Chapter - 6

Computer Vision for Green Technology and Sustainability

Unit

1

Introduction to Computer Vision

DISCLAIMER

The content is curated from online/offline resources and used for educational purpose only.

Learning Objectives

- Understand the fundamental concepts of computer vision and its importance in AI.
- Explore applications of computer vision within green technology and sustainability.
- Gain familiarity with essential tools and libraries, specifically OpenCV.
- Familiarize with image and image processions basics
- Learn core image analysis techniques:
    - Image Classification: Categorizing images into predefined classes.
    - Object Detection: Identifying and locating objects within an image.
    - Image Segmentation: Dividing an image into segments for detailed analysis.
    - Feature Extraction: Recognizing and extracting significant visual elements from images.
- Develop foundational knowledge to apply computer vision techniques in sustainability-focused contexts.

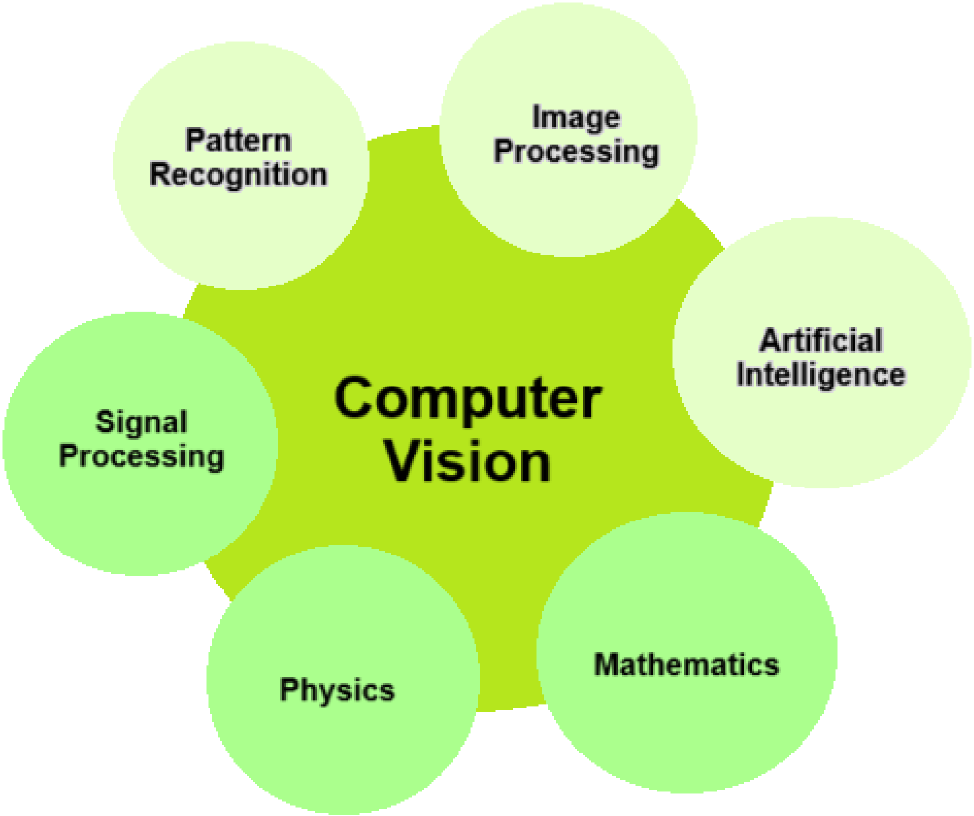
Source : www.freepik.com/

What is Computer Vision?

- Computer vision is a cross-disciplinary field within artificial intelligence wherein computers are enabled to interpret or understand visual information from the world, much like humans do.
- It empowers computers to process and analyze images and videos for automation and decision-making.
- Role in Sustainability:
    - Monitors environmental conditions,
    - Optimizes resources,
    - Supports sustainability initiatives.

Functionality of Computer Vision

- Extracts useful insights from digital images/videos.
- It combines principles from computer science, engineering, cognitive science.
- Mainly focused on task automation in Object recognition, scene understanding, motion detection.
- Applications:
  - Health,
  - Security,
  - Automotive,
  - Entertainment.



Source : https://towardsdatascience.com/understanding-semantic-segmentation-with-unet-6be4f42d4b47

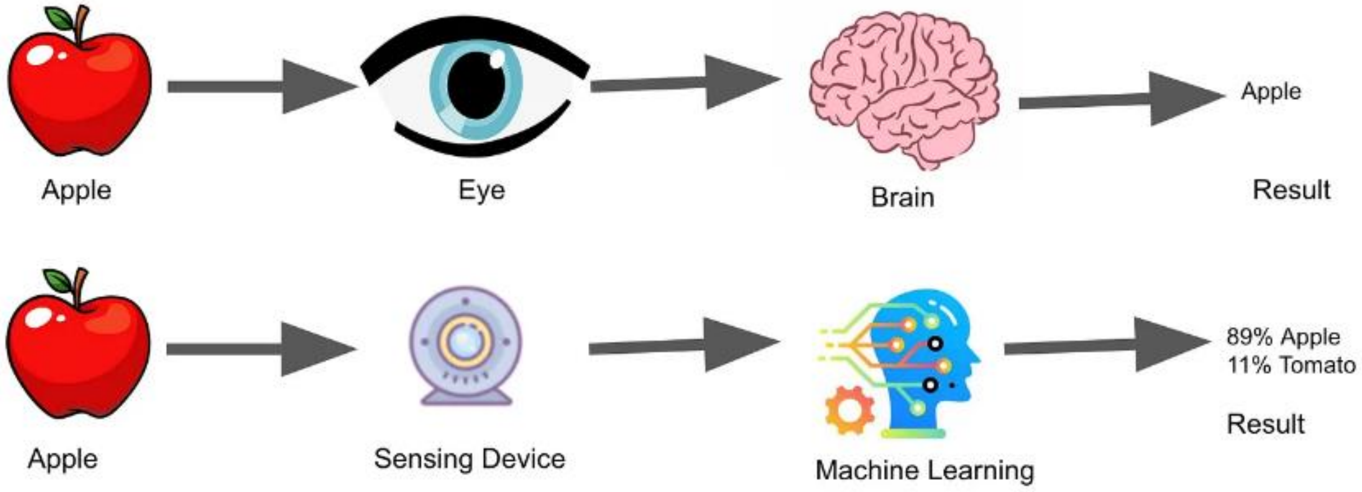
Deep Learning and Semantic Segmentation- Boost the Computer Vision

- Advances in Deep Learning Impact on computer vision and boosted performance and its applications.
- Semantic Segmentation: Classifies each pixel in an image by category.
- Application Areas: Medical imagery, navigation, autonomous vehicles.

Source : https://nanonets.com/blog/how-to-do-semantic-segmentation-using-deep-learning/

Computer Vision vs. Human Vision

Human Vision	Computer Vision
Relies on eyes, brain, and cognitive context; adaptable and nuanced.	Uses cameras, sensors, algorithms; excels in high-speed, large-scale data analysis.
Strengths: Contextual adaptability	Strengths: Consistency and endurance, e.g., wildlife monitoring.



Source : https://medium.com/@dy.dylanyang/computer-vision-and-autonomous-vehicles-503df394bd73

Basic Operations in Computer Vision

Image Classification	Object Detection	Object Tracking	Semantic Segmentation
• Assigns a category label to images • Eg.: facial recognition, content moderation	• Identifies and locates items within images • Eg.: pedestrians in self-driving cars	• Tracks movement across video frames • Eg.: surveillance, sports analytics).	• Assigns class labels to pixels for detailed image analysis • Eg.: street scene distinctions).

Source :

Applications of Computer Vision in Green Technology and Sustainability

1. Agriculture Operations & Environmental Impact Reduction

- Computer vision is transforming agriculture by making it more efficient, precise, and sustainable.
- Enhances productivity while minimizing environmental impact.

Applications:

- Crop Monitoring by Drones: Detects plant health, nutrient deficiencies, and soil conditions.
- Disease Detection: Early intervention to reduce crop loss and chemical usage.
- Harvest Automation: Identifies ripe produce, reducing labor costs and waste.
- Livestock Monitoring: Tracks animal health, enhancing productivity and biosecurity.
- Soil Health Analysis: Assesses nutrient and moisture content for optimized crop growth.

Source : https://easyflow.tech/computer-vision-in-agriculture/

Applications of Computer Vision in Green Technology and Sustainability

2. Wildlife Monitoring and Protection

- Computer vision helps in wildlife monitoring and protection, which enhance conservation efforts and improve safety and efficiency for conservationists.

Computer Vision Solutions:

- Camera Traps: Tracks wildlife, detects poaching, monitors population dynamics.
- Case Study: Kaziranga National Park – Tiger tracking with motion-sensitive cameras.
- Satellite Imaging: Tracks migrations and habitat changes with high-resolution data.

Source : https://viso.ai/applications/computer-vision-in-environmental-conservation-applications/

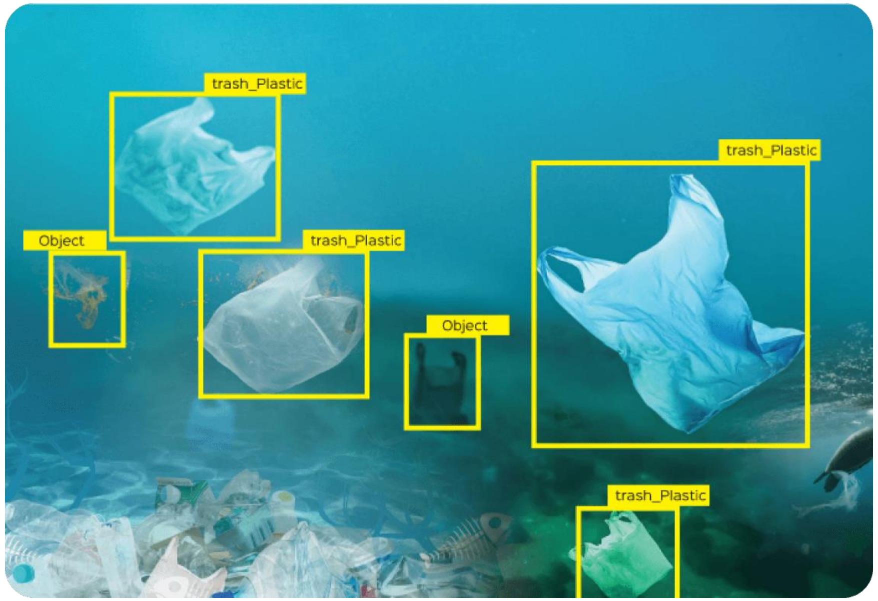
Applications of Computer Vision in Green Technology and Sustainability

3. Ocean and Marine Life Conservation

- Conservation in marine environments is complex and poses unique challenges due to the vast and often inaccessible nature of the oceans.

Computer Vision Solutions:

- Remotely Operated Vehicles (ROVs): Underwater monitoring of species and ecosystems.
- Marine-Specific AI Models: Ocean Vision AI by MBARI uses deep-learning for marine research.
- Fish Counting with AI: Automates stock assessments, supporting sustainable fisheries.



Source : https://www.ultralytics.com/blog/ai-in-the-maritime-industry-and-conservation-efforts

Applications of Computer Vision in Green Technology and Sustainability

4. Monitoring Forest Coverage

- Computer vision and satellite data helps for tracking changes in forest coverage, helping conservationists and governments respond to threats more proactively.

Applications:

- Threat Detection: Monitors illegal logging, disease, and grazing impacts.
- Case Studies:
- ISRO Forest Mapping: Detects illegal logging, assesses ecosystem health.
- Green India Mission: Tracks forest growth and health with satellite data.

Source : https://viso.ai/applications/computer-vision-applications-for-sustainable-forestry-solutions/

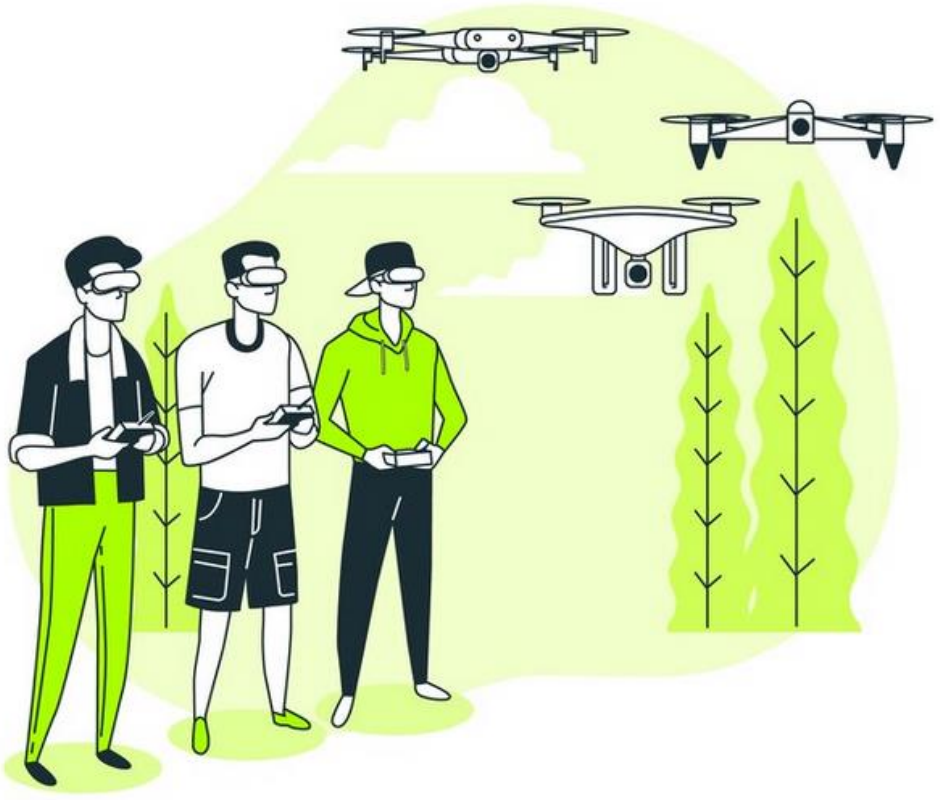
Applications of Computer Vision in Green Technology and Sustainability

5. Pollution Detection and Control

- Importance: Mitigates adverse health and environmental impacts from pollution.

Computer Vision Solutions:

- Heatmaps & Drones: Identify pollution hotspots with computer vision.
- Detection Models: YOLO, Faster R-CNN, and EfficientNet for high-precision pollutant tracking.
- Case Study: Coastal monitoring in India to detect illegal discharges in port waters.



Source : www.freepik.com

Tools for Computer Vision

- Here are some of the popular tools for computer vision applications

Tools:

- OpenCV - Real-Time Computer Vision Library
- Viso Suite - Enterprise Vision Platform
- TensorFlow - Deep Learning & Computer Vision
- CUDA - NVIDIA’s Parallel Computing Platform
- MATLAB - Engineering & Research Platform
- Keras - Python Deep Learning API

Source : https://en.wikipedia.org/wiki/

OpenCV - Real-Time Computer Vision Library

- Created by Intel in 1999, now maintained by the OpenCV Foundation
- Primarily developed for real-time computer vision and image processing
- Applications: Facial recognition, object detection, motion tracking, augmented reality, and mobile robotics

Key Features of OpenCV:

- Extensive Algorithm Library
- Multi-Language Support
- Cross-Platform Compatibility
- Optimized for Real-Time Processing

Source : https://en.wikipedia.org/wiki/

Installing OpenCV on Windows (Using pip)

The following are the steps to install OpenCV using pip

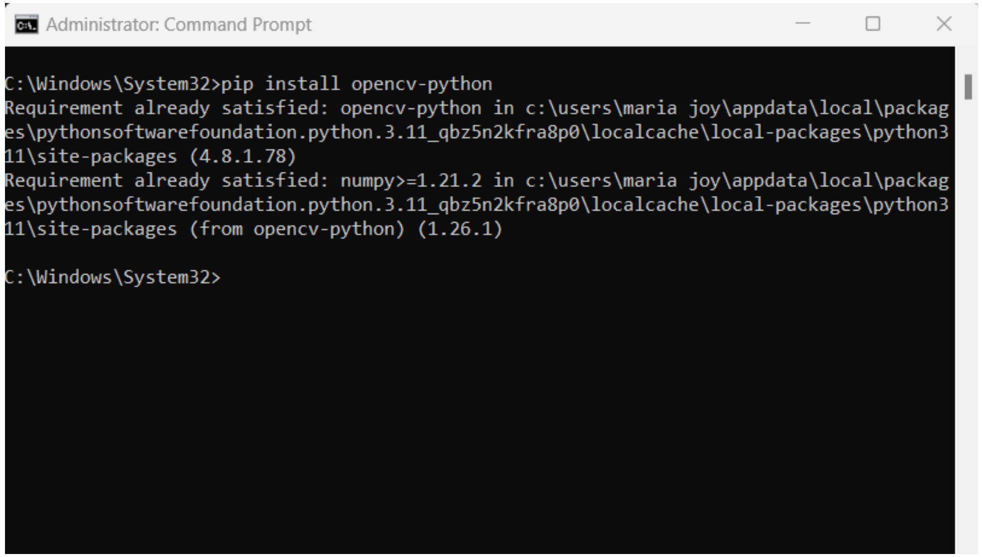
1. Check Python and pip:
   python --version
   pip --version

2. Open Command Prompt

3. Update pip
   pip install --upgrade pip

4. Install OpenCV:
   Basic installation:pip install opencv-python
   With additional features:pip install opencv-contrib-python

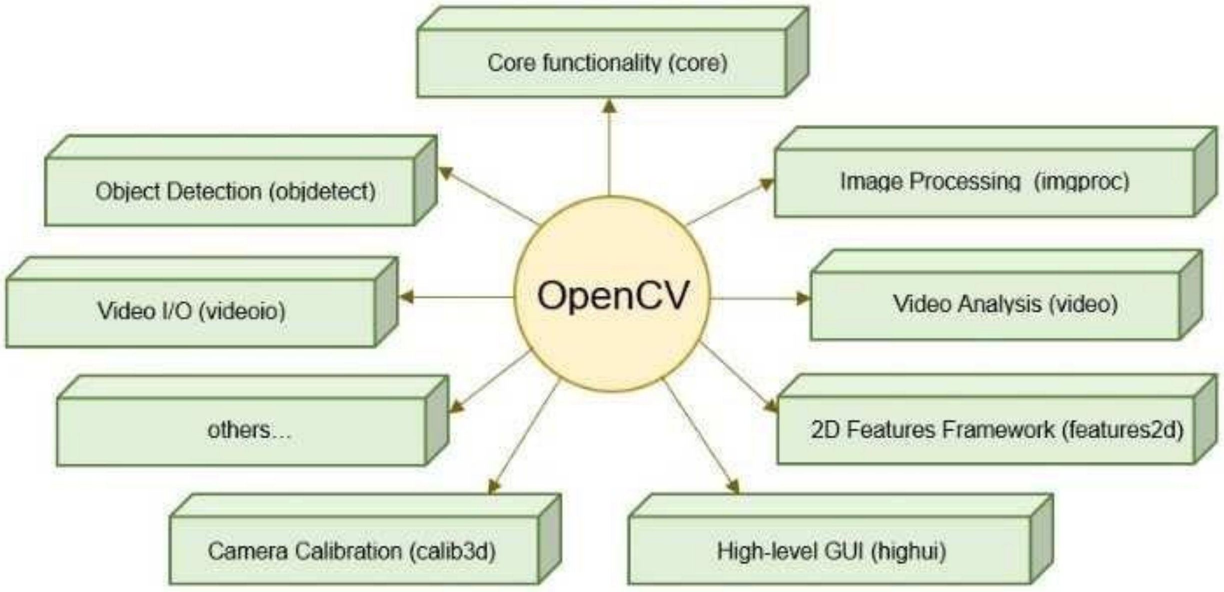
5. Verify Installation:
   import cv2
   print(cv2.__version__)



Source :

Modules in OpenCV library

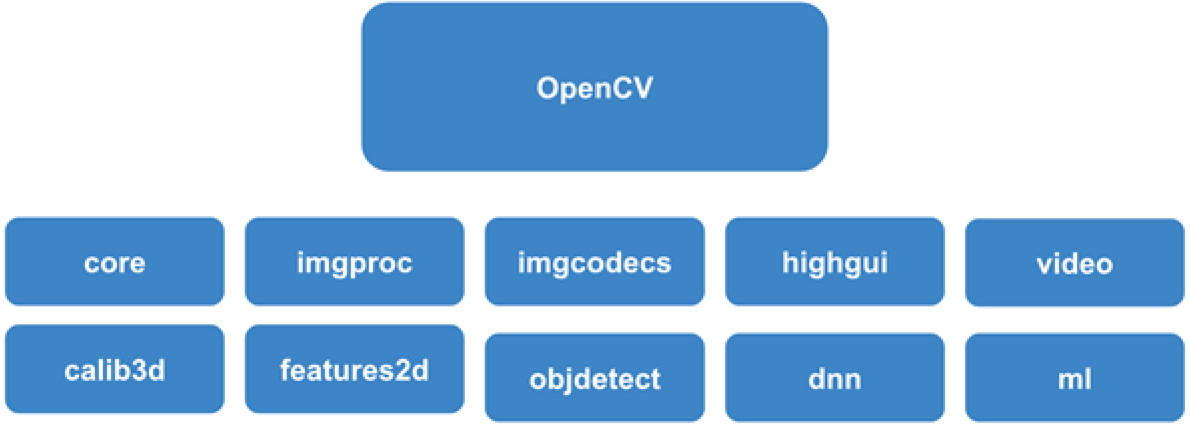
1. Core (core): Basic data structures and mathematical operations
2. Image Processing (imgproc): Filtering, color conversions, transformations
3. Video I/O (videoio): Video input/output from files, cameras, streams
4. Image I/O (imgcodecs): Reads/writes images in formats like JPG, PNG
5. High-Level GUI (highgui): Basic GUI functions for images and videos



Source : https://www.researchgate.net/figure/Modular-structure-of-OpenCV_fig2_361594451

Advanced Modules in OpenCV library

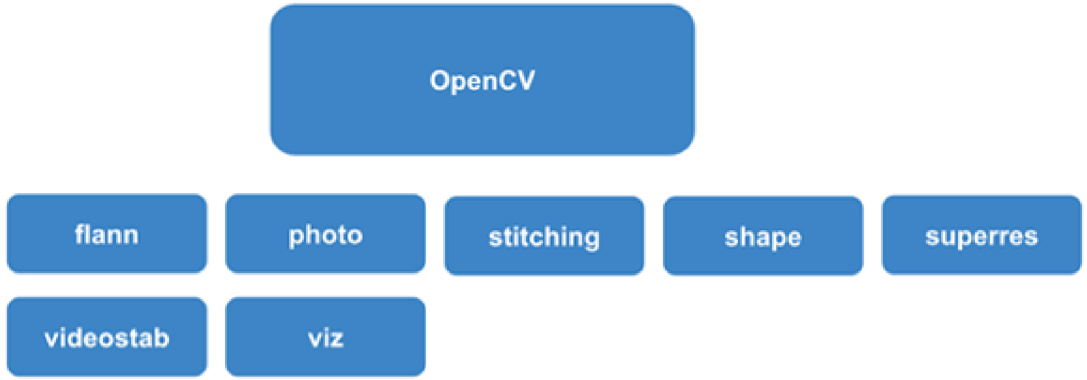
1. Video Analysis (video): Motion analysis, background subtraction, optical flow
2. Object Detection (objdetect): Algorithms for face, eye, body detection
3. Features2D (features2d): Feature detection and tracking (e.g., SIFT, SURF)
4. Machine Learning (ml): Classification, regression, clustering algorithms
5. Deep Neural Network (dnn): Loads models trained in TensorFlow, Caffe, etc.



Source : https://saineshnakra.medium.com/demystifying-cv-the-ultimate-guide-to-choosing-the-right-module-and-library-for-any-computer-86d35ac9fa8a

Specialized Modules in OpenCV library

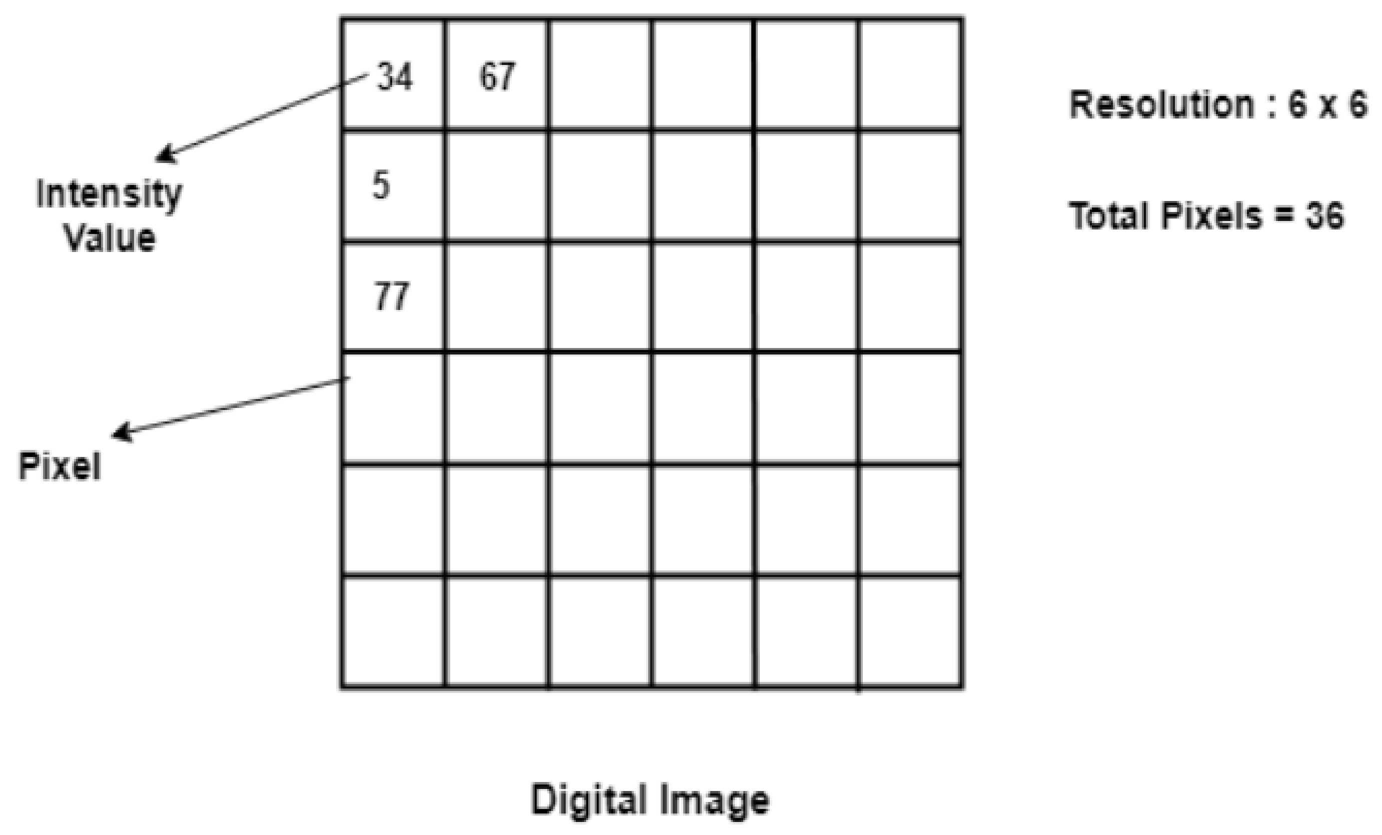
1. Photo Processing (photo): Image denoising, inpainting, color correction
2. 3D Reconstruction (calib3d): Camera calibration, stereo vision, 3D depth
3. Shape Analysis (shape): Shape descriptors, contour matching
4. Optical Flow (optflow): Motion estimation, video stabilization
5. Tracking (tracking): Object tracking across frames
6. Stitching (stitching): Image stitching, panorama creation



Source : https://saineshnakra.medium.com/demystifying-cv-the-ultimate-guide-to-choosing-the-right-module-and-library-for-any-computer-86d35ac9fa8a

What is a Digital Image?

- A digital image is like a picture made of tiny dots called pixels.
- These pixels are arranged in rows and columns, similar to tiles on a floor.
- Each pixel has a number that shows how bright or dark it is, helping to create the image we see.



Source : https://theailearner.com/2018/10/06/what-is-a-digital-image/

What is an Image Processing?

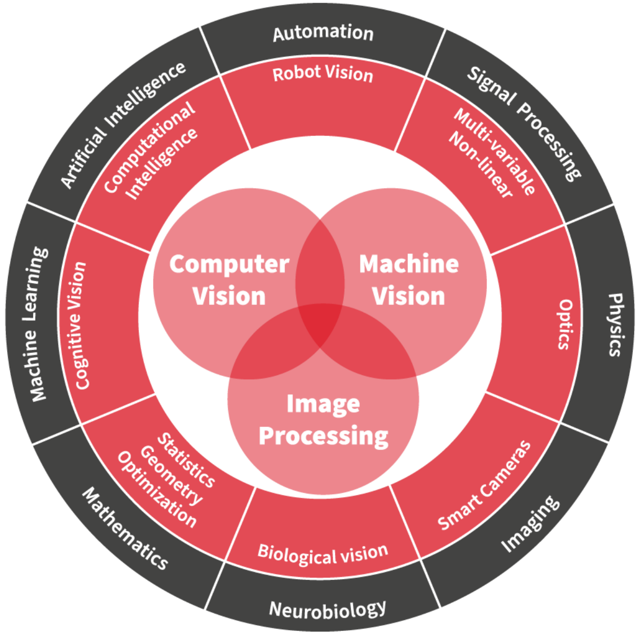
- In digital techniques, the manipulation and analysis of images to enhance or gather meaningful information regarding them are usually referred to as image processing.

- This is mainly used to enhance, modify, or analyze visual information.

Source : www.flaticon.com

Computer vision Vs Image Processing Vs Machine vision

Aspect	Computer Vision	Image Processing	Machine Vision
Goal	Understand and interpret visual data	Enhance and transform image quality	Automate inspection in industrial settings
Main Use	Recognition, classification, analysis	Improvement, correction, transformation	Quality control, automated analysis
Techniques	Deep learning, machine learning	Filtering, transformations	Image processing + industrial hardware
Examples	Self-driving cars, facial recognition	Noise reduction, edge detection	Defect detection, barcode reading

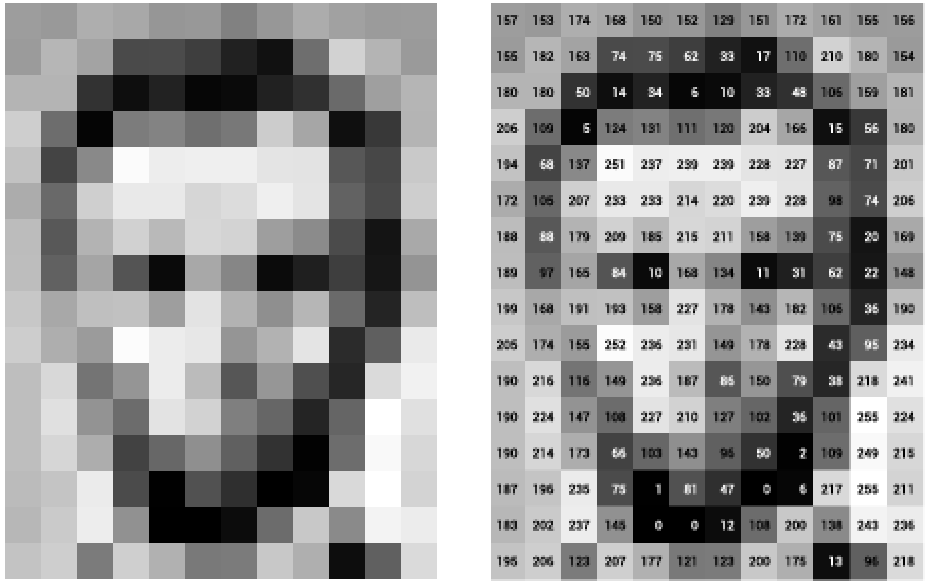


Source : https://www.industrialvision.co.uk/news/machine-vision-vs-computer-vision-vs-image-processing

Key Concept of Image Processing

Pixel

- A pixel is the smallest unit of a digital image or display.
- Each pixel represents a single point of color or intensity in an image.



157	153	174	168	150	152	129	151	172	161	155	156
155	182	163	74	75	62	33	17	110	210	180	154
180	180	50	14	34	6	10	33	48	106	159	181
206	109	5	124	131	111	120	204	166	15	56	180
194	68	137	251	237	239	239	228	227	87	71	201
172	105	207	233	233	214	220	239	228	98	74	206
188	88	179	209	185	215	211	158	139	75	20	169
189	97	165	84	10	168	134	11	31	62	22	148
199	168	191	193	158	227	178	143	182	106	36	190
205	174	155	252	236	231	149	178	228	43	95	234
190	216	116	149	236	187	86	150	79	38	218	241
190	224	147	108	227	210	127	102	36	101	255	224
190	214	173	66	103	143	96	50	2	109	249	215
187	196	235	75	1	81	47	0	6	217	255	211
183	202	237	145	0	0	12	108	200	138	243	236
195	206	123	207	177	121	123	200	175	13	96	218

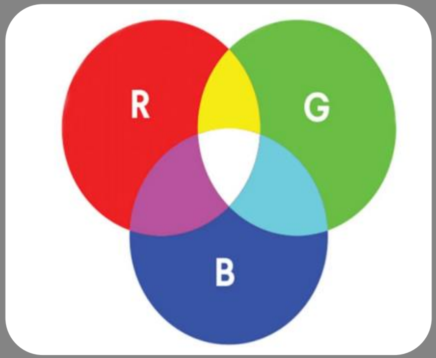
Source : https://assets.runemadsen.com/classes/programming-design-systems/pixels/index.html

Key Concept of Image Processing

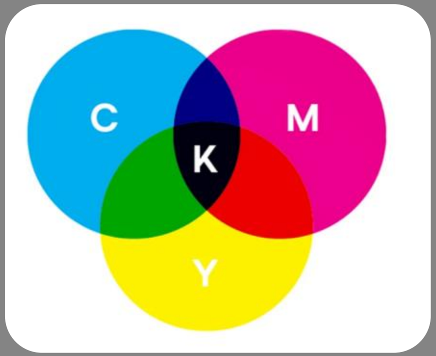
Color Models

- Frameworks for representing colors in images

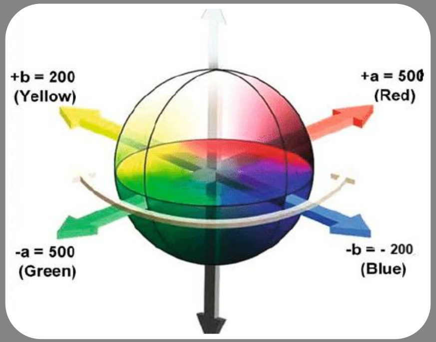
Types



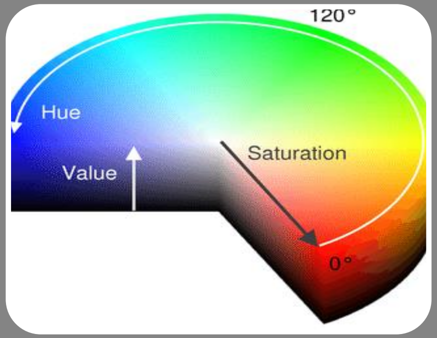
RGB (Red-Green-Blue)



CMY(K) (Cyan-Magenta-Yellow-Key/Black)



LAB Lightness-A-B



HSV (Hue-Saturation-Value)

Source : https://www.vistaprint.com/hub/correct-file-formats-rgb-and-cmyk
https://www.luxury-minds.com/what-is-lab-color-space-and-what-should-you-know-about-it-print-peppermint
https://www.researchgate.net/figure/Conceptual-depiction-of-the-Hue-Saturation-Value-HSV-space-at-the-heart-of-our-first_fig2_340001129

Key Concept of Image Processing

Image Types

Images are classified according to the number of values a pixel can take

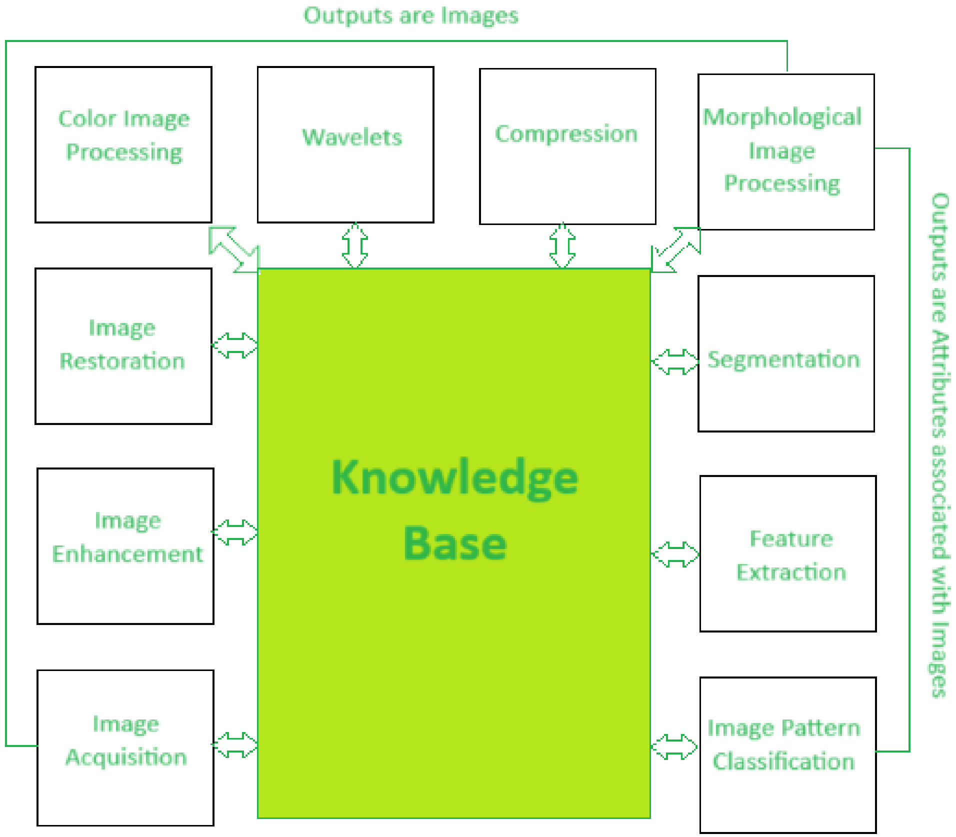
- Color Images
- Grayscale Images
- Binary Images

(a) RGB image (b) Gray Scale image (c) Binary image

Source : https://www.researchgate.net/figure/Figure2-a-RGB-image-b-Gray-Scale-image-c-Binary-image_fig2_344249310

Core Components in Image Processing

1. Image Acquisition
2. Image Enhancement
3. Image Restoration
4. Color Image Processing
5. Wavelets
6. Compression
7. Morphological Image Processing
8. Segmentation
9. Feature Extraction
10. Image Pattern Classification



Source : https://www.geeksforgeeks.org/fundamental-steps-in-digital-image-processing/?ref=ml_lbp

What is Image Classification ?

- Image classification is a task in computer vision where a model is trained to categorize images into specific labels based on their visual content.

- Example- Given images of various animals, the model can learn to classify each as a dog, cat, or bird.

Importance of Image Classification

- Enables computers to understand and categorize visual data, which can enhance decision-making, automate tagging, and improve safety.
- Real-World Impact: Helps in sustainable solutions, such as monitoring wildlife, improving healthcare diagnostics, and optimizing resources in agriculture.

How Does Image Classification Work?

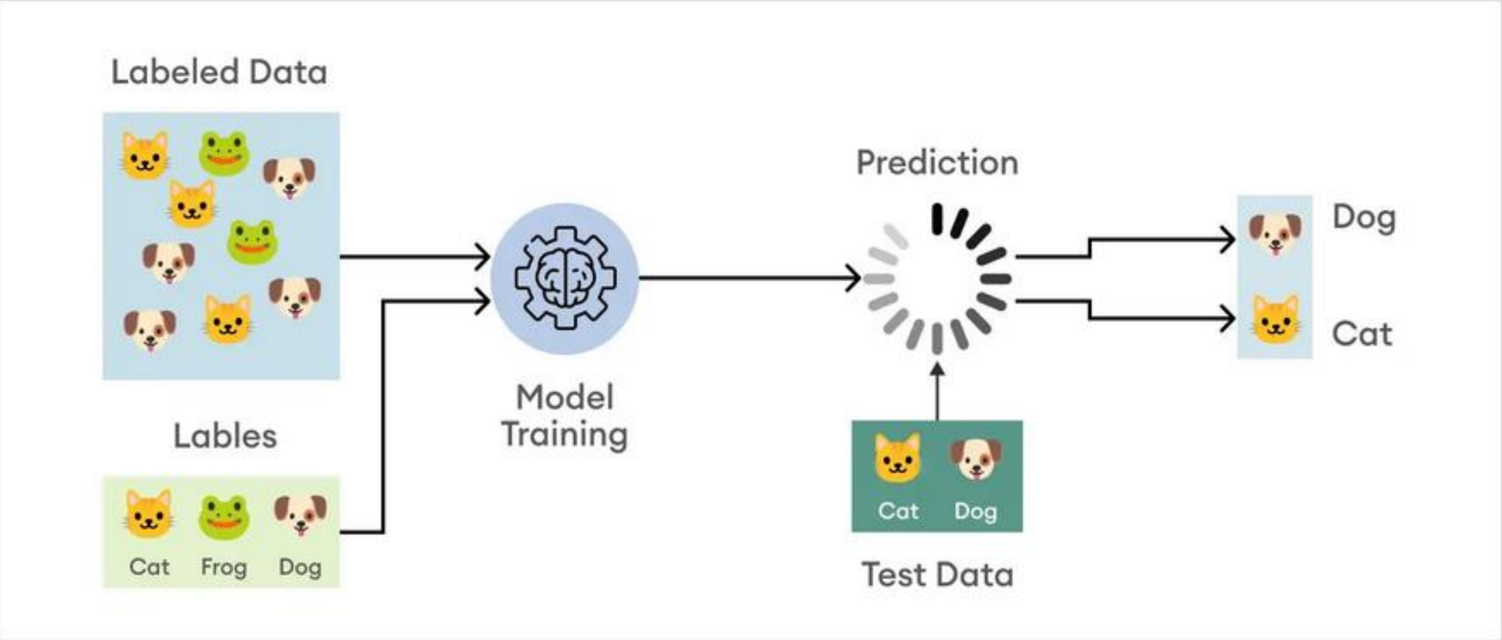
Process Overview:

Step 1: Data Collection: Gather a labeled dataset with images assigned to categories (e.g., animals, vehicles).

Step 2: Training the Model: The model learns patterns within labeled images using supervised machine learning.

Step 3: Feature Extraction: Identifies features like colors, textures, shapes, and edges.

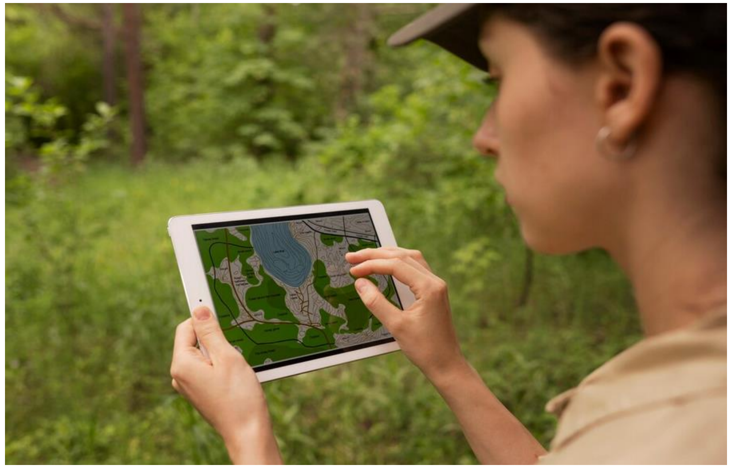
Step 4: Classification: Assigns labels to new, unseen images based on learned features.



Source : https://www.superannotate.com/blog/image-classification-basics

Examples of Image Classification in Green Technology

- **Waste Sorting for Recycling :** Recycle materials like plastic, paper, and metal, which helps reduce waste
- **Ecosystem Monitoring:** Computers can look at these pictures and classify what they see, like identifying different plants, animals, or even pollution in the water.
- **Smart Farming for Healthier Crops:** The computer can classify the plants into categories like "healthy" or "needs help."



Source : www.freepik.com

What is Object Detection?

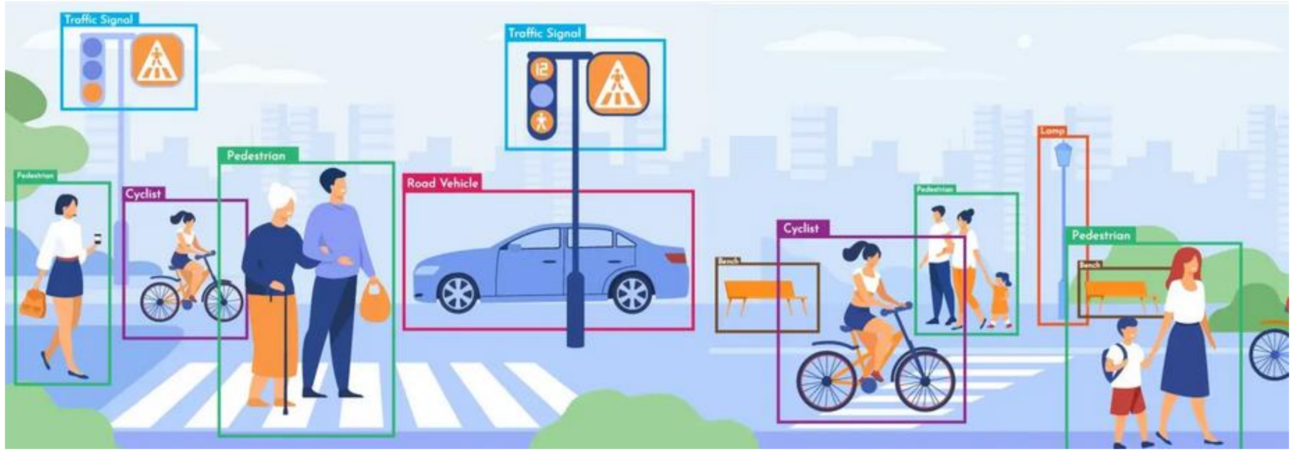
- Object detection allows computers to recognize and locate objects within an image.

Key Components of Object Detection

- Recognition: It detects objects, such as animal, cars, trees, people, and others
- Localization: It identifies location of where the object is situated in the image.

How Object Detection Works

- Step 1: The computer scans the image.
- Step 2: It identifies the objects within the image.
- Step 3: It locates the position of each object.
- Step 4: Outputs the object's label and location.



Source : https://futuristech.com.au/services/computer-vision/object-detection/

Applications of Object Detection in Real Life

Object detection has a wide range of applications in real life

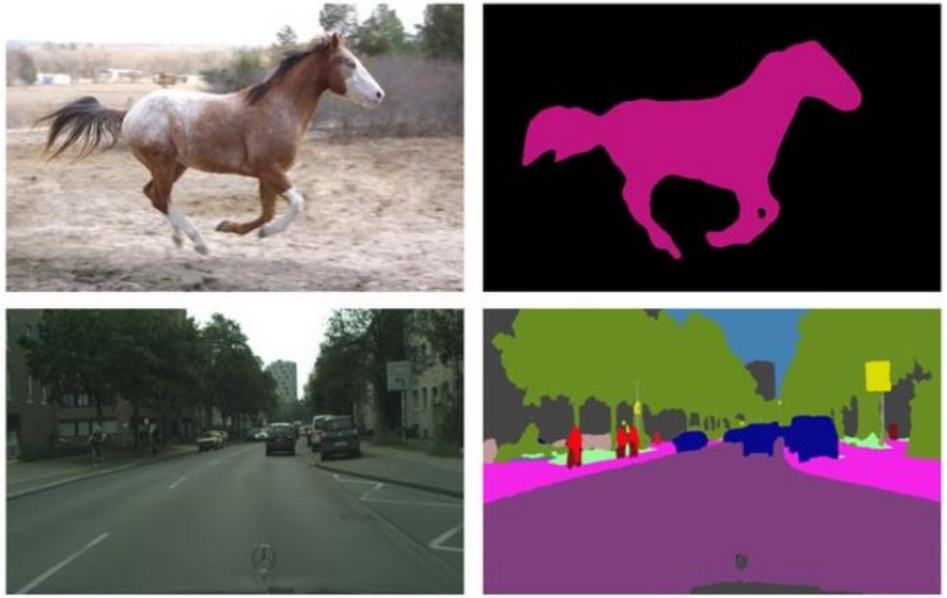
- Wildlife Monitoring: Drones capture images of forests to detect animals.
- Self-Driving Cars: Self-driving cars identify other cars, pedestrians, and road signs.
- Medical Imaging: Detects anomalies like tumors, fractures, or infections in medical images
- Security and Surveillance: Detects intruders, weapons, or unusual movements in video surveillance feeds.
- Retail and Inventory Management: Tracks products on shelves in real-time and manages stock levels.
- Augmented Reality (AR): AR apps detect physical objects and allow users to visualize them in real-world settings.
- Manufacturing and Quality Control: Inspects products for defects, misalignments, or missing parts on production lines.
- Traffic Management and Law Enforcement: Detects vehicles, red-light violations, and tracks license plates for speed enforcement.
- Disaster Response and Rescue Missions: Drones locate survivors or people in danger after natural disasters.

What is Image Segmentation?

- In image segmentation, it divides an image into smaller, meaningful parts called segments.

Why is Image Segmentation Important?

- Each segment represents a different object or area, making it easier for the computer to understand the image.
- Helps computers focus on individual parts of an image to understand what is happening in the picture.
- Increases accuracy and precision in tasks like object recognition, medical imaging, and autonomous driving.



Source : https://www.researchgate.net/publication/337771814_Waterfall_Atrous_Spatial_Pooling_Architecture_for_Efficient_Semantic_Segmentation

Types of Image Segmentation

Semantic Segmentation:

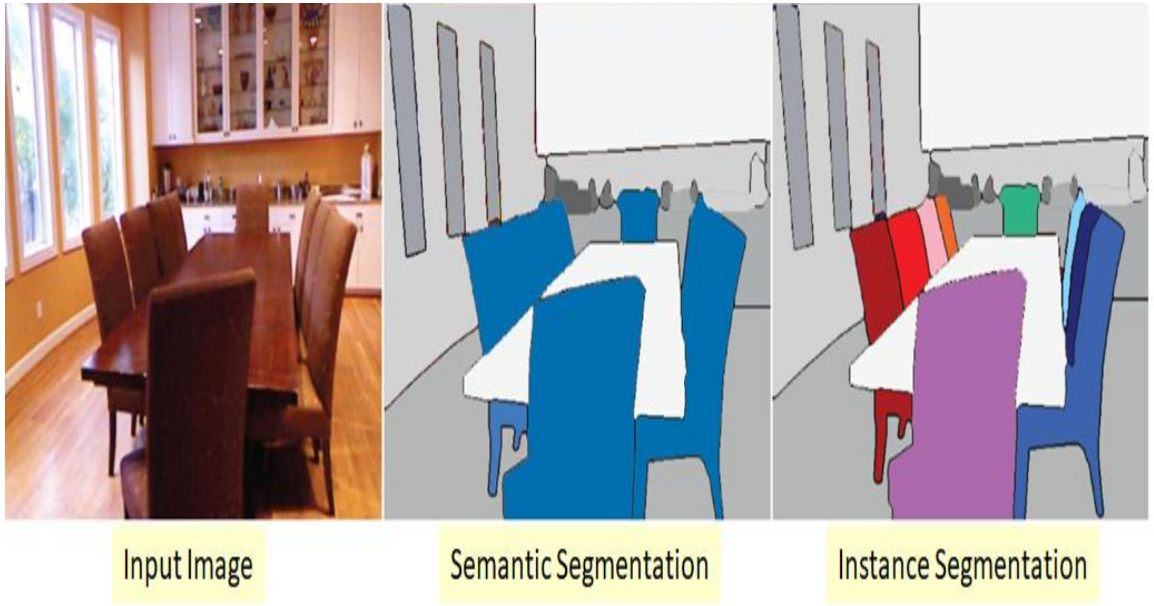
Assigns each pixel to a class.

No differentiation between instances of the same class.

Instance Segmentation:

Identifies and labels each individual object in an image.

Differentiates between instances of the same class



Source : https://blog.roboflow.com/difference-semantic-segmentation-instance-segmentation/

Segmentation Techniques

- Deep Learning Models: Convolutional Neural Networks (CNNs) are often used for segmentation tasks.

Popular Architectures:

- U-Net: Specialized for medical imaging and precise segmentation.
- Mask R-CNN: Performs instance segmentation, distinguishing objects within the same class.
- Fully Convolutional Networks (FCNs): Used for pixel-wise segmentation tasks.

Importance of Image Segmentation in Green Technology and Sustainability

Resource-Efficient Agriculture	• Analyzes crop and prevents waste and reduces environmental damage
Environmental Monitoring and Conservation	• Serves in the conservation and monitoring of sustainable ecosystem health
Energy Efficiency in Smart Cities	• Used to examine land use, energy use, and traffic flow within smart cities
Waste Management and Recycling	• Automatic sorting of recyclables, such as plastics, metals, and organics
Climate Research and Disaster Response	• Identify changes in climate and the development of storms

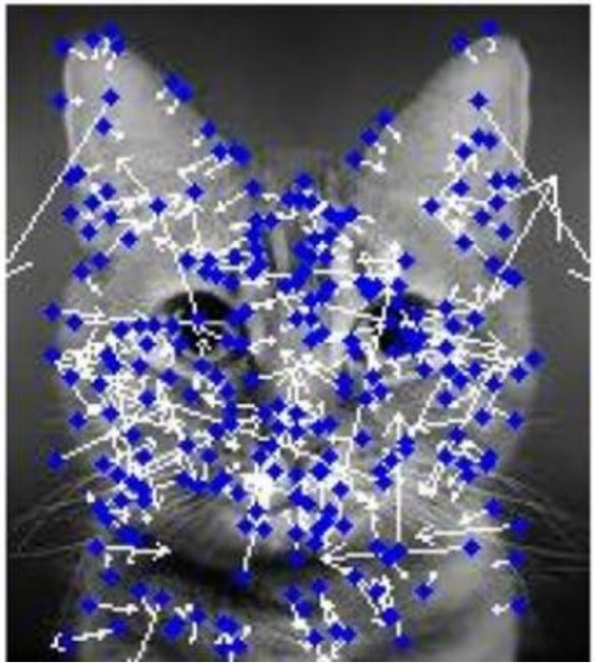
Source :

What is Feature Extraction?

- Identifying key visual elements within an image.

Examples of features:

- Edges: Boundaries within objects.
- Textures: Patterns or smoothness of surfaces.
- Shapes: Geometric structures.
- Colors and Spatial Patterns: Color distributions and arrangements.



Source : https://www.researchgate.net/publication/264273290_Bilateral_Symmetry_Detection_on_the_Basis_of_Scale_Invariant_Feature_Transform/figures?lo=1

Importance of Feature Extraction in Green Technology and Sustainability

Precision Agriculture and Resource Management	• Extracts the features of soil texture, leaf color, crop patterns.
Renewable Energy Optimization	• Provide weather conditions, terrain characteristics, and environmental indices.
Wildlife and Biodiversity Monitoring	• Identify plant and animal species, forest types, and the health of vegetation.
Smart Waste Management	• Automated sorting of different types of material
Disaster Risk Assessment and Climate Monitoring	• Analyzes features in coastal areas, flood plains, etc., for risk forecasting

Lab Activity

Hands On

Lab 1

[Forest Fire Detection Using Satellite Imagery]

Lab Activity

Hands On

Lab 2

Waste Sorting Using Computer Vision

Conclusion

- Computer vision stands out as the most ultimate and transformative machine tool in interpreting the human visual world.
- The applications are in green technology and sustainability to change for better- from monitoring the ecosystem to optimizing resources.
- Few of the widely used very general tools include OpenCV, modules and basic tasks
- Image classification, object detection, segmentation, and feature extraction techniques with some examples.
- Such capabilities can be used towards developing innovations that support two important ideas: technology innovation and sustainability.

Source : www.freepik.com/

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Q&A
Let’s Start

Quiz

1. **Computer vision primarily involves which of the following tasks?**

(a) Developing 3D computer graphics

(b) Creating efficient database storage systems

(c) Analyzing and interpreting visual data from images or videos

(d) Performing text-based language translation

Answer: C

Analyzing and interpreting visual data from images or videos

Quiz

2. Which of the following is an example of how computer vision can aid in green technology?

(a) Automatic crop monitoring to improve agricultural efficiency

(b) Voice recognition for AI assistants

(c) Data compression algorithms for faster processing

(d) Creating video games with realistic graphics

Answer: A

Automatic crop monitoring to improve agricultural efficiency

Quiz

3. Which of the following statements about OpenCV is true?

(a) OpenCV is primarily a data processing library for financial transactions.

(b) OpenCV is an open-source library focused on image processing and computer vision tasks.

(c) OpenCV was developed to primarily support machine learning-based data analysis.

(d) OpenCV is a closed-source, commercial software for video analysis only.

Answer: B

OpenCV is an open-source library focused on image processing and computer vision tasks.

Quiz

4. Which of the following functions is used in OpenCV to read an image?

(a) cv2.imshow()

(b) cv2.imread()

(c) cv2.detect()

(d) cv2.segment()

Answer: B

cv2.imread()

Quiz

5. What is the primary goal of image segmentation?

(a) To classify the entire image into a single label

(b) To divide the image into meaningful regions or segments

(c) To enhance the color quality of an image

(d) To reduce the resolution of an image

Answer: B

To divide the image into meaningful regions or segments

Thank You