Data Analytics and Artificial Intelligence
Vol: 1(3), 2021
REST Publisher
ISBN: 978-81-948459-4-2
Website: http://restpublisher.com/book-series/daai/

The Rise of Machine Learning in Computer Vision: Exploring Potential Applications and Implementation

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Abstract

In recent years, there has been a significant shift in computer applications from basic data processing to machine learning, primarily due to the abundance and accessibility of vast amounts of data gathered via sensors and the internet. The concept of machine learning illustrates and disseminates the knowledge that computers are capable of self-improvement over time. Through the hosting of conferences, workshops, group discussions, experimentation, and practical application, the western countries have demonstrated a strong interest in the fields of machine learning, computer vision, and pattern recognition. This research on computer vision and machine learning examines, assesses, and forecasts the potential uses of machine learning in computer vision. This research on computer vision and machine learning examines, assesses, and forecasts the potential uses of machine learning in computer vision. The study discovered that supervised, unsupervised, and semi-supervised machine learning techniques are used in computer vision. Neural networks, support vector machines, and k-means clustering are the algorithms that are frequently utilized. Object detection, object classification, and the extraction of pertinent data from pictures, graphic documents, and videos are the most recent uses of machine learning in computer vision. In addition, the Anaconda software development environment, Tensor flow, and Faster-RCNN-Inception-V2 model are used to identify cars and people in images.

Keywords: machine learning; image processing; object detection; computer vision; artificial intelligence; image classification; neural network; support vector machine.

1. Introduction

The goal of computer vision and machine learning is to imbue computers with human abilities such as data sensing, data understanding, and decision-making based on historical and current results. Research in computer vision and machine learning is still developing [1]. Brain-human interfaces, the Industrial Internet of Things, and the Internet of Things all depend on computer vision. With computer vision and machine learning, complex human activities are detected and tracked in multimedia streams. Numerous tried-and-true techniques for analysis and prediction exist, including semi-supervised, unsupervised, and supervised learning. These techniques make use of machine learning algorithms like support vector machines and KNNs, among others. The three main components of machine learning solutions are data collection, model training, and prediction using the trained model. For text analysis, picture classification, and speech recognition, there are models and services offered by private businesses. Through application programming interfaces (API), one can make use of their models. As an example, consider IBM Watson, Microsoft Azure Cognitive Services, Polly, Lex, and Amazon Recognition. Analysing and detecting objects is a crucial aspect of daily existence. Applications for object detection include facial expression recognition, emotional recognition based on human postures, and preventing traffic collisions. developed an automated system in [2] that uses orientations to identify the information present in human faces in pictures and videos. The software libraries used in computer vision and object detection are TensorFlow and Open Pose. Numerous tried-and-true techniques for analysis and prediction exist, including semi-supervised, unsupervised, and supervised learning. These techniques make use of machine learning algorithms like support vector machines and KNNs, among others. One of the tasks convolution neural networks (CNNs) complete without information loss for successful object detection is zfeature extraction [5]. This research study aims to explore and critically assess machine learning applications in computer vision. Google Scholar was one of the databases that was searched, and advanced search methods were used to find results for the keywords "machine learning," "computer vision," "deep learning," and "artificial intelligence." There were 258 articles that included both patents and citations in the first search results. The total was reduced to 175 articles after looking through the articles' contents and removing the citations. Ultimately, this research study's central component consisted of twenty articles. Five sections are included. Section 2 is related to the background research. Groups of the current machine learning applications are grouped together in Section 3. Results and discussions are presented in Section 4. Finally, a section dedicated to future work and comments is included.

II. Background Study

Two prominent fields of recent research are computer vision and machine learning. The image and pattern mappings are used by the computer vision system to identify solutions [8]. It views an image as a collection of pixels. The tasks of surveillance, inspection, and monitoring are automated by computer vision [6]. Artificial intelligence has a subset called machine learning. The result of computer vision and machine learning is the automatic analysis and annotation of videos. Classification, object detection, and instance segmentation are displayed in Figure 1. Using Tensor flow and the Faster-RCNN-Inception-V2 model in the Anaconda environment, Figure 2 illustrates object detection in images.

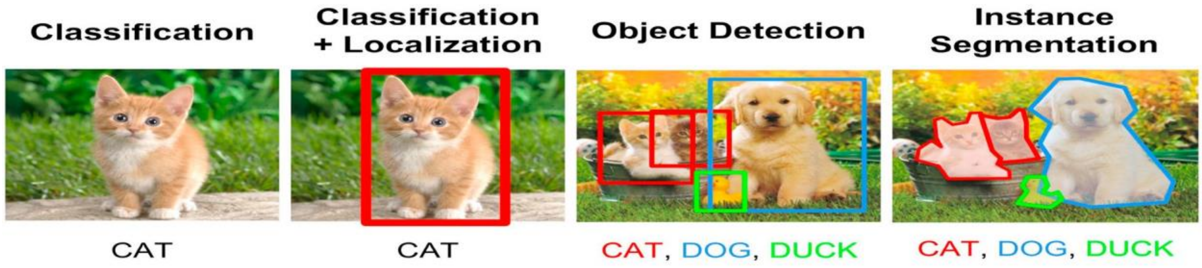

FIGURE 1. Classification, object detection, and instance segmentation [9]

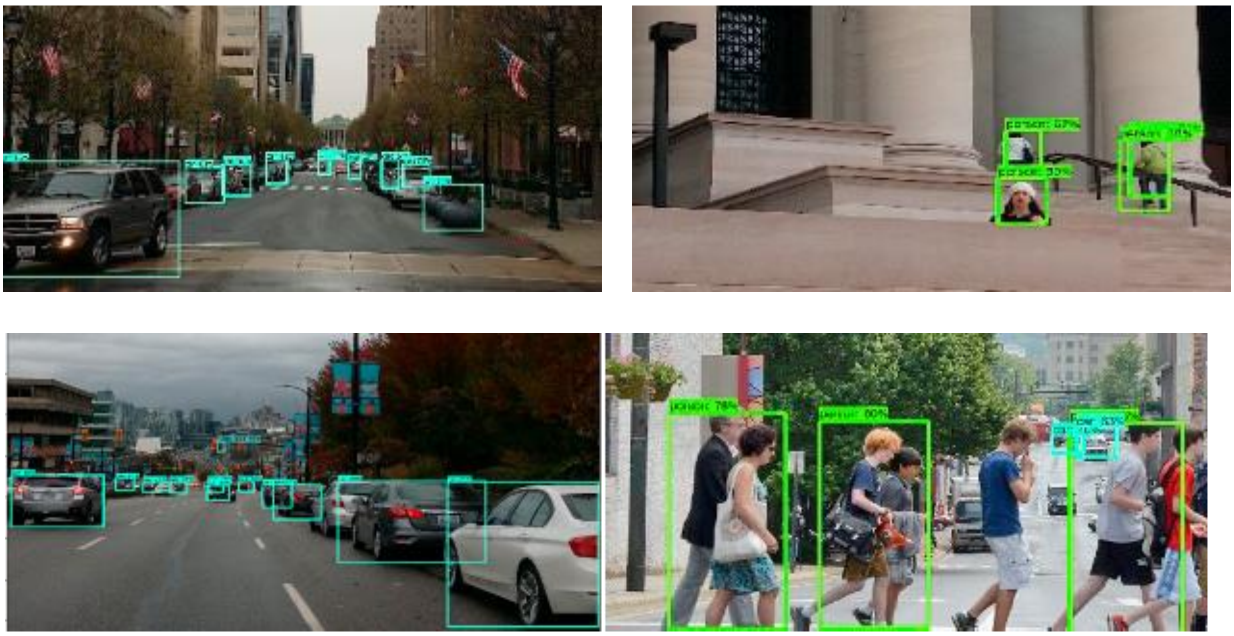

FIGURE 2. Detecting cars and persons in images applying Deep learning and Faster-RCNN-Inception-V2 model

Supervised, unsupervised, and semi-supervised learning are the three methods used in computer vision and machine learning. Training data for supervised learning has been labeled. Data labeling is a costly, time-consuming, and specialized process. Conversely, in semi-supervised learning, some of the data is labeled while the rest is not. It is better to use Bayesian network classifiers when learning from unlabeled data. However, real-world issues fall into the category of unsupervised learning, in which clustering drives the evolution of patterns.

Neural networks, probabilistic graphical models, and support vector machines are the machine learning paradigms used in computer vision. Popular in classification, support vector machines (SVMs) are a subset of supervised machine learning techniques [10]. Layered networks of interconnected processing nodes make up a neural network. One type of neural network used for image recognition and classification is called a convolutional neural network (CNN). Its neurons have three dimensions: depth, width, and height. Recently, CNN has become more and more popular because of GPUs, regularization techniques, and datasets that are generally accessible [10]. OpenCV is a library, which can be integrated with programming languages such as Android, .NET, 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.

FIGURE 3. Image processing and object detection process

III Machine Learning in Computer Vision

The study investigated a wide range of computer vision applications for machine learning. As an illustration, consider the following: shape representation, surface reconstruction, pattern matching, segmentation, feature extraction, and modeling for biological sciences. Computer vision uses machine learning to interpret data from images of cars and pedestrians, automatically classify faults in railroad ties using images [10], interpret data from remote sensing for geographic information systems [13], distinguish mango verities based on size attributes [14], and extract text and graphics from document images. Other uses include the recognition of faces and gestures, machine vision, handwritten characters and numbers , sophisticated driver assistance systems behavioral research and the estimation of a cyclist's full body kinematics and pose [11]. Curb ramp detection in Google Street View, including automatically recognizing and analyzing curb ramps in photos. The use of computer vision and machine learning in medical science, including magnetic resonance imaging, ultrasound, microscopy, endoscopy, nuclear medicine, retinal blood vessels, and cardiovascular imaging, was examined in. Innovative uses of machine learning and computer vision can be found in engineering, medicine, sports, astronomy, agriculture, and education, among other fields. Table 1 groups these applications into categories.

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 algorithm 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 Angles 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. The 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 requires a lot of efforts [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 state of tools in milling process. The tools used in milling process their states, as a wear level is analysed and classified using computer vision and machine learning.

2. Results And Discussion

There is a lot of graphical information and images on the internet, but unlike textual data, it takes work to be able to categorize and store them based on their unique characteristics. Computer interventions requiring sophisticated model-based vision capabilities and learnability are needed for the indexing and storing of graphical data. The research in computer vision and machine learning across a range of fields is highlighted in this study. In engineering, science, and technology, machine learning and computer vision techniques have cut costs, effort, and time. Human emotions are detected by an automated system that uses computer vision and machine learning to identify likes and dislikes as well as confidence levels. The probabilistic models use pattern recognition and labeling to predict human behavior. In professional sports, computer vision and machine learning are used to track and evaluate player and team performance. Additionally, industries have been using it for predictive maintenance. The efficacy and efficiency of manufacturing units are greatly impacted by the industries' timely replacement of machinery and tools prior to failures. A significant source of data is the public camera and smart devices that have sensors. When applied to this data, computer vision and machine learning techniques aid in the prediction and monitoring of urban traffic. The developing fields of computer vision and machine learning research are depicted in Figure 4. According to this study, the fields of biological science (19%), human activity (19%), and traffic management (13%) and and professional sports (13%) are the most advanced in this field of study.

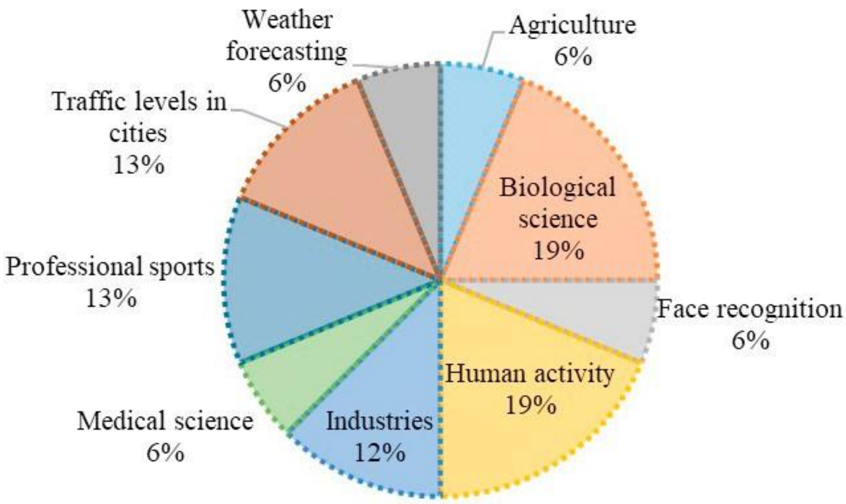

FIGURE 4. Machine learning and computer vision research areas

The field of machine learning has developed from conventional image processing and pattern recognition methods to sophisticated image understanding techniques. It has a great chance of influencing how the computer vision system changes dynamically. While computer vision is capable of interpreting and extracting information from audio and video on its own, machine learning enhances the predictive capabilities of previously processed data. It is challenging to distinguish between an explosion and a fire from the still images. The ongoing research in computer vision and machine learning is depicted in Figure 5 with respect to time. Most of the studies conducted in this field began after 2015.

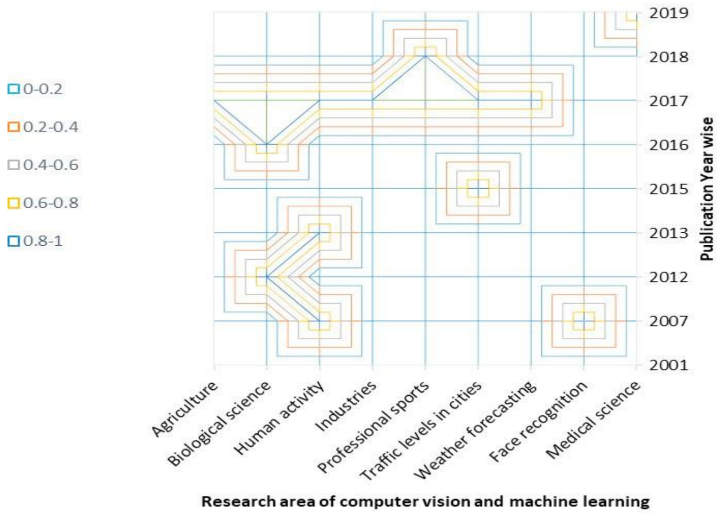

FIGURE 5. Distribution of machine learning and computer

vision research with respect to time (years) 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 represents the features in many applications for vision. The researchers in pattern recognition captures 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 frequent used themes of machine learning in computer vision. Machine learning in computer vision works for object classification, object detection, instance recognition, sequence recognition/ classification. Building object and image detection systems based on examples and experiences is made easier by learning algorithms. The integration and synthesis of vision algorithms and models is made possible by machine learning algorithms, which offer enormous capabilities. In computer vision, object detection and tracking remain an open challenge despite promising results from alignment with machine learning algorithms and open source libraries. Furthermore, the precision, recall, and accuracy of predictions all affect how well machine learning produces results. The methods that a learning system would employ to raise performance are determined by the data gathered from the surroundings.

3. Conclusion

The field of computer vision research, both in academia and industry, is expanding thanks to new models, algorithms, processes, and techniques. Numerous problems with feature extraction and processing in computer vision have been solved by machine learning. Understanding complex problems has been aided by computer vision synthesis and machine learning. Depending on the domain, computer vision machine learning applications produce different results. This paper analyzes, categorizes, and discusses machine learning applications in computer vision. The study has revealed the effective use of machine learning in computer vision applications for biological science, sports, food security, species classification, weather forecasting, traffic flow monitoring, and predictive maintenance in industries. The biological science, human activity interpretation, traffics management, and professional sports are the emerging areas. The object detection, classification, and prediction are the most frequent use of machine learning in computer vision. The future work would assess accuracy of the machine learning algorithms in computer vision.

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