can be people visiting shopping websites and getting emails, alerts on predictable products, services later based on network of algorithms running in the background that records, processes, and analyses the data of such online behavior:

There has been many a literature on current advances in AI and the consequential implications related to jobs, skills, allied sectors and society. Not much analysis has been conducted on the explicit impact of AI on India's promising economy.

Also, India must surely and transitionally create

workforce and environment to adopt based on a programmed framework of national policy to propel AI growth, innovation, adaptation, and propagation in various sectors and not just concentrating on merely consumer goods and information technology (IT) services. AI's inclusion shall bring in new distinctive opportunities with challenges for India, both in the short, medium and long term periods [42].

Therefore, the goal of this paper is to understand how the concept of AI can be applied in various manufacturing applications so that Indian manufacturing companies can fulfill the necessary requirements for its successful implementation and development.

II. LITERATURE REVIEW

The technology of Artificial Intelligence (AI) has been a point of discussion for university researchers for a period of 30 years [6],[38]. It has been seen that the Japanese have shown the world business community successes in the form of manufacturing steel, cars, electronics, and computer chips. In recent times, Japan declared their Fifth Generation Project goal, "think". There were instantaneous reactions from the rest of the world. The U.S. Government also came up with programs such as the Defense Advanced Research Projects Agency (DARPA) Also, Britain started the Alvey Committee and European community formed European Strategic Programs for Research and Development in Information Technology (ESPRIT).

During the early stages in 1960s, work on artificial intelligence experienced a rise in fame when some relatively audacious claims were made about future capabilities which may emerge, more in the vicinity of machine translation. As these claims could not occur as thought, research funds also became scant. These were later activated in some ways with the Japanese declaration of their Fifth Generation Project. In the 21st century artificial intelligence (AI) has developed into an important domain of research in practically all categories that include science, engineering, medicine, business, accounting, finance, marketing, economics, stock market, education and law, including others [16], [19], [20], [24], [26], [29], [37]. Tracking of such AI expansion has become a very difficult task [1], [2], [13]. There are many other fields of knowledge which are being looked upon as AI applications tend to increase [9], [10], [14], [15], [18], [28], [35].

Both businesses and non businesses using information technology are now considering a major shift to AI, clearing major obstacles and hindrances in the path of applications [3], [4], [8], [12], [30], [34]. One of the main motivators for AI caters to requirements of new players to understand the basic structure of AI literature [5], [7], [11], [17], [22], [25], [27], [31], [32].

Different literatures point towards different areas of artificial intelligence that can be divided into sixteen categories [5], [7], [17], [25], [27]. These are reasoning, programming, artificial life, belief revision, data mining, distributed AI, expert systems, genetic algorithms, knowledge representation , systems, natural language understanding, machine learning, neural networks, theorem proving, constraint satisfaction, and computation theory [23],[33], [39], [40].
There are certain objectives:
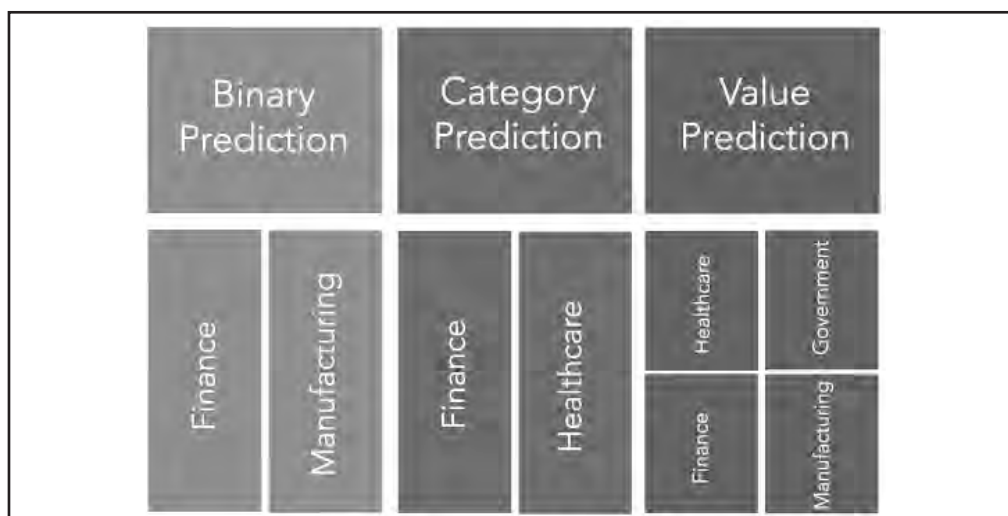
Fig. 1. Prediction types for different sectors
Source: https://www.cloudtp.com/doppler/hot-topics/ai-is-here-and-it-will-change-everything/ [43]

(i) To identify different aspects of Artificial Intelligence.
(ii) To understand the characteristics of Artificial Intelligence in manufacturing process.
(iii) To observe the trends in AI applications in manufacturing and allied sectors.
(iv) To understand availability of funding in AI research in manufacturing.

III. RESEARCH METHODOLOGY

In this research paper, our intention was to identify the practicalities of Artificial Intelligence applications in manufacturing sector. To understand this, we collected secondary data from various published sources such as journals, published reports. Some tables and figures have also been used based on secondary data sources. The trends were also collected from reputed sources and were acknowledged. A preliminary investigation helped in construction of the literature review part and observation technique was used to build the periphery of discussion and analysis.

IV. DISCUSSION AND ANALYSIS

A. Areas of AI Applications

In manufacturing, there are different areas where manufacturing and allied brands can explore these as separate AI projects:
1. Maintenance
2. Supply Chain
3. Yield Optimization
4. Fault Detection / QA Automation
5. Facility Operations
6. Staffing

1) Maintenance

Different AI techniques such as machine learning with neural networks and fuzzy logic leads to predictive maintenance. Predictive maintenance can be defined as a technique to forecast or anticipate the future failure point of machine components, so that such can be replaced just before it reaches failure stage, according to planned arrangement. This helps in minimizing equipment downtime along with maximization of component lifetime. In this technique, different parameters are measured continuously so that connections can be predicted within the component life cycle. An example can be readings of the vibration of a bearing at regular intervals until the component fails. This involves using machine learning techniques using training, testing, and validation of samples for future estimation of possibility of component failure with immediate replacement of such component [47].

According to Deloitte, an AI-enabled predictive maintenance system can increase equipment uptime by 10%-20%, reduce material spend by 10%, reduce maintenance planning time by upto 50%, and as a result shave off at least 10% off the overall maintenance costs. This is millions of dollars of savings per year, with a triple-digit ROI if everything is operationalized properly.

2) Supply Chain

A complex manufacturing process can utilize tens of thousands of parts. All of them have to be sourced, delivered, and stocked. It is essential that this chain remains highly functional and operational. It is one of the tenants of lean manufacturing.

Machine learning is considered the most important activity in the domain of supply chain. According to Adeel Najmi (Chief Product Officer at Symphony Retail AI), machine learning takes place when a machine reads the output, supervises the output accuracy, and continuously updates its own algorithmic model so that improved outputs can be achieved in future. He also contemplates that these may or may not always require use of data science techniques. He emphasizes on the ability of the machine to learn with experience and not just concentrate on just neural networks or some other form of supervised or unsupervised learning technique [45].

Also, machine learning is estimated to reduce costs related to transport and warehousing and supply chain administration by 5 to 10% and 25 to 40% respectively.

According to Satpathy [36], supply chain and logistics can be augmented to a great extent with IoT by the use of radio frequency identification (RFID), global positioning system (GPS), and in-vehicle monitoring technology (IVMT).

3) Yield Optimization

In modern times, most manufacturing concerns think on finding innovative ways to grow, improve product quality, and at the same time achieve short lead-time production fulfillment for customers.

As per a recent survey by A.T. Kearney and the World Economic Forum [53], the future of production lies in how manufacturers are considering pool suitable emerging technologies including Internet of Things, Artificial Intelligence, and machine learning that can

lead to accuracy of asset tracking, visibility of supply chain, and optimization of inventory.

4) Fault Detection / QA Automation

One of the most common methods used by multi-national corporations is Automation testing where test automation software is created and operationalized for automated tests for detection of faults and errors [51].

It has been observed that even cloud technologies like Selenium Grid are vulnerable in terms of lags in execution time, based on the frequency of nodes running, actual memory used, and the frequency of concurrent tests. Cloud computing enables increasing the ability to execute swift multi level scaling of applications (up and down), depending on the application workload, with sharing information across all implementable instances. Optimized solutions sought by testers can be achieved with the very high bars if AI is infused for large scale improvement in such processes. An acceptance criteria for such can be:

(i) Such tests should be executable at scale within the cloud to create more efficient and reliable solutions with every consequent run and release.

(ii) Such tests should not be location specific but rather be executable from any place around the globe, be device independent with different levels of bandwidth, and suitable for all possible environments.

(iii) Speed tests should be easy even for the most complex problems and should take minimum executable minutes and not stretch to longer or indefinite periods of time [44].

(iv) Facility Operations: Facilities managers face a very complex task of overviewing and recollecting details linked to everyday operations. Artificial intelligence in facilities management increases the ability of systems to use self-optimizing systems, power-driven by the Internet of Things (IoT), reduces machine-work time for team members. For instance, self-vacuuming and self-mopping devices are using artificial intelligence to chart out a floor, clean them, and return to docking station upon completion of predetermined work [40].

Artificial intelligence provides supplementary view into and much larger span of control over environmental and facility controls, along with realizing these benefits:

(i) Artificial Intelligence can open new source of revenue. For instance, minimizing energy usage to construct a net-zero energy location can efficiently double capital planning ability.

(ii) Improved predictability and demand forecasting

through Artificial Intelligence can improve preventative maintenance planning and predictability. Facilities managers can strategically segment capital and operational costs, thereby, controlling overall facilities expenditures.

(iii) Automated reporting and self-optimization can detect potential problems before they can take place. Artificial intelligence leads to automated reporting and scheduling of work orders that includes entering data into a computerized maintenance management system (CMMS), when integrated properly.

(iv) Artificial Intelligence using IoT helps in integration virtually with any system that is interconnected. This can lead not only to easy reporting but also can be stored and processed in cloud-based technologies, Therefore, IoT systems connected systems can combine with more systems and augment potential savings.

(v) Artificial Intelligence enhances inhabitant experiences by locating potential risks. Reduction in poor facilities management can lead to higher profitability; it can result in reducing health problems, like severe allergies or uncomfortable work conditions. Artificial intelligence can smoothly identify these risks in the same way as identifying potential equipment malfunctions.

(vi) Staffing: New opportunities can arise when artificial intelligence (AI) facilitates recruiters by increasing hiring time more efficiently and managing candidate preliminary short listing and selection. Large datasets can be worked upon using machine learning to perform tasks and gather insights, AI solutions can also provide necessary support during many diverse stages of the recruitment process [49]. AI tools can also be flexibly used for increasing human effectiveness and endeavor in the sourcing process. Software based solutions can help companies by writing suitable job descriptions with language analysis and providing suitable recommendations for hiring outputs that the system has processed.

Chatbots using Natural language processing (NLP) is a foundational concept in Artificial Intelligence. It refers to a machine's ability to create information based on analyzing human language. Artificial intelligence can be applied to gather highly specific information from visual data. Statements and facial expressions can be analyzed to give recruiters data about potential dishonesty or emotions like contempt or surprise (interview process using Skype). Subjective factors like culture fit are still too difficult for computers to interpret, and still many developments are to be made in natural language processing and sentiment analysis. AI is, however, still

improving rapidly, thanks to the constant generation of new data in the world [49].

B. Trends of AI in Manufacturing

As seen in fig. 2, forecasts have been made for different sectors including manufacturing sector, where growth forecast without AI stands at $73.3 US billion. With AI, manufacturing forecasts have been made to around $32.8 US billion. This is an additional 44.74% of the base estimate. Some of the areas where the impact is already visible include quality assurance where computer visualization enhancements using AI algorithms are detecting product defects with greater efficiency. Another important aspect can be to detect efficiency of factory employees with accuracy for compensation determination. Also, factory workers can gather raw materials from the shelf with automatic stock recording and updation without any manual process having been involved.

AI is also capable of tracking causes and reasons by analyzing variety of data captured using IoT (Internet of Things).This can lead to generation of new ideas and unimaginable solutions for manufacturing and logistical problems.

C. Funding in AI Research in Manufacturing

Funding has always been a critical issue for AI research. Although, in the beginning in the 1960s, AI concept could not go more than just a concept. Recent trends show massive funding arriving from high growth potential companies and new AI based startups are encouraged to redesign the industrial framework. In 2017, around $12 billion of venture funds were raised in US and Chinese companies. Based in Japan, Softbank managed to gather USD 100 billion from many international investors which also included Saudi Arabian investors. US companies have also raised USD 1.2 billion with Silicon Valley's VC funds. Chinese startup, SENSETIME also garnered more than USD 1.2 billion with an additional USD 1 billion also being raised up [48].

The two major powerhouses in AI have been China and USA. On one hand, China has multibillion dollar companies such as Alibaba, Baidu, Tencent, and Huawei technologies which are very interested and continue to invest huge funds in AI research. These companies have received healthy support from their own government which has already embraced the use of facial recognition. On the other Side, the US companies such as Google, Microsoft, IBM, Facebook, Amazon, Apple, and other
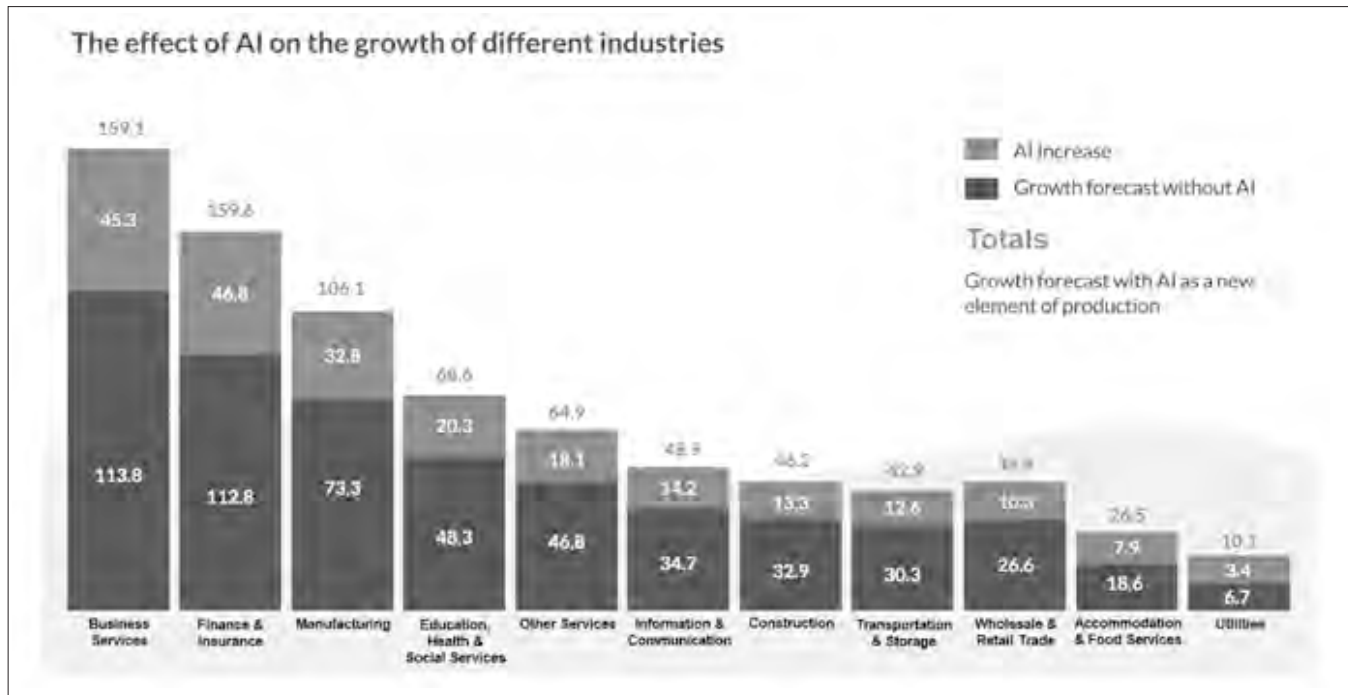

Fig. 2. Growth prediction of AI in the year 2035
Source: https://www.plantautomation-technology.com/articles/the-future-of-artificial-intelligence-in-manufacturing-industries [51]

firms have invested trillions of dollars into AI research in phases [48].

V. RESEARCH FINDINGS AND CONCLUSION

Some of the major findings of this research can be summarized as follows:
(i) Maintenance, supply chain, yield optimization, fault detection / QA automation, facility operations, staffing etc. are some of the major areas of manufacturing where continuing research is going on in the field of AI.
(ii) Manufacturing with AI shows a major boost in manufacturing production as seen in fig. 2 (almost 44%).
(iii) The rate of funding for AI is increasing, with global powers like US, China, and Japan integrating AI research as a part of their future transformational plan [41].
(iv) The future prospects of AI have just begun with more major and significant transformation of manufacturing sector yet to be seen in India and worldwide [21].

VI. SUGGESTIONS

In India, AI implementation can start with Make in India program as has been initiated by government of India. It must generate special advantages for manufacturers that can include soothing rules and regulations along with removing trade barriers so that the following can be achieved:

More investments are needed in automation research within the country by building special research laboratories and engineering design studios in the next two to three years.

They must initiate region based innovation clusters, districts, and corridors by structuring strong networks around manufacturing automation, and robotics between educational universities and new businesses in India.

They must raise ideas to make India a global center for machine intelligence based innovation in manufacturing and allied areas. Larger MNCs should work on PPP (public –private partnerships) to align AI implementation policies with actual implementable plans to be carried out by private companies.

VII. FUTURE WORK

Current research is based on secondary sources which highlight the prospects of AI in manufacturing and allied areas. Future research can be conducted at a much deeper level for the manufacturing sector that shall lead to understanding of certain areas of manufacturing and need for AI implementation in those areas.

REFERENCES

[1] J. L. Ambite and C. A. Knoblock, "Planning by rewriting," *Journal of Artificial Intelligence Research*, vol. *15*, pp. 207-261, 2001. doi: https://doi.org/10.1613/jair.754

[2] M. Balazinski, E. Czogala, K. Jemielniak, and J. Leski, "Tool condition monitoring using artificial intelligence methods," *Engineering Applications of Artificial Intelligence*, vol. *15*, no. *1*, pp.73-80, 2002.

[3] R. Barzilay, N. Elhadad, and K. R. McKeown, "Inferring strategies for sentence ordering in multidocument news summarization," *Journal of Artificial Intelligence Research*, vol. *17*, no. 1, pp. 35-55, 2002. Retrieved from https://dl.acm.org/citation.cfm?id=1622812

[4] J. Baxter and P. L. Bartlett, "Infinite-horizon policy-gradient estimation," *Journal of Artificial Intelligence Research*, vol. *15*, pp. 319-350, 2001. Retrieved from https://arxiv.org/abs/1106.0665

[5] A. Becker, R. Bar-Yehuda, and D. Geiger, "Randomized algorithms for the loop cutset problem," *Journal of Artificial Intelligence Research*, vol. *12*, pp. 219-234, 2000. [Online]. Available: https://arxiv.org/pdf/1106.0225.pdf

[6] R. A. Brooks, "Cambrian Intelligence: The early history of the new AI," *The International Journal of Systems & Cybernetics*, 2001.

[7] X. Chen and P. V. Beek, "Conflict-directed backjumping revisited," *Journal of Artificial Intelligence Research*, vol. *14*, pp. 53-81, 2001.

[8] A. Darwiche, and P. Marquis,"A knowledge compilation map," *Journal of Artificial Intelligence Research*, vol. *17*, pp. 229-264, 2002. [Online]. Available: https://arxiv.org/abs/1106.1819

[9] T. Eiter, W. Faber, N. Leone, G. Pfeifer, and A. Polleres, "Answer set planning under action costs," *Journal of Artificial Intelligence Research*, vol. *19*, pp. 25-71, 2003.

[10] L. Finkelstein, S. Markovitch, and E. Rivlin, "Optimal schedules for parallelizing anytime algorithms: The case of shared resources," *Journal of Artificial Intelligence Research*, vol. *19*, pp. 73-138, 2003.

[11] D. Gamberger and N. Lavrac, "Expert-guided subgroup discovery: Methodology and application," *Journal of Artificial Intelligence Research*, vol. *17*,no. *1*, pp. 501-527, 2002. [Online]. Available:

https://dl.acm.org/citation.cfm?id=1622825

[12] Y. Gao and J. Culberson, "An analysis of phase transition in NK landscapes," *Journal of Artificial Intelligence Research*, vol. *17*, vol. *1*, pp. 309-332, 2002. doi: https://doi.org/10.1613/jair.1081

[13] J. Diez, A. Bahamonde, J. Alonso, S. Lopez, J. J. del Coz, J. R. Quevedo, J. Ranilla, O. Luaces, I. Alvarez, L. J. Royo, and F. Goyache, "Artificial intelligence techniques point out differences in classification performance between light and standard bovine carcasses," *Meat Science*, vol. *64*, no. *3*, pp.249-258, 2003. Doi: https://doi.org/10.1016/S0309-1740(02)00185-7

[14] P. D. Grunwald and J. Y. Halpern, "Updating probabilities," *Journal of Artificial Intelligence Research,* vol. *19*, pp. 243-278, 2003. [Online]. A v a i l a b l e : https://www.aaai.org/Papers/JAIR/Vol19/JAIR-1909.pdf

[15] C. Guestrin, D. Koller, R. Parr, and S. Venkataraman, "Efficient solution algorithms for factored MDPs," *Journal of Artificial Intelligence Research*, vol. *19*, pp. 3 9 9 - 4 6 8 , 2 0 0 3 . [O n l i n e] . A v a i l a b l e : https://www.jair.org/index.php/jair/article/download/10341/24723/

[16] W. E. Halal, "Artificial intelligence is almost here," *On the Horizon - The Strategic Planning Resource for Education Professionals*, vol. *11*, no. *2*, pp. 37-38, 2003. Doi: https://doi.org/10.1108/10748120310486771

[17] J. Hong, "Goal recognition through goal graph analysis," *Journal of Artificial Intelligence Research*, v o l . *1 5* , p p . 1 - 3 0 , 2 0 0 1 . d o i : https://doi.org/10.1613/jair.830

[18] F. Lin, "Compiling causal theories to successor state axioms and STRIPS-like systems," *Journal of Artificial Intelligence Research*, vol. *19*, pp. 279-314, 2003. doi: https://doi.org/10.1613/jair.1135

[19] V. P. Masnikosa, "The fundamental problem of an artificial intelligence realization," *Kybernetes*, vol. *27, n o . 1 ,* p p . 7 1 - 8 0 , 1 9 9 8 . d o i : https://doi.org/10.1108/03684929810200549

[20] K. Metaxiotis, K. Ergazakis, E. Samouilidis, and J. Psarras, "Decision support through knowledge management: The role of the artificial intelligence," *Information Management & Computer Security*, vol. *11*, n o . *5* , p p . 2 1 6 - 2 2 1 , 2 0 0 3 . D o i : https://doi.org/10.1108/09685220310500126

[21] NITI Aayog. (2018). *National Strategy for Artificial Intelligence (Discussion-Paper)*. Accessed: May 25, 2 0 1 9] . [O n l i n e] . A v a i l a b l e : https://niti.gov.in/writereaddata/files/document_publica

tio n / N a t i o n a l S t r a t e g y - f o r - A I - D i s c u s s i o n - Paper.pdf?utm_source=hrintelligencer

[22] P. F. Patel-Schneider and R. Sebastiani," A new general method to generate random modal formulae for testing decision procedures," *Journal of Artificial Intelligence Research*, vol. *18*, pp. 351-389, 2003. [O n l i n e] . A v a i l a b l e : https://www.aaai.org/Papers/JAIR/Vol18/JAIR-1810.pdf

[23] Y. Peng and X. Zhang, "Integrative data mining in systems biology: From text to network mining," *Artificial Intelligence in Medicine*, vol. *41*, no. *2*, pp. 83-86, 2007. doi: 10.1016/j.artmed.2007.08.001

[24] W. Raynor, *The International Dictionary of Artificial Intelligence*, 2008.

[25] J. Singer, I. P. Gent, and A. Smaill, "Backbone fragility and the local search cost peak," *Journal of Artificial Intelligence Research,*" vol. *12*, pp. 235-270, 2000. doi: https://doi.org/10.1613/jair.711

[26] V. L. Stefanuk and A. V. Zhozhikashvili, "Productions and rules in artificial intelligence," *Kybernetes: The International Journal of Systems & C y b e r n e t i c s* , v o l . *3 1 ,* n o . *6* , 2 0 0 2 . d o i : https://doi.org/10.1108/03684920210432790

[27] P. Stone, M. L. Littman, S. Singh, and M. Kearns, "ATTac-2000: An adaptive autonomous bidding agent," *Journal of Artificial Intelligence Research*, vol. *15*, pp. 189-206, 2001.

[28] P. Stone, R. E. Schapire, M. L. Littman, J. A. Csirik, and D. McAllester, "Decision-theoretic bidding based on learned density models in simultaneous, interacting auctions," *Journal of Artificial Intelligence Research*, vol. *19*, pp. 209-242, 2003. [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.336.6816&rep=rep1&type=pdf

[29] D. P. H. Tay and D. K. H. Ho, "Artificial intelligence and the mass appraisal of residential apartments," *Journal of Property Valuation and Investment*, vol. *10*, n o . *2* , p p . 5 2 5 - 5 4 0 , 1 9 9 2 . D o i : https://doi.org/10.1108/14635789210031181

[30] M. Tennenholtz, "Competitive safety analysis: Robust decision-making in multi-agent systems," *Journal of Artificial Intelligence Research*, vol. *17*, pp. 3 6 3 - 3 7 8 , 2 0 1 1 . [O n l i n e] . A v a i l a b l e : https://arxiv.org/abs/1106.4570

[31] S. M. Kim, "Irrelevance and relevance of Godel's theorems to artificial intelligence," *Kybernetes*, vol. *24*, n o . *4* , p p . 7 7 - 8 3 , 1 9 9 5 . D o i : https://doi.org/10.1108/03684929510089367

[32] S. W. Kim and S. M. Kim, "Turing-computability

and artificial intelligence: Godel's incompleteness results," *Kybernetes*, vol. *24*, no. *6*, pp. 57-62, 1995. doi: https://doi.org/10.1108/03684929510094316

[33] S. Wang, Y. Wang, W. Du, F. Sun, X. Wang, C. Zhou, and Y. Liang, "A multi-approaches-guided genetic algorithm with application to operon prediction," *Artificial Intelligence in Medicine*, vol. *41*, no. *2*, pp.151-159, 2007. Doi: https://doi.org/10.1016/j.artmed.2007.07.010

[34] E. Wiewiora, "Potential-based shaping and Q-value initialization are equivalent," *Journal of Artificial Intelligence Research*, vol. *19*, pp. 205-208, 2003.

[35] D. E. Wilkins, T. J. Lee, and P. Berry, "Interactive execution monitoring of agent teams," *Journal of Artificial Intelligence Research*, vol. *18*, pp. 217-261, 2003. doi: https://doi.org/10.1613/jair.1112

[36] D. Satpathy, "Internet of things: A boon for supply chain management," *Indian Journal of Computer Science*, vol. *4*, no. *2*, 2019. doi: 10.17010/ijcs/2019/v4/i2/144273

[37] N. Wongpinunwatana, C. Ferguson, and P. Bowen, "An experimental investigation of the effects of artificial intelligence systems on the training of novice auditors," *Managerial Auditing Journal,* vol. *15*, no. *6*, pp. 306-318, 2000. doi: https://doi.org/10.1108/02686900010344511

[38] B. Zanuttini, "New polynomial classes for logic-based abduction," *Journal of Artificial Intelligence Research*, vol. *19*, pp. *1-10*, 2003. [Online]. Available: https://arxiv.org/abs/1106.5263

[39] X. Zhou, B. Liu, Z. Wu, and Y. Feng, "Integrative mining of traditional Chines medicine literature and MEDLINE for functional gene networks," *Artificial Intelligence in Medicine*, vol. *41*, no. *2*, pp. 87-104, 2007. Doi: https://doi.org/10.1016/j.artmed.2007.07.007

[40] QSI Facilities, "Artificial intelligence in facilities management: How will AI impact FM in the next 5 years?" 2018. [Online]. Available: http://blog.qsifacilities.com/artificial-intelligence-in-facilities-management

[41] D. M. West and J. R. Allen, "How artificial intelligence is transforming the world," 2018. [Online]. Available: https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/

[42] A. Basu and E. Hickok, "Artificial intelligence in the governance sector in India (Working Draft)." (n.d.) [Online]. Available: https://cis-india.org/internet-governance/ai-and-governance-case-study-pdf

[43] D. Linthicum, "AI is here and it will change everything," 2017. [Online]. Available: https://www.cloudtp.com/doppler/hot-topics/ai-is-here-and-it-will-change-everything/

[44] T. Cser, "AI in test automation." [Online]. Available: https://dzone.com/articles/ai-in-test-automation

[45] S. Banker, "20 things to know about artificial intelligence for supply chain management," 2019. [Online]. Available: https://www.forbes.com/sites/stevebanker/2019/01/01/20-things-to-know-about-artificial-intelligence-for-supply-chain-management/#5b93a3a25371

[46] Y. Kuflinski, "AI in manufacturing: The rise of intelligent production." [Online]. Available: https://www.iflexion.com/blog/ai-manufacturing

[47] Petrochemical maintenance.com, "What is the predictive maintenance." [Online]. Available: http://www.mantenimientopetroquimica.com/en/rcm/144-articles-of-interest/100-what-is-predictive-maintenance.html

[48] K. Walch, "The race for AI dominance is more global than you think," 2018. [Online]. Available: https://medium.com/cognilytica/the-race-for-ai-dominance-is-more-global-than-you-think-e01a0c34d64e

[49] A. Paramesh, "How can AI help in staffing and recruiting," 2018. [Online]. Available: https://medium.com/the-future-of-staffing/how-can-ai-help-staffing-agencies-cce8cce179e7

[50] PlantAutomation Technology.com, "The future of artificial intelligence in manufacturing industries." [Online]. Available: https://www.plantautomation-technology.com/articles/the-future-of-artificial-intelligence-in-manufacturing-industries

[51] A. Pradhan, "Automated testing – the future of quality assurance,". [Online]. Available: https://www.softwebsolutions.com/resources/qa-automation-consulting-services.html

[52] K. Schwab, "The fourth industrial revolution: What it means, how to respond," 2016. [Online]. Available: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/-respond/

[53] World Economic Forum, "Technology and innovation for the future of production: Acclerating value creation," 2017. [Online]. Available: http://www3.weforum.org/docs/WEF_White_Paper_Technology_Innovation_Future_of_Production_2017.pdf

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Professor Sandeep Bhattacharjee has been working as an Assistant Professor (Grade- II, Marketing Management)with Amity University, Kolkata for four years. He was previously working as Assistant Professor of Marketing with Usha Martin Education & Solutions group. He has more than 11 years of experience with over 10 years in academics & a year of corporate experience under his belt. He has qualified NET (UGC) in Management in December 2012. His previous experience includes working with IIM Calcutta as a teaching associate for a year and a half in the domain of neural networks, data mining, and corporate social responsibility. His research areas include applied data-mining in marketing & other social areas of development with applied analytics. He has also conducted training on SPSS and statistics modules for academics and industries. He is also certified in business intelligence tools and data analytics.