A Different View: Virtual Interactive Engineering on the Web

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Computer Science & Engineering Studies
Outline

• Why Materials Engineering?
• Web3D Engineering Labs
  – Tensile Testing Experiment
  – Simulator Implementation
  – Graphical User Interface
  – Simulation Functionality
  – Machine and Material Sample Modeling
  – Format Conversion Issues
• Expected Impact on Education
• Conclusions and Future Work
• Team
• Acknowledgements
Why Materials Engineering?

- Engineering courses often seem as abstract concepts difficult to understand and apply.
- Laboratory experience is an essential part of engineering education.
- Possible issues:
  - no space for large equipment in labs
  - lab setups are too costly
  - students have no time to finish the experiments during labs
- Virtual Interactive Engineering on the Web (VIEW) is Web3D-based laboratories accessible from any computer with Internet connection.
- Tensile Testing Laboratory (TTL) is a part of Engineering Materials course which introduces students to the analysis of mechanical properties of materials.
Related Work

Non-Web3D:

• The department of Mechanical Engineering at the University of Colorado, Boulder – Integrated Teaching and Learning Online Lab [1], including the tensile test, the torsion test, beam deflection, heat treatments experiments, etc.
  – Drawback: 2D Flash movies, reduced interactivity.

• The faculty at Rutgers University and the University of Illinois at Urbana-Champaign – Instructional Remote Laboratory Environment [2], including combustion and jet thrust labs

• M. Karweit at John Hopkins University – virtual laboratory for experiments showing the diffusion process, a robotic arm control [3]

• Bhargava et. al – a virtual torsion laboratory [4]
  – Drawback: reduced interactivity, no 3D perspective

• Demidov et. al. – crystal models for an engineering materials course [5]

• Rehan et. al. – teaching the Solid State course at Mansoura University, Egypt [6]

• Liarokapis et al. – broad engineering education [7]
  – A few ideas, no implementation
Technologies for Web Simulation

Technologies for Web3D:

• VRML
• Java 3D
• WireFusion
• Adobe Shockwave
• X3D – new, XML based
X3D vs. VRML

- Compatible with the next generation of graphics files - e.g. Scalable Vector Graphics.

- Open source, so no licensing issues.

- Has been officially incorporated within the MPEG-4 multimedia standard.

- XML support makes it easy to expose 3D data to Web Services and distributed applications.

- 3D objects can be manipulated in C or C++, as well as Java
Tensile Testing Experiment

Figure 1: InstronTM 5566 real TTM (left) and simulator (right)
Tensile Testing Experiment

• Objective – introduce basic testing techniques required to evaluate mechanical properties of materials (hardness, ductility, and stiffness)

• Setup involves a Tensile Testing Machine (TTM); our Virtual TTL (VTTL) models an InstronTM 5566 TTM (figure 1).

• Sample of a certain material is mounted into the holding grips of the TTM, and the upper grip pulls the sample upward (figure 2).

Figure 2: Sample fixation in the grips of TTM
Tensile Testing Experiment

• TTM controller measures load and strain and transmits the information to the computer.

• A load-strain linear graph with the results is obtained.

• These data can be used for further analyses with MATLAB™ and other software.
Simulator Implementation

• Three key components:
  – PHP
  – X3D
  – JavaScript

• PHP is the web scripting language of choice for generating web pages.

• X3D [8] is an ISO standard - real-time graphics processing.

• JavaScript provides the interaction between the elements of the graphical user interface (GUI).

• Additional components:
  – ECMAScript
  – AJAX (Asynchronous JAvascript and Xml)
Graphical User Interface

Figure 3: VTTL’s GUI
Multimodal
Graphical User Interface (3D & sound)

- GUI components (figure 3):
  - HTML controls
  - virtual 3D scene
  - graph/displays panel

- HTML controls:
  - clickable images to choose a material sample
  - “Start Experiment” button for starting the experiment
  - “Examine Specimen” button for examining the current sample in a close view
  - “Download Data” button for downloading experimental data in an MS Excel™ file

- Experiment is initiated using button once a sample is selected.

- During the experiment the TTM motion is simulated, and the graph of load-strain dependence is drawn.

- Audio imitating the hum of the real machine and the breaking sound of the sample
Simulation Functionality

- A special plug-in is needed to show X3D graphics (we chose BitManagement Contact™ Player).

- Scene Authoring Interface (SAI) enables the developer to dynamically modify or create X3D worlds.

- The experimental data is preloaded unnoticeably using AJAX – not affected by the fluctuations of the network delay.

- JavaScript function reads pairs of strain-load values and updates the scene and the graph.
Figure 4: *Polyethylene sample breakage*
Simulation Functionality

• The virtual material sample has three parts:  
  – two ends that are held by the grips  
  – the middle part that brakes

• Upper grip moves upward based on the strain values from the data set.

• Upper grip’s shift equals $gauge \times strain (%) / 100$:  
  – Upper end of the sample is translated along with the upper bar.  
  – Middle part is lifted half that distance and elongated to appear as a single piece with the other parts.  
  – Lower end remains static.

• To “brake” the sample, we replace it with a preloaded “broken” elongated version.
Simulation Functionality

- Graph is calibrated based on the experimental values (figure 4):
  - Plotting area adjusts automatically to fit the functional curve.
  - Grating period is such that a reasonable number of graduation marks is displayed.

Figure 5: VTTL experimental graphs for Aluminum 2024 (left) and Steel 1006 (right)
Machine and Material Sample Modeling

- We use SolidWorks™ to model the TTM and material samples.
- Each part was measured with a digital caliper.
- All elements were assembled into a single part; colors and surface textures were added.
- Five samples of different material types were modeled: Aluminum 2024, Aluminum 6061, Steel 1006, Polycarbonate, and Polyethylene.
Machine and Material Sample Modeling

Figure 6: “Broken” samples of different material types
Format Conversion Issues

- SolidWorks™ only exports to VRML, not X3D.
- Contact™ player can easily convert the scene from VRML to X3D via saving dialog.
- Graphical objects are downloaded from the website: file sizes grow -> download and visualization time grows.
- Scene can be cached by the X3D client.
- Objects with fewer polygons are desired.
- For instance, a cube could be constructed with 12 triangles instead of hundreds or even thousands.
Expected Impact

• The virtual lab will be assessed in the fall semester in the Introduction to Engineering Materials course (ENGR 2000) at AASU.

• The tool already stimulates the students’ interest in the course. (we showed the demo to a few eng. students)

• VTTL will provide the students with an opportunity to transfer and apply knowledge from other courses (e.g., Computing for Engineers using MATLAB™) to complete the virtual lab assignment.
Assessment

• Initial assessment of this tool will be achieved using student surveys and pre/post laboratory quizzes.

• Further modifications will be based on students’ and instructors’ feedback.

• Other courses in the engineering curriculum such as Engineering Graphics and Introduction to Thermodynamics may benefit from this project.
Conclusions and Future Work

• We have presented the initial stage of a virtual laboratory for engineering materials that uses the X3D standard.

• Models were developed in CAD software and employed in the implementation of a VTTL accessible on the Web.

• This lab will be used by engineering students in the fall 2008 semester.

• We will report the details of our assessment of and modifications to the tool in fall 2008.
Conclusions and Future Work

Figure 7: Project’s website
Team

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Figure 8: Patrick Hager, Carlos Sanchez, Dr. Wayne Johnson, Dr. Felix Hamza-Lup, Ivan Sopin, and Dr. Priya Goeser
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References


References


Thank you!
Any questions?