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1 Introduction

Scientific visualization is an area which has grown greatly in size and importance in the last five years. This growth has been driven by a number of factors. One is the change in the types of calculations which are being done by CFD researchers. Ten years ago, the standard CFD calculation would be of steady, 2D inviscid flow, which could be easily understood by straightforward 2D computer graphics (e.g. monochrome contour plots, line plots of surface pressure, etc.). Now, 3D, unsteady, and/or viscous calculations are becoming common, and these are very much more difficult to imagine or visualize in our minds, let alone on a two-dimensional computer screen. Therefore, the development of tools for the visualization of such flows is very important if we are to properly understand the results of our calculations.

A related driving force is the huge increase in computer power over the last decade. A numerical simulation can be split into three phases: pre-processing (defining the geometry and constructing the computational grid), computation and post-processing (trying to understand the computational results). Ten years ago, most of the time and cost was in the computation phase. Due to faster computing speeds and much more complex geometries and flows, most of the time is now spent in the pre- and post-processing phases. Also, decreasing computer costs and increasing salaries mean that a larger fraction of a company's overall computing costs comes from personnel costs. Therefore, for industry which is both cost-conscious and anxious to reduce design times, there is a strong economic benefit to investing in visualization to increase user productivity.

The final most important factor is the emergence in the last few years of reasonably-priced computer hardware (and associated software) for visualization. SGI (Silicon Graphics) was the pioneer in developing custom chips to perform the general 3D transformations, Gouraud-shading and Z-buffering needed for 3D visualization. The competition increased with the formation of the Stellar and Ardent companies which later merged to form Stardent. Three years ago these companies were the only ones to offer true visualization platforms, offering 80,000–120,000 Z-buffered, Gouraud-shaded (smooth shading based on corner values) triangles/second, 250,000–500,000 3D vectors/second and CPU performance in excess of 10 Mflops. Also, these machines cost in excess of $100,000, making it impossible to think of putting one on the desk of every engineer or researcher. Today, such machines are offered by SGI, Stardent, DEC, HP, IBM, SUN and others, with discount prices around $30,000. In five years time it is perfectly reasonable to expect that such machines will have dropped in cost by another factor of four, and will be on the desk of every person who needs it.

The software side of the picture is also very important. In the past there have been numerous efforts to create software standards, but many of these have failed, leaving users with the difficult task of porting complex graphics programs onto different low-level graphics libraries. It appears that this situation is now ending. X-windows, which was developed