International Journal of Image Processing and Vision Science

Volume 2 | Issue 3 Article 2

May 2022

Digital Image Processing

Abhinav Deshpande
Internal Full Time (IFT) Ph.D. Research Scholar,School of Electronics Engineering (SENSE),Vellore Institute of Technology (VIT),Vellore,Tamil Nadu (T.N.),India-632014, avd.a.deshpande@gmail.com

Digital Image Processing

Cover Page Footnote

We thank the management of VIT University for their timely cooperation and kind support in facilitating this program and providing all necessary materials. We should not forget the contributions made by the staff and faculty members of this university to the realization of this project.

Digital Image Processing (DIP)

Mr. AbhinavV. Deshpande

Internal Full Time (IFT) Ph.D. Research Scholar

School of Electronics Engineering (SENSE)

VIT University

avd.a.deshpande@gmail.com

Abstract:

Digital image processing is the use of a digital computer to process a digital image using an algorithm. As a subcategory or area of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as noise accumulation and distortion during processing. This review article provides a comprehensive literature review of various image processing techniques along with a brief introduction to digital image processing that defines its scope and importance, thereby highlighting the importance of its use in the field of electronic engineering applications that are used in today's commercial and industrial scenarios. It takes into consideration the research work done by various leading scholars in the field of electronic engineering and also the description of various software tools like MATLAB which is used for the practical implementation of the given problem lying in its domain.

Keywords: Digital Image Processing (DIP), Image, Pixel, Noise, Filtering

1.Introduction:

1.1. Digital Image Processing (DIP):

Digital image processing is the use of a digital computer to process digital images using an algorithm[1-5]. As a subcategory or area of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as noise accumulation and distortion during processing. Since images are defined in two dimensions (perhaps more), digital image processing can be modeled in the form of multidimensional systems. The emergence and development of digital image processing is mainly influenced by three factors: first, the development of computers; second, the development of mathematics (especially the creation and improvement of the theory of discrete mathematics); third, the demand for a wide range of applications in the environment, agriculture, military, industry and medical science has increased.

1.2. History:

Many digital image processing techniques, or digital image processing as it was often called, were developed in the 1960s at Bell Laboratories, the Jet Propulsion Laboratory, the Massachusetts Institute of Technology, the University of Maryland, and several other research facilities. with application to satellite imagery, wire-to-photo standards conversion, medical imaging, videophone, character recognition, and photo enhancement[6-10]. The purpose of early image processing was to improve image quality. It was aimed at human beings to improve the visual effect of people. In image processing, the input is a low-quality image and the output is an improved quality image. Common image processing includes image enhancement, restoration, encoding and compression. The American Jet Propulsion Laboratory (JPL) was the first successful application.

They applied image processing techniques such as geometric correction, gradation transformation, noise removal, etc. to thousands of lunar photographs sent back by Space Detector Ranger 7 in 1964, taking into account the position of the sun and the lunar environment. The impact of successfully mapping the surface of the Moon by computer was a huge success. Later, more complex image processing was performed on nearly 100,000 photos sent back by the spacecraft, resulting in a topographic map, a color map and a panoramic mosaic of the Moon, which achieved extraordinary results and laid a solid foundation for a human landing on Earth. Moon.

However, processing costs were quite high with the computing equipment of the time. This changed in the 1970s when digital image processing proliferated as cheaper computers and dedicated hardware became available. This led to real-time image processing for some specialized problems, such as TV standards conversion. As general-purpose computers became faster, they began to take over the role of dedicated hardware for all but the most specialized and demanding operations. With fast computers and signal processors available in the 2000s, digital image processing has become the most common form of image processing and is generally used because it is the cheapest as well as the most versatile.

1.3. Image Sensors:

The foundation of modern image sensors is metal-oxide-semiconductor (MOS) technology,[11-15] which dates back to the invention of the MOSFET (MOS field-effect transistor) by Mohamed M. Atalla and Dawon Kahng at Bell Labs in 1959.[5] 6] This led to the development of digital solid-state image sensors, including CCD (charge-coupled device) and later CMOS sensors.Williard S. Boyle invented the charge-coupled device and George E. Smith at Bell Laboratories in 1969[16-20].While researching MOS technology, they realized that electric charge is analogous to a magnetic bubble and that it can be stored on a small MOS capacitor. Since it was relatively simple to make a series of MOS capacitors in series, they connected the appropriate voltages so that they could be charged sequentially from one to the other[1-5]. The CCD is a solid-state circuit that was later used in the first digital video cameras for broadcast television. The NMOS active pixel sensor (APS) was invented by Olympus in Japan in the mid-1980s. This was made possible by advances in MOS semiconductor device fabrication, with MOSFET scaling reaching the sub-micron and then sub-micron levels[6-10]. The NMOS APS was produced by Tsutomu Nakamura's team in 1985 at Olympus [11-15]. The Eric Fossum’s team later developed the CMOS active pixel sensor (CMOS sensor) at the NASA Jet Propulsion Laboratory in the year 1993.The sales of CMOS sensors had surpassed CCD sensors by 2007.

1.4. Image Compression:

In 1972, Nasir Ahmed proposed a lossy compression technique which was known as the Discrete Cosine Transform (DCT) that is an important development in the digital image compression technology. The basis for JPEG became the DCT compression, which was introduced by the Joint Photographic Experts Group in 1992[16-20].JPEG compresses images into much smaller file sizes and has become the most widely used image file format on the Internet[1-5]. Its highly efficient DCT compression algorithm was largely responsible for the widespread proliferation of digital images and digital photographs, [6-10] with several billion JPEG images produced each day as of 2015.

1.5. Digital Signal Processor (DSP):

Electronic signal processing was revolutionized by the widespread adoption of MOS technology in the 1970s[11-

15].MOS integrated circuit technology was the basis for the first single-chip microprocessors and microcontrollers in the early 1970s[16-20] and then for the first single-chip digital signal processor (DSP) chips in the late 1970s[1-5].Since then, DSP chips have been widely used in digital image processing. With many companies which develop DSP chips that are based on DCT technology, the DSP chips employ the discrete cosine transform (DCT) image compression algorithm. DCTs are widely used for encoding, decoding, video encoding, audio encoding, multiplexing, control signals, signaling, analog-to-digital conversion, luminance and color difference formatting, and color formats such as YUV444 and YUV411. DCTs are also used for coding operations such as motion estimation, motion compensation, interframe prediction, quantization, perceptual weighting, entropy coding, variable coding, and motion vectors, and decoding operations like the display purposes which employ the inverse operation in between different color formats (YIQ, YUV and RGB). The encoder/decoder chips which are present in the high-definition television (HDTV) commonly use the DCT's.

1.6. Medical Imaging:

In 1972, an engineer from the British company EMI Housfield invented an X-ray computed tomography machine for head diagnostics, usually called CT (computed tomography). The CT nucleus method is based on the projection of a section of the human head and is computerized to reconstruct the cross-sectional image, which is called image reconstruction. In 1975, EMI successfully developed a whole-body CT machine that obtained a clear tomographic image of various parts of the human body. In 1979, this diagnostic technique won the Nobel Prize[6-10]. Digital Image Processing Technology for Medical Applications was inducted into the Space Foundation Hall of Fame in 1994.

1.7. Tasks:

Digital image processing allows the use of much more complex algorithms, and therefore can offer both more sophisticated performance for simple tasks and the implementation of methods that would not be possible with analog means. In particular, digital image processing is a specific application and practical technology based on:

[1] Classification

[2] Feature extraction

[3] Multilevel signal analysis

[4] Pattern recognition

[5] Projection

Some of the techniques used in digital image processing include:

[1] Anisotropic diffusion

[2] Hidden Markov models

[3] Image editing

[4] Image recovery

[5] Independent component analysis

[6] Linear filtering

[7] Neural networks

[8] Partial differential equation

[9] Pixelation

[10] Point feature matching

[11] Principal component analysis

[12] Self-organizing maps

[13] Ripples

1.8. Digital Image Transformations:

1.8.1. Filtering:

Digital images are blurred and sharpened by using digital filters. Filtering can be done:

[1] convolution with specifically designed kernels (filter arrays) in the spatial domain.

[2] masking of specific frequency regions in the frequency (Fourier) domain.

1.8.2.Image padding in Fourier domain filtering:

Images are typically padded before being transformed into Fourier space; The high-pass filter images below illustrate the consequences of different padding techniques:

Examples of filter code:

A MATLAB example for spatial domain high-pass filtering.

img=checkerboard (20); % generate the checkerboard

% ***************************** SPATIAL DOMAIN ********************* ***** ********

clapper= [0 -1 0; -15-1; 0-10]; % Laplacian filter kernel

X=conv2(img, claps); % convolve test img with

% 3x3 Laplacian Kernel

figure ()

imshow (X, []) % show Laplacian filtering

title ('Laplacian Edge Detection')

1.8.3. Affine Transformations:

Affine transformations allow basic image transformations including scaling, rotation, panning, mirroring, and shearing, as shown in the following examples:

To apply an affine matrix to an image, the image is converted to a matrix in which each entry corresponds to the pixel intensity at a given location. The location of each pixel can then be represented as a vector giving the coordinates of that pixel in the image, [x, y], where x and y are the row and column of the pixel in the image matrix. This allows the coordinates to be multiplied by an affine transformation matrix that specifies the position to which the pixel value will be copied in the output image.

However, 3-dimensional homogeneous coordinates are needed to enable transformations that require translational transformations. The new co-ordinate which is [x, y,1] is created that is 1 usually by setting the third dimension to 1 usually which is a non-zero constant. This allows the coordinate vector to be multiplied by a 3 x 3 matrix, allowing translation offsets. The translation is allowed by the third dimension which is the constant 1. Since matrix multiplication is associative, multiple affine transformations can be combined into a single affine transformation by matrix multiplication of each individual transformation in the order in which the transformations are performed. The result is a single matrix that, when applied to a point vector, gives the same result as all the individual transformations performed on the [x, y, 1] vector in the sequence. Thus, a single affine transformation matrix is created due to reduction of a sequence of affine transformation matrices. For example, 2D coordinates only allow rotation around the origin (0, 0). But 3-dimensional homogeneous coordinates can be used to first translate any point to (0, 0), then perform a rotation, and finally translate the origin (0, 0) back to the original point (the opposite of the first shift). These 3 affine transformations can be combined into a single matrix, allowing rotation around any point in the image. In order to apply the noise reduction method to the image, the image is converted to grayscale. Denoising methods start from the center of the image with half the height, half the width and end with the border of the image with the row number, column number. A neighbor is a block in the original image with a border [point below center: point above, point left of center: point right of center]. Neighbor convolution and the structuring element and then replace the center with the minimum of the neighbor.

Take the closing method for example.

First dilation.

Read the image and convert it to grayscale using MATLAB.

Get the image size. The row and column numbers with the return value are the boundaries we will use later.

structural elements depend on your dilation or erosion function. The minimum of the pixel neighbor leads to the erosion method and the maximum of the neighbor leads to the dilation method.

Set the time for dilation, erosion and closure.

Create a null matrix of the same size as the original image.

First dilation with a structuring window.

the structuring window is a 3*3 matrix and convolution

For loop extract minimum with window from row range [2 ~ image height - 1] with column range [2 ~ image width - 1]

Fill the minimum value into the null matrix and save the new image

For the border, it can be improved even more. Because the boundary is ignored in the method. Filler elements can be used to deal with borders.

Then erosion (take dilation image as input)

Create a null matrix of the same size as the original image.

Erosion with a structuring window.

the structuring window is a 3*3 matrix and convolution

For loop, extract maximum using window from row range [2 ~ image height - 1] with column range [2 ~ image width - 1]

Fill the maximum value into the null matrix and save the new image

At the border, it can be improved even more. Because the boundary is ignored in the method. Filler elements can be used to deal with borders.

2.Applications:

2.1.Digital camera images:

Digital cameras generally contain specialized digital image processing hardware—either dedicated chips or added circuitry on other chips—to convert the raw data from their image sensor into a color-corrected image in a standard image file format.

2.2. Film:

The first feature film which used digital image processing to pixelate photography to simulate an android’s point of view was Westworld (1973).

2.3. Face Detection:

Face detection can be implemented using mathematical morphology, discrete cosine transforms, usually called DCT, and horizontal projection (mathematics).

2.3.1.General method with feature-based method:

The feature-based face detection method uses skin tone, edge detection, face shape, and facial features (such as eyes, mouth, etc.) to achieve face detection. Skin tone, face shape, and all the unique elements that only a human face has can be called features.

2.3.2. Process Explanation:

Given a batch of face images, first extract the skin tone range by sampling the face images. The skin tone range is only a skin filter. Structural similarity index measurement (SSIM) can be used to compare images for skin tone extraction. Normally HSV or RGB color spaces are suitable for skin filter. For example, in HSV mode, the skin tone range is [0,48,50] ~ [20,255,255]. After filtering the images using skin tone, morphology and DCT are used to remove the noise and fill in the missing skin regions to obtain the edge of the face. The opening or closing method can be used to fill in the missing skin. DCT is to avoid the subject with skin tone. Because human faces always have a higher texture. The Sobel operator or other operators can be used to detect the face edge. To place human features such as eyes using projection and find the peak of the projection histogram, you can get details such as mouse, hair and lips. Projection is just projecting the image to see the high frequency, which is usually the position of the element.

2.4.Improvement of image quality method:

Image quality can be affected by camera shake, overexposure, overly centralized gray level distribution, and noise, etc. For example, a noise problem can be solved with Smoothing, while a gray level problem can be improved with histogram equalization.

2.5.1.Smoothing method:

If there is an unsatisfied color when drawing, some color is taken around the unsatisfied color and averaged. This is an easy way to think about the smoothing method. The smoothing method can be implemented using a mask and convolution.

2.5.2. Gray Level Histogram Method:

Generally, the gray level histogram from the image as shown below. Changing the histogram to a uniform distribution from an image is usually what we call histogram equalization.

3.Fatigue detection and monitoring technologies:

The past decade has seen significant advances in fatigue monitoring technology. These innovative technology solutions are now commercially available and offer real safety benefits to drivers, operators and other shift workers in all industries. Software developers, engineers and scientists are developing fatigue detection software using various physiological cues to determine the state of fatigue or sleepiness [11-15]. The standard which is widely accepted in fatigue monitoring is the measurement of brain activity (electroencephalogram). Other technologies used to determine fatigue-related damage include measuring behavioral symptoms such as; eye behavior, gaze direction, micro-corrections in steering and throttle use as well as heart rate variability [16-20].

4.Conclusion and Future Scope:

In this review article, we have studied the importance of digital image processing and its practical use in various commercial and industrial applications. A brief overview of the MATLAB software tool used for programming was also given, which taught us how to design a given program in MATLAB and use it for image processing applications. We should also take into account the significant contribution made in this field by various researchers, thus stating its utility value in today's world, making rapid progress in the field of technology leading to the growth of the nation.

5.References:

[1] Ganesh Venkitachalam, Tzi-ckerChiueh, “High Performance Common Gateway Interface Invocation”, IEEE Transactions on Computer Aided Design and Integrated Circuits and Systems,

Volume 20, No. 2, pp. 281-288, February 2001.

[2] Dubrovnik Croatia, “Embedded Web Server Technology for Remote Online Labs”, IEEE ISIE 2005, pp. 120-145.

[3] Michael Sweeney, “BUS: Browser Based User Interface Service for Web Based Application”, Foreign Electronic Measurement Technology, Volume 25, No. 11, 2006.

[4] Jagadeesh Chandra A. P., “A Client-Friendly near Real Time Multimedia Technology for Web-Browser Based Remote Experimentation”, IEEE Transactions on Education, Volume 48, No. 3, pp. 520-525, 2007.

[5] Yan Shi, “Development of Direct Current Motor Control System Based on Embedded Linux System”, in the Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems, 2007.

[6] Zhan Mei-Qiong, Ji Chang-Peng, “Research and Implementation of Embedded Web Server”, International Conference on Multimedia and Information Technology, pp. 305-308, 2008.

[7] Wang Zhen Xing, Ren Xian Yi, “A Study on CGI of Embedded Web Server”, International Symposium on Computer Science and Computational Technology (ISCSCT), Volume 4, No. 2, pp. 180-184, 2008.

[8] Mo Guan, Minghai Gu, “Design and Implementation of an Embedded Web Server Based on ARM”, Computer Engineering and Design, pp. 808-811, February 2009.

[9] Zhou Chuan Sheng, Chong Fu, “Implementation of a General Reduced TCP/IP Protocol Stack for Embedded Web Server”, International Journal of Network Management (IJNM), Volume 10, No. 5, May 209, pp. 261-264.

[10] Zhou Chuan-Sheng, Fu Chong, “Implementation of a General Ethernet Interface for Embedded System”, in the Proceedings of the 9th International Conference on Hybrid Intelligent Systems, 2009, pp. 754-758.

[11] Dan Li, Chongquan Zhong, Xiaofeng Yuan and Li Zhang, Liqian Zhang, “Study on Embedded Equipment Web Monitoring and Control Based on Ethernet”, in the Proceedings of the 6th World Congress on Intelligent Control and Automation, June 21-23, 2009, Dalian, China.

[12] Weichen, Shu-Bo Qiu, Ying-Chun Zhang, “The Porting and Implementation of Light-Weight TCP/IP for Embedded Web Server”, Computer Engineering, Volume 31, No. 5, 2010, pp. 219-222.

[13] A. H. Namin, K. Leboeuf, “High Speed Hardware Implementation of a Serial-in Parallel-out Finite Field Multiplier using Recorded Normal Basis”

[14] Lidl R. Niederreiter H., “Introduction to Finite Fields and their Applications”, Cambridge University Press, Cambridge, England, 1997.

[15] Menezes A. J., Van Oorschot P. C. Vanstone S. A., “Handbook of Applied Cryptography”, CRC Press Series on Discrete Mathematics and its Applications, October 1996, 816 pages.

[16] Lidl R., Niederreiter H., “Finite Fields”, Addison-Wesley, Reading, MA, 1983.

[17] Itoh T., Tsujii S., “A Fast Algorithm for Computing Multiplicative Inverse in GF (2m) using Normal Bases”, Informative Computing, 1998, 78, pp. 171-177.

[18] Geiselmann W., Gollman D., “Symmetry and Duality in Normal Basis Multiplication”, in the Proceedings of Applied Algebra, Algebraic Algorithms and Error Correcting Codes Symposium, July 1998, pp. 230-238.

[19] Wu H., Hasan M. A., Blake I. F., Gao S., "Finite Field Multiplier using Redundant Representation", IEEE Transactions on Computing, 2002, 51 (11), pp. 1306-1316.

[20] B. Sunar, C. K. Koc, "An Efficient Optimal Normal Basis Type II Multiplier", IEEE Transactions on Computers, 83-87, January 2001.