Preface

A previous issue of the *IBM Journal of Research and Development* (May 1987) addressed the topic of computer-aided design (CAD) of products. The present issue is a logical successor, exploring modeling techniques implemented in software for the representation and analysis of products and their manufacturing processes. These techniques, which have come to be known as virtual prototyping, have as basic goals meeting competitive needs in reducing product cycle time and increasing product quality. This is to be done in an environment where product and process complexity is increasing rapidly. The virtual prototyping approach is based on developing fundamental understanding of a product and its manufacturing processes, validating this understanding through physical experiment, and implementing it in software models. The goals of virtual prototyping are met through exhaustive analysis of products and processes as part of the product and manufacturing engineering design process, thereby reducing both the need for physical experiment and the chance of problems arising later. In manufacturing, virtual prototyping can play important roles—for example, in yield learning (improving the production yield of the manufacturing process) from initial low-volume production to full-scale output.

Virtual prototyping also provides a mechanism for accumulating knowledge. Models are valid only for the phenomena they include. When an unforeseen problem arises—for example, with product reliability—the analysis and solution may be based on previously unrecognized phenomena and mechanisms not incorporated in the design model. Model-based solutions permit integration of the new understanding into the previously available modeling tools.

The papers in this issue may be divided into three categories: design and analysis of products, design and analysis of manufacturing tools, and the underlying geometry of designs, its representation and computation.

The paper by Mäntylä on top-down design of assembled products describes means of expressing the relationships between components and of viewing the components in terms of different phenomena, different levels of detail, and design constraints to be satisfied. This allows a CAD system incorporating the top-down design capability to support the design flow, from rough concept to final release of a fully detailed design. The survey paper by Deckert on slider bearing simulation shows how the modeling of a critical technology in direct-access storage devices (DASD) has evolved to a high degree of completeness on which designers can rely. A related paper by Cooper, on the design of critical DASD access mechanism components, highlights the importance of modeling to optimize the performance of high-technology products.

In the modeling of manufacturing process steps, both the process phenomena and the manufacturing tools must be considered. The paper by Jones and Logan on analysis of reactive sputtering systems analyzes the performance of a sputtering tool in terms of its geometric layout and gas flow rates, and correlates the modeled performance with physical observation. This can then lead to optimization of the tool design, for improved product uniformity or throughput. The survey paper by Dukovic on modeling current distribution in electrodeposition relates to a well-established and widely used technology in micro-electronics that is continually being pushed toward satisfying more demanding product applications. This evolutionary development will bring a need for better 3D model-based understanding to allow development and optimization of processes and their control for plating cells. The paper by Young on analyzing the properties of magnetic recording heads produced by thin-film processes illustrates relationships between product design and constraints imposed by the manufacturing processes and materials selections. The paper by Shareef et al. on the behavior of X-ray lithography masks under two different irradiation regimes illustrates an important use of virtual prototyping in the introduction of a radically new process technology based on phenomena for which previous experience is limited. Here, the modeling allows comparison of the two regimes and hence process selection to meet needs. In all these papers on processes, a common theme is the numerical computation of properties over complex geometric domains, generally using the finite element method.

The papers on geometric aspects of design cover topics of practical importance and significance, directed at improving the understanding, and hence performance and reliability, of modeling systems and the results they produce. The representation of curves and surfaces has received much attention over the years. The paper by Farouki and Sakkalis on Pythagorean hodographs presents a new approach to, and understanding of, a representation that offers many practical advantages in CAD for manufacturing problems, such as tolerancing and numerically controlled machine-tool path planning. The paper by Milenkovic and Nackman on compact representations addresses problems arising from attempts to perform exact computations on geometric data. They prove that an important goal—determination of methods for rounding geometric data—is NP complete, and propose methods for finding approximate solutions. The paper by Neff on the very basic CAD problem of finding the distance between two circles shows that the problem is deceptively complex and does not have a closed-form

solution. Again, practical methods of achieving robust solutions are presented.

The papers presented in this special issue on software modeling techniques for products and processes demonstrate the multidisciplinary nature of this field. The range of physical phenomena to be modeled is very wide and requires much work. There are fundamental issues on representation, manipulation, and solution techniques still to be solved. These techniques must be incorporated into easy-to-use, integrated systems to facilitate widespread use. There are many modeling tasks being addressed by many workers. Since these integrated modeling systems, which are essential for the introduction of new product technologies, are large and complex, there is an urgent need for standardization and adoption of modern software engineering techniques. Fortunately, these issues are currently being addressed by industry consortiums working toward framework standards that will allow integration and effective use of complete sets of modeling tools assembled from many sources.

Michael A. Wesley

Manager, Virtual Prototyping Department
IBM Thomas J. Watson Research Center

Guest Editor