# Research Opportunities and Challenges in Image Processing

Hemanth Kumar Gutlapalli*

**Abstract:** The processing of image data for storage, transmission, and representation for autonomous machine perception are the two primary application fields that have contributed to the growing interest in digital image processing technologies. The development of improved pictorial information for human interpretation is the other primary application field that has contributed to this growing interest. The purpose of this paper is to describe the scope of image processing, examine the numerous phases and techniques involved in a typical image processing, and provide examples of applications of image processing tools and procedures in cutting-edge fields of study.

**Keywords:** Image processing, Visual inspection system, Defense surveillance, Visual sense

## 1. Introduction

An image may be described as a two-dimensional function $f(x, y)$ where $x$ and $y$ are spatial (plane) coordinates. The amplitude of $f$ at any pair of spatial (plane) coordinates $(x, y)$ is referred to as the intensity or gray level of the picture at that point in the image. We refer to the picture as a digital image when all of its components, including $x$, $y$, and the magnitude values of $f$, are quantifiable and individual [1]. The processing of digital photographs by means of a digital computer is what is meant when we talk about the area of digital image processing. Take into consideration the fact that a digital picture is made up of a certain amount of pieces, separately of which has a specific position and value [2].

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*Corresponding author: Department of Data Science, Universität Trier, Universitätsring-54296, Trier

E-Mail: hemanthgutlapalli0301@gmail.com

Picture elements, image elements, pels, and pixels are some of the names that have been given to these components. The word "pixel" is the one that is used the most often to refer to the components of a digital picture [3]. It should come as no surprise, given that visualization is the best established of our senses, that the function that pictures play in human perception is the single most crucial one. Imaging machines, on the other hand, cover practically the whole electromagnetic spectrum, from gamma waves all the way down to radio waves [4]. This is in contrast to human beings, who can only see in the visible band of the electromagnetic (EM) spectrum. They are able to perform operations on pictures produced by sources that people do not often consider associated with images. Ultrasound, electron microscopy, and computer-generated pictures are all examples of these techniques. Therefore, digital image processing covers a broad and diversified range of application areas [5].

## 2. Review of literature

The stages involved in digital image processing may be broken down into two primary classifications: those whose input and yield are pictures, and those whose inputs may be pictures, but whose productions are characteristics retrieved from those images [6]. Each of these can be further subdivided into numerous subcategories.

The initial step in the process of digital image processing is known as "image acquisition." It is important to keep in mind that the acquisition process might be as easy as receiving a picture that is already in digital form. In most cases, the preprocessing step that comes before the picture capture stage includes scaling. Image enhancement is the following phase, and it is often considered to be one of the greatest user-friendly and visually engaging aspects of digital image processing [7]. The determination of image improvement approaches is to, in the most fundamental sense, bring out details that are concealed or simply to emphasize certain interesting characteristics that are present in a picture. Enhancement may be shown by the common practice of boosting the contrast of a picture so that "it looks better." It is essential to bear in attention that development is a exact subjective aspect of image processing, since this will help keep expectations realistic.

Image restoration is a subfield of digital photography that focuses on enhancing the visual quality of photographs. picture enhancement, on the other hand, is a more subjective process than picture restoration, which is objective [8]. Objective image restoration approaches tend to be based on scientific or probabilistic simulations of image deterioration, in contrast to subjective image improvement techniques. On the other hand, enhancement is reliant on human tastes for what makes a "good" enhancement outcome, and these choices are entirely subjective. The vast expansion in the transmission of digital pictures over the internet has led to a rise in the significance of the field of color image processing. This rise in relevance is mostly attributable to the proliferation of online photo sharing websites. The study of fundamental ideas in color models as well as fundamental color processing in a digital domain are required for the field of color picture processing [9]. The color of an image may serve as the foundation upon which aspects of an image that are of interest are extracted. Wavelets are the fundamental building blocks for displaying pictures with a wide range of granularities. In particular, wavelets may be used for the purpose of visual data compression as well as pyramidal representation, which is a method in which images are sequentially segmented into more compact sections.

The term "compression" refers to a group of approaches that aim to cut down on the amount of space that is needed to store a picture or the amount of bandwidth that is necessary to send it. In spite of the substantial advancements made in storage technology over the last decade, there has not been a corresponding increase in transmission capacity. This is especially evident in applications of the internet that are characterized by extensive graphical material, such as online gaming and photo sharing. The majority of people who use computers are probably already aware with picture compression in the form of image file extensions, such as the jpg file extension that is used in the JPEG image compression standard [10]. This may be the case unintentionally. The field of morphological processing is concerned with the development of methods and programs for the extraction of picture components that may be used in the representation and characterization of form. The move from procedures that produce pictures to processes that output image characteristics begins with the morphological image processing and continues with other image processing techniques. The processes of segmentation break a picture down into the individual sections or objects that compose it. The process of autonomous segmentation is generally considered to be one of the most challenging jobs involved in DIP. A robust segmentation approach puts the process a significant way toward successfully solving imaging challenges that call for individual objects to be recognized [11]. On the other hand, segmentation algorithms that are either too weak or too unpredictable nearly certainly ensure ultimate failure. In general, the accuracy with which the segmentation is performed directly correlates to the success rate of the recognition. The output of a segmentation step is often raw pixel data, which constitutes either the border of an area (i.e., the set of pixels dividing one image region from another) or all the points in the region itself. Representation and description nearly always follow the output of a segmentation stage. In either scenario, the data will need to be transformed into a format that is acceptable for processing by a computer. The very first choice that has to be made is if the data need to be shown as a border or as a whole area [12]. When the emphasis is placed on the outside features of the form, such as the corners and inflections, the boundary representation is the one that should be used.

When the emphasis is on the interior qualities of an object, such as its texture or skeletal geometry, it is suitable to use regional representation. These representations are complementary to one another when used in certain contexts. The selection of a representation is simply one piece of the puzzle when it comes to translating raw data into a form that is appropriate for later computer processing. In addition to this, a strategy must be given for characterizing the data in such a way that the elements of interest are brought to the forefront. The process of description, which is also known as feature selection, involves the extraction of qualities that either result in some quantitative information that is of interest or are fundamental for distinguishing one class of objects from another. A process called recognition is one in which an item is given a label (such as "vehicle") based on the descriptors that describe it. The techniques that may be used to identify certain items within a picture are the subject of the Recognition topic.

## 3. Image processing applications

There are a great variety of applications of image processing across a varied spectrum of human activities, ranging from the interpretation of remotely sensed scenes to the interpretation of images used in biomedicine. In this part, we will just be providing a high-level overview of a few of these applications.

### *3.1 Automatic Visual Inspection System (AVIS)*

AVIS are an absolute need in the manufacturing sector and other related businesses in order to boost both productivity and product quality simultaneously [13]. Here, we will discuss just a few visual inspection techniques in short.

- Inspection of the filaments of incandescent lamps performed automatically: Inspection of the production process for bulbs is an intriguing use of automated visual inspection that has been developed recently. The incorrect geometry of the filament, such as a lack of consistency in the pitch of the wire in the lamp, is often to blame for the rapid fusing of the filament in light bulbs after just a short period of time. The manual inspection process is inefficient at spotting such irregularities [14].
- A binary image slice of the strand is created using an automatic vision based inspection method. The silhouette of the filament is then constructed from this slice of the binary image. The analysis of this profile is done so that non-uniformities in the pitch of the filament geometry within the bulb may be determined. The General Electric Corporation is responsible for the design and installation of this kind of system.
- Identification of defective components In electrical or electromechanical systems, AVIS may also be used in order to determine the presence of defective components. In most cases, the defective parts produce a greater amount of heat energy. The distribution of thermal energy inside the assembly may be used to produce infrared (IR) pictures, which can be viewed on a computer. We are able to determine which components of the assembly are flawed by doing an IR analysis on these photos.
- Systems for the automatic examination of surfaces: In a lot of different metal sectors, the ability to spot defects on the surface is a crucial necessity [15]. For instance, in the hot or cold rolling mills that are found in a steel factory, it is necessary to identify any aberration on the surface of the rolled metal. Image processing methods such as edge recognition, texture identification, and fractal analysis, amongst others, might be used to achieve this goal.

### *3.2 An interpretation of the remotely sensed scene*

Image analysis that is based on remotely sensed data may be used to extract a variety of information relevant to natural resources, including agricultural, hydrological, mineral, forestry, and geological resources, amongst others. pictures of the earth's surface are obtained for the purpose of remotely sensed scene analysis by sensors located in remote sensing satellites or by a multi-Spectra) scanner that is housed in an aircraft. These pictures are then transferred to the Earth Station for additional treating [16]. In Fig. 1, we provide instances of two remotely sensed pictures whose color versions have been supplied in the color figure pages. These color versions may be found on the color figure pages. Block diagram of remote sensing process for weather forecasting is shown in Fig.1. The area shown in light blue represents the sediments that can be found in the delta region of the river, the region depicted in deep blue is the water body, and the regions depicted in deep red are the mangrove swamps that can be found on the neighboring islands. The glacier flow in the Bhutan Himalayas may be seen in Fig.2. The whitish area depicts the ice that has become stationary and has a decreased basal velocity [18]. Techniques for analyzing the areas and objects seen in satellite photos have applications in a wide variety of fields, including urban planning, resource mobilization, flood management, agricultural productivity monitoring, and many more.

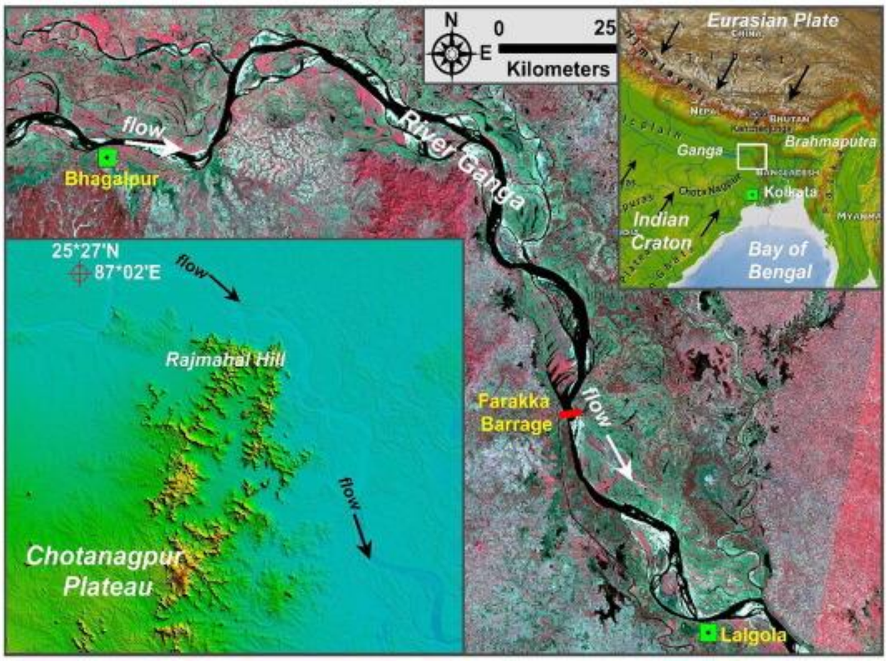



**Fig. 1:** Block diagram of remote sensing process for weather forecasting

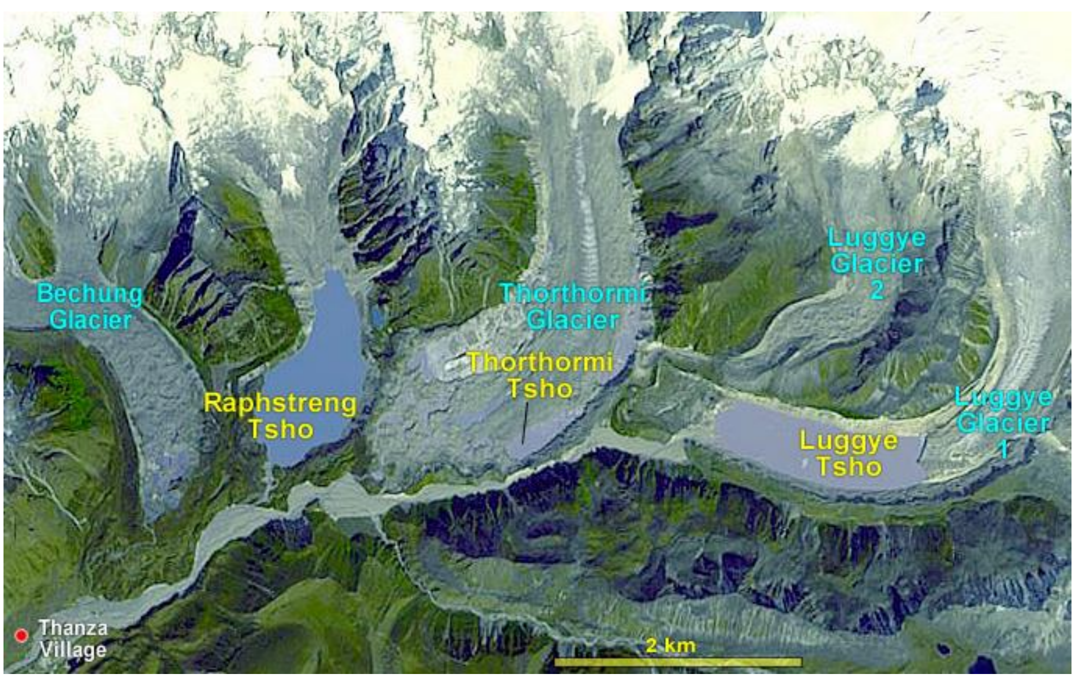
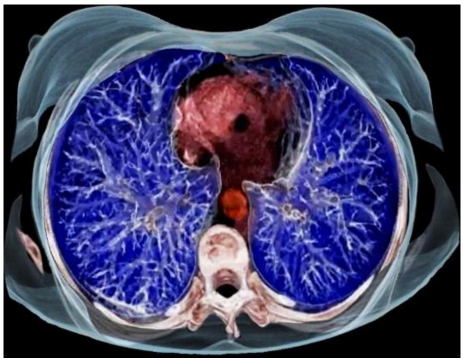



**Fig. 2:** Satellite monitoring of bhutan himalayas

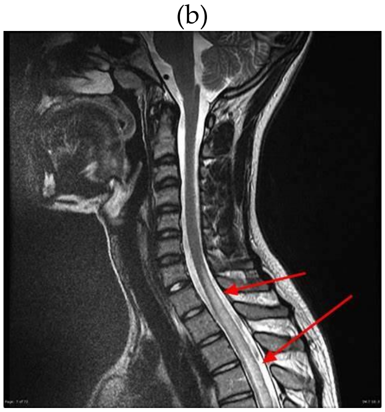
### *3.3 Techniques Utilized in Biomedical Imaging*

For the aim of medical diagnosis, a wide variety of imaging tools, such as X-rays, computer assisted tomographic (CT) pictures, ultrasound, and many others, are used to an extensive degree [19]. Fig.3 displays several examples of medical pictures obtained using various image generation modalities such as computed tomography (CT), x-ray, and magnetic resonance imaging (MRI).



(a)

(b)



(c)

**Fig. 3:** Sample biomedical images (a) CT-Scan of head (b) Palm x-ray and (c) MRI of spinal cord

(i) Locating the items of interest, such as the various organs in the picture;
(ii) Measuring the extracted objects, such as cancers in the image; and
(iii) Understanding the objects to arrive at a diagnosis.

The following are some of the applications that can be performed using biomedical imaging [20-21].

(A) The detection of lung illness may be accomplished using chest X-rays by observing that structures that hold air look darker, whereas solid tissues seem lighter in the images. When compared to soft tissue, bones have a higher radio opacity. Diaphragm, the thoracic spine, the heart and Ribs are the anatomical components that are readily apparent on a typical chest X-ray film. The diaphragm is the tissue that separates the chest chamber from the abdominal cavity. In order to determine whether or not there is anything aberrant in these areas of the chest radiographs, the respective segments are analyzed.

(B) The detection of heart illness quantitative procedures, such the shape and size of the heart are substantial diagnostic criteria that are used to categorize heart ailments. Radiographic pictures are a good candidate for using image analysis methods, which may result in a more accurate diagnosis of cardiac problems.

(C) Digital mammograms (DM): DM are very helpful in diagnosing breast tumors because they may identify abnormalities such as micro calcification. For the purpose of analyzing mammograms, many image processing methods like as shape analysis, segmentation, contrast enhancement, feature extraction, and others are used. The degree of uniformity in the contour of the tumor is one of the factors that defines whether it is benign or malignant.

### *3.4 Defense surveillance*

The study of how image processing methods may be used in the context of military surveillance is an important field of research. There is an ongoing need for airborne surveillance methods to be used for the purpose of monitoring the land and seas. Let's say we have an aerial photograph of the ocean's surface and we want to identify the different kinds of naval ships and how they are arranged [22]. The fundamental objective of this exercise is to separate the many elements that make up the image's watery background. After the segments have been extracted, the attributes used to categorize each of the segmented objects, such as area, position, perimeter, compactness, form, length, width, and aspect ratio, are discovered. These vessels might be as tiny as kayaks or as large as whole fleets of warships [23]. It is feasible to detect and locate these items by using the characteristics that were discussed before. It is necessary for us to be able to recognize the delivery of these things in the eight potential instructions in order for us to be able to characterize all of the possible forms of the vessels [24]. The sample defense survival system is shown in Fig. 4.

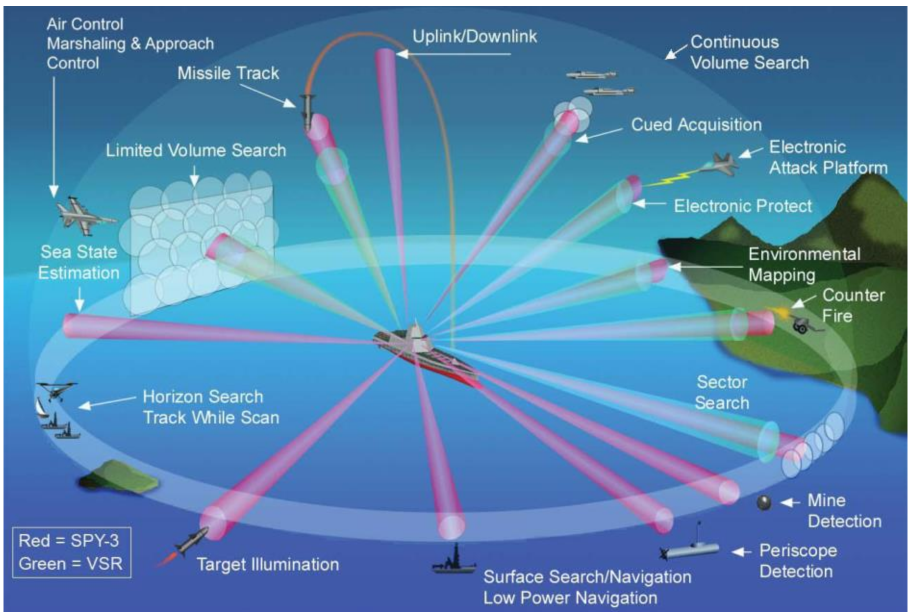



**Fig. 4:** US navys dual band radar achieves defense surveillance system

### *3.5 Searching for Pictures Based on Their Content*

Picture processing has a number of essential applications, one of which is the retrieval of a query picture from a vast image library [25]. The proliferation of massive multimedia collections and digital libraries has resulted in an enormous need for the development of search tools that can index and retrieve content from inside these collections and libraries. There are now a number of effective search engines that can get the text in a form that is understandable by machines; however, there are not a lot of quick tools that can extract the intensity and color of photographs. The conventional methods of searching for and indexing photographs are both time-consuming and resource-intensive [26]. Therefore, the development of algorithms for recovering images by making use of the material that is encoded inside them is an immediate need. It is possible to search for and retrieve pictorial information from a vast picture database by using the characteristics of a digital image as index keys. These characteristics include the shape, texture, and color of an image as well as the topology of the objects in the image. The process of locating pictures based on the information contained inside those images is often referred to as content-based image recovery [27-28]. The sample image shown in Fig.5 of block diagram of image searching based on its content.

### *3.6 Track of moving objects*

One of the most significant areas of application in image processing is tracking moving objects. This allows for the measurement of motion characteristics as well as the acquisition of a visual record of the moving item [29]. There are often two distinct methods for object tracking, which are as follows: (i) Tracking based on the object's recognition (ii) Tracking based on the object's motion.

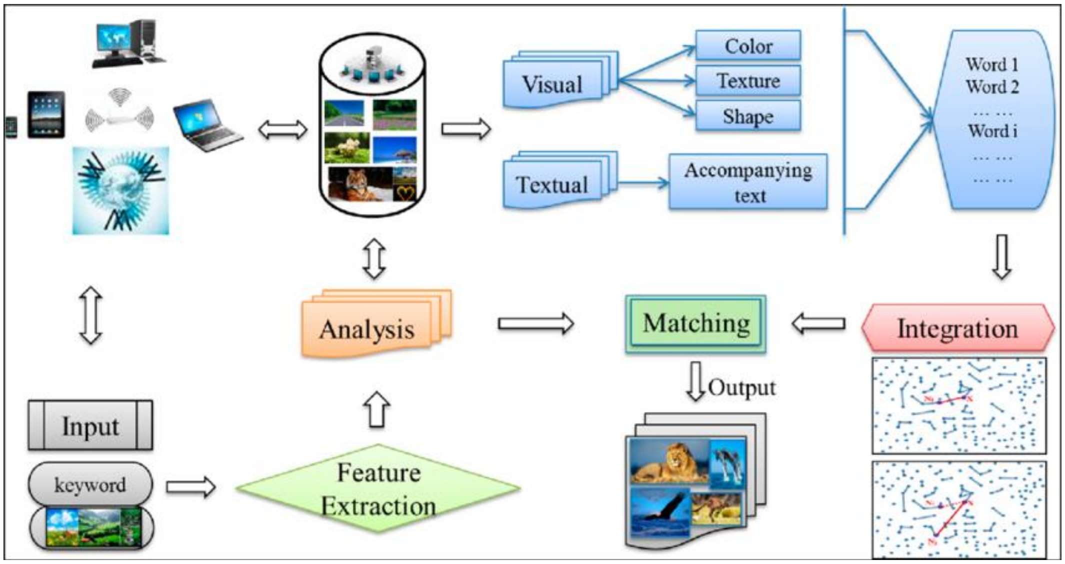



**Fig. 5:** Block diagram of image searching based on its content

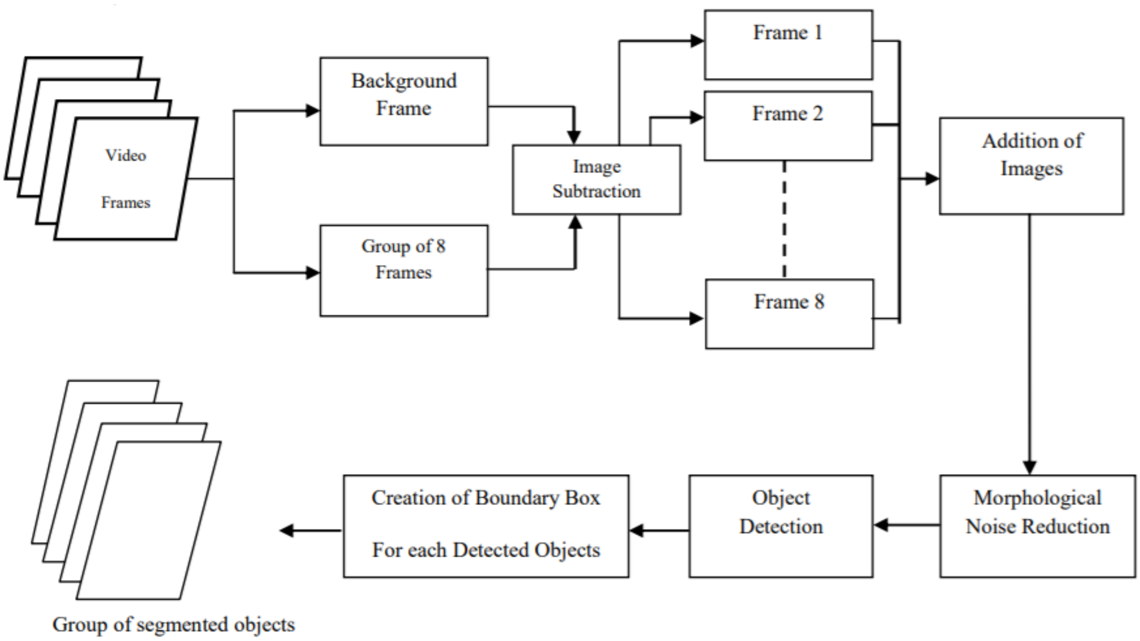



**Fig. 6:** Moving objects tracking using live recorded video

Motion-based forecast approaches such as Kalman filtering (KF), extended KF, particle filtering, and other similar approaches are used in the development of a tracking system for fast targets [30]. This system is used to monitor and keep tabs on moving objects. Target items that come within the sensor's field of vision may be captured automatically in automated object tracking systems that are based on image processing. This procedure does not need any involvement from a person. In tracking that is based on recognition, the object pattern is recognized as it is passed across consecutive picture frames, and tracking is performed utilizing the positional information that it provides [31]. Fig.6, depicts the sample moving objects tracking using live recorded video.

### 3.7 *Visual Sense*

The optic nerve is a component of our visual system that travels from the back of the eye to the back of the eyeball, where it joins with the rods and cones. Dendrites serve as inputs to the neurons, and each neuron has a long axon that terminates in an arborization to serve as outputs. Synapses are the means through which the neurons interact with one another. The transmission of signals is connected to the diffusion of the chemicals over the interface, and the receiving neurons are either activated or inhibited by these chemicals as they diffuse across the contact. The ganglion cells on one side of the retina give rise to the bundles of axons that eventually develop into the optic nerves. On the other hand, the rods and cones are linked to the ganglion cells via bipolar cells. In addition, there are parallel nerve cells that make lateral influences, which are also related to the ganglion cells. The horizontal cells in the retina aggregate the signals from adjoining receptors to create an interested field that has contrasting comebacks in the center and the boundary [32].

This ensures that a uniform lighting of the ground does not result in a net stimulus being received by the brain. In the event that the lighting is not uniform, stimulations will result from the variation in radiance between the center and the perimeter. Approximately approachable fields make advantage of color variances, such as green-red or blue-yellow, and as a result, the differencing of stimuli applies not only to brightness but also to color. For directional edge defection and eye dominance, there is additional clustering of accessible field reactions in the adjacent geniculate bodies and the graphical cortex. The processes behind this low-level processing that comes before the high-level interpretation are not entirely understood. Nevertheless, this exemplifies the significant function that differencing plays in the senses, which is the fundamental component of contrast phenomena [33].

There will be relatively little activity in the nerves if the retina is irradiated uniformly in terms of brightness and color. In a typical human retina, there are around 110 million to 130 million rods and 6 million to 7 million cones. The fibers in the optic nerves are responsible for the transmission of the optical impulses that are sent by the rods and cones in the retina. All of the indications from the right sides of the two retinas are directed to the right half of the brain, while all of the signals from the left are delivered to the left half of the brain at the point where the optic nerves cross [34].

This point is called the optic chiasma. Each hemisphere of the brain is shown one-half of the image. This guarantees that the incapacity of the visual system will not result from the loss of one of the eyes. The optical nerves terminate at the lateral geniculate bodies, which are located around halfway back through the brain, and from there, the impulses are sent to the visual cortex. The visual cortex retains the architecture of the retina and serves just as the first step in the perceptual process, during which information is made accessible. The corpus callosum is responsible for uniting the left and right sides of the visual field. It does this by connecting visual areas that are located in the two hemispheres of the brain. Fig.7 shows the sample visual sensing system.

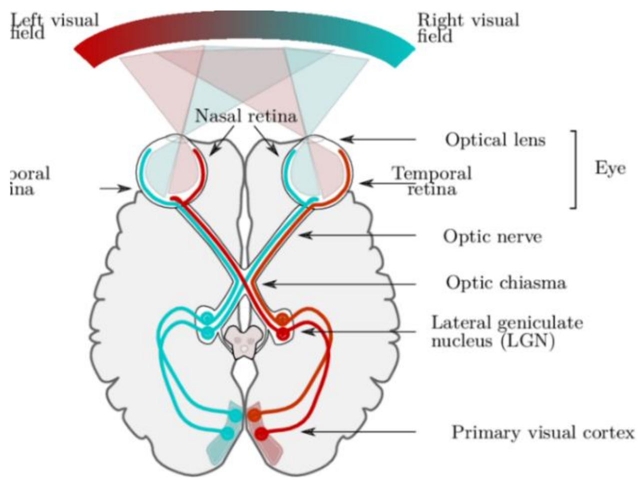



**Fig. 7:** Visual sensing system

## 4. Conclusion

The researcher has the opportunity to select one of the regions of attention to him from the large variety of applications that may be achieved via image processing. Even if many discoveries from study are released, there are still many research fields that have not been explored. In addition, since firm computers and signal processors were readily available in the 2000s, DIP became the maximum frequent type of image processing. DIP is usually employed because it is not only the approach that offers the greatest flexibility, but it also offers the lowest cost.

## Conflict of Interest

Authors declare "No conflict of interest"

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