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Image recognition with machine learning

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Abstract
Image recognition or computer vision is a method that allows machines and computers to parse and piece together relevant information from images. It is a fast-growing field of AI with many real-world applications in robotics, artificial intelligence, self-driving car, surgical tool and much more. Computer vision can also be used to implement and render 3D models from 2D images and automating the rendering process. Massive leaps have been made in the technology allowing for AI to implement real world images within the software. A subset of this is seen in self driving cars, and leading companies like Tesla which allow for quick and efficient image processing in both visual and non-visual mediums like infrared to allow for the cars to navigate through their surroundings on their own. Even with the growth Artificial Intelligences (AI) are far from perfect and are as of yet incapable of beating human cognition, but that day may not be too far away before it arrives. Technological improvements have already made self-driving cars a reality, propagating the value of image recognition and computer. Probes to interplanetary missions will be requiring self-governing AIs due to the lacking capability of instantaneous communication, which makes the field all the more relevant for the future growth and progression of humanity.

Keywords: Facial recognition, machine learning, edge detection, pattern recognition, deep fake

1. Introduction
Machine learning has progressed significantly over the past few decades, overcoming many challenges and becoming capable enough to recreate complicated 3D structures like the human face accurately. The technology has only improved in recent years extending from simplistic detection models working on objects to more complicated methods of analysing visual input to recreate, enhance, modify and process the information being presented to the systems. The capabilities of these algorithms and neural networks have increased even further when they've been provided the datasets formed from previous neural networks to work with and refine their algorithms for better results. A subset of Deepfake images, videos and other multimedia methods have arisen with the rise of this technology. Simultaneously, a rise in Artificial Intelligence geared towards differentiating and detecting these deep fakes have also seen a rise in the past few years. One big application of this technology can be seen in obtaining underwater images and using neural networks to remove the water, allowing for a clearer view [1]. Another application can be seen with the usage of multiple images to create a 3D render and model of the given images, allowing for processing and data to be collected with ease [3]. With the increasing demand for self-driving cars and the need for safety, better resource management, traffic and decreased pollution, we need better AI models capable of learning faster than ever [4].
Definition of Machine Learning as a term varies depending on the context but the basis of the idea all include using images and processing them to obtain data. Machine learning with security cameras, have allowed investigations to more easily detect and tell apart criminals, with many security approaches using machine learning and facial recognition for investigation and criminal identification [7]. Biometrics analysis and forensic rports have also begun using the help of image recognition for selecting out clues and information that may have otherwise been lost, or to process infrared imaging and ultrasonic mapping to obtain a better and more thorough investigation of the crime scene. Last, perhaps the largest use of machine learning has been in product inspection for objects such as microprocessors, automobiles and agricultural and food produce [8]. The use of machine learning has automated the inspection of such processes, especially with regards to small and easy to miss errors present in microprocessors etc.
A large part of image processing relates to machine learning and the development of Artificial intelligence (AI).

Machine vision has become a more and more important assets and component in the development of neural networks as it has turned out to be one of the easiest modes of obtaining information that can be taught to a neural network. The improved capability and application in robotics alongside the various algorithms that can recreate faces, image, geographical locations, terrains, ecological and global mapping, art, and help enhance visual images, and video editing in towards modern world has made Machine Vision synonymous with Artificial intelligence. Neural networks are becoming increasingly more capable at processing and analysing images, with real time application and analysis providing a new level of reach to the field. Many machines, robots, systems are already making use of this new technology inducing rapid growth. From the largest to the smallest sector, machine vision and artificial intelligence are helping enhance and improve development and lifestyle all over the globe. The increasing popularity of self-driving cars also serve to make traffic accidents rarer and help reduce carbon emissions from vehicles as electric cars become more prominent alongside them.

With vast applications and many uses that only keep growing, there is in an increasing need for research and understanding to create better neural networks and machine learning for image processing, and machine vision. To better develop, understand and improve upon this technology.

2. Neural Network Training Models for Image Processing

Computer vision systems uses technology based on image recognition, primarily based upon cameras and other visual devices to obtain data. The machine learning algorithm then processes the data with a feedback loop checking for the accuracy of the data and then assigning feedback on the basis of the accuracy of the detection. The feedback is taken in by the algorithm and applied on a larger data set linked together through and processed through multiple algorithms and run through many iterations to enhance the accuracy of the algorithm. There is an inevitable human part in the usage of this method where the human operators actively train the machine and provide it with feedback on the accuracy of its recognition. The most popular means of providing the dataset so far has been the modern Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA) training methods [5]. Originally intended as a means of telling humans and bots apart, the image recognition method has become a way to provide an accurate data set and method to train modern Artificial Intelligences (AI) by providing human feedback. The efficacy of this method will soon turn the current CAPTCHA methods of image recognition obsolete as machines would be just as capable as humans in telling apart objects, if not better.

Another method arising for training Neural networks to recognise and tell apart images, including better edge recognition, segmentation and pixel counting has been the usage of other machine learning algorithms to train newer ones. Training machine learning for processing images based on synthetic dataset has opened a much vaster and much more flexible dataset to train neural networks and databases from. An application of such can be seen with machine learning algorithms used to recognises faces, and reconstruct them performing better with the synthetic data set in comparison to the limitations present from real images as shown in the following figure [6].

Table 1: Real vs Synthetic data set for facial recognition algorithms

	Common NME	Challenging NME	Private FR 10%
CVPR' 17			3.67
CVPR' 18	2.98	5.19	0.83
ICCV' 19	2.72	4.52	0.33
CVPR' 19	3.56	6.67	-
ICCV' 19	3.19	6.87	-
CVPR'20	3.36	5.74	0.17
(real)	3.37	5.77	1.17
(synthetic)	3.09	4.86	0.50

The data shows the results of synthetic training for facial recognition as a faster and more efficient way to train new algorithms. It allows for improved facial landmark processing and removes any hindrances such as lighting and angle concerns due to the synthetic nature of the database. Additionally, this approach also provides an increased control over the fidelity of the data and allows for a much more variable dataset that can be exponentially generated, tweaked, modified and reiterated.

A similar approach can be seen in image recognition performed by virtual simulations for self-driving cars [4]. The same can be used as a training method for humans which provides more safety for learning and beginner drivers in handling the new and as of yet unfamiliar vehicle. Random generation of terrain and image recognition allows for the creation of realistic models of real-world terrain to provide for these simulations, combined with physical simulations.

3. Applications of Machine Vision and Image Processing

There are an increasing number of applications for computer vision ranging from collecting data, processing information, facial recognition, landmark recognition, real time self-driving cars, modifying image processing and much more [25-42]. In this section, some of the major applications of this technology will be highlighted.

Facial recognition

Neural networks and AI play a massive role in Facial recognition, which forms one of the primary uses of image recognition. It's a technology that has been rapidly expanding in its usage, from biometrics and identification to information and data analysis model and graphics rendering. Deep fake and complicated video editing has allowed for extremely realistic renders and videos to be developed by training an AI and feeding it enough source images about a person. Alongside the many practical usage this has also developed concerned for abuse and misuse and has raised concerns on an individual's privacy and security on the internet even more so than ever before. Facial recognition is also, used in government and military Airports [9] as a means of keeping track of passengers and personnel that have arrived and are departing. It is used for face id unlocks in modern smart phones [10], a widely used and popular method of security but with concerns over how the same can sometimes be tricked using an image of a person which has led to be the development of infrared and 3D face mapping which develops a 3D face database of a person and cannot be tricked using a flat image. The same technology can be

seen certain college classrooms to take attendance. It is used on social media platforms like Facebook [11]. Cameras and other devices come with facial recognition software to take better images and for improved lens focus [6]. Facial recognition databases also play a major role in crime investigation and modern-day law enforcement [7]. Facial recognition is used in automobiles to prevent car theft and increase security. There is increasing usage of Facial recognition in marketing for better targeting ads and more effective usage of resources [12].

Bar code reading

A major usage of image recognition is barcode reading and QR code reading where the images are used to encode a certain piece of data and can then be decoded by the application reading the image. It is often used to store data on physical goods and products in grocery stores and other physical appliances [13]. They form a way to store data physically on devices in a compact manner allowing people to track specific devices, their dates of manufacture, stature, location of origin and product descriptions with the usage of a barcode reader through any local system. This allows for a far easier distribution and tracking method than its predecessor and has wildly been spread out as a means of product management and tracking. The further evolution of the technology has come in the form of QR codes which uses a different format of image coding to store information.

Vision guided robots

Vision guided robots (VGR) play an important role in multiple sectors with applications ranging from medical and surgical robots that improve procedure and safety of the operation to drones and environmental scanning robots for rescue operations. There is also a big role of visual guided robots in military applications and guided missiles alongside anti-aircraft and missile security systems meant to take out any unidentified aircrafts navigating the borders or entering a country's aerospace without authorisation. They are also used for inspection in the manufacturing and processing industry [14]. This field also pertains to self-driving car, otherwise known as automatic vehicles (AV) which has seen a massive increase in its popularity with large tech companies like Tesla spreading the technology and making it more and more feasible than ever before [4]. The same technology is used in security and traffic cameras to detect collision and inform medical or police services if required [18]. Speeding tickets can also be charged and automatically added based on the license plate of the speeding vehicle [19]. Alongside the practical application, robotics and animatronics have developed massively with autonomous robots capable of mimicking conversations using vision guidance to study their environments, the people participating in the conversation and appropriate responses to any given situation. Other robots can help speed up manufacturing processes and reduce faulty products from being produced by relying on machine vision and guidance to analyse and maintain quality for the parts being produced.

Medical Usage

Image processing can be used for X-rays, ultrasounds, chemotherapy, cancer detection and guided application and cancer cell extermination [15, 16]. It can be used to treat cancer, tumour and help with a far more targeted approach towards treatment of many illnesses and conditions. There is a wide application of image processing software combined with VGR's in examples such as the da Vinci surgical systems [17]. The development of machine vision in these sectors has made increasingly difficult procedures and terminal injuries less of a risk. Cancer treatment, and delicate surgical procedures for neurological surgeries and organ transplants have both greatly benefitted from the development of this technology as image processing and machine vision allows the use of far more complex robotic surgical tools that can provide a better and more controlled environment for the surgeons to work in.

Satellite imaging and navigation

Imagine processing is used in forming maps across the globe using satellites. GPS and navigation systems can also rely on image processing to detect and locate various terrains. Real world views and 3D maps formed by google showing each location on their maps are mapped using 360 cameras set on vehicles which are then processed via image processing software to provide. Locating rescue spots, research locations, monitoring changes to the polar caps and many other uses tie into this segment of image recognition. Things such as wildfires, flood and other natural disasters can be detected before they occur with the help of satellite imaging and image recognition. In [21], Weather prediction models, detection and studies of climate change, increasing carbon emissions, sea levels rising also make use of image recognition to predict these weather patterns. In [22], Hurricane and cyclone detections make use of Image recognition as well to improve their detection methodologies and get predictions for harvesting rainfalls to help farmers and the agriculture sector prepare accordingly for planting and harvesting their crops. This plays a vital role in the development and tracking of agricultural cycles and the economy of nations that depend heavily on the weather for their agriculture. The same can be used to track the changing weather conditions across any given region for further climate change and weather studies.

4. Technologies of Machine Vision

There are various technologies pertaining to machine vision and image recognition [30-40]. With various methodologies and technologies meant for different subsets of image processing and recognition. The following list contains some of the prominent methods and technologies used in machine vision.

Image Stitching and Registering

Image stitching is one of the most basic forms of machine vision where multiple images are stitched together and overlapped to form a singular image. It can be used for higher resolution, for software implementations of focus and zoom in cameras and for a wider-angle view using multiple images. The technology uses algorithm to determine image alignment by relating coordinates of pixel from one to another to form a rough guideline of positioning and angle. Image Registering then can use a set of key point and matching features to minimize the errors and differences that may crop up from the combination of multiple images. The most common method used for this purpose is Random Sample Consensus (RANSAC) which is an iterative method that uses mathematical models based on a given dataset of observed points. This technology then further has models for calibration whose purpose is to minimize the differences

between a camera lens image and the image formed using the image stitching and registering method used in this machine vision technology. The algorithm would observe distortion and exposure differences before correcting and optimising the image to be uniform with the overall composition. Another method for image stitching is image blending, which takes image comparison information from the calibration stage and uses the given information to combine and adjust the image for an output projection.

Edge Detection

Edge detection is a technology that combines mathematical methods to detect edges, corves and lines. The technique simplifies the process of image detection by reducing the amount of information that needs to be processed by converting a 3D image into its subsequent 2D representation while still containing the needed structural composition to maintain the image's integrity and information [23]. There are various different methods applied with edge detection with two primary categories, zero-crossing based and search-based. Search based applied a first order derivative to detect edges by a measure of edge strength. The zero-crossing method on the other hand applies a second order derivative to find the edges in the image. Some of the masks for edge detection are Prewitt Operator, Sobel Operator, Robinson Operator, Laplacian operator. The first of them is used to detect horizontal and vertical edges. Sobel operator works quite similarly to Prewitt operator, detection both horizontal and vertical edges. Robinson operator makes use of a mask, rotating it all over in 8 separate directions to get direction edges and vectors for all of them. Kirsch compass mask is another mask operator that can find edges in all directions. Finally, the Laplacian operator is a second order derivative mask, which has two sections, positive Laplacian and negative Laplacian. One big usage of edge detection is in sharpening images, where the more edges are found, the sharper the image becomes after the edges have been applied. It can be used in adding many outlines and effects in photo editing that are based around the shapes and edges present in an image.

Blob Detection

Blob detection, otherwise known as Connected-component labelling (CCL), connected-component analysis (CCA), blob discovery or region extraction is an algorithm that applies graph theory to analyse and process images. In it, subsets of uniquely identified groups of pixels and sections are labelled, giving it the name connected-component labelling. It is used to scan, analyse and detect connected regions in an image. The process works with binary images but colour images can also be analysed using this method. Since images contain various forms of information, pre-processing to filter the irrelevant information out before using blob detection is required often times. Blob detection locates and finds any large clusters of pixels, bright pixels, set against a dark background. That is, a set of pixels that can form a distinctive collection and can distinguish itself from the background of the image. Blob Detection is often used in pair with other image recognition systems, mechanisms and component and can work based on a variety of information and data points depending upon the nature of the image processing and detection system. There are multiple usages of real time blob detection which can help in processing and understanding an image by breaking it down into smaller and smaller components interconnected and tied together [24]. Some of the primary methods of blob detection are Laplacian of Gaussian (LoG), Difference of Gaussian (DoG), Determinant of Hessian (DoH) and Connected Components Labelling.

5. Conclusion and Future Remarks

In this paper we analysed the usage of Artificial Intelligence, Neural Networks and Machine Learning for the development of machine vision, and examined the various methodologies, models, approaches used in the technologies that make use of this field of Image processing. We have shown the widely spread-out usage of image processing across multiple fields such as education, medicinal development, surgical processes, quality maintenance, security, national defence, military operations, robotics, manufacturing and processing, agricultural development, geo satellite mapping, navigation, graphic rendering, 3D modelling and many other fields, and we've shown the application of Machine learning, Artificial intelligence and Neural networks in the development of this technology. While widely prevalent, the technologies for machine vision and neural networks still remains in its infancy. With better technological advances being made each day and development being made in the field alongside increasing research, and capabilities of hardware devices to run and refine these algorithms, we are on the cusp of a world with enhanced and quick image processing capabilities, and robotics capable of navigating and understanding the world around them in a way that had not been possible up until now. The development of this technology, which has become synonymous with artificial intelligence has come up with concerns and pushback from concerned individuals about the abuse of deep fakes and the ease with which these can be produced, but various articles and research papers have highlighted the benefits far outweighing the disadvantages. Image processing and Artificial Intelligence are technologies that carry significant impact on the development of the future of humanity and mark a vital step in the growth of the field of artificial intelligence and computer science. The developments made in just the last decade have been astronomical and with more importance being given to the field, the research and growth has only increased with time.

In this paper, the models described above, proposed by various authors and research papers for the development of image processing and the approach with which to tackle machine learning in regards to image processing has highlighted multiple directions for the development of this technology. The paper discusses the various approaches in which machine learning algorithms can be trained and refined using the varying nature of data sets and feedback loops dependant on both human input and machine input. The paper has also highlighted the differences between the two approaches alongside their advantages and disadvantages. Various application and usage of the technology have been highlighted in the paper as well, alongside the processes and technologies that form the basis of image processing and the methods in which these algorithms analyse and process any given image. Taking in account the various methods of development, the advantages and disadvantages of a synthetic dataset, the methods used for developing and training machine vision, it's varied and diverse usage methods alongside various

technologies present in it such as Image Stitching and Registering, Edge Detection and Blob Detection, the author concludes as such:

There is an ever-increasing need for the development of image processing algorithms in today's growing multimedia world of technology and internet, with more and more avenues and technologies such as Computer-Generated Imagery (CGI) in movies and other industries relying more and more on machine learning algorithms to refine and process vast quantities of image and video data. There is also a need for increasing security and infrastructure to prevent fraud and scams using deepfakes and machine generated images, faces, identities and other similar applications in this new growing world of image processing capabilities. A deeper look into the developmental processes and a better understanding of today's needs for the technology is required.

6. Authorship Statement

All persons who meet the authorship criteria have been listed as authors and took public responsibility for the content including participation in the concept, analysis, writing, and revision of the manuscript.

7. Conflict of Interest

The authors declare that they have no conflicts of interest.

8. References

1. Derya Akkaynak Tali Treibitz University of Haifa Sea-thru: A Method For Removing Water From Underwater Images.
2. Mathias Lechner, Ramin Hasani, Alexander Amini, Thomas A. Henzinger, Daniela Rus and Radu Grosu. Neural circuit policies enabling auditable autonomy
3. Thomas Müller, Alex Evans, Christoph Schied, Alexander Keller. Instant Neural Graphics Primitives with a Multiresolution Hash Encoding. https://nvlabs.github.io/instant-ngp/
4. Mariusz Bojarski, Davide Del Testa, Daniel Dworakowski, Bernhard Firner, Beat Flepp, Prasoon Goyal, *et al*. End to End Learning for Self-Driving Cars.
5. Fabian Stark, Caner Hazırba S, Rudolph Triebel, Daniel Cremers. Technical University of Munich, Germany. CAPTCHA Recognition with Active Deep Learning.https://www.researchgate.net/publication/301620459_CAPTCHA_Recognition_with_Active_Deep_Learning
6. Erroll Wood, Tadas Baltrušaitis, Charlie Hewitt, Sebastian Dziadzio, Matthew Johnson, Virginia Estellers, Thomas J Cashman and Jamie Shotton. Face analysis in the wild using synthetic data alone. microsoft.github.io/FaceSynthetics/
7. Nurul Azma Abdullah, Md Jamri Saidi, Nurul Hidayah Ab Rahman, Chuah Chai Wen, Isredza Rahmi A Hamidd. Information Security Interest Group (ISIG). Fakulti Sains Komputer dan Teknologi Maklumat, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia. Face Recognition for Criminal Identification: And implementation of principal component analysis for face recognition.
8. Krishna Kumar Patel, Kar A, Jha SN, Khan MA. Machine vision system: a tool for quality inspection of food and agricultural products. https://www.researchgate.net/publication/236189439_Machine_vision_system_A_tool_for_quality_inspection_of_food_and_agricultural_products_
9. NimraKhan, Marina Efthymiou. DCU Business School, Dublin City University, Glasnevin, Dublin 9, Ireland. The use of biometric technology at airports: The case of customs and border protection (CBP)
10. Prof. Hassan, Soliman, Ph.D, Department of communication, Engineering, Mansoura University, Egypt. Ahmed Saleh, Ph.D, Department of Computer, Engineering, Mansoura University, Egypt. Eman Fathi, Department of communication, Engineering, Mansoura University, Egypt, 2013 Jul, 73(2).
11. Yaniv Taigman Ming, Yang Marc'Aurelio Ranzato, Facebook AI Research Menlo Park, CA, USA. Lior Wolf, Tel Aviv University, Tel Aviv, Israel. DeepFace: Closing the Gap to Human-Level Performance in Face Verification. https://research.facebook.com/file/266870805034649/deepface-closing-the-gap-to-human-level-performance-in-face-verification.pdf
12. Senior Systems Engineer, Information Technology. Master of Science in IT, Wilmington University, New Castle, Delaware, USA. Facial Recognition Technology.https://www.researchgate.net/publication/342067011_Facial_Recognition_Technology
13. Hashim NMZ, Ibrahim NA, Saad NM, Sakaguchi FZ. Zakaria International Journal of Emerging Trends & Technology in Computer Science (IJETTCS) Web Site: www.ijettcs.org. 2013 July-August, 2(4). ISSN 2278-6856. Barcode Recognition System.
14. Aamir Khan, Carmelo Mineo, Gordon Dobie, Charles Macleod, Gareth Pierce. Journal of Remanufacturing Vision guided robotic inspection for parts in manufacturing and remanufacturing industry, 2021.
15. Efimenko M, Ignatev A, Koshechkin K. Review of medical image recognition technologies to detect melanomas using neural networks. BMC Bioinformatics. 2020;21:270. https://doi.org/10.1186/s12859-020-03615-1.
16. Velusamy, Priyadarshini, Karandharaj, Porkumaran. Medical image processing schemes for cancer detection: A survey, 2014, 1-6. 10.1109/ICGCCEE.2014.6922267.
17. Jiahai Chen, You Li, Jianping Gong, Yakun Wu. Application of da Vinci surgical robotic system in hepatobiliary surgery. International Journal of Surgery and Medicine, 2017, 4(1). 10.5455/ijsm.da-Vinci-surgical-robotic-system-in-hepatobiliary-surgery.
18. Kussia Bulbula, Zhang Fengli, Oluwasanmi Ariyo, Owusu Forster, Assefa Maregu, Amenu, Temesgen. Vehicle Accident and Traffic Classification Using Deep Convolutional Neural Networks, 2020.
19. Ramasamy Balasubramani. A Review on Vehicle Speed Detection using Image Processing. 2017;l(4):23-28.
20. Sparavigna, Amelia Carolina. Image Processing: Methods, Applications and Challenges, 2012.
21. Mohanty SP, Czakon J, Kaczmarek KA, Pyskir A, Tarasiewicz P, Kunwar S, *et al*. Deep Learning for Understanding Satellite Imagery: An Experimental Survey. Front. Artif. Intell. 2020;3:534696. DOI:10.3389/frai.2020.534696
22. Govindhasamy G Ayappan. Prediction of rainfall using

image processing, 2010.
23. Canny John. A Computational Approach To Edge Detection. Pattern Analysis and Machine Intelligence, IEEE Transactions on. PAMI-8, 1986, 679-698. 10.1109/TPAMI.1986.4767851.
24. Petrović Vladimir, Popović-Bozovic Jelena. Towards Real-Time Blob Detection in Large Images with Reduced Memory Cost, 2016.
25. Sekar K, Tyagi AK. Study of Data Behaviour and Methods for Data Prediction and Analysis, 6th International Conference on Intelligent Computing and Control Systems (ICICCS), 2022, 1-6. DOI:10.1109/ICICCS53718.2022.9788360.
26. Malik S, Tyagi AK, Mahajan S. Architecture, Generative Model, and Deep Reinforcement Learning for IoT Applications: Deep Learning Perspective. In: Pal S., De D., Buyya R. (eds) Artificial Intelligence-based Internet of Things Systems. Internet of Things (Technology, Communications and Computing). Springer, Cham, 2022. https://doi.org/10.1007/978-3-030-87059-1_9
27. Varsha R, Nair SM, Tyagi AK, Aswathy SU, Radha Krishnan R. The Future with Advanced Analytics: A Sequential Analysis of the Disruptive Technology's Scope. In: Abraham A., Hanne T., Castillo O., Gandhi N., Nogueira Rios T., Hong TP. (eds) Hybrid Intelligent Systems. HIS 2020. Advances in Intelligent Systems and Computing, 2021, 1375. Springer, Cham. https://doi.org/10.1007/978-3-030-73050-5_56
28. Goyal D, Goyal R, Rekha G, Malik S, Tyagi AK. Emerging Trends and Challenges in Data Science and Big Data Analytics, 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE), 2020, 1-8. DOI: 10.1109/ic-ETITE47903.2020.316.
29. Malik S, Mire A, Tyagi AK, Arora V. A Novel Feature Extractor Based on the Modified Approach of Histogram of Oriented Gradient. In: Gervasi O. *et al*. (eds) Computational Science and Its Applications – ICCSA 2020. ICCSA 2020. Lecture Notes in Computer Science, Springer, Cham, 2020, 12254. https://doi.org/10.1007/978-3-030-58817-5_54
30. Gillala Rekha V. Krishna Reddy, and Amit Kumar Tyagi, "KDOS - Kernel Density based Over Sampling - A Solution to Skewed Class Distribution, Journal of Information Assurance and Security (JIAS). 2020;15(2):44-52. 9p.
31. Gillala Rekha, Amit Kumar Tyagi, Krishna Reddy V. Solving Class Imbalance Problem Using Bagging, Boosting Techniques, with and without Noise Filter Method, International Journal of Hybrid Intelligent Systems. 2019;15(2):67-76.
32. Gillala Rekha V, Krishna Reddy, Amit Kumar Tyagi. A Novel Approach for Solving Skewed Classification Problem using Cluster Based Ensemble Approach, Mathematical Foundations of Computing, 2020 Feb;3(1):1-9.
33. Mishra S, Tyagi AK. The Role of Machine Learning Techniques in Internet of Things-Based Cloud Applications. In: Pal S., De D., Buyya R. (eds) Artificial Intelligence-based Internet of Things Systems. Internet of Things (Technology, Communications and Computing). Springer, Cham, 2022. https://doi.org/10.1007/978-3-030-87059-1_4
34. Gillala Rekha V, Krishna Reddy, Amit Kumar Tyagi. CIRUS - Critical Instances removal based Under-Sampling - A solution for Class Imbalance, IJHIS. 2020;16(2):55-66.
35. Kumari S, Vani V, Malik S, Tyagi AK, Reddy S. Analysis of Text Mining Tools in Disease Prediction. In: Abraham A., Hanne T., Castillo O., Gandhi N., Nogueira Rios T., Hong TP. (eds) Hybrid Intelligent Systems. HIS 2020. Advances in Intelligent Systems and Computing, vol 1375. Springer, Cham, 2021. https://doi.org/10.1007/978-3-030-73050-5_55
36. Amit Kumar Tyagi, Poonam Chahal. Artificial Intelligence and Machine Learning Algorithms, Book: Challenges and Applications for Implementing Machine Learning in Computer Vision, IGI Global, 2020. DOI: 10.4018/978-1-7998-0182-5.ch008
37. Amit Kumar Tyagi, Rekha G. Challenges of Applying Deep Learning in Real-World Applications", Book: Challenges and Applications for Implementing Machine Learning in Computer Vision, IGI Global, 2020, 92-118. DOI: 10.4018/978-1-7998-0182-5.ch004
38. Gillala Rekha, Krishna Reddy V, Amit Kumar Tyagi. An Earth mover's distance-based undersampling approach for handling class-imbalanced data, International Journal of Intelligent Information and Database Systems, 2020 13(2/3/4).
39. Akshara Pramod, Harsh Sankar Naicker, Amit Kumar Tyagi. Machine Learning and Deep Learning: Open Issues and Future Research Directions for Next Ten Years, Book: Computational Analysis and Understanding of Deep Learning for Medical Care: Principles, Methods, and Applications, 2020, Wiley Scrivener, 2020.
40. Tyagi, Amit Kumar, Rekha G. Machine Learning with Big Data (March 20, 2019). Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University Rajasthan, Jaipur - India, 2019 Feb 26-28.
41. Gillala Rekha, Amit Kumar Tyagi, Krishna Reddy V. A Wide Scale Classification of Class Imbalance Problem and its Solutions: A Systematic Literature Review, Journal of Computer Science. 2019;15(7):886-929. ISSN Print: 1549-3636.
42. Deekshetha HR, Shreyas Madhav AV, Tyagi AK. Traffic Prediction Using Machine Learning. In: Suma, V, Fernando X, Du KL, Wang H. (eds) Evolutionary Computing and Mobile Sustainable Networks. Lecture Notes on Data Engineering and Communications Technologies, Springer, Singapore, 2022, 116. https://doi.org/10.1007/978-981-16-9605-3_68