Special Issue on Reverse Engineering and Computational Metrology: Part 2—Computational Metrology Strategies and Methods

Computational metrology has recently begun to play a prominent role in the evolution of engineering systems and the improvement of production technologies. Indeed, this field has become essential due to the use of advanced inspection technologies in manufacturing industries. These technologies, primarily emerging scanning technologies such as coordinate measuring machines (CMMs), laser scanners, and three-dimensional cameras, have led to rising industrial demands for digital geometric processing (DGP) of sampled data. In response, new methodologies have been developed to cope with the complex metrology problems of data fusion, surface reconstruction, feature verification, and handling tolerances of sampled data. These computational metrology methods are used mainly for design, manufacturing, inspection, and quality control applications.

This series of special issues focuses on methodologies, fundamental theories and practical solutions for reverse engineering and computational metrology. The previous issue (Journal of Computing and Information Science in Engineering Vol. 6 issue 4, December 2006) presented the state-of-the-art research in reverse engineering and surface reconstruction. The current issue focuses on emerging measurement techniques, computational metrology, and software algorithms for analyzing data from measuring devices, including laser scanners and CMMs.

The fourteen papers in this issue cover a wide variety of topics, dictated by the interests of the engineering, scientific, and manufacturing communities:

- Computational metrology strategy and scanning methods
- Tolerancing methods
- Verification of features and geometric specifications
- Performance analysis of measuring devices
- Engineering applications of computational geometry

Four papers in this issue discuss computational metrology strategy and propose scanning methods. In the first, “Computational Metrology for the Specification, Production, and Verification of Product Geometry,” Srinivasan defines the field of computational metrology and describes state-of-the-art methods for specification, production, and verification of product geometry. The solutions involve both continuous and combinatorial optimization problems. The second paper, “3D Digitizing Strategy Planning Approach Based on CAD” by Derigent et al., presents a new method to test the visibility of a given part in a five-axis model. The method involves a newly developed heuristic for choosing the minimal number of directions required to entirely digitize a part using a laser or CMM. In the third paper, entitled “Multimodal Industrial Inspection and Analysis,” Singh et al. propose a data fusion method for inspection. The method involves nondestructive scanning technologies such as infrared thermography, ultrasound, CT/X-Ray, and CMM and is based on data fusion, construction of a solid model, representation of material variation, and defects and model analysis. The fourth paper, “Adaptive Range Sampling Using a Stochastic Model” by Devir and Lindenbaum, presents a new stochastic method for sequential point-sampling for 3D surface reconstruction. The paper focuses on terrestrial topographic mapping using mechanical devices such as a laser scanner.

Tolerancing methods are the main focus of three of the papers. In “Three-Dimensional Verification of Geometric Tolerances With the Fitting Gauges Model,” Pairel defines the tolerances of a part as 3D virtual gauge models that can be assembled with a part geometric model for inspection application. In “Tolerance Analysis of Free-Form Surfaces in Composite Material,” Polini et al. present a method for the tolerance analysis of an assembly involving freeform surfaces based on dimensional and geometric tolerances. The method has been implemented for aircraft application. The third paper, “Form Defects Tolerancing by Natural Modes Analysis” by Samper and Formosa, proposes a method to represent part defects. The method is based on modal tolerancing that represents the measured feature together with its tolerances.

Three papers deal with verification of features and geometric specifications. In “Substitute Geometry of the Features of Size: Applications to Multidimensional Features,” Portman et al. describe a method that recovers substitute geometry for multidimensional features. The paper concentrates on types that have an incomplete set of position and orientation deviations, among them cylindrical surfaces, surfaces of revolution, and helical surfaces. The second paper, “A New Variational Association Process for the Verification of Geometrical Specifications” by Choley and Riviere, describes a verification method for planar and cylindrical parts according to geometric specifications. The representation contains variations of the orientation, position, and intrinsic dimensional parameters.

Performance analysis of measuring devices is the subject of two papers. The first, “Methods and Artifacts for Comparison of Scanning CMM Performance” by Farooqui and Morse, analyzes the effects of scanning speed on the performance of different CMMs. The analysis measures CMM accuracy at different scanning speeds and directions. In the second paper, “Design of a Universal Software System for Controlling Geometric Measuring Devices,” Lubke et al. describe a platform developed to control and process diverse geometric data from different inspection devices. The platform has one uniform interface for all devices. Barbato, D’Agostino, and Levi propose a method for identification of maximum material over a machined surface in order to simulate tolerancing procedures according to the new version of ISO 5459 GPS.

Another two papers focus on engineering applications. “Measurement Techniques for the Inspection of Porosity Flaws on Machined Surfaces” by Steiner and Katz describes an inspection method that measures the porosity flaws on a surface. This method is crucial for determining the functionality of a product. The method is based on edge-connected pore algorithms. In the second paper, “An Approach Based on Process Signature Modeling for...
Roundness Evaluation of Manufactured Items,” Moroni and Pamella describe a new method for inspecting mechanical features by reconstructing and analyzing the signature of the process. The error is evaluated by means of a signals model due to the machined profile in the frequency domain.

The above papers together present the state-of-the-art in computational metrology methods from a broad perspective. The methods are based on up-to-date methodologies and theories with practical implementations that can meet industrial demands and improve current sophisticated production systems. It is our hope that this issue can provide the reader with a wide-ranging view of the role of advanced measuring methods in the field of computational metrology.

We would also like to thank Professor Deba Dutta and Professor Elaine Cohen for their advice and guidance in putting together this series of special issues.

Anath Fischer
Technion,
Haifa, Israel

Raffaello Levi
Politecnico di Torino,
Italy