INTEGRATION OF SIMULATION AND VISUALIZATION FOR VIRTUAL ENGINEERING AND EDUCATION

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“Where Ideas Become Reality”
COMPUTER SIMULATION

Definition: application of computational models to predict behavior of engineering systems
- Computational Fluid Dynamics (CFD)
- Finite Element Analysis (FEA)

Benefits:
- Insights
- Foresight – “what if…”
- Efficiency
VISUALIZATION

➢ Scientific/Data/Information Visualization:
  • Aid for understanding
  • Aid for communication

➢ Technologies
  • Virtual Reality: creates a virtual environment to inhabit (not just observer) – CAVE, Oculus Rift, ...
  • Augmented Reality: simulates virtual objects in the real environment – Mobile devices, Hololens, ...

“Computer visualization will be integral to our ability to interpret and utilize the large data sets generated in SBES applications” - Revolutionizing Engineering Science through Simulation, NSF Report, 2006
INTEGRATION OF SIMULATION AND VISUALIZATION

- Efficient, effective, and economical
  - Better communication
  - Faster and lower risk for new ideas and scale-up
  - Interactive virtual design
  - Smart manufacturing

“A picture is worth a thousand words.” - F. Barnard, 1921
“An interactive simulation is worth a thousand pictures.”
INTERACTIVE VIRTUAL LEARNING / TRAINING

- Interactive, engaged
- Authentic, immersive
- Situated, work-based, real phenomena and scenarios (**not just animations**)
UNLIMITED APPLICATIONS

- Logistics & Scheduling
- Design
- Troubleshooting
- Optimization
- Scale-up
- Training
- VR Visualization
- Simulation
- High Performance Computing
- Facilities Planning
- Marketing
- Data Visualization

• Energy
• Environment
• Productivity
• Quality
“Advanced manufacturing M&S is a potential game changer”
STEEL MANUFACTURING SIMULATION AND VISUALIZATION CONSORTIUM (SMSVC)

1) Workplace Safety  
2) Energy Efficiency  
3) Operation Efficiency  
4) Reliability and Maintenance  
5) Workforce Development  
6) Environment Impacts  
7) Raw Materials  
8) Smart Manufacturing
METHODOLOGY

- Application driven
- Section-by-section, Step-by-step, Integration
- Validation & verification
- 3-D interactive multiple platforms (immersive VR environment, AR, PC, mobile, or web versions)
PARTNERSHIPS

Universities
- MSV courses
- Advanced facility and software
- Talented faculty and students
- Future work force

Industry
- Real-world technical know-how
- Real constraints
- Validation data
- Fast and low cost solutions

“This project was an excellent example of collaboration between industry and a university. Together, we developed a very convenient and user-friendly tool which can be used by researchers and mill metallurgists in troubleshooting and optimizing our process.” - Rick Bodnar, the Director of SSAB Americas R&D
3D SIMULATION AND VISUALIZATION OF BLAST FURNACE

Issues:
• Furnace campaign life
• Energy efficiency
• Pollutant emissions
• Furnace downtime
• Training

Outcome:
• Virtual blast furnaces
• Copyrighted software packages
• Multimillion dollars savings
• Significant downtime reductions

Collaborators: AISI, AIST, ArcelorMittal USA, ArcelorMittal Dofasco, AK Steel, U.S. Steel, U.S. Steel – Canada, and Union Gas
Virtual Blast Furnace
**U.S. Steel Blast Furnace Ironmaking Academy**  
Total 20 Participants

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The VBF simulator was <strong>beneficial</strong> as a visual learning aid in this training course.</td>
<td>95%</td>
<td>5%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>The VBF simulator enables me to <strong>better visualize</strong> the blast furnace and its equipment in a way that is difficult for me to do with presentation slides or text alone.</td>
<td>85%</td>
<td>15%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Training courses on <strong>other process</strong> (i.e., cokemaking, steelmaking, etc.) should develop similar simulations in the futures as a learning aid.</td>
<td>80%</td>
<td>20%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
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"excellent training tool; great problem-solving capabilities"; "This interactive model helped me visualize the material flowing through the process. It was very helpful in understanding the flow"
LIFE PREDICTION IN INDUSTRIAL EQUIPMENT

**Issues:**
- Expensive maintenance
- Inefficient inspections

**Outcomes:**
- Six-step methodology
- Improved inspection planning ($251,000 annual savings)
- $8 million cost avoidance

**Collaborators:** U.S. Steel
VIRTUAL WIND TURBINE SIMULATORS

Mixed Reality Simulators for Wind Energy Education

- Wind Farm Siting
  - This iPad application lets users place wind turbines on a map and use augmented reality to see what they will look like once installed.

- Wind Turbine Wakes
  - This simulator demonstrates CFD analysis results for wind turbine wakes which affect available power and wind turbine placement.

- Wind Turbine Template
  - This application shows different wind turbine templates for comparison. It gives users full 360 degrees view of the selected turbine.

- Virtual Wind Turbine
  - This is a generic virtual wind turbine simulator that users can interact with all the components and learn each's function.

- Control and Monitoring
  - This is a wind farm monitor simulator that users can control and monitor all the sensor of wind turbines.

- Wind Turbine Design
  - This application is for Undergraduate & Graduate students learning introductory concepts of utility scale wind turbines and blade aerodynamics.

- Maintenance/Troubleshooting/Safety
  - This is a first person perspective simulator that a user could take work orders and perform maintenance to a wind turbine. The system will evaluate the user based on whether he/she has followed the safety procedures.
Six universities and community colleges used simulators in courses

Increased student content knowledge

- > 10% test score increase in Engineering Courses
- > 20% test score increase in Technician Courses

Increased motivation to learn about Wind Energy
OPPORTUNITIES AND CHALLENGES

- More demonstration and greater awareness of practical, real world applications
- Multi-scale and multi-physics models
- Validation and verification
- Real-time integration of MSV with sensors
- Big data storage and visualization
- Computer power and internet speed
- Education of next generation in MSV
- Integration and collaboration
Thank You!
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