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Research Opportunities and Challenges in 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

The amplitude of fat any pair of coordinates (x, y) is called the intensity or grey level of the image at that place. An image can be defined as a two-dimensional function, f(x, y), where x and y are spatial (plane) coordinates. The image is called a digital image when x, y, and the amplitude values of f are all finite, discrete quantities. The field of digital image processing refers to the use of a digital computer to process digital images. It's important to remember that a digital image is made up of a finite number of pieces, each of which has its own location and value. Picture elements, image elements, pels, and pixels are all terms used to describe these elements. Pixel is the most commonly used term to describe the components of a digital image. Because vision is the most advanced of our senses, it's no surprise that images are the most crucial factor in human perception. Imaging machines, on the other hand, cover practically the whole electromagnetic (EM) spectrum, extending from gamma to radio waves, unlike humans, who are limited to the visual band of the EM spectrum. They can work with visuals that come from sources that humans aren't used to identifying with images. Ultrasound, electron microscopy, and computer-generated images are examples of these. . Thus, digital image processing encompasses a wide and varied field of applications

2. Fundamental steps in digital image processing

The digital image processing procedures can be divided into two categories: ways with images as input and output, and techniques with images as input but attributes extracted from those images as output.

Picture enhancement is the next phase, and it is one of the most straightforward and appealing aspects of digital image processing. Enhancement techniques are used to bring out detail that has been concealed or to simply highlight certain features of interest in an image. When we raise the contrast of an image because “it looks better,” this is an example of enhancement. It's vital to remember that picture enhancement is a highly subjective process.

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. Image color can be used as the basis for extracting features of interest in an image. Wavelets are the foundation for representing images in various degrees of resolution. In particular, wavelets can be used for image data compression and for pyramidal representation, in which images are subdivided successively into smaller regions.

Segmentation is a technique for dividing a picture into its component components or objects. In general, one of the most difficult tasks in digital image processing is autonomous segmentation. A robust segmentation approach takes the process a long way toward solving image challenges that need individual object identification. Weak or irregular segmentation methods, on the other hand, virtually invariably result in failure. In general, the more precise the segmentation, the better the chances of recognition.

The output of a segmentation step, which is normally raw pixel data, is nearly always followed by representation and description, which constitutes either the region's boundary (i.e., the set of pixels dividing one image region from another) or all the points within the region itself. In either situation, the data must be converted into a format that can be processed by a computer. The first option to be taken is whether to portray the data as a border or as a complete regionWhen the focus is on external shape properties such as corners and inflections, boundary representation is appropriate. When the focus is on internal qualities such as texture or skeletal shape, regional representation is acceptable. These representations complement one other in various applications.

Choosing a representation is simply one aspect of the process of translating raw data into a format that can be processed by a computer. A strategy for characterizing the data must also be defined in order to highlight features of interest. Description, also known as feature selection, is the process of selecting features that produce quantitative information of interest or are necessary for distinguishing one object class from another. The practise of assigning a label (e.g., "car") to an item based on its descriptors is known as recognition. The methods for recognising specific items in an image are covered in the Recognition subject.

3. Applications of image processing

Picture processing has a wide range of applications in human activities, ranging from remotely sensed scene interpretation to biological image interpretation. We simply give a quick look at some of these applications in this section.

3.1. Automatic Visual Inspection System

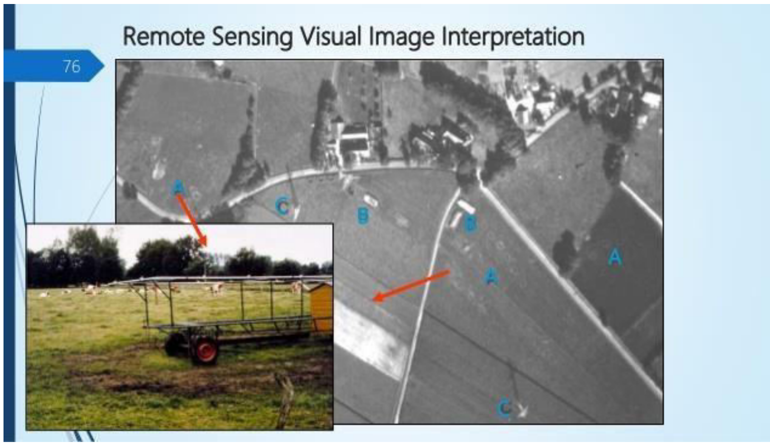
In the manufacturing and related industries, automated visual inspection systems are critical for increasing productivity and product quality [2]. A few visual inspection systems are briefly presented below. • Automated filament checking for incandescent lamps: Inspection of the bulb production process is an intriguing use of automatic visual inspection. Because of incorrect filament geometry, such as nonuniformity in the pitch of the lamp wiring, the filaments of the bulbs frequently fuse after a short time. Manual inspection is ineffective in detecting such anomalies.

• Identification of problematic components in electronic and electromechanical systems: Automated visual inspection can also be used to identify problematic components in electronic and electromechanical systems. The thermal energy generated by malfunctioning components is frequently higher. The distribution of thermal energy in the assembly can be used to generate infrared (IR) images. We can detect the faulty components in the assembly by studying these infrared photos.

• Automatic surface inspection systems: In many metal sectors, detecting faults on the surface is a must. It is necessary to detect any irregularity on the rolled metal surface in a steel plant's hot or cold rolling mills, for example. Edge detection, texture identification, fractal analysis, and other image processing techniques can help with this.

3.2. Remotely Sensed Scene Interpretation

Remotely sensed image analysis can be used to extract information about natural resources such as agricultural, hydrological, mineral, forest, and geological resources. Images of the earth's surface arc collected by remote sensing satellite sensors or a multi-Spectra) scanner housed in an aircraft for remotely sensed scene analysis, and then transferred to the Earth Station for additional processing [3, 4]. Figure 1 shows two remotely sensed images, one of which has a colour version that may be found on the colour figure pages. The Ganges delta in India is seen in Figure 1(a). The light blue section depicts the river's delta sediments, the deep blue segment depicts the water body, and the deep red portions indicate the nearby islands' mangrove swamps. The glacier flow in Bhutan's Himalayas is seen in Figure 1.1(b). The stalled ice with reduced basal velocity is depicted in white.



In city planning, resource mobilisation, flood management, agricultural production monitoring, and other applications, techniques for analysing areas and objects in satellite pictures are applied.

3.3. Biomedical Imaging Techniques

Various imaging devices, such as X-rays, computer-aided tomographic (CT) pictures, ultrasound, and others, are widely utilised for medical diagnostics [5]-[7]. Figure 2 shows examples of biological images collected by various image generation modalities such as CT scan, X-ray, and MRI.

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(b) (c)

(a) CT scan of the brain, (b) X-ray image of the wrist, and (c) MRI imaging of the brain.

(i) locating the objects of interest, such as different organs; (ii) measuring the retrieved objects, such as tumours in the image; and (iii) diagnosing the objects. The following are some examples of biomedical imaging applications. (A) Diagnosis of lung disease: The structures containing air look dark on chest X-rays, while the solid tissues appear lighter. Soft tissue is more radio opaque than bones. The ribs, thoracic spine, heart, and diaphragm that separates the chest chamber from the abdominal cavity are all plainly visible anatomical components on a typical chest X-ray film. (B) Diagnosing heart disease: Quantitative measurements such as heart size and shape are significant diagnostic criteria for classifying heart illnesses. For better diagnosis of heart disorders, image analysis techniques can be applied to radiography images. (C) Digital mammograms: Digital mammograms are extremely useful for detecting characteristics (such as microcalcification) that can help diagnose breast cancer. Mammograms are analysed using image processing techniques such as contrast enhancement, segmentation, feature extraction, shape analysis, and so on. The benign or malignant nature of a tumour is determined by the regularity of its shape.

3.5. Content-Based Image Retrieval

The retrieval of a query image from a vast image archive is a common image processing task. The introduction of enormous multimedia collections and digital libraries has necessitated the creation of search tools for indexing and retrieving data from them. There are several good search engines available now for retrieving machine-readable text, but there are few quick tools for retrieving intensity and colour images. Traditional methods for searching and indexing photographs are time- consuming and costly. As a result, techniques for recovering images utilising the embedded content in them are urgently needed. Shape, texture, colour, topology of objects, and other characteristics of a digital image can be used as index keys for searching and retrieving pictorial information from a vast image collection. The typical term for image retrieval based on such image contents is content-based retrieval.

3.7. Neural Aspects of the Visual Sense

Our visual system's optic nerve enters the eyeball and links to the rods and cones at the rear of the eye. Dendrites (inputs) and a lengthy axon with an arborization at the end are seen in neurons (outputs). Synapses are the connections between neurons. The diffusion of chemicals over the interface is related with signal transmission, and the receiving neurons are either activated or inhibited by the chemicals that are diffusing across the interface. On one side of the retina, the optic nerves originate as bundles of axons from ganglion cells. Bipolar cells connect the rods and cones to the ganglion cells on the other hand, and there are also horizontal nerves. The formation of lateral connections between nerve cells.

A normal human retina contains 6 to 7 million cones and 110 to 130 million rods. Optical impulses from rods and cones are transmitted by the optic nerve fibres. All signals from the right sides of the two retinas are conveyed to the right half of the brain, and all signals from the left are sent to the left half of the brain, where the optic nerves cross at the optic chiasma. Each hemisphere of the brain receives half of a picture. This prevents the visual system from being disabled if one of the eyes is lost. The optical nerves terminate halfway back in the brain at the lateral geniculate bodies, where the impulses are relayed to the visual cortex. The visual cortex retains the retina's architecture and is only the initial stage in perception, when data is made available. The corpus callosum , which connects the halves of the visual field, connects visual regions in two cerebral hemispheres.

4. Conclusion

Image processing provides a wide range of applications, allowing the researcher to focus on one of his interests. Many study discoveries have been published, yet many study areas remain unexplored. Furthermore, with the fast computers and signal processors accessible in the 2000s, digital image processing has become the most frequent kind of image processing, and it is frequently employed since it is not only the most versatile but also the most cost-effective way.

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