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DIRECTIONS FOR DIGITAL IMAGE PROCESSING

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ABSTRACT: *Applications of digital imaging include a wide variety of fields, and advances in image processing allow for the generation of three-dimensional reconstructions, object detection, and analysis, providing new possibilities for image visualization and recognition.*

KEY WORDS: *Digital images, Photogrammetry.*

1. Introduction

Digital image processing is developing as a scientific discipline dealing with the analysis and modification of raster images presented in digital form. The foundation for this process was laid in the middle of the 20th century with the invention of electronic sensors and algorithms for data processing, which gradually replaced classical analog methods. Early approaches involved transforming analogue images into digital ones by scanning or by directly capturing with digital cameras. These processes led to the possibility of creating discrete two-dimensional functions, which became the basis for the development of modern algorithms for image enhancement, compression and analysis [4,5,6].

The evolution of these technologies highlights the importance of digital images as a means of collecting, processing, and interpreting visual data. This process combines the mathematical principles of sampling, algorithmic image enhancement and their application in practice [2,4,5,6].

2. Main areas of digital image processing

Digital image processing is a key area in modern technology that includes various methods and algorithms that allow images to be created, manipulated, analyzed, and enhanced. Digital image processing technologies are fundamental to many industries, including medicine, security, animation, arts and many others, and each field of digital image processing has its own significance and application in practice [1,4,5,6,7,8,9].

2.1 Low-level image processing – it involves basic image manipulations that improve their quality and visual characteristics. This stage usually consists of removing noise, improving contrast, sharpening details and correcting brightness, namely [4,5,6]:

❖ ***Image filtering***

One of the main methods in low-level image processing is filtering, which involves using various filters to manipulate the pixel values in the image. Common filters include:

- Gaussian filtering – used to reduce image noise and smooth out color transitions while preserving important characteristics;
- Median filtering – an effective method of removing noise by replacing each pixel with the median value of the surrounding pixels;
- Convolutional filters – these filters can be used for a variety of purposes such as blurring and sharpening edges.

The use of these filters is particularly important in fields such as medicine (for example, to better distinguish organs or tissues) and in satellite images to remove images that may be due to weather conditions [4,5,6].

❖ ***Improve contrast and brightness***

One of the main aspects in low-level image processing is adjusting the brightness and contrast of images. This may include the use of adaptive contrast correction, which makes details clearer by adjusting light and darkness in the image. Adjustments can be made by adjusting pixel levels or by local adaptation, allowing algorithms to work with specific areas of the image rather than applying the adjustments globally [4,5,6].

Another major strand for digital image processing is mid-level image processing, which involves more complex stages such as segmentation and classification, which require the use of more complex algorithms to extract information from the image. These processes are critical for object recognition and analysis and are [4,5,6]:

❖ ***Image segmentation***

Segmentation is the process of dividing an image into different parts or objects that have common characteristics. This is an important milestone because it allows systems to identify and locate important structures in the image. Some of the main segmentation methods include [4,5,6]:

- Edge-based segmentation – uses algorithms such as "Canny edge detection" to detect edges in the image and separate objects along those edges;

- Segmentation based on areas – methods such as pixel classification or global optimization to divide the image into areas with different textures or color characteristics;
- Active Outlines – A method that uses outlines that adapt and move through the image to depict the objects in the image.

Segmentation is widely used in medical imaging as well as autonomous vehicles, where the recognition of road objects and signs is critical.

❖ ***Image classification***

Once an image has been segmented, it can be subjected to classification, which assigns labels to different parts or entire images. Classification can be carried out using various techniques [4,5,6]:

- Machine learning methods, such as reference vector machines (SVMs), which are used to categorize images into different classes;
- Convolutional neural networks (CNNs), which are used in the latest algorithms. They are particularly effective at recognizing objects in images, being able to achieve very high accuracy in a variety of industrial applications, including face and object recognition.

2.2 High-level image processing – it involves complex analyses and interpretations that extract useful information from the image, such as object recognition or interpretation of the context in the image, and include [3,4,5,6]:

❖ ***Object recognition***

Object recognition is the process by which image analysis algorithms are used to identify and classify specific objects or structures within them. These technologies are fundamental in the field of autonomous vehicles, surveillance systems, and security applications that need automatic recognition of people, vehicles, or other objects. Basic object recognition technologies include [4,5,6]:

- Deep neural networks that can perform object recognition in high-level images using big data training;
- Image aggregation models that cover not only individual objects but also the context in the image (e.g. road condition recognition in car cameras).

❖ ***Image interpretation***

Image interpretation requires not only identifying objects, but also understanding the relationships between them. This involves the use of semantic segmentation technologies, in which each pixel in an image is categorized according to the meaning it carries, for example, as part of a sky, water, building, etc. This is necessary to create fully automated image analysis systems. Context-gathering models can analyze images to detect complex structures and interpret them in accordance with the real world [4,5,6,10].

Digital image processing can also be divided into the following areas [4,5,6]:

❖ ***Improve image quality***

Image enhancement includes methods to reduce noise, increase contrast, and improve resolution. This process is carried out through:

- Filtration – using linear and non-linear filters to smooth or sharpen images;
- Gamma Correction – non-linear brightness conversion to optimize visualization;
- Histogram methods – techniques such as histogram alignment and stretching improve the brightness distribution in the image.

❖ ***Image compression***

Compression aims to reduce the amount of data required to represent the image. There are two main types of compression:

- Lossy compression – techniques such as JPEG remove unnecessary details that are barely visible to the human eye;
- Lossless compression – formats such as PNG and TIFF store images in their entirety.

Compression plays a key role in image storage and transmission, especially in telecommunications and internet applications [4,5,6].

❖ ***Image segmentation***

Applications of segmentation include:

- Medical analysis – separation of organs and tissues during imaging diagnostics (ultrasound, X-ray, CT);
- Computer vision – object recognition.

Segmentation methods include gradient-based threshold processing and machine learning methods [4,5,6].

❖ ***Image restoration***

Restoration focuses on restoring damaged images. Unlike improvement, here the goal is to eliminate specific defects such as:

- Noise – removal by mathematical filters (Gaussian and median filters);
- Blurring – using methods such as reverse filtration and deconvolution.

Restoration is especially useful when processing images from old or defective devices [4,5,6].

❖ ***Geometric transformations***

Geometric transformations involve changing the shape and size of an image by:

- Rotation and zoom – change the orientation or dimensions of images;
- Interpolation – methods such as bilinear and bicubic interpolation are used to recalculate pixel values in transformations.

Such processes are used in cartography and three-dimensional modeling.

❖ ***Color correction and processing***

Colour treatment covers:

- Convert between color patterns – e.g. from RGB to CMYK for printing;
- Color correction – optimizing the color gamut for better visualization;
- White Balance – Light correction to remove color distortion.

Color processing is critical in the advertising industry and photography.

❖ **Image analysis** – it includes object recognition (using algorithms to identify objects and faces) and feature extraction (analyzing textures, contours, and shapes). This type of processing is the basis for artificial intelligence and autonomous systems [4,5,6].

Digital image processing is a multifaceted field that combines technologies for image enhancement, restoration, compression, and analysis. Advances in computer technology and machine learning algorithms are accelerating the development of new methods that make image processing faster and more efficient, and its diverse applications, from medicine to robotics, demonstrate its enormous potential in the modern technological world [4,5,6,10].

It can be summarized that digital image processing is a multifaceted and rapidly evolving process that includes multiple stages and technologies. From basic tasks such as filtering and brightness correction to complex methods for segmentation, classification, and object recognition, image processing is an essential part of many modern applications in industries such as medicine, security, automotive, and the arts. In the future, with the advancement of AI and machine learning, digital image processing will continue to develop and play an even greater role in our daily lives, providing new opportunities for analyzing and using visual data [4,5,6].

3. Conclusion

The main directions of digital image processing cover different levels, from basic pixel-level manipulations to complex algorithms for segmentation, classification and interpretation. At the low level, operations such as filtering and quality enhancement are performed, while at the medium and high levels, technologies such as deep neural networks for object recognition, scene segmentation and context analysis are used. Artificial intelligence and machine learning play a key role in the automation of these processes, contributing to the development of new and innovative applications in areas such as medical diagnostics, security, autonomous vehicles and virtual reality [4,5,6].

The development of digital images and their processing is not only an example of the progress of technology, but also of the importance of these technologies in our society. From historical experiments to modern innovations, digital images continue to play a central role in many fields, offering unlimited possibilities for future scientific discoveries and technological applications [4,5,6].

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