Eur. Phys. J. Special Topics **182**, 1–2 (2010)

DOI: 10.1140/epjst/e2010-01222-3

THE EUROPEAN PHYSICAL JOURNAL
SPECIAL TOPICS

Editorial

Editorial

Revealing the invisible – classical methods of flow visualization revisited

In recent years, relatively simple and well-known flow visualization techniques have been revitalized with the introduction of modern electronic imaging and digital, post-processing techniques. These technologies and techniques have eased the way images are gathered, from extending the spectral range to ultraviolet to infrared, and providing high resolution, high speed and so forth. The tedium of darkroom work in developing film and waiting hours or days for the pictures to arrive are no longer a concern. The digital format also opens up exciting ways of manipulating the images to extract features of interest. However, it is probably safe to say that, despite a relatively long history, image processing for fluid mechanics applications remains a largely untapped area of scientific endeavor. It is expected that this endeavor will grow rapidly since the advent of powerful computers and software makes it within universal reach.

The implementation of flow visualization ranges from basic laboratory situations to industrial and field setups. Most of the papers in this issue concentrate on high-speed gasdynamics where shocks and expansions occur. The simplicity of the techniques, however, belies their capabilities. For example, inroads in the understanding of many complex gasdynamics phenomena have been made through them. In addition, these techniques have aided in the discovery of complex flow structures that could not be easily confirmed by other experimental diagnostics and, for a long time, outside the ability of computer simulations. Even in this era of high performance computing, there is reliance on simple flow visualization techniques when it comes to educing flow structures. Thus, I hope that "revealing the invisible" is not an overly trite but justifiable theme for these papers.

The collection consists of four general review papers and four papers on specific applications. Kleine highlights the importance of videography for revealing invisible or minute features in high-speed flows. The challenge at high speed is simply the speed, which is well overcome by modern, high-speed digital cameras. Kleine argues that there are numerous advantages that normally outweigh the shortcoming of a loss in resolution at the highest speeds. One of the advantages of videography, be it time resolved or not, has to do with human physiology in that we can track minute changes from frame to frame, thereby identifying phenomena that may not be detected by a single, short duration snapshot (although this visual capability may be supplanted by computerized techniques nowadays). Kleine suggests that "if such unexpected phenomena appear on single images, they may be interpreted as noise or spurious experimental side effects because the single image provides little to no clue towards the development and/or cause of these phenomena. The danger of such misinterpretation is greatly reduced if one can observe the temporal development of the process."

Following the theme of time-resolved visualization, Durgesh et al. discuss the application of proper orthogonal decomposition for isolating large structures. This well-known and powerful quantitative procedure is rarely applied to imaging. As described by Durgesh et al., this procedure allows for further insight into unsteady and turbulent flows.

Turning to schlieren imaging, the contribution by Weinstein, one of the world's foremost practitioner of this technique, also highlights the power of including motion. In addition, the paper introduces lens and grid schlieren systems which can be used in circumstances where conventional schlieren may be difficult to apply. Weinstein discusses very large field schlieren, even utilizing the sun as the light source. These techniques show the versatility of schlieren systems, from implementations in the laboratory to the field.

The paper by Lu shows that surface flow visualization plays an important role in facilitating the understanding complex fluid flows, obviously with a surface present, despite the lack of temporal response. Surface flow visualization has also undergone a remarkable advance through the introduction of digital imaging, both still and video, and image processing. Lu showed how the surface topology is revealed and tied to flow phenomena. The review concludes with a summary of techniques and an example where the surface topology between experiment and high-order large eddy simulation is compared.

A number of papers are more specific in applying various techniques together to understand complex flow processes. For example, Alvi and Cattafesta show through examples how careful visualizations can be used to guide subsequent quantitative study, specifically for flow control. They show that flows over a large range of scales in typical laboratory situations, down to sub-millimeter, can be observed without considerable expense. Song et al. show how the schlieren technique can be used to obtain quantitative data of acoustic disturbances. This is an innovative approach in combining optics, electronics and data processing. Kimmel et al. demonstrate the effectiveness of a combination of visualization techniques in a low-density plasma channel for understanding those types of flows. A most practical application is provided by Hackett and Garg who show the promise of visualization techniques in the harsh environments of plasma-arc and gas assisted laser cutting to help in the understanding of complex flow processes.

Finally, it is my distinct pleasure to present this collection of papers to honor Professor Gary Settles on the occasion of his 60^{th} birthday. The papers are all written by Professor Settles' associates, the preponderance of which is written by his former students. In more than one sense, these papers reflect the influence of Gary over a span of 30 years. This is a strong influence for after all these years we are still applying these well-tried techniques albeit in new guises.

I still remember my first encounters with Gary who introduced me to the art of science, encouraging me to produce esthetically appealing visualizations in addition to ensuring their scientific value. I have been trying ever since! I also remember that Gary has a knack for setting up optical hardware and in having an extraordinary amount of patience. Gary not only is a pioneer in many of the techniques discussed in this collection but is also a futurist. As early as the mid-1980s,[1] he saw the potential of digital technology for improving flow visualization. Thus, the purpose this collection of papers is not to review all the possible digital techniques but to provide a platform from which imaginative use of digital technology can rejuvenate simple flow visualizations, still keeping the overall simplicity.

Gary's contributions to flow visualization continue to be prolific. Our papers pale in comparison but we trust that they are a worthy tribute to a scientist, educator, mentor and friend.

Throughout the editorial process, I benefited greatly from the assistance provided by Dr. Christian Caron, Sabine Lehr and Isabelle Houlbert. I thank them and the rest of the production staff for their encouragement and patience.

Frank K. Lu
University of Texas at Arlington
May 20, 2010

[1] Settles, G.S., "Modern developments in flow visualization", AIAA Journal **24**, No. 8, 1313–1323 (1986).