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An analysis on Research Opportunities and Challenges in the field of Image Processing

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ABSTRACT *Interest in digital image processing methods stems from two principal application areas: improvement of pictorial information for human interpretation; and processing of image data for storage, transmission, and representation for autonomous machine perception. The objectives of this article are to define the meaning and scope of image processing, discuss the various steps and methodologies involved in a typical image processing, and applications of image processing tools and processes in the frontier areas of research.*

1. Introduction

An image may be defined as a two-dimensional function, $f(x, y)$, where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point. When x, y, and the amplitude values of f are all finite, discrete quantities, we call the image a digital image. The field of digital image processing refers to processing digital images by means of a digital computer. Note that a digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pels, and pixels. Pixel is the term most widely used to denote the elements of a digital image.

Vision is the most advanced of our senses, so it is not surprising that images play the single most important role in human perception. However, unlike humans, who are limited to the visual band of the electromagnetic (EM) spectrum, imaging machines cover almost the entire EM spectrum, ranging from gamma to radio waves. They can operate on images generated by sources that humans are not accustomed to associating with images. These include ultrasound, electron microscopy, and computer-generated images. Thus, digital image processing encompasses a wide and varied field of applications [1].

2. Fundamental steps in digital image processing

The digital image processing steps can be categorized into two broad areas as the methods whose input and output are images, and methods whose inputs may be images, but whose outputs are attributes extracted from those images.

Image acquisition is the first process in the digital image processing. Note that acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves pre-processing, such as scaling.

The next step is image enhancement, which is one among the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. A familiar example of enhancement is when we increase the contrast of an image because "it looks better." It is important to keep in mind that enhancement is a very subjective area of image processing.

Image restoration is an area that also deals with improving the appearance of an image. However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation. Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a "good" enhancement result.

Color image processing is an area that has been gaining in importance because of the significant increase in the use of digital images over the Internet. Color image processing involves the study of fundamental concepts in color models and basic color processing in a digital domain.

Compression, as the name implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it. Although storage technology has improved significantly over the past decade, the same cannot be said for transmission capacity. This is true particularly in uses of the Internet, which are characterized by significant pictorial content. Image compression is familiar (perhaps inadvertently) to most users of computers in the form of image file extensions, such as the jpg file extension used in the JPEG image compression standard.

Boundary representation is appropriate when the focus is on external shape characteristics, such as corners and inflections. Regional representation is appropriate when the focus is on internal properties, such as texture or skeletal shape. In some applications, these representations complement each other. Choosing a representation is only part of the solution for transforming raw data into a form suitable for subsequent computer processing. A method must also be specified for describing the data so that features of interest are highlighted. Description, also called feature selection, deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another.

Recognition is the process that assigns a label (e.g., "ve-

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hicle") to an object based on its descriptors. Recognition topic deals with the methods for recognition of individual objects in an image.

3. Applications of image processing

There are a large number of applications of image processing in diverse spectrum of human activities-from remotely sensed scene interpretation to biomedical image interpretation. In this section we provide only a cursory glance in some of these applications.

3.1. Automatic Visual Inspection System

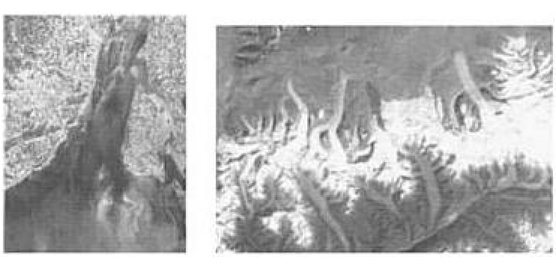
Automated visual inspection systems are essential to improve the productivity and the quality of the product in manufacturing and allied industries [2]. We briefly present few visual inspection systems here.

• Automatic inspection of incandescent lamp filaments: An interesting application of automatic visual inspection involves inspection of the bulb manufacturing process. Often the filament of the bulbs get fused after short duration due to erroneous geometry of the filament.

• Automatic surface inspection systems: Detection of flaws on the surfaces is important requirement in many metal industries. This can be accomplished by using image processing techniques like edge detection, texture identification, fractal analysis, and so on.

3.2. Remotely Sensed Scene Interpretation

Information regarding the natural resources, such as agricultural, hydrological, mineral, forest, geological resources, etc., can be extracted based on remotely sensed image analysis. For remotely sensed scene analysis, images of the earth's surface arc captured by sensors in remote sensing satellites or by a multi-Spectra) scanner housed in an aircraft and then transmitted to the Earth Station for further processing [3, 4]. We show examples of two remotely sensed images in Figure 1 whose color version has been presented in the color figure pages. Figure 1(a) shows the delta of river Ganges in India. The light blue segment represents the sediments in the delta region of the river, the deep blue segment represents the water body, and the deep red regions are mangrove swamps of the adjacent islands. Figure 1.1(b) is the glacier flow in Bhutan Himalayas. The white region shows the stagnated ice with lower basal velocity.



(a) (b)

Fig. 1: Example of a remotely sensed image of (a) delta of river Ganges, (b) Glacier flow in Bhutan Himalayas

Techniques of interpreting the regions and objects in satellite images are used in city planning, resource mobilization, flood control, agricultural production monitoring, etc.

3.3. Biomedical Imaging Techniques

Various types of imaging devices like X-ray, computer aided tomographic (CT) images, ultrasound, etc., are used extensively for the purpose of medical diagnosis [5]-[6]. Examples of biomedical images captured by different image formation modalities such as CT-scan, X-ray, and MRI are shown in Figure 2.

(a) (b) (c)

Fig. 2: Examples of (a) CT Scan image of brain, (b) X-ray image of wrist and (c) MRI image of brain

(i) localiz ing the objects of interest, i.e. different organs
(ii) taking the measurements of the extracted objects, e.g. tumors.
(iii) interpreting the objects for diagnosis.

Some of the biomedical imaging applications are presented below.

(A) Lung disease identification: In chest X-rays, the structures containing air appear as dark, while the solid tissues appear lighter. Bones are more radio opaque than soft, tissue. The anatomical structures clearly visible on a normal chest X-ray film are the ribs, the thoracic spine, the heart, and the diaphragm separating the chest cavity from the ab-dominal cavity. These regions in the chest radiographs are examined for abnormality by analyzing the corresponding segments.

(B) Heart disease identification: Quantitative measurements such as heart size and shape are important diagnostic features to classify heart diseases. Image analysis techniques may be employed to radiographic images for improved diagnosis of heart diseases.

(C) Digital mammograms: Digital mammograms are very useful in detecting features such as micro-calcification in order to diagnose breast tumor. Image processing techniques such as contrast enhancement, segmentation, feature extraction, shape analysis, etc. are used to analyze mammograms. The regularity of the shape of the tumor determines whether the tumor is benign or malignant.

3.4. Defense surveillance

Application of image processing techniques in defense surveillance is an important area of study. There is a continuous need for monitoring the land and oceans using aerial surveillance techniques.

Suppose we are interested in locating the types and formation of naval vessels in an aerial image of ocean surface. The primary task here is to segment different objects in the water body part of the image. After extracting the segments, the parameters like area, location, perimeter, compactness, shape, length, breadth, and aspect ratio are found, to classify each of the segmented objects. These objects may range from small boats to massive naval ships. Using the above features it is possible to recognize and localize these objects.

3.5. Neural Aspects of the Visual Sense

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The optic nerve in our visual system enters the eyeball and connects with rods and cones located at the back of the eye.

The neurons contain dendrites (inputs), and a long axon with an arborization at the end (outputs). The neurons communicate through synapses. The transmission of signals is associated with the diffusion of the chemicals across the interface and the receiving neurons arc either stimulated or inhibited by these chemicals, diffusing across the interface. The optic nerves begin as bun-dles of axons from the ganglion cells on one side of the retina. The rods and cones, on the other side, are connected to the ganglion cells by bipolar cells, and there are also horizontal nerve cells making lateral connections.

The signals from neighboring receptors in the retina are grouped by the horizontal cells to form a receptive field of opposing responses in the center and the periphery, so that a uniform illumination of the field results in no net stimulus. In case of nonuniform illumination, a difference in illumination at the center and the periphery creates stimulations. Some receptive fields use color differences, such as red-green or yellow-blue, so the differencing of stimuli applies to color as well as to brightness. There is further grouping of receptive field responses in the lateral geniculate bodies and the visual cortex for directional edge defection and eye dominance.

Conclusion

Image processing has wide verity of applications leaving option to the researcher to choose one of the areas of his interest. Lots of research findings are published but lots of research areas are still untouched. Moreover, with the fast computers and signal processors available in the 2000s, digital image processing has become the most common form of image processing and generally, is used because it is not only the most versatile method, but also the cheapest.

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