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The Machine Learning for Computer Vision and Networks Data Analysis

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Abstract

The recent development in the areas of deep learning and deep convolutional neural networks has significantly progressed and advanced the field of computer vision (CV) and network data analysis and understanding. Complex tasks such as classifying and segmenting medical images and localising and recognising objects of interest have become much less challenging. This progress has the potential of accelerating research and deployment of multitudes of medical applications that utilise CV. However, in reality, there are limited practical examples being physically deployed into front-line health facilities. In this paper, we examine the current state of the art in CV as applied to the medical domain. We discuss the main challenges in CV and intelligent data-driven medical applications and suggest future directions to accelerate research, development, and deployment of CV applications in health practices. During the last few years computer applications have undergone a dramatic transformation from simple data processing to machine learning, thanks to the availability and accessibility of huge volumes of data collected through sensors and the internet. The idea of machine learning demonstrates and propagates the fact that the computer has the ability to improve itself with the passage of time. The western countries have shown great interest on the topic of machine learning, computer vision, and pattern recognition via organizing conferences, workshops, collective discussion, experimentation, and real-life implementation. This study on machine learning and computer vision explores and analytically evaluates the machine learning applications in computer vision and predicts future prospects. The study has found that the machine learning strategies in computer vision are supervised, un-supervised, and semi- supervised. The commonly used algorithms are neural networks, k-means clustering, and support vector machines. The most recent applications of machine learning in computer vision are object detection, object classification, and extraction of relevant information from images, graphic documents, and videos. Additionally, Tensor flow, Faster- RCNN-Inception-V2 model, and Anaconda software development environment are used to identify cars and persons in images.

Keywords: Machine learning and Computer Vision, Processing Image, Data Availability and Quality, Artificial Intelligence, Network and Data Bias, Using Analysis.

1. INTRODUCTION

Machine learning and computer vision hopes to bring into computers human capabilities for data sensing, data understanding, and action taking based on past and present outcomes. Machine learning and computer vision research is still evolving [1]. Computer vision is an essential part of Internet of Things, Industrial Internet of Things, and brain human interfaces. The complex human activities are recognized and monitored in multimedia streams using machine learning and computer vision. There are a number of well-established methods for prediction and analysis such as supervised learning, un-supervised learning, and semi supervised learning. These methods use machine learning algorithms such as support vector machines, KNN etc.

The machine learning solutions revolve around data gathering, training a model, and using the trained model to make predictions. There are models and services provided by private companies for speech recognition, text analysis, and image classification. One can use their models through application programming interfaces (API). For instance, Amazon Recognition, Polly, Lex, Microsoft Azure Cognitive Services, IBM Watson. Object detection and analysis is an important part of everyday life. Object detection has applications in avoiding traffic collisions, facial expression recognition and emotional recognition based on human postures. In [2], developed an automated system to detect the information contained in human faces from images and video with the help of orientations. TensorFlow and OpenPose are software libraries used in object detection and computer vision. The traffic detection models use convolutional neural network, recurrent neural network (RNN), long short-term memory (LSTM), gated recurrent unit (GRU), and Bayesian networks. In an intelligent environment sensors capture the data which is later used for analysis and forecasting [3, 4]. The feature extraction is one of the task convolution neural networks (CNN) accomplishes without information loss for successful object detection [5]. The supervised learning of a deep convolutional neural network recognizes faces with a large set of face images [6]. The only challenge in computer vision and machine learning application is the data annotation/ labelling [7]. The machine learning algorithms are now running on cloud as a "machine learning as a service", "cloud machine learning" [6]. Moreover, companies, such as Amazon, Microsoft, and Google, have machine learning as a cloud service.

The objective of this research study is to investigate and analytically evaluate applications of machine learning in computer vision. The database searched includes Google scholar applying advanced search techniques with respect to keywords- "machine learning", "computer vision", "Deep learning", and "Artificial intelligence". The initial search resulted in 258 articles, which included both patent and citation. After examining article contents and excluding the citations, the number came down to 175 articles. Finally, 20 articles formed the core part of this research study. There are five sections. Section 2 corresponds to background study. Section 3 clusters the existing machine learning applications in groups. Section 4 presents results and discussions. The last section concludes with comments and future work.

2. LITERATURE REVIEW

Computer vision and machine learning are two important areas of recent research. The computer vision computer uses the image and pattern mappings in order to find solutions [8]. It considers an image as an array of pixels. Computer vision automates the monitoring, inspection, and surveillance tasks [6]. Machine learning is the subset of artificial intelligence. The automatic analysis/annotation of videos is the outcome of computer vision and machine learning. Figure-1 shows the classification, object detection, and instance segmentation. Figure-2 shows the object detection in images using Tensor flow and Faster-RCNN-Inception-V2 model in the Anaconda environment.

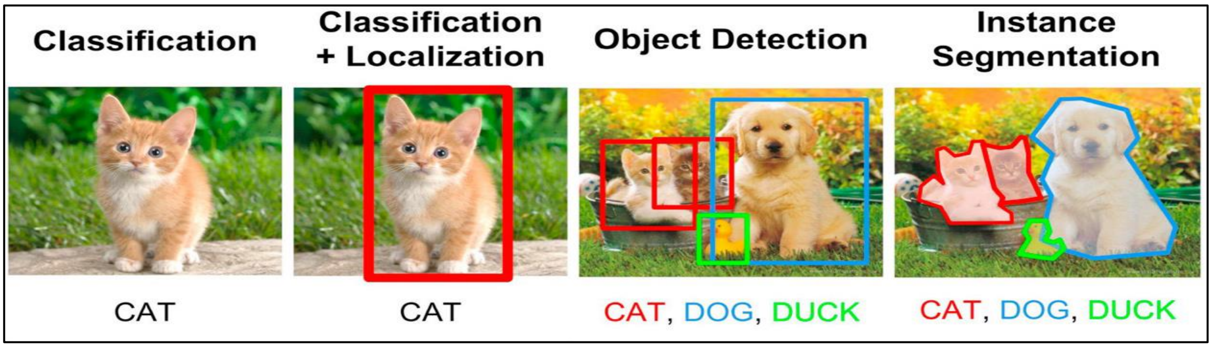

Fig-1: Classification, object detection, and instance segmentation [9].

Fig-2: Detecting cars and persons in images applying Deep learning and Faster-RCNN-Inception-V2 model

There are three approaches to machine learning and computer vision: supervised, unsupervised, supering. The supervised learning has labelled training data. The labelling of data is expensive, time consuming and requires expertise. On the other hand, the semi-supervised learning has some of the data labelled and others not. The Bayesian network classifiers have the edge for learning with unlabelled data. Nevertheless, the real-world problems fall in the unsupervised learning category where patterns evolve based on clustering. The machine learning paradigms for computer vision are support vector machines, neural networks, and probabilistic graphical models. Support vector machines (SVMs) is a subdomain of supervised machine learning methods and popular in classification [10]. A neural network consists of layered networks of interconnected processing nodes [11]. Convolutional neural networks (CNNs) is a category of neural networks used in image recognition and classification. It has neurons with dimensions: width, height and depth [10]. CNN has gained popularity in recent times due to largely accessible datasets, GPUs, and regularization techniques [10]. OpenCV is a library, which can be integrated with programming languages. Such as, Java, iOS on platforms such as Eclipse and Visual Studio in Windows, iOS, and Linux for image processing and analysis. It is used in image processing, video analysis, object detection, and machine learning. Figure-3 shows the object detection process in the machine learning and computer vision environment.

Fig-3. Image processing and object detection process

3. MACHINE LEARNING IN COMPUTER VISION

The study explored numerous applications of machine learning in computer vision. For example, segmentation, feature extraction, refining visual models, pattern matching, shape representation, surface reconstruction, and modelling for biological sciences. Machine learning in computer vision is used in interpreting data contained in car and pedestrian detection images [12], automatic classification of faults in railway ties using images [10], interpretation of remote sensing data for geographical information systems [13], differentiating mango varieties based on size attributes [14], extraction of graphical and textual information from document images [15]. Similarly, other applications include gesture and face recognition [16], machine vision [17], recognizing handwritten characters and digits [18], advanced driver assistance systems [19], behavioural studies [20], and estimation of human full-body kinematics for a cyclist and pose estimation [11]. Detecting Curb Ramps in Google Street View such as automatically identification and examination of curb ramps in images [21]. In [22], studied the use of computer vision and machine learning in medical science such as cardiovascular imaging, retinal blood vessels, nuclear medicine, endoscopy, thermography, angiography, magnetic resonance, ultrasound and microscopy. Machine learning and computer vision has innovative applications in engineering, medicines, agriculture, astronomy, sports, education etc. These applications are categories and clustered in Table-1.

Table-1: Machine learning and computer vision research

Researchers	Demonstrated application area	Description
[23, 24]	Food security, agricultural production, flood prediction, and oil palm tree counting.	The agricultural fields and land cover is mapped after processing the satellite images. For example, Mapping Sub-Saharan African Agriculture, the satellite images are processed and classified using machine learning algorithms such as random forest [23]. In [24], proposed a method to detect, differentiate, and count the oil palm tree using machine learning and computer vision. The method worked 96 % accurately.
[25]	Rainfall, flood, wind, temperature, humidity, and front detection.	The computing power is used for fast and accurate weather forecasting. The computer vision and machine learning is used in the front detection (meteorological phenomena where two distinctly different air masses meet and interact) for weather forecasting [25]
[26-28]	Occupancy detection, traffic detection, tracking, classification and counting.	The detection of traffic flow on a road and categorization viz., cars, bicycles, and pedestrians [26]. For example, the traffic in Montreal is predicted using computer vision and machine learning techniques [27]. In [28], developed an end-to-end system to detect, track, count, and manage traffic (pedestrians and bicyclists) in Los Angeles using machine learning and computer vision.
[29, 30]	Haemorrhoid detection, Bleeding detection, Endoscopic image enhancement, and clinical decision support	In [29] used computer vision and machine learning for breast cancer diagnosis. Computer vision and machine learning are employed in gastrointestinal (GI) endoscopy [30].
[2, 31, 32]	Human behaviours, face-to- face conversations, emotion recognition, and phone conversations.	The complex human behaviours' are modelled using Bayesian networks. The semantic events from audio-visual data with spatial-temporal support detected by fusing the information extracted from multiple modalities [2]. In [31], proposed an approach to detect and classify human behaviours as confident/ not confident based on human posture using machine learning and computer vision. In [32], proposed Gesture Learning Module Architecture (GeLMA), for hand gesture recognition in real time. The architecture proved successful with 99 % accuracy.
[33-35]	Classification of biological fluorescence images of synapses, protein localization, phenotyping, and phylogenetic reconstructions	The k-nearest neighbour (kNN) classification for protein localization, Naïve Bayes Classifiers for phylogenetic reconstructions [35]. The traditional method to evaluate crop Biotic and abiotic stresses are time taking and require a lot of effort [33, 34].
[36, 37]	Performance evaluation, scoreboard updating, and predicting the game outcomes.	In [36], automated the cricket scorecard with computer vision and machine learning. This is useful for updating the cricket scoreboard based on the umpire gesture in the field. Likewise, in-Play Tennis Analysis, analysing the players performance and predicting the future outcomes [37].
[38]	State of machine tools, repairing, predictive maintenance.	In [38], identified the state of tools in the milling process. The tools used in milling process their states, as a wear level is analysed and classified using computer vision and machine learning.

4. CHALLENGES

The progress that took place in computer vision (CV) is unprecedented, and various inherently challenging (CV) tasks are now considered solved problems. Typical inherent (CV) challenges include data variation (e.g.lights, pose), occlusion (overlapping objects in the images/videos), and others. However, despite this significant progress, there remain challenges that need to be addressed to scale up the use of deep learning (DL)-based methods across a wider range of applications in the medical domain. In this paper, we argue that many of these challenges are related to data quality and data availability. However, in the medical domain, some data will always need to be gathered opportunistically, so it may not be possible to overcome these challenges through data gathering alone. These challenges apply to the full range of medical applications, including complex medical settings such as robotic surgery [39] and comparatively simple settings such as the detection of fever with thermal cameras. In both of these settings, (CV) algorithms need to account for the dynamic environment.In robotic surgery, this includes navigation, movement, object recognition and deforming objects and actions.In other settings, data variability caused by the environment and equipment used to capture the images can lead to issues. Clearly, data availability and quality play a crucial role in the learning process.

4.1: Data Availability and Quality:

The quality and viability of (CV) models developed through machine learning (ML) often depend directly upon the quality of available data used to train the models. This is especially important in medical imaging, where specialist imaging technology is required to capture the images, and expert knowledge is required to select,annotate and label data. It should be noted that the performance of many DL-based methods relies on large surgery images, and in supervised learning settings, these should be fully labelled and annotated. The annotation of medical images, in particular, continues to be one of the most demanding tasks and requires long hours of medical experts' time. Despite the latest development in (CV), annotating medical images as well as images and videos across other domains is still largely carried out manually, often done by drawing bounding boxes around the area of interest, or creating a mask manually, so that such data can be used in the training process. In a complex and dynamic environment, the challenge of collecting and annotating the data is even more demanding, labour-intensive and often expensive. Consider, for example,a simple task (for medical experts) such as analysing operative videos to detect steps in laparoscopic sleeve gastrectomy surgery [40], where the authors had to collect and annotate videos, using two experts, capturing patients' operations. Although good results were reported, it is practically infeasible to scale this approach to capture all data variation in such scenarios. Therefore, more work needs to be done in the area of unsupervised or semi-supervised DL-based methods.

In the medical domain, data must often be captured opportunistically, using equipment, patients and specialists as and when they are available. Strictly controlled and consistent conditions specifically for data gathering purposes are not always possible. This leads to challenges in the generalisability of models. For example, in the field of thermal imaging, even data gathered specifically for the purposes of study exhibits high levels of diversity between datasets [41]. A large dataset specifically for febrile identification from thermal images, does not yet exist [42]. However, a meta-analysis of existing studies into the use of thermal scanners for febrile identification demonstrated high levels of diversity between the studies [41], with this partly attributed to differences in equipment, scanner location, demographics of the study population. This diversity means that models trained on one dataset might not generalise to other datasets, let alone situations of widespread use. The International Organization for Standardization has produced a standard specifically for the purpose of mass temperature scanning for fever detection [43], though some evidence suggests the standard is not yet widely adopted [44].A complete lack of standardisation in data gathering protocols in some fields will produce diverse but disjoint datasets, making model generalisation exceptionally difficult.

4.2: Data Bias:

One of the inherent problems related to CV and ML in general is the data bias or, as commonly known, class imbalance problem. Classification with imbalanced class distribution poses a challenge for researchers in the field of ML [45]. An imbalanced dataset is a common term describing a dataset that has a remarkably unequal distribution of classes. Such a dataset is likely to cause a bias in the learning process of a ML algorithm. This is because typical learning algorithms are designed to maximize the overall accuracy in classification regardless of the model's per-class accuracy. Hence, in an imbalanced dataset, the learning algorithm will be more compromised for misclassification of minority class instances than majority class ones. This can lead to an undesirable scenario when the minority class accuracy is nil while the overall class accuracy still reaches over 90% due to a high imbalance ratio of the minority class to the minority class. This high overall accuracy will be misleading if one is not aware that the predictive model has totally failed to detect anomaly cases. The problem becomes more concerning when the minority class is the class of interest and has a higher cost [46].

In the medical domain, imbalanced datasets are often seen due to the limited availability of samples, generally patient data, belonging to the group of interest [47]. For example, the data of patients with benign tumours may greatly outnumber the data of cases with malignant tumours, which is a natural phenomenon of many existing types of tumours that the overwhelming majority of these tumours are benign [48]. Predictive analysis of other diseases such as heart disease, cerebral stroke, Parkinson's, and epilepsy are also good examples of imbalanced data classification tasks [49]. Results achieved from the analysis will be crucial and have a high impact on society since these are major threats to public health globally. There have been a number of research articles on handling the class imbalance in medical datasets. The approaches range from simply utilising existing solutions to designing new techniques. However, many works have focused on tabulated medical data [50], which is easier to deal with compared to medical images. The emerging generative adversarial networks (GANs) have played an important role in data augmentation in the minority class, especially in CV [51]. Qasim et al [52] presented a new GAN-based method that generates synthetic images to improve medical image segmentation. Similarly, Rezaei et al. [53] designed new architectures of GANs for minority class oversampling in Magnetic Resonance Imaging for brain disease diagnosis.

As can be seen in the works mentioned above, using complex and advanced techniques seems to be a requirement for solving the imbalanced class distribution in CV tasks. This makes class imbalance a very challenging problem in medical image analysis, which results in limited growth of research in this domain.

4.3: Explainability of Computer Vision Algorithms Using Data Analysis:

As well as issues in data quality and quantity and the inherent class imbalance within some datasets, there is the question of trust in the algorithms themselves. There are increasing legal regulations and social responsibilities for ML models to be explainable [54]. Recent studies have highlighted that the lack of robust explanation capabilities in existing algorithms is a challenge to be resolved before AI can see further widespread application within the medical domain [55]. Within this field, explaining the outcomes of CV algorithms is challenging in general and typically, the need for an explanation is subjective and highly dependent on an individual user's context [56]. Within the medical domain, there is a broad range of stakeholder, each of whom possesses very different requirements and expectations which must be satisfied by an explanation [57]. The list of stakeholders include: patients, clinicians, care providers, regulatory and governance bodies; and algorithm developers, among others. While there are existing models to link users based upon aspects such as their experience with AIor domain knowledge [58], in medicine and similar there is the added complexity of non-overlapping expertise in the form of clinical specialisations [59]. As a result, ensuring that an explanatory algorithm can comprehensively meet the explanation needs of all stakeholders is a challenge to be resolved.

4.3: Dynamic Environment Challenges:

Much of the published literature related to medical image analysis and understanding and other domains have used datasets of images and videos that were largely compiled in a controlled environment. This may include controlling light conditions, movement, quality of the images, the position of the camera and subjects, equipment used to capture the data and so on. However, in a very dynamic setting, such controls may not be possible. This still poses a challenge for the CV research community. A typical controlled environment is a surgical environment and applications related to robotics surgery [59]. However, as controlled as a surgical environment may be in isolation, there may not be any degree of standardisation between separate operating theatres and data gathering equipment. In such scenarios, the performance and generalisation of the DL models will largely depend on the quality and diversity of the data, regardless of the CV task. However, it should be noted, that in such a scenario, CV tasks become more complicated, where accurate object detection and tracking under various conditions become paramount.

The ability to construct a 3D representation out of 2D visual content (video streams and images) continues to be a challenging problem for the research community. Consider, for example, the need for estimating depth information for endoscopic surgery images, which is an important task to facilitate navigation in a surgery setting. In the DL era, if we can obtain large volumes of good quality videos with the corresponding depthmaps, then such a task may be very possible [60]. However, this is quite impossible in a medical setting due to the dynamic and diverse nature of such an environment. The depth information will be unique to individual patients, but models which predict the depth information will need to be able to generalise across many different, unique patients. Labelling and annotating the amount of data required to achieve generalisable models is labour-intensive and often very expensive, as discussed above. Similar to 3D representation, 3D image registration, as well as learning from different data modalities to improve generalisation of the deep models are still considered as key challenges in the CV research community.

5. RESULTS AND DISCUSSION

In the world of the internet, tons of graphical information and images move but unlike the textual data the capability to classify and store them according to the special characteristics is a labour-intensive task. The indexing and storing of graphical data require computer interventions with advanced model-based vision capabilities and learnability.

This study highlights the research in machine learning and computer vision in various domains. The machine learning and computer vision techniques have reduced the cost, effort, and time in engineering, science, and technology. An automated system based on machine learning and computer vision detects human emotions (likes and dislikes, confidence levels). The probabilistic models predict human activities through labelling and pattern recognition. The machine learning and computer vision in professional sports measures and analyses the performances of team and individual players. Moreover, it has been in use in industries for predictive maintenance. The machine and tools replacements in industries on time before failures have a significant impact on the effectiveness and efficiency of the manufacturing units. The public camera and smart devices with sensors are a huge source of data. The computer vision and machine learning techniques when applied on these data helps in prediction and monitoring the traffics in cities. Figure-4 shows the evolving research areas in machine learning and computer vision. This study has found advancing areas of research in this field as- the biological science (19%)

and human activity (19%) followed by traffic management (13%) and professional sports (13%).

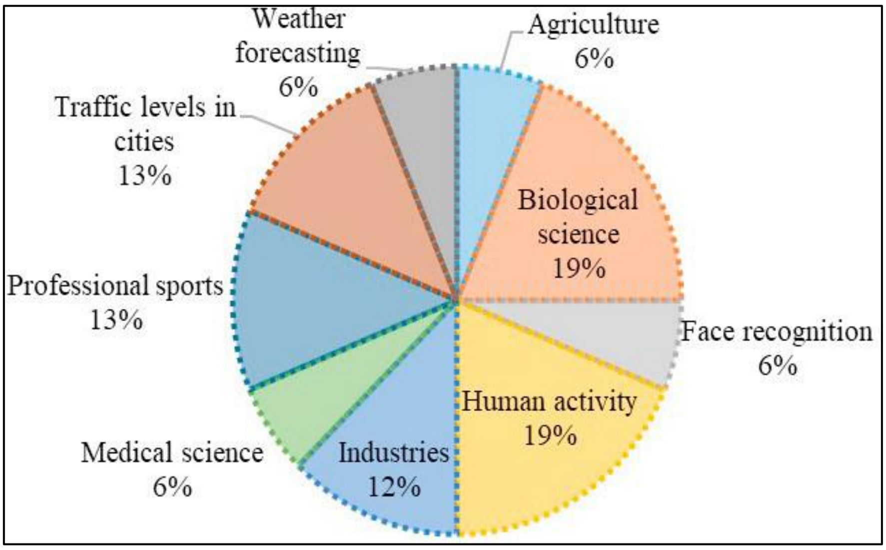

Fig-4: Machine learning and computer vision research areas

The machine learning field has evolved from the traditional methods of pattern recognition and image processing to advanced techniques of image understanding. It has a strong potential to contribute to the changing dynamic of computer vision systems. Although computer vision interprets and extracts information from audio and video and can work independently of machine learning, machine learning adds the predictive feature of already processed data. Based on the pure visuals it is difficult to differentiate between fire and explosion. Figure 5 shows the undergoing research in machine learning and computer vision with respect to time. The majority of the research in the area started after 2015. During the last three years, the research has been on agriculture, biological and medical science, human activity interpretation, predictive maintenance in industries, analysis and prediction of sports, traffic management and control in the cities. The research works of machine learning and computer vision on brain computer interfaces are scant.

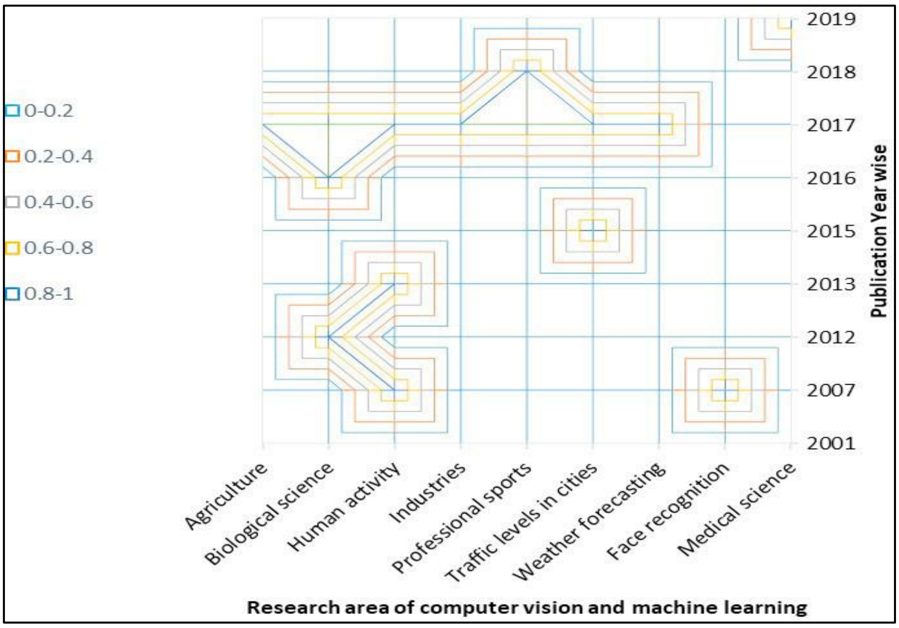

Fig-5: Distribution of machine learning and computer vision research with respect

Moreover, the inputs to machine learning in computer vision is either of the form as a direct input (Pixels / Voxels / 3D Points) or of vectors (shape measures, edge distributions, colour distributions, texture measures / distributions). Vectors represent the features in many applications for vision. The researchers in pattern recognition capture the structure of objects and scenes using graphs as opposed to machine learning where first order logic formalism is preferred [8]. Figure 6 shows the frequently used themes of machine learning in computer vision. Machine learning in computer vision works for object classification, object detection, instance recognition, sequence recognition/ classification.

Fig-6: Frequently used themes of machine learning in computer vision

The learning algorithms help in creating object and image detection systems based on the instances and experiences. The machine learning algorithms render enormous capabilities for integration and synthesis of vision algorithms and models. Object detection and tracking is still an open challenge in computer vision, even though alignment with machine learning algorithms and open-source libraries have yielded exciting results. Moreover, the machine learning output quality depends on the predictive accuracy, recall, and precision. The data collected from the environment dictates the strategies that a learning system would use to improve the performance.

6. CONCLUSION

The progress that has taken place in the area of medical image analysis and understanding over the past decade is considered unprecedented, and can be measured by orders of magnitude. Complex computer vision (CV)tasks such as classifying images, localising and segmenting areas of interest, and detecting and tracking objects from video streams became relatively easy to achieve. This development can be largely attributed to the development that took place at the algorithm levels, especially the development of convolutional neural networks-based methods, the progress in computing power, and finally the availability of large volumes of medical images and related data in the public domain. In this paper, we have reviewed and summarised some of the key technologies and underlying methods behind this progress, and outlined the vast range of medical applications that have greatly benefited from the latest developments in CV and image processing and analysis. This paper also outlined key challenges and barriers to scaling up the practical use of AI-driven solutions across a wider range of medical applications. Data was found to be the fundamental building block in developing these solutions. There is clear evidence in the literature that with high-quality data, good performance can always be achieved. However, in reality, preparing the data can be very labour-intensive, time-consuming and often expensive. Key tasks such as image classification require accurately labelled data, and in the medical domain,this needs to be carried out by more than one medical expert, to ensure that minimal bias is injected into the data. Similarly, to build a model that is capable of tracking an object of interest, in a surgery video, enough videos and images need to be labelled and fully annotated (drawing a bounding box or a mask around the region of interest). It can be said that most of these data labelling/annotation tasks are still based on manual orsemi-automated approaches. However, algorithms currently under development have the ability to work from partially annotated data and intelligently and automatically annotate images successfully.

The commercial and academic research on computer vision is growing in the form of new techniques, processes, models, and algorithms. Machine learning has been able to address many issues of feature extractions and processing in computer vision. Machine learning and computer vision synthesis has helped in understanding complex problems. The machine learning applications in computer vision have varied outputs depending upon the domain. This study includes the analysis, classification, and discussion on the use of machine learning in computer vision. The research has identified the successful implementation of machine learning applications in computer vision for weather forecasting, biological science, expression reading, food security, species classification, sports, monitoring the traffic flows, and predictive maintenance in industries. Biological science, human activity interpretation, traffic management, and professional sports are the emerging areas. Object detection, classification, and prediction are the most frequent uses of machine learning in computer vision. The future work would assess accuracy of the machine learning algorithms in computer vision.

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