Computer Vision and Internet of Things

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Vukoman R. Jokanović
Vinča Institute of Nuclear Sciences, Universiy of Belgrade, Serbia

Computer Vision and Internet of Things

Technologies and Applications

Edited by

Lavanya Sharma

Mukesh Carpenter

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Dedicated to my Dada Ji (Late Shri Ram Krishan Choudhary Ji)

Ek prerna mayeh Vyaktitavh

Dr. Lavanya Sharma

Contents

Preface

This book explores the utilization of Internet of Things (IoT) with Computer Vision and its underlying technologies in different applications areas. Using a series of present and future applications – business insights, indoor-outdoor securities, smart grids, human detection and tracking, intelligent traffic monitoring, e-health department, medical imaging and many more – this publication will support readers to acquire more deeper knowledge in implementing the IoT with visual surveillance.

This book comprises five parts that provide an overview of basic concept from rising of machines and communication to IoT with computer vision, critical application domains, tools, technologies, and solutions to handle relevant challenges. This book provides a detailed description to the readers with practical ideas of using IoT with visual surveillance (motion-based object data) to deal with human dynamics, challenges involved in surpassing diversified architecture, communications, integrity, and security aspects. IoT in combination with visual surveillance proved to be most advantageous for the companies to efficiently monitor and control their day-to-day processes such as production, transportation, maintenance, implementation, and distribution of their products.

Overall *Computer Vision and Internet of Things: Technologies and Applications* helps the readers to understand the value of Internet of Things with Computer Vision to individuals as well as organizations.

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Editors

Dr. Lavanya Sharma completed her M.Tech. (Computer Science and Engineering) in 2013 at Manav Rachna College of Engineering, affiliated with Maharshi Dayanand University, Haryana, India. She completed her Ph.D. at Uttarakhand Technical University, India, as a full-time Ph.D. scholar in the field of digital image processing and computer vision in April 2018, and received a TEQIP scholarship for the same. Her research work is on motion-based object detection using background subtraction technique for smart video surveillance.

She is the recipient of several prestigious awards during her academic career and qualified certification courses from ISRO Dehradun unit, India. She has published 40+ research papers to her credit in reputed journals of Elsevier (SCI Indexed), Inderscience, IGI Global, IEEE Explore, and many more. She has published three books with Taylor & Francis and two books with CRC Press in 2019, 2020, and 2021, respectively. She also has two patents in her account on object detection in visual surveillance. She has also contributed as an Organizing Committee member to Springer's ICACDS 2016, Springer's ICACDS 2018, Springer's ICACDS 2019, Springer's ICACDS 2020, ICRITO 2021, and Springer's ICACDS 2021 conferences. Presently, she is the editorial member/reviewer of various journals of repute and also an active program committee member of various IEEE and Springer conferences. Her primary research interests are digital image processing and computer vision, artificial intelligence, machine learning, deep learning, and IoT. Her vision is to promote teaching and research, providing a highly competitive and productive environment in academic and research areas with tremendous growing opportunities for the society and her country.

Dr. Mukesh Carpenter completed his MBBS at Manipal Academy of Higher Education, Kasturba Medical College, Mangalore, India, in 2011 and Master of Surgery at Mallya Hospital, Vittal Mallya Road, Bangalore, India, in 2014. He is the recipient of several prestigious awards and recognition in his career. He is presently working as a Unit Head and consultant with Alshifa Hospital, Delhi, India, and is having more than 6 years of experience. He has published several articles and research papers, and contributed as hospital committee member and unit head. He has also delivered expert talk in prestigious hospitals and educational institutes of India on topics including breast cancer awareness, cancer awareness drive, Covid-precautions and measures, and also serves as the brand ambassador of Pro Biotic (Expert Talk on Fever 104 FM, January 2021). He is also guiding Ph.D. students in the field of computer science for medical imaging domain.

List of Contributors

Alpana
Department of Computer Science and Technology
Manav Rachna University
Haryana, India

Sunil L. Bangare
Department of I.T.
Sinhgad Academy of Engineering
Pune, India

Thierry Bouwmans
Lab. MIA
University of La Rochelle
La Rochelle, France

Dharmendra Carpenter
Department of Anaesthesiology & Critical Care
Narayana Multispecialty Hospital
Jaipur, India

Mukesh Carpenter
Department of Surgery
Alshifa Multispecialty Hospital
Okhla, India

Nikhil J. Chaudhari
Department of I.T.
Sinhgad Academy of Engineering
Pune, India

Soumitra Das
DYPIT
Pune, India

Belmar Garcia-Garcia
Lab. MIA
University of La Rochelle
La Rochelle, France

Deepa Gupta
Amity Institute of Information Technology
Amity University
Noida, India

Kavish Gupta
Amity Institute of Information Technology
Amity University
Noida, India

Priyanka Gupta
Department of Computer Science and Technology
Manav Rachna University
Haryana, India

Yaman Hooda
Faculty of Engineering and Technology
Manav Rachna International Institute of Research and Studies
Haryana, India

Pramod Jadhav
Department of Computer Engineering
G. H. Raisoni Institute of Engineering and Technology
Pune, India

Vinod Kumar Jangid
Department of Respiratory Medicine
Medical College Kota
Rajasthan, India

Vukoman Jokanović
ALBOS doo, Innovative Company
Belgrade, Serbia
Vinča Institute of Nuclear Sciences
Belgrade, Serbia

Isha S. Kuchangi
Department of I.T.
Sinhgad Academy of Engineering
Pune, India

Nirvikar Lohan
University of Patanjali
Uttarakhand, India

Yash M. Lokhande
Department of I.T.
Sinhgad Academy of Engineering
Pune, India

Sandeep Dwarkanath Pande
DYPIT
Pune, India

Shantanu S. Pathak
DHI Training and Research Consultancy
Pune, India

Amol D. Sawant
DYPIT
Pune, India

Kamal Sehairi
Lab. LTSS
University of Laghouat
Laghouat, Algeria

Sudhriti Sengupta
Department of Computer Science and Engineering
Galgotias University
Greater Noida, India

Lavanya Sharma
Amity Institute of Information Technology
Amity University
Noida, India

Jaskirat Singh
Amity Institute of Information Technology
Amity University
Noida, India

Hardeo Kumar Thakur
Department of Computer Science and Technology
Manav Rachna University
Haryana, India

Aditya N. Varade
Department of I.T.
Sinhgad Academy of Engineering
Pune, India

El-Hadi Zahzah
Lab. L3i
University of La Rochelle
La Rochelle, France

M. Živković
School of Dentistry
University of Belgrade
Belgrade, Serbia

S. Živković
School of Dentistry
University of Belgrade
Belgrade, Serbia

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Lavanya Sharma

Part 1

Introduction to Computer Vision and Internet of Things

1

Rise of Computer Vision and Internet of Things

Lavanya Sharma

Amity Institute of Information Technology, Amity University, Noida, India

CONTENTS

1.1 Introduction

Computer Vision (CV) represents the domain of artificial intelligence (AI) which trains the system to identify and interpret the visual world. Machines detect objects and classify them into various categories as per the vision. To detect objects, digital cameras, video stream, and deep learning (DL) models are used. CV involves various important tasks such as three-dimensional scene modeling, multi-model camera geometry, motion-based, stereo correspondence, point cloud processing, motion estimation, and many more. There are three basic steps involved in this process as shown in Figure 1.1. With the advancements of AI, systems can proceed to the next level and take appropriate actions based

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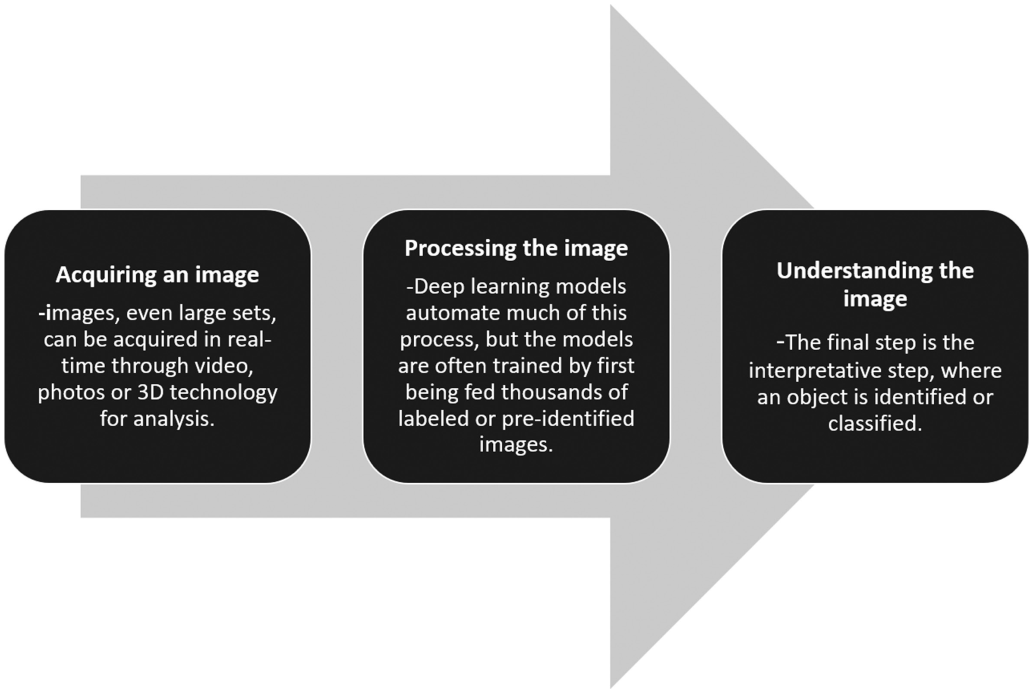

FIGURE 1.1
Working of Computer Vision.

on the first step (Figure 1.1.). In literature, various kinds of CV can be used in a different manner such as segmentation, object detection, face recognition, and edge and pattern detection. CV is an emerging technology that captures and stores an image, or frames and then transforms them into valuable information which can be further acted upon [1–11]. It comprises various technologies working all together such as ML, AI, sensor technology, image processing, and computer graphics. CV, combined with Internet Protocol connectivity, advanced data analytics, and AI, acts as a catalyst for each other and gives rise to revolutionary leaps in the Internet of Things (IoT) innovations and technology [7,11–14].

- **Image segmentation**
  This technique segments a digital image into various smaller segments or set of pixels to be examined separately. These segments correspond to different objects or parts of objects. Every pixel in a frame is allocated to one of these categories [15–17].
- **Object detection**
  This identifies that a particular object from a video stream may be a single object or multi objects in a frame sequence in case of both outdoor and indoor scenes as shown in Figure 1.2. These models use a coordinate system (X, Y) to create bounding boxes and identify all the objects in a frame. In Figure 1.2, object detection is done using background subtraction (BGS) techniques to detect foreground objects by hiding all the background pixels [17–24]. Figure 1.2 shows two different scenarios—outdoor and indoor—along with the ground truth images and output results.

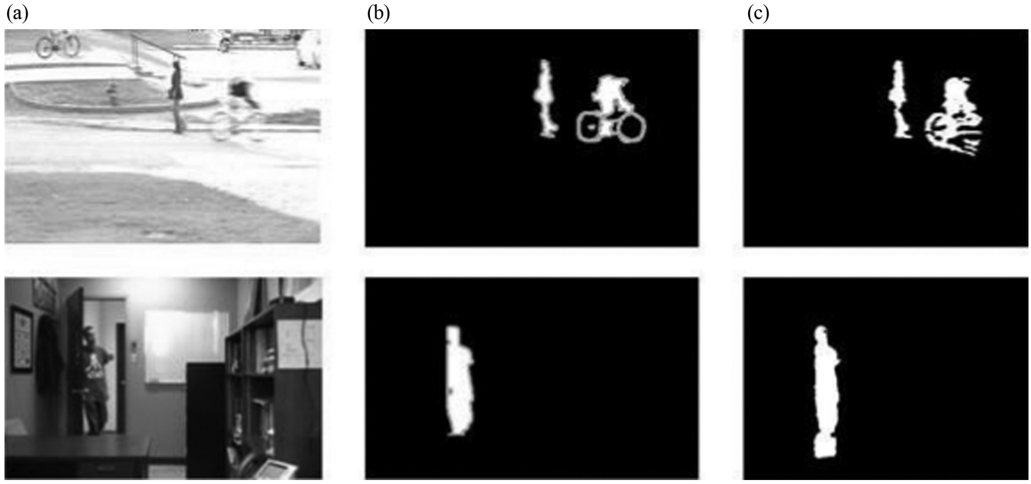

FIGURE 1.2
Detection of moving object in outdoor and indoor video sequence (row wise): (a) video frames, (b) ground truth, and (c) desired output.

- **Facial recognition**
  It is an advanced type of technique which identifies a human face and detects an individual in a frame as shown in Figure 1.3. This technique identifies or verifies the individual's face using their faces, and it also captures, analyzes, and compares the pattern based on the existing details of a person [7,23,25,26].
- **Edge detection**
  This technique is used to detect the outer boundary edge of an object or landscape for clear identification of the content of an image. It identifies points in an image with discontinuities, and these points where brightness changes are known as edges [19,23,24].
- **Pattern detection**
  This technique recognizes repeated shapes, colors, and other visual indicators in the frame. This technique is an automated identification of patterns and regularities in data and is widely used in statistical data analysis, signal processing, image processing, and CV [20,21,26].
- **Image classification**
  This groups images into various categories. The most common image classification technique is supervised and unsupervised image classifications. In literature, various algorithms are present for image classification such as support vector machine, regression, and K map [20,21,23–26].
- **Feature matching**
  It is a kind of pattern detection that matches the similarities in a frame to classify them accurately. It is a part of various CV applications such as image registration, camera calibration, and object detection [26–28].

Simple real-time applications use one of these techniques. It can be advanced ones like driverless cars rely on multiple techniques to achieve their specific goal.

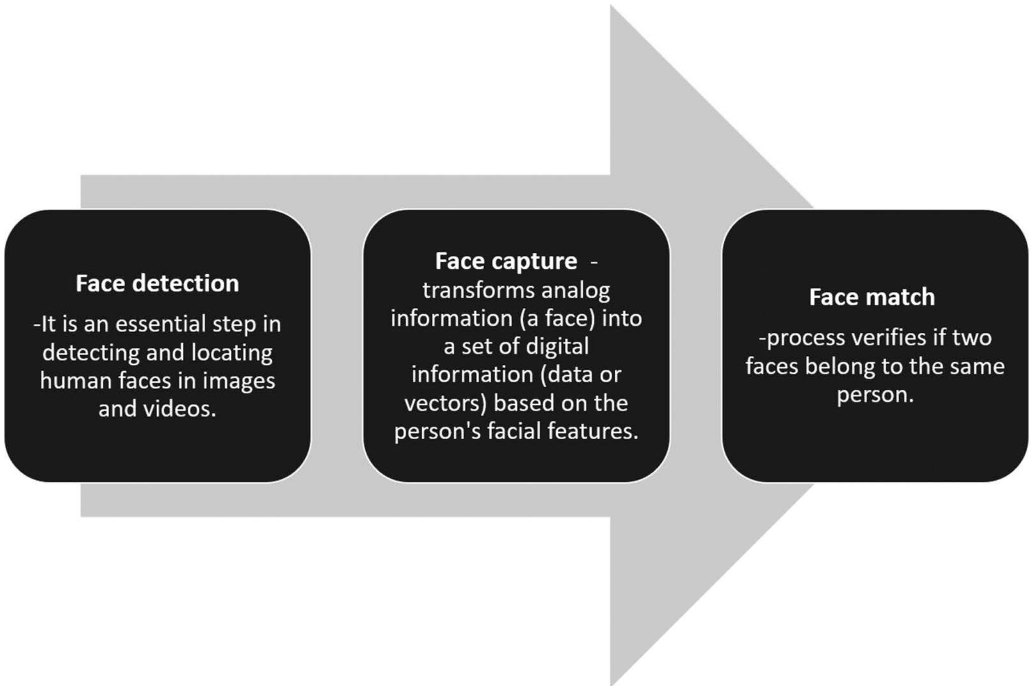

FIGURE 1.3
Facial recognition steps.

FIGURE 1.4
Factors affecting renaissance in Computer Vision.

1.2 Evolution of CV and IoT

In 1950, early experiments in CV took place with the first neural network to detect an edge of an object and sorting of objects such as a circle or square. Later, in 1970, the first commercial use of CV interpreted typed or handwritten text using optical character recognition. This advancement was used by the visually impaired to interpret written text. In the 1990s, usage of internet was also increased, and large datasets were easily available to developers or researchers for analysis and recognition. With the presence of a large amount of dataset, machines can classify objects from frames or videos [2,23]. Today, several factors have come together to bring about a renaissance in CV as shown in Figure 1.4. There is an outstanding effect of these advancements on CV, and the accuracy rate also increases from 50% to 99%. So, systems can accurately detect and track objects more accurately than humans.

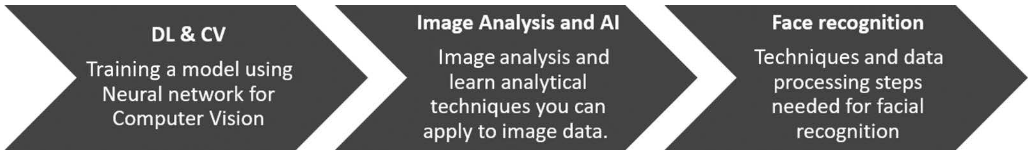

FIGURE 1.5
Computer Vision and innovative technologies.

1.3 Evolving Toward CV and IoT

It is one of the most remarkable technologies to come out of DL and AI domain. The advancements that DL has contributed to the CV have set this domain apart. From face detection to processing the live action of a football game, CV rivals and surpasses humanoid visual abilities in various areas as shown in Figure 1.5. This technology is widely used in industries to enhance the client experience, cost reduction, and security, in manufacturing industries to identify product defects in real time, and in the healthcare system such as MRIs, CAT scans, and X-rays to detect abnormalities as accurately as clinicals.

IoT provides new costs and benefits to CV and has a route toward integrating AI, ML, and DL into an inspection system. The rapid growth of IoT devices has been drastically aided by the availability of several light-weighted internet protocols such as Bluetooth and Zigbee that share low-bandwidth messages. These protocols have good communication connectivity in applications where delays may be acceptable.

Traditional CV analysis deals with identifying defects or pattern matching with an unknown dataset. But AI is trainable and has wide scope in locating, identifying, and segmenting a large number of objects or defects. New techniques can be added to smart frame grabbers to perform better in complex situations with a camera and video data transmitted from the device to CV software. The embedded device offers a direct path to integrate AI into vision applications, and with the help of cloud-based processing it provides data sharing between multiple smart devices. These techniques trained the model to identify objects, defects, matching patterns while supporting a migration toward self-learning robotics systems [5,11,23].

1.4 Enhancement of IoT Using CV and 5G Technology

CV gives rise to new IoT innovation and application when merged with advanced data analytics and AI. In today's world, CV is present everywhere from a smartphone camera to games, robotics, and many more. The ability to detect and match predefined patterns in real-time conditions represents a large amount of opportunity with hundreds of use cases. An improvement such as a face-filtering app can affect our lives. This app can scan the images using face detection, identify facial characteristics, and add an augmented reality concept to it [3,9,15,23].

The performance of IoT depends on the time taken for communication with devices, smartphones, or any other software. With the help of 5G, the speed of data transfer can be increased easily and have a more stable connection between the devices. This is a very important factor for any IoT especially for connected devices such as monitoring system which depends on real-time updates. It also results in the reduction of power consumption that is up to 90% and provides a guarantee of battery for 10 years in low-powered IoT devices.

1.5 Challenging Issue

There are various obstacles to overcome in building the technology more feasible, realistic, and economical for the masses [4,11,23]:

- Embedded platforms require incorporating deep neural design for less power consumption, less cost, more flexibility, and more accuracy.
- There should be a common standard or set of protocols to allow systems and IoT devices to communicate with each other and data sharing.
- There should be less amount of human intervention. The system should be unsupervised learning and improve themselves without human intervention. The complete software update has new significance in ML.
- Systems are no longer passive collectors of data. They need to act upon the data with minimal human intervention. They need to learn and improvise by themselves. The whole software/firmware update process has new values in the ML domain.
- Hackers can also take advantage of new security vulnerabilities in CV and AI. So, developers must take this into account.

1.6 CV and IoT in Real-Time Applications

CV represents AI domain that trains the system to interpret the visual world. Machines can detect, classify, and react accordingly. In real time there are various CV applications with IoT from smart parking to object detection [2–4]. Some of the major applications are listed as follows.

1.6.1 Autonomous Vehicles

As per the WHO report, about 1.25 million persons die every year due to roadside accidents. To overcome this situation, driverless cars are developed using CV to bring this ratio down and enhance transportation. Several companies are using ultrasonic sensors, cameras, and radar to acquire images from the surrounding environment [3,6,29–35]. Autonomous vehicles can easily detect objects, signals, LiDAR, marked lanes, and traffic signs for a safe drive. Autonomous vehicles can be seen in cities next door as shown in Figure 1.6.

- In Boston, a company named "nuTonomy" has recently got approval to test its driverless cars throughout the city.

FIGURE 1.6
Self-driven cars with distance from each other.

- Another example is a grocery chain called Kroger (Scottsdale, Arizona), which has begun to pilot driverless vehicles for grocery delivery services.
- In Phoenix, Google has been actively testing its driverless cab service, and by the end of this year, they will launch it as a full-fledged business.

1.6.2 Healthcare System

In this department, CV technology plays an important role by providing accurate illness or condition prediction that may save patient lives. New CV-based technologies such as X-ray, CT, and mammography help doctors to detect the issues at an early stage [11,23,36,37]. CV technology that can assist health systems is described as follows.

1.6.2.1 Precise Diagnosis

CV systems offer precise diagnosis, which reduces false positives. This technology can potentially eliminate the requirement for unnecessary surgical operations and other high-priced therapies. The algorithms are trained using a large amount of dataset that can easily detect the presence of a condition that was unidentified by doctors due to sensory limitations. In the healthcare system, this technology provides a high level of precision for up to 100% correction.

1.6.2.2 Timely Detection of Illness

Fatal illnesses such as ovarian cancer, lung cancer, throat cancer, gall bladder cancer, and breast cancer must be diagnosed at the early stage. CV enables the detection of these illnesses at an early stage with pattern recognition capability as shown in Figure 1.7. This results in early diagnosis and timely treatment of a patient [11,23].

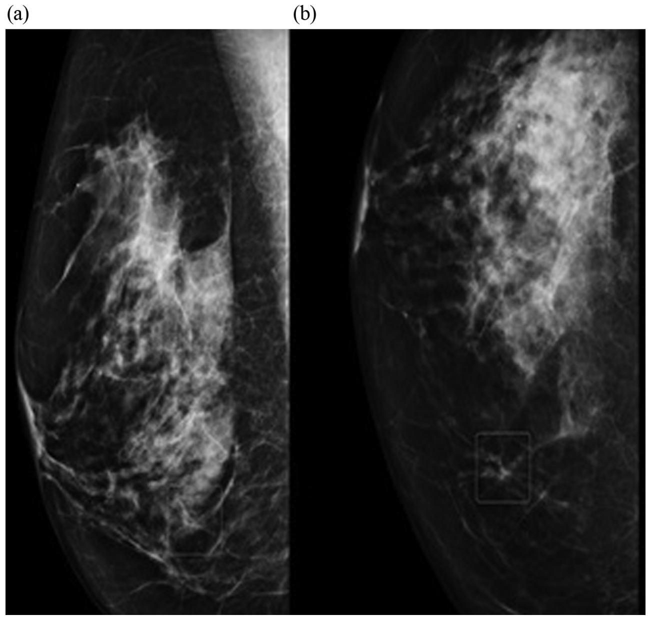

FIGURE 1.7
Detection of the breast using neural network (row wise): (a) input image and (b) resultant image.

1.6.2.3 Facial Recognition

This technique is very useful from both indoor and outdoor security perspectives. In today's world, advanced hacking and cyberattack are increasing day by day, so various companies can be benefited from this technology. It is capable of match-making human faces from an image or video stream to authenticate users via ID verification, checkpoints, and measuring features from the input image. Anand et al. [7] provide an efficient local binary pattern histogram-based technique for facial pattern recognition which is well suited for realistic scenarios using python [7]. A facial recognition using the binary histogram technique is shown in Figure 1.8.

1.6.3 CV-Based Agriculture

Agriculture is among the economy-booster area that makes every country stand out in the international market. In agriculture, CV provides a strong foothold. It provides agriculturalists with an efficient technique to increase profit, cost reduction, and detection of objects [2,8,12,11,23,38,39]. For example, "semi-autonomous combine harvester" can detect the optimal route and analyze the quality of crops. Some of the most significant contributions that exist at present are discussed as follows.

1.6.3.1 Drone-Based Monitoring and Smarter Farming

Drone technology is a very innovative and advanced technology well equipped with AI, ML, and remote-sensing features. Drones have become an essential factor in crop monitoring with their flying capabilities and inbuilt camera. They can cover a significant amount of distance and capture data that can be used to detect unfavorable conditions, pesticide spraying, crop damage information, irrigation monitoring, aerial view of the field, and

FIGURE 1.8
A facial recognition using binary histogram technique (row wise): (a) original frame, (b) grayscale, (c) Haar cascade technique, and (d) local binary classifier-based technique.

soil analysis with its geo-sensing features [11,23,40]. For example, segmentation and image annotation are used for object detection.

1.6.3.2 Yield Analysis

DL-based models are used for yield analysis. The data collected from drones, satellite imaging, nitrogen and moisture level information, climatic condition, and soil analysis are fed as an input smart system which is trained to handle a large amount of data. The overall report helps in prediction beforehand about any natural disruption [1–9,12].

1.6.3.3 Crop Grading and Sorting

There is a high demand for AI-powered CV technologies in farming. Grading and sorting of crops becomes easy with the use of this technology. The smart system can detect crop's longevity and infection in crops which results in less crop damage. Both vegetables and fruits cab be graded as per the quality and packed accordingly [3,6,39].

1.6.3.4 Automated Pesticide Spraying and Phenotyping

CV-based drone technology is used for pesticide spraying, which results in an increase in production and quality of crops. This technology can effectively monitor and detect the infected crops and spray an adequate amount of pesticide as per the requirement. Using this technology, both the intervention of humans and chances of pesticide exposure are less. Phenotyping is an effective approach based on an advanced CV to detect the crop traits for precision farming. The CV algorithms embedded with image processing features

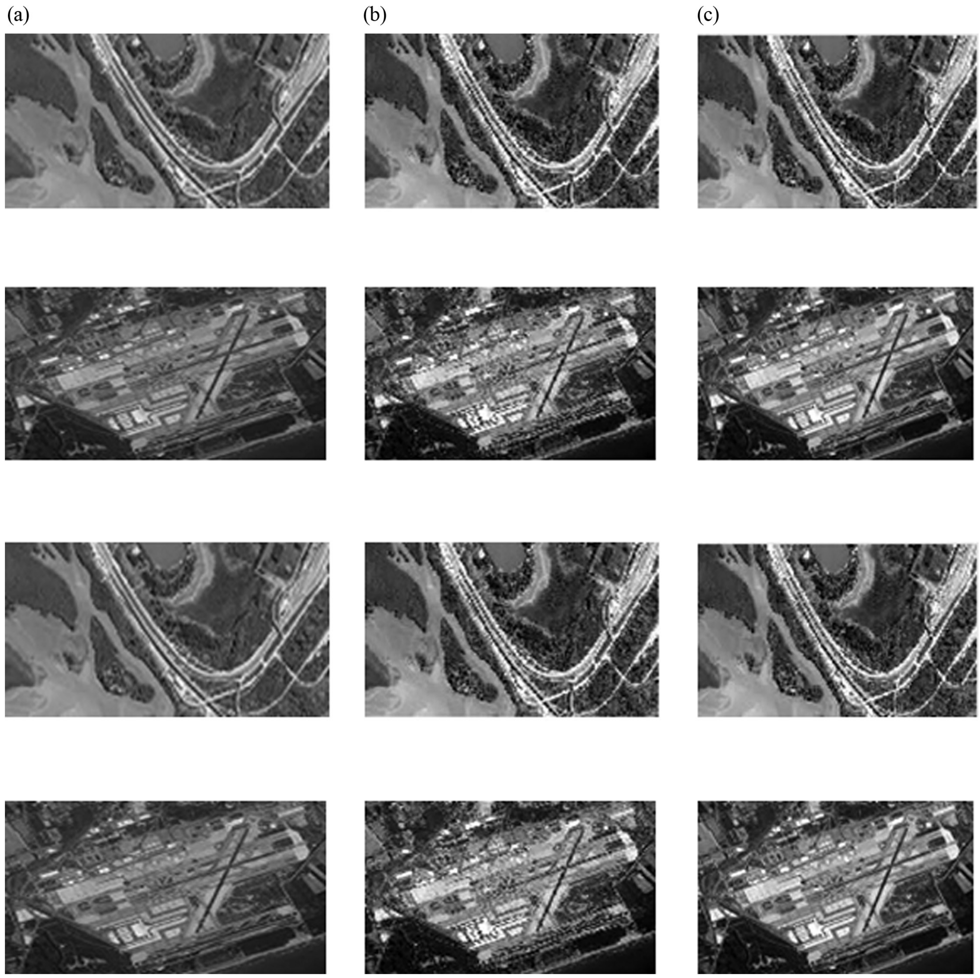

FIGURE 1.9
Satellite imaging (row wise): (a) test frame, (b) histogram-based technique, and (c) conventional technique.

can help in discarding the unwanted or damaged crop data and keep a record of relevant information on precise measurement as shown in Figure 1.9.

1.6.3.5 Forest Information

Drone and CV technologies are used for aerial view and collection of data. The data collected using this technology can be used for object detection in the forest such as yield estimation, tree counting and classification, stem drainage information, unused land and boundary of the forest, and animal counting as shown in Figure 1.10 [23].

1.6.4 Less Traffic Congestion

With the help of AI-powered CV technology, the government can monitor and detect the traffic flow and report abnormalities. It also provides valuable insight for the operation

FIGURE 1.10
Animal detection in the forest using AI-based drone technology in thermal images.

and management of suitable resources such as repairing of roads, snow removal, congestion due to animals, and lifesaving methods. This system can store traffic data to classify various vehicles on a road and also provide information about traffic flows (congestion, damaged road). This information can be further used to avoid that disruption [1,11,23,40].

1.6.5 Smart Parking

In smart cities, IoT-enabled technology is used for parking issues. This technology consists of inbuilt sensors that can detect the vacant parking space. All the data is gathered and transferred to a cloud server which results in easy access to a map of available space. The IoT sensors can detect the distance to its undercarriage in case of an occupied area. To scan the number plate of vehicles smart cameras and parking meters are used. Smart video surveillance is used by the government to mark parking points without the use of parking meters [1,2,3,6,11,23]. These cameras can detect the object or vehicles in the parking space and time duration. In this smart parking system, automatic number plate detection is used. With the help of this, all the free space data can be updated on a real-time basis. As a result, drivers can use the app to allocate the parking space as shown in Figure 1.11. Using this CV technology, driver identification, car model, number plate of a car can be easily scanned and any unwanted activities at parking space detected.

1.6.6 Object Detection and Tracking

Detection of motion-based objects is the first step in ML and image processing applications. This step involves the extraction of the most informative pixel from the video frame. In literature, various algorithms are present that can efficiently detect the moving object from a video frame [5–31]. This is a pivotal and initial step which is applied by several researchers for motion detection, unauthorized or illegal activities, traffic monitoring, medical imaging, industries, defense, and indoor–outdoor security aspects as shown in Figure 1.10. Figure 1.12 presents object detection and tracking using the BGS technique. This technology is often combined with IoT to detect multiple objects in a single frame such as a car, a person, or an animal.

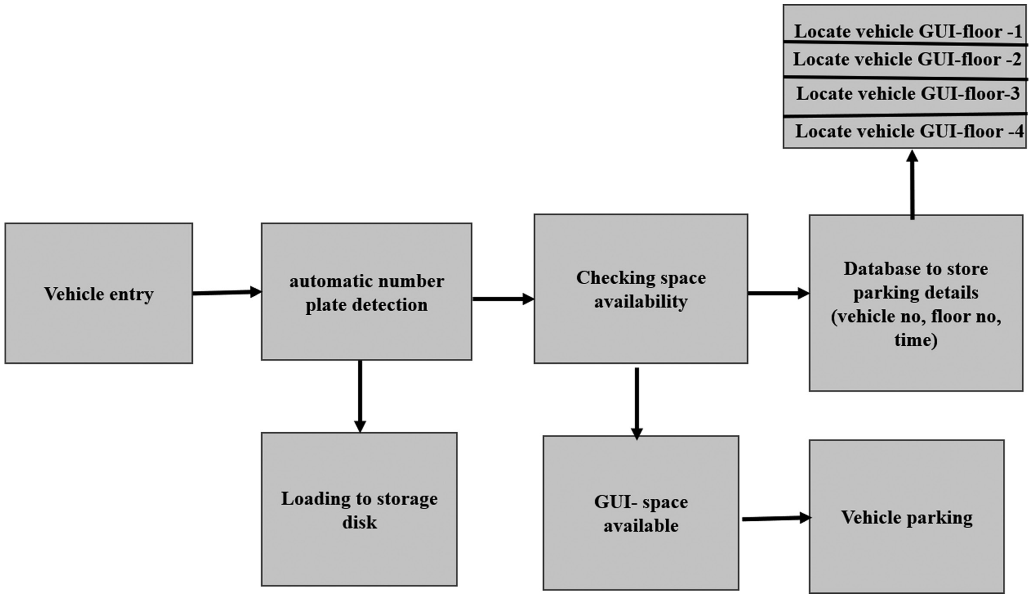

FIGURE 1.11
AI-powered CV technology for smart parking.

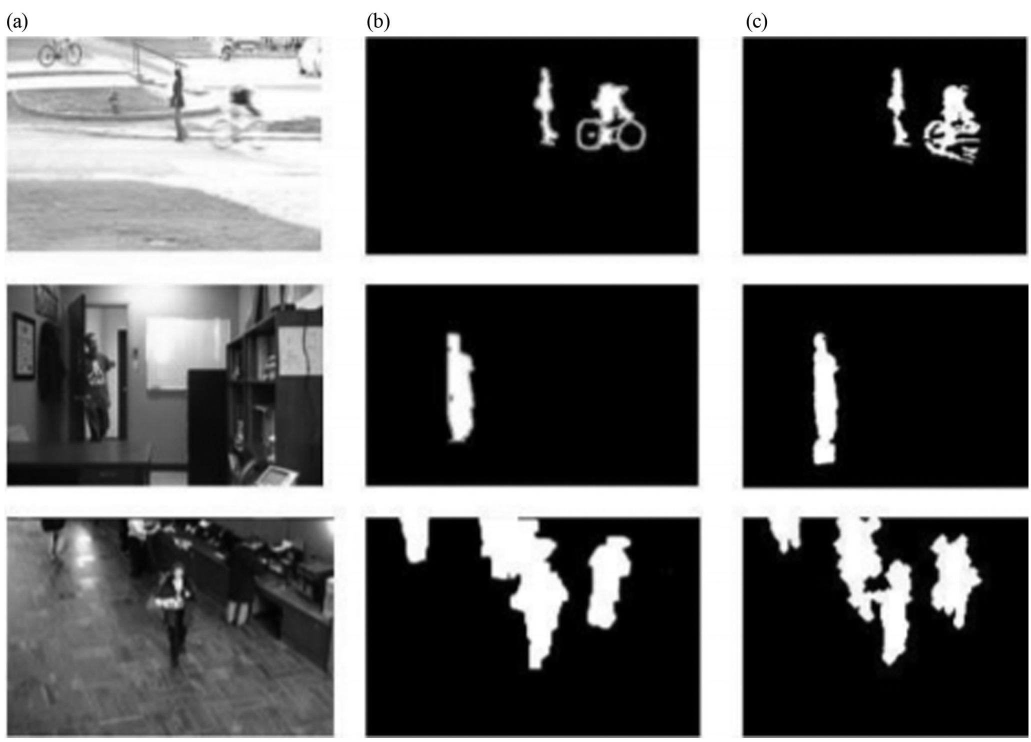

FIGURE 1.12
Detection of a motion-based object in indoor and outdoor sequence (row wise): (a) original image, (b) ground truth, and (c) desired output.

1.7 Conclusion

This chapter gives an overview of CV and its different kinds of techniques such as image segmentation, facial and pattern recognition, object detection & tracking, edge detection, and feature matching. This chapter also provides details of an evolution of CV and IoT, enhancement of IoT using CV and 5G technology, various challenging issues, and real-time applications such as automated cars, early diagnosis and detection of illness in the healthcare system, object detection (cars, animals, and humans) and tracking using BGS technique, drone technology in smart farming, satellite imaging in agriculture, facial recognition smart parking, and forest information.

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