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Opinion

# Report from a 2013 ASME panel on geometric interoperability for advanced manufacturing

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During the Summer of 2013 in a conference organized by the American Society of Mechanical Engineers (ASME) at Madison, Wisconsin, a panel of academic, industrial, and government researchers engaged in a spirited discussion on the issue of geometric interoperability for advanced manufacturing.[1] It was set in the background of heightened anxiety in various Western countries about the relative decline in their manufacturing activity and keen interest in reviving it through research and development. The Government of the United Kingdom, for example, has recently created several centers for innovative manufacturing.[2] The US Government has already set up a National Additive Manufacturing Innovation Institute,[3] and is poised to set up several more such national institutes to spur manufacturing innovation. While the challenges these countries and their institutes face have several dimensions, the ASME panel focused on a particularly nagging technical problem of geometric interoperability that is plaguing the progress in many advanced manufacturing systems, tools and technologies.

The panelists had considerable experience in the use of geometry in various design and manufacturing functions in industry. In spite of the widespread use of geometry throughout the lifespan of a manufactured product, it is the Computer-Aided Design (CAD) systems that serve as the dominant source for the geometric information needed in all modern Product Lifecycle Management (PLM) systems. Current CAD systems are built on the geometric and solid modeling foundations initially laid nearly 40 years ago. As the panelists described some of the industrial problems in advanced manufacturing and how they were solving them, it became clear that they are resorting to various 'workarounds' in the CAD-initiated representations of geometric information.

The manufacturing of layered composite structures serves as an interesting and useful example of advanced manufacturing. It has all the elements that illustrate the challenges faced by modern manufacturing industry. The aerospace and defense industry has embraced structures made from composite materials due to their superior strength-to-weight ratio. But today a wide range of industries – from commercial airframe, automobile and marine manufacturers to consumer and sports equipment producers – have come to depend on composite structures to improve the performance and efficiency of their products. Fiber reinforced plastics used in these composite structures are governed by complex polymer chemistry and the manufacturing processes are only partially automated. In a typical composite structure, scores of thin fiber-impregnated plies are laid on top of each other, often manually, and cured by applying temperature and pressure. The net geometry resulting from such layered manufacturing processes possesses all ingredients of classical solid modeling, but can have free-form shape, including exacting aerodynamic forms, and determines structural properties via spatial distributions of fibers. In fact, the net shape of a composite structure is defined by its complex manufacturing processes. This is very reminiscent of semiconductor chip design and manufacturing, with the additional considerations of much larger size and more complex three-dimensional shape.

A multitude of geometric representations and CAD systems are being used to support such advanced manufacturing, but none appear to be able to support the whole product design and manufacturing cycle, with interoperability emerging as one of the key issues. The notion of interoperability is often invoked loosely as the ability of a system or a product to work with other systems or products without special effort on the part of the customer.[4] Interoperability is usually made possible by the implementation of standards. In practice, any meaningful realization of interoperability requires a careful consideration of the domain – in the current case, geometry – of discourse.

The panelists quickly came to the conclusion that we have hit a hard limit with the geometric representations offered by current CAD systems, for several reasons that may not be entirely obvious:

- Scale and heterogeneity of geometry in material structures are orders of magnitude more complex than those supported by traditional homogeneous rigid solid and surface modeling;

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1 http://conferencing.uwex.edu/conferences/namrcmsec2013/Panels.cfm#Geometricpanel.

2 http://www.epsrc.ac.uk/research/centres/innovativemanufacturing/Pages/centres.aspx.

3 http://namii.org.

4 http://www.ieee.org/education_careers/education/standards/standards_glossary.html.

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- Complex, evolving multi-physics simulation and models, often based on empirical data, demand equally flexible and adaptive geometric foundations and representations that are not supported by any one system;
- The practical necessity of accommodating legacy data and systems are in direct conflict with the need for introducing new models, representations, algorithms and systems.

These observations lead to the inevitable conclusion that it is time to rethink the very concept of a CAD system as we know it. Recognizing the need to share geometric, material, and physical information across systems, tools, and manufacturing technologies, it might be possible to deliver this information not as a 'system' but as a 'service' throughout the product design and manufacturing lifecycle. How would such a service be conceived, developed, implemented, and standardized? The panel concluded that these questions lead to numerous exciting research and development opportunities that should be of interest to the larger CAD community.

Some of the research opportunities lie in the very notion of interoperability of geometric models and systems. A better scientific exploration of this topic, with an eye towards ubiquitous geometry information services across the entire lifecycle applications, will be a good start. As more of such information resources are virtualized – for example, using cloud services – this line of inquiry will provide the necessary scientific foundation for architecting and guiding software development to enable virtualization. In addition to supporting the traditional manufacturing enterprise, these foundations and virtualization will also empower the emerging collaborative CAD platforms and the movement of 'making' things anywhere as witnessed in the explosive growth of additive manufacturing.

Given its historical strength and focus in the broad field of geometry-based engineering information systems, the Journal of Computer Aided Design is in a unique position to influence and lead this transformation. The commercial success of today's CAD systems, as well as many technologies enabled by them, can be traced to the research foundations laid down by CAD pioneers several decades ago. Success of future geometry-based engineering information systems, in whatever form they may take to support the design and manufacturing enterprise, may very well depend on the research directions we choose to pursue today. Let us not miss this exciting and important opportunity.