Image Processing: What, How and Future

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2 authors:

Mansi Lather
Deenbandhu Chhotu Ram University of Science and Technology, Murthal

Parvinder Singh
Deenbandhu Chhotu Ram University of Science and Technology, Murthal

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Mansi Lather and Parvinder Singh

Abstract There is a well-known saying: an image is worth more than a thousand words. The wonders of this proverb are very well visible in our day-to-day life. In this paper, we have presented the current and trending applications of imaging in our day-to-day life having a wide scope of research. The digital image processing has revolutionized the field of technical endeavor and there is a lot more yet to be researched in this field. A huge amount of work can be carried out in the area of image processing. This paper summarizes the fundamental steps involved in digital image processing and focuses on the applicative areas of image processing in which research can be carried out for the betterment and quality improvement of human life.

Keyword Biomedical imaging · Digital image processing · Image · Image processing · Imaging applications

1 Introduction

An image is generally a 2D function $f(x, y)$ where x and y are spatial coordinates and the magnitude of f at (x, y) is known as gray/intensity level of an image. An image is known as a digital image when the values of x, y and f are all finite. A digital image is made up of a finite number of entities called pixels, each having a particular location and value [1]. An image can be processed to get a better understanding of useful information contained in the image or to get an enhanced image. This process is called image processing. It is a kind of signal disbursement having an image as input and producing some image characteristics as output [2]. Image processing is of two types: analog and digital image processing. Analog image processing is used for

M. Lather (✉) · P. Singh
Department of Computer Science and Engineering, DeenBandhu Chhotu Ram University of Science and Technology, Murthal, Sonipat 131039, India
e-mail: mansi.schcse@dcrustm.org

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taking photographs and printouts, that is, for hard copies. On the other hand, when images are manipulated by digital computers, it is known as digital image processing [2].

The major focus of digital image processing is on two things:

- Enhancement of image data for human evaluation;
- Image data processing for communication, caching and representation for uncontrolled machine perception [1].

The fundamental steps involved in digital image processing are shown in Fig. 1 [1]. It is not necessary to apply all the steps to each and every type of image. The figure shows all the steps that can be applied to images, but the steps are chosen depending on the purpose and objective of the image. The description of all the steps is as follows [1]:

- **Image Acquisition**: This step involves getting the image that needs to be processed. The image can be acquired using sensor strips, sensor arrays, etc.
- **Image Enhancement**: Image is enhanced to focus on certain characteristics of interest in an image or to get out the hidden details from an image. Image enhancement can be done using frequency and spatial domain techniques. The spatial domain technique focuses on direct pixel manipulation. Frequency domain methods, on the other hand, focus on the modification of the Fourier transform of an image.
- **Image Restoration**: It is an objective process that improves the image appearance by making use of probabilistic and mathematical models of image degeneration. This step restores the degraded image by making use of earlier knowledge of

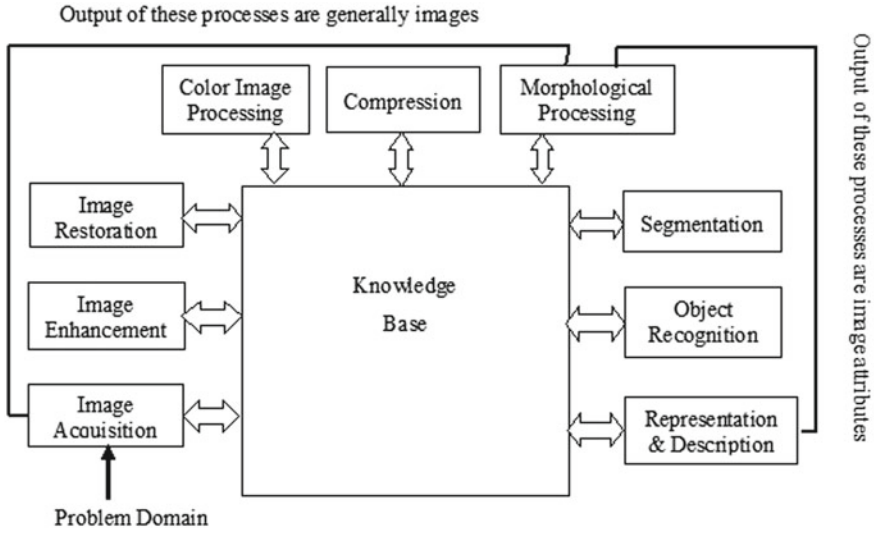


Fig. 1 Fundamental steps in digital image processing

the degradation phenomenon. Noise removal from images by using denoising techniques and blur removal from images by using deblurring techniques come under image restoration.

- **Color Image Processing**: This is basically of two types—full-color and pseudo-color processing. In the former case, images are captured through full-color sensors like a color scanner. Full-color processing is further divided into two categories: In the first category, each component is processed individually and then a composite processed color image is formed, and in the second category, we directly manipulate color pixels. Pseudo-color or false color processing involves color assignment to a particular gray value or range of values on the basis of a stated criterion. Intensity slicing and color coding are the techniques of pseudo-color processing. Color is used in image processing because of the human ability to differentiate between different shades of color and intensities in comparison with different shades of gray. Moreover, color in an image makes it easy to extract and identify objects from a scene.
- **Image Compression**: It means decreasing the quantity of information required to express a digital image by eliminating duplicate data. Compression is done in order to reduce the storage requirement of an image or to reduce the bandwidth requirement during transmission. It is done prior to storing or transmitting an image. It is of two types—lossy and lossless. In lossless compression, the image is compressed in such a way that no information is lost. But, in lossy compression, to achieve a high level of compression, loss of a certain amount of information is acceptable. The former is useful in image archiving such as storing medical or legal records, while the latter is useful in video conferencing, facsimile transmission and broadcast television. Lossless compression techniques involve variable length coding, arithmetic coding, Huffman coding, bit-plane coding, LZW coding, run-length coding and lossless predictive coding. Lossy compression techniques involve lossy predictive coding, wavelet coding and transform coding.
- **Morphological Image Processing**: It is the technique for drawing out those parts of an image that can be used to represent and describe the morphology, size and shape of an image. The common morphological operators are dilation, erosion, closing and opening. The principal applications of morphological image processing include boundary extraction, region filling, convex hull, skeletons, thinning, extraction of connected components, thickening and pruning.
- **Image Segmentation**: It is the process of using automated and semi-automated means to extract the required region from an image. The segmentation methods are broadly categorized as edge detection methods, region-based methods (includes thresholding and region growing methods), classification methods (includes K-nearest neighbor, maximum likelihood methods), clustering methods (K-means, fuzzy C-means, expectation-maximization methods) and watershed segmentation [3].
- **Representation and Description**: The result of the segmentation process is raw data in the form of pixels that needs to be further compacted for representation and description appropriate for additional computer processing. A region can be represented either in terms of its external features such as boundary

or in terms of its internal features such as pixels covering the region. Representation techniques include chain codes and polygonal approximations. In the next task, on the basis of the chosen representation, the descriptor describes the region. Boundary descriptors are used to describe the region boundary and are of the following types—length, diameter, curvature, shape numbers, statistical moments and Fourier descriptors. Regional descriptors, on the other hand, are used to describe the image region and are of the following types—area, compactness, mean and median of gray levels, the minimum and maximum values of gray levels and topological descriptors.

- **Object Recognition**: It involves recognizing the individual image regions known as patterns or objects. There are two approaches to object recognition—decision-theoretic and structural. In the former case, quantitative descriptors are used to describe patterns like texture, area and length. But in the latter case, qualitative descriptors are used to describe the patterns like relational descriptors.

2 Applications of Digital Image Processing

Digital image processing has influenced almost every field of technical inclination in one way or the other. The application of digital image processing is so vast and diverse that in order to understand the broadness of this field we need to develop some form of organization. One of the easiest ways to organize the applications of image processing is to classify them on the basis of their sources such as X-ray and visual [1].

2.1 Gamma-Ray Imaging

Nuclear medicine and astronomical observations are the dominant uses of imaging based on these rays. The entire bone scan image obtained using gamma-ray imaging is shown in Fig. 2. These kinds of images are used for locating the points of bone pathology infections [1].

2.2 X-Ray Imaging

X-rays are dominantly used in medical diagnostics, industry and astronomy [1]. Figure 3 shows the chest X-ray.

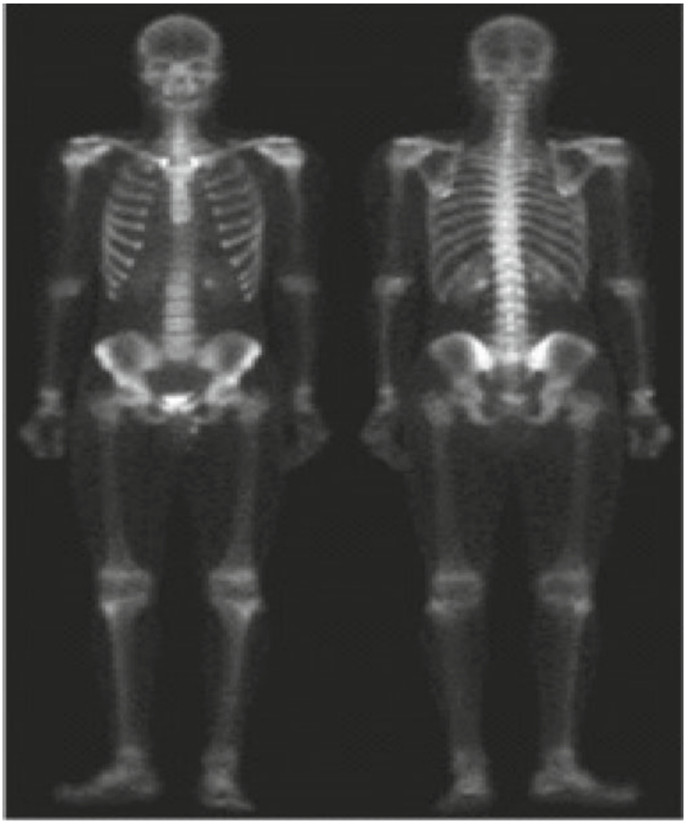
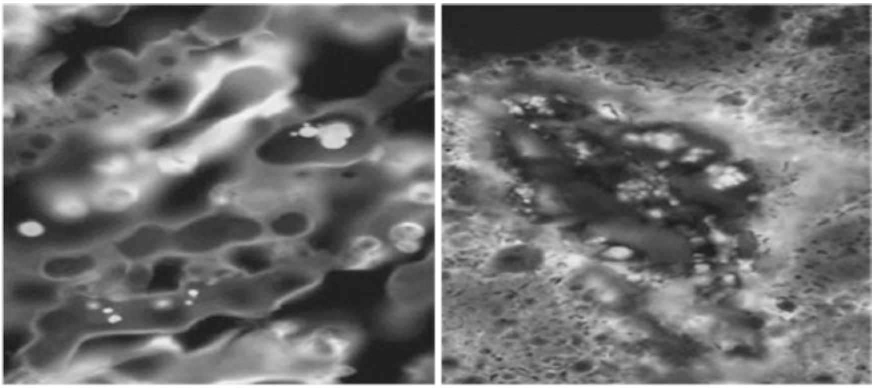


Fig. 2 Example of gamma-ray imaging [1]

Fig. 3 Example of X-ray imaging: chest X-ray [1]



(a) (b)

Fig. 4 Examples of ultraviolet imaging: **a** normal corn; **b** smut corn [1]

2.3 Ultraviolet Band Imaging

Lithography, lasers, astronomical observations, industrial inspection, biological imaging and microscopy are the main applications of ultraviolet light [1]. The capability results of fluorescence microscopy are shown in Fig. 4a and b.

2.4 Visible and Infrared Bands Imaging

The main applications include light microscopy, industry, astronomy, law enforcement and remote sensing [1]. Some examples of imaging in this band are shown in Fig. 5. CD-ROM device controller board is shown in Fig. 5a. The objective here is to inspect the board for missing parts. Figure 5b shows an image of a pill container. The task is having a machine to identify the missing pills. The objective of Fig. 5c is to identify the bottles not filled up to a satisfactory level.

Some other examples of imaging in the visual spectrum are shown in Fig. 6. A thumbprint is shown in Fig. 6a. The objective here is to process the fingerprints using a computer either for enhancing the fingerprints or using them as security aid in bank transactions. Figure 6b shows the paper currency. The objective here is to automate the currency counting and is used in law enforcement by reading the serial numbers so as to keep track and identify the bills. Figure 6c shows the use of image processing in automatic number plate reading of vehicles for traffic monitoring and surveillance.

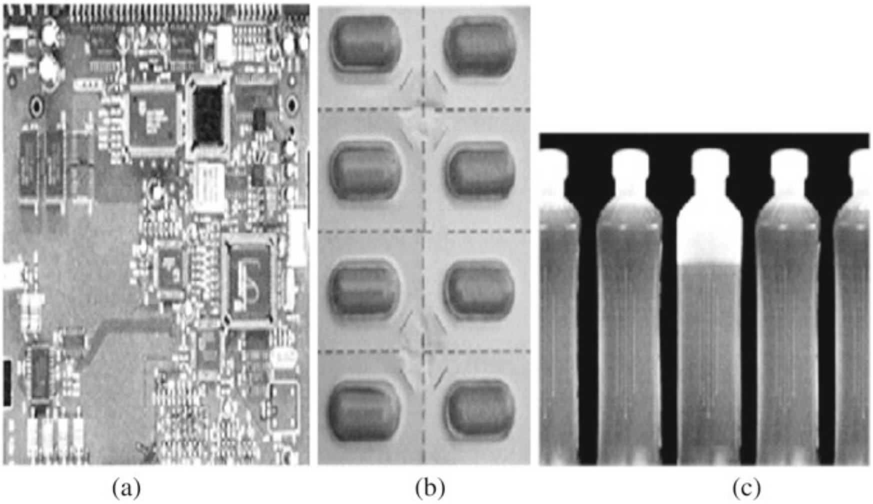


Fig. 5 Examples of manufactured goods often checked using digital image processing: **a** circuit board controller; **b** packaged pills; **c** bottles [1]

2.5 Microwave Band Imaging

Radar is the major use of imaging in a microwave band. The exclusive characteristics of radar imaging are its data-gathering capability relatively at any time and at any place, irrespective of lighting and weather conditions [1]. The spaceborne radar image of the rugged mountainous area of southeast Tibet is shown in Fig. 7.

2.6 Imaging in Radio Band

The main application of imaging in radio band is in medicine and astronomy. In medicine, magnetic resonance imaging (MRI) uses radio waves [1]. MRI images of the human knee and spine are shown in Fig. 8.

3 Imaging Applications

3.1 Intelligent Transportation System

Intelligent transportation system (ITS) combines the conventional transportation infrastructure with the advances in information systems, sensors, high technology,

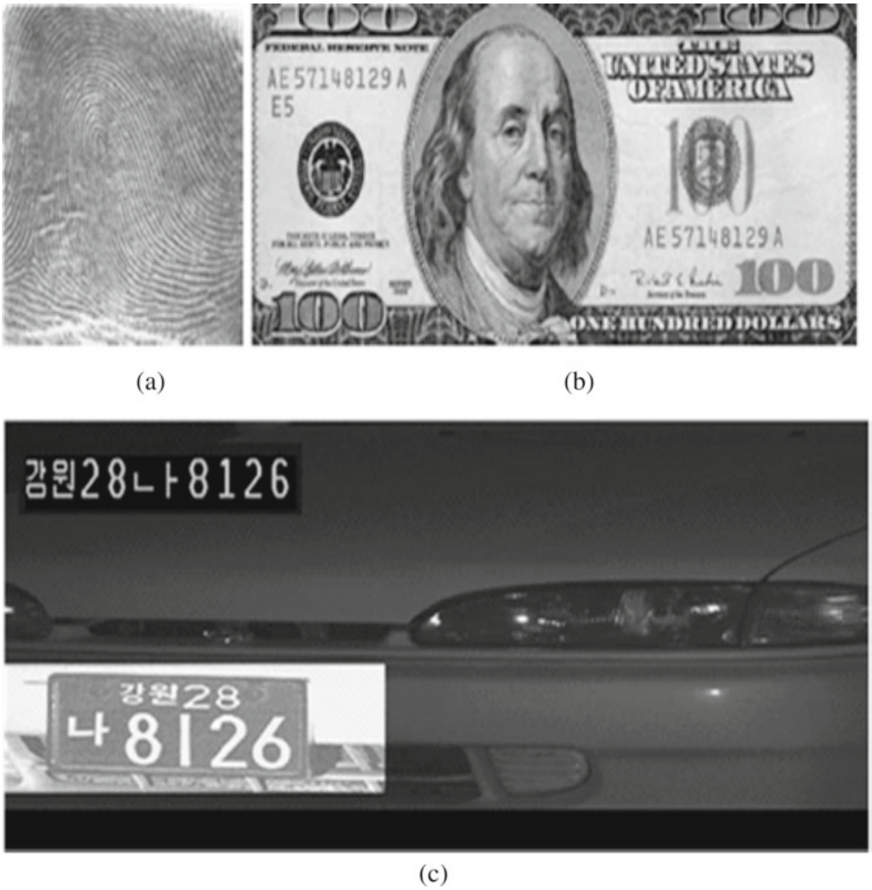


Fig. 6 Some additional examples of imaging in visual spectrum: **a** thumbprint; **b** paper currency; **c** automated license plate reading [1]

controllers, communication, etc., and their integration alleviates the congestion, boosts productivity and increases safety [4].

In [5], a bi-objective urban traffic light scheduling (UTLS) problem is addressed to minimize the total delay time of all the pedestrians and vehicles.

Another important application of ITS is in the shared bike system. In order to save the time spent waiting for bikes at the bike stations, the bike-sharing system's operator needs to dispatch the bikes dynamically. For this, a bike repository can be optimized by forecasting the number of bikes at every station. The solution to this issue of predicting the number of bikes is given in [6].

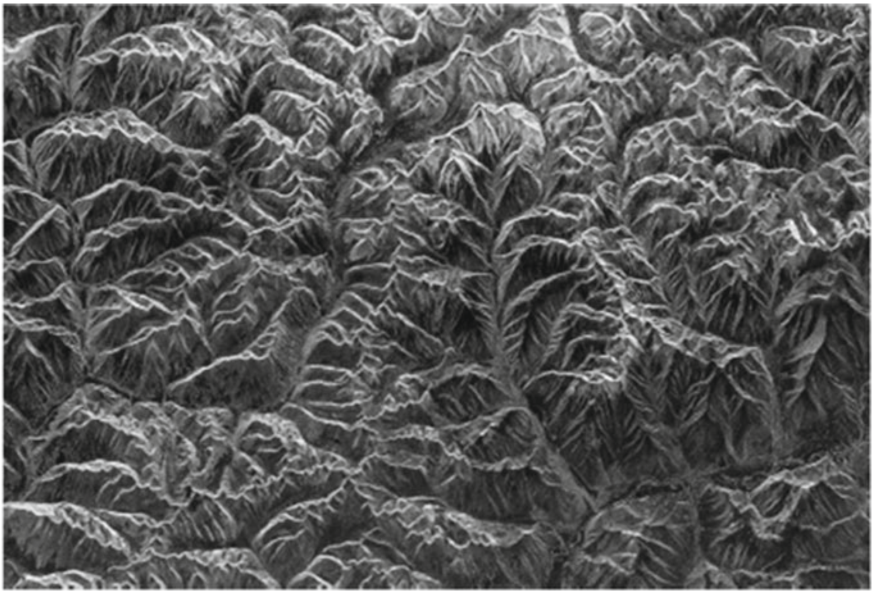


Fig. 7 Spaceborne radar image of mountains in Tibet [1]

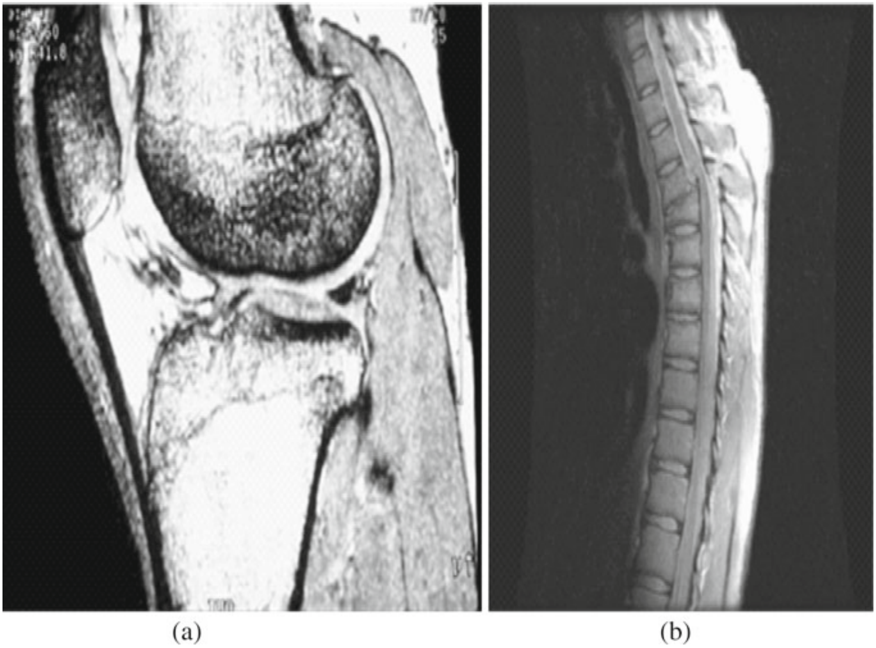


Fig. 8 MRI images of a human **a** knee; **b** spine [1]

3.2 Remote Sensing

In this application, pictures of the earth's surface are captured using remote sensing satellites mounted on aircraft and these pictures are then sent to the earth station for processing. This is useful in monitoring agricultural production, controlling flood, mobilizing the resources, city planning, etc. [2].

In [7], remote sensing imagery is used to identify soil texture classes. Soil texture is very significant in figuring out the water-retaining capacity of the soil and other hydraulic features and thereby affecting the fertility of the soil, growth of the plants and the nutrient system of soil.

Another important application of remote sensing is to detect the center of tropical cyclones so as to prevent the loss of life and economic loss in coastal areas [8].

3.3 Moving Object Tracking

The main task of this application is to access the locomotive parameters and visual accounts of moving objects [2]. Motion-based object tracking basically relies on recognizing the moving objects over time using image acquisition devices in video sequences. Object tracking has its uses in robot vision, surveillance, traffic monitoring, security and video communication [9]. An automated system to create 3D images and object tracking in the spatial domain is presented in [9].

3.4 Biomedical Imaging System

This application uses the images generated by different imaging tools like X-ray, CT scan, magnetic resonance imaging (MRI), positron emission tomography (PET) and ultrasound [1]. The main applications under this system include the identification of various diseases like brain tumors, breast cancer, epilepsy, lung diseases, heart diseases, etc.

The biomedical imaging system is widely being used in the detection of brain tumors. The brain is regarded as the command center of the human nervous system. It is responsible for controlling all the activities of the human body. Therefore, any abnormality in the brain will create a problem for one's personal health [10]. The brain tumor is an uncontrolled and abnormal propagation of cells. It not only affects the immediate cells of the brain but can also damage the surrounding cells and tissues through inflammation [11]. In [12], an automated technique is presented to detect and segment the brain tumor using a hybrid approach of MRI, discrete wavelet transform (DWT) and K-means, so that brain tumor can be precisely detected and treatment can be planned effectively.

Another application of medical imaging is gastrointestinal endoscopy used for examining the gastrointestinal tract and for detecting luminal pathology. A technique to automatically detect and localize gastrointestinal abnormalities in video frame sequences of endoscopy is presented in [13].

3.5 Automatic Visual Inspection System

The important applications of automatic visual inspection system include [14]:

- Online machine vision inspection of product dimensions,
- Identifying defects in products,
- Inspecting quantity of material filled in the product,
- Checking proper installation of airbags in cars,
- License plate reading of vehicles,
- To ensure proper manufacturing of syringes,
- Irregularity detection on flat glasses,
- Person recognition and identification,
- Dimensionality checking and address reading on parcels,
- Inspection of label printing on the box,
- Surface inspection of bathtubs for scratches and so on.

The benefits of an automatic visual inspection system include speedy inspection with less error rate and with no dependability on manpower [14].

3.6 Multimedia Forensics

Multimedia is data in different forms like audio, video, text and images. Multimedia has become an essential part of everyday life. A huge amount of multimedia content is being shared on the Internet every day by online users because of the high use of mobile devices, availability of bandwidth and cheaper storage [15]. Multimedia forensics deals with the detection of any kind of manipulation in multimedia content as well as the authenticity of the multimedia content. Multimedia forensics is about verifying the integrity and authenticity of multimedia content [16]. It follows the virtual traits to disclose the actions and intentions of hackers and to detect and prevent cybercrime. Watermarking and digital signature are used in multimedia forensics. The biggest challenge in multimedia forensics is that the amount of multimedia data is so massive that it has surpassed the forensic expert's ability of processing and analyzing it effectively. The other challenges are limited time, dynamic environment, diverse data formats and short innovation cycles [15].

Every day, a huge amount of image content is shared over the Internet. Thus, the integrity of image data is doubtful because of the easy availability of image manipulation software tools such as Photoshop. In order to tamper an image, a well-known technique of replicating a region somewhere else in the same image to imitate or hide some other region called copy–move image forgery is being used. The replicated regions are invisible to the human eye as they have same texture and color parameters. In [17], a block-based technique employing translation-invariant stationary wavelet transform (SWT) is presented to expose region replication in digital images so that the integrity of image content can be verified. In [18], a copy–move image forgery is detected by using a discrete cosine transform (DCT). DCT has the ability of accurately detecting the tampered region.

4 Conclusion

Image processing has a wide range of applications in today's world of computer and technology. It has impacted almost every field of technical endeavor. The impact of digital image processing can also be seen in human life to a great extent. Imaging applications have a wide scope of research. There is a lot yet to be developed in this field. The power of modern computer computation can be utilized to automate and improve the results of image processing and analysis. Human life has achieved great heights and can become better in the years to come through the intervention of computer technology in imaging applications.

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