Preface

Machine vision is defined as a process of integrating a variety of technologies and computational methods to provide imaging-based information. The scope of machine vision is broad, and it has been applied to a wide range of applications including robot guidance, quality assurance, sorting, material handling, optical gauging, automated assembly, industrial inspection. This book focuses on the industrial inspection, which is to ensure the safety and reliability of the products through the measurements and tests of certain characteristics for an object or activity. Integrated imaging and machine vision techniques are the key technologies to achieve such measurements and tests. With the evolution of machine vision hardware, such as smart camera, LED illumination, time-of-flight camera, multicore processor, and graphics processing unit (GPU), it becomes possible to offer a cost-effective solution for inspection tasks with high-performance capabilities. Moreover, the expansion of wavelength gains the visibility of features not available in visible spectrum and thus greatly enhances the reliability and performance.

Advanced machine vision systems may incorporate multiple imaging and/or vision modalities to provide robust solutions to complex situations and problems in industrial applications. A diverse range of industries, including aerospace, automotive, electronics, pharmaceutical, biomedical, semiconductor, and food/beverage, and manufacturing, have benefited from recent advances in multimodal inspection technologies. This book is a collection of pioneering contributions in machine vision from academia and industries for varied inspection tasks. It highlights both the advances in technologies and vision system integration for practical applications. The advances provide an insight into recent progresses and developments of imaging and vision techniques for varied industrial inspection tasks, while the applications present the state of the art of imaging and vision system integration, implementation, and optimization.

This book consists of two major parts, that is, (Part I) Technology Advances and (Part II) Applications and System Integration for Vision-Based Inspection. The "Technology Advances" provide an insight into recent progresses, developments, and future trends of imaging and vision techniques for varied industrial inspection

tasks, while the "applications and system integration" present the state of the art of imaging and vision system integration, implementation, and optimization. The first chapter is contributed by the editorial team. A comprehensive review of the technology advances in machine vision is presented. This chapter screens the state of the art in machine vision technologies in the light of hardware, software tools, and evolution of algorithms for industrial inspection. The inspection techniques beyond visual spectrum, such as infrared thermal imaging, ultraviolet imaging, acoustic and ultrasonic imaging, gamma-ray and X-ray imaging, Terahertz imaging, millimeter-wave imaging, are described. This chapter also highlights multispectral and multimodal imaging in inspection, which can provide complementary information not available in unimodal imaging systems.

Part I of this book contains eight chapters. Ibarra-Castanedo et al. describe the reflectography/transmittography in the near-infrared (NIR) and short-wave infrared (SWIR) spectra and the infrared thermography in the mid-wave infrared (MWIR) and long-wave (LWIR) infrared bands. The NIR/SWIR reflectography/transmittography is applied to inspect semitransparent composite materials such as glass, aramid–phenolic, and a variety of natural fibers, while MWIR/LWIR thermography can detect surface and subsurface defects in varied types of materials. The complementary nature between NIR/SWIR reflectography/transmittography and MWIR/LWIR thermography makes it possible to provide an integrated solution for the specific inspection task. Metal surface introduces challenges to the visual inspection with its varying surface characteristics from one material to another. In the chapter contributed by Huber-Mörk et al., different configurations or setups for image acquisition and illumination are presented for the applications such as rail surface inspection, weld quality assessment, inspection of holograms on metallic foils, and reconstruction of coins. The algorithms for weld quality assessments are also described and discussed in detail. Multiview approaches are proposed for the inspection of optically variable security elements on metallic foil, and light-field data processing is applied to the inspection of coins. In automated visual inspection, the purpose of registering multiple images is to associate corresponding pixels to the same physical points on the object under inspection. In the next chapter, Penz et al. describe a real-time nonparametric 2D image registration method, namely "FlexWarp," which is based on image warping with grids and image pyramids. The FlexWarp algorithm can automatically select and assign control points, where only the most salient image features are correlated. A parallel implementation of the time-critical parts with GPU is applied to the print inspection in real time. Further discussions on the settings and performance of FlexWarp are available in this chapter. The background and recent advances in the development of portable optical coordinate measurement machine (CMM) and handheld scanner are explained in the chapter written by Larue et al. The unique capabilities of the new portable 3D measurement offer a more reliable and operator-independent tool for 3D metrology. More specifically, the dynamic referencing, automatic drift detection, and automatic alignment functionality make the measurement productive and efficient at a low cost. The significant impact to the 3D metrology is foreseen. A solution for fast 3D shape inspection is presented in the chapter by Ishii. A light-section method, which uses

multisided mirror between an image sensor and object under inspection, is proposed for 3D shape measurement. The measurement system is implemented with a high-speed vision hardware, which allows real-time image (1024 × 1024) processing at 1000 fps. Printed circuit board (PCB) with solders was inspected to verify the measurement accuracy at submillimeter level. The European project "3DComplete" is to create a low-cost and flexible quality inspection system capable of capturing 2.5D color data for the completeness of the inspection. The chapter by Munaro et al. is devoted to providing details of this work. The 3DComplete system employs a single color camera and a laser triangulation system to capture 3D data, which are then combined into a color 2.5D model in real time. This 2.5D color scanner can be applied to the inspection of objects within a production line for the completeness. This system is competent to perform the inspection tasks that remain challenges for state-of-the-art 2D-based methods. X-ray computed tomography (XCT) is used to detect and characterize the heterogeneities of materials by Kastner et al. Their work on cone beam XCT with micro-focus and sub-micro-focus X-ray sources is reported in the next chapter. Advanced image processing and visualization methods are developed for quantitative evaluation of the properties of metals and polymeric materials. To tackle the challenges introduced by curved surface with highly specular reflection to the defect inspection, Sho et al. proposed a novel vision system in their chapter, in which a set of images are captured under various illumination directions. This image set is then integrated to construct a single image suitable for defect detection, which is based on morphologic and template matching operations.

Part II of this book mainly focuses on applications and system integration. There are six chapters in this part. In modern manufacturing, industry robots are employed to conduct the inspection tasks with machine vision systems. The chapter from Eitzinger et al. covers topics relevant to the implementation of robotic inspection systems for industrial quality control from machine vision's point of view. Progresses in increasing the level of autonomy of the inspection process and making the inspection system easier to handle are highlighted. Condition assessment is critical for the management of civil infrastructure. Among all the methods, visual inspection is a key technology for assessing the physical and functional conditions of civil infrastructure. Koch et al. contribute their chapter to the machine vision techniques for the condition assessment of civil infrastructure. The chapter begins with the current practices in civil infrastructure condition assessments. The state-of-the-art machine vision techniques available for the condition assessment of civil infrastructure are described. The benefits and limitations of each technique as well as the corresponding challenges associated with the techniques are highlighted. Several case studies on inspecting bridges, buildings, and roads are presented to demonstrate the effectiveness of these techniques in condition assessment. Another work from the "3DComplete" project is presented in the chapter by Carlon et al., which targets inspecting a complex solid part. A 3D vision system is mounted on a manipulator robot arm to perform the inspection. This system integrates three software modules, i.e., visual inspection, 3D simulation, and motion planning of the manipulator. The system can automatically generate the needed points of view in order to perform 3D reconstruction and automatic visual inspection. Next chapter

contributed by Crawford et al. describes the ultrasonic techniques for the inspection of nuclear power plant welded components. Modern ultrasonic imaging techniques such as synthetic aperture focusing technique (SAFT), phased-array (PA) technology, and sound field mapping were applied to assess the integrity of the component and estimate the remaining useful life through the data interpretation and analyses. The use of electromagnetic wave imaging for concrete and wood structures is reported by Fujii et al. in Chap. 14, which comprises the description for the principle, system architecture, and image processing approaches. The last chapter of the book about magneto-optic imaging (MOI) is contributed by Deng et al. MOI, which combines electromagnetic and optical energies, is applied to the inspection of surface and subsurface cracks and corrosion in aircraft structures. The generated image is easy to interpret in comparison with conventional eddy current impedance data. The relatively new technique is insensitive to lift-off variations and can cover large inspection area. This chapter describes state of the art in the recent MOI system development and advances in processing algorithms.

This book offers the in-depth description of advances in inspection methodologies and machine vision technologies for specific needs, which makes it an excellent reference for researchers on developing innovative solutions to tackle practical challenges. The engineers will also benefit from the applications at both the system and component levels and be able to assure a smooth and efficient manufacturing process with a successful inspection system. For dealing with real engineering stuff, some thoughts about pitfalls and barriers of such systems are given for better understanding of their behavior in the automation process in the industry. This book will bridge the gap between theoretical knowledge and engineering practice for university graduate students, who are studying imaging, machine vision, and industrial inspection.

This book is a dedicated team work of all the contributors. Their great research work achieves the excellence of this collection. They deserve the greatest appreciations for their significant contributions. During the course of this project, the editorial team received continuous support from the publisher. We are grateful for all their help and effort on this work. Finally, Mr. Chenxi Yang at Toyota Technological Institute (Japan) is acknowledged for his sincere help on creating the index page of this book.

http://www.springer.com/978-1-4471-6740-2

Integrated Imaging and Vision Techniques for Industrial Inspection
Advances and Applications
Liu, Z.; Ukida, H.; Ramuhalli, P.; Niel, K. (Eds.)
2015, X, 541 p. 407 illus., 13 illus. in color., Hardcover
ISBN: 978-1-4471-6740-2