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GOOGLE ARDA TOOL USING ARTIFICIAL INTELLIGENCE IN SELF-OPTIMIZING ALGORITHM TO PREVENT DIABETIC RETINOPATHY AND DIABETIC MACULAR EDOEMA (DME)

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Abstract
Diabetic retinopathy is an aspect of diabetes which produces vascular abnormalities that might result in blindness. Since the symptoms with this illness are lasting, detection at an early stage is crucial because untreated eye disease may lead to blindness. The detection of microaneurysms using digital color fundus images is an essential initial step in automated diabetic retinopathy testing. Manually diagnosis (by physicians) for such ailment requires time and is vulnerable to inaccuracy. There have been several computer vision-based algorithms created for autonomously recognizing Diabetic Retinopathy. In this study on Automated Retinal Disease Assessment, or ARDA, employs artificial intelligence to aid healthcare professionals in detecting diabetic retinopathy, providing the potential for AI algorithms to assist physicians in diagnosing additional illnesses in future research.
Keywords: Aritificial Intelligence (AI), Deep Learning, Diabetic Retinopathy (DR), Diabetic Macular Edoema (DME)

I. Introduction

Diabetic retinopathy causes abnormalities during the rear part of the retina, which can cause blindness. It is critical to identify those detected with diabetes in advance, but now over 420 million diabetics worldwide, monitoring on each patient is unfeasible. The disease's lack of knowledge, as well as the tools needed for diagnosing for it, is also major challenges. Google's artificial intelligence accurately analyzed retinal images to diagnose diabetic retinopathy in a study released by JAMA. Google collaborated with an enormous group of ophthalmologists who's assisted us in training the AI models by hand examining over 100,000 de-identified retinal images. This resulted in the creation of Automated Retinal Disease Assessment, an AI-based programme. This tool can assist clinicians in expanding excellent in quality diabetic retinopathy screening programmes in countries where retinal specialists are scarce, like India and Thailand.

II. Survey from 2015 to Present

In 2015, a tiny Google study group discussed how AI may assist enhance people's health. At Aravind Eye Hospital, we met experts like Dr. Kim Ramasamy, who has a lifetime goal of expanding chances for sight-saving treatment for patients. Several areas of the globe lack experts,

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and an AI-powered screening system [7] might help physicians access more patients. We attempted to see how we could train AI to detect diabetic retinopathy (DR), a prominent and rising cause of avoidable blindness, and by 2016, we had created an artificial intelligence (AI) algorithm that outperformed eyecare clinicians. [1]ARDA has already examined over 200,000 patients in hospitals worldwide, from big centers in the European Union to rural villages in India.

III. Five Myths and Reality of Medical AI in Diabetic Retinopathy

However, as our assumptions met with the facts of designing and implementing a medical AI tool (Fig.1& Table1), we faced unforeseen hurdles throughout the way. Observations learnt through model building and implementation at numerous locations in India and Thailand might prove beneficial to others working on medical artificial intelligence. The following are the five most important things we acquired through the work we did:

- Data
- People
- Readiness
- Integration
- Post-Launch

Data includes two components: the information that is input, which could be an image of the retinal fundus, and the goal-directed labeling or prediction, such as disease severity. Trained on a variety of datasets is widely regarded to improve AI generalization and produce better-quality artificial intelligence models [8]. We worked via collaborators from all over the world to ensure diversity across various areas, including demographics of participants (age, gender, race, and ethnicity); the acquisition of images (clinical environment, camera devices, camera operator expertise); as well as illness spectrum (number of years with diabetes, illness severity). Tests for medicinal treatments frequently enforce strict criteria for inclusion and exclusion to eliminate covariates and increase the population of patient’s specificity [2], but AI modeling must include a wide range of dataset in order to encourage generalization and equality in practice.

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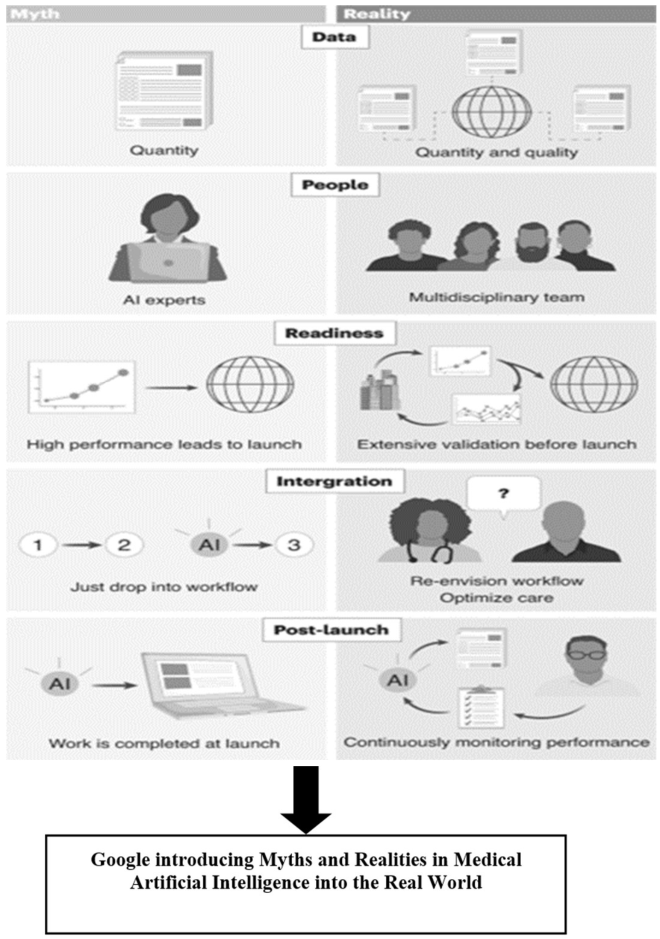

Figure1. Illustrates the myths and realities when developing medical AI. Five past predictions for the development of medical artificial intelligence are illustrated, in addition to the facts and insights gained.

Table 1. Myths and Reality in Medical Artificial Intelligence

Myths	Reality
Data	Although a great deal of data is vital in constructing a correct AI approach, the quality of the data is more vital. Training data ought to reflect real-world data variety (e.g., patient details, quality of data matching in real-world scenarios, etc.), and allowing experts judge difficult instances would enhance labeling accuracy.
People (AI Experts)	It requires a village of multidisciplinary groups to build a well-functioning medical artificial intelligence system, involving physicians, creators, and human-machine interface researchers, regulatory, ethical, and legal specialists, among others.
Readiness	Validating the AI effectiveness in a controlled environment does not ensure an identical degree of accuracy as when it is used in actual clinics. In order to guarantee AI's outstanding efficiency and modeling generalizability, rigorous checks in real-world situations are required.
Integration	We must create AI with people in mind rather than the other way around. The greatest applications of artificial intelligence may not always be the same as the initial expectations. We've also seen that incorporating AI into a workflow might result in unanticipated changes to entire healthcare operations, including education for patients and schedule optimization.

Post-Launch	Following the original introduction, the patient population or environmental circumstances may change. These factors might have an unanticipated impact on AI effectiveness. Implementing a system that actively tracks the performance of artificial intelligence can aid in the detection of possible difficulties.

Robust software architecture was created to support massive grade using a varied set of graders all over the world. We were initially startled by the level of variety among graders [3], having inter-grader agreement ranging from around 60%. Grading accuracy has been improved by fine-tuning standards for scoring and developing tests to test graders' comprehension of the assignment and expertise with the evaluation tool. Whenever the reference standard was changed from graders' majority viewpoints to grades assessed by a panel [4], the artificial intelligence (AI) model efficiency increased even more. To help with adjudications, a platform was created for graders to asynchronously debate issues and establish consensus while remaining anonymous to each other's identities to minimize excessive impact of any single voice throughout discussions[5].

Grading both quantity and quality were increased up via those attempts from a previous stage that had poor inter-rater agreement (as measured by Krippendorff's alpha) over small samples to repeatable scoring by more than 100 trained graders, generalist ophthalmologists, and subspecialists. Such higher-quality labels were critical for modeling evaluation [6] as well as improvement.

IV. Diabetic Retinopathy (DR) and Diabetic Macular Edoema (DME)

A. Diabetic Retinopathy (DR)

Diabetic retinopathy (DR) is an eye disorder that is that results from high blood sugar levels in the body of humans, which harms the blood vessels in the retina. Early detection and continuous monitoring of diabetic patients are required for effective DR therapy, becoming an enormous challenge given the disease's delayed onset and lack of signs[8]. The first in every three diabetic in the United States suffers from diabetic retinopathy. Completing eye tests manually, on the other hand, takes an enormous amount of time, focus, and effort. Injury to the retina induces blood vessels to stop working, leaks, and develop abnormally, resulting in retinal. As a result, 78% of people over the age of thirty who suffered from diabetes for more than fifteen years will develop diabetic retinal damage before the disease gets worse; diabetic retina is asymptomatic and has virtually no impact on vision. This is the result of long-term diabetes [9,10]. Visual loss can occur when DR advances to a critical level.

DR generates 2.6% of blindness globally; this risk of blindness can be lowered by early detection and therapy of DR through continuous retinal testing. Because the primary impact of DR is constriction of the blood vessels within the retina, the retinas react in two dist
inct ways: The main region (vitreous), which must be clean so as for lights to reach the retina—the most sensitive component of the eyes—first notices new blood vessel creation and bleeding. In addition, the blood vessels leak, inflicting damage that affects the retina, particularly the macula (the central portion that makes up the retina which is responsible for detailed vision).

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B. Diabetic Macular Edoema (DME)

Swelling of the macula, or its core, region of the retina of our eye, is known as diabetes-related macular edema (DME). Our retina, which is located at the outermost part of the eye, is the area of the eye where the light-sensing cells are located. We can notice minute details due to our macula. If we suffer from diabetes-related retinopathy, we run the risk of developing DME. Our eyes' blood vessels are impacted by diabetes, becoming weaker and more prone to bleeding. Additionally, it might encourage the growth of additional, more delicate blood vessels when none should.

C. Supported Screenings and Rising

In India and the European Union, our approach is utilized to identify diabetic retinopathy. Having over 3000 novel tests sponsored by ARDA every week, we keep working to increase up access to diabetic retinopathy screenings. The treatment is presently being tested in clinical investigations in both the United States and Thailand. We are collaborating with a number of partnerships in order to make this approach accessible across the globe, particularly in places with limited access to expert care.

D. How AI Learns to Detect Diabetic Retinopathy

Using deep learning algorithm, Google Brain researchers created a self-optimizing algorithm that can analyze huge numbers of fundus pictures and diagnose diabetic retinopathy (DR) and diabetic macular edoema (DME) with high accuracy shown in Fig 2. Google Brain is a financial disclosure that is relevant. Once the screening technique was evaluated on two distinct sets of images (N = 11,711), it showed a sensitivity value of 96.1 % and 97.5%, as well as an accuracy of 93.9% for Diabetic Retinopathy and diabetic macular edoema, correspondingly. "This is an actual achievement which Google was capable to achieve a high level of specificity and sensitivity during at the same time," stated Peter A. Karth, MD, MBA, a vitreoretinal subspecialist in Eugene, Ore., and a consultant to the Google Brain project.

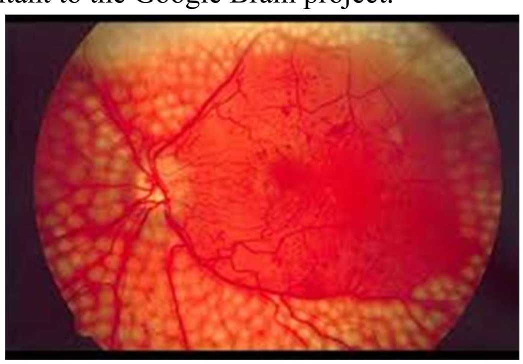

Figure 2. Diabetic Retinopathy - Using a self-optimizing algorithm, computers learn to recognize diabetic eye diseases in fundus images.

E. How System Learns

Deep machine learning is a sort of artificial intelligence (AI) technology through which a neural network "learns" to accomplish tasks via repetitions and self-rectification. In this case, the computerized system was trained using 128,175 human-graded fundus photographs displaying varied degrees of diabetic retinal damage. "Then, for each image, the level of severity grade provided by the [algorithm] will be compared to the actual grade from the training data set, and values are altered slightly to reduce the errors on that image."This method is done several times for each picture in the training set, and the [algorithm] 'learns' the how to properly determine the diabetic retinopathy severity given the image's pixel intensity values for all photos in the training set.

This algorithm performs despite the reality its design was never intended to search particularly for the lesion-based traits which a person might search for on fundus images. "What's fascinating about deep learning is that at this point we don't yet know what the algorithm is aiming at. All we understand is the fact that it makes accurate diagnoses as frequently as ophthalmologists did. We have no real understanding of how the system operates functioning. It may be added and observing the exact same things we are, such as microaneurysms, haemorrhages, or neovascularization. However, it's also probable which the algorithm will examine beyond those characteristics, especially at things which we as humans don't notice when we look at an image.

AI will not be able to replace physicians' intelligence. A great deal more research is required while the algorithm is suitable for clinical application, although the ultimate objective is to enhance accessibility and lower the price of diabetic eye disease screening and treatment, particularly in underserved areas. In reality, it will increase the number of people with actual diseases who require real therapies. This is a critical initial step in screening for diabetic retinopathy and, as a result, greatly raising the number of persons who are screened.

V. Conclusion

With neuronal injury or dysfunction occurring before the present one clinically understood microvascular damage, diabetic retinopathy is now understood to be an inflammatory neuro-vascular complication of the systemic disease. Additionally, it is suggestive of the inflammatory tissue injury simultaneously in other organs. Diabetic retinopathy's current diagnosis and care are inadequate. Modern screening techniques and diagnostic standards are highly constrained, resulting in treatment starting much later than necessary. There are presently few available treatments for diabetic retinopathy. The examination of a larger range of prospective ocular as well as systemic treatments for this widespread and debilitating diabetes-related consequence is made possible by considering diabetic retinopathy from the framework that diabetes and all of its problems. As AI applications in medicine grow, we aspire to assist others in developing useful medical AI tools that enhance healthcare for everybody. However, Google Brain researchers created a self-optimizing algorithm that can easily analyze diagnose diabetic retinopathy (DR) and diabetic macular edoema (DME) with high accuracy.

VI. Future Enhancement

More research is being conducted, includes ongoing clinical trials in India, where screenings will be conducted for the very first time at this level of detection. In addition the Google and Verily teams are upbeat about the prospects beyond diabetic retinopathy. Since we've made much more progress. We just released a report in Nature Biomedical Engineering demonstrating that we can

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predict not only various cardiovascular health risk factors but also your likelihood of a major cardiovascular event from a retina picture. One day, taking a temperature or testing the blood pressure might be enough to diagnose severe conditions. However, millions of diabetics may be able to maintain their vision in the near future owing to an AI programme that assists clinicians in detecting diabetic retinopathy. We are confident that numerous additional diabetic patients will be able to maintain their eyesight, mainly to part to the Automated Retinal Disease Assessment, which assists clinicians in detecting diabetic retinopathy. Our preliminary study on the ongoing potential of AI algorithms in identifying major diseases is exciting, and we predict a scenario whereby simple screening techniques may be employed to identify disorders.

VII. Acknowledgement

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VIII. References

[1] Al-Kamachy, I.M.R.K. (2019). Classification of diabetic retinopathy using pre-trained deep learning models. Master's thesis.

[2] Alyoubi, W.L., Shalash, W.M., Abulkhair, M.F. (2020). Diabetic retinopathy detection through deep learning techniques: A review. Informatics in Medicine Unlocked, 20: 100377. https://doi.org/10.1016/j.imu.2020.100377.

[3] Andrew N. Phillips, George Davey Smith, The design of prospective epidemiological studies: More subjects or better measurements?, Journal of Clinical Epidemiology, Volume 46, Issue 10, 1993, Pages 1203-1211, ISSN 0895-4356, https://doi.org/10.1016/0895-4356(93)90120-P.

[4] FDA, https://www.fda.gov/media/134754/download, 2018.

[5] Gulshan V, Peng L, Coram M, et al. Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs. JAMA. 2016; 316(22):2402–2410. doi:10.1001/jama.2016.17216

[6] Krause J, Gulshan V, Rahimy E, Karth P, Widner K, Corrado GS, Peng L, Webster DR. Grader Variability and the Importance of Reference Standards for Evaluating Machine Learning Models for Diabetic Retinopathy. Ophthalmology. 2018 Aug; 125(8):1264-1272. doi: 10.1016/j.ophtha.2018.01.034. Epub 2018 Mar 13. PMID: 29548646.

[7] Noriega A, Meizner D, Camacho D, Enciso J, Quiroz-Mercado H, Morales-Canton V, Almaatouq A, Pentland A. Screening Diabetic Retinopathy Using an Automated Retinal Image Analysis System in Independent and Assistive Use Cases in Mexico: Randomized Controlled Trial. JMIR Form Res. 2021 Aug 26;5(8):e25290. doi: 10.2196/25290. PMID: 34435963; PMCID: PMC8430849.

[8] Schaekermann M, Hammel N, Terry M, Ali TK, Liu Y, Basham B,Campana B, Chen W, Ji X, Krause J, Corrado GS, Peng L, Webster DR, Law E, Sayres R. Remote tool-based adjudication for grading diabetic retinopathy. Trans Vis Sci Tech. 2019; 8(6):40, https://doi.org/10.1167/ tvst.8.6.40 Copyright 2019 .

[9] Zhang Y, Shi J, Peng Y, et al Artificial intelligence-enabled screening for diabetic retinopathy:

a real-world, multicenter and prospective studyBMJ Open Diabetes Research and Care 2020;8:e001596. doi: 10.1136/bmjdrc-2020-001596

[10] Widner, K., Virmani, S., Krause, J. et al. Lessons learned from translating AI from development to deployment in healthcare. Nat Med 29, 1304–1306 (2023). https://doi.org/10.1038/s41591-023-02293-9.

[11] Mehraj, H., Jayadevappa, D., Haleem, S. L. A., Parveen, R., Madduri, A., Ayyagari, M. R., & Dhabliya, D. (2021). Protection motivation theory using multi-factor authentication for providing security over social networking sites. Pattern Recognition Letters, 152, 218-224.

[12] Soni, M., Khan, I. R., Babu, K. S., Nasrullah, S., Madduri, A., & Rahin, S. A. (2022). Light weighted healthcare CNN model to detect prostate cancer on multiparametric MRI. Computational Intelligence and Neuroscience, 2022.

[13] Sreenivasu, S. V. N., Gomathi, S., Kumar, M. J., Prathap, L., Madduri, A., Almutairi, K., ... & Jayadhas, S. A. (2022). Dense convolutional neural network for detection of cancer from CT images. BioMed Research International, 2022.

[14] Sharma, D. K., Chakravarthi, D. S., Boddu, R. S. K., Madduri, A., Ayyagari, M. R., & Khaja Mohiddin, M. (2022, June). Effectiveness of machine learning technology in detecting patterns of certain diseases within patient electronic healthcare records. In Proceedings of Second International Conference in Mechanical and Energy Technology: ICMET 2021, India (pp. 73-81). Singapore: Springer Nature Singapore.

[15] Mannepalli, K., Vinoth, K., Mohapatra, S. K., Rahul, R., Gangodkar, D. P., Madduri, A., ... & Mohanavel, V. (2022). Allocation of optimal energy from storage systems using solar energy. Energy Reports, 8, 836-846.

[16] Rubavathy, S. J., Kannan, N., Dhanya, D., Shinde, S. K., Soni, N. B., Madduri, A., ... & Sathyamurthy, R. (2022). Machine Learning Strategy for Solar Energy optimisation in Distributed systems. Energy Reports, 8, 872-881.

[17] Bansal, P., Ansari, M. J., Ayyagari, M. R., Kalidoss, R., Madduri, A., & Kanaoujiya, R. (2023, April). Carbon quantum dots based nanozyme as bio-sensor for enhanced detection of glutathione (U) from cancer cells. In AIP Conference Proceedings (Vol. 2603, No. 1). AIP Publishing.

[18] Kadam, P. S., Rajagopal, N. K., Yadav, A. K., Madduri, A., Ansari, M. J., & Patil, P. Y. (2023, April). Biomedical waste management during pandemics. In AIP Conference Proceedings (Vol. 2603, No. 1). AIP Publishing.

[19] Torres-Cruz, F., Nerkar Charushila, K., Chobe Santosh, S., Subasree, N., Madduri, A., & Pant, B. (2023, April). A review on future prospects on magnetic levitation for disease diagnosis. In AIP Conference Proceedings (Vol. 2603, No. 1). AIP Publishing.

[20] Sugumar, D., Dixit, C. K., Saavedra-Lopez, M. A., Hernandez, R. M., Madduri, A., & Pant, B. (2023, April). White matter microstructural integrity in recovering alcoholic population. In AIP Conference Proceedings (Vol. 2603, No. 1). AIP Publishing.

[21] Hariharasuthan, R., Radha, K. S., Meena, M., & SenthilKannan, K. (2023). Characterizations of AMPF Micro-Crystals for Photonic, Dielectric, Nano-Influx and Anti-diabetic Relevances. Acta Physica Polonica A, 143(4), 309–315. https://doi.org/10.12693/APhysPolA.143.309

[22] Meena, M, Umapathy, M. J. (2020). Toxic- solvent-free: Radical polymerizations of vinyl monomers using a di-site phase-transfer catalyst – a kinetic approach. Bulgarian Chemical

Communications, 52(3), 348–354. https://doi.org/10.34049/bcc.52.3.5167
[23] Meena, M., Kavitha, A., Karthick, S., Pavithra, S., & Shanmugan, S. (2022). Effect of decorated photoanode of TiO2 nanorods/nanoparticles in dye-sensitized solar cell. Bulletin of Materials Science, 45(4). https://doi.org/10.1007/s12034-022-02828-9
[24] Meena, M., Nanjundan, S., & Umapathy, M. J. (2016). Free Radical Polymerization of Methyl and Ethyl Methacrylates by Green Methodology. International Journal of Applied Engineering Research, 11(04), 2177. https://doi.org/10.37622/IJAER/11.4.2016.2177-2184
[25] Meena, M., & Umapathy, M. J. (2016). Efficiency of single site phase transfer catalyst in free radical polymerization of butyl methacrylate - A kinetic study. Brazilian Archives of Biology and Technology, 59(Specialissue2), 1–9. https://doi.org/10.1590/1678-4324-2016161045
[26] Meena, M., Umapathy, M. J., & Yoganand, K. S. (2021). Efficiency of single and di- site phase transfer catalyzed polymerization of glycidyl methacrylate in the two-phase system : A kinetic study. Indian Journal of Chemical Technology, 28, 445–452.
[27] Senthil Kumar, S., Uma Mageswari, S. D., Meena, M., Nagaraju, V., & Yakkala, B. (2022). Effect of energy storage material on a triangular pyramid solar still operating with constant water depth. Energy Reports, 8, 652–658. https://doi.org/10.1016/j.egyr.2022.10.203
[28] Uma Mageswari, S. D., Suganthi, P., & Meena, M. (2022). Carbon Footprint of Information and Communication Technologies. 2022 International Conference on Edge Computing and Applications (ICECAA), 338–342. https://doi.org/10.1109/ICECAA55415.2022.9936485
[29] Yoganand, K. S., Meena, M., & Umapathy, M. J. (2022). Corrosion inhibition efficiency of newly synthesized quaternary ammonium salt in 1M HCl. Indian Journal of Chemical Technology, 29(January), 68–74.
[30] Yoganand, K. S., Srikumar, D. S., Meena, M., & Umapathy, M. J. (2009). Kinetics of phase transfer agent-aided free-radical polymerization of acrylonitrile and methyl methacrylate using water-soluble initiator. International Journal of Polymeric Materials and Polymeric Biomaterials, 58(3), 150–159. https://doi.org/10.1080/00914030802565574
[31] M. Tiwari, Y. Gupta, F. M. Khan, and A. Adlakha, “UTAUT3 model viability among teachers due to technological dynamism during COVID-19,” Inf. Discov. Deliv., vol. 50, no. 3, pp. 245–259, 2022, doi: 10.1108/IDD-02-2021-0018.
[32] M. Tiwari, Himanshu, and M. Y. Gupta, “Ramification of Online Advertisements& Hedonic Value Via Social Media Platform on Impulse Buying for Indian Street Food,” J. Content, Community Commun., vol. 14, no. 7, pp. 188–196, 2021, doi: 10.31620/JCCC.12.21/15.
[33] M. Tiwari, D. Sharma, and S. Narula, “COVID-19 trepidation: repercussions on air travel anxiety, anger and trust among travellers,” Int. J. Spa Wellness, vol. 5, no. 3, pp. 271–284, 2022, doi: 10.1080/24721735.2022.2099094.
[34] Mansi Tiwari, Monica Chauhan Bhadoriya, G Radha Krishna Murthy, Munmun Goswami, Y Suryanarayana Murthy, and Neha Singh, “Examining The Effects of Factors Influencing Organizational Citizenship Behavior With Respect to IT Managers In Gujarat,” Business, Manag. Econ. Eng., vol. 20, no. 2, pp. 2154–2167, 2022, [Online]. Available: https://creativecommons.
[35] S. Chowdhury et al., “Recent trends of plastic waste management for sustainable environment in Indian context,” Mater. Today Proc., no. xxxx, 2023, doi: 10.1016/j.matpr.2023.06.063.
[36] M. Tiwari and S. Srivastava, “Generous remuneration fostering organisation towards

sustainability: A strategy to make HR practices socially responsible," Multidiscip. Approaches to Sustain. Hum. Dev., pp. 75–96, 2023, doi: 10.4018/978-1-6684-8223-0.ch004.
[37] S. K. Jha, J. Wang, and R. Shanmugam, "An accurate soft diagnosis method of breast cancer using the operative fusion of derived features and classification approaches," Expert Syst., vol. 39, no. 7, pp. 1–18, 2022, doi: 10.1111/exsy.12976.
[38] S. D. Bhat, "Beyond geography: A study of smart culture and digital surrogates in Komagata Maru historical material," Sikh Form. Relig. Cult. Theory, vol. 0, no. 0, pp. 1–18, 2023, doi: 10.1080/17448727.2023.2218794.
[39] M. Arunachalam and D. K. Patel, "Human-Centered Design (HCD) of Rural Cooking Stove," Journal of 7The Institution of Engineers (India): Series C, vol. 104, no. 2. pp. 403–417, 2023. doi: 10.1007/s40032-023-00914-3.
[40] A. Muthiah, S. Prajapati, and A. Lingam, "An investigation of universal design (UD) features in Indian household products," Work, vol. 76, no. 1, pp. 355–368, 2023, doi: 10.3233/wor-220340.
[41] B.T. Geetha, Prakash A., S. Jeyasudha, K.P. Dinakaran, Hybrid approach based combined allocation of electric vehicle charging stations and capacitors in distribution systems, Journal of Energy Storage, Volume 72, Part C, 2023, 108273, ISSN 2352-152X, https://doi.org/10.1016/j.est.2023.108273.
[42] S. Shome, M. K. Hassan, S. Verma, and T. R. Panigrahi, "Impact investment for sustainable development: A bibliometric analysis," Int. Rev. Econ. Financ., vol. 84, no. February 2022, pp. 770–800, 2023, doi: 10.1016/j.iref.2022.12.001.
[43] S. Mall, T. R. Panigrahi, and S. Verma, "Bibliometric Analysis on Big Data Applications in Insurance Sector: Past, Present, and Future Research Directions," J. Financ. Manag. Mark. Institutions, vol. 11, no. 1, 2023, doi: 10.1142/S2282717X23300015.
[44] A. K. Singh et al., "Modeling the Nexus Between Perceived Value, Risk, Negative Marketing, and Consumer Trust With Consumers' Social Cross-Platform Buying Behaviour in India Using Smart-Pls," J. Law Sustain. Dev., vol. 11, no. 4, pp. 1–24, 2023, doi: 10.55908/sdgs.v11i4.488.
[45] A. Hasan et al., "Factors Influencing Behavioural Intention To Embrace Sustainable Mobile Payment Based on Indian User Perspective," J. Law Sustain. Dev., vol. 11, no. 4, pp. 1–19, 2023, doi: 10.55908/sdgs.v11i4.627.
[46] Mane, V. B., Mahind, L. H., Jadhav, K. D., Waghmode, S. A., & Dagade, S. P. (2013). Structural characterization of nanosized Fe2O3-CeO2 catalysts by XRD, EDX and TEM techniques. Applied Science Innovations Pvt. Ltd., Carbon—Sci. Technol, 5(2), 260-264.
[47] Zaware, S. B., Dagade-Waghmode, S., Gonnade, R. G., Srinivas, D., & Rane, S. Y. (2009). Magnetic phase transition in valence tautomers as polymorphs of 3-iodolawsone: Single crystal X-ray structure, DSC and EPR studies. Journal of Molecular Structure, 938(1-3), 328-335.
[48] Nigam, P., Waghmode, S., Yeware, A., Nawale, L., Dagde, P., Dhudhane, A., & Sarkar, D. (2014). Aptamer functionalized multifunctional fluorescent nanotheranostic platform for pancreatic cancer. Journal of Nanopharmaceutics and Drug Delivery, 2(4), 280-287.
[49] Alegaonkar, A. P., Kumar, A., Alegaonkar, P. S., Waghmode, S. A., & Pardeshi, S. K. (2014). Exchange interaction of itinerant electron donors of tetrakis (dimethylamino) ethylene with localized electrons in graphene. Synthesis and Reactivity in Inorganic, Metal-Organic, and

ISSN:2153-182X, E-ISSN: 2153-1838
Vol. 17 No. 02 (2023)

Nano-Metal Chemistry, 44(10), 1477-1482.
[50] MESRAR, M., LAMCHARFI, T., ECHATOUI, N., ABDI, F., & AHJYAJE, F. (2019). AJ Csian OURNALOF HEMISTRY AJ Csian OURNALOF HEMISTRY. Asian Journal of Chemistry, 31(2), 309-316.
[51] Mane, V., Lalaso, M., Waghmode, S., Jadhav, K. D., Dongare, M. K., & Dagade, S. P. (2014). Nitration of benzene using mixed oxide catalysts. IOSR J. Appl. Chem, 7, 50-57.
[52] Mahind, L. H., Waghmode, S. A., Nawale, A., Mane, V. B., & Dagade, S. P. (2013). Evaluation of antimicrobial activities of zirconium (IV) complex. J Pharm Biol Sci, 5, 102-5.
[53] Vanjare, K. J., & Waghmode, S. (2020). Lipase enzyme based green chemistry detergents for cleaning industry.
[54] Dagade, S. P., Mane, V. B., Jape, A. A., Waghmode, S. A., Dhapte, V. V., & Mahind, L. H. (2012). Synthesis, Characterization and Antimicrobial Study of Cr (III), Mn (II), Y (III) and Zr (IV) Schiff Base Complexes. Int. J. of Chem. Anal. Sci, 12, 1672-1674.
[55] Shaikh, A., Meroliya, H., Dagade-Gadale, S., & Waghmode, S. (2021). Applications of Nanotechnology in Precision Agriculture: A review.
[56] Kadam, S., Patul, V., Waghmode, S., & Dagade-Gadale, S. (2021). Use of Nano pesticide in Agriculture and its Toxicity–A Review.
[57] Waghmode, S. A., Gupta, V. S., & Rane, S. Y. (2010). Structure-function mimicry of oxidized purple acid phosphatase-PAP ox–A new functional model.