Using interactive Simulations, Virtual and Augmented Reality for intuitive Product optimization

Uwe Wössner, HLRS
INDUSTRIAL USAGE

CPU Hours

- Bertrandt
- BTB
- Daimler
- Kärcher
- Mahle
- Porsche
- RECOM
- Transsolar
- Stellba
PRODUCT DEVELOPMENT PROCESS

3 Phases:
- Planning
- Development
- Production

Practical example (Daimler):
- Definition
  - Concept
- Design
  - Series development
- Startup
  - Series production

Focus of this presentation:
- Hybrid Prototypes
BUILDING BLOCKS OF A WORKSPACE

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<th>User Interface</th>
<th>VR Userinterface (VRUI)</th>
<th>Tablet-PC (TabletUI)</th>
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<td>Virtual Reality (VR)</td>
<td>Augmented Reality (AR)</td>
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Hybrid Prototypes
Virtual Reality
Features:

– Flexible plugin system
– Support for projection based VR, tiled Displays and HMDs
– Augmented Reality
– CSCW
– Volume rendering
– VRML97
– 3D VR GUI (VRUI)
– Parallel rendering
VRUI USERINTERFACE

- The API resembles that of QT, AWT,…
- Supports hierarchical menu systems.
- Supports concurrent interaction in collaborative VEs
  - Automatic synchronization of values
  - Kontext dependent GUIs for collaborative work
  - Locking to support concurrent interaction

Transferfunktionseditor

Menu system

Toolbar
TABLET-PC USER INTERFACE

- Easy input of Text and numbers
- Precise interaction
- Independent of frame rate
- Development of optimized complex GUIs (Material editor, transfer funktion editor, scene graph browser)
- Scalable from smartbords over tablet PCs to mobile phones
Combustion Modelling in Power Plants

RECOM Services
PROCESS INTEGRATION

Geometry generation

Mesh generation

Domain decomposition

Simulation

Post Processing

Visualization

Geometry modification

Mesh refinement

Number of domains / algorithm

Boundary condition

Interactive visualization

< 1 Minute
## SIMULATION COUPLING

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Coupling mode</th>
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<td>StarCD</td>
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<td>SimLib, C Plugin, Loose</td>
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<td>Diablo</td>
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<td>Uranus</td>
<td>CFD</td>
<td>Socket interface, coupling module, C++, Loose</td>
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<td>SunFace</td>
<td>Radiation</td>
<td>COM/DCOM, coupling module, C++, Hybrid</td>
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INTERACTIVE SIMULATION IN COVISE

Grid generation
Domain decomposition
Simulation
Post processing
Rendering
VIRTUAL WATER TURBINE TEST-BED

Simulation of the river power station Kiebingen, Neckar

Through interactive simulation, the output could be increased by 30%, simply by substituting runner and wicked gate.
VIRTUAL TURBINE TEST-BED

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AUGMENTED REALITY
DEEP DRAWING OF A CUP
MINI / RS 1200 GS (SC 09)
PANAMERA (SC 10)
WIND TUNNEL AT FKFS

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COLLABORATIVE WIND TUNNEL
Interactive Simulation in Architecture
Stadtraumlabor TU-Wien

Supercomputer Education
Masterplan Seestadt Aspern

Supercomputer Education
INTERACTIVE SIMULATION IN ARCHITECTURE
AIR CONDITIONING

Simulation of Racks in the HLRS server room
- 5MW of Power
- 1.5MW cooled by air
- Temperature distribution has to be optimized
- Simulation using Ansys CFX

Tangible interface on a Microsoft Surface
PARALLEL POST PROCESSING

- Parallel Rendering
- Remote Rendering
- VR / Desktop
Visualization Cluster
• Multiple Nodes
• Multiple CPUs / Node
• highly parallel GPUs

Data Processing on GPUs
• Preparation
• Processing
• Rendering / Readback

Datamanager stores (partial) data objects
• Host memory
• Device memory
CUDA ISO/CUTTINGSURFACE COMPUTATION

- Classify Elements / number of vertices (TLT)
  - Tetrahedron, Hexahedron, Prism

- Exclusive Prefix
  - Sum (scan)

- Reduce (scatter)

- Interpolate /

- Generate Triangles

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Initialization | Isosurface extraction | reduce | 59208
PARALLEL SURFACE EXTRACTION (GPU)

Parallelization of iso-/cutting surface extraction for interactive post-processing on unstructured grids

- NVIDIA Quadro 6000 (Fermi):
  >5x faster than 16 Xeon E5472
INTERACTIVE TEXTURE BASED FLOW VISUALIZATION

**Line Integral Convolution**
- Convolute a noise texture alongside a flow field
- Vector field tracing (Euler/Runge-Kutta)
- Pixels along field lines show strong correlation
- Pixels orthogonal to the field lines are uncorrelated

-> **Qualitative** view of a slice of the flow field

**Interactive speeds through**
- Flow field as per-vertex attribute in fragment shader (obtained from CUDA cutting-surface kernel)
- Evaluating the flow-field *once* per fragment
- Convoluting the noise texture along interpolated vector

High gradient in the flow field -> wrong vectors (esp. far away from fragment position)
INTERACTIVE LIC COMPARISON

64 vector field evaluations

1 vector field evaluation

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PARALLEL PARTICLE TRACING
INITIAL CELL LOCATION / NEIGHBOR SEARCH

- KD-Tree
- Walk to neighboring element
- On-the-fly decomposition to tetrahedra
- Interpolation in tetrahedra
- Runge-Kutta(4)

\[
\begin{align*}
\alpha & \quad (0,0) \\
\beta & \quad (0,1) \\
1 - \alpha - \beta & = 0
\end{align*}
\]
MASSIVE PARTICLE TRACING

Simulation of erosion in a turbine runner

• In postprocessing on a hybrid many-core CPU/GPU cluster
MASSIVE PARTICLES

Assumptions:

- Spherical, monomorphic particles
- Particles do not influence fluid and walls
- No interaction between particles

\[
\frac{dU_P}{dt} = \frac{F_D + F_B + F_{VM} + F_P}{m_P}
\]

\[
F_D = \frac{1}{2} C_D \rho_F A_F |U_F - U_P| (U_F - U_P)
\]

\[
F_B = (m_P - m_F) g
\]
\[ E = f(\gamma) \cdot \left( \frac{V_P}{V_1} \right)^2 \cdot \cos^2 \gamma \cdot (1 - R_T^2) + f(V_{PN}) \]

\[ f(\gamma) = \left[ 1 + k_2 \cdot k_{12} \cdot \sin(\gamma \cdot \frac{\pi}{2\gamma_0}) \right]^2 \]

\[ R_T = 1 - \frac{V_P}{V_3} \cdot \sin \gamma \]

\[ f(V_{PN}) = \left( \frac{V_P}{V_2} \cdot \sin \gamma \right)^4 \]

\[ k_2 = \begin{cases} 1.0 & \text{if } \gamma \leq 2\gamma_0 \\ 0.0 & \text{if } \gamma > 2\gamma_0 \end{cases} \]
EROSION IN TURBINE RUNNERS

Tracing of massive sand particles

CFD Simulation: Ansys CFX

15,215,488 hexahedral elements

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GP-GPU POST-PROCESSING

- Post-processing of numerical simulation data at interactive speeds on the visualization cluster using GPGPU
  - immediate rendering of VBOs
  - asynchronous / overlapping streaming memcpy of transient data
- Interactive qualitative visualization of vector data (LIC)
- Integrates with parallel rendering (sort last)
VALIDATE

Virtual Automotive Lab for Integrated Digital Automation Technologies

Driving Simulation at University of Stuttgart
PORSCHE 997 TURBO (BEFORE)
AFTER

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VALIDATE

- 3 degrees of freedom
- 3 linear motors
- a-max 2g
- V-max 1m/s
- Force feedback steering wheel
- Active gas pedal (Conti)
- Active brake pedal
COMPONENTS OF THE DRIVING SIMULATOR

- Hardware
- Restbus Simulation
- Vehicle dynamics

- Road surface
- Street logic
- Third party vehicle simulation

- Landscape
- Buildings
- Traffic signs
- Side rails
- Trees

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THIRD PARTY VEHICLE SIMULATION

- Realistic behavior
- Respecting traffic rules
- Car to car / car to infrastructure communication
APPLICATIONS

- Standard tests, e.g. lane change test
- Evaluation of driver assistance systems
- Test of new HMI concepts
- Entertainment, GPS, Telephone, air conditioning
- Driver reaction in critical situations
- Visibility studies
- Evaluation of rear view mirrors
THE HLRS VIS-TEAM

- Blasius Czink
  - (SCALB)
- Andreas Gottlieb
  - Automatic optimization (Daimler CFD)
- Andreas Kopecki
  - Parallel Rendering; Collaborative Working (VisPME/VISIONAIR)
- Florian Niebling
  - Parallel Visualization; Grid; Infiniband; (VisPME)
- Jutta Sauer
  - Video streaming; Video Conferencing; COVISE Dev.; 3D Modeling
- Florian Seybold
  - Driving Simulator; interactive vehicle dynamics (VALIDATE); GP-GPU SPH
- Uwe Zimmat
  - Video service
- N.N.
  - Parallel and Remote Visualization (CRESTA)
- N.N.
  - Interactive Simulation (Cool-Em-All)
- N.N.
  - Virtual Reality (VISIONAIR)

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