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Review on Real-time Applications of Computer Vision Systems

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Abstract: ***Advancements in Artificial Intelligence in recent times have marked a new beginning in the technological era pushing subsets of it such as Computer Vision and Machine Learning for an inclusive development. Computer Vision has been a popular research topic for decades, and as a result, a wide range of applications have been developed using computer vision-based technologies. With the increasing computational power of machines with help of vision-based analysis, we can achieve accuracy, precision, and quality of products and services in a very short period. In this paper, we present some insights on real-time applications of Computer Vision systems in different fields and the researches being carried out currently for its future all-round applicability. Some applications are based on the experiments and researches conducted by various institutions and organizations in a limited area, while some are being executed on a pilot basis in many fields.***
Keywords: Computer Vision, vision-based, real-time, algorithms.

I. INTRODUCTION

As one of the most important fields of Artificial Intelligence, Computer Vision can dominate the AI-based services market and is projected to be deployed in almost every sector in the near future. With significant innovations in Artificial Intelligence and advancements in deep learning and neural networks, this field, which has been around since the 1960s, has undergone a phenomenal transformation. Computer Vision is a field that employs computers to interpret and analyze visuals, just like the human brain does, in a digital format using specialized algorithms. These algorithms can recognize and process objects in videos and images in much the same sense as humans do. There are several different stages in doing this and the output or target will be obtained in the last stage. Image and video interpretation, image and video processing, and feature extraction are some of the important methods that realize the applications of vision systems. It has a wide range of applications in the fields of automobiles, automation, defense, healthcare, aerospace, agriculture, transportation, and banking. It can be deployed in operations such as crime investigation, counter-terrorism, traffic management, transaction security, advanced medical diagnostics, crop management, passenger identification on transport terminals, etc. In this paper, we will be reviewing the same with a key focus on traffic management, industrial automation, medical imaging, agriculture, and space exploration.

II. ROAD TRAFFIC MANAGEMENT USING COMPUTER VISION

Traffic problems are one of the most important problems in the urban ecosystem presently and there are many causes for them to occur. A significant cause, however, is inefficient traffic management due to a lack of real-time traffic information. A vision-based approach can be deployed for gathering real-time traffic information, through which road users can select the best route to drive and escape traffic congestion. On the other hand, traffic administrations can utilize the traffic information in their traffic control systems, resulting in better traffic management. To alleviate traffic congestion, adaptable lane dividers built on a Computer Vision-based approach to real-time traffic video monitoring and pattern recognition can be introduced. Highway lanes are often not fully packed, particularly during rush hours, where most of the traffic is only going one way. The dividers are automated to change lane-span by teaching a model to learn certain trends and changes in traffic flow as a function of time and place. This essentially provides auxiliary space for the varying influx of public transportation by manipulating the tracks as a whole rather than constantly utilizing more ground. Since the model would be subject to continuous fluctuations, the real-time analysis compensates for any anomalies. This technique can also be used to limit road accidents and combat crimes, as well as to move emergency and rescue vehicles more versatile [1], [4]. An intelligent traffic light monitoring system that uses an algorithm that collects real data from closed-circuit television (CCTV) cameras can efficiently handle road traffic. A deep neural network algorithm is generated by picking the lightest classifiers, such as YOLO and Faster R-CNN. The image processing from the road cameras is used as a reference to this algorithm. Following that, identical road conditions are recreated, i.e., the same number of vehicles are parked at the intersection, and the traffic light working method for the specified road conditions is simulated [2].

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The second technique for traffic decongestion that has been studied is using real-time image processing on live camera recordings to assist control room personnel with traffic monitoring. These days, this is the most commonly used tool for traffic management. By detecting the number of vehicles on every single road, this system determines a load of vehicles on a particular road and allocates an appropriate amount of waiting time (red signal light) and running time (green signal light). This technology is fully automated and can be used to replace the traditional timer-based traffic management system with a dynamically controlled traffic management system. It can also sense the condition of the vehicle on the road and automatically adapt the system to varying road conditions, making the system smart [3]. Vehicle identification and counting methods play an important role in the intelligent transportation system, especially to monitor the traffic. To track driving vehicles more effectively, many computer vision techniques are used, including thresholding, hole filling, and adaptive morphology operations. A virtual detection zone is used to count the number of vehicles on the road [4], [5]. It is important to read the license plates of people involved in car collisions to locate them. Automatic license plate recognition (ALPR) is a vision-based technology that can be used as an electronic traffic management system, digital fee collection methods, inspection equipment, and safety management systems. On inputs received from cameras, ALPR employs visual character perception or OCR (Optical Character Recognition). It provides comprehensive and permanent documentation of vehicle sightings, including time, date, and location, as well as the specifics for each set of observations. This information will greatly enhance the investigative capabilities of federal agencies and will significantly lead to the increased efficiency of the intelligence community [6].

III. COMPUTER VISION FOR ROBOTICS & INDUSTRIAL AUTOMATION

Computer Vision systems are picking pace nowadays in industrial automation and mobile robots as real-time output is achieved in a very short period with more efficacy and precision. They can support autonomous mobile robots in recognizing and perceiving their surroundings to accomplish the aimed objective. A vision-based system helps robots to interpret input data and respond promptly by identifying and removing obstacles in their path without damaging themselves or others. Embedded vision platforms, such as FPGA, can be used to develop mobile autonomous robots. These robots can move by observing the visual characteristics of their environments. This system can be used to detect a given obstacle in front of a robot and determine the distance between it and the obstacle. Using it as a medium, experimentation work can be easily done on mobile robots and any item with varying shape, size, and color could be further improved for detection [7], [8]. Concrete cracks can be observed automatically using mobile robots fitted with an automated peak detection algorithm for image segmentation. They have the potential to remove visible cracks from the background of pictures they have collected. The line emphasis filter is used to process scanned images with a crack potential [10]. Similarly, autonomous robots can be used in military applications for vision-based target detection using a surveillance camera. To meet the requirement, the vision system organizes numerous image processing elements in a tree diagram form using common computational resources, if necessary. Any planar surface in the camera's line of sight can be used with this interface. Image mapping is used to match photographs with various views so that static camera motion detection can be implemented for real-time motion detection using a camera fixed on a pan-tilt platform [17].

In many industries, vast quantities of production make it difficult to verify the quality of production. Checking only a certain quantity of product defects leads to the loss of customers by manufacturers. But by using computer vision systems, quality tests of all items in real-time can be conducted and defective products can be identified on the spot. These systems are used in the food industry for the control of PET preparation quality by detecting the defects in plastic preforms with help of digital image processing algorithms [9]. Another major application of these systems can be seen in Printed Circuit Board (PCB) manufacturing where an automated optical inspection (AOI) system is used for quality control. The AOI system's capabilities include the ability to easily capture concentrated images of inspected components, as well as monitor and compare their patterns to the ideal component or product. As a consequence, instead of using the conventional approach, machine vision technology has been used. The AOI application can be deployed in capturing the images and detecting the copper leakage in the automatic loop cycle through proper inspection in the PCB manufacturing process. Its signal may also be used to show the state of the inspection. However, when it comes to adapting device technologies to real-world operating conditions at the industrial level, practical implementations remain a challenge [11]. Computer Vision in industrial automation has been successfully achieved by the Seimens Corporate Research, where they are focusing on its task-specific applications. They've created real-time object identification, monitoring, and event analysis algorithms, as well as a multi-camera real-time vision system for parcel detection, tracking, and estimation, as well as integration with parcel sorting control. They have also used it for Object model construction, Object localization, Recognition, and Classification, improved video compression, intelligent video communication, pose estimating, and monitoring of the viewer in the environment, and real-time overlay of augmented graphics information on a head-mounted display (HMD) [12].

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IV. VISION SYSTEMS FOR MEDICAL DIAGNOSTICS

In clinical diagnosis, image processing has played a significant role. Magnetic resonance imaging (MRI), mammography, computed tomography, and ultrasound scans are typical examples. However, as more complex image processing and pattern recognition algorithms are sought, as well as the dimensions of medical images to be processed are increased, it becomes clear that dedicated technology and complex systems are needed. Knowing this, a medical image processing system was developed by the Department of Electrical Engineering, the University of Sydney that uses cutting-edge technologies in real-time image processing and neural computing to analyze posture and action in neurological conditions like Parkinson.[13]. A vision-based approach can also be used for vessel detection and separation of different vessel regions in fetoscopic images during fetus surgery. This assists surgeons during decision-making and helps them overcome the problems due to misperception in real-time during surgery [14]. Researches are on for the embryo quality evaluation methods using image analysis and many have obtained successful results. The automated computer vision and image processing techniques would enhance the assessment of embryo fertility as well as would lower the value judgments of the user in the embryo selection process. In the tracking-based approach, computer vision algorithms sense the outlines of the embryo cells, measures the total area of every cell, and tracks them through the entire growth process. Whereas, in tracking free approach, low-intensity features derived from timely image analysis of embryo are used that lead to certain stages of the embryo where we can see a sharp divide [15]. Selfies are very popular nowadays and they have a social connection with the user's emotion and perception. For outpatient healthcare, selfies are crucial data sources that can offer some helpful clinical observations. They may also be used as diagnostic indicators, signaling a possibly masked illness prognosis and demanding action to avert an emergency, ultimately saving a huge amount of money. We can classify and arrange the selfies taken for medical imaging purposes for outpatient Electronic Health Records (EHR) through vision-based Machine Learning algorithms, resulting in novel data-driven diagnostic and therapeutic pathways that could eventually bypass healthcare systems rendering decision-making processes for enhanced efficiency, saving significant time and money [16].

V. VISION-BASED AGRICULTURAL PRACTICES

Agricultural output can be enhanced by vision-based analysis of crop patterns by creating an aerial dataset, and real-time tracking of environmental conditions using AI products such as vision-based sensors and robots, and Deep Neural Networks. Experimental research carried out by candidates of the University of Oregon developed an image dataset named 'Agriculture-Vision', which contains aerial images of farmland for feature extraction of agricultural patterns. They were able to research aerial agricultural pattern recognition with traditional picture sizes with the help of this dataset. They aim to extend this research to develop agricultural visual recognition techniques, based on large-scale, multi-channel aerial farmland semantic segmentation. Agriculture-vision can then be used to evaluate crop trends easily to improve agricultural production [19]. We can also implement this vision for vegetation detection to make it an even more selective application. For this, a system model based on inexpensive cameras was made with a unique algorithm for detecting crops based on real computer vision techniques and the ability to detect other materials, as compared to existing methods that can only detect green or non-green areas. Furthermore, the device will sense the position of the plants, helping one to employ a different method of weed control [20]. From the research work conducted in [21], we can conclude that computer vision systems can be deployed for automating the precise yield prediction process to achieve higher output than traditional practices. Produce can be identified and counted by a vision-based algorithm to get real-time insights and ease the manual process for farmers which then have taken more time with low precision for the same process.

Agriculture, along with the food industry, has become one of the most important applications of computer vision, as it necessitates a replication of human experience concerning the appearance of the object, requiring the study of characteristics such as scale, form, structure, light, color, and others, all of which have a direct effect on quality evaluation. Using computer vision, it is possible to perform an inspection of grains and cereals, defects detection in potato produce, seed's shape and color analysis, characterization and sorting of fruits, and determination of the amount and the distribution of pesticides over a particular area of the field [22].

VI. COMPUTER VISION FOR SPACE EXPLORATION

Space and Astronomy is a vast and most complex field to explore where the key focus is on innovative approaches for space exploration. Planet imaging, satellite mapping, satellite communication, exoplanet observation, space junk minimization, and increasing the autonomy of space vehicles are all part of the study of space science. In each of these applications, Computer Vision plays a key role and also opens up other space technology research fields, such as spacecraft docking and orbital maneuvering. It is possible to use Computer Vision extensively to automate the operations in space exploration.

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It has applications in planetary body detection, earth mapping, satellite imaging, obstacle detection for aircraft navigation, and, most notably, it eliminates the threats astronauts face during human space flights. The following are the main aspects that computer vision tools can be used to track space junk and find ways to minimize it:

1) Use computer vision models to detect and monitor space debris
2) Monitoring the operating movements of spacecraft using real-time video analysis
3) Machine Learning algorithms that have been pre-trained can be used to anticipate potential risks on missions caused by space debris.

Vision-based algorithms can be deployed and utilized to estimate the relative position, motion, and altitude during research missions such as the Mars exploration mission. During the descent process of a spacecraft, computer vision algorithms play an important role in executing the following tasks:

a) Detection and Avoidance of Obstacles
b) Keeping track of the appropriate equipment's loading and unloading.
c) Operations such as rock storage, digging, and drilling
d) Conducting regular inspections and monitoring.
e) Payload launch and retrieval
f) Surveillance of the Martian surface and development of terrain charts.

Algorithms for computer vision would be even easier to learn, and their accuracy would be improved even further. Many other innovations, such as Artificial Intelligence and Machine Learning, will make it possible to create strong autonomous systems when combined with Computer Vision. With deep neural networks, full automation of spacecraft and space robots could be achieved. Soon, computer vision and artificial intelligence will conquer the whole space industry. It is not wrong to say far more work has to be done in the field of computer vision, which will see a paradigm shift in the coming years [18].

VII. CONCLUSION

We have reviewed the applications of Computer Vision systems and the research work being done on them presently. We have covered all the topics of prime importance and also showed how they utilize the algorithms developed to cater to different computer vision services in various fields. Using vision-based systems, we can automate the industrial processes, reduce the complexity in road traffic management, get real-time insights into internal body parts during medical operations, conduct space missions more conveniently, train mobile robots for dedicated tasks and make agricultural practices more convenient. The ongoing research on it in different fields will see its worldwide attention in the coming years and will be an enormous field of innovation for technocrats. In addition, computer vision will alleviate the human complexity to solve critical infrastructural problems in various realms and will bring an enormous transformation in the industrial manufacturing sector in the near future.

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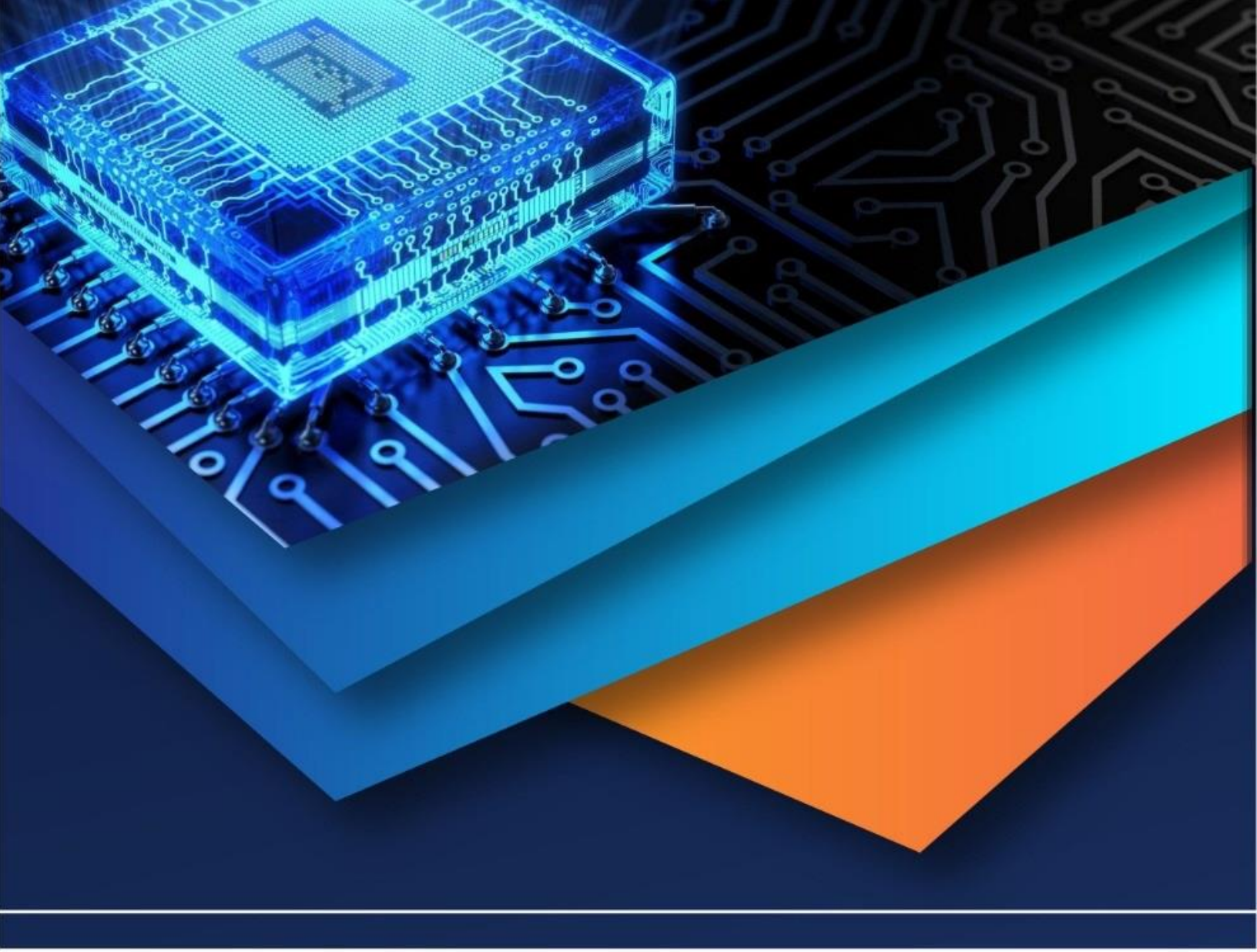

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