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Chapter 1

Image Processing Techniques

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Abstract: Image processing techniques are the *basic building blocks* of many image processing applications where images will be processed in order to extract important information. There are many techniques which can be used *to process the 'n' images, identifying different patterns, segmentation, transforming images into desired formats etc.* Even it is also possible to process real-time videos by dividing them into '*f*' frames. Image enhancement, restoration, feature extraction, segmentation, linear filtering, pixelation, reducing the noise, compression & decompression etc. are the few image processing techniques which are discussed in this chapter. These all tasks are very useful in automating the image processing tasks and retrieving important information.

Keywords: Compression, Detecting objects, Feature extraction, Image segmentation, restoration, Linear filtering, Neural networks, Noise reduction.

1.1 Introduction to Digital Image Processing

Computer system understands the image in terms of '*arrays*'. Chapter gives introduction to image processing with many methods and techniques. Image processing applications helps end users to better understand, analyse and acquire minute features. One of the major concerns in image processing is '**image quality**' which can be *noisy, and blur*. Therefore, 'sample of the image' must be taken and process carefully. Programming languages and their supported libraries helps developing an image processing applications. There are many methods, techniques and algorithms that can be used to process different images and 'frames' retrieved from videos. With the help of existing methods one can increase the quality of input images, extracting required features etc. As discussed following are the tools those can used in image processing applications –

- *Scikit-image*
- *OpenCV*
- *Matplotlib*
- *Tensorflow*

- *Pytorch*
- *NumPy*
- *CUDA*
- *Mahotas*
- *Keras*

1.2 Literature review

A research paper (Fernandes et. al., 2021) focused on different image processing methods required for autonomous vehicles, useful in controlling the autonomous cars. There are many challenges in autonomous vehicles like different signs on the roads, detecting proper lanes, overcoming the obstacles etc. However, different devices like camera, sensors etc. help controlling the autonomous vehicle. There could be many high resolution cameras planted on the car capturing real time images. Authors have discussed '*canny edge*' detection method to detect the '**edges**' from the input images. Authors have also used '*Hough transform method* detecting the proper lanes as per the destination route decided. This research paper emphasizes on the importance of road safety by considering all the required safety measures. Further authors have discussed different parameters to measure the performance of the proposed autonomous vehicle research. A research paper (M. Tripathi, 2021) focuses on *CNN – convolutional neural network* with classifier approach. In this research paper author has discussed '*visualization*' with camera for instant billing procedure. This approach will drastically reduce the time and efforts required for billing. Research paper emphasizes on the use of convolutional neural network (CNN) and classification method. Classifier helps classifying the objects by maintaining the accuracy in the billing procedure.

Authors (Kartikeyan & Shrivastava, 2021) have discussed the application of recent technologies in agriculture sector. Farmers always face many challenges like *changing climate conditions, different diseases on the plants and utilization of other important resources*. Manual observation and controlling the plant diseases are not practical and require more efforts & time. With the help of recent technologies like machine learning, deep learning and artificial intelligence one can automate the process of plant disease detection. High resolution cameras will capture the plant images and input them to the system in order to perform further steps like pre-processing, segmentation, feature extraction and classification. Digitized image processing technique will detect the possible disease and suggest remedial steps instantly. With the help of this approach, diseases can be control in their initial stages and helps improving the crop yield. Authors have discussed different classification approaches like support vector machine (SVM), artificial neural network, k-nearest neighbors (KNN), etc. Authors (Ali et. al., 2022)

discussed the use of CNN – convolutional neural network in many image processing applications. Application of CNN gives higher accuracy & precision in variety of applications like medical, logistics, and facial expression analysis etc. Authors have discussed application of recent technology to detect the '*cracks*' in civil construction. Proposed research work focused on detecting the cracks using classification & segmentation methods. A system similar to crack detection and image processing requires pre-processing steps, segmentation & classification of the images. Research work also discusses the comparison of manual detecting the cracks & crack detection using CNN approach. This research work also gives outline about the future research directions and helps exploring the challenges in application of CNN in different areas. A research work (AlDera & Othman, 2022) emphasizes on skin disease detection methods. Many research studies identified 'skin disease' a global health issue. However, identifying and controlling the skin diseases in their early stages is quiet challenging task. The proposed research work discusses the use of different image processing steps and machine learning methods to effectively detect and diagnose the skin disease in its early stages. Authors have discussed different diseases like acne, angioma, melanoma, psoriasis etc. Research work highlights different image processing steps like image acquisition, pre-processing, segmentation, extracting different features, and classifying the images etc. Authors have focused on different machine learning algorithms to evaluate the proposed model e.g. support vector machine (SVM), random forest, K-nearest, etc. along with their precision & accuracy. A research work (Abisha & Jayasree, 2022) gives most promising guidelines in applying the recent technologies for the farming. A farmer may face losses due to variety of plant diseases. Plant diseases have impact on the crop yield and contribute in the monetary losses. However, it is very challenging task to manually observing if there are any disease on the plants. Therefore, application of the recent technologies helps reducing the manual efforts and time to detect the plant diseases. Authors have used *DWT – discrete wavelet transform*, segmentation, and classification methods. In this research work, different features from colour, textures, and other feature sets were '***fused***' using artificial neural network approach to give better accuracy and precision. Authors (Saleh et. al., 2022) have proposed a 'fusion' approach in image processing where different features can be fused to give higher accuracy & precision. Authors have discussed multimodal medical image fusion (MMIF) approach combining '*n*' images to have better quality fused image. This fused image will be clear than the original image. In this research work authors have explained different steps involved in the 'fusion' approach. This research work highlights different modalities like *CT- computed tomography, MRI- magnetic resonance imaging*, etc. MMIF approach works on different levels like pixel, feature, and decision. Authors (Khairandish et. al., 2022) proposed a research work focusing on

CNN-SVM hybrid approach for tumor detection. This research work focuses on 'brain cancer' a life threatening disease across the globe. This disease has maximum death rate and detecting it in the early stage is crucial task. In this disease it is necessary to observe the abnormal growth of cells, location, and shapes. Medical imaging faces difficulty in identifying the same in early stage so that survival rate can be increase. MRI – magnetic resonance imaging helps analysing brain tumor and then categorizing the acquired images. Authors (Goel & Nagpal, 2023; Roopali, G., & Verma, T., 2020) have proposed a research study focusing on plant disease management. Different diseases on the plant have direct impact on the yield and ultimately contribute in the monetary losses. Application of recent technologies helps farmers to monitor the farm remotely, helps taking necessary actions i.e. decision making, reduces efforts and time etc. Authors have enlisted floral, foliar, and soil borne diseases which affect the crop yield. This research work highlights 'leaf disease' identification with its different issues & challenges. Conclusion of this research study highlights support vector machine (SVM) gives good results and hence widely used in many plant disease detection system. A research work (Tian et. al., 2023) proposed a deep learning approach for denoising the images'. This is a multistage denoising approach based on convolutional neural network (CNN). In this proposed work authors have used wavelet transform method to de-noise the images. There could be multiple convolutional layers in the CNN helps increasing the performance of the system by maintain the computational cost. There are multiple image processing applications & the research work (Ma, P et. al., 2023) focuses on detecting microorganisms. Authors have enlisted the challenges of manual detection of microorganisms like; it requires maximum time to detect the microorganisms, less accuracy, hard to differentiate the variety of microorganisms etc. Hence, application of recent technologies help detecting the microorganisms properly, with higher accuracy & precision, requires less time than the manual approach etc.In this research work authors have used visual transform methods to analyse & differentiate variety of microorganisms. As discussed earlier the application of image processing techniques have already revolutionized different sectors. With the help of different methods from machine learning, deep learning and artificial intelligence researchers, academicians and industries are developing new applications to process different images & videos. The research work (Saeedi et. al., 2023) emphasizes on detection of brain tumor in its early stages. The proposed 2D CNN approach optimally classifies ''n' brain tumor images. Such applications require less computational cost, minimal time, higher accuracy & precision etc. Authors (He, et. al., 2021; Xiang et. al., 2023) have proposed an 'image inpainting' with enhanced features. The main advantage of image inpainting in this proposed approach is to focus on 'missing region'. This research work produces texture for the missing regions if the image is damaged. There are many image inpainting

techniques with similarities & distinguishable characteristics. Authors have summarized & gave detailed view of different used on image inpainting based on deep learning. Authors have focused on different strategies used in image inpainting, structure of the network, loss functions, detailed analysis of the algorithms used in image inpainting. Research work also summarizes strategies, & techniques used in image inpainting and give future research directions.

1.3 Different types of images

- **Binary image**
  - It is a simple image type which consider only '0' & '1'. As it considers only '0' and '1' it requires 1-bit to represent the pixel. Generally these type of images used to represent the 'outline'.

Fig. 1 Colour Image

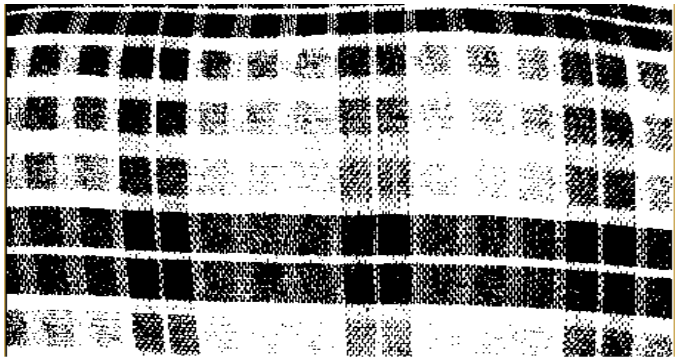

Fig. 2 Binary Image

- **Colour image**
  - These images are represented using RGB bands (red, green and blue) & if the application uses 24 bits/pixel then it means proposed model represents 8 bits/pixel.

Fig. 3 Colour Image

- **Grayscale image**

  - These images are also called as ‘monochrome’ images i.e. gray-scale representing only one colour.

Fig. 4 Colour Image

Many image processing applications converts the input images (e.g. fig.4 colour image) or frames (retrieved from the input video) into grayscale (like fig.5) before processing.

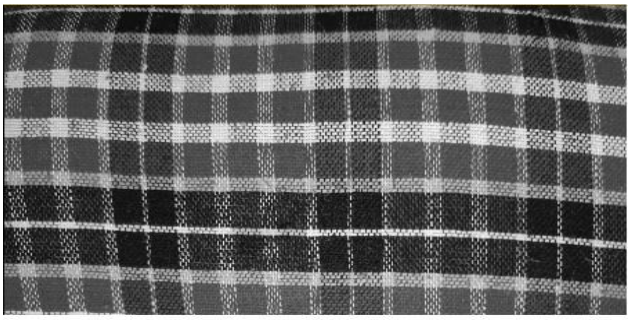

Fig. 5 Grayscale Image

1.4 Image processing techniques

This section enlists & explains different image processing techniques:-

1.4.1 Compression

Many image processing applications initially convert the colour image into grayscale. Additionally, many applications 'compress' the given input images before processing if the input video, or images are larger. There are many methods, and algorithms used to compress and decompress the images. There are 02 most popular compression techniques widely used in image processing applications i.e. *lossless and lossy compression* & mathematical transformation plays crucial role in the same. Image transformation, quantization and encoding & decoding sequences are the basic steps in the image compression and decompression techniques.

There are many motivations behind application of the 'compression' in image processing. Currently everyone uses handheld devices like mobile with high resolution cameras & storing the images obviously consumes more space. Additionally, once the high resolution image with max. size is stored it requires a bit more time to upload the same. Therefore, high resolution images with maximum size can increase the communication time which ultimately increases the cost of communication. To overcome such challenges one can go for applying 'compression' techniques. It is proved that, lossless compression technique data can be restored into its original form at the decompression stage. It ensures there would be no loss in quality and file (data) consumes less space. Following are key points to be consider for the lossless & lossy compression techniques –

Lossless compression techniques-

1. Restores the data in its original form
2. It must be used in the applications where "*no data loss*" policy is applicable
3. Applications of lossless compression are – text, image & audio.
4. Its examples are – audio file (WAV), pictures (BMP & PNG) etc.
5. It can reduce the file size slightly
6. It maintains the quality

Lossy compression techniques –

1. As its name indicates it removes the data permanently
2. It can be used where "*data loss*" (partial loss) is acceptable
3. Applications of the lossy compression are – images, video and audio etc.
4. Its examples are – image (JPEG), audio (MP3) etc.
5. Advantage of lossy compression is "small file size"
6. Quality after application of the lossy compression degrades.

1.4.2 Object detection

The ultimate use of image processing is to 'detect the objects' from the input images & video. In image processing it can be termed as 'localization' where identifying and localizing the specific objects is a crucial task. Many image processing applications considers this as an initial step and execute sub-tasks like

1. *Object localization*
2. *Classifying the localized objects*
3. *Highlighting the identified objects using – box structure etc.*

However, discussing object detection without 'image pre-processing steps' would be incomplete. Therefore, following steps must be used in image pre-processing like

1. Image resizing

It is also known as up-scaling OR down-scaling the input image in order to 'resize' it. Many researchers termed it as 'scaling' of the given images. Image resizing helps minimizing the pixel requirement for the input image which ultimately minimizes the training time of the network.

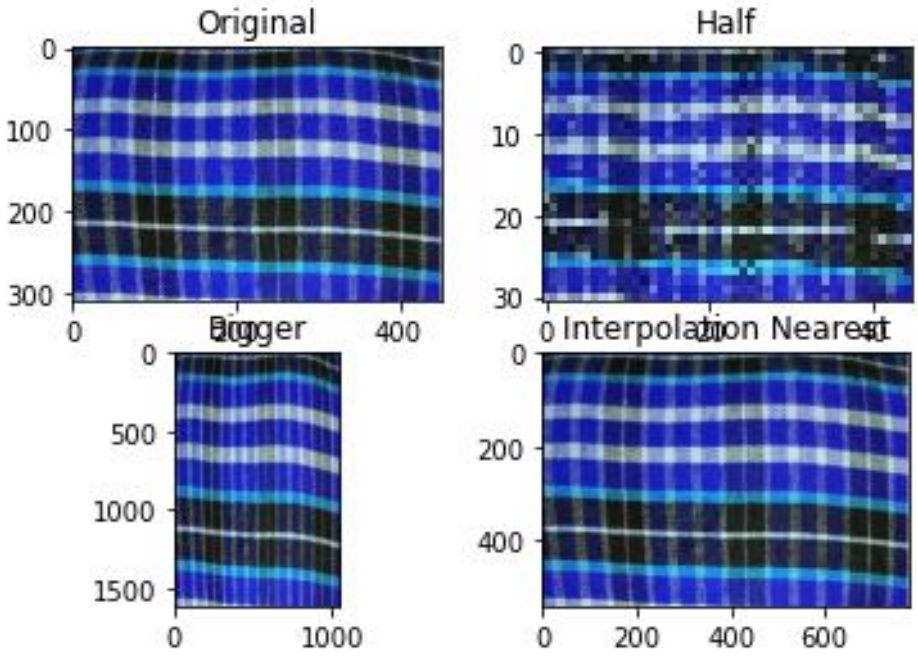

Fig. 6 Image resizing

If the image requires more pixels it means training time of the network could be maximum and complexity of the proposed model could be higher. *Interpolation* plays crucial role in the image resizing. E.g. OpenCV provides following interpolation methods like INTER_AREA (to shrink an image), INTER_CUBIC, INTER_LINEAR (for zooming purpose). Above example illustrates the image resizing with different approaches.

2. Normalization

It normalizes the pixels requirements of the image to the desired range i.e. normalizes the given input images for better processing. To train the proposed model with available 'neurons' requires 'consistent' architecture of the network.

Following fig.7 illustrates the application of 'normalization' and distinguishes it from the original image.

Fig. 7 Normalized image

3. Noise reduction

Noise reduction is the important step in image processing where it removes noise in an image by applying different filter like Gaussian, bilateral or median etc. Once the noise is successfully reduced it ensures more efficient extraction of the different features. Noise reduction minimizes the time complexity of the proposed model.

4. Contrast adjustment

Extracting the important features and enhance the quality of images many image processing applications require “contrast adjustment’. This step ‘remaps’ the image intensities to a full range. Histogram equalization method enhances the contrast quality of the images to match it with the specified histogram values. Adjusting the contrast for the original image i.e. fig. 3 colour image the ‘adjusted contrast image’ would be as shown below in the *fig. 8 contrast adjustment*. Histogram equalization method is very useful in many image processing applications especially in medical image processing e.g. reading X-rays.

Fig. 8 Contrast adjustment

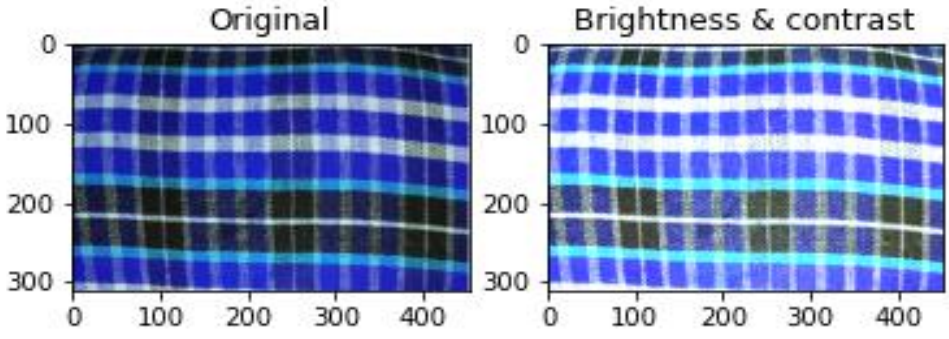

Fig. 9 Brightness & Contrast adjustment

Fig. 9 gives another example of adjusting the brightness & contrast for the input image. Brightness & contrast adjustment gives better visualization & effectiveness of the proposed system.

5. Colour conversion

Colour conversion is useful in differentiating & segmenting the input images. It also helps in converting the image from one colour space to another colour space. Many image processing applications use following colour conversion techniques like- colour to grayscale, HSV to grayscale, Binarization (grayscale to black & white) etc.

6. Image augmentation

With the help of various image augmentation techniques one can obtain the newer version of augmented image. It may help to train the proposed model to have additional data obtained after augmenting the input images. Following are the different techniques of image augmentation that are supported by various programming languages & supported libraries like –

a. Image rotation
b. Image shifting
c. Flipping the images
d. De-noising the images (already discussed in the previous section)
e. Blurring and sharpening the input images.

7. Edge detection

Given input image can be divided into 'n' regions for better processing. Every region 'r' has boundaries (edges) & those can be categorized into horizontal, vertical & diagonal edges. *Edge detection is the basic method used in many image processing applications and widely used especially in pattern recognition, morphology of the images, and extracting the important features from the input images.*

Following are the edge detection techniques widely used in many applications –

a. Canny edge detection
b. Prewitt operator
c. Sobel operator

Following fig. 10 depicts the 'edge detection' for the input 'original image'. These edge detection methods are supported by many programming languages & libraries.

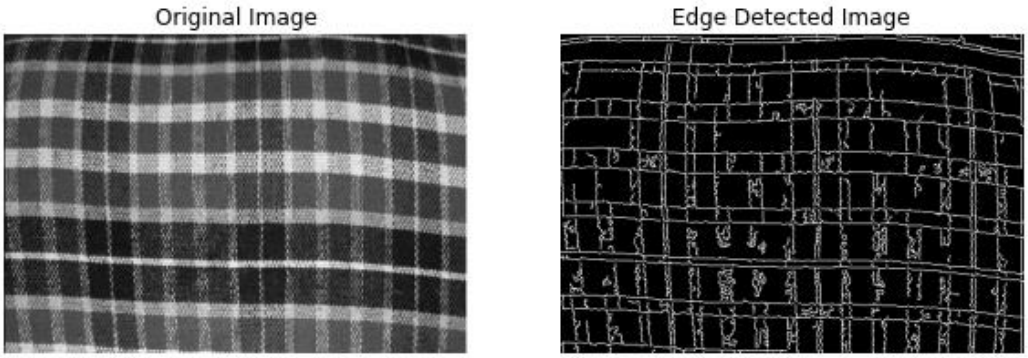

Fig. 10 Edge detected image

Applications of the edge detection are as follows-

a. Medical imaging
b. Robotics applications
c. Computer vision
d. Autonomous vehicles

8. Sharpening

Many image processing applications reduces the contrast of the input & applies 'sharpening' to highlight the image boundaries. As discussed in the previous section, 'edge detection' methods works on the highlighted regions of the images. Following fig. 11 illustrates the application of 'sharpening' of the original image.

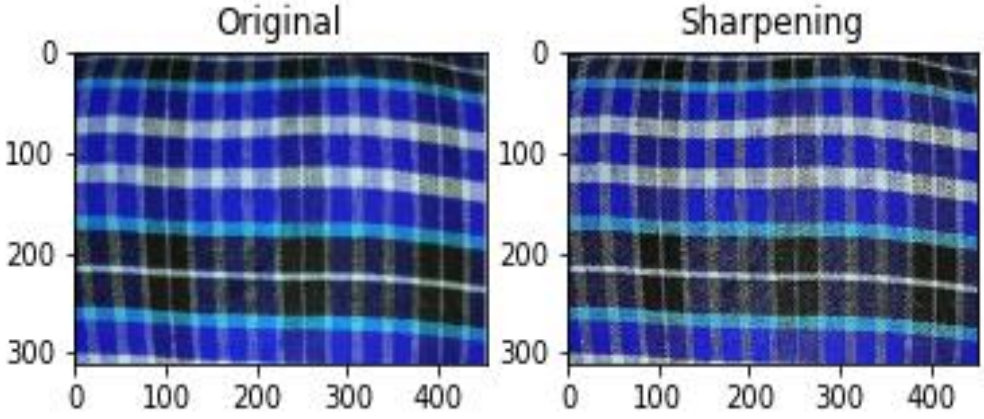

Fig. 11 Sharpening of the image

1.4.3 Image segmentation

'Segmentation' indicates dividing the input image into multiple parts (segments/regions). Segmentation is basic step in many image processing applications. It simplifies the process if training of the proposed model & helps analyse individual segment. Therefore, segmentation gives more efficient image processing model and helps focusing on the particular region/segment.

Existing image segmentation techniques are as follows-

a. *Cluster based segmentation*
b. *Thresholding*
c. *Edge detection*
d. *Region-based segmentation*

Convolutional neural network (CNN) contains convolutional layers, epochs and batch sizes etc. Hence, the CNN models can process the image or data of any size with the help of convolutional layers. It is known as 'segmentation' i.e. segmenting the data into parts & image pixel wise.

Tools & techniques used for image segmentation are as follows-

a. *Open CV*
b. *MATLAB*
c. *Python libraries (Tensorflow, Pytorch, Scikit image)*
d. *Deep learning models (U-Net, SegNet, Mask R-CNN)*

1.4.4 Linear filtering

Linear filtering indicates application of the 'filters' to remove unwanted features/components & focusing on only the required components. We have already discussed this concept in the previous section i.e. de-noising. These are divided into 'linear' and 'non-linear' filters. As the name indicates 'linear filters', it works on the linear mathematical operation helps removing the noise, extracting the features from input images etc. Non-linear filters works on the non-linear operations used in complex tasks like edge detection and de-noise etc.

Applications of the linear filters –

a. *Smoothing the given input images*
b. *Blurring the input images*
c. *Edge detection*

d. *Signal processing*

Applications of the non-linear filters –

a. *Reducing the noise*
b. *Edge detection*
c. *Medical imaging*
d. *Enhancing the input images*

1.4.5 Convolutional Neural networks (CNN)

CNN networks are the powerful tool for image processing and also help detecting the objects in the input image. A computer system processes the input images in terms of 'arrays'. The important dimensions processed with the help of CNN models are height, width and colour represented for each pixel.

CNN mainly have 03 layers and 01 activation function –

a. *Convolutional layer*
b. *Fully connected layer*
c. *Pooling layer*
d. *Activation function (ReLU)*

Key steps must be considered while using CNN for image processing are as follows-

a. *import the required libraries*
b. *reshaping the data*
c. *normalizing the data*
d. *defining the model function*
e. *executing the model with specified batch sizes and epochs*

Different CNN models that can be used in image processing are as follows –

a. *GoogleNet*
b. *ResNet*
c. *AlexNet*
d. *VGG*

Applications of the CNN models are as follows-

a. Classifying the images
b. Detecting the objects in the given images
c. Segmentation

d. Analysing videos or real time streaming

CNN are very powerful type of neural network and used in many sectors especially in image processing. With the help of CNN it is possible to extract features from the given input images at different scales.

1.5 Applications of Image processing

- *Computer vision*
- *Robotics applications*
- *Medical imaging*
- *Recognizing patterns*
- *Processing video streaming*
- *Monitoring the environment*
- *Satellite imaging*
- *Civil engineering (e.g. crack detection)*
- *Facial expression recognition*
- *Autonomous vehicles*
- *Gaming*
- *Optical character recognition*
- *Multimedia application*

Conclusion

This chapter gives brief introduction to basics of image processing with different methods and techniques used in many image processing applications. Image processing is very popular research area for the research scholars and academicians. Image processing is widely used in different sectors like medical imaging, security, geospatial imaging and gaming etc. It is accepted that future of the image processing based applications is bright & definitely will change the future of many sectors like defence, traffic, smart cities, medical, and education etc. Chapter enlists and explains many methods widely used in image processing, basic steps to be followed, different aspects etc.

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