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Review of Applications of Artificial Intelligence in Health Care

Muhammad Hibatullah Channa[1], Bushra Memon[1]

Abstract:

Twenty-first century is famously termed the age of the fourth industrial revolution, which is because of the massive amount of data being generated and stored which could be interpreted and analyzed by intelligible programs. Just as the discovery of the microscope in the sixteenth century led humans to discover things about human biology that the naked eye could not see, likewise artificial intelligence could be used to look for patterns in the data which humans otherwise would have less likely perceived. This paper will capitalize on this. How much potential could aid in the health care field A review and guide are compiled for any researcher or student who might want to practically implement the ideas discussed. The implementation of artificial intelligence for the analysis of medical images and beyond is to be discussed in this paper. Tools and software developed from these ideas could help medical practitioners make more accurate decisions.

Keywords: *Machine Learning; Neural Network; Convolutional Neural Network; Supervised Learning; Unsupervised Learning; Reinforcement Learning, Labelled dataset, medicine, health.*

1. Introduction

History is often described in eras. From a prehistoric perspective, each era brought on new innovations and a means to improve lives in general. Prehistoric times encompass the Paleolithic, Neolithic, Bronze, and Iron Ages. In each era, something new was discovered. Sometime during the Paleolithic age, the use of fire was discovered, the beginning of agriculture marked the starting of the Neolithic age, creation of metal tools marked the start of the Bronze Age, followed by the Iron Age. In the modern history medieval era emerges into modern times marked by the industrial revolution. Today we are living in the age of big data, as billions of terabytes of data are being generated every year and the size is just beginning to increase. The industrial revolution was marked by the invention of machines which replaced physical human labor work. However, the intellectual and cognitive skills of humans could not be mimicked by machines previously, until recently. Scientists have now understood that it is a matter-of-fact biochemical reaction in the human brain that equip humans with intelligence. Since these biochemical reactions can now be understood by science, they could be applied as algorithms in computers. At this time, there have been numerous instances where artificially intelligent systems have outperformed humans in analyzing skills.

[1], [2] Furthermore, day by day machines are improving in their cognitive skills such as learning and analyzing. The artificially intelligent systems simply work by accessing data in the form of inputs, processing it, and outputting the result.

[1] Department of Computer Science, SZABIST, Hyderabad Campus, Pakistan
Corresponding Author: bushra.memon@hyd.szabist.edu.pk

Artificial Intelligence processes data by various methods, Machine Learning is one of the subfields of artificial intelligence. Machine learning works by processing a dataset by using some algorithm and learning iteratively in the process. The use of machine learning could draw novel conclusions from studies that which human eye or mind could not encompass. The Artificial Intelligent system functions in the environment to meet its defined goals. As per Turning's test, AI should have its memory, be contagious, be able to conclude, and thereby, adapt to the new circumstances [3]. On the other hand, machine learning is just an aspect of artificial intelligence, machine learning algorithms are techniques that perform calculations and make predictions [4].

2. Literature Review

Several studies regarding review do guide applications of the domain of artificial intelligence in healthcare. However, studies are mostly limited to specific problems and are limited in scope. An article was published regarding the review of applications but its scope was limited to drug discovery, clinical trials, and patient care [39].

Mannee et al [40] published a review that explored areas such as Dermatology, Radiology, and Electronic Health Records the scope of this paper was mainly focused on image-processing tasks and the implementation of neural networks.

Jiang et al [41] published a review and comparison of different data types used for diagnosis techniques and proposed a roadmap for natural language processing from clinical data, commonly used machine learning algorithms in medical literature throughout the years. The paper greatly focuses on natural language processing tasks with limited reviews of diagnostic mechanisms.

Davenport et al [42] in their review focused on applications such as patient engagement, administrative activities, treatment recommendations, and diagnosis, ethical issues were also highlighted in the study.

Tran et al [44] focused on the applications of artificial intelligence in the context of infectious diseases, from laboratory diagnostics to clinical prognosis and clinical diagnosis, the infectious diseases applications would aid in a wide range of diseases such as COVID-19, Lyme disease, malaria, and tuberculosis.

The literature review was conducted to access the information provided within different reviews of applications in artificial intelligence in healthcare, the reviews were descriptive but were limited in their context and limited in their applications. Due to limitations in premises available limited deductive reasoning can be made and the review would aid little to the practitioner.

3. Methodology

In everyday life, there are many things where we encounter that apply artificial intelligence, such as the recommendation systems on Netflix. Machine learning can be characterized into three subfields: Supervised, unsupervised, and reinforcement. Which model to choose amongst three of these, depends upon the type of input. Each model has its algorithms.

To implement supervised learning algorithms, the data must be labeled. In supervised learning, features are extracted from the input and linked with the output labels [5] This is the process by which the algorithm performs predictions on the non-labeled data. Classification works by defining the elements into the discrete group based on their features which are extracted from training data calculations [6]. Supervised learning is broadly divided into classification and regression algorithms.

A probabilistic model is one of the classification algorithms, where the application of probability distribution is used to view unnoticed quantities and their relation to the data [7]. Logistic regression is also one of the classification algorithms, it works by comparing a decision tree or logit function and predicting probability [8]. Naïve Bayes classifier is another classification algorithm. It functions by an assumption that the feature available in a class is not related to other elements' presence [6]. Support vector machine is one of the most famous classification algorithms, this algorithm works by deducing the hyperplane which is at mean distance from two or more classes [9].

Amongst regression, simple linear regression is an algorithm that makes value prediction, it works by deducing the relationship of a single independent variable to a single dependent variable using a straight line [10]. Multiple linear regression is another regression algorithm that functions by deducing the relationship of two or more independent to a single dependent variable by making use of hyperplane [11]. Polynomial regression, decision trees, and random forests are also algorithms applied in supervised learning.

Unsupervised learning does not have labeled data. In these models, the algorithms try to deduce correlations and patterns within data which is raw and is not classified, labeled, or categorized [12]. The techniques used in this subfield are clustering, association rules, and dimensionality reduction [13], [14]. K-means is a clustering algorithm used in unsupervised learning; it forms clusters by deducing points of clusters in proximity from the groups of data points [13]. DBSCAN is another algorithm that forms clusters of high-density regions, compared to low-density regions [3]. The dimensionality reduction follows two main techniques namely; feature selection and feature extraction [15]. The redundant features are refined and removed to fine-tune the compressed data. The principal component analysis is used for large-scale dimensionality reduction [16].

Reinforcement learning follows the path which increases the probability of the system being rewarded. It functions by trial-and-error method and iteratively improves upon receiving the feedback [17]. The system work by reacting to the environment, the actions of the system change the environment, a self-supervisory mechanism evaluates the environment, upon proper action it rewards the system, for example, a score of 1, and for error it penalizes the system, for example, 0 as a score [18].

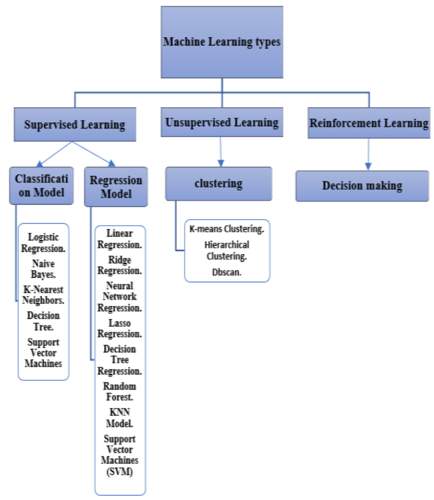

Fig. 1: Machine learning can be categorized into three subfields.

Deep Learning is also a subfield of Machine Learning. It employs the model of neural networks, modeled after the human brain. Artificial neural networks (ANN) have many layers of functions connected by weights just as neurons are connected in the human brain. ANNs that have more than one layer are termed as 'deep'. The networks of these layers self-evaluate the relationship in the raw data.

Deep learning can fall into the supervised, unsupervised, semi-supervised, or reinforcement learning categories. [21] The advantage of deep learning over other models is that the model does not demand any human intervention and automatically extracts features. It consists of an input layer followed by some hidden layers and an output layer. The layers are connected to the next level of layers by a series of weights, upon training these weights iteratively change to make the best approximation and reach the desired output.

Amongst the categories of neural networks, feedforward is the simplest one where no feedback occurs between layers, it is often used with some backpropagation algorithm. Convolution neural network (CNN) is another type of deep neural network. Within these layers are the convolution layer, activation layer, pooling layer, and the fully-connected classification layer. These algorithms are good for classifiers, for example, the region is normal or tumor. CNN's ability to analyze and identify images makes it helpful in fields like radiology [18]. A full convolution network (FCN) is an improvement of CNN, it consists of convolutional layers instead of fully connected layers. This allows pixel-wise prediction. Therefore, this is a good model for semantic segmentation in medical imaging. Region-based CNN (R-CNN) classifies any sort of object within an image by mixing proposals of rectangle objects with CNN. Recurrent Neural Network (RNN) functions by forming cycles that allow the recycling of computational resources. RNN was facing a vanishing gradient problem during backpropagation [19]. So, its variant Long-short term memory network (LTSM) was created which replaced the recurrent hidden layer with a memory cell.

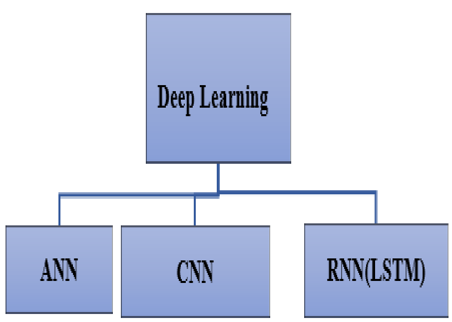

Fig. 2: categories of neural networks

The machine learning process can be described in five distinct stages; Model build-up, training, optimizing, evaluation, and prediction. In the first stage, the data is first, preprocessed, and the noise, redundant and missing values are dealt with. A high-quality database is necessary for the algorithm to perform better [23]. After this, the data is spitted into training, validation, and testing sets. Then the appropriate algorithm is selected. Then the model is trained on the dataset. In the third stage, hyper parameters are adjusted, the validation dataset is presented and the validation error is checked. In the fourth stage, the algorithm is tested on the test dataset and its performance is evaluated. Lastly, the model is used to conduct predictions on unlabeled raw data.

4. Proposed Models

4.1 Cardiology

Adler et al. depict that we can use the decision tree to evaluate the mortality risk in patients with a heart attack. Therefore, make timely decisions [24]. Li et al. findings could be utilized in the early detection of abdominal aortic aneurysms by applying the agonistic learning mechanism of machine learning [25].

4.2 Radiology

Image reconstruction and image analysis could be made possible by machine learning. Deep neural networks could be employed to attain high-resolution and quality images [26]. Furthermore, Convolutional neural networks could be applied for accurate and fast analysis [27].

TABLE 1. Summary of Proposed Models

Branch of medicine	AI Algorithm	Application	References
Cardiology	Decision tree, agnostic machine learning	Risk of heart attack, early detection of abdominal aortic aneurysms	[24-25]
Radiology	CNN, DNN	High quality images, fast and accurate analysis	[26-27
Nephrology	DNN, CNN	Kidney injury detection, global glomerulosclerosis detection	[28-29]
Psychiatry	SVM	Schizophrenia by MRI	[30]
Neurology	ANN	Parkinson's by handwriting	[31-32]
Dentistry	KNN, SVM, Decision tree, Naïve bayes, logistic regression	Growth of bone for orthodontal	[33]
Opthalmology	NN	Optical coherence tomography (OCT) images for diabetic retinopathy	[27]
Nutrition and Diabetology	Boosted decision tree	Personalized nutrition response to post meal glucose	[34]
Infectious Diseases	NN, SVM, Random forest	Epidemic trend of covid 19	[35-36]

4.3 Nephrology

Machine learning techniques could be applied to the prediction of organ damage. Deep neural networks could be applied to detect kidney injury 48 hours in advance, which can ensure timely treatment [28]. Altini et al. conducted a study where they analyzed the histological slides of the kidney and determines the global glomerulosclerosis, which is a necessary step in the pre-transplantation process. Using convolution neural networks, the whole analysis process could be quickened [29].

4.4 Psychiatry

Lei et al. conducted a study where schizophrenia could be analyzed at the level of the individual [30]. This is made possible by a support vector machine which analyzes the MRI images and makes a fast diagnosis of schizophrenia

4.5 Neurology

Cascara no et al. suggests that Parkinson's disease could be predicted by analyzing handwriting [31]. Artificial Neural Networks could be employed to analyze the handwriting of subjects and deduce Parkinson's disease. Interestingly, the model could detect even the progression such as mild to moderate course of the disease. Mellema et al. implemented machine learning techniques for MRI analysis and diagnosis of autism spectrum disorder [32]. A naïve Bayes, support vector machine, adaptive boosting, decision tree base, neural network, logistic regression, random forest, all these techniques go into image analysis and diagnosis.

4.6 Dentistry

Kok et al. advised artificial intelligence techniques could be used for the prediction of the growth of bone [33]. These techniques could be applied to make personalized decisions as to when to seek orthodontal treatment. K-nearest neighbors, support vector machine, decision tree, a naïve Bayes, neural network, logistic regression, and random forest could be applied in this section.

4.7 Opthalmology

Kermany et al. conducted a study where they used neural networks to evaluate the optical coherence tomography (OCT) images of the retina of the human eye, Diabetic retinopathy or muscular degeneration was predicted with high accuracy [27].

4.8 Nutrition and Diabetology

Zeevi et al. advises personalized nutrition in response to post-meal glucose response [34]. A boosted decision tree could be utilized here to predict the glucose response of the patient and therefore make relevant decisions in the nutrition and diet setting of patients especially those with diabetes.

4.8.1 Infectious Diseases

At this time the world is struck by the novel Coronavirus. Artificial intelligence should aid the healthcare sector in many perspectives. Liu et al conducted a study aimed at evaluating the trend of the epidemic trend of Covid-19 [35]. Such an application could be useful in mobilizing public health services. Neural networks could be used to predict possible future cases of coronavirus so hospitals could be mobilized likewise. Furthermore, early diagnosis of covid-19 could be made by applying CNN, SVM, and random forests [36].

5. Conclusion

The discovery of the microscope in the sixth century transformed traditional medicine. Since the human eye could have a limitation and could not look at structures as small as cells in living things. The microscope enabled mankind to look beyond what the naked eye could see. Likewise, the advent of artificial intelligence helps researchers find patterns and correlations between the data that otherwise human intellect might not have been able to perceive. It is just the beginning of the big data era, every year more and more data is being produced and faster computers are being developed to process that data. Aforetime mentioned techniques could be used by students or researchers to make practical medical diagnostic tools growth of bone [33]. These techniques could be applied to make the personalized decision as to when to seek orthodontal treatment. K-nearest neighbors, support vector machine, decision tree, a naïve Bayes, neural network, logistic regression, and random forest could be applied in this section.

6. Future work

Yuval Noah Hariri, discusses in his book 21 Lessons for the 21st Century, the concept of AI doctors. As communication between every single doctor on earth is not possible but AI doctors could be connected with other doctors who could communicate in real-time. An AI doctor in Mongolia could communicate with other AI doctors in Kansas, which is not possible in the case of human doctors. The AI doctor could be connected to all other doctors in the world. The idea might be too futuristic but AI is rapidly advancing and the once thought-impossible cognitive skills are being developed within machines. The human senses such as hearing, sight, touch, and even smell is developed using an electric nose [37]. However, there are still some challenges such as if a human doctor performs malpractice he could be brought to a court of law. If an AI doctor makes a misdiagnosis, who is to blame? And will the whole connected system of AI doctors mimic that error? Even if each AI system is localized there are still moral and legal issues that would need to be solved.

REFERENCES

[1] C. Brooks, "Linear and non-linear (non-) forecastability of high-frequency exchange rates," *Journal of forecasting*, vol. 16, pp. 125-145, 1997.

[2] N. Ernest and D. Carroll, "Genetic Fuzzy based Artificial Intelligence for Unmanned Combat Aerial Vehicle Control in Simulated Air Combat Missions," *J. Def. Manag.*, vol. 06, no. 01, 2016, doi: 10.4172/2167-0374.1000144.

[3] F. Stulp and O. Sigaud, "Many regression algorithms, one unified model: A review," *Neural Networks*, vol. 69, pp. 60–79, Sep. 2015, doi: 10.1016/J.NEUNET.2015.05.005.

[4] M. W. Libbrecht and W. S. Noble, "Machine learning applications in genetics and genomics," *Nat. Rev. Genet. 2015 166*, vol. 16, no. 6, pp. 321–332, May 2015, doi: 10.1038/nrg3920.

[5] Z. Ghahramani, "Probabilistic machine learning and artificial intelligence," *Nat. 2015 5217553*, vol. 521, no. 7553, pp. 452–459, May 2015, doi: 10.1038/nature14541.

[6] J. S. Cramer, "The Origins of Logistic Regression," *SSRN Electron. J.*, 2005, doi: 10.2139/ssrn.360300.

[7] S. Neelamegam and E. Ramaraj, "Classification algorithm in Data mining : An Overview," *Int. J. P2P Netw. Trends Technol.*, vol. 4, no. 8, pp. 369–374, 2013.

[8] K. H. Zou, K. Tuncali, and S. G. Silverman, "Correlation and Simple Linear Regression1," *https://doi.org/10.1148/radiol.2273011499*, vol. 227, no. 3, pp. 617–622, Jun. 2003, doi: 10.1148/RADIOL.2273011499.

[9] "The Concise Encyclopedia of Statistics - Yadolah Dodge–Google 368.&ots=9n21631kn_&si Books."https://books.google.com.pk/books?hl=fnd&lr=&id=k2zklGOBRDwC&oi=fnd&pg=PP6&dq=Multiple+Linear+Regression.+In+The+Concise+Encyclopedia+of+Statistics%3B+Springer:+New+York,+NY,+USA,2008%3B+pp.+364–368.&ots=9n21631kn_&sig=T-1Cw1nSjl14TzvU17XBDvYu0c&redir_esc=y#v=onepage&q&f=false(accessed May 26, 2023).

[10] S. Lloyd, M. Mohseni, and P. Rebentrost, "Quantum algorithms for supervised and unsupervised machine learning," Jul. 2013, Accessed: May 26, 2023. [Online]. Available: https://arxiv.org/abs/1307.0411v2

[11] M. Wang, F. Sha, and M. I. Jordan, "Unsupervised Kernel Dimension Reduction," *Adv. Neural Inf. Process. Syst.*, vol. 23, 2010.

[12] K. J. Cios, R. W. Swiniarski, W. Pedrycz, and L. A. Kurgan, "Unsupervised Learning: Association Rules," *Data Min.*, pp. 289–306, Oct. 2007, doi: 10.1007/978-0-387-36795-8_10.

[13] E. Schubert, J. Sander, M. Ester, H. P. Kriegel, and X. Xu, "DBSCAN Revisited, Revisited," *ACM Trans. Database Syst.*, vol. 42, no. 3, Jul. 2017, doi: 10.1145/3068335.

[14] C. Lazar *et al.*, "A survey on filter techniques for feature selection in gene expression microarray analysis," *IEEE/ACM Trans. Comput. Biol. Bioinforma.*, vol. 9, no. 4, pp. 1106–1119, 2012, doi: 10.1109/TCBB.2012.33.

[15] C. Peng, Y. Chen, Z. Kang, C. Chen, and Q. Cheng, "Robust principal component analysis: A factorization-based approach with linear complexity," *Inf. Sci. (Ny).*, vol. 513, pp. 581–599, Mar. 2020, doi: 10.1016/J.INS.2019.09.074.

[16] G. Choy *et al.*, "Current Applications and Future Impact of Machine Learning in Radiology," *https://doi.org/10.1148/radiol.2018171820*, vol. 288, no. 2, pp. 318–328, Jun. 2018, doi: 10.1148/RADIOL.2018171820.

[17] D. Silver *et al.*, "A general reinforcement learning algorithm that masters chess, shogi, and Go through self-play," *Science (80-.).*, vol. 362, no. 6419, pp. 1140–1144, Dec. 2018, doi: 10.1126/SCIENCE.AAR6404/SUPPL_FILE/AAR6404_DATAS1.ZIP.

[18] Learning Approaches for Health Informatics," *Deep Learn. Parallel Comput. Environ. Bioeng. Syst.*, pp. 123–137, Jan. 2019, doi: 10.1016/B978-0-12-816718-2.00014-2.

[19] T. M. Navamani, "Efficient Deep Learning Approaches for Health Informatics," *Deep Learn. Parallel Comput. Environ. Bioeng. Syst.*, pp. 123–137, Jan. 2019, doi: 10.1016/B978-0-12-816718-2.00014-2.

[20] S. Zhang, C. Zhang, and Q. Yang, "Data preparation for data mining," *http://dx.doi.org/10.1080/713827180*, vol. 17, no. 5–6, pp. 375–381, May 2010, doi: 10.1080/713827180.

[21] E. D. Adler *et al.*, "Improving risk prediction in heart failure using machine learning," *Eur. J. Heart Fail.*, vol. 22, no. 1, pp. 139–147, Jan. 2020, doi: 10.1002/EJHF.1628.

[22] J. Li *et al.*, "Decoding the Genomics of Abdominal Aortic Aneurysm," *Cell*, vol. 174, no. 6, pp. 1361-1372.e10, Sep. 2018, doi: 10.1016/J.CELL.2018.07.021.

[23] B. Zhu, J. Z. Liu, S. F. Cauley, B. R. Rosen, and M. S. Rosen, "Image reconstruction by domain-transform manifold learning," *Nat. 2018 5557697*, vol. 555, no. 7697, pp. 487–492, Mar. 2018, doi: 10.1038/nature25988.

[24] D. S. Kermany *et al.*, "Identifying Medical Diagnoses and Treatable Diseases by Image-Based Deep Learning," *Cell*, vol. 172, no. 5, pp. 1122-1131.e9, Feb. 2018, doi: 10.1016/J.CELL.2018.02.010.

[25] N. Tomašev *et al.*, "A clinically applicable approach to continuous prediction of future acute kidney injury," *Nat. 2019 5727767*, vol. 572, no. 7767, pp. 116–119, Jul. 2019, doi: 10.1038/s41586-019-1390-1.

[26] V. Bevilacqua *et al.*, "A comparison between two semantic deep learning frameworks for the

autosomal dominant polycystic kidney disease segmentation based on magnetic resonance images," *BMC Med. Inform. Decis. Mak.*, vol. 19, no. 9, pp. 1–12, Dec. 2019, doi: 10.1186/S12911-019-0988-4/TABLES/6.

[27] D. Lei *et al.*, "Integrating machining learning and multimodal neuroimaging to detect schizophrenia at the level of the individual," *Hum. Brain Mapp.*, vol. 41, no. 5, pp. 1119–1135, Apr. 2020, doi: 10.1002/HBM.24863.

[28] G. D. Cascarano *et al.*, "Biometric handwriting analysis to support Parkinson's Disease assessment and grading," *BMC Med. Inform. Decis. Mak.*, vol. 19, no. 9, pp. 1–11, Dec. 2019, doi: 10.1186/S12911-019-0989-3/TABLES/18.

[29] C. Mellema, A. Treacher, K. Nguyen, and A. Montillo, "Multiple deep learning architectures achieve superior performance diagnosing autism spectrum disorder using features previously extracted from structural and functional mri," *Proc. - Int. Symp. Biomed. Imaging*, vol. 2019-April, pp. 1891–1895, Apr. 2019, doi: 10.1109/ISBI.2019.8759193.

[30] H. Kök, A. M. Acilar, and M. S. İzgi, "Usage and comparison of artificial intelligence algorithms for determination of growth and development by cervical vertebrae stages in orthodontics," *Prog. Orthod.*, vol. 20, no. 1, pp. 1–10, Dec. 2019, doi: 10.1186/S40510-019-0295-8/TABLES/5.

[31] G. D. Cascarano *et al.*, "Biometric handwriting analysis to support Parkinson's Disease assessment and grading," *BMC Med. Inform. Decis. Mak.*, vol. 19, no. 9, pp. 1–11, Dec. 2019, doi: 10.1186/S12911-019-0989-3/TABLES/18.

[32] C. Mellema, A. Treacher, K. Nguyen, and A. Montillo, "Multiple deep learning architectures achieve superior performance diagnosing autism spectrum disorder using features previously extracted from structural and functional mri," *Proc. - Int. Symp. Biomed. Imaging*, vol. 2019-April, pp. 1891–1895, Apr. 2019, doi: 10.1109/ISBI.2019.8759193.

[33] H. Kök, A. M. Acilar, and M. S. İzgi, "Usage and comparison of artificial intelligence algorithms for determination of growth and development by cervical vertebrae stages in orthodontics," *Prog. Orthod.*, vol. 20, no. 1, pp. 1–10, Dec. 2019, doi: 10.1186/S40510-019-0295-8/TABLES/5.

[34] D. Zeevi *et al.*, "Personalized Nutrition by Prediction of Glycemic Responses," *Cell*, vol. 163, no. 5, pp. 1079–1094, Nov. 2015, doi: 10.1016/J.CELL.2015.11.001.

[35] D. Lei *et al.*, "Integrating machining learning and multimodal neuroimaging to detect schizophrenia at the level of the individual," *Hum. Brain Mapp.*, vol. 41, no. 5, pp. 1119–1135, Apr. 2020, doi: 10.1002/HBM.24863.

[36] B. P. Little *et al.*, "Artificial intelligence-enabled rapid diagnosis of patients with COVID-19," *Nat. Med.*, doi: 10.1038/s41591-020-0931-3.

[37] D. Karakaya, O. Ulucan, and M. Turkan, "Electronic Nose and Its Applications: A Survey", doi: 10.1007/s11633-019-1212-9.

[38] R. V. Yampolskiy, "Turing test as a defining feature of AI-completeness," *Stud. Comput. Intell.*, vol. 427, pp. 3–17, 2013, doi: 10.1007/978-3-642-29694-9_1.

[39] M. Y. Shaheen, "Applications of Artificial Intelligence (AI) in healthcare: A review," *Sci. Prepr.*, Sep. 2021, doi: 10.14293/S2199-1006.1.SOR-.PPVRY8K.V1.

[40] R. Manne, S. K.-C. J. of A. S. and, and undefined 2021, "Application of artificial intelligence in healthcare: chances and challenges," *papers.ssrn.com*, vol. 40, no. 6, pp. 78–89, 2021, doi: 10.9734/CJAST/2021/v40i631320.

[41] F. Jiang *et al.*, "Artificial intelligence in healthcare: past, present and future," *svn.bmj.com*, doi: 10.1136/svn-2017-000101.

[42] T. Davenport, R. K.-F. healthcare journal, and undefined 2019, "The potential for artificial intelligence in healthcare," *ncbi.nlm.nih.gov*, Accessed: May 30, 2023. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6616181/

[43] N. Tran, S. Albahra, L. May, … S. W.-C., and undefined 2022, "Evolving applications of artificial intelligence and machine learning in infectious diseases testing," *academic.oup.com*, Accessed: May 30, 2023. [Online]. Available: https://academic.oup.com/clinchem/article-abstract/68/1/125/6490223

[44] Y. Harari, "21 lessons for the twenty-first century," 2018, Accessed: May 30, 2023. [Online]. Available: http://www.waverleyseniorcitizensclub.org.au/files/21-Lessons-For-the-Twenty-First-Century.pdf