Digital Volumetric Processing Using High Performance Computing

Thomas Kurfess, Christopher Saldana, Tommy Tucker, Roby Lynn
Pedro Urbina Coronado, Clayton Greer
Georgia Institute of Technology

Historically, analog representations have been converted to the digital domain to enable the use of digital computing, yielding substantial improvements in performance. For example, 1D signals such as sound are digitized and analyzed via digital signal processing (DSP). Furthermore, compression and connectivity enabled new business models, such as cloud-based music management, delivery and marketing systems (*e.g.*, iTunes). Although it required more time due to memory and computational power constraints, digitization progressed to 2D data (*e.g.*, images and video). Once again, this shift from the analog to the digital world enabled new technologies and business models. As with 1D signals and DSP, most image processing today is done via digital image processing. The premise of this concept for Blue Sky manufacturing is that digitization will transition from 2D to 3D resulting in digital *volumetric* processing (DVP). The initial instantiation of DVP is the voxel, which can be considered a 3D version of the pixel. DVP in combination with data compression, high-speed connectivity, and parallel operation formulation will enable next generation opportunities in manufacturing from a variety of perspectives including analytic, business and education.

Processing of digitized 3D models is not a new concept; it is used regularly in CAD/CAM/CAE applications with finite element meshes and STL-type representations. A voxel model provides a simple 3D structure for a part that is readily parallelizable, much in the same sense that the pixels on displays are processed in parallel using a graphics processing unit (GPU). Consequently, many of the parallel high performance computing (HPC) techniques used to accelerate graphics on a GPU can also be used on voxel models. Current research in the Precision Machining Research Consortium (PMRC) at Georgia Tech has leveraged such capabilities to both process 3D metrology data and program CNC machine tools at rates well over 1000 times faster than was previously viable. Additionally, as new cloud-based computing services purport another 1000-fold increase in speed using next-generation GPU platforms, the potential for a reduction in processing time by a factor of 1 million is quickly becoming a reality. Such capabilities, currently implemented at incremental cost on cloud services platforms, have enabled next-generation programming systems that include video game-like interfaces for programming 3-, 4- and 5-axis machine tools. As the engineer is designing a part with this game-like interface, a real-time analysis of the part's manufacturability provides instant feedback to the designer regarding the cost, quality, and viability of the design. Extension of these DVP concepts into the realm of additive manufacturing, which already relies on digital models (*e.g.*, STL), enables natural extensions of machine tool programming, metrology, and additive/subtractive design for manufacturability into fully integrated hybrid manufacturing operations. Furthermore, DVP is starting to gain traction in many types of finite element analyses (*e.g.*, thermal, solid mechanics, fluid flow, *etc*.), moving DVP into a more ubiquitous state in manufacturing, design, and analysis. Integration of DVP with digital twins that rely on empirical data for complete model definition enables a fully unified approach to process monitoring and control using discrete geometry.

An initial implementation of DVP on a GPU platform has generated a number of interesting results, the most substantial of which is a Desktop as a Service (DaaS) system that is now being used to support large-enrollment undergraduate design/build courses. Students are using game-like interfaces on a cloud-based HPC system to design, validate, and plan CNC machining processes to manufacture parts. Integration of the machine tools with the factory network allows real-time feedback in the design/build processes. These same systems have also been used to enable high school students to program 5-axis machine tools. Based on low-cost cloud HPC implementations, easy to use tools for real-time design, analysis, and manufacturing with both additive and subtractive processes are a reality. These tools will not only migrate into the Maker movement, but they will also provide the path for Makers to become Manufacturers.