

2004

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Chaturvedi, Sushil; McKenzie, Rick; Akan, O. A.; and Priyadershini, A., "Mapping of Thermo-Fluids Laboratory Experiments Into Web-Based Experiments" (2004). *Mechanical & Aerospace Engineering Faculty Publications*. 85.

https://digitalcommons.odu.edu/mae_fac_pubs/85

Original Publication Citation

Chaturvedi, S. K., McKenzie, R., Akan, O. A., & Priyadershini, A. (2004). *Mapping of thermo-fluids laboratory experiments into web-based experiments*. Paper presented at the 2004 American Society for Engineering Education Annual Conference and Exposition, Salt Lake City, Utah.

MAPPING OF THERMO-FLUIDS LABORATORY EXPERIMENTS INTO WEB-BASED EXPERIMENTS

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Abstract

A methodology is being developed for transforming physical experiments from the undergraduate thermo-fluids laboratory into a web-based virtual experiments. Important characteristics of physical experiments are identified in order to preserve them in physical to virtual domain mapping. Several commercially available software are employed to incorporate in the web-based experiments characteristics such as recreation of physical phenomenon in the virtual domain, measurement of physical quantities on a computer screen, assembly of virtual probes and coupling of the virtual experiment with a data acquisition software. A virtual reality software has been incorporated to enable web-based students to navigate through the virtual laboratory, and perform the virtual experiment on-line. The web-based virtual experiment module has the potential of becoming a building block for virtual laboratories for web-based undergraduate engineering programs.

1. Introduction

Televised and online courses, virtual collaborative learning environments, synchronous and asynchronous video-streaming of courses, multi-media courses, and virtual laboratories are emerging information technology based learning tools¹⁻¹⁵ that enable engineering educators to improve the quality of instruction, and develop innovative course materials, and delivery methods that cater to learning styles of present generation of engineering students. Current students are more familiar with computers, the Internet, and interactive video games. As a result, they are more attuned to a learning style based in visualization and animation. In order to engage fully in this ongoing educational technology revolution, and to meet the objective of graduating engineers who are fully prepared to practice in a world transformed by computer and Internet technologies, the College of Engineering and Technology at Old Dominion University has developed a vision to transform its undergraduate curricula through computer-based learning modules that utilize simulation and animation. Also, the University has recently launched the e-Dominion initiative, a bold strategy that proposes to educate distance-learning students through web-based courses. Consistent with the College vision and recent University initiatives, we propose the creation of a web-based virtual experiment module as a test bed for further development using a computer software and an animation technique. Initially, this and other

web-based modules will be used by students in laboratory classes for practice runs before they conduct physical experiments. This educational tool is expected to enhance students understanding of experimental procedure, analysis, data acquisition software and type of data to be taken, and will teach them about anticipated trends describing relationships between inferred parameters and measured parameters. This tool has other applications that will be described later.

2. The Vision and Broad Impacts

Our vision is to develop web-based virtual engineering laboratories that will closely emulate the learning environment of physical engineering laboratories. Using recent paradigm shifts in visualization technology, together with advances in computer solutions of physical phenomena, design and implementation of truly interactive, life-like virtual experiments has become feasible. We do not suggest that a one-to-one (perfect) mapping of physical experiment into a web-based virtual experiment will ever be possible. However, by ensuring that important characteristics of the physical experiment are identified and preserved during the proposed mapping, a methodology will evolve that we believe will be very useful in development of web-based virtual experiment modules that can be used in physical laboratories, lecture classes and for web-based virtual laboratories for distance learning engineering programs.

Students in the Thermo-Fluids Laboratory (ME 305) course are using a web-based virtual experiment module, mimicking the physical experiment, for practice runs before performing the actual experiment. This is expected to reinforce student learning due to module features such as interactivity as well as accessibility via the Internet, and will promote safety due to students having more familiarity with experimental procedures. The overall quality of lab experience will improve because students will be exposed to hands-on experience in both physical as well as virtual domains. Another benefit of the web-based virtual experiment module is that instructors will be able to download web-based virtual experiment modules on their laptop computers in lecture classes for clarification of concepts and reinforcement of physical principles. Instead of taking students to a laboratory demonstration during a lecture, an instructor will be able to use computer-based virtual experiment modules to illuminate and reinforce basic concepts. As a result, web-based virtual experiments have the potential of becoming powerful visualization tools in a classroom setting where an instructor can discuss “what if” scenarios as he or she performs a virtual experiment interactively. These virtual experiments will provoke classroom discussions and transform students from being passive listeners to active participants.

Finally, the proposed methodology will provide the framework for development of virtual laboratories at Old Dominion University and other institutions, and will facilitate efforts to implement web-based engineering programs. It is interesting to note that, despite technological advances, there is a scarcity of undergraduate engineering programs available through distance learning networks. This is primarily due to difficulty in providing laboratory experience on the Internet¹⁶. There are only two or three distance learning engineering programs in the nation and most of them either require campus visits for laboratory courses³ or rely on videotapes or CD-ROM of laboratory experiments¹⁵ for laboratory courses. Development of real life like web-based virtual laboratories will cause distance network based undergraduate engineering programs to become more viable, and reach a diverse student population base that would not have otherwise enrolled due to geographical or other limitations.

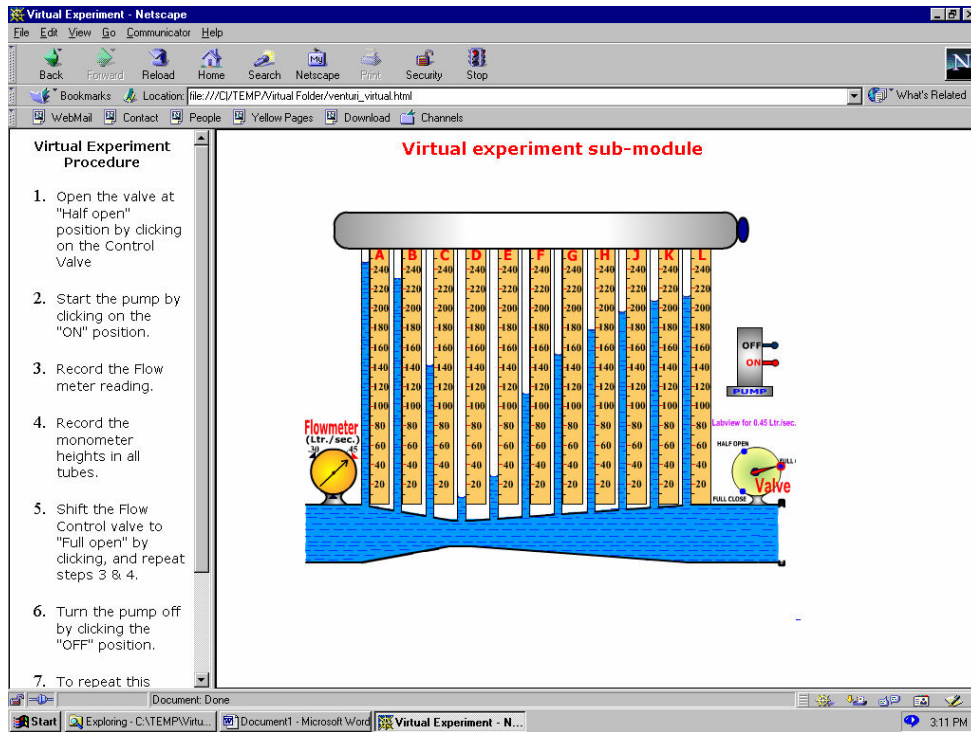


Figure 2 A Snapshot from Animation of Virtual Venturimeter Experiment

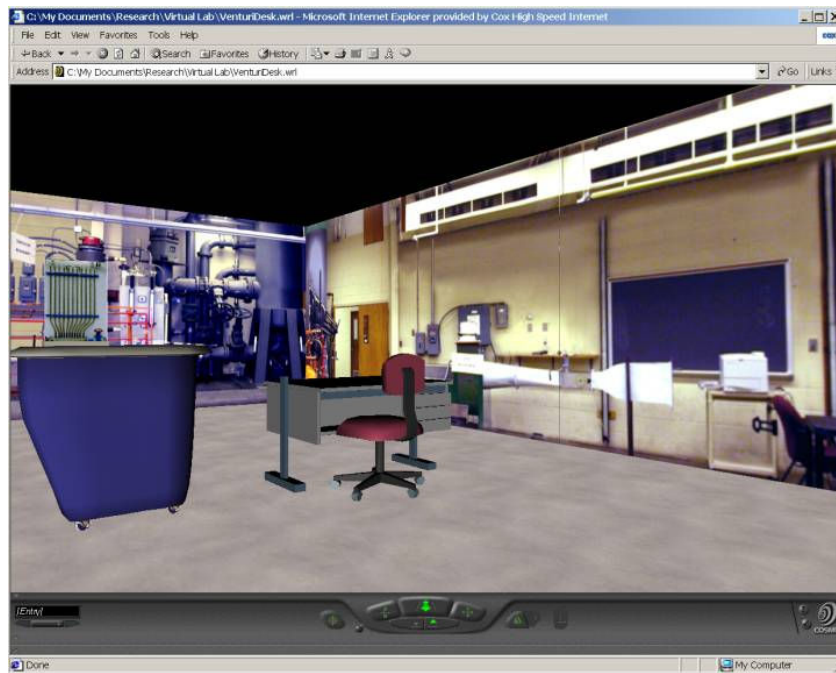


Figure 3 The Virtual Reality Laboratory

3.2 Virtual Measurement Devices and Virtual Assembly

Three types of virtual probes, namely e-pitot tube for velocity measurement, e-manometer for pressure measurement, and e-differential pressure transducer for differential pressure measurement, are being developed for data acquisition. These devices will be modular and transportable on the computer screen by clicking and dragging the mouse. In the cylinder drag experiment (Fig. 1), a survey of the upstream velocity profile at section AB by traversing an e-pitot probe will determine the quality of the incoming flow, as characterized by the uniformity of the velocity profile (Fig. 1). Similarly, the cylinder wake velocity profile will be measured by moving the e-pitot probe along section CD. The e-pitot probe connected to an e-manometer will yield the prevailing dynamic pressure distribution at sections AB and CD. In order to facilitate virtual measurements, the velocity field from numerical results from the CFD code will be converted into the Δh (height differential in manometer) field. Placing the e-pitot probe at a given location, for example at point E in Fig. 1, will prompt the transfer of the numerically pre-calculated Δh value at that point to the animation program controlling the operation of the e-pitot probe. This program will also direct the movement of liquid levels in the e-manometer. As a result of this interaction, the liquid level in the left limb will decline by $\Delta h/2$ and rise by $\Delta h/2$ in the right limb, yielding a measurable reading of manometer deflection of Δh on the computer screen.

The total drag and the drag coefficient will be determined by applying the momentum integral equation to the control volume ABCD in Fig. 1. The procedure and the governing equation are reported elsewhere (19) in some detail and, therefore, will not be repeated here. The proposed experiment has been chosen because it reinforces two important concepts in fluid mechanics, namely the drag coefficient and the application of momentum integral equation for determination of forces acting on a body submerged in a moving fluid.

The concept of virtual assembly is being developed to facilitate students' participation in assembly and operation of the experiment. Using an e-probe box, students will be able to move and mount test objects as well as virtual probes before commencing the experiment. The e-probe box will house test objects as well as e-probes required for virtual measurements. The proposed design, for the experiment titled "Drag on a cylinder in cross-flow," is shown schematically in Fig. 4. The wind-tunnel will have windows that can be removed by the clicking action of the mouse to facilitate insertion and movement of pitot-tube inside the tunnel. The devices in the e-probe box located in the top left corner of Fig. 4 can be activated by the clicking action of the mouse and can be positioned at appropriate locations for measurement by the clicking and dragging action of the mouse. Figure 5 shows the close-up view of the set-up once virtual probes are assembled.

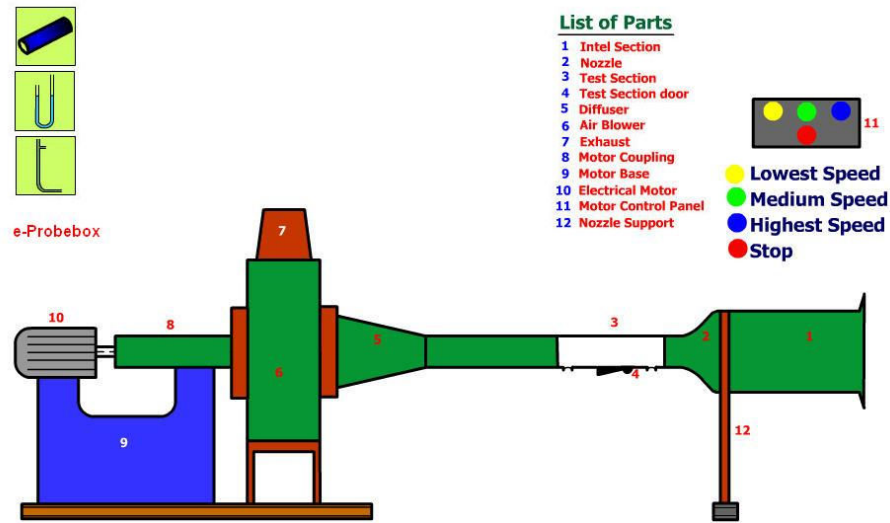


Figure 4 Proposed Virtual Experiment Design with Wind-Tunnel and the e-Probebox

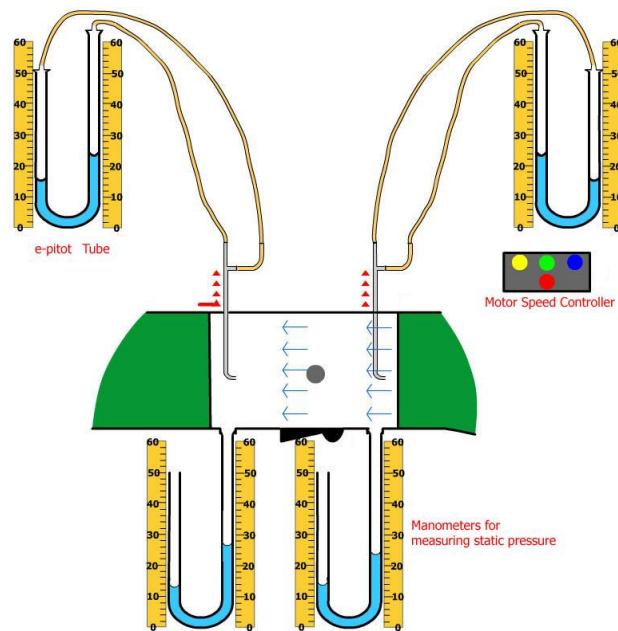


Figure 5 Details of Instrumentation for the Virtual Experiment

4. Conclusions

A framework for developing a web-based virtual experiment has been established. The virtual experiment modules currently being developed will allow students to run an experiment and make measurements on a computer screen. A virtual reality software facilitates a web-based distance learner to navigate the virtual reality laboratory, and perform the embedded virtual experiments. The authors have introduced the virtual assembly methodology to allow students to assemble virtual probes on a computer screen prior to commencement of the experiment. One of

the web-based experiment (venturimeter) has been introduced in the undergraduate thermo-fluids laboratory course as a practice tool. Student participation thus far has been voluntary, but there are plans to make it mandatory to increase student involvement.

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