Preface

This book has been written in many *spatiotemporal coordinates*. For instance, some equations and figures were performed during my Ph.D. at the Technical University of Berlin (1996–2000). During that period, but in Hamburg, I took several X-ray images—that have been used in this book—in YXLON X-ray International Labs. After completing my Ph.D., and during my work in Santiago, Chile as associate researcher at the University of Santiago of Chile (2001–2003) and faculty member at the Catholic University of Chile (2004–to date) I have written more than 40 journal papers on computer vision applied to X-ray testing. During this time, I have developed a Matlab Toolbox that has been used in my research projects and in my classes teaching image processing, pattern recognition and computer vision for graduate and undergraduate students. Over the last few years, my graduate students have taken thousands of X-ray images in our X-ray Testing Lab at the Catholic University of Chile. Moreover, in my sabbatical year at the University of Notre Dame (2014–2015), I had the time and space to teach the computer vision course for students of computer sciences, electrical engineering, and physics, and I have been able to bring together all those related papers, diagrams, and codes in this book.

The present work has been written not only in three different countries (Germany, Chile, and the United States) over the last 15 years, but also in many different small places that provided me with the time and peace to write a paragraph, a caption of a figure, a code, or whatever I could. For example, I remember a Café in Michigan City where I spent various hours last winter writing this book with a delicious cappuccino beside me; or my study room in Fisher Apartments on Notre Dame Campus, looking out the window at a squirrel holding a nut; or on a narrow tray table while taking an Inter-Regio train between Berlin and Hamburg, which was where I drew a diagram using a pen and probably a napkin; and of course, my delightful office at the Catholic University of Chile with its breathtaking view of the Andes Mountains.

This book has been put together on the basis of four main pillars that have been constructed over the last 15 years: the first pillar is the set of journal and conference papers that I have published. The second corresponds to the material used in my

classes and the feedback received from students when I have been teaching image processing, pattern recognition, and computer vision. The third pillar is the Matlab Toolbox that I was able to develop during this time, and which has been tested in several experiments, classes, and research projects, among others. The fourth pillar is the thousands of X-ray images that my research group has been taking in recent years at our Lab, and the X-ray images of die castings that I took in Hamburg. Over all this time, I have realized that this amount of work can all be brought together in a book that collects the most important contributions in computer vision used in X-ray testing.

Scope

X-ray imaging has been developed not only for its use in medical imaging for humans, but also for materials or objects, where the aim is to analyze—nondestructively—those inner parts that are undetectable to the naked eye. Thus, X-ray testing is used to determine if a test object deviates from a given set of specifications. Typical applications are analysis of food products, screening of baggage, inspection of automotive parts, and quality control of welds. In order to achieve efficient and effective X-ray testing, automated and semi-automated systems are being developed to execute this task. In this book, we present a general overview of computer vision methodologies that have been used in X-ray testing. In addition, some techniques that have been applied in certain relevant applications are presented: there are also some areas—like casting inspection—where automated systems are very effective, and other application areas—such as baggage screening—where human inspection is still used. There are certain application areas—like welds and cargo inspections—where the process is semi-automatic; and there is some research in areas—including food analysis—where processes are beginning to be characterized by the use of X-ray imaging. In this book, Matlab programs for image analysis and computer vision algorithms are presented with real X-ray images that are available in a public database created for testing and evaluation.

Organization

The book is organized as follows:

Chapter 1 (X-ray Testing): This chapter provides an introduction to the book. It illustrates principles about the physics of X-rays, and describes X-ray testing and imaging systems, while also summarizing the most important issues on computer vision for X-ray testing.

Chapter 2 (Images for X-ray Testing): This chapter presents a description of the $\mathbb{GDX}$ray database, the dataset of more than 19,400 X-ray images used in this book

to illustrate and test several computer vision methods. The database includes five groups of X-ray images: castings, welds, baggage, natural objects and settings.

Chapter 3 (Geometry in X-ray Testing): This chapter presents a mathematical background of the monocular and multiple view geometry that is normally used in X-ray computer vision systems.

Chapter 4 (X-ray Image Processing): This section covers the main techniques of image processing used in X-ray testing, such as image pre-processing, image filtering, edge detection, image segmentation, and image restoration.

Chapter 5 (X-ray Image Representation): This chapter covers several topics that are used to represent an X-ray image (or a specific region of an X-ray image). This representation means that new features are extracted from the original image; this can provide us with more data than the raw information expressed as a matrix of gray values.

Chapter 6 (Classification in X-ray Testing): This section covers known classifiers with several examples that can be easily modified in order to test different classification strategies. Additionally, the chapter covers how to estimate the accuracy of a classifier using hold-out, cross-validation and leave-one-out approaches.

Chapter 7 (Simulation in X-ray Testing): This chapter reviews some basic concepts of the simulation of X-ray images, and presents simple geometric and imaging models that can be used in the simulation.

Chapter 8 (Applications in X-ray Testing): This section describes relevant applications for X-ray testing such as the inspection of castings and welds, baggage screening, quality control of natural products, and inspection of cargos and electronic circuits.

Who Is This Book For

This book covers an introduction to computer vision algorithms that can be used in X-ray testing problems such as defect detection, baggage screening, 3D recognition, quality control of food products, and inspection of cargos and electronic circuits, among others. This work may not be ideal for students of computer science or electrical engineering who want to obtain a deeper knowledge of computer vision (for which purpose there are many wonderful textbooks on image processing, pattern recognition, and computer vision[1]). Rather, it is a good starting point for undergraduate or graduate students who wish to learn basic computer vision and its application in problems of industrial radiology.[2] Thus, the aim of this book is to cover complex topics on computer vision in an easy and accessible way.

[1]See for example [1–8].

[2]Obviously, the algorithms outlined in this book can be used in similar applications such as glass inspection [9] or quality control of food products using optical images [10]—to name but a few.

For instance, we present complex topics (such as support vector machines and SIFT descriptors) in such a straightforward way that any student who does not have much knowledge of these fields, can still understand how they work without having to analyze complicated equations.

Hands on!

In this book there is a Matlab Toolbox called 𝕏vis Toolbox.[3] with around 150 functions for computer vision in X-ray testing. Each function has a 'help' with an example in order to show its use in X-ray testing. Additionally, the book gives several Matlab examples that can be followed by the reader. These examples use 𝕏vis Toolbox. Moreover, there are around 19,400 X-ray images on the 𝔾𝔻𝕏ray database[4] that can be used to test different algorithms and codes. The available examples, toolbox and X-ray images can help people to learn more about computer vision for X-ray testing. The reader can modify the codes and can create his/her own codes in order to develop new functions for X-ray testing. The reader does not need any advance knowledge of Matlab to read and understand this document; however, he/she must have familiarity with basic linear algebra, geometry, and general knowledge of programming. If the reader does not (want to) use Matlab, he/she can also understand the examples from a traditional perspective by way of analyzing the input and the output given in each example. For more online resources, such as papers, figures and slides, the reader can visit the webpage of the present book at the following address: http://dmery.ing.puc.cl/index.php/book/.

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References

1. Bishop, C.M.: Pattern Recognition and Machine Learning. Springer (2006)
2. Duda, R., Hart, P., Stork, D.: Pattern Classification, 2 edn. John Wiley & Sons, Inc., New York (2001)
3. Faugeras, O., Luong, Q.T., Papadopoulo, T.: The geometry of multiple images: The laws that govern the formation of multiple images of a scene and some of their applications. The MIT Press, Cambridge MA, London (2001)
4. Forsyth, D.A., Ponce, J.: A modern approach. Computer Vision: A Modern Approach (2003)
5. Gonzalez, R., Woods, R.: Digital Image Processing, third edn. Pearson, Prentice Hall (2008)

[3]Available online on http://dmery.ing.puc.cl/index.php/book/xvis/.

[4]Available on-line on http://dmery.ing.puc.cl/index.php/material/gdxray/.

6. Hartley, R.I., Zisserman, A.: Multiple view geometry in computer vision, second edn. Cambridge University Press (2003)
7. Klette, R.: Concise computer vision: an introduction into theory and algorithms. Springer Science & Business Media (2014)
8. Szeliski, R.: Computer vision: Algorithms and applications. Springer-Verlag New York Inc (2011)
9. Carrasco, M., Pizarro, L., Mery, D.: Visual inspection of glass bottlenecks by multipleview analysis. International Journal of Computer Integrated Manufacturing **23**(10):925–941 (2010)
10. Mery, D., Pedreschi, F., Soto, A.: Automated design of a computer vision system for visual food quality evaluation. Food and Bioprocess Technology **6**(8):2093–2108 (2013)

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