Evolution of Digital Tools Used in Complex Product Design

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Overview

• Historical background ... what led to our adoption and development of Digital Engineering (Immersive Collaboration) Tools

• Vision and Current State

• Example Applications ... Lessons Learned ... Benefits

• Challenges and Opportunities

• A Possible Future

• Q&A
John Deere – global growth in Agricultural and Turf Equipment, Construction & Forestry Equipment, and Intelligent Systems
John Deere Manufacturing Locations
My start at John Deere ... 1978 ... established a Human Factors Research Lab to support off-road vehicle operator workstation design. Featured physical simulation with high-fidelity, 6 degree-of-freedom motion base and low-fidelity visual scene.
Searching for a better digital human modeling tool leads to Dr. Norman Badler at U Penn. ... 1989 ... “Jack” software (Badler and Phillips, U Penn) ... became early foundation for “VR” (Immersive Collaboration) in John Deere
Our Vision

A Virtual ("Digital") Engineering Future

Design, analyze, evaluate products and manufacturing processes within a shared virtual environment ... enabling concurrent and collaborative decision making by geographically distributed participants.

Perform critical product and manufacturing process evaluations (serviceability, manufacturability, operator and product performance, customer acceptance) interactively from concept to production.

Transform from physical test and evaluation processes to simulation-based prediction and verification processes.
Businesses are process driven ... processes evolve
Tools and technology used in product development are evolving ... advancing ...
Product development is an information intensive decision-making process.
Digital Engineering

... Immersive Collaboration ...

is about making **better decisions**
in designing, analyzing, and evaluating complex and uncertain systems
Current John Deere VR Facilities

Charlotte, NC
Des Moines, IA
Dubuque, IA
East Moline, IL
Mannheim, Germany
Moline, IL Technology Innovation Center
Montenegro, Brazil
Univ. of IL, Urbana-Champaign
Waterloo, IA (3 Factory Sites)
Waterloo, IA (Product Engr. Center)
Business Applications

**Product Development**
- Concept Creation and Visualization
  - * Collaborative Design/Styling Reviews
- Operator Visibility Evaluations
- Control Layout Evaluations
- Display Layout Evaluations
- Serviceability Evaluations
- Alternative Design Assessments
- Evaluating Combinations of Product Options
- Operator and System Performance Evaluations (vehicle simulation)

**Training/Education**
- Assembly/Disassembly Procedures
  - * Painter Training
- System Behaviors: visualizing and understanding science (e.g., Bowen Loftin’s “Maxwell’s World”)
- Training Customers and Dealers

**Data Analysis (multi-dimensional)**
- * Engineering Data (CFD, FEA) Analysis

**Facilities and Operations Planning**
- * Manufacturing Process Analysis
- * Methods Design & Analysis
- Resource Planning
  - * Factory and Production Cell Layout

**Marketing**
- * Customer Participation in Design
- Product Promotions
- Virtual Showrooms

**Multi-dimensional User-Interface**
- Remote vehicle monitoring and control
Deere Digital Engineering Innovation

- 16 year relationship (1st VR project in 1994)
- Broad range of applications (product design, manufacturing process design, training, data analysis, ...)

Commercial Technology vendors
Example Applications

Digital 3D Human Modeling
Virtual Painter Training
Tool Tracking

Product Analytics: Linking Information
Factory Workstation and Process Design
Immersive Collaboration with Digital Humans

- Moves prototyping from the realm of simulation to experience
- Real size (or scaled) images
- Designer can display complete population
- Uses real working postures
- Allows greater visibility of the individual within a population
- A population of people can be viewed in reference to their workstation allowing better accommodation of anthropometric diversity
Using Virtual Reality for Painter Training

Accelerates training; reduces cost; increases efficiency of instruction

Actual paint gun is integrated into VR

Immediate visual feedback

Feedback: overspray, thickness, and time
VIRTUAL PAINT

Pull the trigger to continue
Tool Tracking for Complex Manufacturing Tasks

1) Load Part Data
   - CAD Library
   - Data

2) Track the Tool
   - Part Schematic
   - Tracking Data

3) Recognize Part and Track Progress

4) Generate a Report
   - Analysis of Results
   - Incomplete Task

Tool Tracking for Complex Manufacturing Tasks

- Welding
- Bolt Tightening

Welding Gun
Air Gun
Tool Tracking Video
Product Analytics: Linking Information

We have lots of product data ...

... that represent missed opportunities

Example product data sources
The problem is that ...

... finding opportunities when complex associations have to be made in your mind is hard.
Developing a 3D immersive (and desktop) application to integrate all product data ... creating an easily understood interface for:
Quality Control
Cost Management
Program Management
Supply Management
Manufacturing, and others
Discrete Event Simulation + Virtual ("Digital") Engineering = Better Manufacturing Decisions
JD Montenegro, Brazil: Simulated before factory investment was approved and factory built
Immersive Collaboration Enables Manufacturing Engineers to Design Factory Layout for Future Production

Combine Harvester manufacturing engineers, in reviewing proposed layout, make important discoveries
Immersive Collaboration Enables Customer Input on New Product Design

Customers evaluating and commenting on early design concepts ... expressing their interests and assessments
VR Contributing to Product Innovation

New JD 7760 Cotton Harvester
### Air Handling Subsystem

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Details</th>
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<tbody>
<tr>
<td>Design cycle time</td>
<td>Reduced by 12 to 18 months</td>
</tr>
<tr>
<td>Cost to get verifiable model</td>
<td>Reduced by over $100K; eliminated several developmental prototypes exceeded goals</td>
</tr>
<tr>
<td>Performance</td>
<td>Increased; exceeded goals</td>
</tr>
<tr>
<td>Material cost of production parts</td>
<td>Reduced</td>
</tr>
<tr>
<td>Direct labor</td>
<td>Reduced by 50%</td>
</tr>
<tr>
<td>Part count</td>
<td>Reduced by 60%</td>
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<tr>
<td>Integrated design for assembly</td>
<td>First physical parts for validation, not development</td>
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**New process took 9 months; old process took 27 months**
Lessons Learned

- Digital Engineering tools enable early and better communication ... yielding better decisions
- Digital Engineering tools enable participation among multiple key stakeholders ... leading to discovery, important new perspectives, and innovation
- Digital Engineering tools provide significant financial and system performance benefits

A principal benefit is the reduction in time to make decisions; “off-agenda” issues discussed among multiple stakeholders in immersive, collaborative design review sessions lead to accelerated decision making.
Challenges and Opportunities

• “downstream” users of 3D virtual models expect lower investment (lower cost and less skill/knowledge)

• transitioning from “university” to “internal” to “commercial” software … (overcoming the “IT Code Certification” barrier)

• displacing “incumbent” tools and processes; new digital engineering tools and processes generally mean new work flows … and some “pain” associated with change

• developing better tool integration and human interfaces (more time doing real work within a shared, immersive environment... less time dealing with tool interfaces)

• providing multiple, simultaneous viewpoints (not just one tracked viewer) in immersive environments
We’ve come along way since the 1980s ...

Product and manufacturing process design today is:

- more simulation-based
- more globally integrated
- being performed more immersively and more collaboratively

Business decisions today are being made IN shared, immersive environments with representation of multiple, key stakeholders
A Prediction:

• there will be even less physical prototyping, and less independent “desk-top” activity in the future

• the evolution of “Digital Engineering” (and Immersive Collaboration) will continue to advance and broaden in all system engineering domains
Thank You!

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