Fundamentals of Image Processing

(Capturing Clarity: The Essence of Image Processing)

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DEDICATION

Er. A C S. ARUNKUMAR
B.Tech (Hons)., LMISTE., MIET.,(UK)., LMCSI.,
President
Dr. M. G. R. Educational and Research Institute
Chennai, Tamil Nadu, India.

- We take immense pride and heartfelt reverence in dedicating this book to **Er. A C S. Arunkumar, B.Tech (Hons)., LMISTE., MIET.,(UK)., LMCSI.,** who holds the esteemed position of President at our illustrious Dr. M. G. R. Educational and Research Institute, located in the culturally vibrant city of Chennai, Tamil Nadu, India.

Our President's unwavering devotion to cultivating academic excellence and fostering the expansion of knowledge is a testament to his global vision. His educational philosophy not only stimulates us but is a beacon that has helped light the path towards academic and personal growth for countless students, leaving an indelible impact on the landscape of academia.

Our gratitude for our President's leadership is profound, as his guidance persistently propels us to strive for pinnacle of excellence in all aspects of our pursuits. It is more than an honour; it is indeed a privilege to dedicate this book to such a luminary a tangible expression of our respect, admiration, and appreciation.

We extend our deepest gratitude to you, sir, for your extraordinary contributions to the field of education, and for ceaselessly inspiring us all with your visionary leadership. Your legacy, like this book, shall serve as a beacon of inspiration for future generations.

- **Dr. P. S. Rajakumar**
- **Dr. S. Geetha**
- **Dr. T. V. Ananthan**

PREFACE

In a world increasingly dominated by digital images, understanding the intricacies of image processing has never been more vital. "Fundamentals of Image Processing" has been crafted with the intent to provide a comprehensive guide on this vast and intriguing subject.

Unit I begins with an overview of what image processing entails and gradually delves into the more nuanced components such as sampling, quantization, and pixel connectivity. By examining the essential steps in image processing and detailing the structure and essence of a digital imaging system, this segment of the book builds the foundation for the topics that follow.

Unit II transitions from the basics and ventures into the realm of image enhancement. We journey through the dynamic world of image transforms and understand how these tools enable modification and improvement of images. From spatial filtering to sharpening, this section encapsulates the techniques that breathe life and clarity into images.

UNIT III examines into the critical task of image restoration and the fascinating world of multi-resolution analysis. Here, we touch upon wavelets, image degradation models, and restoration algorithms, providing a thorough understanding of the tools available to recover and refine images that have been distorted or degraded.

Unit IV is dedicated to segmentation and feature extraction – fundamental tasks in image processing. This section walks the reader through the methods to divide an image into meaningful parts and subsequently extract significant features from them. The inclusion of topics such as SIFT, SURF, and texture analysis ensures that readers gain an in-depth understanding of current state-of-the-art techniques.

Unit V explores the numerous applications of image processing. With a focus on classifiers, learning models, and clustering algorithms, this segment expands the reader's horizon, showcasing how image processing techniques can be applied in various domains and industries.

Throughout the book, emphasis has been placed on explaining concepts in a clear, concise manner, ensuring that both beginners and seasoned professionals can benefit. Diagrams, real-world examples, and practical applications have been incorporated to make the learning process intuitive and engaging.

This journey of "Fundamentals of Image Processing" is not just about learning theories and algorithms; it's about gaining the capability to see, understand, and enhance the world of images around us. We hope you find it as enlightening and captivating as I found it while writing.

Happy Reading!

- **Dr. P. S. Rajakumar**
- **Dr. S. Geetha**
- **Dr. T. V. Ananthan**

ABSTRACT

"Fundamentals of Image Processing" offers a comprehensive exploration of image processing's pivotal techniques, tools, and applications. Beginning with an overview, the book systematically categorizes and explains the multifaceted steps and methodologies inherent to the digital processing of images. The text progresses from basic concepts like sampling and quantization to advanced techniques such as image restoration and feature extraction. Special emphasis is given to algorithms and models crucial to image enhancement, restoration, segmentation, and application. In the initial segments, the intricacies of digital imaging systems, pixel connectivity, color models, and file formats are dissected. Following this, image enhancement techniques, including spatial and frequency domain methods and histogram processing, are elaborated upon. The book then addresses image restoration, discussing degradation models, noise modeling, and blur, and offers insights into the compelling world of multi-resolution analysis with in-depth discussions on wavelets and image pyramids. Segmentation processes, especially edge operators, boundary detections, and thresholding techniques, are detailed in subsequent chapters. The text culminates by diving deep into the applications of image processing, exploring supervised and unsupervised learning, clustering algorithms, and various classifiers. Throughout the discourse, practical examples, real-world applications, and intuitive diagrams are integrated to facilitate an enriched learning experience. This book stands as an essential guide for both novices aiming to grasp the basics and experts looking to hone their knowledge in image processing.

Keywords: Digital Imaging Systems, Image Enhancement, Image Restoration, Multi-resolution Analysis, Wavelets, Image Segmentation, Feature Extraction, SIFT, SURF, Image Classifiers, Supervised Learning, Clustering Algorithms.

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UNIT I INTRODUCTION TO IMAGE PROCESSING

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Introduction

The term "image processing" refers to a series of operations carried out on a picture to produce an improved version of the image or derive some helpful information from it. It is a sort of signal processing where the input is an image, and the output might be either the picture itself or the characteristics or features related to that image. Image processing is now one of the technologies that are expanding quickly. In addition, it serves as a central research field for engineering and computer science disciplines.

- Image processing consists of the following three steps in its most basic form.
- Importing the picture using several techniques to acquire images;
- Analysing and modifying the picture;
- The output might be either a transformed picture or an analysis based on the analysis of the image.

Image processing can be done in one of two ways: analogous or digital. Both technologies have their advantages and disadvantages. The analogue image processing method may be used for tangible copies, such as prints and pictures. During work with these visual approaches, image analysts use a variety of interpretation principles from their toolkit. Digital image processing methods allow digital images to be manipulated through personal computers. When employing digital techniques, there are three main steps through which all different kinds of data must go through. These steps are preprocessing, augmentation, presentation, and information extraction.

What exactly does "Digital Image Processing" refer to?

An image can be defined as a two-dimensional function called f (x, y), where 'x' and 'y' are spatial coordinates (plane). The amplitude of 'f' in any pair of spatial coordinates (plane) (x, y) is called the intensity or grey level of the image at that point.

We refer to the picture as a digital image when all its components, including x, y, and the intensity values of 'f', are quantifiable and distinct.

The processing of digital photographs utilising a digital computer is what we mean when we talk about the area of digital image processing. Consider that a digital picture comprises several pieces, each of which has a specific position and value. These are called picture elements, image elements, pels, and pixels. The word 'pixel' is often used to refer to a digital picture's components. It should come as no surprise, given that vision is the most developed of our senses, that pictures' function in human perception is the single most crucial.

On the other hand, imaging machines can cover almost the entire electromagnetic spectrum, from gamma to radio waves. This contrasts with human beings, which can only see in the visible band of the electromagnetic (EM) spectrum. They can perform operations on pictures produced by sources that people do not often consider associated with images. These techniques are examples of ultrasound, electron microscopy, and computer-generated images.

As a result, digital image processing covers a broad and diversified range of applications in the modern world. There is not a widespread consensus among writers about the point at which image processing concludes and other closely related fields, such as computer vision and image analysis, begin. Sometimes a difference may be created by describing image processing as a field of study in which both the input and output of a process are images. This kind of definition is used in image processing. We see this as a border that is both restricting and somewhat artificial. For instance, following this definition, even the little effort of calculating the average intensity of an image (which only results in a single number) would not be regarded as an operation related to image processing. On the other hand, there are subfields, including computer vision, whose ultimate objective is to use computers to emulate human vision.

This includes learning and being able to draw conclusions and take actions based on visual input. This field is a subfield of artificial intelligence (AI) whose overarching goal is to model the human intellect. In terms of its development, the area of artificial intelligence (AI) is still in its early infancy;

nevertheless, progress has been much slower than was once predicted. The fields of computer vision systems are separated by the domain of picture analysis, which is often referred to as image comprehension.

No discrete limits can be identified on the continuum that extends from image processing with one end to computer vision with one. However, one paradigm might be constructive in thinking of three levels of computerised processes along this continuum: low-, mid-, and high-level. Primitive procedures, such as preprocessing the image to minimise noise, enhance contrast, and image sharpening, are examples of low-level processes. One of its defining characteristics is that a low-level process takes pictures as input and produces images as output. The tasks involved in the mid-level processing of images include segmentation, which is the process of partitioning an image into regions or objects; describing those objects to reduce them to a form suitable for computer processing; and classification, which is the process of recognising individual objects. The fact that a mid-level process takes images as its input but generates attributes based on those images as its output distinguishes it from lower-level processes (e.g., edges, contours, and the identity of individual objects). Finally, higher-level processing involves "making sense" of an ensemble of recognised objects, such as in image analysis, and, at the extreme continuum, having to perform the cognitive functions typically associated with vision.

Since the previous remarks, we see that a prominent place of crossover between image processing and image analysis is the area of recognising individual regions or objects within an image. This is the case because of the similarities between the two fields. Therefore, what we refer to as digital image processing encompasses processes whose inputs and outputs are images, and processes that extract attributes from images, all the way up to and including the recognition of individual objects. This book uses the term "digital image processing" to refer to both types of processes. Consider the field of automated text analysis as an example to help illustrate these ideas.

The processes of acquiring an image of the area containing the text, preprocessing that image, extracting (segmenting) the individual characters, describing the characters in a form suitable for computer processing, and recognising those individual characters are in the scope of what we call digital image processing in this book. Based on the scale of complexity suggested by the statement "making sense," one interpretation of the phrase "making sense" places the task of "making sense" of the page's content within the purview of image analysis and possibly even computer vision.

It will become apparent in a short while that digital image processing, in the sense that we have defined it, is successfully applied in a wide variety of domains with exceptionally high social and economic value. The methodologies used in those application areas are based on the principles established in the following chapters.

Applications of Image Processing

Digital image processing gives objects a more lifelike appearance and has been shown to increase in importance throughout time, as well as with the introduction of new technology.

1) Image enhancements include retouching and sharpening.

It is a term that refers to the procedure by which we may change the appearance and texture of a picture. It does this by manipulating the photos to get the desired result. Conversion, sharpening, blurring, finding edges, retrieval, and identification of pictures are all included in this process.

2) Medical Field

- Several applications fall under the umbrella of the medical profession that depends on the operation of digital image processing.
- Gamma-ray imaging
- PET scan, X-ray imaging, medical CT scan, Diagnostic imaging
- UV imaging

3) The vision of robots

Digital image processing is carried out with several different types of robotic equipment. Robots can navigate their environments using image processing techniques, such as line follower robots and those that can identify obstacles.

4) Pattern recognition

It is a combination of the study of image processing and artificial intelligence, and it is done this way so that computer-aided diagnosis, handwriting recognition, and image recognition can be easily implemented. Pattern recognition in modern times often makes use of image processing.

5) Video processing

In addition, it is one of the applications for which digital image processing may be used. An assortment of picture frames or still images have been placed in such a manner as to create the illusion of rapid visual movement. This process includes converting the frame rate, detecting motion, reducing noise, and converting the colour space, among other things.

Steps in Image Processing Applications

Image processing is a method that involves converting an image into digital form and then performing some operations on it to get an improved process of extracting several valuable information from it. Image processing can also refer to converting an image into digital form.

This is a form of signal dispensation where the input is an image, such as a video frame or photograph, and the output may be the image itself or characteristics that relate to that image.

Treating pictures as though they were two-dimensional signals and then using signal processing techniques that have previously been established is often part of an image processing system.

The reason for image processing

The aim of image processing may be broken down into five distinct categories. They are as follows:

- **Visualisation** is the process of seeing things that are not apparent to the naked eye.
- I**mage sharpening and restoration** are to produce a picture of higher quality.
- **Picture retrieval** - Search for the image that we are interested in seeing.
- **Pattern measurement** is counting the number of distinct elements within a picture.
- **Image recognition** involves identifying the many things that may be seen in a picture.

The following are the fundamental stages involved in digital image processing:

1. Image Acquisition

This is the initial step or procedure in the essential processes involved in processing digital images. The process of acquiring a picture might be nothing more complicated than having to receive an image that is already in digital form. Preprocessing steps, such as scaling and rotation, are often included in the picture capture stage.

2. Image Enhancement

Enhancing images is one of the digital image processing techniques that is straightforward and visually attractive. In the most fundamental sense, image enhancement methods aim to bring out details that have been concealed or to emphasise certain exciting aspects of a picture. Altering brightness and contrast, among other things, are examples.

3. Restoring images

The enhancement of a picture's look is another focus of the field of image restoration, which studies these issues. Image enhancement, on the other hand, is a more subjective process than image restoration, which is objective. Objective image restoration techniques tend to be based on mathematical or probabilistic models of image degradation, in contrast to subjective image enhancement techniques.

4. The Processing of Colour Images

Due to the significant rise in the usage of digital pictures sent over the Internet, the field of colour image processing has been steadily gaining ground in terms of its significance. This might include colour modelling and processing in a digital environment, among other similar activities.

5. Multiresolution wavelet processing and other wavelet methods

Wavelets are fundamental building blocks for displaying pictures with a wide range of granularities. The process of gradually subdividing an image into smaller sections for data compression and pyramidal representation.

6. Compression

Compression is a set of methods that reduce the amount of storage space needed to store a picture or the amount of bandwidth necessary to send it. Compressing data is a critical practice for those who use the Internet extensively.

7. The Processing of Morphological Information

The field of morphological processing is concerned with developing methods and programmes for extracting picture components that may be used in the representation and characterisation of form.

8. Segmentation

Segmentation processes break down a picture into individual sections or objects that make up it. Autonomous segmentation is considered one of the most challenging jobs in digital image processing. A robust segmentation approach places the process in a significant way toward successfully solving imaging challenges that require individual objects to be recognised.

9. Representation and Specific Detailed Description

The output of a segmentation stage is typically raw pixel data, which constitutes either the boundary of a region or all the points within the region itself. Representation and description most often implement the output of a segmentation stage. The selection of a representation is simply one piece of the puzzle when translating raw data into a form appropriate for later computer processing. The description process involves isolating attributes that contribute to generating quantitative information that is of interest or is essential for distinguishing one category of objects from another.

10. Recognising various objects

A label, such as "car," is given to an item via the recognition process based on that thing's descriptors.

11. Information Repository:

Knowledge can be as simple as describing areas in an image where information of interest is known to be located, thereby reducing the amount of searching needed to find the information. The knowledge base can also be quite complex, such as an interrelated list of all significant possible defects in a materials inspection problem or an image database containing high-resolution satellite images of a region connected with change detection applications. Another example of a complex knowledge base is a list of all significant possible defects in a problem involving the inspection of materials.

Digital Imaging System

Facets of Visual Perception

(1) The Internal Organization of the Human Eye:

The human eye is shown in Figure 1 as a simplified horizontal cross-section. The human eye has the shape of a spherical virtually and has an average diameter of around 20 millimetres. The outer cover consists of the cornea, sclera, choroid, and retina, and the three membranes encase the eye. The front layer of the eye is covered by a layer of tough tissue called the cornea, which is also transparent. The sclera is an opaque membrane that is continuous with the cornea and encloses the rest of the optic globe. It is found at the back of the eye. The choroid is located underneath the sclera in its immediate vicinity. This membrane houses a network of blood vessels that are the primary source of nourishment for the eye. These vessels are in the retina.

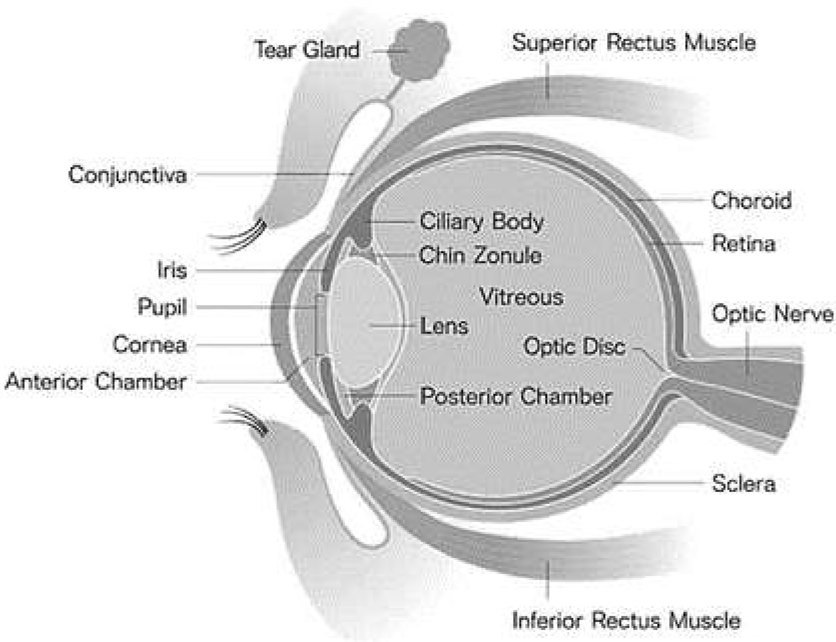

Figure 1: Cross section of a human eye

Even a minor cut or scratch to the choroid, often not considered dangerous, can cause severe damage to the eye because it causes inflammation, inhibiting blood flow. Because the choroid coat contains much pigment, it can help minimise the quantity of extraneous light that enters the eye and the amount of light reflected inside the optical globe. The choroid divides at its most anterior point into the ciliary body and the iris diaphragm. This marks the beginning of the iris. The ciliary body may contract or extend to regulate the amount of light reaching the retina. The diameter of the aperture in the middle of the iris, known as the pupil, may range from around 2 to 8 millimetres. The visible pigment of the eye is in the front of the iris, while the rear of the iris contains a black pigment.

The lens is held in place by fibres attached to the ciliary body and composed of layers of fibrous cells arranged in a concentric pattern. It comprises between 60 and 70% water, approximately 6% fat, and an abundance of protein that exceeds any other tissue in the eye. The lens takes on a somewhat yellow hue due to a pigmentation that becomes more concentrated as one age. In extreme cases, the excessive clouding of the lens caused by the condition, more commonly referred to as cataracts, can lead to a loss of clear vision and a reduction in one's ability to differentiate between colours. The lens takes about 8% of the visible light spectrum, with a significantly higher absorption at shorter wavelengths. The retina is the innermost membrane of the eye and borders the inside of the wall throughout the posterior section of the eye. When the eye's focus is correct, the light from something not in the eye creates a picture on the retina. The distribution of different light receptors on the retina's surface allows for a kind of vision known as pattern vision. Cones and rods are the two primary receptor types in the human body. The proteins found within the lens structure are responsible for the significant absorption of infrared and ultraviolet light, which, in excess, can cause damage to the eye. The cones in each between 6 and 7 million individuals can see correctly. They are found in the area of the retina known as the fovea, which is in the centre of the eye and is very sensitive to colour. Because each cone is attached to its nerve terminal, humans could even discern the minutiae of details with their eyes. The muscles that regulate the eye spin the eyeball so that the picture of what is of interest is focused on the fovea. Vision in the cones is referred to as photopic vision or vision in intense light.

The quantity of rods is significantly greater: Between seventy-five and one hundred and fifty million are found on the retina's surface. The degree of detail of these receptors is diminished due to their widespread dispersion and the fact that several rods are attached to a single nerve terminal. The purpose of the rods is to provide an overall generalised image of the area of vision. They do not contribute to the ability to see colours and have a heightened response to dim light. For example, things with vibrant colours during the day appear as colourless shapes when seen in the moonlight. This is because only the rods are activated by moonlight. Scotopic vision, sometimes known as dim-light vision, is the name given to this phenomenon.

(2) The Eye's Role in the Formation of an Image:

The primary distinction between the two lens types is that an ordinary optical lens is rigid, but the eye's lens is flexible. The radius of curvature of the anterior surface is higher than the radius of its posterior surface, as shown in Figure 4.1. This is because the anterior surface of the lens is closer to the pupil. The level of tension in the fibres that make up the ciliary body determines the curvature of the lens. The lens's muscles caused it to become somewhat flattened so that it could concentrate on things in the distance.

Similarly, these muscles make the lens thicker to focus on things near the eye. The focal length is the distance separating the lens's centre from the retina. This distance can range from approximately 17 millimetres to approximately 14 millimetres. As the refractive power of the lens increases when focusing on an object that is further away than approximately 3 metres, the lens displays its lowest refractive power. When the human eye is focused on something quite close to it, the eye's lens behaves in the most powerfully refractive manner. With this information, determining the dimensions of the retinal picture of any given object is a simple process.

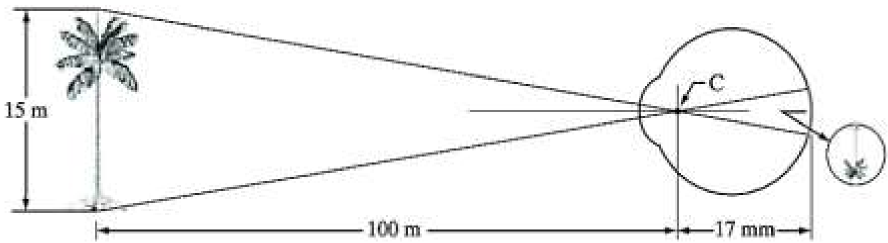

Figure 2: The image of the eyes at point C of the palm trees is the centre of the lens's vision. Image source: Gonzalez, R.C. & Woods, R.E. (2007). Digital image processing.

For instance, in Fig. 2, the observer is 100 metres away from a tree that is 15 metres tall. Using the geometry of Fig.2, we can determine that the height of that item in the retinal picture is 2.55 millimetres if h is the height of the object in millimetres. The fovea is where most of the picture captured by the retina is reflected. The next step in the process of seeing anything is the relative activation of light receptors. These receptors convert radiant energy into electrical impulses, which the brain decodes.

(3) Adaptation to Variable Brightnesses and Discrimination: Because digital images are displayed as a discrete set of intensities, the ability of the eye to differentiate between various intensity levels is an essential factor to consider when presenting the results of image processing. From the scotopic threshold to the glare limit, the human visual system can adapt to an extensive range of light intensities (1010). This range begins with the scotopic threshold. According to the findings of various experiments, the subjective brightness of an object, also known as the intensity as the human visual system perceives it, is a logarithmic function of the light intensity that is incident on the eye.

This quality is shown graphically in Figure 3, which shows a plot of light intensity versus perceived brightness. The long solid curve depicts the range of intensities the human visual system can adjust. When considering just photopic vision, the range is around 106. The transition from scotopic to photopic vision is made gradually in the approximate range of 0.001 to 0.1 millilambert (–3 to –1 mL on the log scale), as the double branches of the adaptation curve are in this range. The human visual system cannot function simultaneously over such a wide range is essential to remember when attempting to make sense of the impressive dynamic range shown in Fig. 3.

Instead, it can achieve such a wide range of sensitivity by adjusting its overall sensitivity, referred to as brightness adaptation. In contrast with the broad adaption range, the complete range of various intensity levels that can discriminate concurrently is minimal.

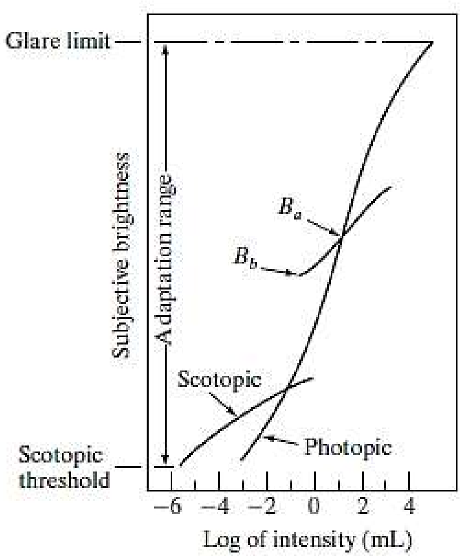

Figure 3: The range of subjective brightness sensations that show a specific level of adaptation. Image Source: Gonzalez, R.C. & Woods, R.E. (2007). Digital image processing

The present sensitivity level of the visual system is referred to as the brightness adaptation level, and it can correspond, for instance, to the brightness Ba in Fig. 4.3. The conditions under which the visual system operates can be anything at all. The range of subjective brightness that the eye has acclimated to this level is represented by the short intersecting curve in the graph. This range is somewhat limited, with a level Bb above which all stimuli are regarded as indistinguishable blacks and a level Bb below which none are. The portion of the curve above the dashed line is not restricted; however, if extended too far, it loses its meaning. This is because much higher intensities would simply raise the adaptation level higher than Ba.

Sampling and Quantisation

Most sensors produce a continuous voltage waveform as their output. This waveform's amplitude and spatial behaviour are connected to the physical phenomena being felt. Converting the continuous data that was detected into digital format is a necessary step in the process of creating a digital picture. This requires two steps: sampling and then quantisation of the data.

Concepts Crucial to the Sampling and Quantisation Process: Figure 4 visually represents the fundamental concept behind sampling and quantisation. A continuous picture, denoted by f (x, y), is shown in Figure 4(a), and this image we want to digitise. A picture can be continuous in terms of the x- and y-coordinates and amplitude. We need to sample the function's coordinates and amplitude before converting it to digital form. Sampling refers to the process of digitising coordinate values. Quantisation refers to the process of digitising the amplitude values. A plot of the continuous picture's amplitude (grey level) values is given in Fig.4(b), which is a one-dimensional function. This plot is shown along the line segment AB in Fig.4(a). Image noise is to blame for the unpredictable variances. To sample this function, we collect samples along the AB line that are evenly spaced apart, as illustrated in Figure 4. (c).

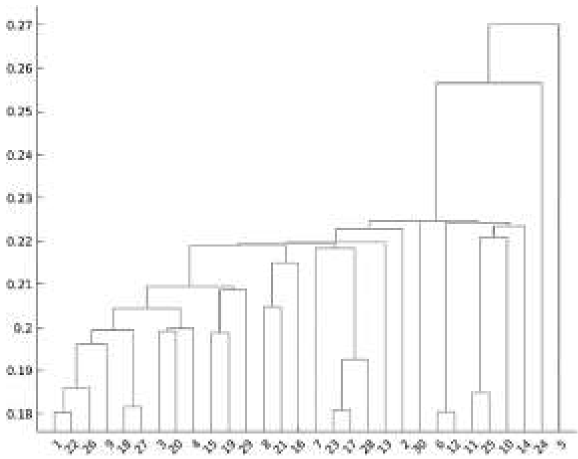

Figure 30: Nearest Clustering

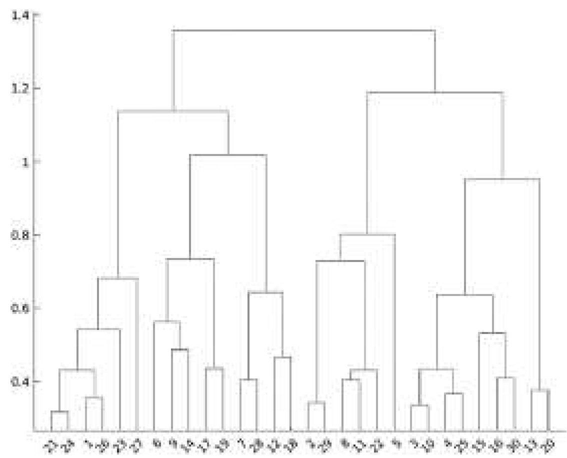

Figure 31: Farthest Clustering

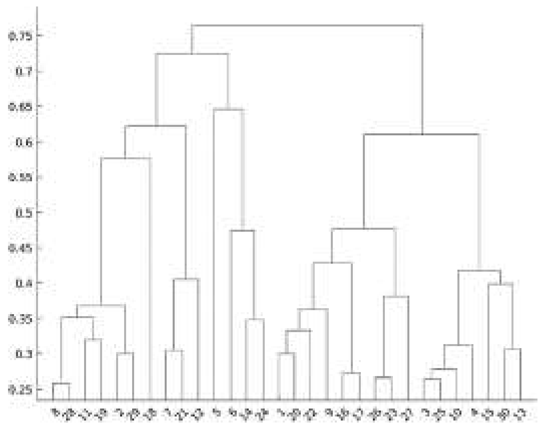

Figure 32: Average Clustering

Formation of clusters by division or splitting by division

We use a top-down methodology, which implies that the pixel that is physically located in the most convenient location is the one that gets assigned. The following is the algorithm that will be used to conduct the agglomerative Clustering:

- ✓ Develop a single cluster that incorporates all of the points.
- ✓ For a certain amount of epochs or until the Clustering reaches an acceptable level.
- ✓ The cluster should be divided in half along the line that creates the most space between the clusters.

- ✓ Proceed with the same steps as before.

Clustering based on partitions

The kind of data determines the available options for feature types and measurement levels. Because of this, many different clustering algorithms have been created. These approaches may be categorised as hierarchical Clustering, partitional Clustering, artificial system clustering, kernel-based Clustering, or sequential data clustering, according to the different clustering methodologies that have been developed. This chapter looks at some of the more common strategies and algorithms for partitional Clustering.

On the other hand, partial clustering approaches strive to create consecutive clusters by using iterative procedures, in contrast to hierarchical clustering methods. Iterative procedures are partitioning data points into k-clusters in the partitional clustering method. During these procedures, n pieces of information are partitioned into k distinct clusters. The maximising and minimisation calculations in k sets are used to determine where the datum should be placed once it has been assigned by the predetermined criteria function J.

K-Means Clustering

K-means clustering is a relatively common method used in situations where the dataset in question does not have its labels specified. The purpose of this endeavour is to locate particular groups that have some form of resemblance in the data with the total number of groups that K represents. This method is often used in domains such as the segmentation of markets and customers, amongst other domains. On the other hand, it may also be used to separate various things present in the photos based on the values of the pixels.

The algorithm for image segmentation works as follows:

- ✓ First, we need to select the value of K in K-means clustering.
- ✓ Select a feature vector for every pixel (colour values such as RGB, texture etc.).
- ✓ Define a similarity measure b/w feature vectors such as Euclidean distance to measure the similarity b/w any two points/pixel.
- ✓ Apply the K-means algorithm to the cluster centres
- ✓ Apply the connected component's algorithm.
- ✓ Combine any component of size less than the threshold to an adjacent component similar to it until we cannot combine more.

Following are the steps for applying the K-means clustering algorithm:

Select K points and assign them one cluster centre each. Until the cluster centre will not change, perform the following steps:

- Allocate each point to the nearest cluster centre and ensure each cluster centre has one point.
- Replace the cluster centre with the mean of the points assigned to it.
- End

EM Algorithm

In situations where the equations cannot be solved directly, the EM technique is used to discover the parameters of a statistical model with the (local) highest possible probability. In most cases, these models include latent variables in addition to unknown parameters and observations of known data. That is to say, some of the data are missing values, or the model may be simplified by supposing the availability of additional unobserved data points. One of these possibilities must be the case. A mixed model, for instance, may be defined more straightforwardly by assuming that each seen data point corresponds to an unobserved data point, also known as a latent variable, which specifies the component of the mixture to which the data point belongs.

In order to find a solution that has the highest possible likelihood, it is customarily necessary to take the derivatives of the likelihood function concerning all of the unknown values, the parameters, and the latent variables and then simultaneously solve the equations that are produced as a result of this process. It is almost always challenging to do this in statistical models that include latent variables. Instead, the outcome is often a series of interlocking equations in which the solution to the parameters needs the values of the latent variables and vice versa. However, if we were to substitute one set of equations with the other, the result would be an equation that could not be solved.

The EM algorithm is based on the realisation that there is a method to numerically solve these two sets of equations. This realisation is the starting point of the algorithm. One can choose arbitrary values for one of the two sets of unknowns, use those values to estimate the other set, then use the newly estimated values to find a better estimate of the first set, and then continue alternating between the two sets of unknowns until the values that are produced both converge to fixed points. It is not immediately evident that this will be successful, but its applicability may be shown in this setting. In addition, it is possible to demonstrate that the derivative of the likelihood is (arbitrary close to) zero at that point, which indicates that the point in question is either a local maximum or a saddle point. This conclusion is reached as a result of the fact that the point in question can be proven. In general, there is a possibility that numerous maxima may occur, and there is no assurance that the global maximum will be discovered. There are also singularities in certain likelihoods, often known as nonsensical maxima. For instance, one of the solutions that ey may find in a mixture model involves setting one of the components to have zero variance and the mean parameter for the same component to be equal to one of the data points. Another solution that ey may find in a mixture model involves setting all components with the same value.

BIBLIOGRAPHY

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BIBLIOGRAPHY

1. Acharya, T., & Ray, A. K. (2005). *Image processing: principles and applications*. John Wiley & Sons.
2. Bailey, D. G. (2023). *Design for embedded image processing on FPGAs*. John Wiley & Sons.
3. Castleman, K. R. (1996). *Digital image processing*. Prentice Hall Press.
4. Debevec, P. E., & Malik, J. (2023). Recovering high dynamic range radiance maps from photographs. In *Seminal Graphics Papers: Pushing the Boundaries, Volume 2* (pp. 643-652).
5. Ekstrom, M. P. (2012). *Digital image processing techniques* (Vol. 2). Academic Press.
6. Gan, W. S. (2022). Quantum image processing. In *Quantum Acoustical Imaging* (pp. 83-86). Singapore: Springer Singapore.
7. Gonzales, R. C., & Wintz, P. (1987). *Digital image processing*. Addison-Wesley Longman Publishing Co., Inc..
8. Kalwar, S., Patel, D., Aanegola, A., Konda, K. R., Garg, S., & Krishna, K. M. (2023, May). Gdip: Gated differentiable image processing for object detection in adverse conditions. In *2023 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 7083-7089). IEEE.

9. Kanya, N., Rani, P. S., Geetha, S., Rajkumar, M., & Sandhiya, G. (2021). An efficient damage relief system based on image processing and deep learning techniques. *Revista Geintec-Gestao Inovacao E Tecnologias*, *11*(2), 2124-2131.
10. Liu, H., Liu, M., Li, D., Zheng, W., Yin, L., & Wang, R. (2022). Recent advances in pulse-coupled neural networks with applications in image processing. *Electronics*, *11*(20), 3264.
11. Liu, Y. (2022). 2022 IEEE International Conference on Image Processing (ICIP).
12. Magesh, S., & Rajakumar, P. S. (2023). Ensemble feature extraction-based prediction of fetal arrhythmia using cardiotocographic signals. *Measurement: Sensors*, *25*, 100631.
13. Marion, A. (2013). *Introduction to image processing*. Springer.
14. Martin, A., & Tosunoglu, S. (2000). Image processing techniques for machine vision. *Miami, Florida*, 1-9.
15. Niblack, W. (1985). *An introduction to digital image processing*. Strandberg Publishing Company.
16. Petrou, M. M., & Petrou, C. (2010). *Image processing: the fundamentals*. John Wiley & Sons.
17. Rajakumar, P. S., Ravi, S., & Suresh, R. M. (2010, December). Speech enhancement models suited for speech recognition using composite source and

wavelet decomposition model. In *2010 International Conference on Signal and Image Processing* (pp. 511-514). IEEE.

18. Rajakumar, P. S., Ravi, S., & Suresh, R. M. (2011, December). Automated Heart Sound Diagnosis Using Feature Extraction Model for Bio-signals. In *International Conference on Computing and Communication Systems* (pp. 103-109). Berlin, Heidelberg: Springer Berlin Heidelberg.
19. Russ, J. C. (2006). *The image processing handbook*. CRC press.
20. Sahin, G., Cabuk, S. N., & Cetin, M. (2022). The change detection in coastal settlements using image processing techniques: a case study of Korfez. *Environmental Science and Pollution Research*, *29*(10), 15172-15187.
21. Wichtmann, B. D., Harder, F. N., Weiss, K., Schönberg, S. O., Attenberger, U. I., Alkadhi, H., ... & Baeßler, B. (2023). Influence of image processing on radiomic features from magnetic resonance imaging. *Investigative Radiology*, *58*(3), 199-208.

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