Augmented Intelligence for Advancing Healthcare

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ABSTRACT

Augmented Intelligence (AuI) is being integrated in a variety of our daily activities and applications. Healthcare is one of those applications and, in fact, it will greatly benefit from AuI leading to impressive improvements. Although, as with the use of any new innovations, the use of AuI in healthcare is not without concerns, the benefits are expected to outweigh the concerns. It is also expected and adequate education about AuI related innovations in healthcare and their potential benefits, will build trust among consumers and alleviate perceived concerns. For the process to be relatively smooth, an interdisciplinary dialogue must take place between medical professionals, AuI experts, engineering professionals, and consumers. This paper discusses a brief history of AI and AuI, its potential applications in healthcare, potential benefits that all stakeholders will reap, and potential challenges that we will need to overcome, to fully benefit from using AuI in healthcare.

Keywords: Artificial intelligence (AI), Augmented intelligence (AuI), AuI in Healthcare.

1. INTRODUCTION

The concept of intelligence has always been closely affiliated with human beings. Although some limited form of intelligence with varying degrees may exist in other creatures, humans are considered to be by far most intelligent creature. Intelligence has been defined by many in several different forms. However, most of the characteristics of intelligence are common in all the definitions. These characteristics of intelligence include abilities to think, to reason, to learn from surrounding experiences, to adapt, to survive in unfamiliar surroundings, and to solve complex problems [1,2].

Humans, by birth, have abilities to observe their surroundings, use of sensory abilities to absorb information through their interactions, analyze the information, and learn. This is a life-long learning process that continues to feed their cumulative knowledge repository. This processes somehow integrates all human experiences and observations including emotions, perceptions, interests, cultural values, religious preferences, and social interactions. Some experts refer to it as collective wisdom that influences the level and status of human intelligence. Scientists have been and are expected to continue investigating this very complex subject of human intelligence (HI) [3].

Humans know that their intelligence has some limitations [2]. Therefore, for centuries, there has been interest in finding ways to supplement human intelligence to do things fast and automate the processes as much as possible. With lack of scientific advancements, such interests and desires did not materialize and were limited to casual discussions and fictions. In early 1700s, the word "engine" was coined in the context of automation. The pace of progress was still slow. In late 1900s, the interest in intelligent machines grew rapidly. For the first time, in 1921, a fictional concept was created to make artificial people called robots, and scientists started discussing computing machines with intelligence. In 1956, for the first time "artificial intelligence (AI)" phrase was mentioned. Throughout, the progress in this field, leading to the development of intelligence machines, was to use these machines to augment the human intelligence. The field of artificial intelligence (AI) witnessed several major developments from 1960 to 2000. From 2000 onward, there has been tremendous interest in artificial intelligence and AI is rapidly infiltrating in life around humans. Some of the most visible developments include IBM's Watson playing Jeopardy and winning big, humanoid Sophia and others intelligently interacting with humans, Amazon's Alexa, and autonomous self-driving vehicles [4,5].

Augmented intelligence (AuI) refers to the process of supplementing human intelligence (HI) with artificial intelligence (AI) with the sole purpose of enhancing the human capabilities to do things faster and achieve automation. The goal of augmented intelligence is to use artificial intelligence to work closely with humans and help them in their activities rather than replace them. While AI is viewed as working independently (autonomously), AuI is expected to use human intelligence and artificial purpose together and to keep humans in the loop. The motivation behind augmented intelligence is to score or attempt to score what human intelligence alone has not been able to score. Historically, that has been the motivation for developing artificial intelligence. For every development, big or small, in artificial intelligence, there was a

proportional advancement in augmented intelligence. This trend of parallel growth among artificial intelligence and augmented intelligence continues to this day. In fact, advances in artificial intelligence keep propelling the advances in augmented intelligence.

There is a broad range of applications where augmented intelligence can be used to improve efficiency and productivity. These applications literally relate to all aspects of human existence, growth, and development. These applications include healthcare, energy, environment, agriculture, transportation, finances, business operations, marketing, education, art, information security, city planning, and many more. Among all these applications, the most critical one is healthcare where augmented intelligence can be used very effectively to produce the best possible healthcare outcomes including diagnostics, treatment options, surgeries, drug discovery, and recovery processes. In all these applications, augmented intelligence help humans in, understanding and sorting through a large amount of data (relevant to the application), interpreting the data, reasoning, identifying any discrepancies, learning from these analyses, and assuring the legitimacy of these processes [6,7].

The focus of this paper is on advancing healthcare with the use of augmented intelligence. The next section of this paper discusses a brief history of augmented intelligence. Section 3 discusses emerging role of augmented intelligence in advancing healthcare including a few typical examples. Some of the challenges associated with the role of augmented intelligence in healthcare are discussed in section 4. Section 5 presents summary and conclusions of the paper.

2. BRIEF HISTORY OF AUGMENTED INTELLIGENCE

As mentioned earlier, the term augmented intelligence implies human intelligence supplemented by artificial intelligence. Therefore, the history of augmented intelligence, must be closely related to the history of artificial intelligence. After all, existence of augmented intelligence is because of artificial intelligence. In other words, if artificial intelligence did not exist, there would be no reason for the existence of augmented intelligence.

Humans have always sought help through various means, to overcome their limitations including the limitations of human intelligence. They always directed their efforts to develop tools to enhance their faculties. However, their efforts were not very productive until a few decades ago. The word "engine", with automation in view, was mentioned for the first time in early 1700s. With slow but steady progress, in late 1800s, scientists started actively discussing that future machines may possess consciousness. This notion of machines having consciousness was as controversial then as it is now. This

aspect of machines is expected to remain so for the foreseeable future.

The interest in developing intelligent machines (not necessarily with consciousness) started growing rapidly in early 1900s. In the same context, creation of artificial people – named as "robots" – was mentioned in 1921, and the scientific community started expressing keen interest in this field. Robots were envisioned to help humans by working with them thus augmenting human capabilities. In 1950, one of the pioneers in the field of computing machinery – Alan Turing – published "Computing Machinery and Intelligence" [8].

The term "artificial intelligence" was used for the first time in 1956 as theme of a workshop on this topic. That event marked the beginning of steady developments in artificial intelligence with some periods of hypes and winters. Propelled by many advancements in computing and communications during the past few decades (1960-2000), artificial intelligence has become an essential part of human activities and continues to augment our abilities, enhance operational aspects, and improve efficiencies [9]. In 1969, the first general purpose mobile robot was developed which was able to perform tasks with a purpose. In 1997, a supercomputer named "deep blue" was introduced and this computer was able to play chess. It defeated the world chess champion in a match and, of course, made news headlines. The progress in this field continued and several other significant developments took place in the past two decades (2000-2020). These developments include speech recognition, process automation, extensive use of robots, very realistic humanoids (including dancing ones), and natural language processing. Some of the innovations remain proprietary and thus confidential. However, in 2020, one such innovation (AI algorithm) was released to scientific teams working on COVID-19 vaccine development. This algorithm immensely hastened the process of vaccine development because it was 120 times faster than others. What an impressive example of augmented intelligence advancing healthcare [10].

The first formal reference to augmented intelligence goes back to 1962 when Engelbart in a research report discussed augmenting human intellect [11]. From 2000 onward, based on serious research in the field of artificial intelligence and augmented intelligence, many other major developments have taken place. As of 2021, it is estimated that 70% of organizations are using artificial intelligence and augmented intelligence. These organizations widely vary in size and have a wide range of activities [12]. Some of the other prominent developments stemming from the use of artificial intelligence and augmented intelligence include IBM's Watson playing Jeopardy and winning big, humanoid Sophia and others, capable of intelligently interacting with humans, virtual assistants, autonomous vehicles, Amazon's Alexa, visual recognition, natural language processing, and many more.

Many of the experts are of opinion that the process of artificial intelligence supplementing human intelligence, is revolutionary. However, it will not be unreasonable to view the growth and popularity of augmented intelligence as an evolution. The facts that support the idea of an evolution include that all the ingredients necessary for rapid AI-related developments, and applications that need augmented intelligence, have been steadily emerging. Other factors include access to enormous amount of data, massive processing power, and efficient data storage systems. There is no indication that the rapid pace of these developments will slow down. Therefore, developments in artificial intelligence, and their integration with human intelligence (leading to augmented intelligence), are expected to continue and will have transformational impact on our society.

3. ROLE OF AUGMENTED INTELLIGENCE IN HEALTHCARE

Augmented intelligence (AuI) refers to supplementing human intelligence (HI) with artificial intelligence (AI) to improve human cognitive abilities and make better decisions. The process of combining HI and AI to achieve AuI may vary for one application to another, and can be governed by the following equation:

$$AuI = a * HI + b * AI$$

Where parameter a indicates the percentage of HI, and parameter b indicates the percentage of AI used in the combination process. Conventional wisdom suggests that both parameters a and b should be 100% to make the best use of HI and AI together. However, there may be some situations where HI should weigh more than AI. In those situations the value of parameters a and b can be adjusted.

Augmented intelligence can be applied to almost any of the commonly used applications, to make better, informed, and efficient decisions. However, one application that will benefit the most from augmented intelligence, and will deliver the most benefits to our society, is the field of healthcare. This is the field that can use 100% of human intelligence and 100% of available artificial intelligence to serve the healthcare needs of our society. Because of the sentimental and emotional aspects of this healthcare application, we all prefer that decisions about health be made by fellow humans and not by the machines. However, no one seems to object to using whatever help from any source including artificial intelligence, to make healthcare decisions quickly, precisely, and effectively. Therefore, no one is opposed to taking the help from artificial intelligence to augment the human intellect and enhance the process of healthcare [13].

There are a few other factors and trends that are relevant to the healthcare and are pushing for making the healthcare process faster and effective. These factors and trends are fueling the desire of using augmented intelligence, and smart devices in healthcare to keep people healthy and to effectively treat those who become sick. One of the major factors is the growing world population which is expected to reach 10 billion by 2050. That is a 7.5 billion increase in a span of 100 years (world population was 2.5 billion in 1950). Such a growth necessitates an intelligent, smart, and efficient approach to healthcare. Another factor is unprecedented connectivity among world citizens provided by the information and communications technologies (ICTs). It is anticipated that by 2050, there will be an average of five connected devices per capita. Such connectivity will certainly be useful in monitoring health condition of individuals, collecting health related information, and building their health profiles. Such an environment is ideal for using artificial intelligence to analyze data, and develop some treatment options, essentially augmenting the capabilities of healthcare professionals. Such an environment is also expected to lead to a transformational shift in healthcare and that is to focus on keeping people healthy rather than treating the sick people. That will require genetic analyses of individuals, identification of their unique vulnerabilities and dispositions, and preparing individualized plans for treatment. Rise of quantum computing that is expected to bring manifold increase in processing power, will be a very timely resource for implementing transformational approach to healthcare. All these factors point to an exciting, transformational, and beneficial future of healthcare [14].

Healthcare is one of the most important needs of any society. It can be viewed as an ecosystem that involves patients, doctors, nurses, pharmaceuticals, healthcare facilities, healthcare tools, healthcare infrastructure, and, of course, prevailing technologies relevant to healthcare. The role of technologies in healthcare has always been crucial and desired to deliver the best possible healthcare. Technologies dating back to the rudimentary form of tools including stethoscope, were always viewed as tools that are assistive and augment the abilities of healthcare professionals. For the same reasons, every aspect of the healthcare ecosystem has always been adaptive and receptive to using the latest technological innovations available including augmented intelligence [13].

For effectively reaping the benefits of augmented intelligence, it is important to emphasize that healthcare professionals and technology professionals must work together and share ideas for a common purpose of using augmented to improve healthcare, and to find effective solutions for healthcare needs. This applies to almost all the healthcare-related needs including, diagnostic tools, radiology, robotic surgeries, telemedicine, focused and personalized healthcare treatments, drug development, tools for monitoring patients inside hospitals and/or at their homes, and tracking progression of diseases including pandemics such as COVID [14]. Integration of technologies in healthcare has improved many aspects and

one of the most important is healthcare access in urban as well as rural settings. In addition, pervasive connectivity, and communication technologies such as Internet of Things (IoT), have created widespread awareness about healthcare issues among citizens. IoT has also emerged as one of the most effective platforms for gathering information about many applications including healthcare. The data thus collected forms the basis of applying artificial intelligence to analyze and combine the findings with human intelligence leading to augmented intelligence. These developments are creating a transformational shift in healthcare including the focus on keeping people healthy rather than treating the sick individuals [14]. There are many examples of using augmented intelligence in improving various aspects of healthcare. In the remainder of this section, three healthcare areas are discussed, and these areas are diagnostics, treatment, and drug discovery.

Augmented intelligence in medical diagnostics

The process of medical diagnoses is based on several aspects, but three items are essential. These three items are information about symptoms to be treated, knowledge, training, and experience of the healthcare professional(s) administering the diagnosis, information about the past cases (or history) with similar symptoms and conditions. If these three aspects are properly addressed, there is a strong possibility of correct diagnosis.

The source of information about the symptoms is primarily the individual or the patient seeking medical help. It is also responsibility of the healthcare professional to ask the right questions to extract all the relevant information from the patient. The information should also include patient's vital signs, previous medical history of the patient including surgeries and/or medical treatments, and any medications (prescribed or otherwise) being consumed.

The second aspect is the knowledge, training, and experience of the healthcare professional(s). This aspect is generally assumed to be solid and well-grounded because all healthcare professionals go through very strenuous process of medical education, training, and passing their board examinations. The experience, however, is gained through the practice and accumulates through longevity of professional practice. In addition, medical professionals strive for keeping themselves current about the ongoing developments in their field of medical practice. This may, however, be limited to the number of patients seen and diagnosed by the healthcare professionals and that may, in the best cases, be no more than a few thousands. The number may reduce if you limit the diagnosis to a specific medical condition.

The third aspect is the information about the past cases with similar symptoms and conditions. This information can play a crucial role in correct diagnosis of a medical condition. The information about the patient being

diagnosed, can be compared with the past similar cases, to diagnose the patient. Larger the number of cases being accessible and compared with, better will be the expectation of a correct diagnosis. It is not humanly possible to compare the symptoms of one patient with a very large number (hundreds of thousands or even millions) of cases quickly to make a timely diagnosis. That is where artificial intelligence can play its role.

Artificial intelligence (AI) is expected to play an important and transformational role in advancing the medical diagnosis. Emerging communication technologies such as Internet of Things (IoT), are providing pervasive connectivity and ideal platform for collecting healthcare information about individuals, groups, cities, countries, and the world. It is anticipated that by 2050, 50 billion devices will be connected through IoT. The information collected on such a wider scale, can be analyzed using AI algorithms for identifying correlations between symptoms and diagnosis. With that reservoir of knowledge, computing machines can compare the symptoms of the patient being diagnosed with the previous similar cases in a very short duration of time and present the findings/options to the healthcare professionals. With that information in hand, the healthcare professionals can make an informed decisions about the diagnosis. The process of extending this additional help by the artificial intelligence, essentially augments the capabilities of healthcare professionals. This is referred to as augmented intelligence advancing the healthcare [15,16].

For instance, while diagnosing skin lesions, a healthcare professional can take a picture of the lesions and feed this to a machine along with the information about symptoms and prior medical history of the patients. The machine can apply artificial intelligence algorithms and come back with possible diagnosis and possibly the rationale about the decision. The healthcare professional can use the best judgement to make a final diagnosis decision. Similarly, pathologists can use the same technique to reach a diagnostic decision about a tissue sample. Radiologists can use artificial intelligence to extract findings from the medical images by comparing them with a large set of medical images accessible, and present to the medical professionals for a final decision. The added advantage of using augmented intelligence in that it leads to faster, and precise diagnosis and is, therefore, beneficial for the entire healthcare ecosystem. Many other medical fields such as cardiology, gastroenterology, nephrology oncology etc. all can achieve better results with the use of augmented intelligence [17,18,19].

Augmented intelligence in medical treatment

Once a disease diagnosis has been established, the next step is to find an appropriate treatment option. The treatments options depend on many factors including, of course the disease diagnosis, patient's medical history, family's medical history, age, gender, and in some cases

even ethnicity. The knowledge, training, and the experience of healthcare professionals is the most important factor is charting the approach for treatment. Some of the common sicknesses may have straightforward treatment option. However, more complex diagnoses such as cancer, brain tumor, epilepsy, or other severely complex medical conditions, may need multiple medical specialties working together to develop a treatment plan. Artificial intelligence can play a vital role and help healthcare professionals in selection of an appropriate treatment option. This approach will require that all relevant medical information about the patient be provided to a computer to process it using the artificial intelligent algorithms. This will analyze the patient's information in the light of all the prior similar cases, determine what treatment options worked in the past and what did not. The expected outcome of this analysis through artificial intelligence will be the suggested treatment options for the patient. The healthcare professionals can then use their best judgement to select one of the suggested options, modify these options, or not use any of those. Although, the help provided by the artificial intelligent is expected to augment the precision and effectiveness of the process of selecting an appropriate treatment option, it is very important that healthcare professionals stay in control and make a final decision. This is necessary for the patients to maintain trust in the medical treatment being offered to them for the diagnosed condition and feel comfortable. In addition, the healthcare professionals should also feel comfortable using the augmented intelligence in making decisions about the treatment options [20].

There are many examples of using augmented intelligence in selecting an approach for treating a medical condition. For instance, let us take an example of a brain tumor. There may be several options to treat that condition. However, selecting the right treatment option will depend on many factors including the general health of the patient, current health condition, prior medical history, age, gender, and ethnicity. Once all the information is provided to a computing machine to process using artificial intelligence, suggested treatment options will be presented to the healthcare professionals. The treatment option may include surgery, chemotherapy, radiation therapy, or combination of these. Artificial intelligence may suggest anyone, or combination of these treatment options. It may also suggest a sequence of these treatment options such as surgery followed by other therapies or chemotherapy/radiation therapy followed by a surgery, if necessary. Such information is very valuable for healthcare professionals to decide the course of action. The healthcare professionals may decide any of the suggested options or something different. However, knowing that what has worked in the past and what did not and how effective the treatment was, gives healthcare professional added confidence in selecting the treatment option. Thus, using augmented intelligence by combining artificial intelligence and human intelligence is beneficial for both healthcare professionals and the patients [21,22].

After the medical treatment has been administered, the patient goes through a recovery phase. How intensive intervention is needed during the recovery phases, depends upon the nature of the medical treatment. The artificial intelligence can help in that phase too. Patients' recovering at home after medical treatment may require special assistance such as continuous monitoring to ensure their wellbeing. Augmented intelligence can use artificial intelligence to create ambience that is conducive to better recovery and offers services to the patients including administering the medicines on time, intelligent machines (such as robots, also known as cobots or humanoids) having conversation with patients, keeping track of patients' activities, doing house chores, and calling for help when something does not seem right. Such an environment is a typical example of augmented intelligence as a service and is referred to as ambient assisted living [23]. Thus, augmented intelligence is useful not only in medical diagnosis but also in identifying treatment options, and poste-treatment recovery process.

Augmented intelligence in drug discovery

The drug discovery process is known to be expensive and long. Typically, discovery of a new drug costs billions, and takes more than ten years from start to completion. Reducing the cost and reducing the duration have been challenging. However, artificial intelligence is coming to rescue and augmenting the human/manual efforts. As mentioned earlier in this paper, use of artificial intelligence algorithms did help speed up the process of COVID vaccine.

The process of drug discovery can be considered as a sequence of four stages. These are, selection of target, classification of compounds, preclinical studies, and clinical trials. Each stage is time intensive and costly. Artificial intelligence can be used to augment the human intelligence and effort, and that is reducing the duration as well as the cost associated with the drug discovery process. Artificial intelligence is particularly very helpful in the second phase where classification of compounds can be automated by scanning the images and applying artificial intelligence algorithms to complete the process in much less duration of time. In addition, artificial intelligence can augment the efforts in many other parts of process including prediction of physical properties and bioactivity of structures, and their interactions [24].

This environment of augmented intelligence by integrating the human intelligence and the artificial intelligence will lead to speedy drug discoveries by reducing the time duration and hence the cost. The process will also much more precise and trustworthy. However, as in all medical applications, due to their nature, humans need to stay in control and ensure that no detail will be overlooked. The process of deploying augmented intelligence will become more common and present, because of massive amount of historical information that has been collected in the past,

continued advancement is computational resources, and pervasive connectivity made available by emerging communication technologies such as Internet of Things. Therefore, augmented intelligence continues to prove as transformational in the field of drug discovery [25,26,27].

4. CHALLENGES AND OPPORTUNITIES

Augmented intelligence is a trend that is expected to impact every aspect of our lives. Infiltration of augmented intelligence is, no doubt, going to bring tremendous benefits and opportunities, it does not come without challenges. One of the major challenges is lack of trust in the growing influence of technologies in our lives. There is also a fear of unknown primarily stemming from the fact that use of artificial technologies may expose their personal information (including health information) and how that may impact them. No one wants their personal and private information to fall in the hands of unauthorized individuals and/or corporations. To alleviate these fears, some efforts must be directed to educate the society and enhance their level of comfort to build their trust [28,29].

Another sustained concern is about the impact of augmented technologies on the future of workforce. Current workforce is fearful that infiltration of technologies such as artificial and augmented intelligence will replace humans with machines. While that may seem to be somewhat true, a broader view will reveal that introduction of technologies will create many more opportunities for humans. Introduction of new technologies will create an equal or higher number of jobs of different nature. It is understandable that each disruption caused by introduction of new technologies, will lead to a new normal for the societal ecosystem [30].

Some of the challenges that come with the artificial and augmented intelligence may be very different than those from other technologies. These challenges need to be viewed in the light of emerging technologies. What will the future be with growing use of augmented intelligence? The answer to this question remains to be seen and we all have that concern knowingly or unknowingly. It is anticipated that with the increasing infiltration of augmented intelligence, mapping the entire human brain will be possible. That may lead to the scenarios that future generations may be able to interact with the digital versions of their forefathers, scholars, leaders, and others who are no longer alive. This is being referred to as the era of digital immortality [31,32]. Such scenarios may pose some concerns but are also beneficial in advancing the human knowledge. We have an opportunity to put the artificial intelligence and the augmented intelligence to a good use that is beneficial for our society and humanity. We need to find ways to work with and coexist with emerging technologies. Let us hope that with all the advancements in technologies such as augmented

intelligence, we humans can stay in control and do not become subservient to machine intelligence.

5. SUMMARY AND CONCLUSIONS

This paper has discussed the emerging role of augmented intelligence in advancing healthcare. It is expected that augmented intelligence will greatly impact all aspects of healthcare. The paper begins with the introduction and brief history of augmented intelligence. Three main areas of the healthcare were discussed and how these areas can make the best use of augmented intelligence for advancing healthcare. There three areas are, medical diagnosis, medical treatment, and drug discovery. All three areas can reap tremendous benefits from the use of augmented intelligence. Some future challenges and opportunities stemming from the infiltration of augmented intelligence, are also discussed.

REFERENCES

[1] Colom, R., Karama, S., Jung, R.E., and Haier, R., "Human Intelligence and Brain Networks", Dialogues in Clinical Neuroscience, Vol. 12, No. 4, 2010, pp. 489-501.

[2] Griffiths, T. L., "Understanding Human Intelligence Through Human Limitations", Trends in Cognitive Sciences, Vol. 24, No. 11, 2020, pp. 873-883.

[3] Snyderman, M, and Rothman, S., "Survey of Expert Opinion on Intelligence and Aptitude Testing", Am Psychol. 1987, 42, pp. 137-144.

[4] Reynoso, R., "A Complete History of Artificial Intelligence", https://www.g2.com/articles/history-of-artificial-intelligence, Retrieved on December 20, 2022.

[5] Lu, Y., "Artificial Intelligence: A Survey on Evolution, Models, Applications, and Future Trends", Journal of Management Analytics, Vol. 6, No. 1, 2019, pp. 1-29.

[6] Hester, A., "Augmented Intelligence: An Introduction to the New AI", https://nividous.com/blogs/augmented-intelligence, Retrieved on January 4, 2023.

[7] Taylor, K., "Know the Examples and Concept of Augmented Intelligence", https://www.hitechnectar.com/blogs/examples-of-augmented-intelligence/, Retrieved on January 4, 2023.

[8] Reynoso, R., "A Complete History of Artificial Intelligence", https://www.g2.com/articles/history-of-artificial-intelligence, Retrieved on December 20, 2022.

[9] Lu, Y., "Artificial Intelligence: A Survey on Evolution, Models, Applications, and Future Trends", Journal of Management Analytics, Vol. 6, No. 1, 2019, pp. 1-29.

[10] Kelley, K., "What is Artificial Intelligence: Types, History, and Future", https://www.simplilearn.com/tutorials/artificial-intelligence-tutorial/what-is-artificial-intelligence#a_brief_history_of_artificial_intelligence, Retrieved on January 5, 2023.

[11] Engelbart, D., "Augmenting Human Intellect: A Conceptual Framework", Summary Report AFSOR-3233,

Stanford Research Institute, Menlo Park, California, USA, 1962.

[12] Viswanathan, V., "The Rise of Augmented Intelligence in the Global Workplace", https://www.starmind.ai/resources/70-of-organizations-will-use-ai-to-boost-productivity-within-the-next-24-months, Retrieved on January 4, 2023.

[13] Davenport, T., and Kalakota, R., "The Potential for Artificial Intelligence in Healthcare", Future Healthcare Journal, 2019, 6(2), pp.94-98.

[14] Gordon, C., "AI in Healthcare is Making our World Healthier", https://www.forbes.com/sites/cindygordon/2022/10/31/ai-in-healthcare-is-making-our-world-healthier/?sh=11ab6c5013ea, Retrieved on December 21, 2022.

[15] Jain, H., Padmanabhan, Pavlou, P. A., and Raghu, T. S., "Editorial for the Special Section on Humans, Algorithms, and Augmented Intelligence: The Future of Work, Organizations, and Society", Information Systems Reseaerch, Vol. 32, No. 3, 2021, pp. 675-687.

[16] Dilmegani, C., "AI in Healthcare: Benefits and Challenges in 2023", https://research.aimultiple.com/healthcare-ai/, Retrieved on December 21, 2022.

[17] Liew, C., The Future of Radiology Augmented with Artificial Intelligence: A Strategy for Success", European Journal of Radiology, 102, 2018, pp. 152-156.

[18] Jussupow, E., Spohrer, K., Heinzl, A., and Gawlitza, J., "Augmenting Medical Diagnosis Decisions? An Investigation into Physicians' Decision-Making Process with Artificial Intelligence", Information Systems Research, 32(3), 2021, pp. 713-735.

[19] Vashista, R., Chhabra, D., and Shukla, P., "Integrated Artificial Intelligence Approaches for Disease Diagnostics", Indian Journal of Microbiology, 58(2), 2018, pp. 252-255.

[20] Ahuja, A. S., "The Impact of Artificial Intelligence in Medicine on the Future Role of the Physician", PeerJ 7:e7702, 2019, http://doi.org/10.7717/peerj.7702.

[21] Patil, S., Moafa, I. H., Alfaifi, M. M., Abdu, A. M., Jafer, M. A., Raju, L. K., Raj, A. T., and Sait, S. M., "Reviewing the Role of Artificial Intelligence in Cancer", Asian Pacific Journal of Cancer Biology, Vol. 5, Issue 4, 2020, pp. 189-199.

[22] Jiang, Y., Yang, M., Wang, S., Li, X., and Sun, Y., "Emerging Role of Deep Learning-based Artificial Intelligence in Tumor Pathology", Cancer Communications, 2020;40, pp. 154-166.

[23] Ahmed, S., Ilyas, M. and Raja, M.Y.A., "Smart Living: Ubiquitous Services Powered by Ambient Intelligence (AmI)", 16th IEEE International Conference on Smart Cities: Improving Quality of Life using ICT, IoT, and AI, Charlotte, North Carolina, October 2019.

[24] Chen, H. C. S., Shan, H., Dahoun, T., Vogel, H., and Yuan, S., "Advancing Drug Discovery via Artificial Intelligence", Trends in Pharmacological Sciences, Vol. 40, No. 8, 2019, pp. 592-604.

[25] Vijayan, R. S. K., Kihlberg, J., Cross, J. B., and Poongavanam, V., "Enhancing Preclinical Drug Discovery with Artificial Intelligence", Drug Discovery Today, Vol. 27, No. 4, 2022, pp. 967-984.

[26] Patel, V., and Shah, M., "Artificial Intelligence and Machine Learning in Drug Discovery and Development", Intelligent Machine, 2(2022), pp. 134-140.

[27] Jimenez-Luna, J., Grisoni, F., Weskamp, N., and Schneider, G., "Artificial Intelligence in Drug Discovery: Recent Advances and Future Perspective", Expert Opinion on Drug Discovery, Vol 16, No. 9, 2021, pp. 949-959.

[28] Nadikattu, R. R., "The Emerging Role of Artificial Intelligence in Modern Society", International Journal of Creative Research Thoughts", Vol. 4, Issue 4, 2016, pp. 906-91.

[29] Wirtz, B. W., Weyerer, J. C., and Geyer, C., "Artificial Intelligence and the Public Sector—Applications and Challenges", International Journal of Public Administration, 2019, Vol. 42, No. 7, pp. 596-615.

[30] Pavlou, P. A., "Internet of Things – Will Humans be Replaced or Augmented?, AI and Augmented Intelligence, Vol. 10, No. 2, 2018, pp. 42-47.

[31] Shabbir, J., and Anwer, T., "Artificial Intelligence and its Role in Near Future", Journal of LaTex Class Files, Vol. 14, No. 8, August 2015, pp. 1-11.

[32] Holt, M., "Artificial Intelligence in Modern Society", (2018), Integrated Studies. 138. https://digitalcommons.murraystate.edu/bis437/138.