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VIRTUAL REALITY IN CHEMICAL ENGINEERING EDUCATION

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Virtual Reality

Virtual reality, VR, is an emerging computer interface that strives to make simulations so realistic that users believe, if only for a moment, that they are experiencing "the real thing." Highly realistic and believable simulations are accomplished using high-speed graphics supercomputers, three-dimensional graphics accelerators, head-mounted display devices, wired gloves, spatial audio processing, psychological and cognitive skills and numerous other technologies and techniques [7]. Less realistic though still effective VR is available on modern personal computers. As the speed and capabilities of personal computers rapidly increase, and as the cost of high-performance graphics computers continues to drop, we can expect to see high-quality VR on the average desktop within the next 5 to 10 years.

The question then, is "How can we take advantage of this new technology to enhance and improve engineering education, and how can the skills we gain as a result be applied to other areas of engineering?" In order to answer these questions, work has been conducted at the University of Michigan to develop a series of VR-based educational modules [1-2]. This paper will briefly discuss these modules, as well as some of the things that have been learned during their development, and how educators can download and implement the modules.

Educational Benefits of VR

The important distinguishing features of VR are that it is highly immersive, interactive, visually oriented, highly sensory, colorful, and generally exciting and fun. VR is a good media for presenting three-dimensional objects and relationships, and for illustrating concepts that have been covered elsewhere. VR is **NOT** an appropriate medium for delivering written information (at least on low-cost systems), and it is not a substitute for traditional educational methods. However when used properly, it can augment traditional methods to the benefit of some students.

Dale Edgar [4] has shown that we only remember 10% of what we read, and 20% of what we hear, but that we retain up to 90% of what we learn through active participation. Thus the action and immersion of VR should improve long-term retention of material. The other strong benefit of educational VR involves reaching students with differing learning styles [5]. Some students learn very well from oral lectures and written words. These verbally oriented students generally do not need virtual reality. Other students are more visually oriented, and do not fully understand the words they hear and read until they can visually see an illustration of the concepts. VR can help this latter group to better understand material covered in class and texts.

Vicher 1

Vicher 1, (Virtual Chemical Reactors 1), is the most significant and well-developed module produced to date. The focus of this module is to illustrate concepts in heterogeneous catalysis, or more specifically, mechanisms for dealing with decaying catalyst. Vicher 1 opens with a welcome center containing doorways leading to five other areas. In addition to serving as a central gathering point, the welcome center fulfills a psychological role by providing a familiar environment in which students can become accustomed to VR and learn to work the controls.

There are three reactor rooms in Vicher 1, (as shown in Figure 1), illustrating slow, medium, and fast rates of catalyst decay. Slow decay is illustrated in the time-temperature room, where reactor temperature is increased over days to weeks to compensate for slowly decaying catalyst. The moving-bed room illustrates medium decay with catalyst pellets that fall from one packed bed to another over a period of several hours. A pilot plant scale catalytic cracker in the transport reactor room illustrates rapid decay with time frames of seconds to minutes.

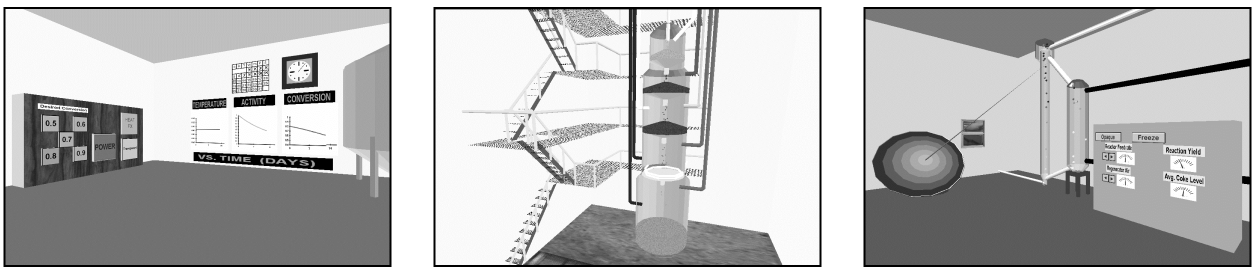

Figure 1: The Time-Temperature, Moving-Bed, and Transport Reactor Rooms.

There are also three microscopic environments in Vicher 1, as shown in Figure 2, in which students can observe heterogeneous catalytic reaction mechanisms at the molecular level. The first of these is the exterior of a catalyst pellet, (a fine powder in the real world), illustrating external diffusion. The pellet exterior also serves as a transition between the macroscopic and microscopic worlds. Entering the interior of the catalyst pores, students observe up to 100 molecules that diffuse, adsorb, react, and desorb according to kinetic principals. Because this area can become highly congested, students can also pass through the walls to a close-up environment where a single molecule reacts in an orderly, labeled manner. An undesired side reaction also occurs, which fouls the catalyst with a tar-like material called coke.

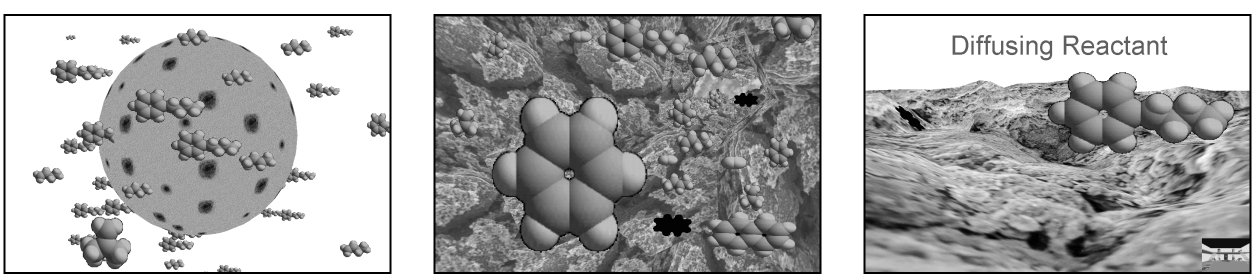

Figure 2: Exterior and Interior of a Catalyst Pellet, and a Close Up View of the Interior Surface.

Vicher 2

Vicher 2, (Virtual Chemical Reactors 2), is similar in form and function to Vicher 1, but deals with non-isothermal effects in kinetics and reactor design. The non-isothermal packed bed reactor room features a color-coded, 3-D kinetics surface and a similarly colored packed bed reactor. The colors serve to relate the abstract mathematics to the physical reactor, and also indicate temperature profiles down the length of the reactor. The staged reactor area shows four reactors in series, with a common furnace pre-heater. A 2-D kinetics inset is related to the equipment through color coding and a moving tracer. The multiple steady-state room illustrates a common control problem with exothermal jacketed reactors.

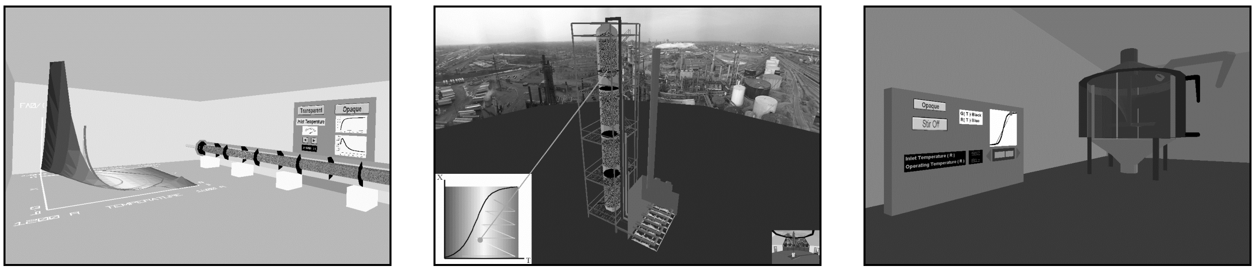

Figure 3: Non-Isothermal PBR room, Staged Reactor Area, and Multiple Steady States Room.

Interactivity and Help

In each of the simulations discussed above, students can change the operating conditions of the reactors using virtual control panels, as illustrated in Figure 4a. This interaction allows them to experience the effects caused by these changes. Students can toggle the transparency of the reactors to observe internal conditions, and there are several other interactive mechanisms, such as signs that initiate teleports, escalator pads, and virtual television sets.

Students can also request area-specific help from within the VR simulation, which launches the HTML (web) based help system. This format was chosen to make the help system platform independent, to allow for stand-alone help, and to provide support for photographs from real chemical plants as well as newly emerging web standards QTVR and VRML. Figures 4b and 4c show a catalyst micrograph and a QTVR still frame, respectively, extracted from the Vicher 1 help system. The safety module to be discussed next also includes an HTML-based help system.

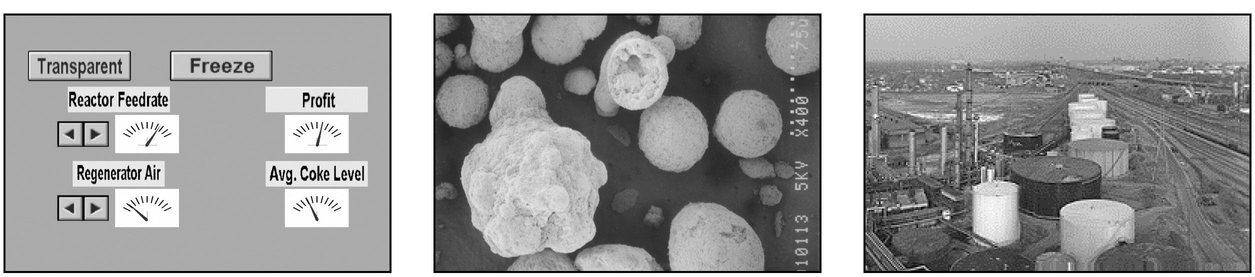

Figure 4: Vicher 1 Control Panel; Catalyst Micrograph and QTVR Image From “Help” System.

Additional Modules

The third major module to be produced deals with the area of chemical plant safety. In this simulation, students explore a pilot-plant scale polyether-polyol production facility, in order to analyze the hazards and safety systems present. Based upon preliminary studies, major revisions are underway to improve the effectiveness of this module. (Without sufficient direction and guidance, students would not benefit significantly even from a real chemical plant.)

A number of smaller modules have also been developed, as proof-of-concept tests and to explore some of the other capabilities of educational VR. Two crystals structures modules and a fluid flow simulation explore VR's usefulness for visualizing three-dimensional phenomena. The latter application also uses color, motion, and size to convey information. Similarly, a PVT simulation indicates four physical properties (pressure, volume, temperature, and entropy) simultaneously through four "dimensions" of a single icon (shape, size, color, and sound respectively.) Another thermodynamics related application uses VR to portray abstract relationships (Maxwell's thermodynamic relationships) as opposed to physical objects. A final minor application displays azeotropic distillation residue curves in four dimensional space.

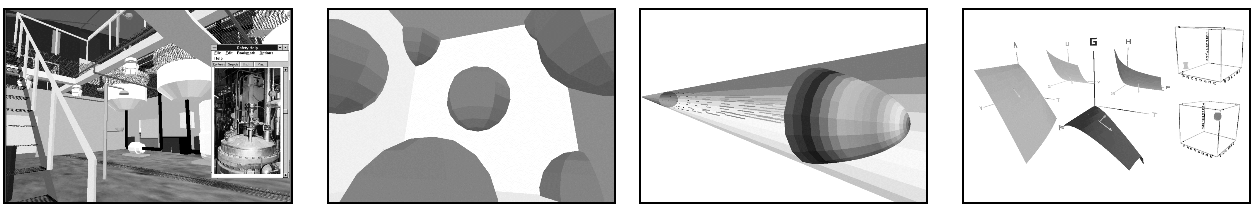

Figure 5: Other Applications: Safety, Crystal Structures, Fluid Flow, and Thermodynamics.

The Making of The Modules

The modules described here have all been programmed in C, using the WorldToolKit software package from Sense8 corporation [8] and undergraduate chemical engineering student programmers. With suitable guidance and building upon existing infrastructure, it currently takes one student one semester to develop the first version of a new room for Vicher 1 or 2. The minor modules require less effort, as little as a single day for some of the first versions. In addition to C programming, students must also learn some combination of 3D geometry, CAD, computer graphics, web authoring, audio processing, educational methods, cognitive science, interior decorating, landscaping, theatrical set construction, magic tricks, psychology, computer hardware maintenance, SEM microscopy, photography, and of course the chemical engineering principals illustrated by the modules. Obviously no single student masters all of these skills.

In the 3 years since work commenced on this project, newer and simpler methods for developing VR have been developed, such as VRML (Virtual Reality Modeling Language [3]) and WorldUp from Sense8. The former is an HTML-style language for creating 3D interactive web pages, and the latter is a point-and-click development tool. While neither is as powerful as C programming, they do provide for rapid development and easy widespread product distribution.

Downloading and Implementing The Software

Educators can download the VR modules described here free of charge by accessing the VRiChEL (Virtual Reality in Chemical Engineering Laboratory) web site at:

http: / / www.engin.umich.edu / labs / vrichel.

The Windows NT and Windows 95 versions are delivered as self-extracting compressed executable files (using InstallShield software [6]), and the Silicon Graphics versions are tar archives. The Windows NT and Windows 95 versions are based upon Open GL and DirectX graphics respectively, and will run much faster when using video cards that support hardware-level acceleration of these graphics standards, and in particular, hardware-level texture map acceleration. (This is really only a concern for Vicher 1, Vicher 2, and the safety module; The minor modules should run reasonably fast on almost any modern computer.) Although the programs support the use of several VR-related hardware devices, (including head-mounted displays, BOOM, and CAVE displays), the use of such equipment is completely optional.

It is recommended that VR be used as an optional exercise, since the benefits vary from student to student (as discussed on the first page of this paper.) Instructor's guides for the Vicher modules are under development, and should be available by the time this paper is presented.

References

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