

IMPLEMENTATION AND SENTIMENT ANALYSIS OF ARTIFICIAL INTELLIGENCE IN HEALTH CARE INDUSTRY

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Abstract

The implementation of Artificial Intelligence and Information Technology is taking a quantum leap in every industry. In recent years there has been an intensified focus on the utilization of Artificial Intelligence in different areas to take care of the complex issue. The same goes for the healthcare services industry. With the increase in complexity and rise of data in medical industry adaptation of Artificial Intelligence is growing at a rapid pace, it is bringing a paradigm shift to healthcare. The use of AI can enhance patient engagement and also through prediction it can help the hospitals better resource allocation. Although there are lots of opportunities for Artificial Intelligence in the health care sector but currently there are limited examples of such techniques being successfully deployed. This study aims to understand the consumer behaviour towards the adaptation of Artificial Intelligence in Health Care.

Key words: Artificial Intelligence, Sentiment Analysis, Structured and Unstructured Data

Introduction

Healthcare is a very important and crucial sector. Recently Artificial Intelligence already started making a mark in this industry. Technology is the driving force for any industry. In healthcare also AI assists the doctors in their practice and it helps to make better decisions in critical areas like radiography. AI helps in medical research. Modern medications face significant challenges to understand or analyse structured and unstructured data to detect or treat disease. Artificial Intelligence having analytical capabilities can understand the data through pattern recognition predict diagnosis and treatment of the disease. Artificial Intelligence gathers clinical data from a large data set and compares those data with a predefined category and finally provides accurate results. It also helps in medical screening, echocardiography, or even in surgeries. In surgeries, robotic tools controlled by AI can be used to tying the knots to close wounds. Because of AI using a remote presence of a robot doctors can easily communicate with his/her patients or kinds of stuff and even operate from a remote location. In the field like healthcare, a small can cost a life, so by implementing AI it provides fast accurate, and at the same time reduce errors. AI has the potential to predict infectious disease outbreak and source of the epidemic.

According to the study, it is shown that with the implementation of AI medical treatment is improved by 40%, at the same time it reduces the cost by 50%. According to a survey conducted by PwC 54% of worldwide consumers are ready to receive AI-enabled healthcare service. According to Accenture strategies health AI, the market size will increase from \$600 mn in 2014 to \$6.6bn in 2021 which is approximately 40%. Since the medical field is very critical, the healthcare market is always revenue-generating.

Although there are lots of benefits and applications of using AI in healthcare sector and also it generates more revenue but at the same time the primary concern for the patients is whether AI is going to replace human physicians or not. Customer Satisfaction is very important for any industry. In this context Sentiment Analysis plays crucial role in understanding of the customers.

Sentiment Analysis is to find out information, which are generally available in textual format and analysis those data. The information can be available in different form like it can be judgmental or an opinion or an emotional state or attitudes. It uses different tools and techniques to find key phrases from a textual document and finally searches different positive words like happy, great, satisfied and negative words like sad, disappointed etc. And

thus, understand the consumer behavior. Before adaption of any change its required to understand what, the consumers are thinking about the change and thus, implement the changes accordingly.

Objective:

The primary objective of this paper is is mainly focus on the adaptation of Artificial Intelligence in the healthcare Industry. Also perform Sentiment Analysis regarding AI in healthcare.

Literature Review:

The Healthcare industry is the most sensitive industry. That is why researchers are trying their best to find conclusive evidence before the full-fledged implementation of AI in the health care domain. The main aim of this literature review is to find the importance of AI in the healthcare sector, also find out the key concern area in this domain and finally find out the gap in this field.

Technology is the backbone of any industry, and that is why healthcare sector also feels the importance of the technology and have started to put more money in technology like Artificial Intelligence or Machine learning for the betterment of the sector. Although artificial intelligence in health care domain have provided many encouraging solutions but at the same time some challenges still exists during the assessment off the tools and technologies during literature review, that is why it is very hard to interpret the effect of these tools. When innovation meets with the technical solutions that can provide a fruitful solution. Like when an AI based results coupled with different technology like AR/VR, RPA, automation or IOT, those solutions can be very encouraging. For this reason, it is difficult to predict in advance [1].

In the “self-administration” space, conversational specialists are already there to provide information related to quit alcohol or smoking, breathing problem, diabetes, depression. There may be many Embodied Conversational Agents or chatbots available but the assessment of these specialists is less [2]. The vast majority of the youth believe the utilization of a smart virtual coach of the shrewd virtual medical assistant to observe their medical problems at their houses. At the same time, there is not much interest in psychological well-being assists carry out by the technology [3].

Legitimate usage of information sources, for example, Electronic Health Record databases could dramatically affect health care research and delivery. Since there are enormous amounts of free data and information is accessible in EHRs, there has been a colossal increment in research methodology in Artificial Intelligence, Machine Learning and Natural Language Processing techniques and applications for the clinical space [4].

Social support helps to improve treatment outcome [3]. Informal or casual agents have the tendency to manage the machines to act as a social operator like humans. This type of help can help the individuals to fight against separation or despondency or abandonment or seclusion [5]. At the same time, studies have shown that individuals will by and large be dynamically more honest while cooperating with technology and innovation rather with humans [6].

AI Techniques

Usually, there are 3 types of AI techniques, i.e. (1) Machine Learning (2) Deep Learning (3) NLP

Machine Learning: ML involves the development of different algorithms for data analysis. Patient attributes which include name, age, gender, and medical outcomes like medication history, symptoms are the inputs of these algorithms. At the same time prediction of the disease, patient survival time, and tumor size is the output of the algorithm.

There are three types of the machine learning algorithm.

- **Supervised learning** – It is like the grouping of similar patients or similar diseases based on prior knowledge when you already know the feature or characteristics of different diseases [7].

- **Unsupervised learning** – When new diseases arrive and we classified those diseases by giving different names [7].
- **Semisupervised learning** – It is the mixture of both supervised and unsupervised learning. It is like we might aware of some form of viral diseases but we do not know all of them. However, semisupervised learning is not trustworthy compare to supervised learning algorithm [7].

Deep Learning: Deep learning is the sub-set of the machine learning algorithm. It is inspired by the neural network when we have to fetch data or output from a larger amount of data. When there is a large amount of data available then we have to layer them based on different parameters like a priority [8].

NLP (Natural Language Processing): The main aim of NLP is to extract and process textual or graphical or voice information to facilitate better decisions in clinical studies. From the disease-specific keyword or image NLP stores the data in the dataset to utilize it in the future [9]. NLP can able to read the X-ray report and also provide medication for the same having an accuracy of 90% [10].

Roles of AI in Healthcare

Some of the key areas of healthcare where AI played an important role are:

Health Examination and Risk Assessment

Artificial Intelligence takes unprocessed and uncleaned data from different devices like microphones or g-force sensors or cameras or gyrostats even devices like laptops or smartphones. Various ML techniques are used to understand different outputs from the unprocessed data and after that classify the outputs according to the behaviour of an individual and their wellbeing condition. This type of framework would now be able to permit the patients to figure out about their symptoms or the diseases and which in turn help them to treat themselves by own and at the same pass the information to the doctors. Currently, the use of smart healthcare devices, portable devices, and health monitoring devices has increased significantly [11].

Assist Individuals having different Disabilities

As per the study, there is about 16M people are currently suffering from different types of disabilities in the USA. And this figure is growing at a rapid pace mostly due to elderly people. This is a matter of concern since the ongoing healthcare infrastructure is not prepared to provide services to this huge bunch of patients. At the same, the modern infrastructure cannot even allow them to set up similar services at their houses rather transferring them to the hospitals [12]. To eradicate this type of problem smart healthcare devices or health monitoring robotics will use Artificial Intelligence and Machine Learning algorithms [13]. Presently different types of robots such as PePeRe or PARO give support and motivating Alzheimer patients. In the current time, the utilization of this type of social robots is useful to decrease anxiety in hospital patients having Alzheimer's or mental illness [14]. The clinical preliminaries exhibited the enhancement in sufferer participation, where the reality is that the consequences of psychological indications stay questionable [15].

Critical Care facilities

The information obtainable for patient protection or supervision services are increasing at a rapid pace. All the information recorded via Information stored via Electronic Health records just starts to expose the kinds of information that be utilized for improving patient care. The clinical care services will presumably, rather profoundly be affected by the Artificial intelligence, this service includes the interruption, counteraction, prior discovery, risk evaluation, analyze the benefits, diagnosis, forecasting, or customized therapy. The zone of the forecast, prior discovery, or threat evaluation of patients can be a productive application of Artificial Intelligence implementation [16].

Diagnosis

There are several instances of the utilization of Artificial Intelligence in diagnostic imaging. Diagnostic image recognition would now be able to separate among benign and malignant cancer and recognize the ligament injuries within the knee joint and detect ischemia, or anticipate the result performing successful examination for the bosom malignant growth. To compete for diagnosis or help in scanning an individual or even help the doctors in additional time on complex cases, image recognition can play an important role [17]. To separate malignant cells from or to discover or detect the microbes the use of histopathology diagnoses has been increasing with the help of different types of information. It also helps to analyze bacterial infections of different types of sickness that are caused by viruses or microbes [18].

Surgical Process

Artificial Intelligence currently turning out to be very significant when it comes to managing processes related to the surgery. AI helps in arranging wellsprings amount of data, which incorporates contamination normal history, anatomic data, patient risk factors, perception of qualities and cost, to support the experts and patients settle on better expectations with respect to the choices of surgery-related decision-making Process [19]. Artificial Intelligence applications give a strategic direction to the doctors who are going to perform the surgery in the operation theater, which reduces the risk of the surgery and operations can be performed more safely. Artificial Intelligence helps the team who are going to perform the operation in the OT thereafter, diminishing the risk of the operation, and eventually making surgery more secure and safer [20]. Remote-controlled automated clinical system process has been a critical effect on medications where doctors introduced high dosages of radiation and as a result, now it is possible to reach the anatomic areas where it is difficult to reach by human hands [21].

Personalized Management and Treatment Personalized Management and Treatment

Artificial Intelligence helps the doctors in the chemotherapy process. It helps the doctors to predict the outcome of the dosing on the patients and how they react to the dosing and help to design future dosages [22]. Polyp delineations can now be recognized by Natural Language Processing in the medical reports and thus it will help to give rise to take the critical decision and thus assist practitioners with choosing the best o perception extends for colonoscopy tests [23]. Artificial Intelligence is trying to build a model that will allow the patient to continue their medical therapy in their home [24]. Artificial Intelligence can likewise be utilized to discover similar types of diseases by applying cluster analysis among different groups of patients in the Electronic Health Record. It can be useful to predict or detect the disease from past records [25].

Artificial Intelligence assists to find out the areas or countries which are facing a huge impact for a particular disease. Biomarker or the sociomarkers uses different AI or ML techniques to distinguish the normal asthma patients to those who are having a high level of asthma or breathing problem and have to visit nursing homes on a regular basis [26]. The sociomarker-based approach is able to correctly anticipate two out of three patients in danger without knowing specific symptom-related features [27].

Despite the fact that there are a large number of opportunities and development happen in the field of healthcare due to the effect of AI but at the same time, there are lots of consequences due to the same.

From the last few years, there are many parameters that helped to trigger the enthusiasm and accelerate the publicity of artificial intelligence. Although with the help of different machine learning techniques predictive analytics can now assist the doctors to evaluate the risks associated with a patient at the initial stage understanding the relationship between the input variable with the outcome variable is very problematic. A small error might cost a life [28]. Artificial Language is not able to give assurance about the integrity or the impartiality or the truthfulness [29].

The advancement of Artificial intelligence strategies in clinical areas provides better control and more affordable storing capacities [30]. From the writings of “Geoffrey Hinton”: artificial intelligence and machine learning algorithm will definitely show significant improvement over radiologists in the next 5 years. According to the research by scientists and researchers Over 25 million individuals do not get proper healthcare facilities in

the USA and in rest of world conditions are worse than this With the increase in the elderly population and with the introduction of new types of diseases on a regular basis, the need for doctors is also increasing. But with the lack of doctors, they are not able to full the demand [31].

The literature reviews, provide insights about how AI is transforming the healthcare industry but still, there are some areas where there are some gaps exists in researches like understanding of consumer mindset towards the adaption of AI in healthcare still untouched by the researchers.

Relevance of Sentiment Analysis in Artificial Intelligence in Healthcare

Since there are both positive as well as negative effects in the utilization of artificial intelligence, it is necessity to perform deep down understanding of the sentiment of people when it comes to artificial intelligence in the healthcare industry.

Methodology

Sentiment analysis provides insights about what people are thinking about a particular topic. In this COVID 19 situation when there is limited medication available it is important to understand the mindset of people to understand their thinking on the implementation of automation in this industry. For the research purpose, we take Twitter data to do the sentiment analysis.

Twitter is an American social networking and blogging service where users can post their views or tweets or interact with other users comment on their post use hashtags to reach the post to a wider audience. Twitter is also very informative and has fewer fake profiles compared to other social networking platforms. That is why twitter data is best for further analysis.

Various tools have been used to extract those data and finally different programming language and platforms are used to get final output and then analyze those data.

Tools Used

Several tools and methodology are used to extract data from the twitter account. For the research purpose python programming language has been used to do the web scrapping from the twitter data. Web Scrapping is a powerful technique through which we can collect tweets or information from any website which reduces the time taken during manual scrapping. Python is a developer friendly high-level programming language. So for web scrapping python is very suitable. At the same time to run the python code, Spyder platform has been used. Spyder is user friendly to do the python coding. Also, it is required to create a developer account in app.twitter.com to link python with the twitter account. Also, twitterscraper package was import in the python library to run the web scrapping in python. Finally, after the web scrapping put all the extracted data in a csv format for further procedure.

For sentiment analysis and data visualization, one of the best used programming languages is R-programming. R-Studio is a very useful platform to run the R-programming. R programming is a very user-friendly programming language to perform the statistical analysis. In the R-studio packages like syuzhet, lubridate, ggplot2, scales, reshape2, dplyr have to be added for performing the statistical analysis.

Sample Collection and Data Pre-Processing

This research paper is mainly based on secondary research, where the data has been collected from Twitter to understand the sentiment of people regarding the implementation of artificial intelligence in the healthcare sector. For this purpose, 500 latest tweets were collected using hashtags related to AI in healthcare. Using web scrapping tweets, retweets, no of likes, no of followers were collected from the twitter. Data Pre-processing or data cleaning is a necessary step in analysis. That is why in the pre-processing only the tweets have been extracted from the entire file using the R-programming language. After that, in data cleaning stage punctuation, numbers, URLs, stopwords, white space were removed since these are not required for the analysis.

Following is a sample how a raw input looks like.

```
[1] The future for artificial intelligence in healthcare looks radiant with opportunities consistently on the rise. \n@forbes\n highlights the need for expectation management of the capabilities of AI as its efficiency & value will only improve over time.

[2] Artificial Intelligence in Healthcare MARKET REPORT 2020 TO 2028 MARKET ANALYSIS, SIZE, SHARE, TRENDS, KEY PLAYERS, DRIVERS AND FORECAST - Cole of Duty: Artificial Intelligence in Healthcare MARKET REPORT 2020 TO 2028... http://dlvr.it/RZbSXP #AI #artificialintelligence #CTO

[3] A new AI platform from GNS Healthcare acts as a virtual patient, allowing drugmakers to experiment in the virtual world before treating patients in clinical trials

[4] we are kicking off today our Earth globe europe-africa country of the Month campaign , presenting to you this time some of the ways in which Tunisia is applying #AI solutions in Public finance management and Healthcare.

[5] It's unlikely that #robots & computers will totally take the place of doctors and nurses, but #AI can't be ignored in its efforts to revolutionize the #healthcare industry. Not only does it predict outcomes & improve diagnostics...
```

Figure 1: Sample finding-Before the Data Cleaning stage of the Twitter data

Following is the after the effect of data cleaning performed on the raw data.

```
[1] future artificial intelligence healthcare looks radiant opportunities consistently rise forbes highlights need expectation management capabilities ai efficiency value will improve time

[2] artificial intelligence healthcare market report market analysis size share trends key players drivers forecast cole duty artificial intelligence healthcare market report ... ai artificialintelligence cto

[3] new ai platform gns healthcare acts virtual patient allowing drugmakers experiment virtual world treating patients clinical trials

[4] kicking today earth globe europe africa country month campaign presenting time ways tunisia applying ai solutions public finance management healthcare

[5] unlikely robots computers will totally take place doctors nurses ai cant ignored efforts revolutionize healthcare industry predict outcomes improve diagnostics
```

Figure 2: Sample Finding-After the Data Cleaning stage of Twitter data

Next step is performing the sentiment analysis.

Measurement:

The data generated from the data cleaning stage is the actual input for the sentiment analysis and the data was run into the R programming.

In the first step the most frequent used terms in the data set were identified while searching artificial intelligence in healthcare using term document matrix. Then categorized the tweets into sentiments and classified into 10-point scale such as

- (1) Anger
- (2) Anticipation
- (3) Disgust
- (4) Fear
- (5) Joy
- (6) Sadness

(7) Surprise

(8) Trust

(9) Negative

(10) Positive

And finally measure the sentiment using a bar graph.

Data Analysis:

Term Definition Matrix helps to describe the frequency of any term which are used. So, using the term definition matrix the most common and frequent buzz words were identified. Following is the graph that shows the most common words available in the twitter data.

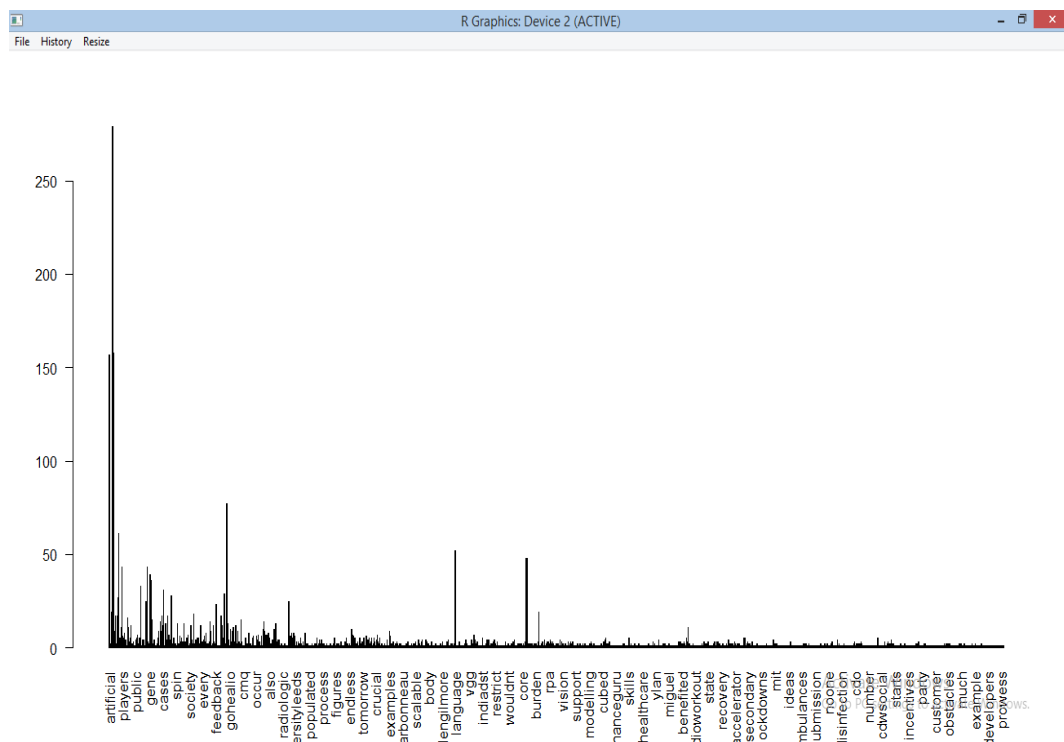


Figure 3:

Sample Finding-Bar Plot of most frequent words from Twitter dataset

From the above barplot we can see that terms like artificial, players, society, feedback, benefited, public, radiologic, gene are commonly used.

Now to get more detail insights about the, world cloud has been introduced for the research purpose. Word Cloud is used for better visualization and provide more detailed result over the bar plot. Word Cloud is cluster of most frequent words. The size of the word depends on the frequency of that particular word. So higher the frequency larger the size of the word and lower the frequency smaller the size of the graph.

Following is the Word Cloud made from the twitter data set.



Figure 4: Sample Finding-Word Cloud generated from the Twitter dataset

So, from the above word cloud, it provides a better understanding of the buzz word. Apart from the regular terms like healthcare, artificial intelligence, machine learning other important words like COVID, future, life, fight, application, which are positive word are visualized while running the code in R-Studio. So, from this visualization it can be understood that people are ready to adopt AI in healthcare in the future.

Next part includes the sentiment analysis of the twitter data.

Following is the sentiment score in the graphical format generated through the tweets.

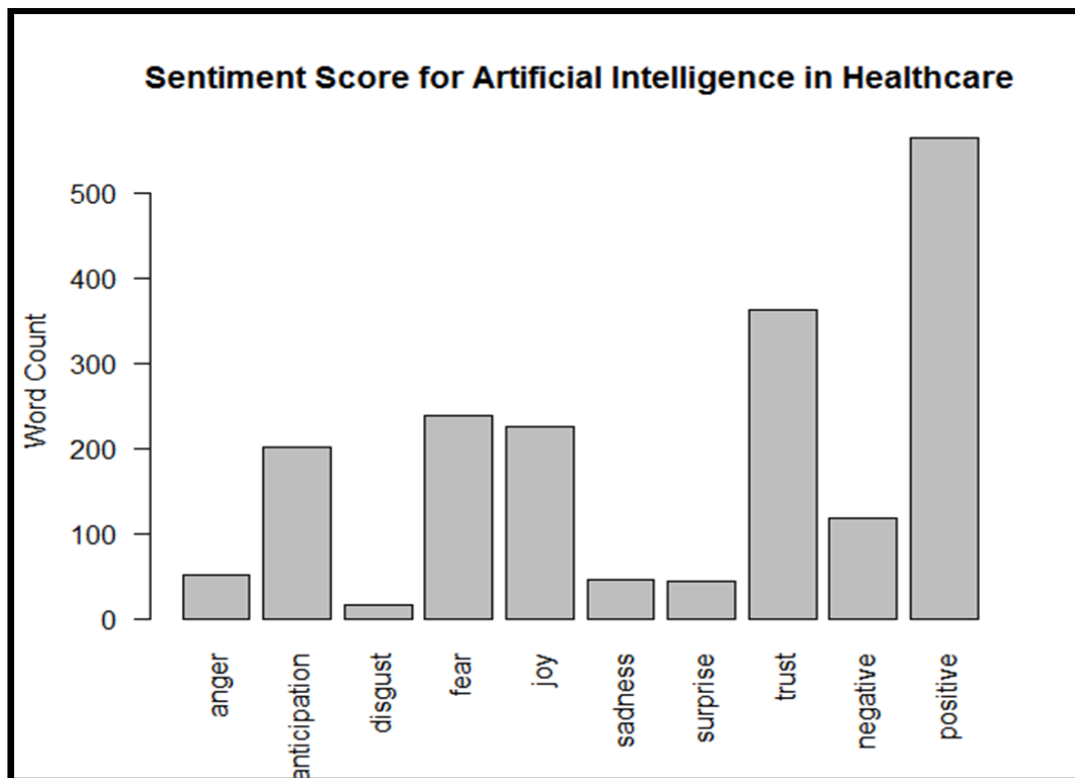


Figure 5: Sample Finding-Bar Plot of Sentiment Score generate from the Twitter dataset

After running the code in R-Studio different parameters/sentiments were generated. These sentiments are anger, anticipation, disgust, fear, joy, sadness, surprise, trust, negative and positive.

It is clearly visible from the sentiment analysis is that consumers are very positive about the implementation of AI in the healthcare industry. In this critical situation when traditional medication is not sufficient to cure the patient, the modern generation trust artificial intelligence, machine learning in this industry. Count of positive words exceeds 500 which is a very good sign and at the same time count of trustworthy words are around 400. But from the bar graph, it is visible that consumers have some fear in the implementation of artificial intelligence but still today's generation is more anticipated and has the joy to adapt to the current trend. Compare to the positivity count negativity count is very low which clearly state that artificial intelligence is a sustainable model in the field of healthcare. Consumers rarely feel disgust or feel sad in this implementation.

Limitations:

In this era of digital disruption technologies are changing at a rapid pace which impact the mindset of consumers. Today a person might very happy and provide good feedback but tomorrow the same person may feel provide bad comments on the same product. There might be some contradiction regarding the same.

Managerial Implications:

This study will be helpful to understand the consumer behaviour towards the adaption of AI in healthcare sector. From this research it is visible that consumers have positive attitude about the same, it surely will motivate other researchers or AI developers or employees who are working in this domain and definitely they will utilize these findings to provide better services.

Conclusion:

From the big MNCs to small production companies in each sectors automation, artificial intelligence is playing an important role. The Healthcare sector is the most sensitive and sophisticated sector for the implementation of AI. Although it is slow but people are now ready to adopt the change. From the development of precision medicine to the clinical areas such as detection of the malignant cell and also diagnosis and operation AI is stepping its footprint.

But still, there are some challenges in the sector. Healthcare is a sector where a small fault can be a reason for someone's death. And AI stands for technology and there is lack of practitioners who can handle such technology. So it is a huge concern. We have to provide knowledge to each employee who is directly or indirectly involved in such activity before the adaptation of the AI.

Also after the implementation of AI, there will be job loss in the market. Either you have to adapt to the new technology or you might be lost the lead in the race.

But at the same time, one of the biggest issues in healthcare is cost. Patients have to pay heavy fees to doctors or hospital administration for their treatment. Adaption of AI can have huge potential to reduce the cost. According to the study, administrative costs will be \$40 bn in 2020. So through the implementation of AI, we can reduce the cost. There will be certain costs like development, testing, R&D, or tuition cost but it will be fixed cost, and return on investment will surely increase thus it will reduce the burden on the patients.

Still, it is an early stage to decide whether AI will be very successful in the healthcare sector but from the research also we can conclude that today's generation is ready to welcome the implementation of artificial intelligence in healthcare domain.

References

1. J. Roski, G. W. Bo-Linn, and T. A. Andrews, "Creating value in health care through big data: Opportunities and policy implications," *Health Aff.*, vol. 33, no. 7, pp. 1115–1122, 2014.
2. K. Fitzpatrick, A. Darcy, M. V.-J., "Delivering cognitive behavior therapy to young adults with symptoms of depression and anxiety using a fully automated conversational agent (Woebot)," *mental.jmir.org*, 2017 [Online]. Available: <https://mental.jmir.org/2017/2/e19> (accessed: Aug. 05, 2020).
3. Accenture, "2018 Consumer Survey on Digital Health Summary," *Accent. Consult.*, pp. 1–17, 2018 [Online]. Available: <https://www.accenture.com/acnmedia/pdf-71/accenture-health-2018-consumer-survey-digital-health.pdf> (accessed Aug 05, 2020).
4. Velupillai, S., Mowery, D., South, B. R., Kvist, M., & Dalianis, H. "Recent advances in clinical natural language processing in support of semantic analysis," *Yearbook of medical informatics*, vol. 24, no. 1, pp. 183-193, 2015.
5. Hixson, J and P. Wicks, "Patients optimizing epilepsy management via an online Community," *Neurology* vol. 85, no. 2, pp. 129–136, 2015
6. Stahl, B. C., & Coeckelbergh, M., "Ethics of healthcare robotics: Towards responsible research and innovation," *Robotics and Autonomous Systems*, vol. 86, no. 2, pp. 152-161, 2016.
7. Borzykowski, "Truth be told, we're more honest with robots," *BBC WorkLife*, 2016 [Online] Available: <https://www.bbc.com/worklife/article/20160412-truth-be-told-were-more-honest-with-robots> (accessed Aug 06, 2020)
8. McNulty E., "What's the Difference Between Supervised and Unsupervised Learning?" *Dataconomy*, 2018 [Online]. Available: <https://dataconomy.com/2015/01/whats-the-difference-between-supervised-and-unsupervised-learning> (accessed Aug 06, 2020)

9. Afzal, N., Sohn, S., Abram, "Mining peripheral arterial disease cases from narrative clinical notes using natural language processing," *Journal of vascular surgery*, vol. 65, no. 6, pp. 1753-1761, 2017.
10. Fiszman, M., Chapman, Aronsky, Evans, & Haug, P. J., "Automatic detection of acute bacterial pneumonia from chest X-ray reports," *Journal of the American Medical Informatics Association*, vol. 7, no. 6, pp. 593-604, 2000.
11. Williams. A, Kamper, Wiggers, Wolfenden, "Musculoskeletal conditions may increase the risk of chronic disease: a systematic review and meta-analysis of cohort studies," *BMC medicine*, vol. 16, no. 1, pp. 167, 2018
12. Family Caregiver Alliance, "Caregiver Statistics: Demographics", National Center on Caregiving, 2019 [Online]. Available: <https://www.caregiver.org/caregiver-statistics-demographics> (accessed Aug 07, 2020).
13. Rabbitt, S. M., A. E. Kazdin, and B. Scassellati, "Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use," *Clinical Psychology*, vol. 35, no. 1, pp. 35-46, 2015.
14. Schulman-Marcus, J., Mookherjee, S., Rice, L., & Lyubarova, R., "New Approaches for the Treatment of Delirium: A Case for Robotic Pets," *The American journal of medicine*, vol. 132, no. 7, pp. 781-782, 2019.
15. Moyle, W., Jones, C. J., Murfield, J. E., Thalib, L., Beattie, E. R., Shum, D. K., ... & Draper, B. M., "Use of a robotic seal as a therapeutic tool to improve dementia symptoms: a cluster-randomized controlled trial," *Journal of the American Medical Directors Association*, vol. 18, no. 9, pp. 766-773, 2017.
16. Sennaar, K., "Machine learning medical diagnostics—4 current applications," *Emerj Artificial Intelligence Research*, 2018 [Online]. Available: <https://emerj.com/ai-sector-overviews/machine-learning-medical-diagnostics4-current-applications> (accessed Aug 07, 2020).
17. Liu, F., Z. Zhou, A. Samsonov, D. Blankenbaker, W. Larison, A. Kanarek, K. Lian, S. Kambhampati, and R. Kijowski, "Deep learning approach for evaluating knee MR images: Achieving high diagnostic performance for cartilage lesion detection," *Radiology*, vol. 289, no. 1, pp. 160–169, 2018
18. Best, J., "AI that knows you're sick before you do: IBM's five-year plan to remake Healthcare", *ZDNet*. 2017. Available: <https://www.zdnet.com/article/ai-that-knows-youre-sick-before-you-do-ibms-five-year-plan-to-remake-healthcare> (accessed Aug 07, 2020)
19. Gelichgerricht, E., B. Munsell, S. Bhatia, W. Vandergrift, C. Rorden, C. McDonalid, J. Edwards, R. Kuzniecky, L. Bonilha, "Deep learning applied to whole-brain connectome to determine seizure control after epilepsy surgery," *Epilepsia* vol. 59, no. 9 pp. 1643–1654, 2018.
20. Newmarker, C. "Digital surgery touts artificial intelligence for the operating room", *Medical Design & Outsourcing*, 2018 [Online]. Available: <https://www.medicaldesignandoutsourcing.com/digital-surgery-touts-artificial-intelligence-for-the-operating-room> (accessed Aug 07, 2020).
21. Shen, H., C. Wang, L. Xie, S. Zhou, L. Gu, and H. Xie, "A novel remote-controlled robotic system for cerebrovascular intervention," *International Journal of Medical Robotics and Computer Assisted Surgery*, vol. 14, no. 6, pp. 1943, 2018.
22. Poon, H., C. Quirk, K. Toutanova, and S. Wen-tau Yih, "AI for precision medicine. Project Hanover," 2018 [Online]. Available: <https://hanover.azurewebsites.net/#machineReading> (accessed Aug 07, 2020).
23. Imler, T. D., J. Morea, T. F. Imperiale. "Clinical decisions support with natural language processing facilitates determination of colonoscopy surveillance intervals," *Clinical Gastroenterology and Hepatology*, vol. 12, no. 7, pp. 1130–1136, 2014.

24. Jackson, G. L., B. J. Powers, R. Chatterjee, J. P. Bettger, A. R. Kemper, V. Hasselblad, R. J. Dolor, J. Irvine, B. L. Heidenfelder, A. S. Kendrick, R. Gray, and J. W. Williams, "The patient-centered medical home: A systematic review," *Annals of Internal Medicine*, vol. 158 no. 1, pp. 169–178, 2013.
25. Schuler, A., A. Callahan, K. Jung, and N. Shah, "Performing an informatics consult: Methods and challenges," *Journal of the American College of Radiology* vol. 15, pp. 563–568, 2018.
26. Shin, E. K., Mahajan, R., Akbilgic, O., & Shaban-Nejad, A., "Sociomarkers and biomarkers: predictive modeling in identifying pediatric asthma patients at risk of hospital revisits," *NPJ digital medicine*, vol. 1, no. 1, pp 1-5, 2018.
27. Cappella, J. N., "Vectors into the future of mass and interpersonal communication research: Big data, social media, and computational social science," *Human Communication Research* vol. 43, no. 4, pp. 545–558, 2017.
28. Esteva, A., B. Kuprel, R. A. Novoa, J. Ko, S. M. Sweter, H. M. Blau, and S. Thrun "Dermatologist-level classification of skin cancer with deep neural networks," *Nature* vol. 542, no. 1, pp. 115–118, 2017.
29. Schulam, P., and S. Saria, "Reliable decision support using counterfactual models," *Advances in Neural Information Processing Systems*, vol. 30, pp. 1697–1708, 2017.
30. Deo, R. C., "Machine learning in medicine," *Circulation* vol. 132, pp. 1920–1930, 2015.
31. Woolhandler, S., and D. U. Himmelstein, "The relationship of health insurance and mortality: Is lack of insurance deadly?" *Annals of Internal Medicine*, vol. 167, pp. 424–431, 2017