Computer Science, Technology and Applications

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EDITOR

ADVANCES IN IMAGE ANALYSIS RESEARCH

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A picture tells a thousand words in any language...

Enjoy and expand the science of image analysis into new heights!

PREFACE

The primary goal of this book is to provide students and practitioners with cohesive information and innovative techniques about the field of Image Analysis. Image analysis is a multi-disciplinary subject that covers expansive subjects on photography, optics, physics, mathematics, software engineering, electronics, computer science, and information technology. The integration of these multi-disciplinary studies became the foundations of specialized and emerging fields of studies, such as medical imaging, machine vision, image processing, and computer graphics. Consequently, the innovative techniques presented in this book are compiled from various independent fields of studies across the globe.

The term Image Analysis deals with process of extracting features from digital images and analyzing these extracted features into parameters into meaning information. Therefore, image analysis is composed of three integrated parts: A device that transform electromagnetic energy into an image (i.e., Photography); a method of extracting features from an image (Image Processing); and an analytical method that measures extracted parameters (Mathematics).

Although a number of books and publications are available in the study of Image Analysis, most describe each discipline into separate and independent subfields. Hence, no true integration is available that provides a singular reference to tie in the foundation of each subject into a unified format (comprehensive overview). Consequently, the overarching aim of this handbook is to fill these gaps and describe each contributing discipline into a science of image analysis. Thereby, this book is presented into three unified sections:

Part I: Image Analysis Timeline and Foundation,
Part II: Advanced Methodologies in Digital Image Analysis; *and*
Part III: Advanced Applications of Image Analysis

Part I: Image Analysis Timeline and Foundation

Part I is subdivided into three chapters. The first chapter is the presentation of the historical timeline associated with Image Analysis. Although the electromagnetic spectrum covers a range of imaging devices, most image analyses are performed on images produced from visible light. The camera is the principal devices that captures light energy and transform them into images. Therefore, chapter 1 begins with a historical timeline behind photography. After all image analysis will not exist without photographic techniques and devices. Consequently, this chapter presents a timeline of major advances in photography and

associated technologies in relation to Image Analysis (i.e., computers and integrated circuits). Nonetheless, it is only fitting to dedicate a chapter about its history; and to give readers, especially students, an insight to visionary works.

The second chapter is a multi-disciplinary approach associated with the analysis of extracted features into measurable parameters. Therefore, the mathematical foundations behind Image Analysis are introduced. Initially, the mathematics is presented as concepts and gradually increased its sophistication with detailed descriptions and examples. Critical to the comprehension of Image Analysis is the understanding of the math and physics behind the transformation of light energy into measurable dimensions (i.e., voltage, intensity, and color). Consequently, detailed discussion on the technologies behind Photo-sensor and Digitization are presented. Therefore, this chapter is composed of three inter-related parts: The physics behind the device that transform electromagnetic energy into an image, the math behind the digitization of electrical signals from photo-sensors into pixels; and the analytical methods that govern the measurements of pixels for pattern recognition, definition, classification and identification of imaging tasks.

Chapter 3 covered the branch of computer science that deals with Image Analysis beginning with the understanding of computer file formats, followed by the extraction of image features. The extraction of image feature is a subfield of image processing that uses a number of computer algorithms for image selection, management, enhancement, and encoding. The selection protocol is often performed with region of interest (ROI) tools. ROI is often a user defined or computer interfaced operations for image segmentation. Image management tools involve the use of pan, tilt, rotation, and magnification of ROI selected images. Image enhancement deals with color and brightness adjustment techniques. Encoding involves image compression, the scanning and reading of electronic codes as well as and rules for encoding that are both human and machine readable. The analysis of extracted parameter encompasses computer graphics for viewing raster images. It also involves the use of computer aided programming for a number of measurements. Lastly, Information Technology is covered in chapter 3 for image acquisition, remote access, and communication of images or data with via the Internet or Ethernet or Wireless Technology.

Part II: Advanced Methodologies in Digital Image Analysis

Part II is composed of selected chapters in capturing the emerging technologies and innovative methodologies in Digital Image Analysis. This section also introduces the subject on automation, Image Acquisition with Smartphones, and 3D- Image rendering with Structured Light Intensity

The topic of automation is presented with Neural Network or Artificial Intelligence. Artificial Intelligence is the cutting edge of future technologies for Machine vision and Automation. This emerging field is the fore-front of many new innovations and patents (inventions). In these chapters the science of Neural Network is discussed in detail with mathematical framework for self-organization and learning. The artificial self-organizing protocols are based on Feed-Forward with Recurrent Neural Network protocols with Learning Vector Quantization method. For Adaptive Neural Network learning (supervised and unsupervised) Backpropagation protocols with Bayesian methods were implemented.

In a separate chapter the topics on Image Acquisition was covered to comprehensively compare CCD and CMOS technologies. The principal reason for this study was to determine the viability and applicability of images collected with Smatphones for Image Analysis

applications. In addition, this chapter introduces the research on Gradient-based Threshold Selection Algorithm to differentiate images of liquids with Light Scattering Effect. Lastly, a chapter in this segment was used to discuss the technology behind 3D image rendering using Structured Light Intensity (SLI) methodologies. SLI is a unique form of 3D rendering using one captured image as opposed to the standard multiple-layering of image slices.

Part III: Advanced Applications of Image Analysis

Part III is a collection of international research works and collaborative applications to advance the science of Image Analysis. In addition, each application offers a wealth of information about this exciting and emerging field. Hence, this volume captures the immense progress made in recent years in topics such as Structural Engineering, Manufacturing, Medical Imaging, Biotechnology, Food Industry and Nutrition Research.

Image Analysis techniques are applied in Structural Engineering and Manufacturing research. This evolving field is critical in the evaluations of mechanical strength of concrete structures under corrosion and erosion conditions. Therefore, in these chapters researchers introduced several groundbreaking Image analysis techniques for evaluating structural integrity and predicting the '*Refractory Concrete Life Time*' under extreme environmental conditions.

In Medical Imaging and Biomedical Researches, the application of Image analyses is innovatively used to study the study the behavior of two-dimensional crystalline arrays of proteins. In a separate chapter, Image Analysis techniques are used to quantitatively evaluate of Facial Pigmentation, Wrinkles, and Pores Using 'Robo Skin Analyzer' prior to facial and reconstructive surgery.

In Biochemistry Application a novel Image Analysis technique quantifying the intensity of the coloured product was developed and demonstrated to measure the Alkaline Phosphatase activity, stability and retention directly on paper under conditions of excess enzyme. A routine was developed to rapidly analyse hundreds of images per sample: the reaction kinetics images were captured using a standard video camera, transferred to a computer and analyzed using standard video editing and image processing software. This approach is technically feasible for other paper diagnostic tests since all modern cell phones and tablet computers have high resolution video cameras with the ability to download and install a diagnostic application module or to rapidly communicate a video. Bioactive papers combined with the camera of a cell phone could well revolutionize telemedicine.

In this book a review of the current Image Analysis procedures used in cheese making is presented as a chapter in the Food Science research. However, the field of Nutrition is divided into validity and reliability of current standard nutritional analysis tools. These tools are questionnaire or interview -based; thus, their reliability decreases when applied to hindered (i.e., small children). In addition, random and system errors are prevalent with these tools. Random errors are human factor errors associated with data collection confounded by food variations. On the contrary, system errors are computational errors due to Food Volume estimations and to Weight Conversions. Consequently, Image Analysis protocols are designed to resolve random and system errors in nutrient analysis. For random errors, the interview process or questionnaire were replaced with photographs for Image Acquisition. System errors in food volume estimation are replaced by Image Processing techniques and Computer aided measurements.

In this volume, Image Analysis techniques are applied in Social Sciences Research and Policy Evaluation. In one study Image Analysis systems of technologies are applied to evaluate newly mandated school nutrition policy as authorized by the Healthy, Hunger-Free Kids Act of 2010. The scope and specificity of the new nutritional standards requires an efficient and reliable form of nutritional analytics for implementation, monitoring, compliance and evaluation. Therefore, this chapter introduces an innovative approach to school-based nutrition policy evaluation using Image Analysis techniques. In another study, Food Imaging Analysis was applied to evaluate School Breakfast Program and its association with academic scores and other school related indicators of elementary school aged children

These volumes of works are independently inspired by the art and science of images. Therefore, the topics under these chapters are intended as instructional materials for students or novel ideas being introduced for the first time in this volume that are beneficial to researchers and practitioners. Therefore, I hope you enjoy reading these chapters and inspired you well enough to expand the science of Image Analysis into new heights!

Roger M. Echon

CONTENTS

Part I: Image Analysis Timeline and Foundation

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Chapter 1

THE ART OF PHOTOGRAPHY AND IMAGE ANALYSIS

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ABSTRACT

The art of photography is a critical element of Image Analysis. Primarily, because researchers examines the content of a photograph in search of patterns and extracts these features for further analysis. Photography is an art of transforming light energy into meaningful information. Therefore, it is only fitting to dedicate a chapter about its history; and give readers an insight into visionary works.

This chapter presents a timeline of major advances in photography and associated technology towards the development of Image Analysis. This timeline begins with the principle of capturing light energy using *Camera Obscura*. The *Camera Obscura* was used in the pioneering works of Joseph Nicephore Niépce who produced the first photograph in 1820s France. He later collaborated with Louis-Jacques-Mandé Daguerre to reduce his concept into practice in the 1880s. Concurrently, in London Sir John Herschel made improvements upon the photographic processes and was credited with the term "Photography." These concepts were subsequently followed by George Eastman's in 1900s into many inventions, who eventually formed a company known as "Kodak." Henceforth, The Kodak Company played a significant role in Images Analysis for the next 100 years. Kodak's devices were first used during the First World War (WWI) for aerial photoreconnaissance (Mapping).

The Germans held the torch of discovery in WWII and after WWII the bulk of discoveries were made in select US laboratories. These laboratories expanded the use of photography and computing technologies beyond military use and into multiple directions. In the 1960s and 70s NASA has taken this torch into new heights for space exploration. The 80s, 90s and the new millennium were dominated by computer technology and digital photography. Currently, with the advent of mobile devices, it appears that this torch is being shared across the globe in the hands of a new generation of innovators.

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Keywords: Photography, Light Energy and Pioneers

INTRODUCTION

The art of photography is a critical element of any Image Analysis. This is because researchers often examines the content of photographs by searching for patterns, followed by the extraction of these patterns for further analysis (Friedman and Ross, 2003; Rosenblum, 1997). Image Analysis is different from Image Processing by the type of output it generates. For Image Analysis the output is a measured outcome; while for Image Processing the output is a converted or manipulated images. Thus, the field of Image Analysis is composed of two parts: A device that transform light or electromagnetic energy into an image; and an analytical system that measures the extracted information from an image (Serra, 1982).

The overarching aim of this chapter is to provide background materials about the subject of Image Analysis and its two sub-parts: Photography and Computers. Therefore, this chapter presents a timeline of major advances in Photography (i.e., camera and optics) and technology (i.e., computers and algorithms) in relation to Image Analysis (Freed and Ishida, 1995). The format of this timeline is written in chronological order. In addition, each timeline is subdivided into three inter-related parts. The first part is presented to highlight the major developments in the fields of Image Analysis: Photography and Computing Technology (Algorithms). The second component was used to give credits to the pioneers of such discovery, invention and or innovations. Lastly, each major development is supported with scientific and mathematical principles. For novices in the field of Image Analysis, these principles are presented as a teaching tool. Consequently, mathematics are initially introduced as concepts to help guide students in establishing their knowledge or understanding about the science and mathematics of Image Analysis. For subject experts, this chapter hold few, if any, surprises. Therefore, it is written as a single source reference intended to cover the wide range of subjects in the field of Image Analysis.

IMAGE FORMATION: THE FOUNDATION OF PHOTOGRAPHY

Camera Obscura

The term *"Camera Obscura"* was popularized by the German astronomer Johannes Kepler in 1604 (Gernsheim, 1969). Kepler was well-known for his contribution in the field of classical Physics. More specifically, because of his contribution to the simple laws of planetary motion. However, Kepler was instrumental in the field of photography. He introduced numerous concepts by expanding his works on Astronomy with observational writings on the following subjects (Hewitt, 1998):

1. Lenses
2. Geometry of optics
3. The behavior of light reflection and refraction

4. He introduced the Inverse-Square Law which governs light intensity, and
5. He pioneered the mathematics behind pinhole cameras.

Camera Obscura was simple device with a pinhole camera (Figure 1). This device captured light and deflected it to form an observed image or a shadow. Thus, it was widely used in the field of Astronomy at the time. However, the first known use of *Camera Obscura* can be traced back to the time of Mozi and Aristotle (Gernsheim, 1969). Thus, the first known mention of the principles behind the pinhole camera was credited to Mozi (470 to 390 BCE). Mozi was a Chinese philosopher who referred to his device as a "collecting plate. "On the contrary, Aristotle was credited with the practical use (safety) of this device used to observe the Sun without its damaging effect on the eyes (Hewitt, 1998).

In figure 1, *Camera Obscura* is composed of three simple parts. The pinhole (Labeled B) is where the light enters (Aperture). The lens was used to bend or manipulate the light; and the mirror (Labeled M) placed inside the device used to reflect light or regenerate the image for observation. This simple device demonstrated that in its simplicity a camera is composed of three parts: an Aperture, a Lens and a photo-sensitive device or sensor. Collectively, these three apparatus was referred to as Optics (Gustavson, 2009; Gernsheim, 1969).

Optics is a branch of Physics that incorporates the study of the behavior and property of light. This discipline also included the development of instruments used to detect the interaction of light with matter. Historically, Euclid (Circa 300 BC) a Greek mathematician was credit for much of the works in classical optics (Euclid's *Optics*) (Hewitt, 1998; Lea and Burke, 1997).

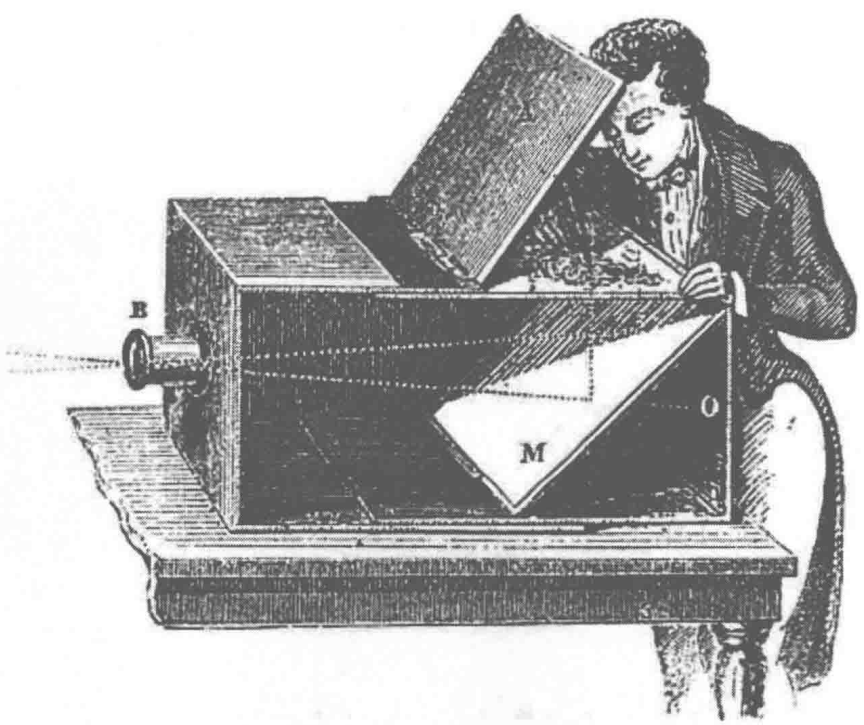

Figure 1. Camera Obscura or the Pin-Hole Camera. The device was composed of three simple parts: The pinhole (B) is where the light enters (Aperture). The lens was used to bend or manipulate the light; and the mirror (M) placed inside the device used to reflect light or regenerate the image for observation.