Image Processing Theory

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"One picture is worth more than ten thousand words" – Explain the fields of image processing used in the statement.

"একটি ছবি দশ হাজার শব্দের চেয়েও বেশি মূল্যবান"

This saying means that a single image can convey a lot of information, often more effectively than words. Image processing plays a crucial role in various fields, including:

এই উক্তির মাধ্যমে বোঝানো হয় যে একটি ছবি অনেক তথ্য বহন করতে পারে, যা ব্যাখ্যা করতে অনেক শব্দের প্রয়োজন হয়। ইমেজ প্রসেসিং বিভিন্ন ক্ষেত্রে গুরুত্বপূর্ণ ভূমিকা পালন করে.

1. Medical Imaging

Doctors use X-rays, MRIs, and CT scans to diagnose diseases. A single image can provide detailed medical insights. এক্স-রে, এমআরআই বা সিটি স্ক্যানের মাধ্যমে ডাক্তাররা রোগ শনাক্ত করেন। একটি ছবিই রোগ সম্পর্কে বিস্তারিত তথ্য দিতে পারে।

2. Satellite Image Analysis

Satellites capture images to predict weather, monitor agriculture, and detect natural disasters like earthquakes and floods. আবহাওয়া পূর্বাভাস, কৃষি বিশ্লেষণ এবং ভূমিকম্প বা বন্যার তথ্য সংগ্রহে স্যাটেলাইট ইমেজ ব্যবহার করা হয়।

3. Facial Recognition

Face recognition technology is used to unlock phones, enhance security, and identify criminals. ফোন আনলক করা, নিরাপত্তা ব্যবস্থা বা অপরাধীদের শনাক্ত করতে মুখের ছবি বিশ্লেষণ করা হয়।

4. Manufacturing & Industry (Machine Vision)

Factories use machine vision to inspect products for defects, ensuring high-quality production.কারখানায় পণ্যের গুণগত মান পরীক্ষা করতে স্বয়ংক্রিয় মেশিন ছবি ব্যবহার করে ত্রুটি চিহ্নিত করে।

5. Self-Driving Cars & Robots

Autonomous vehicles use cameras and image processing to detect roads, signals, and pedestrians for safe driving. স্বয়ংক্রিয় গাড়ি রাস্তা, সিগন্যাল ও মানুষ শনাক্ত করতে ক্যামেরা ও ইমেজ প্রসেসিং ব্যবহার করে।

A single image can provide fast and accurate information. That's why image processing is essential in various real-world applications.

Image Processing

Image processing refers to the manipulation and analysis of visual information contained in images. It involves the use of algorithms and techniques to enhance, modify, or extract information from digital images.

ইমেজ প্রসেসিং হল ছবির মধ্যে থাকা ভিজুয়াল তথ্যের বিশ্লেষণ ও পরিবর্তনের একটি প্রক্রিয়া। এটি অ্যালগরিদম এবং প্রযুক্তির মাধ্যমে ডিজিটাল ছবির উন্নতি, পরিবর্তন বা তথ্য আহরণের কাজে ব্যবহৃত হয়।

Or

Image Processing: refers to techniques applied to images to enhance, analyze, or extract useful information. ইমেজ প্রসেসিং: ছবির গুণগত মান উন্নত করা, বিশ্লেষণ করা বা প্রয়োজনীয় তথ্য আহরণের জন্য প্রয়োগ করা প্রযুক্তিগুলোর সমষ্টি।

[8] Write down the areas of application of image processing.

Ans:

1. Industrial machine vision applications
   - (i) Process control
   - (ii) Parts identification.
   - (iii) Automated visual inspection.
   - (iv) Robotic guidance and control.

2. Security, surveillance and law enforcement.
   - (i) Varification of identity.
   - (ii) Monitoring and surveillance.
   - (iii) Forensic investigations.

3. Diagnostic medical imaging
   - (i) Medical image processing.
   - (ii) Medical image reconstruction.

4. Remote sensing
   (i) Meteorology.
   (ii) Natural resource location.
   (iii) Cartography.
5. Telecommunications
   (i) Video text
   (ii) Video conferencing
   (iii) Video calls.

Components of an Image Processing System

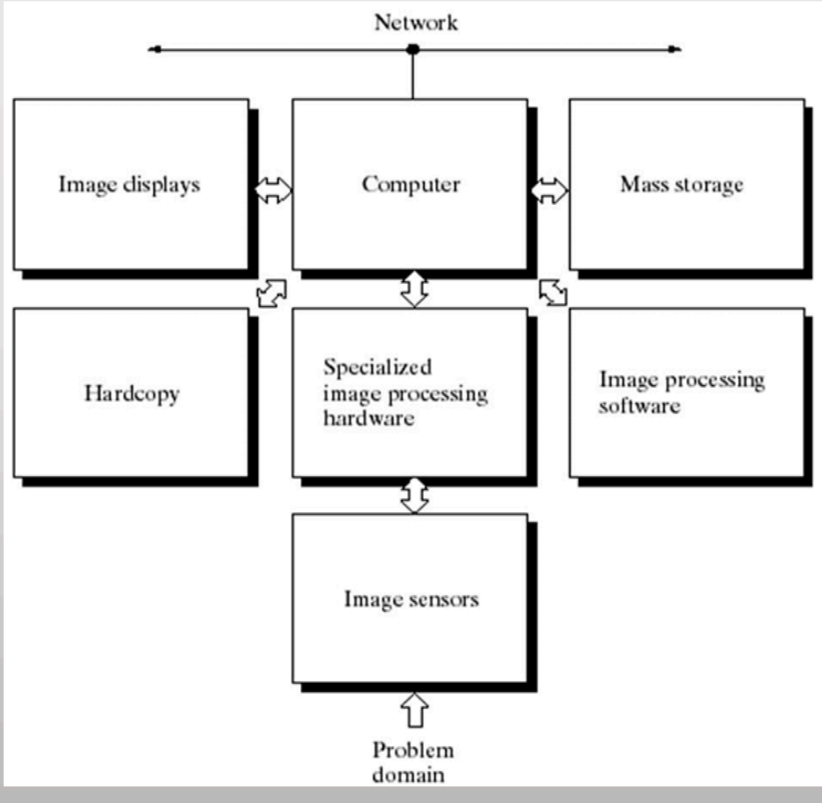


FIGURE 1.24 Components of a general-purpose image processing system.

6 What are the components of general purpose image processing systems.

Ans:
1. Image displays
2. computers
3. Mass storage
4. Hard copy
5. Specialized image processing hardware.
6. Image processing software.
7. Image sensors.

Digital Image Processing

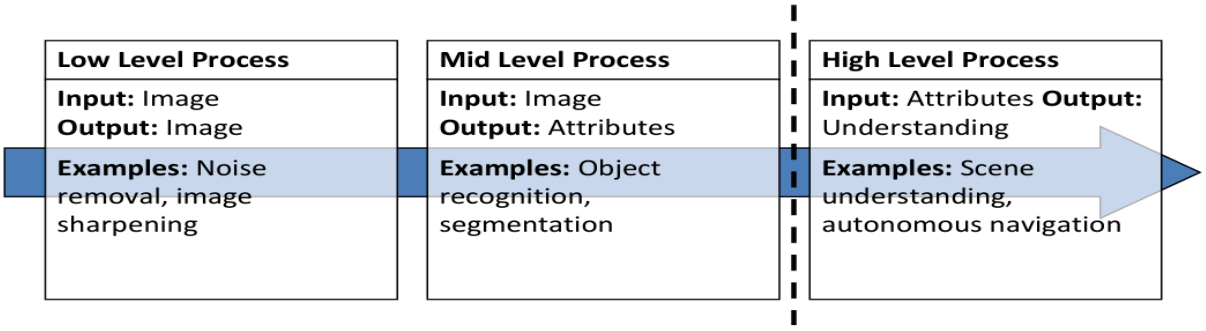
Digital Image Processing is the technique of using computers to manipulate, analyze, and enhance images.

ডিজিটাল ইমেজ প্রসেসিং হল কম্পিউটারের মাধ্যমে ছবি পরিবর্তন, বিশ্লেষণ ও উন্নত করার একটি প্রযুক্তি।

It involves processing digital images using mathematical algorithms to improve their quality, extract information, or prepare them for further use in applications like medical imaging, facial recognition, and satellite imaging.এটি ডিজিটাল ছবিগুলোর গুণগত মান উন্নত করা, তথ্য আহরণ বা মেডিকেল ইমেজিং, ফেসিয়াল রিকগনিশন এবং স্যাটেলাইট ইমেজিংয়ের মতো অ্যাপ্লিকেশনের জন্য প্রস্তুত করতে গাণিতিক অ্যালগরিদম ব্যবহার করে প্রসেসিংয়ের প্রক্রিয়া।

What is DIP? (cont...)

The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes



➥ ইমেজ প্রসেসিং থেকে কম্পিউটার ভিশন পর্যন্ত প্রক্রিয়াটি সাধারণত তিনটি স্তরে বিভক্ত করা যায় – লো-লেভেল, মিড-লেভেল, এবং হাই-লেভেল প্রসেস।

এখানে বলা হচ্ছে যে ইমেজ প্রসেসিং থেকে কম্পিউটার ভিশন-এ যাওয়ার পুরো ধাপটিকে তিনটি পর্যায়ে ভাগ করা যায়।

তিনটি স্তরের ব্যাখ্যা:

১. লো-লেভেল প্রসেস (Low Level Process)

✅ "Input: Image, Output: Image"
➥ **ইনপুট: ছবি, আউটপুট: ছবি**

📌 এই ধাপে **ছবির গুণগত মান উন্নত করা হয়**, কিন্তু ছবির কাঠামো পরিবর্তন করা হয় না।

✅ "Examples: Noise removal, image sharpening"
➥ **উদাহরণ: নয়েজ (অপ্রয়োজনীয় তথ্য) সরানো, ছবি আরও স্পষ্ট করা**

📌 লো-লেভেল প্রসেসে **শব্দ দূর করা** (Noise Removal) এবং **ছবির ধার বাড়ানো** (Sharpening) এর মতো কাজ করা হয়।

২. মিড-লেভেল প্রসেস (Mid Level Process)

✅ "Input: Image, Output: Attributes"
➥ **ইনপুট: ছবি, আউটপুট: বৈশিষ্ট্য** (Attributes)

📌 এই স্তরে, ছবির **গুরুত্বপূর্ণ তথ্য** (features) বের করা হয়, যা পরবর্তী ধাপে ব্যবহার করা হবে।

✅ "Examples: Object recognition, segmentation"
➥ **উদাহরণ: বস্তু সনাক্তকরণ** (Object Recognition), **ছবি বিভাজন** (Segmentation)

📌 **অবজেক্ট রিকগনিশন** (Object Recognition) - ছবির মধ্যে **কোন বস্তুটি কী তা সনাক্ত করা**।
📌 **সেগমেন্টেশন** (Segmentation) - ছবিকে **বিভিন্ন অংশে ভাগ করে নির্দিষ্ট অংশ চিহ্নিত করা**।

৩. হাই-লেভেল প্রসেস (High Level Process)

✅ "Input: Attributes, Output: Understanding"
➥ **ইনপুট: বৈশিষ্ট্য, আউটপুট: বোঝার ক্ষমতা**

📌 এই স্তরে, **সিস্টেম পুরো ছবির অর্থ বোঝার চেষ্টা করে** এবং **স্বয়ংক্রিয় সিদ্ধান্ত নিতে পারে**।

✅ "Examples: Scene understanding, autonomous navigation"
➥ **উদাহরণ: দৃশ্য বোঝা, স্বয়ংক্রিয় নেভিগেশন**

📌 Scene Understanding: পুরো দৃশ্য বিশ্লেষণ করে বুঝতে পারে **ছবিতে কী রয়েছে এবং কী ঘটছে**।
📌 Autonomous Navigation: স্বয়ংক্রিয় গাড়ি বা রোবটের **নিজে চলাচল করার ক্ষমতা**।

- **লো-লেভেল:** ছবির মান উন্নয়ন
- **মিড-লেভেল:** ছবির তথ্য বিশ্লেষণ
- **হাই-লেভেল:** পুরো দৃশ্য বোঝা ও স্বয়ংক্রিয় সিদ্ধান্ত নেওয়া

5 What is digital image processing? Give some example of DIP (Digital Image Processing).

Ans: Digital image processing is the use of computer algorithms to perform image processing on digital images.

Some example of digital image processing—

1. Improve image quality
2. Remove noise from image.
3. Fingerprint recognition
4. Number plate recognition
5. Enhancement of CCTV images.

Fundamental steps of Digital Image Processing

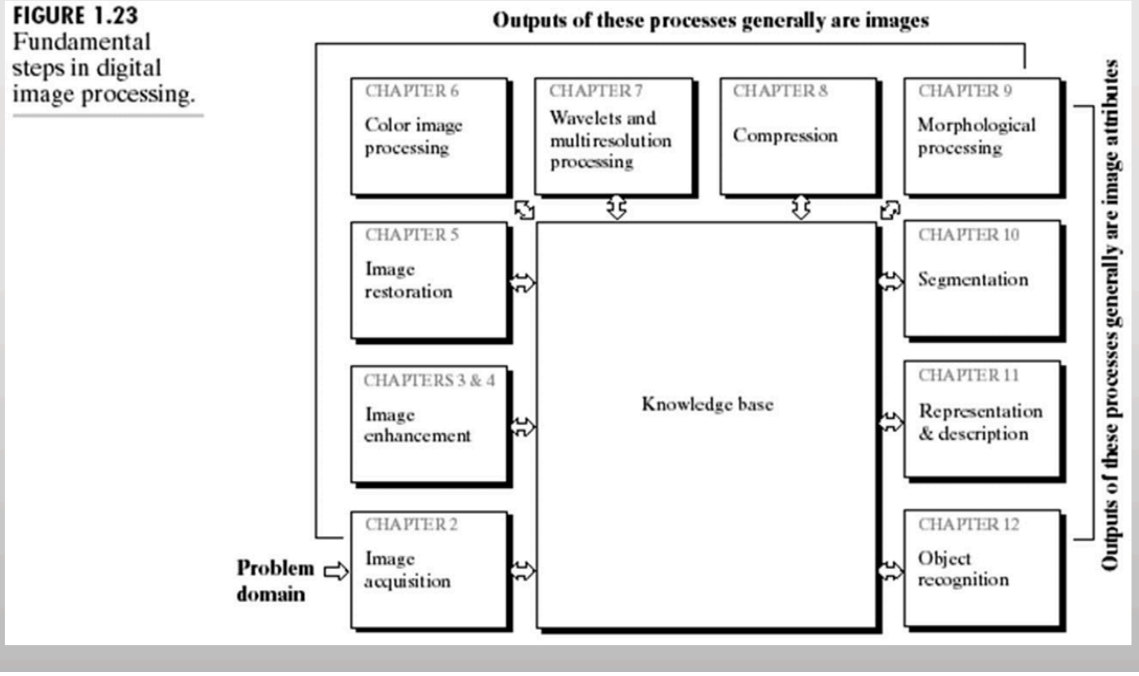


FIGURE 1.23 Fundamental steps in digital image processing.

[9] Explain the fundamental steps of digital image processing.

Ans: The steps of digital image processing –

Image acquisition :
- is the first process
- Capturing the image (camera, scanner)

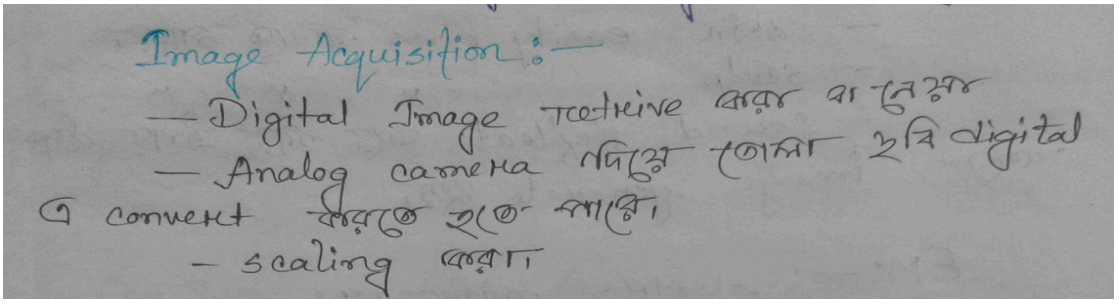
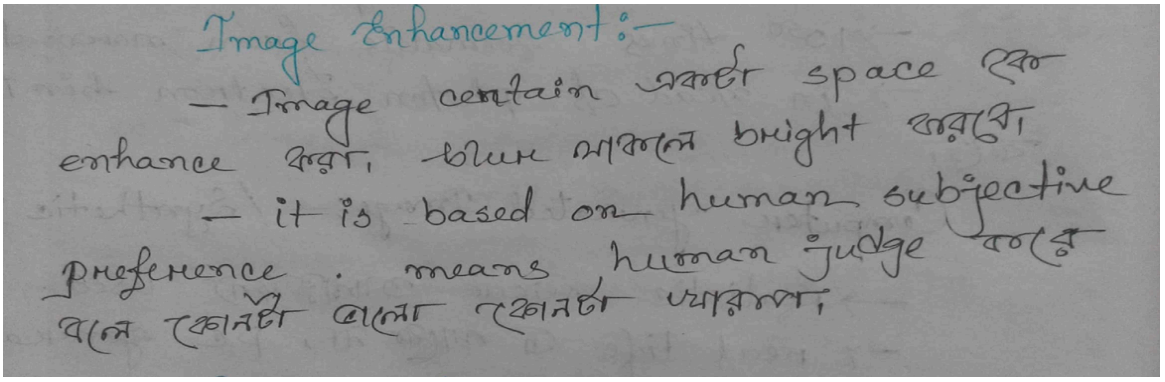
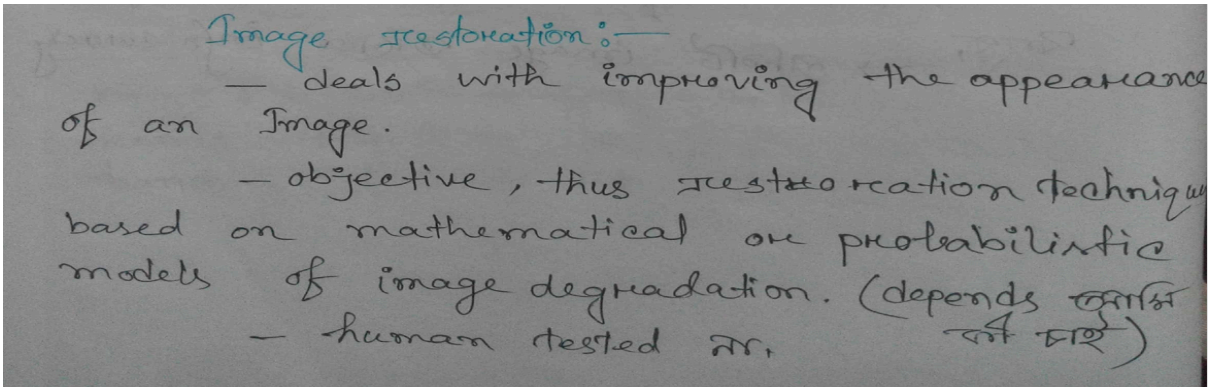


Image enhancement:
- is the process of manipulating an image so the result is more suitable



3. Image restoration

Image restoration is an area that also deals with improving the appearance of an image.



4. Color image processing

The significant of color image processing increase in the use of digital images over the internet.

Color-Image Processing :-
- Image কে compressed করা হয়।
- Normally use করি cost time বেড়ে যায়
- Internet এ upload করার জন্য use হয়
যেমন, ex: fb pp upload.

5. Wavelets and multiresolution Processing

It represents image in various degree of resolution.

Wavlet tansfor :-
- foundation for representing images in various degrees of resolution.
- একটা image কে ছোট করে দেখা।
ex: (1000 X 1000) img কে (25X25) করে দেখা।
- এরে pyramid scale বলা cos original image কে different scale এ দেখি।

6. Compression.

It is the process of reducing image size.

Compression — *) jpg method
*) size reduce করে.
*) transmit করতে সাহায্য করে.
*) কতটুকু information আমি চাচ্ছি তার উপর depened করছে।

7. Morphological processing

It process images based on shapes.

Morphological :—
→ mathematical process
→ image shape change করার জন্য use হয়।

8. Segmentation and representation

It is the process of partioning digital image and simplify the representation of image.

Segmentation :—
→ আমি যা নিয়ে কাজ করবো তা pic থেকে আলাদা করে নেওয়া;
→ digital license plate detection is one of the process of segmentation.

Representation & Description:—

— segmentation এর output নিয়ে কাজ করে almost

— output টা কে define করার, like:

△ → এই pic নিচের এটাকে নাম দেওয়া।

9. object recognition

It is the process of identifying a specific object in a digital image.

Recognition:-

—starts with labeling.

— detect করে সে কোন object টা কী,

—△ signal define করে তাও বলা।

Feature extraction:

- consists of feature detection and feature description
  - Feature detection - finding the features in an image, region, or boundary
  - Feature description - assigns quantitative attributes to the detected features

Feature Extraction

(Representation, Recognition) এই step গুলোর analysis এর output image হতেও পারে নাও পারে।

Computer Vision

Computer vision is a multidisciplinary field that enables computers to interpret and understand visual information from the world, same as the way humans perceive and interpret images.

কম্পিউটার ভিশন একটি বহুমুখী ক্ষেত্র যা কম্পিউটারকে বিশ্বের ভিজুয়াল তথ্য ব্যাখ্যা ও বোঝার সক্ষমতা প্রদান করে, ঠিক যেমনভাবে মানুষ ছবি উপলব্ধি ও বিশ্লেষণ করে।

Image Compression

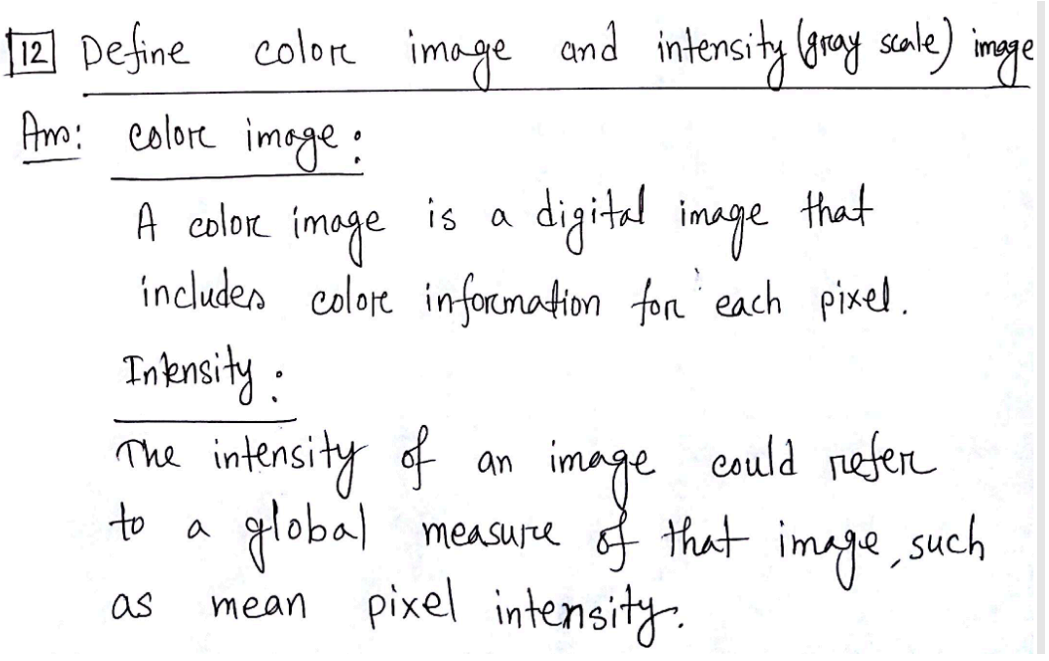
Image compression involves reducing the file size of an image while attempting to preserve its visual quality.

ইমেজ কমপ্রেশন হল ছবির ফাইলের আকার কমানো, তবে এর ভিজুয়াল গুণগত মান যথাসম্ভব অক্ষুণ্ন রাখার প্রক্রিয়া।

Machine Vision

Machine vision is a subset of computer vision that specifically focuses on the use of computer systems to perform visual inspections and tasks traditionally carried out by humans in manufacturing and industrial settings.

মেশিন ভিশন হল কম্পিউটার ভিশনের একটি উপশাখা, যা বিশেষভাবে উৎপাদন ও শিল্প খাতে মানুষের পরিবর্তে স্বয়ংক্রিয় ভিজুয়াল পরিদর্শন ও কাজ সম্পাদনের জন্য কম্পিউটার সিস্টেম ব্যবহারের ওপর কেন্দ্রীভূত।



12 Define color image and intensity (gray scale) image

Ans: color image:

A color image is a digital image that includes color information for each pixel.

Intensity:

The intensity of an image could refer to a global measure of that image, such as mean pixel intensity.

[13] Define aspect ratio. why it is important ?

Ans: Aspect ratio of an image describes the proportional relationship between its width and its height.

Importance of aspect ratio –

1) To print image properly.
2) To maintain high visual quality.

Computer Vision vs Human Vision:

Feature	Computer Vision 💻	Human Vision 👀
How it works?	Uses cameras & software.	Uses eyes & brain.
Speed	Very fast.	Slower but smart.
Learning	Needs lots of training.	Learns naturally.
Flexibility	Works for fixed tasks.	Adapts to anything.
Accuracy	Very precise in some cases.	Good at complex scenes.
Depth Vision	Needs extra cameras.	Naturally sees depth.
Energy Use	Uses lots of power.	Uses very little energy.
Recognizing Things	Needs training.	Recognizes instantly.
Understanding	Can't feel emotions.	Understands emotions.
Used for	Self-driving cars, security.	Daily life, everything!

Types of Images

Monochrome Image: A **monochrome image** is an image that consists of only **one color** or **different shades of a single color**.

🔷 Types of Monochrome Images:

1️⃣ Binary Image 🏁

- Contains only **two colors**: **Black and White** (0 and 1).
- Example: Old newspapers, scanned documents.

2️⃣ Grayscale Image ⚫➡️⚪

- Contains **different shades of gray** ranging from **black to white**.
- Example: Black & white photography, medical X-rays.

Monochrome images **simplify visual data** and are often used in **printing, medical imaging, and computer vision**

Colored Image

A colored image consists of multiple colors and is usually represented using three primary color channels:

✅ Red (R)
✅ Green (G)
✅ Blue (B)

How Colored Images Work?

- A color image is stored as a raster map, which is a 2D array of small integer triplets (R, G, B).
- Each pixel in the image has a combination of these three colors to form the final color.
- Some images use three separate color channels to store color information.

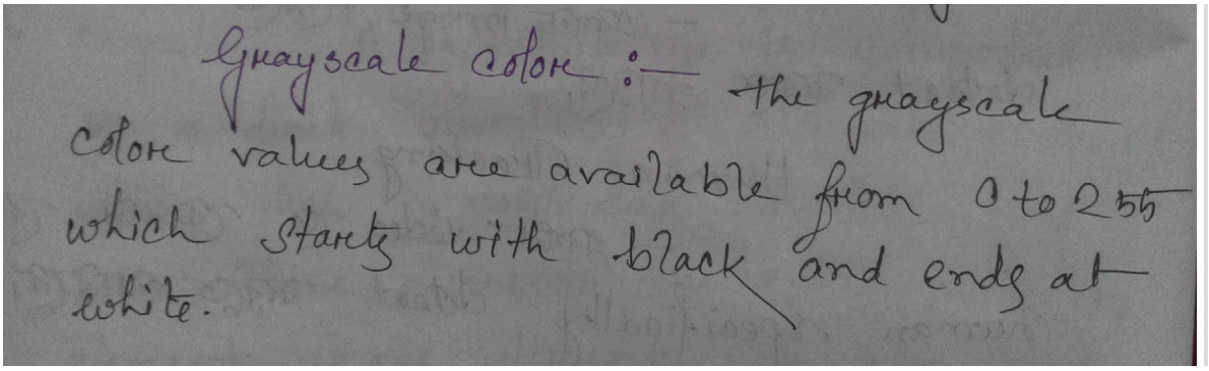
🔷 Color Spaces & Representation

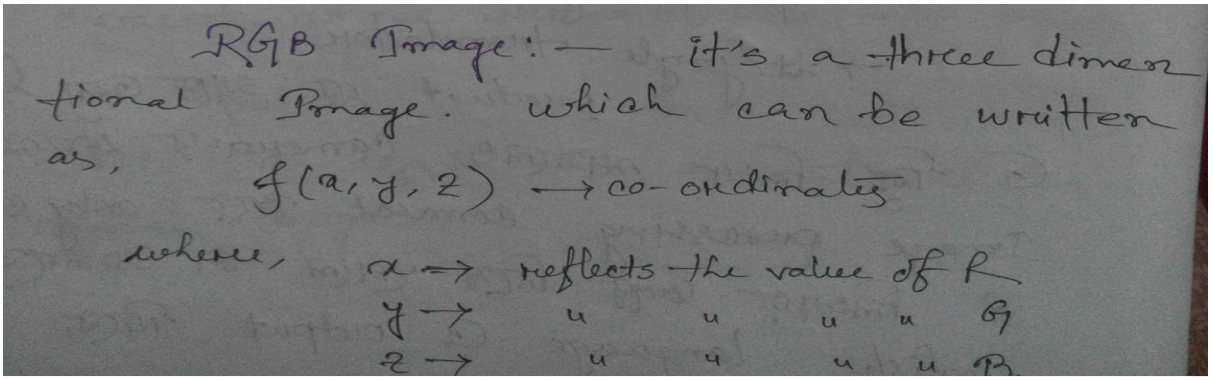
A color space defines how colors are represented, interpreted, and processed in digital images, videos, and graphics.

Different color spaces are used based on the application, such as:
🎨 RGB → Digital displays (monitors, TVs, smartphones).
🖨️ CMYK → Printing and publishing.
📷 YCbCr, HSV → Photography, video processing, and computer vision.

Color Space – CMYK

Used for: printer printing
Use the subtractive color mixing
Axes:
- Cyan
- Magenta
- Yellow
- K: black





Common Color Spaces:

1️⃣ **Grayscale** → Uses a single channel (Black & White).
2️⃣ **RGB (Red, Green, Blue)** → Most common for digital images.
3️⃣ **RGBA (Red, Green, Blue, Alpha)** → Includes **Alpha** for transparency (used in overlays & blending).
4️⃣ **HSV (Hue, Saturation, Value)** → Useful for **color-based object detection & segmentation**.

HSV Color Space

HSV is a color space that makes it easier to work with **color detection and segmentation** in **computer vision**.

🔶 **Hue (H):**

- Represents the **color** itself.
- Measured in **degrees (0° to 360°)** on a color wheel.
- Example: **0° = Red, 120° = Green, 240° = Blue**.

🔶 **Saturation (S):**

- Defines how **pure** the color is.
- **100% saturation** = Full color 🌈
- **0% saturation** = No color (Gray) ⚫⚪

🔶 **Value (V):**

- Represents **brightness**.
- **0% (V = 0)** = **Black (darkest)** 🖤
- **100% (V = 100)** = **Full brightness** 🌞

"Image processing is developed for improvement of pictorial information for human interpretation" - explain.

Image processing is a technique used to enhance the quality of an image so that humans can interpret and analyze it more effectively. It applies various **filtering, enhancement, restoration, and segmentation** methods to improve the visibility and clarity of images.

How Image Processing Improves Images:

1️⃣ **Noise Removal** → Clears blurry or distorted images.
2️⃣ **Brightness & Contrast Enhancement** → Makes images clearer and more vivid.
3️⃣ **Edge Detection** → Identifies important features in an image.
4️⃣ **Color Enhancement** → Improves color quality for better visibility.
5️⃣ **Segmentation & Object Detection** → Identifies and isolates objects for analysis.

📌 Applications of Image Processing:

✅ **Medical Imaging:** Enhancing X-rays, MRIs, and CT scans for accurate diagnosis.
✅ **Satellite Imaging:** Analyzing Earth's surface and weather patterns.
✅ **Facial Recognition:** Identifying people for security and authentication.
✅ **CCTV Footage Analysis:** Improving security footage for crime detection.

The main goal of image processing is to **enhance images and extract meaningful information**, making them easier for humans to analyze and interpret. 🎯✨

Or

Image processing involves techniques and algorithms designed to enhance pictorial information to make it more visually appealing and easier for humans to interpret. This can include improving image quality, enhancing details, reducing noise, adjusting brightness and contrast, and extracting useful information from images for better understanding and analysis. Overall, the goal of image processing is to optimize visual information to aid human perception and interpretation.

3(b): Write a short note with your own word to explain how do human beings perceive color? Given a color Image represented in terms of RGB components, how are the corresponding CMY and HIS coordinates derived?

Human beings perceive color through the eyes and the brain's interpretation of different wavelengths of light. The human eye contains specialized cells called cones that are sensitive to short (blue), medium (green), and long (red) wavelengths of light. The brain processes the signals from these cones to create the perception of a full spectrum of colors. When representing a color image in terms of RGB (Red, Green, Blue) components, the corresponding CMY (Cyan, Magenta, Yellow) and HIS (Hue, Intensity, Saturation) coordinates can be derived as follows:

CMY Coordinates:

Cyan (C) is the complement of Red (R), calculated as C = 1 - R.
Magenta (M) is the complement of Green (G), calculated as M = 1 - G.
Yellow (Y) is the complement of Blue (B), calculated as Y = 1 - B.

HIS Coordinates:

Hue (H): Represents the dominant color wavelength. It is calculated based on the RGB values, but the exact conversion can be complex. Various methods exist, such as using trigonometric functions to determine the angle in a color wheel.
Intensity (I): This represents the brightness of the color and is calculated as I = (R + G + B) / 3.
Saturation (S): Represents the purity of the color and is calculated as S = 1 - (3 / (R + G + B)) * min (R, G, B).

Converting RGB to CMY and HIS provides alternative color representations, each with its own interpretation and advantages for various applications, such as printing, image processing, and color analysis.

Is a Monochrome Image More Suitable for Image Segmentation Than a Color Image? Why?

✅ **Yes, monochrome (black & white or grayscale) images are generally more suitable for image segmentation than color images.** This is because monochrome images store information in a single channel (intensity), making the segmentation process simpler and more efficient.

Monochrome images **are generally more effective for segmentation than color images** because they offer **lower complexity, clearer boundaries, and faster processing**.

📌 Why Is a Monochrome Image More Effective?

🔷 **Single Channel Processing** → Monochrome images contain only intensity values, reducing complexity.
🔷 **Less Computational Complexity** → Color images have three channels (Red, Green, Blue), making segmentation more challenging.
🔷 **Clear Object Boundaries** → Monochrome images provide a more uniform contrast, making it easier to differentiate objects from the background.
🔷 **Faster & More Efficient Algorithms** → With fewer data points to analyze, computers can perform segmentation quickly.

📌 Examples:

✓ Medical Imaging

✓ Object Detection

"In digital image processing high color image is presented by 12 bits where 24 bit is presented by true color"-justify the statement.

The statement explains the difference between **High Color images**, which are typically represented using **12 bits per pixel**, and **True Color images**, which are represented using **24 bits per pixel**.

🌄 1. High Color Image (12-bit)

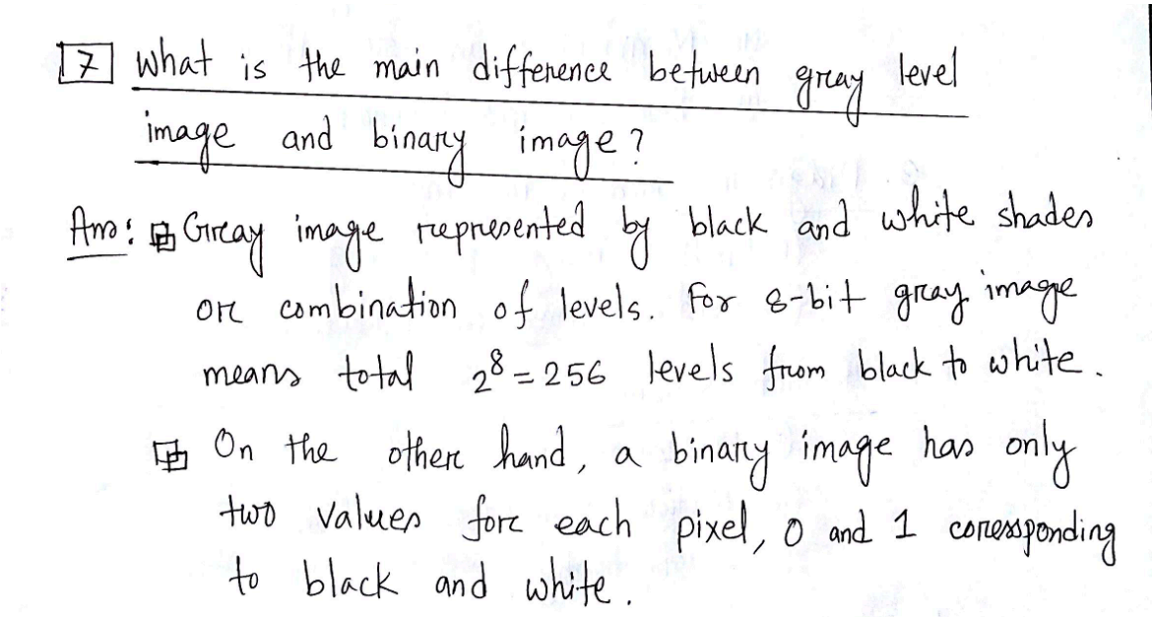
✅ **Uses 12 bits per pixel** for color representation.
✅ Each pixel has $2^{12} = 4,096$ possible color combinations.
✅ Typically, each pixel is divided into **4 bits for Red, 4 bits for Green, and 4 bits for Blue**.
✅ It can represent a broad range of colors but is **not as detailed as True Color images**.

🌈 2. True Color Image (24-bit)

✅ **Uses 24 bits per pixel** for color representation.
✅ Each pixel has $2^{24} = 16,777,216$ possible color combinations.
✅ Typically, each pixel consists of **8 bits for Red, 8 bits for Green, and 8 bits for Blue**.
✅ Provides a **much wider color range and more realistic color representation**.

Feature	High Color (12-bit)	True Color (24-bit)
Bits per Pixel	12-bit	24-bit
Possible Colors	4,096	16,777,216
Channel Distribution	R = 4-bit, G = 4-bit, B = 4-bit	R = 8-bit, G = 8-bit, B = 8-bit
Color Accuracy	Limited	Very High
File Size	Smaller	Larger
Use Case	Suitable for low-memory applications	Ideal for high-quality images and realistic color rendering

Therefore, while **12-bit images are efficient**, **24-bit images provide superior color accuracy and representation**, making them ideal for digital displays, photography, and graphic design.



Feature	Gray Level Image	Binary Image
Definition	An image where each pixel has a range of intensity values (shades of gray).	An image where each pixel has only two possible values: black (0) or white (1).
Pixel Values	Typically 0 to 255 (for 8-bit images), where 0 = black and 255 = white.	Only 0 (black) and 1 (white).
Shades of Gray	Contains multiple shades (grayscale).	Contains only two shades (black & white).
Detail Level	Preserves more details and texture variations.	Loses details due to extreme contrast.
Example Usage	Used in medical imaging, photography, and pattern recognition.	Used in document scanning, barcode detection, and image thresholding.