XXI ICTAM, 15-21 August 2004, Warsaw, Poland

MULTIIMEDIA FLUID MECHANICS: A FLEXIBLE EDUCATIONAL TOOL FOR TEACHING AND LEARNING FLUID MECHANICS

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Summary This paper describes *Multimedia Fluid Mechanics* (Homsy, et al., Cambridge Univ. Press, 2001), a new, versatile multimedia tool for education in fluid mechanics. We discuss the pedagogical principles on which it is based, together with a description of many of its features. The presentation of this paper will include a demonstration of these features, with an emphasis on broad educational approaches that apply to all fields of Applied Mechanics.

INTRODUCTION AND EDUCATIONAL CHALLENGES

"Multi-Media Fluid Mechanics" [1] (MMFM) is a CD-Rom, compatible with a wide range of platforms, processors, and operating systems, containing multimedia materials for teaching undergraduate fluid mechanics. It is marketed by Cambridge University Press and priced at a cost ($20/copy) that ensures its widest possible dissemination. This paper outlines some educational challenges and shows how we have dealt with them.

Fluid mechanics remains a core subject within many disciplines of engineering and applied science. The fundamental basis of the subject is reasonably easy to state, since it is firmly rooted in the principles of conservation of mass and Newton's Second Law of Motion. The mathematical statement and the consequences of these principles for continuously deforming media are, however, often confusing and daunting to the student. The subject is mathematically sophisticated, involving (i) time dependent, 3D partial differential equations, (ii) the essential use of vectors, tensors, and vector analysis, (iii) an often bewildering array of dimensionless groups, (iv) the dependence of fluid phenomena on various parameters over a wide range of those parameters, and (v) the surprising behavior of fluids that often runs counter to a naive set of intuitive concepts.

The teaching of fluid mechanics has been aided by the existence of visual aids, the most notable of which are the series of films produced in the 1960's by the National Committee on Fluid Mechanics Films, and the Album of Fluid Motion [2]. MMFM seeks to improve on these resources by addressing the following challenges to be met by the next generation of educational materials in fluid mechanics.
Connect concrete physical phenomena with mathematical / analytical abstraction. Many of the important concepts in fluid mechanics, e.g. vorticity, velocity, and pressure fields, and vector analysis are not particularly tangible to beginning students. A major challenge is to teach how physical concepts are expressed in mathematical terms, and to develop the ability to move freely between mathematical context and physical reality.
Incorporate modern computer simulation into the curriculum. Learning is enhanced by the ability to simulate and visualize flows which cannot be expressed by analytical theory. The use of computation is invaluable in providing the ability to systematically vary parameters and study the evolution of flow structures and flow physics. However, the time involved in writing and validating of robust software for flow simulations often puts the use of computer simulation outside the range of student projects on the one hand, and the time and expertise of the instructor on the other. Delivery of such robust software through interactive media results in enhanced capabilities that can be widely disseminated.
Expose students to state-of-the-art experiments in fluid mechanics. Experiments and the qualitative and quantitative knowledge they express are invaluable in reinforcing concepts from the mathematical theory of fluid flow. Modern flow visualization using high-speed cameras, along with tracers such as small particles, bubbles, and laser induced fluorescent dyes, has greatly extended the range of flow visualization techniques and the insight gained from them. Such images are indispensable in building physical intuition. However, construction of state of the art apparatus is expensive, difficult to maintain, and often beyond the financial resources of many colleges and universities.
Increase student learning by generating curiosity and exploiting the medium. Instruction in fluid mechanics in the traditional lecture format sometimes suffers from the false perception that the subject is "mature", and that nothing new has happened in it for a long time. Interactive computer exercises, visualizations, and demonstrations can have considerable impact in generating interest and excitement in this vital subject among the best and brightest students.

MULTIMEDIA FLUID MECHANICS

MMFM contains four modules covering the subjects of Dynamics, Kinematics, Boundary Layers, and History. Each has a number of topics, and each of these topics is developed in a number of pages. These visual materials are in 1/4 screen video format, and are viewed using standard QuickTime software, as shown in the Figure. The interactive material includes simulations, virtual labs, and well over 250 video visualizations, animations, and demonstrations of fluid phenomena material that are intended to complement any of the standard fluid mechanics textbooks.

Figure: Examples of pages. (a) Flow visualization. (b) Computational Fluid Dynamics

The videos can be accessed through a separate Video Library, thus enhancing its use by instructors in the classroom. Navigation between and within the modules is clear and easy, and is facilitated through the use of hyperlinks. The structure is flexible, allowing its use in a wide variety of contexts ranging from community college physics courses to first year graduate level courses at universities. The primary features are:

Simulators: Students use computer simulations to vary parameters and/or illustrate a principle. MMFM has three such simulators: Molecular Dynamics, Integration of the Laminar Boundary Layer Equations, and the Potential Flow Builder.

Virtual Labs: Students take quantitative data from videos and/or use a simulator to compare theory and experiment, including (i) matching potential flow theory with Hele-Shaw experiments; (ii) verifying dynamic similarity in vortex shedding; (iii) measurement of laminar boundary layer growth in the Blasius boundary layer; and (iv)verification of self-similarity in the impulsive start of a plate.

Charts and Demonstrations: Extensive series of over 50 charts and demonstrations includes side-by-side comparison of flows at different Reynolds numbers and for different shapes; comparison of potential flow theory with bluff and streamlined shapes; flow structure around sports balls; origin of drag forces as a function of Reynolds number and body shape; techniques and methods of flow visualization; and many others.

The Flow Gallery: In this gallery, the student may view any of a large number of videos of fluid phenomena, including flight, vortices, mixing, swimming, thermal plumes, airplanes, natural and environmental flows, etc. These are arranged pairwise according to the Reynolds number, and include a description of the principles involved.

MMFM AS A MODEL

Conquering abstract concepts in fluid mechanics has positive consequences for students in other contexts. Fluid mechanics is a field theory, and as such provides the student his or her first exposure to a continuum description of mass, momentum, energy, force, and other quantities in a familiar, mechanical context. These concepts will emerge often in later studies, where they may be set in considerably more abstract contexts, e.g., in electromagnetic field theory and solid mechanics. Modern interactive multimedia modules that emphasize experiments and computations (as distinct from simple animations) can be extremely effective in other fields of mechanics. The use of multimedia brings material to the student in an attractive, understandable, visual and stimulating way, piquing curiosity, and drawing the student deeper into the subject. It creates an environment in which students can manipulate experimental and computational knowledge to increase their learning and retention of the subject by engaging them with the material through a series of simulations and virtual laboratories.

MMFM has enjoyed broad support among the community and a second volume is in the production stage. But it has found its greatest use thus far in the USA. Our purpose in submitting this paper is to broaden the exposure to the international community, interact with others involved in Education in Mechanics, and generate ideas for further improvement of educational materials.

Acknowledgement

"Multi-Media Fluid Mechancs" was sponsored by the US National Science Foundation through grant NSF/DUE 9752199.

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[2] "An Album of Fluid Mottion" Milton Van Dyke, Parobolic Press (1982).