Computer Vision with the Internet of Things (IoT)

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1 Introduction

The Internet of things necessitates creating and exchanging data from an endless number of devices [1]. This is why the IoT software platform is complicated and made up of many different things that depend on each other to connect the real world of objects to the virtual world and store and analyze data from sensors to monitor and control connected objects or create a history that allows predictions. Traditional architecture is not the same for every project. Even if there are numerous weak dependencies, it is feasible to draw out a perfect design and employ computer vision technology every day [2]. Many aspects of our lives have been affected by this issue. Computer vision has been around for a long time and is widely employed in both the private and public sectors. There are several more uses for optical sensors that can detect light waves in different spectrum ranges: quality assurance in manufacturing; environmental management; and high-resolution cameras that gather information across battlefields [3]. These instruments are used to keep track of items. A handful of the sensors is fixed, while others are connected to a moving object. Among these are satellites, uncrewed aircraft, and automobiles.

Before, just a select, few of these apps could be used on various sorts of mobile devices [4]. IoT will be increasingly fascinating and lucrative when new technologies like computer vision, IP connection, powerful data analytics, and artificial intelligence come together. Our sense of touch is the most developed of the five senses [5].

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2 What is Computer Vision?

A picture or set of thoughts may be taken, stored, then turned into information that can be utilized to perform other tasks. This is the beginning of computer vision. Various technologies function together in this system [6]. People who work in computer vision engineering must be familiar with multiple technologies, and how they interact to succeed. Real-time motion capture and 3D settings may be combined in games because of this technology. Robotics, virtual reality (VR), augmented reality (AR) applications, and gaming can benefit from this technology [7]. Figure 1 shows computer vision driven by advancements.

Sensor technology is also getting better at many levels, not just camera sensors. There have been some recent examples, as shown in Fig. 2.

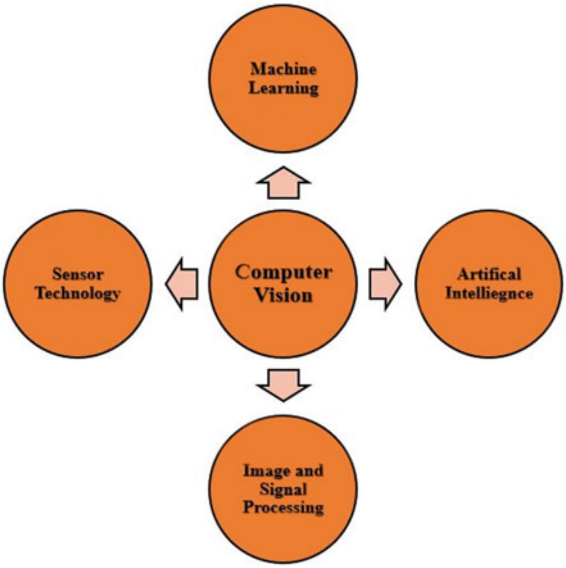

Fig. 1 Advancements drive computer vision. *Image credit* IFA

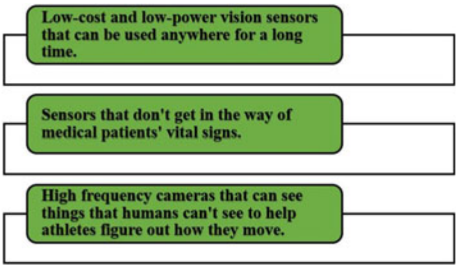

Fig. 2 Sensor technology

3 Computer Vision Gets Smart

3.1 Early Applications

Surveillance is among the first industries to employ image processing and video analytics to make sense of what they are seeing. Video analytics is a form of computer vision that tries to identify patterns in hours of video. The ability to automatically recognize and identify predetermined patterns in real-world circumstances might assist several enterprises [8]. Algorithms built by humans are the first type of video analytics technology. They search photos and videos for particular items. They performed exceptionally well in laboratory and simulation tests. Lighting conditions and camera perspectives impact performance; however, the design was not matched by input data such as these. Working on algorithms and creating new ones that might be used differently took a long time for scientists and engineers. Meanwhile, cameras and video recorders that employ these algorithms still are not powerful enough. Despite modest development over the years, poor performance in the actual world has hampered the usability and acceptance of the technology in the real world [9].

3.2 Deep Learning Breakthrough

In recent years, the emergence of deep learning algorithms has brought new life to computer vision. A method termed an "artificial neural network" (ANN) is used in "deep learning" to mimic sections of the human brain [10]. Research into artificial neural networks (ANNs) became possible in the early 2010s because of graphics processing units (GPUs). Researchers can train their neural networks on a wide variety of video and picture data thanks to video sites and IoT devices. It was found in 2012 that CNN, a kind of deep neural network (DNN), was far more accurate than DNN had previously been. Computer vision engineering became more exciting and popular. Classifying photos and identifying faces have become easier for deep learning algorithms than for people. Also crucial to note is that these algorithms can learn and adapt to diverse conditions, much like people [11]. Computer vision and deep learning can now work together to tackle high-level, complicated issues that were formerly exclusively for the human brain with the assistance of deep understanding. Faster CPUs, better machine learning algorithms, and deeper integration with edge devices will only improve these systems in future [12]. Figure 3 shows IoT architecture with computer vision.

Many things need to be done to make technology more practical and affordable for everyone (Fig. 4).

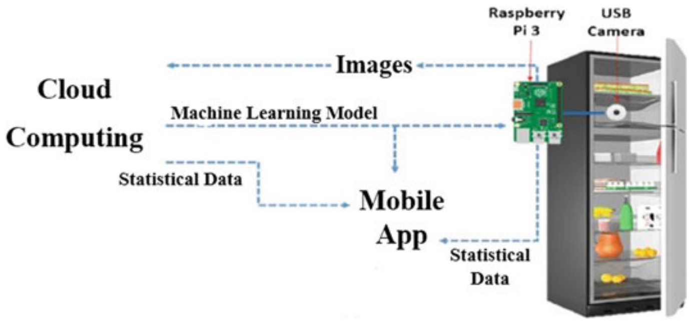

Fig. 3 IoT architecture with computer vision [13]

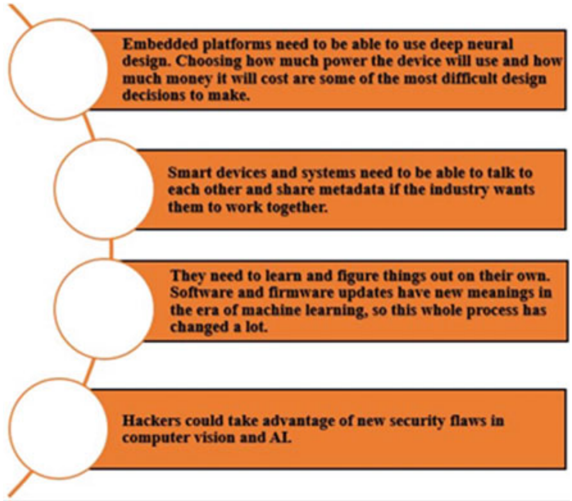

Fig. 4 Challenges in computer vision of IoT

4 Artificial Intelligence, Computer Vision, and Technologies Can be Used to Make Internet of Things

Weld quality inspection demands the capacity to verify each weld every 17 ms, which is hard for an individual to do on their own while inspecting five million car welds daily [14]. The physical and digital worlds are becoming increasingly intertwined thanks to the proliferation of IoT sensors like cameras, microphones, and other high-tech devices. These AI-powered gadgets can instantly analyze medical imaging for worrisome abnormalities, listen to equipment noises for maintenance concerns, or provide more extensive remote monitoring in a wide range of locations. IoT technologies and services like deep learning, computer vision, and audio or voice capabilities may be used by enterprises with Intel and Microsoft Azure [15].

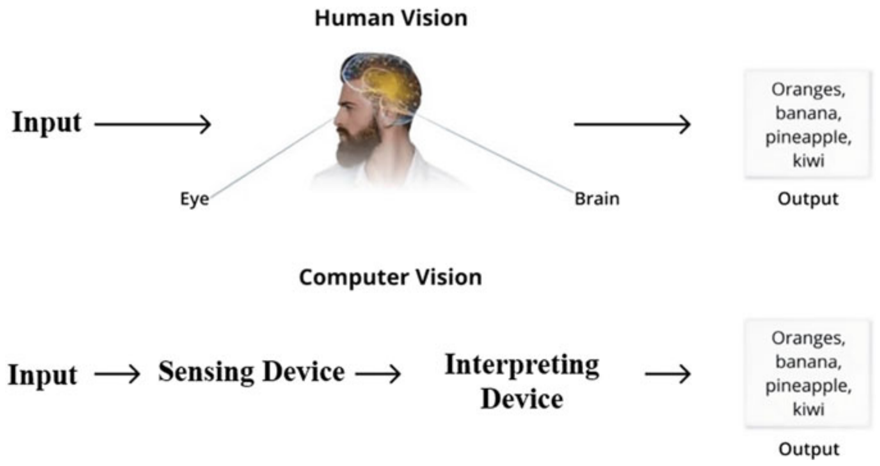

Fig. 5 AI visual inspection for defect detection in manufacturing

Adding computer vision and AI to IoT solutions, for example, enhances their business value by enabling them to address additional challenges. Figure 5 shows AI visual inspection for defect detection in manufacturing.

4.1 Four Ways Enterprises are Benefitting from AI and Computer Vision

In their field, artificial intelligence (AI) and machine learning (ML) algorithms excel due to their ability to process large amounts of data far quicker than humans can and make choices in real-time. Here are four examples of how Intel and Azure IoT solutions are being put to use in a variety of different contexts [16, 17].

4.1.1 Improving Typical IoT-Enabled Applications

These technologies may be used to improve daily IoT-enabled operations, including monitoring devices from afar and foreseeing maintenance needs. Video feeds may be automatically analyzed to detect movement or abnormal activity and deliver alerts immediately. Telemedicine's computer vision enables remote monitoring of patients' health status from afar.

4.1.2 Enhancing Employee Safety, Patient Care, and Customer Service

Computer vision and artificial intelligence can help keep people safe. These technologies can assist medical technicians in scanning medical photographs by automatically identifying irregularities and alerting clinicians to photos that require further investigation. Video streams can be used by AI and machine learning algorithms to monitor employee safety and alert them when there is a danger. Using a system like this, retail shops can keep track of their inventory and alert their staff when it is time to reorder. Additionally, it may be used to limit the number of clients in a congested environment.

4.1.3 Reducing Complexity for Developers and Users

Even as IoT devices and services continue to improve, technology companies are making them easier to set up. To produce IoT devices that are plug-and-play compatible, Intel and Azure encourage developers to create toolkits that connect rapidly and speed up the process of getting them up and running quickly [18]. People that utilize technology and systems daily benefit from this type of attentiveness.

4.1.4 Accelerating Potential Return on Investment

Increasing the IoT solutions' return on investment (ROI) through the use of more advanced technologies is another possibility. Companies using AI are more satisfied with IoT than those using IoT technology are, with 96% saying they are. Because they regard IoT as vital to their business's success, they are more inclined to invest in and use IoT. The technology itself can save companies a significant amount of money and time.

4.2 Advanced Technologies in IoT Solutions

As IoT technology improves, so does its capacity to solve business challenges [19]. As part of their collaboration, Intel and Azure are making it more straightforward for companies of all sizes and across a wide range of sectors to learn about and select the appropriate IoT devices and services to assist them in achieving their objectives. The two firms provide the hardware, software, edge and cloud services, and support. Our technology has been utilized to create ready-to-sell solutions in various industries, including manufacturing, retail, transportation, intelligent spaces, and more.

4.3 Evolving Toward IoT and AI

Machine vision might benefit significantly from the Internet of things. For example, it might save money and speed up the process. Lightweight communication technologies like Bluetooth, MQTT, and Zigbee have contributed to the proliferation of consumer IoT devices. Low-bandwidth messages or beacon data can be exchanged using these protocols. The real-time decision-making capability of imaging is dependent on uncompressed, low-latency data sources. A camera or sensor sends data back to a central processor for processing in the past [20]. Using various pictures and data from many sources, such as hyperspectral and 3D sensors, might be an issue for future IoT applications. Designers are researching intelligent gadgets at the network's edge. As a result, the bandwidth issue may soon be solved. Tiny sensors and embedded processing boards that do not require a camera are examples of devices that may be used in conjunction with an existing inspection network.

When a gadget is considered "intelligent," it gathers and processes data, makes a choice, and then transmits that decision or data to another device or the cloud. The quantity of data sent back to a central computer is significantly reduced when decisions are made locally. More processing power may be employed for more difficult analysis jobs because less bandwidth is required. With the help of these little devices, network intelligence may be dispersed throughout the system. Using an existing camera to feed data into an intelligent frame grabber in a quality inspection line is possible. Other system components will not have to deal with raw video data because of it [21]. It also converts the sensors into GigE Vision devices so that the program has one set of data to work with throughout its many components. As a result, current inspection systems can benefit from new inspection techniques like hyperspectral imaging and 3D scanning. Using an intelligent frame grabber to perform edge processing is more cost-effective than replacing expensive cameras and processing equipment. With this method, it is possible to add additional AI capability to an existing inspection line quickly.

It is particularly good at spotting defects or matching patterns when customized to a known data set. On the other hand, AI can be taught and can detect, identify, and differentiate more items or issues as more information is obtained [22]. Adding an intelligent frame grabber allows for more advanced AI algorithms. The camera and AI-processed video stream may be delivered to machine vision software already compatible with the technology. At the sensor level, embedded intelligent devices allow for more complicated processing. Low-cost and tiny embedded circuits with the computational capacity needed to analyze photos in real-time have been developed. Robotic procedures that require a lot of repetition, like edge detection in a pick-and-place system, benefit significantly from embedded intelligent devices. AI may be used in vision applications more quickly with embedded intelligent devices, just as the intelligent frame grabber. Artificial intelligence (AI) help train computer models to recognize objects and errors and advance robotics systems toward self-learning capabilities [23]. There are several advantages to using AI on both local and cloud-based computers and various smart devices.

4.4 Solving the Connectivity Challenge

The GigE Vision standard in 2006 was a significant change for machine vision system designers. It made it easier for products to work together and connect to the Internet. Today's designers thinking about IoT and AI face the same problems, but they also have to deal with more imaging and non-imaging sensors and new ways to use data that are not just for inspection [24]. This is not the first time that GigE Vision has helped us get to a more sophisticated level of analysis. Industrial IoT promises to use a variety of sensors and edge processing to speed up and improve the quality of inspections. Even though high-definition inspection could use 3D, hyperspectral and infrared (IR) capabilities, each tool has a different interface and data format that would need to be used. High-bandwidth sensors and more data sources make it hard to have enough capacity [25]. This makes it easy for devices to communicate and back to local or cloud processing. Edge processing also significantly reduces the amount of data that needs to be sent, making wireless transmission for real-time vision applications possible. These 3D sensors are small and do not use a lot of power. They are often part of a mobile inspection system without room for more hardware. With software, these devices can be made to look like "virtual GigE sensors" and work together to create a network that's easy to use [26]. GigE Vision is a machine vision processing that can look at images from these sensors. In future, there will be a lot of value in fully integrating the output from all of the sensors in an application so that a complete data set can be used for analysis and AI.

5 Machine Vision and the Cloud

The cloud and access to a larger data set are needed to introduce IoT to the vision market. Historically, production data has been restricted to a single plant. AI and machine learning processing algorithms may be constantly updated and enhanced with a cloud-based method to learn from fresh data sets. Initial AI capabilities can be integrated into vision systems using smart frame grabbers and embedded image sensors [27].

Cloud-based machine learning security is shown in Fig. 6. Rules-based inspection is excellent at detecting faults based on known factors, such as whether a part is present or is too far away from the next part. While a human inspector may struggle to locate and categorize scratches of varying sizes and locations on examined equipment, a computer-based system using machine learning is better equipped to handle these kinds of inspection issues [29]. Because of this, the system can be trained to recognize scratches on various devices or pass/fail tolerances for different clients with a new reference data set. It is possible to utilize a proven data set to configure a robotic vision system for parts assembly to recognize things and determine what action to do next, and then take that action. High-bandwidth sensor data transfer and sharing to the cloud would necessitate new developments in vision industry

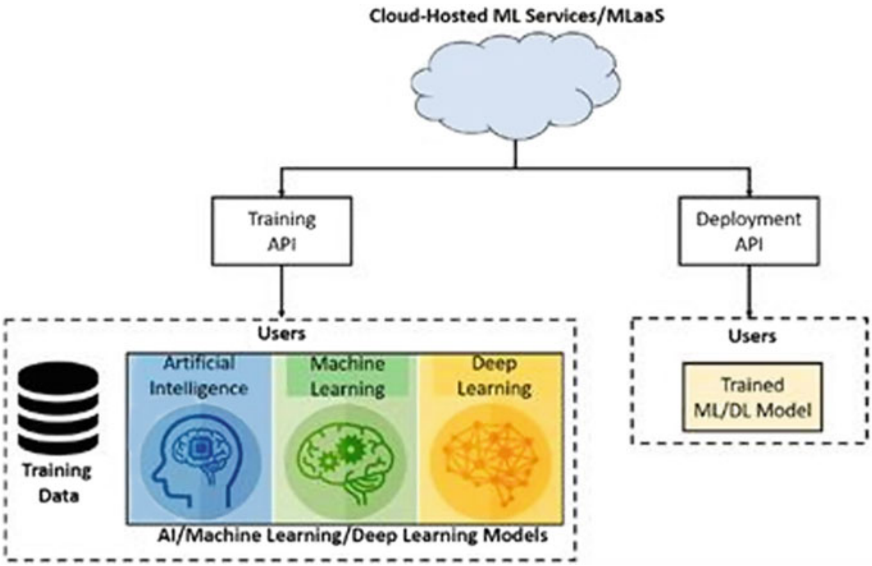

Fig. 6 Shows securing machine learning in the cloud [28]. They are reproduced from Qayyum [28] under the terms of the Creative Attribution Commons License 4.0 (CC-By 4.0). http://creativecommons.org/licenses/by/4.0/

technologies, such as lossless compression, encryption, and security, in addition to higher-bandwidth wireless sensor interfaces [30].

6 Conclusion

They claim that forecasts and analyst papers on how AI would be employed with the Internet of things (IoT) abound. Currently, they are working on how they function together and why "IoT requires AI" and occasionally "IoT needs AI." Even though IoT and AI have been utilized together in many enterprises for a long time, this is a bit surprising. Even yet, it is becoming increasingly difficult to keep up with the fast emergence of various forms of AI throughout the entire IoT equation. Machine learning, big data, and the shift to the edge were previously included on the list of IoT predictions for 2017 as critical stages "to feed machine learning engines and additional AI applications." There were also mentions of moving to the edge and the coming of new data analytics streaming technologies. As Ovum stated, IoT and linked systems also boost AI since intelligent automation is required to make sense of the massive volumes of data that sensors generate. Perhaps it would be helpful to look at examples of this already occurring. Information and enjoyment are displayed on computer and television displays. The rise of IoT technologies has been helped by better main technologies and a lot of different things. There are new sensors, more computing power, and reliable mobile connectivity that can help make things even better in the next few years, which will make things even better. When existing IT devices need to be linked to the IoT, the market for the IoT will grow. As a result of this, there is a lot of demand for integrating devices. There are more than five billion smart phones, two billion PCs, and one billion tablets.

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