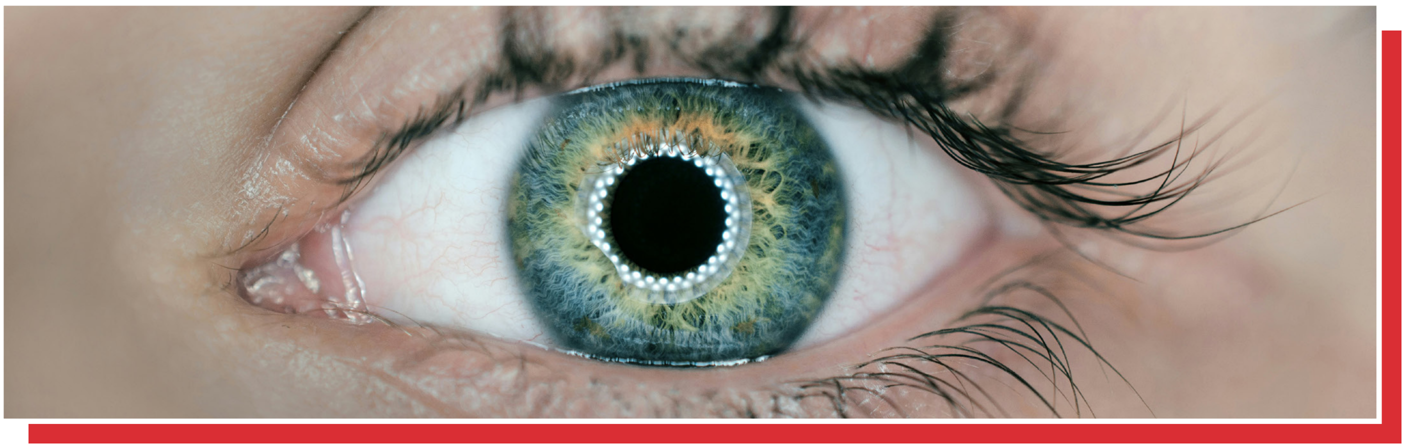
Opinion

The current and potential future roles of artificial intelligence in ophthalmology

Vincent Ng[1,2,3], Cheuk Ying Li[4]

[1] Honorary Tutor, Cardiff University
[2] University Hospitals Birmingham NHS Foundation Trust
[3] Birmingham AI & Digital Health Research & Policy Group
[4] Year 5, Medicine, Cardiff University
Corresponding Author: Cheuk Ying Li
Email: licy3@cardiff.ac.uk



Abstract

Artificial Intelligence (AI), initially conceptualised through Alan Turing's Turing Test in 1950, has since evolved into a transformative technology. AI encompasses a broad range of computational methods that mimic human intelligence, with Machine Learning (ML) as a subfield focused on pattern detection in structured datasets. Deep Learning (DL), a further subset of ML, utilises neural networks modelled after the human brain to solve complex data-driven problems. As computer processing power advances, AI's role in fields such as ophthalmology has expanded. Current applications include AI-powered diagnostic systems, such as IDx-DR for diabetic retinopathy, and DeepSeeNet for age-related macular degeneration (AMD), which have demonstrated high accuracy, sensitivity and specificity. These advancements promise reduced diagnostic costs and improved disease management. While challenges such as algorithmic bias and ethical concerns persist, the potential of AI to revolutionise patient care and medical education remains substantial as AI tools continue to evolve.

Abbreviations

AI – artificial intelligence
AMD – age-related macular degeneration
ML – machine learning
DL – deep learning
DR – diabetic retinopathy
VR – vitreoretinal

Introduction

When Alan Turing introduced the Turing Test in 1950, he could not have anticipated how his idea would lay the groundwork for artificial intelligence (AI), which is described by some as the 'fourth revolution of mankind'.[1] AI integrates datasets with computer science to mimic human intelligence in solving problems. Within AI, machine learning (ML) identifies patterns and models results from structured datasets, while deep learning (DL), a subset of ML, utilises neural networks to process data and solve complex problems[2] **(Figure 1)**. As a result of its potential, there had been an increasing amount of excitement in the research in the application of AI in the medical field. This article explores the current applications of AI in ophthalmology and its untapped potential.

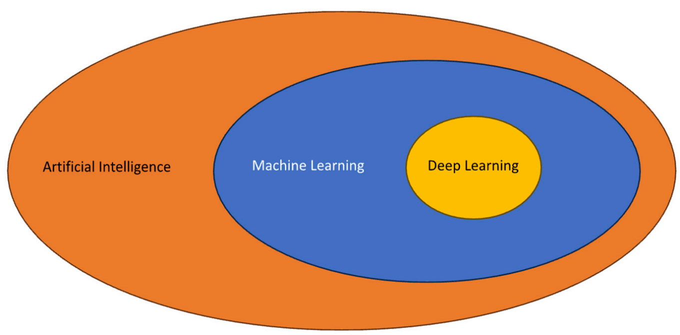


Figure 1. Diagram explaining the terms of Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL)

AI as a diagnostic tool

A good diagnostic tool is characterised by high sensitivity and specificity, cost effectiveness and ease of deployment. Such tools enable ophthalmologists to detect and manage diseases promptly, reducing their progression and avoiding complications.

Diabetic retinopathy (DR), a complication of diabetes, affects one-third of diabetics and can lead to neovascularisation, retinal detachment and vision loss.[3] Ophthalmology became the first medical specialty to adopt a US FDA-approved autonomous AI diagnostic system, IDx-DR.[4,5] This system achieved sensitivities and specificities of 87.2% and 90.7% respectively in detecting DR in patients with diabetes with no previous history of the condition.4 NICE's Medtech Innovation Briefing highlights how AI technologies like RetinaLyze and Retmarker could reduce screening costs from £4.79 per patient to £0.35–£0.86 and decrease reliance on staff.[6]

Age-related macular degeneration (AMD) is the leading cause of irreversible vision loss in developed nations, accounting for over 9% of global blindness.[7] DL models, such as DeepSeeNet, have demonstrated superior accuracy compared to retinal specialists in risk stratification for AMD.[8] One study reported comparable sensitivity, specificity and precision in detecting late AMD progression.[9] Furthermore, a separate system outperformed five out of six retinal experts in predicting disease progression, underscoring AI's potential in diagnostics.[10]

AI as a treatment tool

AI is particularly prominent in vitreoretinal (VR) surgery due to its complexity. AI was shown to be able to localise, classify and segment tissues and instruments during VR procedures, which can be used by surgeons to enhance precision and reduce surgical risks.[11]

AI as an educational tool

AI can be used to track and analyse surgical movements in different stages of cataract surgery and compare the movements with expert surgeons to highlight the difference in techniques.[12] Moreover, AI can also be deployed to highlight key learning points of the surgery to facilitate independent learning.[13] Cybersight, an online training and mentorship service for eye health professionals in developing countries created by Orbis, has integrated AI in the platform to enable users to utilise AI in learning, detecting and diagnosing eye conditions in fundus images.[14]

AI's limits and concerns

Despite its potential, AI has limitations. Algorithms require extensive datasets for training, making it challenging to develop accurate models for rare eye diseases due to limited data availability. Additionally, AI models are susceptible to algorithmic bias, as their effectiveness depends on the quality and diversity of their training datasets. For example, biases in datasets can lead to disparities in diagnostic outcomes across populations.[15]

Ethical concerns also pose challenges. Issues of accountability, data privacy and informed consent must be addressed to ensure AI's responsible implementation.[15] The use of dataset in training AI models presents unique risks to data security, necessitating robust measures to protect sensitive information. Establishing clear guidelines for algorithm transparency and performance evaluation is critical for building trust and ensuring ethical compliance.

Future directions

The capacity of AI as an accurate diagnostic tool will strengthen in the future as more datasets in various ophthalmic conditions are produced and models are trained on them. With the maturation of knowledge in AI diagnostic tools, it is hopeful that deploying AI models will become more cost-effective, especially in developing countries.

The primary challenge for AI is to seamlessly integrate AI research into daily clinical practice while addressing ethical concerns. Ethical concerns can be addressed by adhering to AI-research guidelines such as Consort-AI and Spirit-AI, which aim to improve transparency and completeness of clinical trial protocols involving AI as well as other future guidelines and frameworks.[16]

Conclusion

It is evident that the application of AI in ophthalmology will continue to expand as datasets become more robust and extensive, with more AI algorithms being developed and trained. Coupled with the increasing processing power of computer chips, the potential of AI in enhancing patient care will continue to grow. Equally important is the need to equip future healthcare professionals with AI-related knowledge, enabling them to utilise this multifaceted tool effectively and safely, thereby unleashing its full potential.

Contribution statement

Both authors had substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work and drafting the work or revising it critically for important intellectual content and the final approval of the version to be included in Inspire. Vincent Ng is responsible for the integrity of the work as a whole.

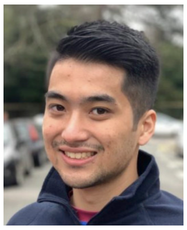
References

1. Klaus S. Foreign Affairs. 2015 [cited 2023 Aug 26]. The fourth industrial revolution. Available from: https://www.foreignaffairs.com/world/fourth-industrial-revolution
2. IBM. What is Artificial Intelligence (AI) ? [Internet]. [cited 2023 Aug 26]. Available from: https://www.ibm.com/topics/artificial-intelligence
3. Yau JWY, Rogers SL, Kawasaki R, Lamoureux EL, Kowalski JW, Bek T, et al. Global prevalence and major risk factors of diabetic retinopathy. Diabetes Care [Internet]. 2012 Mar [cited 2023 Aug 16];35(3):556–64. Available from: /pmc/articles/PMC3322721/
4. Abràmoff MD, Lavin PT, Birch M, Shah N, Folk JC. Pivotal trial of an autonomous AI-based diagnostic system for detection of diabetic retinopathy in primary care offices. npj Digital Medicine 2018 1:1 [Internet]. 2018 Aug 28 [cited 2023 Aug 16];1(1):1–8. Available from: https://www.nature.com/articles/s41746-018-0040-6
5. US Food and Drug Administration. FDA permits marketing of artificial intelligence-based device to detect certain diabetes-related eye problems [Internet]. 2018 [cited 2023 Aug 16]. Available from: https://www.fda.gov/news-events/press-announcements/fda-permits-marketing-artificial-intelligence-based-device-detect-certain-diabetes-related-eye
6. National Institute for Health and Care Excellence. National Institute for Health and Care Excellence. 2021 [cited 2023 Aug 16]. AI technologies for detecting diabetic retinopathy medtech innovation briefing. Available from: https://www.nice.org.uk/advice/mib265/chapter/Summary
7. Stahl A. The diagnosis and treatment of age-related macular degeneration. Dtsch Arztebl Int [Internet]. 2020 Jul 20 [cited 2023 Aug 16];117(29–30):513. Available from: /pmc/articles/PMC7588619/
8. Peng Y, Dharssi S, Chen Q, Keenan TD, Agrón E, Wong WT, et al. DeepSeeNet: a deep learning model for automated classification of patient-based age-related macular degeneration severity from color fundus photographs. Ophthalmology [Internet]. 2019 Apr 1 [cited 2023 Aug 16];126(4):565–75. Available from: https://pubmed.ncbi.nlm.nih.gov/30471319/
9. Keenan TD, Dharssi S, Peng Y, Chen Q, Agrón E, Wong WT, et al. A deep learning approach for automated detection of geographic atrophy from color fundus photographs. Ophthalmology [Internet]. 2019 Nov 1 [cited 2023 Aug 16];126(11):1533–40. Available from: https://pubmed.ncbi.nlm.nih.gov/31358385/
10. Yim J, Chopra R, Spitz T, Winkens J, Obika A, Kelly C, et al. Predicting conversion to wet age-related macular degeneration using deep learning. Nature Medicine 2020 26:6 [Internet]. 2020 May 18 [cited 2023 Aug 16];26(6):892–9. Available from: https://www.nature.com/articles/s41591-020-0867-7

11. Nespolo RG, Yi D, Cole E, Wang D, Warren A, Leiderman YI. Feature tracking and segmentation in real time via deep learning in vitreoretinal surgery: a platform for Artificial Intelligence-mediated surgical guidance. Ophthalmol Retina [Internet]. 2023 Mar 1 [cited 2023 Sep 6];7(3):236–42. Available from: https://pubmed.ncbi.nlm.nih.gov/36241132/
12. Smith P, Tang L, Balntas V, Young K, Athanasiadis Y, Sullivan P, et al. “PhacoTracking”: an evolving paradigm in ophthalmic surgical training. JAMA Ophthalmol [Internet]. 2013 May [cited 2023 Aug 16];131(5):659–61. Available from: https://pubmed.ncbi.nlm.nih.gov/23519488/
13. Zisimopoulos O, Flouty E, Luengo I, Giataganas P, Nehme J, Chow A, et al. DeepPhase: surgical phase recognition in CATARACTS videos. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) [Internet]. 2018 Jul 17 [cited 2023 Aug 16];11073 LNCS:265–72. Available from: https://arxiv.org/abs/1807.10565v1
14. Ophthalmology Training and Mentorship | Cybersight [Internet]. [cited 2023 Aug 16]. Available from: https://cybersight.org/
15. khan B, Fatima H, Qureshi A, Kumar S, Hanan A, Hussain J, et al. Drawbacks of Artificial Intelligence and their potential solutions in the healthcare sector. Biomedical Materials & Devices (New York, N.y) [Internet]. 2023 Feb 8 [cited 2023 Aug 16];1:1. Available from: /pmc/articles/PMC9908503/
16. Liu X, Cruz Rivera S, Moher D, Calvert MJ, Denniston AK, Chan AW, et al. Reporting guidelines for clinical trial reports for interventions involving artificial intelligence: the CONSORT-AI extension. Nature Medicine 2020 26:9 [Internet]. 2020 Sep 9 [cited 2023 Aug 16];26(9):1364–74. Available from: https://www.nature.com/articles/s41591-020-1034-x

Cheuk Ying Li (Coco)

Is a fifth-year medical student at Cardiff University with a keen interest in burns and reconstructive plastic surgery. Passionate about research, she has contributed to various clinical projects and societies, including INSPIRE and OSCEazy. She is also exploring the integration of AI in clinical practice and medical education. Currently, Coco is on elective in New Zealand, gaining hands-on experience at the renowned National Burns Centre. Outside of medicine, Coco enjoys traveling and visual arts, using creativity as a means to explore new perspectives and express her passion for science and humanity.



Vincent Ng

Is an academic F2 doctor at University Hospitals Birmingham Trust. He has a strong passion for ophthalmology, technology and medical education. He is the co-founder of international medical education platform, OSCEazy and he is currently an honorary tutor for Cardiff University and an honorary research fellow for Moorfields Eye Hospital, specialising in artificial intelligence in ophthalmology research. He graduated from Cardiff University in 2023 and was previously innovation lead for Cardiff University Research Society where he cofounded and organised the Learn2Innovate programme for students with a passion in healthtech and entrepreneurship. In his spare time, he enjoys playing squash and rugby.