Computer Graphics

- Introduction -

Philipp Slusallek

Overview

- **Today**
  - Administrative stuff
  - History of Computer Graphics (CG)
- **Next lecture**
  - Overview of Ray Tracing

General Information

- **Core Lecture (Stammvorlesung)**
  - Applied Computer Science (Praktische Informatik)
  - Lectures in English
- **Time and Location**
  - Mon 14:15-15:45h, Zoom
  - Thu 8:30-10:00h, Zoom
- **ECTS:**
  - 9 credit points
- **Web-Page**
  - http://graphics.cg.uni-saarland.de/courses/
  - Schedule, slides as PDF, etc.
  - Literature, assignments, other information
- **Sign up for the course on our Web page now**
  - [Do not forget to sign-out in time before the exams, if you need to]

People

- **Lecturers**
  - Philipp Slusallek, slusallek@cg.uni-saarland.de
- **Assistants**
  - Ömercan Yazici, yazici@cg.uni-saarland.de
  - Hugo Devillers, devillers@cg.uni-saarland.de
  - Stefan Lemme, lemme@cg.uni-saarland.de
- **Tutors**
  - Erik Colin Manasie Johnson, s8erjohn@stud.uni-saarland.de
  - Joschua Loth, s8joloth@stud.uni-saarland.de

Exercise Groups

- **Will be announced through the email list**
- **Please register on the course web page**

Weekly Assignments

- **Weekly assignment sheets**
  - Theoretical & programming assignments
  - You will incrementally build your own ray tracing system
  - This will be the basis for the Rendering Competition
- **Grading**
  - Results of the exercises will contribute to the final grade
  - Bonus points (towards the exam) are possible
- **Handing in assignments**
  - Theoretical: PDF per email (see detailed announcements)
  - Code: See exercise sheet or Web page (usually by email to tutor)
- **Exercise meetings**
  - Discuss lectures and any issues you might have with TAs
- **Groups of max. 2 students allowed**
  - Each one must be able to present and explain his/her results!
  - Please state who did what!!!

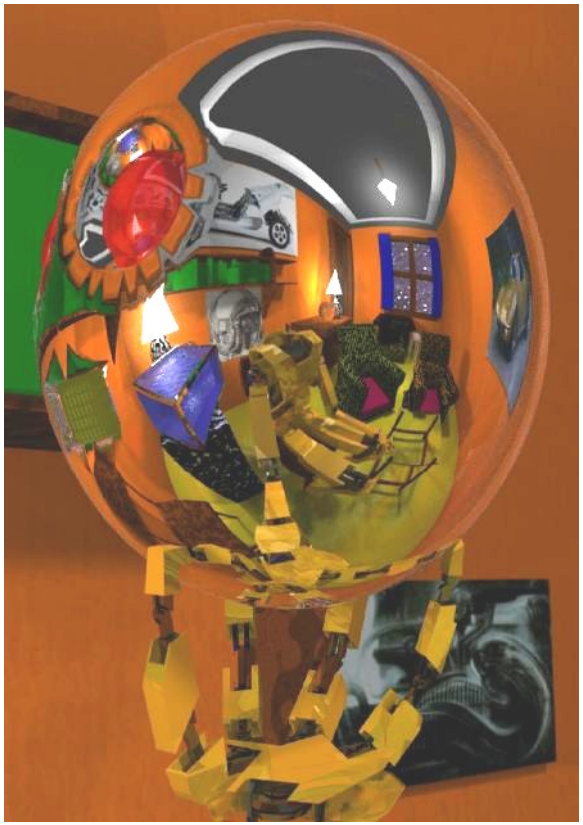
Grading

- **Weekly Assignments**
  - Counts ~~30~~ 40% towards final grade (with +20% bonus points)
- **Rendering Competition (exam prereq.)**
  - Counts 10% towards final grade
  - Grading: Artistic quality (jury)
  - Groups of max. 2 students (but higher requirements then)
- **Exams**
  - ~~Mid-term (exam prereq.), counts 20% towards final grade~~
  - Final exam counts ~~40~~ 50% towards final grade
  - Minimum: 50% to pass (in each of the above)
- **Cheating**
  - 0% of assignment grade on first attempt
  - Possibility to fail the entire course if repeated
- **Chance for Repeated Exam**
  - Oral exam (if possible) at the end of the semester break

Rendering Competition

- **Task**
  - Create a realistic image of a virtual environment
  - Incorporate additional technical features into your ray tracer
  - Bonus points count towards exam
  - Creative design of a realistic and/or aesthetic 3D scene
  - Modeling and shading
- **Hand-out in early in course**
  - You can work on it during the entire course
  - Deadline will be announced (see Web page)
- **Results:**
  - One rendered image
  - Web page with technical detail info

Rendering Competition



Rendering Competition

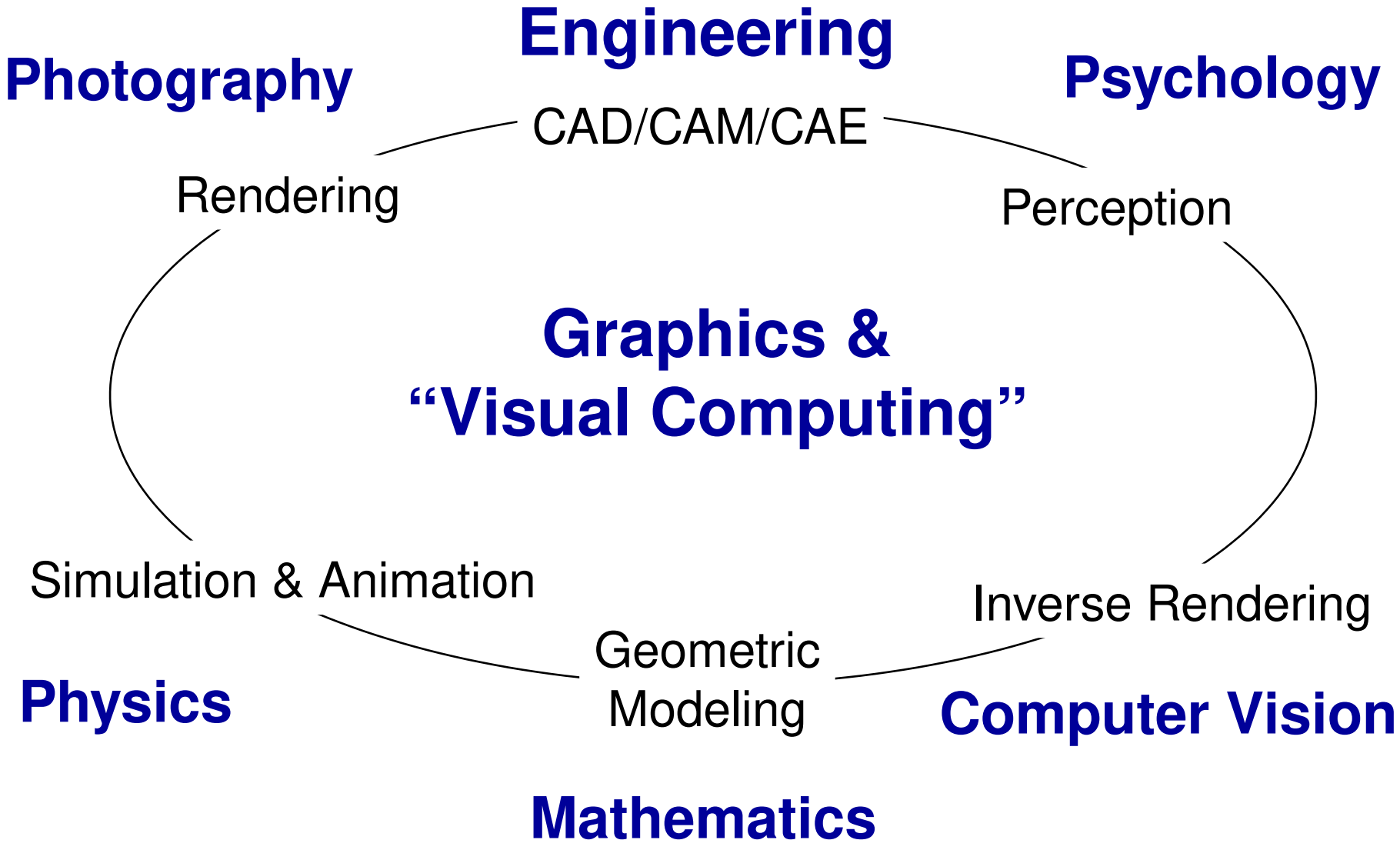
Text Books

- **Suggested Readings:**
  - John Hughes, et al.: **Computer Graphics – Principles and Practice**, Addison-Wesley, 3. Ed, 2013
  - Peter Shirley: **Fundamentals in CG**, 4. Ed, AK Peters, 2016
  - Matt Pharr, Wenzel Jakob, Greg Humphreys: **Physically Based Rendering : From Theory to Implementation**, Morgan Kaufmann Series, 3. Ed., 2016, now freely available: http://www.pbr-book.org/
  - Eric Haines and Tomas Akenine-Möller: **Ray-Tracing Gems**, http://www.realtimerendering.com/raytracinggems
  - Thomas Akenine-Möller, Eric Haines, et al., **Real-Time Rendering**, AK Peters, 4th Ed., 2018
- **Older**
  - Andrew Glassner: **An Introduction to Ray-Tracing**, Academic Press, 1989
  - David Ebert: **Texturing and Modeling – A procedural approach**, Morgan Kaufmann, 2003
  - Tony Apodaca, Larry Gritz: **Advanced RenderMan: Beyond the Companion**, Morgan Kaufmann, 2000

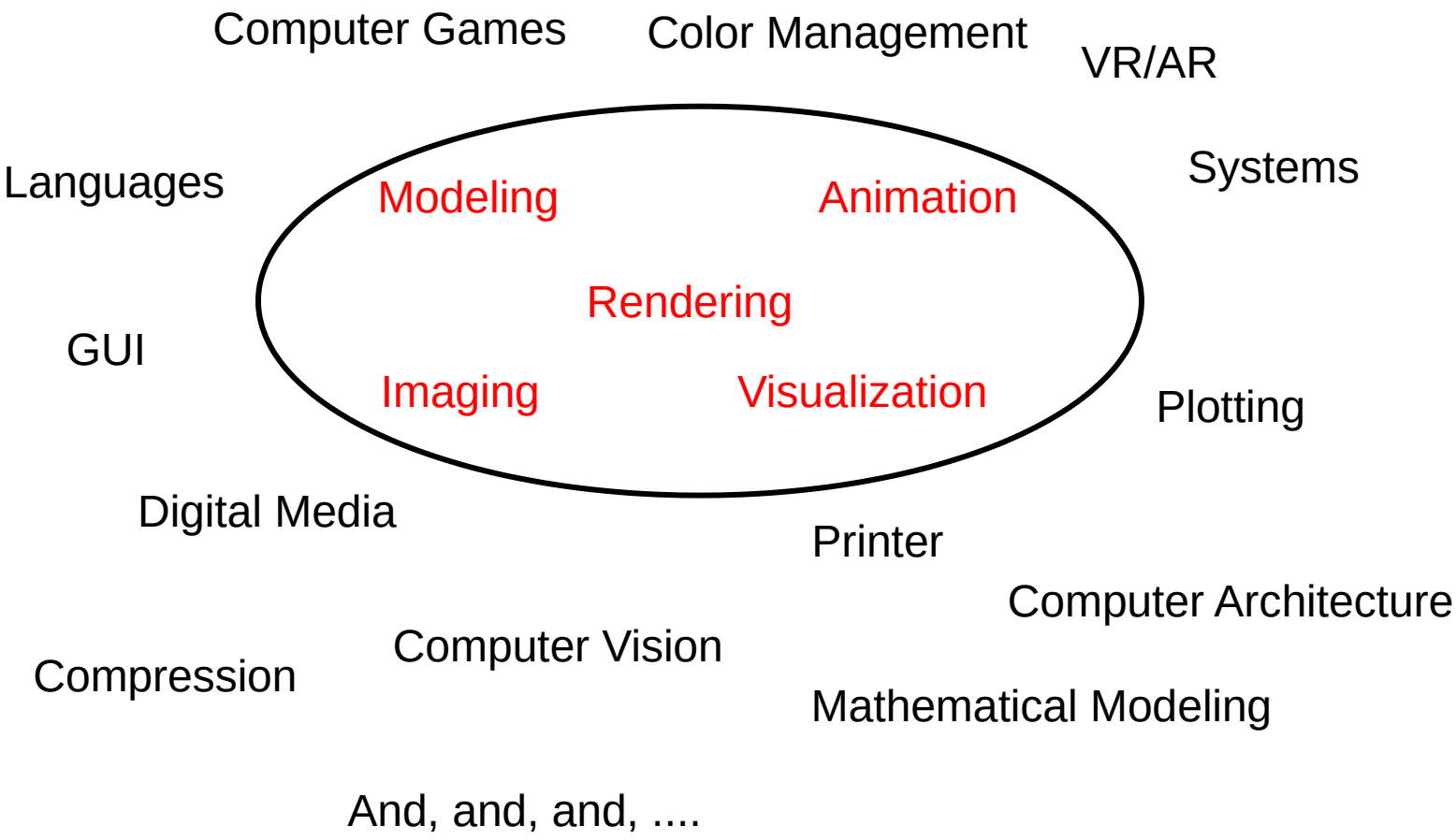
Course Syllabus (Tentative)

- **Overview of Ray Tracing**
- **Geometry Intersections**
- **Spatial Index / Acceleration Structures**
- **Vector Algebra Review**
- **Geometric Transformations**
- **Light Transport / Rendering Equation**
- **Material Models**
- **Shading**
- **Texturing**
- **Spectral Analysis / Sampling Theory**
- **Anti-Aliasing**
- **Distribution Ray Tracing**
- **Human Vision**
- **Color**
- **Splines**
- **Clipping**
- **Rasterization**
- **OpenGL**
- **Volumes**

What is Computer Graphics ?

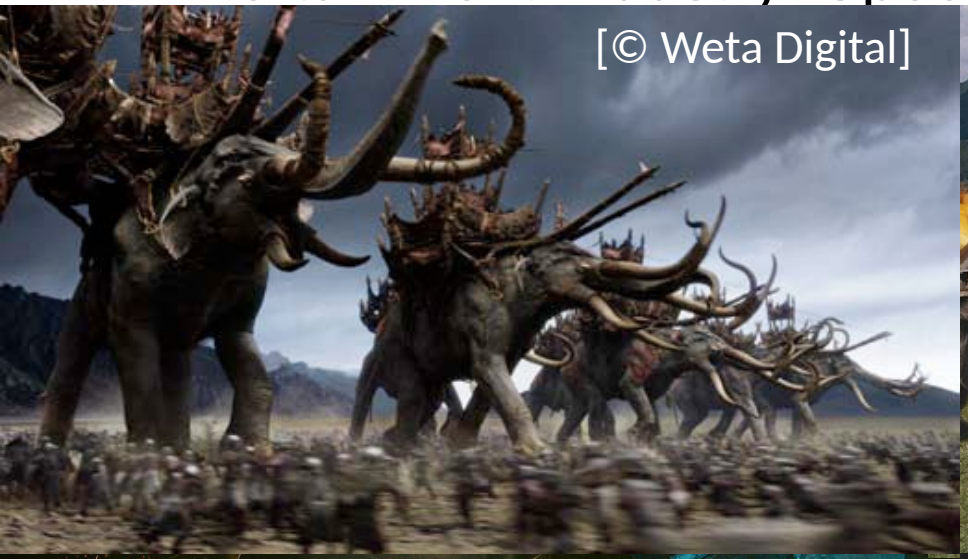


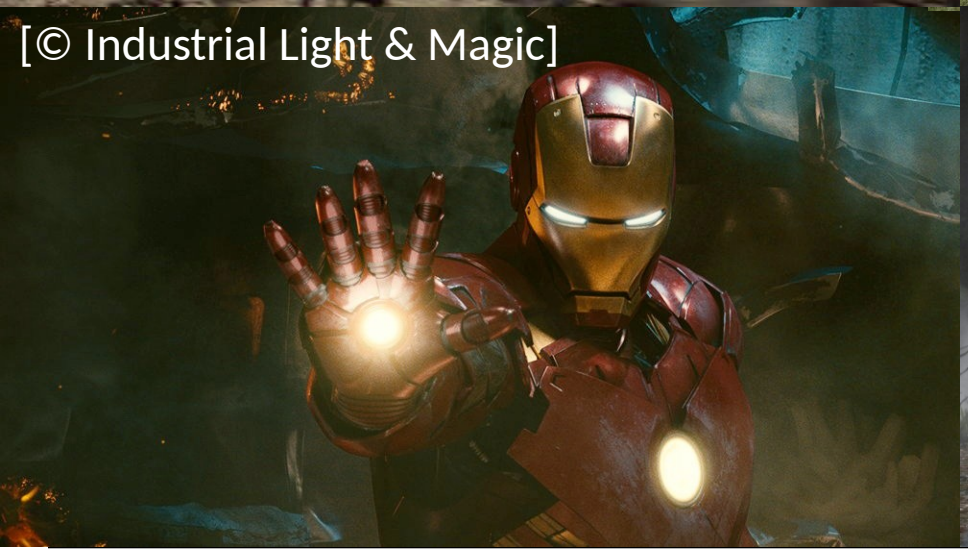
What is Computer Graphics?



Applications

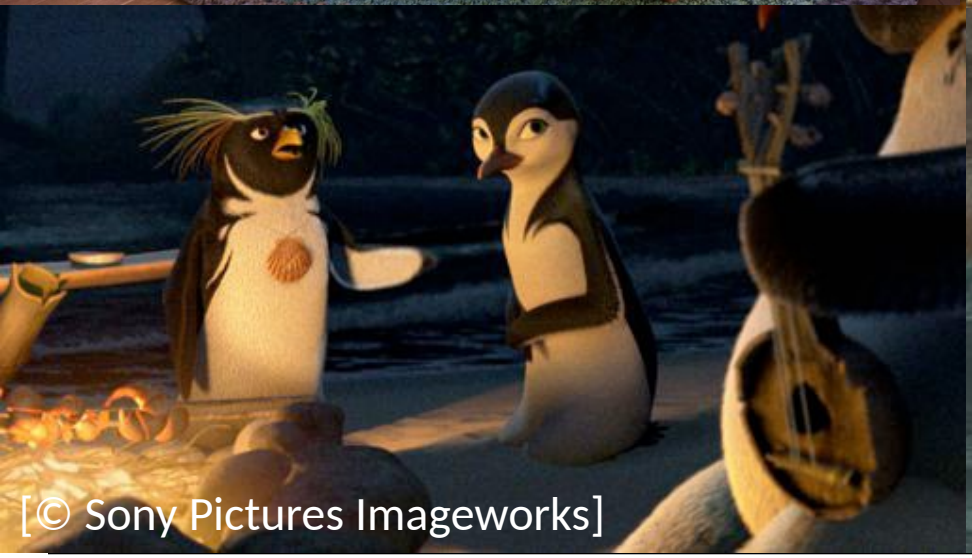
- Entertainment Industry: Special effects for motion pictures

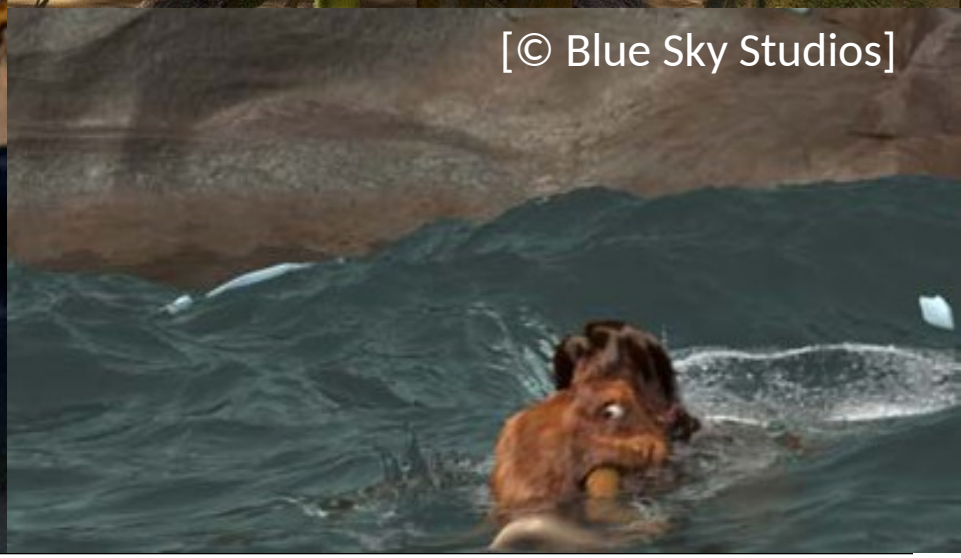




Applications

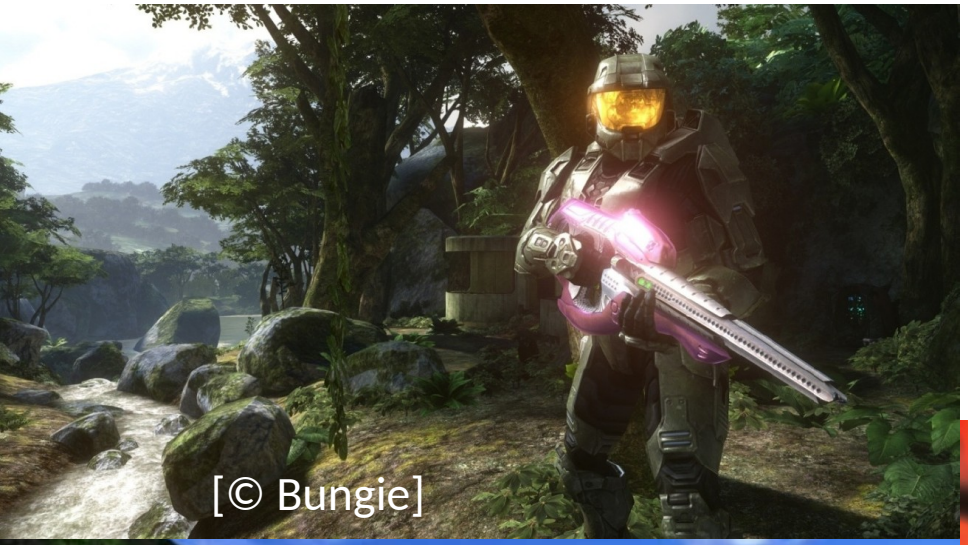
- Entertainment Industry: Animated films





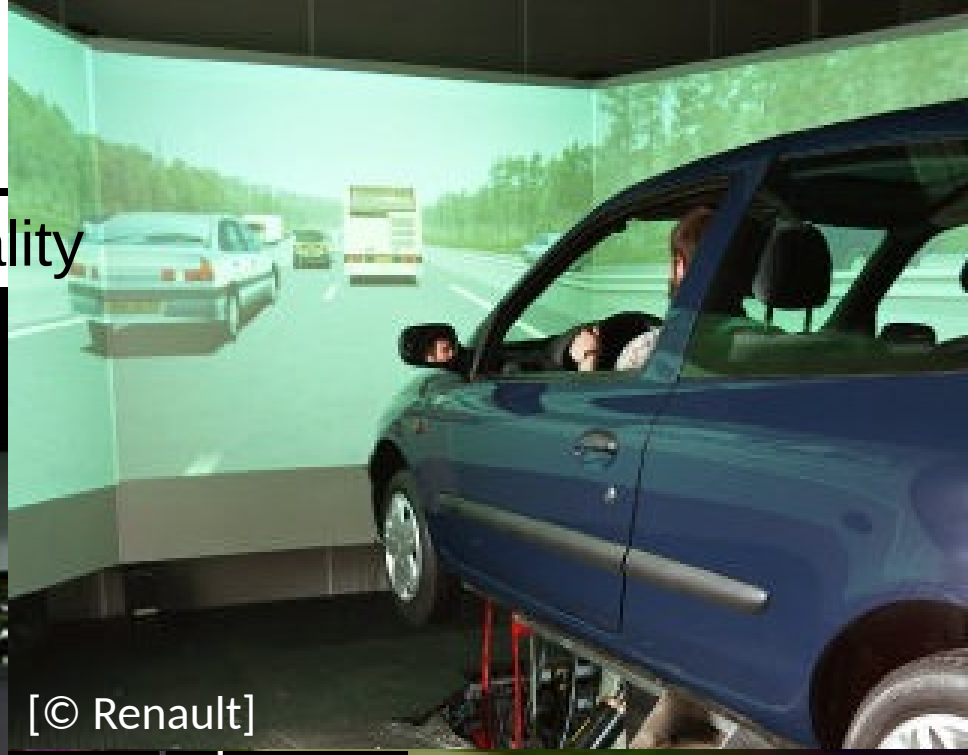
Applications

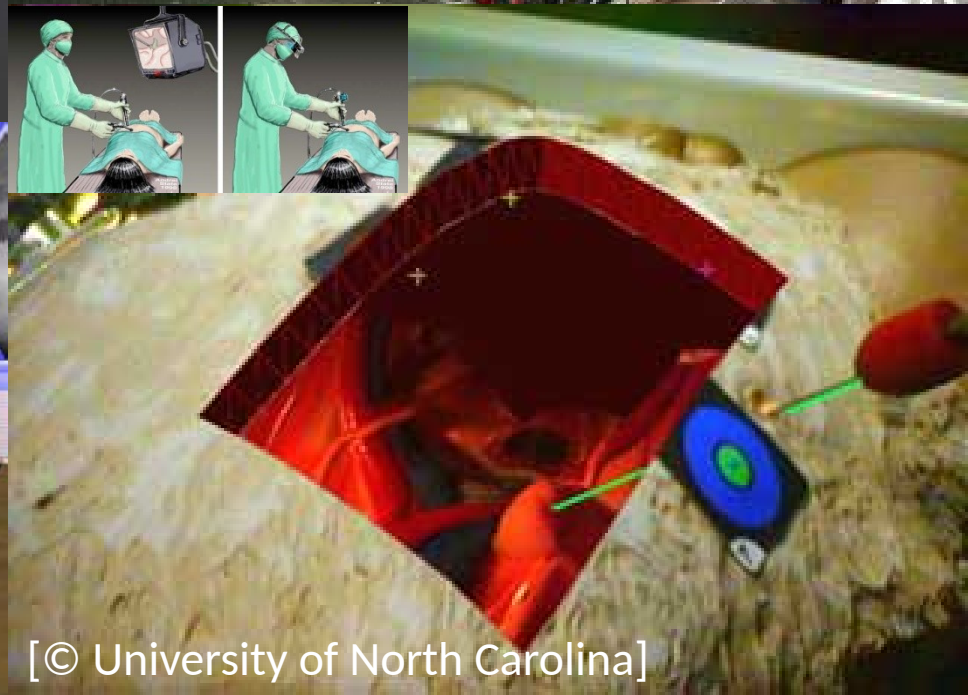
- Entertainment Industry: Video games



Applications

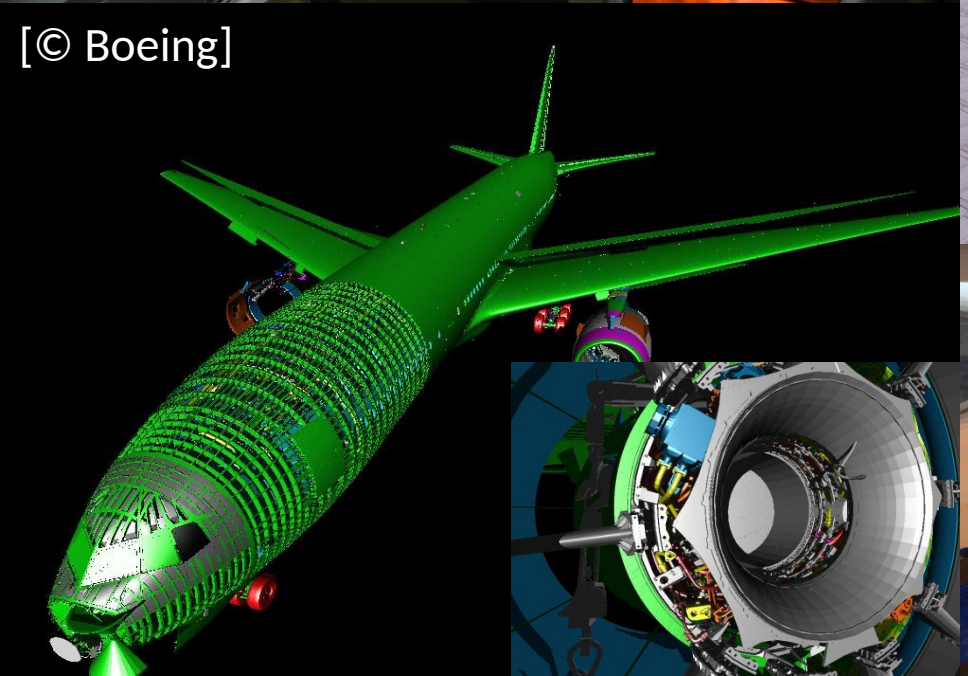
- Simulation & Augmented Reality





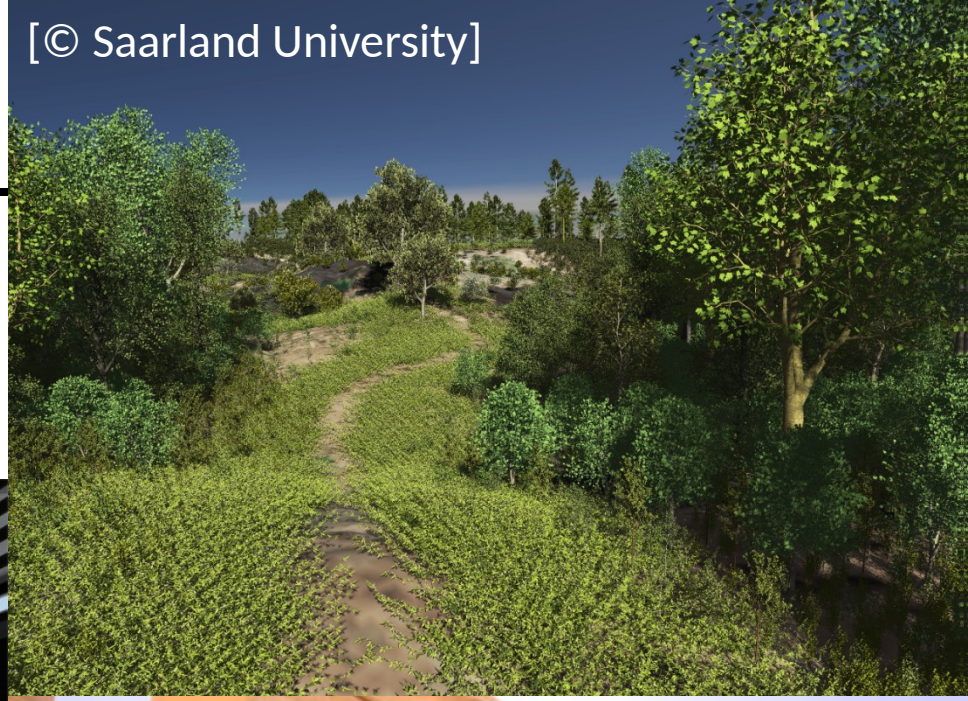
Applications

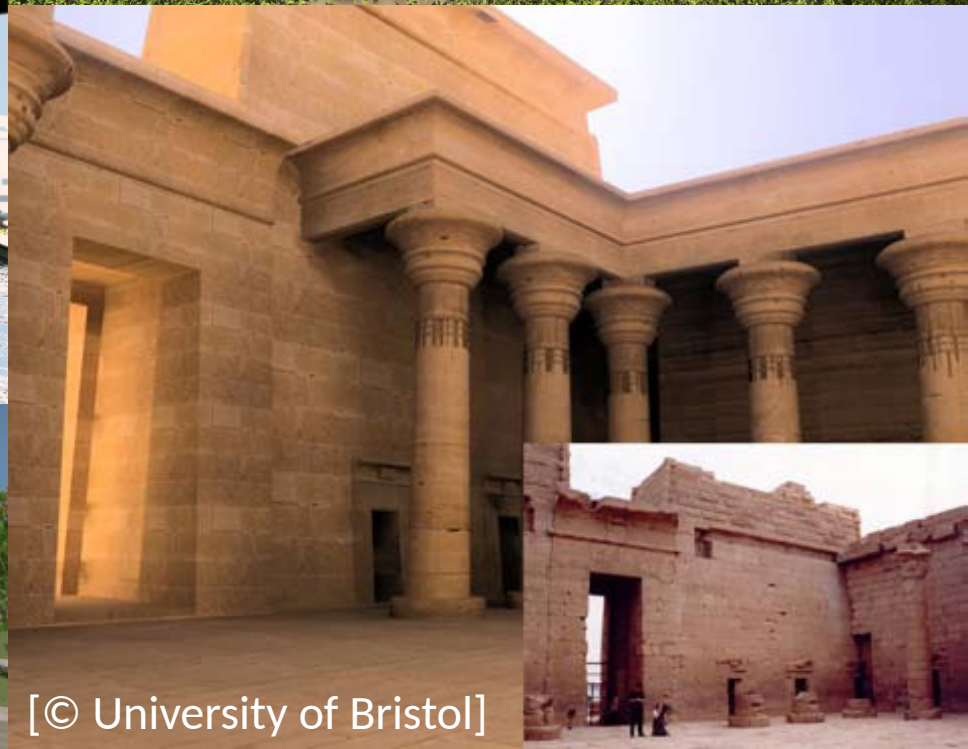
- Industrial Design & Engineering: Automotive / Aerospace

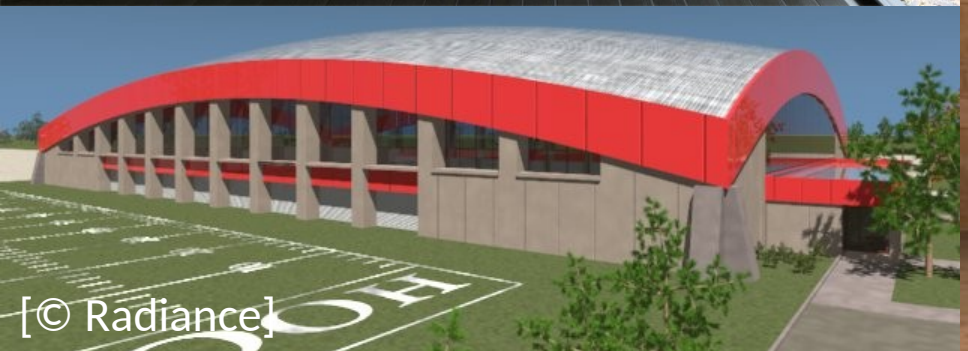


Applications

- Architectural / Interior Design
- Landscape / Urban Planning
- Archeological Reconstruction

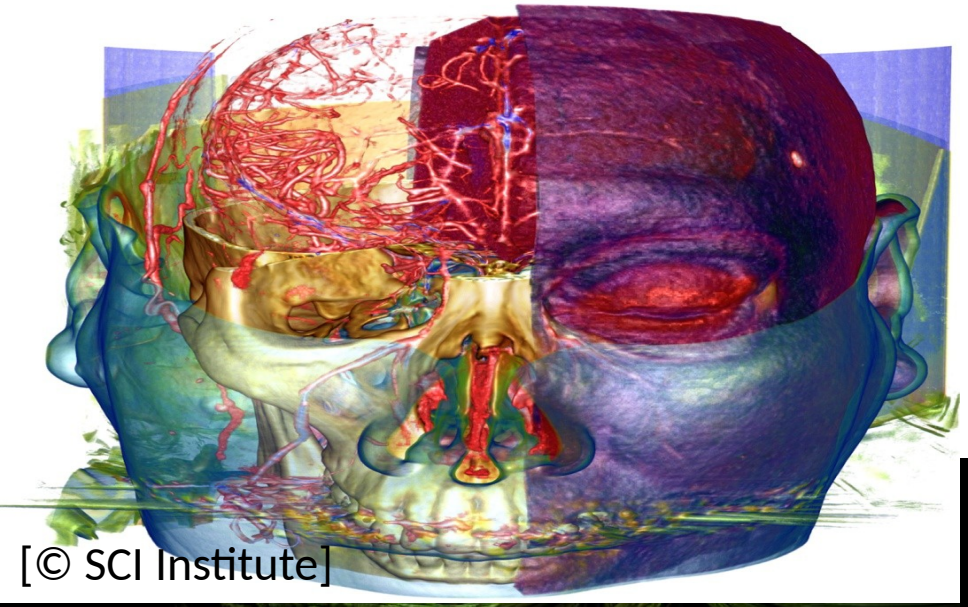




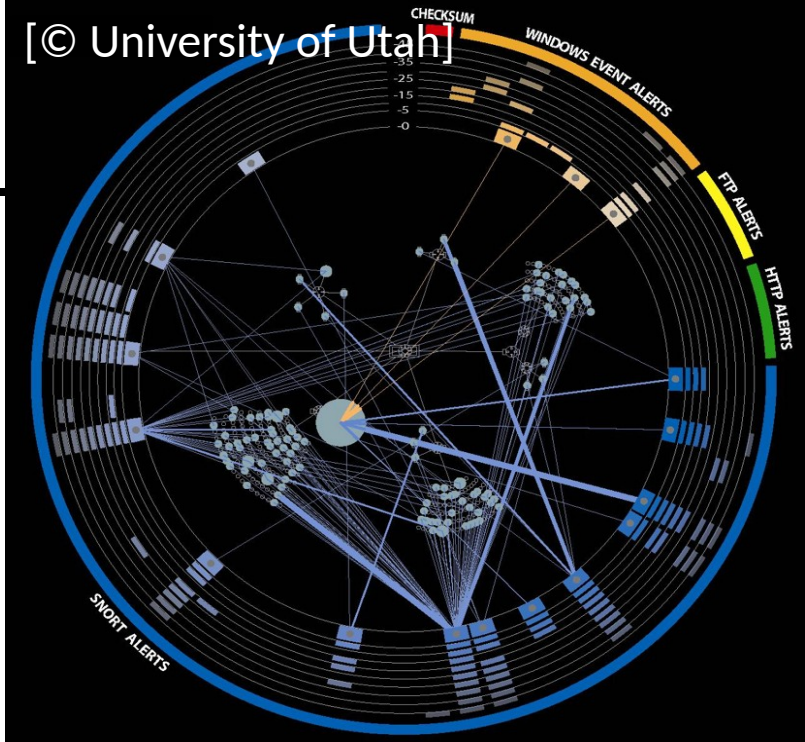


Applications

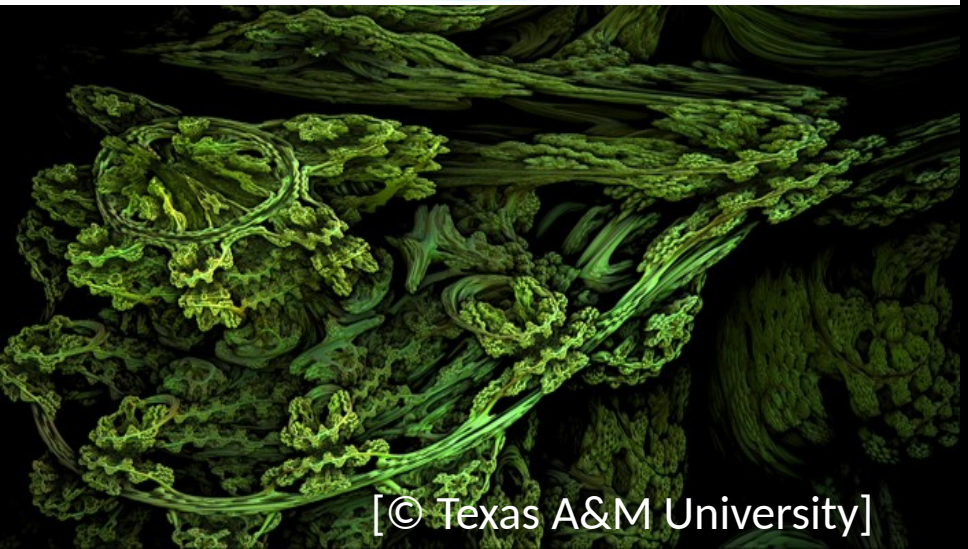
- Scientific/Information Visualization



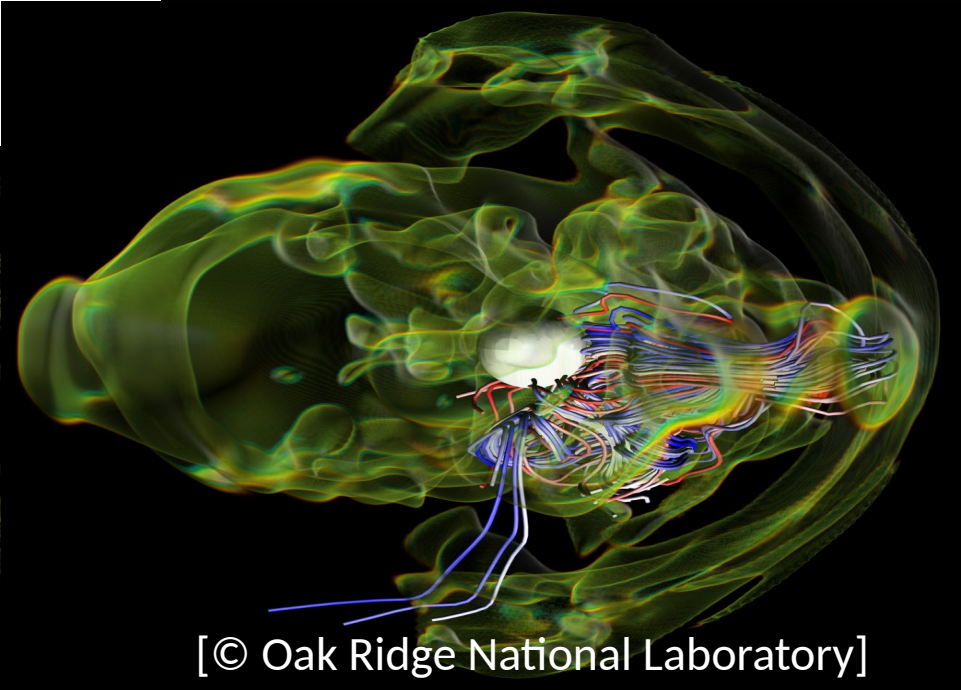
[© SCI Institute]



[© University of Utah]



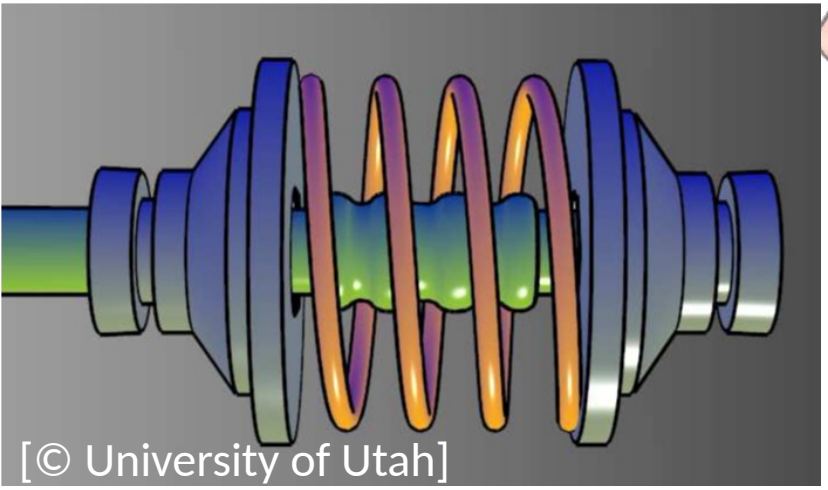
[© Texas A&M University]

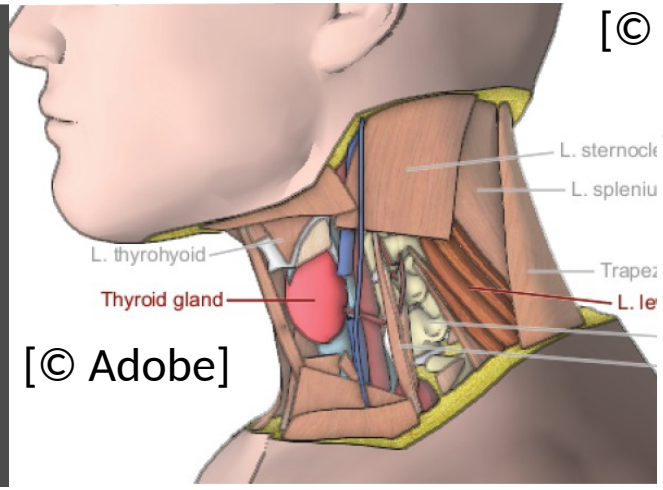


[© Oak Ridge National Laboratory]

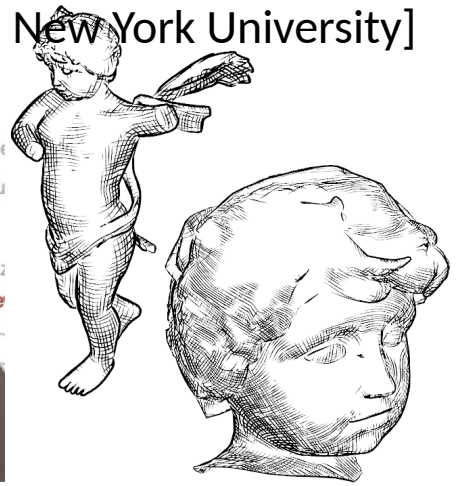
Applications

- Non-photorealistic rendering: art/stylized/pen&ink illustration
- Painterly/Toon Shading, Computational Aesthetics


[© University of Utah]

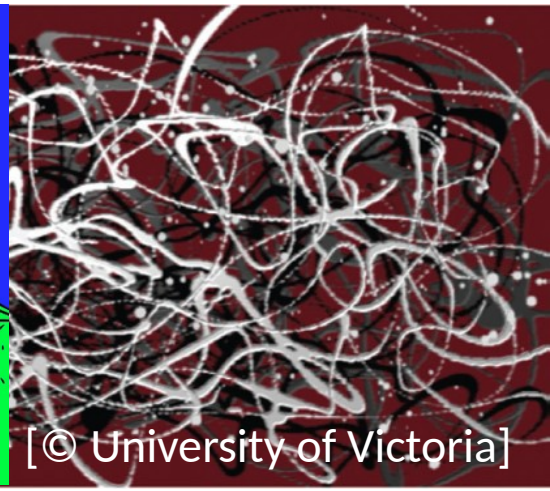


[© Adobe]


[© New York University]

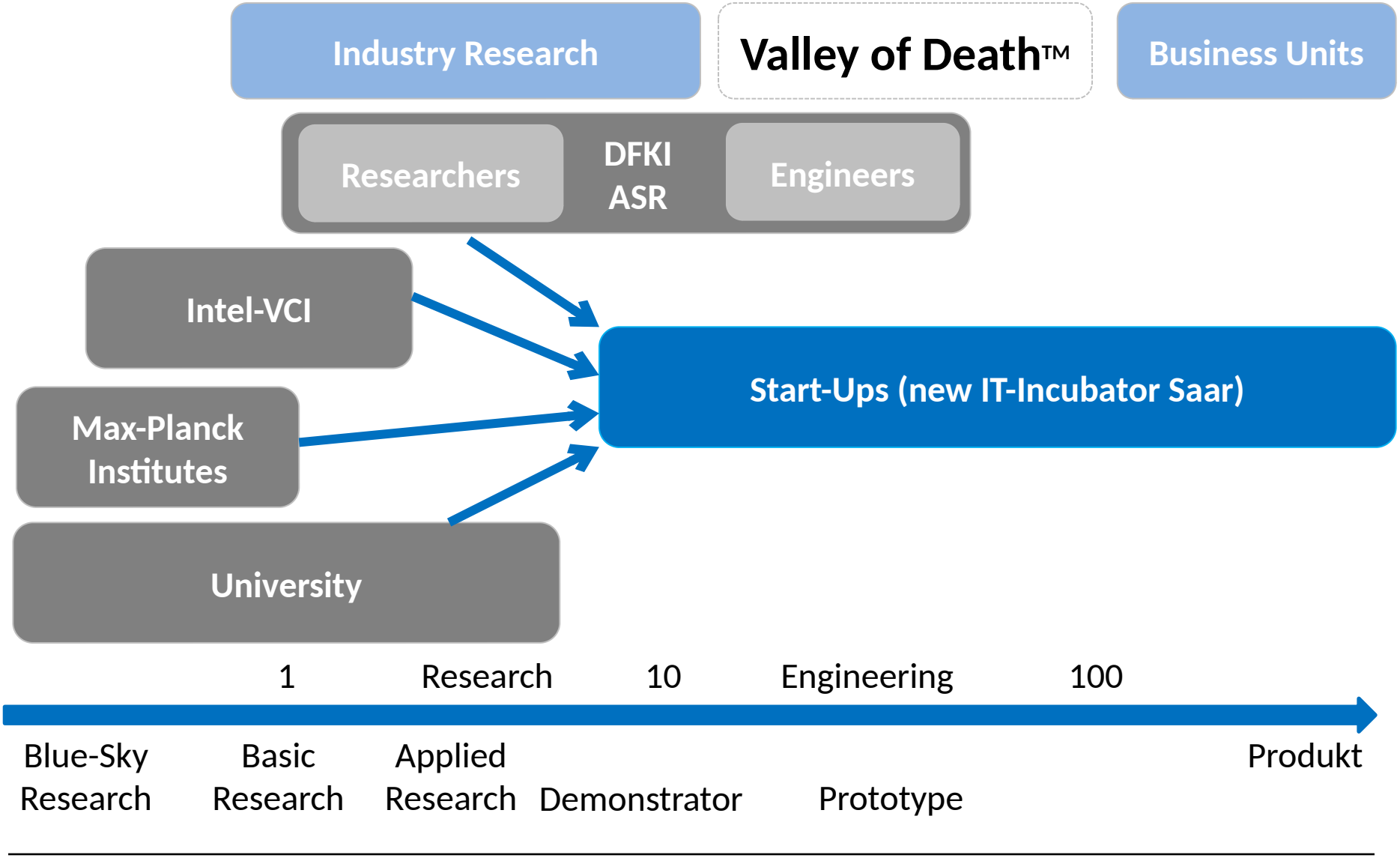

[© University of Washington]


[© Brown University]


[© University of Victoria]

Saarland Informatics Campus

Research & Innovation in SB



German Research Center for Artificial Intelligence (DFKI)

- **Overview**
  - Largest AI research center worldwide (founded in 1988)
  - Germany's leading research center for innovative software technologies
  - 6 sites in Germany
    - Saarbrücken, Bremen, Kaiserslautern; Berlin, Osnabrück, Oldenburg
  - 20 research areas, 8 competence centers, 8 living labs
  - More than 1100 research staff & support
  - Revenues of >58 M€ in 2019 (50 M€ in 2018)
  - More than 90 spin-offs



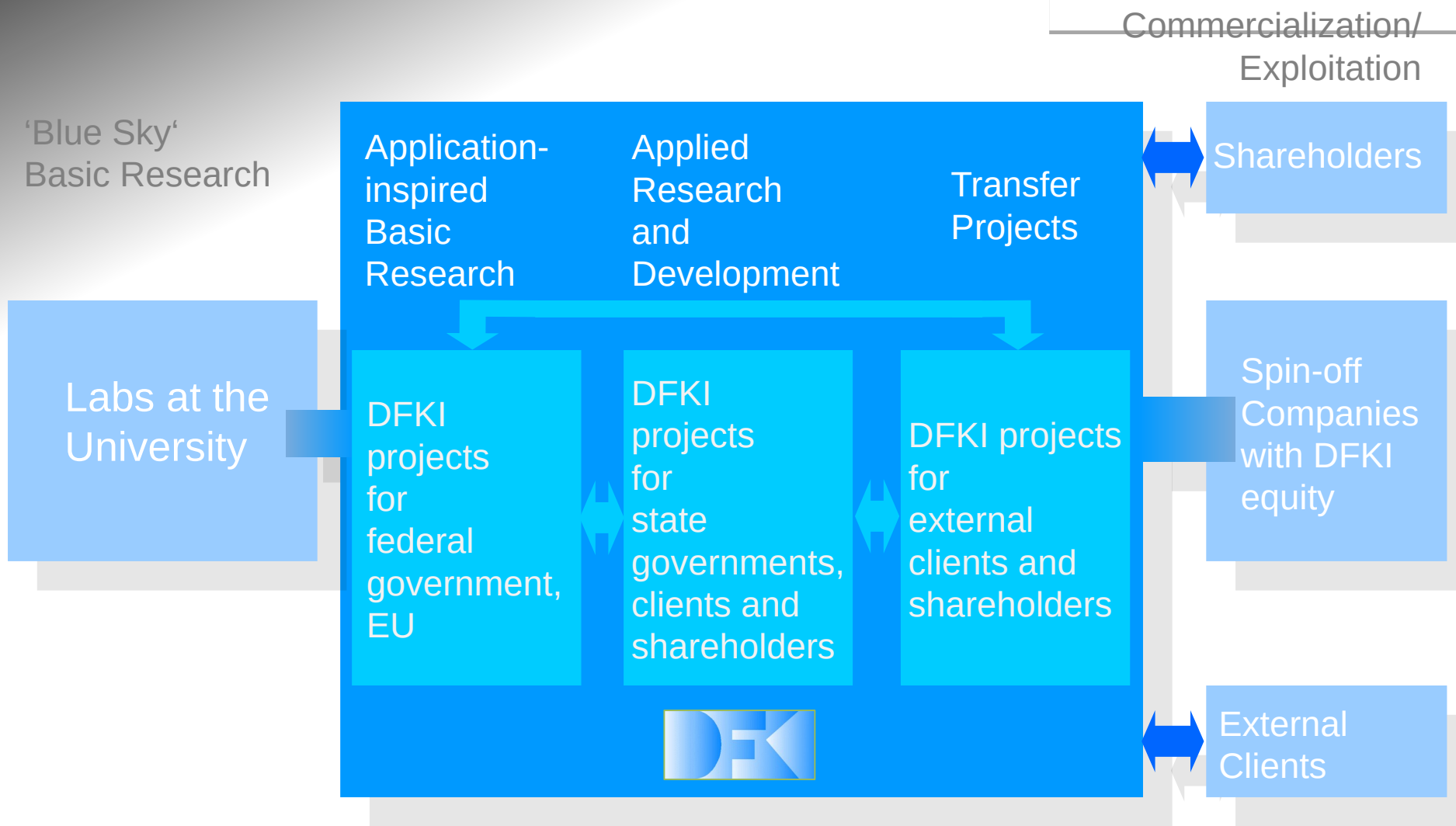


Germany Has a Head-Start

DFKI: The World´s Largest Center for Research & Application in AI

SAP
NVIDIA
intel
SCHWARZ (Lidl, Kaufland)
HARTING
ZF
JOHN DEERE
Deutsche Telekom
CLAAS
software AG
VOLKSWAGEN AKTIENGESELLSCHAFT
Microsoft Deutschland GmbH
DAIMLER
BMW GROUP (MINI, Rolls-Royce)
Google
DEUTSCHE BÖRSE GROUP
BOSCH
AIRBUS GROUP
accenture
RICOH
EMPOLIS INFORMATION MANAGEMENT
VSE
Deutsche Messe
BILFINGER
KIBG
ROSEN empowered by technology
Fraunhofer
cerence
UNIVERSITÄT DES SAARLANDES
Universität Bremen
TECHNISCHE UNIVERSITÄT KAISERSLAUTERN
Munich RE

DFKI Covers the Complete Innovation Cycle



DFKI-Portfolio: Deep Expertise in AI for a Broad Innovation Spectrum

Max Planck Society | Fraunhofer | Helmholtz Society

Application-Oriented Basic Research	**Applied R&D and Transfer**	Large Test- and Demonstration Centers

The entire innovation chain in the horizontal spectrum of DFKI

The vertical specialisation of DFKI on methods and applications of Artificial Intelligence

Deep knowledge and excellence in one important section of Computer Science

DFKI Employees

Broad Methodological and Systems Competence in Artificial Intelligence

Deep Scientific Expertise in AI Technology

Deep Domain Knowledge in an Area of Application

Currently 35 Professors are Working for DFKI

15 Associated and Supernumerary Professors


Prof.
Ziawasch Abedjan


Prof.
Klaus-Dieter Althoff


Prof.
Stephan Busemann


Prof.
Peter Fettke

20 DFKI Heads of Research Labs


Prof.
Sebastian Möller
Executive Director
Berlin


Prof.
Andreas Dengel
Executive Director
Kaiserslautern


Prof.
Frank Kirchner
Executive Director
Bremen


Prof.
Antonio Krüger
CEO


Prof.
Philipp Slusallek
Executive Director
Saarbrücken


Prof.
Joachim Hertzberg
Executive Director
Osnabrück/Oldenburg


Prof.
Rolf Drechsler


Prof.
Gesche Joost


Prof.
Jana Koehler


Prof.
Peter Loos


Prof.
Paul Lukowicz


Prof.
Wolfgang Maaß

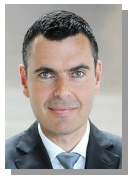

Prof.
Volker Markl

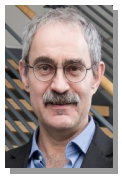

Prof.
Niels Pinkwart


Prof.
Martin Ruskowski


Prof.
Hans Schotten


Prof.
Didier Stricker


Prof.
Oliver Thomas


Prof. Josef
van Genabith


Prof.
Oliver Zielinski


Prof.
Udo Frese


Prof.
Tim E. Güneysu


Prof.
Dieter Hutter

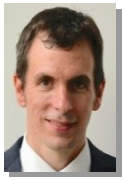

Prof.
Jochen Kuhn


Prof.
Christoph Lüth


Prof.
Günter Neumann


Prof.
David Schlangen


Prof.
Wolfgang
Wahlster
CEA


Prof.
Hendrik Wöhrle


Prof.
Robert Wille


Prof.
Hans Uszkoreit

The R&D Departments and Groups of DFKI

- Smart Data & Knowledge Services
- Cyber-Physical Systems
- Plan-Based Robot Control
- Educational Technology Lab
- Interactive Textiles
- Robotics Innovation Center
- Algorithmic Business and Production
- Marine Perception
- Cognitive Assistants
- Multilinguality and Language Technology
- Institute for Information Systems
- Smart Enterprise Engineering
- Embedded Intelligence
- Augmented Vision
- Agents and Simulated Reality
- Intelligent Networks
- Innovative Factory Systems
- Speech and Language Technology
- Intelligent Analytics for Massive Data
- Smart Service Engineering

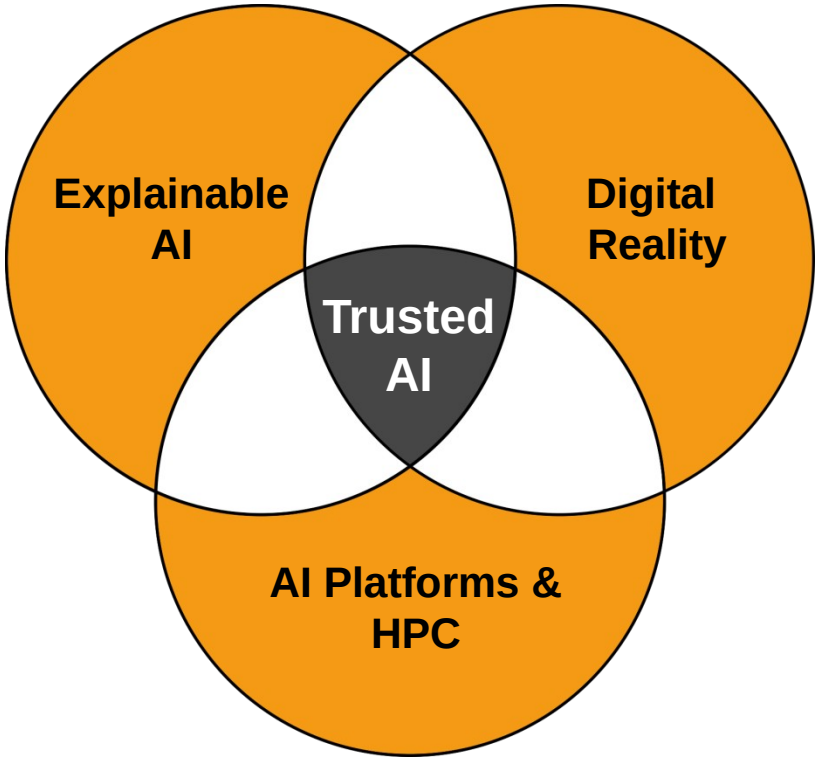
DFKI Recruits Worldwide: 303 Researchers, 64 Countries

DFKI-ASR: Agents and Simulated Reality

- **Trusted AI: Providing guarantees for AI systems**
  - By combining AI, Graphics/Simulation, and HPC

How to design *AI systems that can provide guarantees*

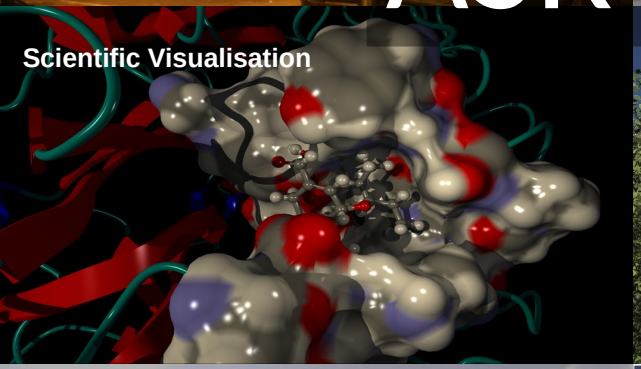
and that *humans can understand and trust?*

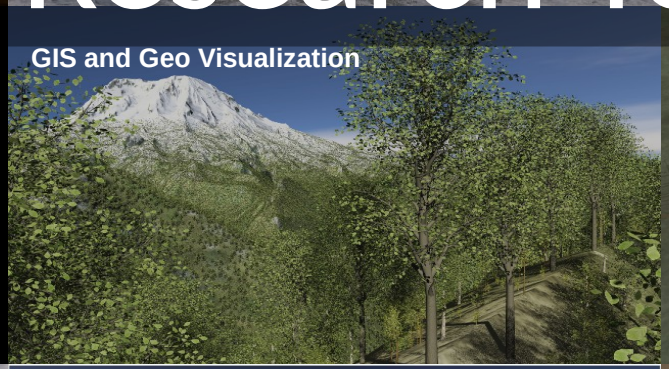


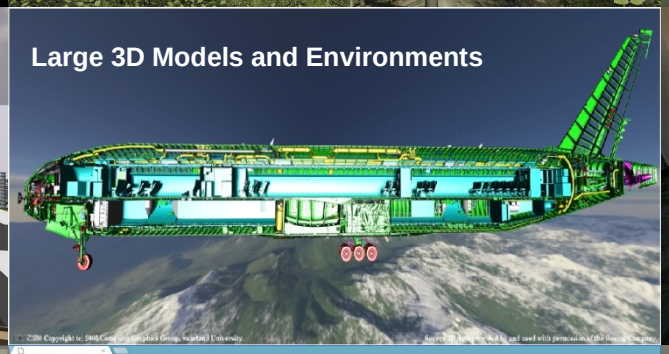
How can *synthetic data from parametric models and simulations* be used for *training, validating, and certifying AI systems?*

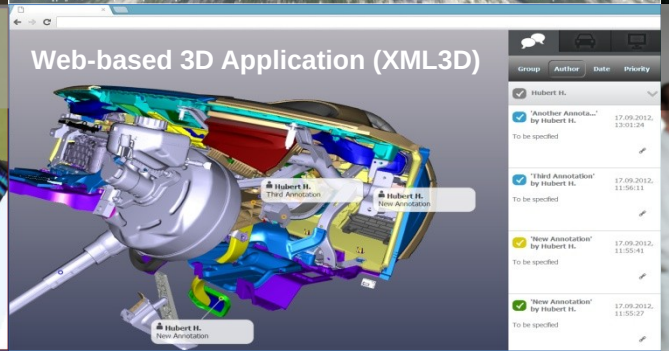
How can AI-systems be realized technically in a *reliable and efficient way?*

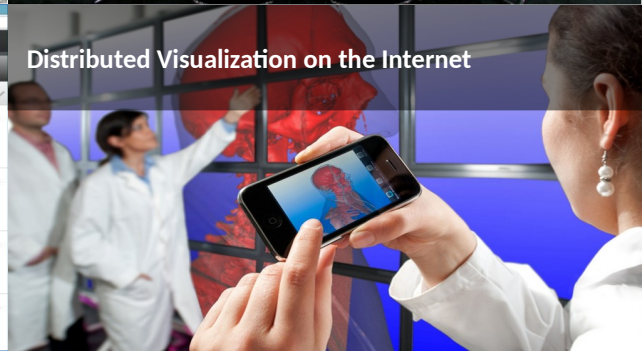
ASR Research Topics







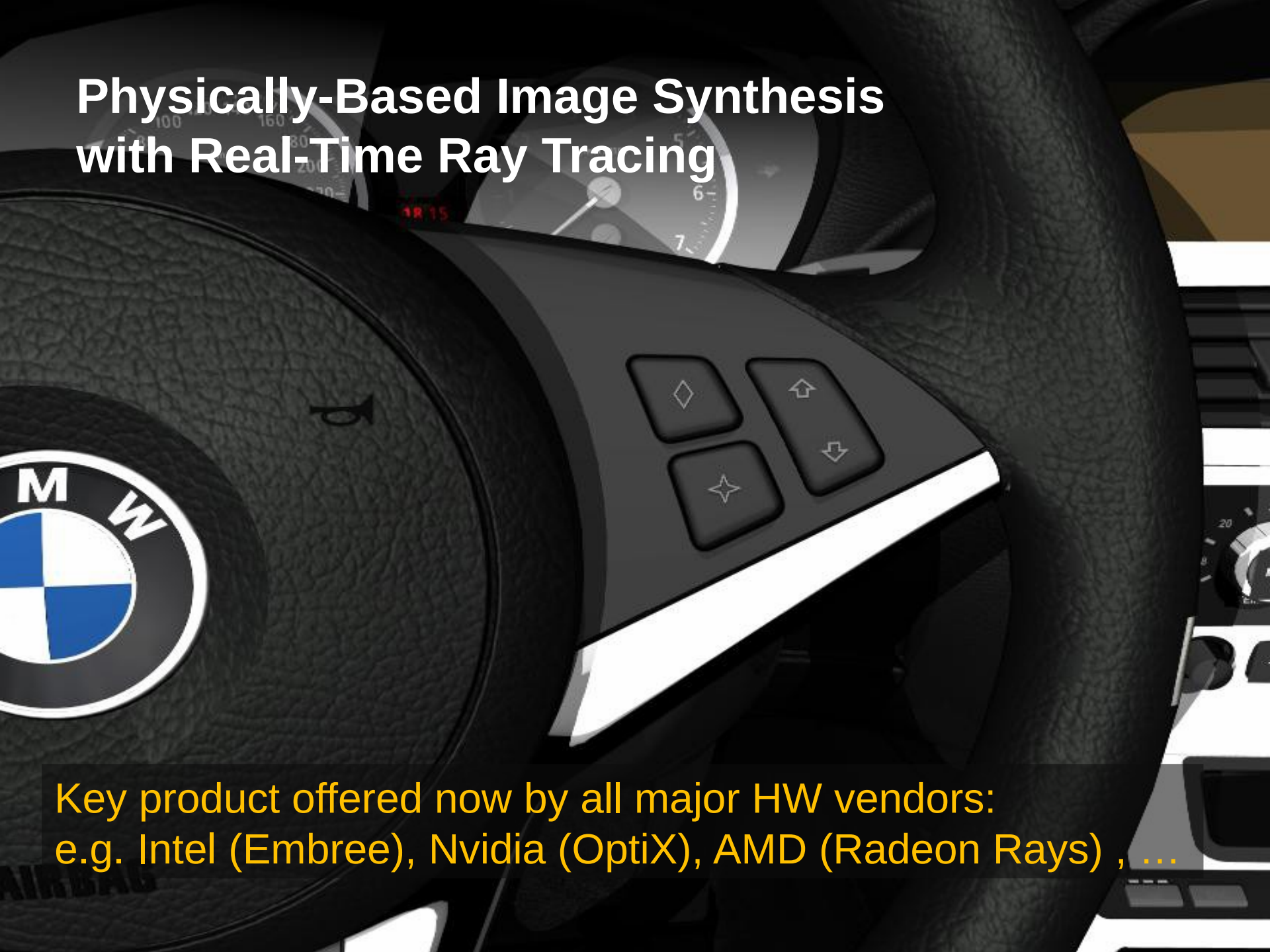




Flexible Production Control Using Multiagent Systems at Saarstahl, Völklingen

DFKI multi-agent technology is running the steelworks, 24/7 for >12 years, 5 researchers transferred

Physically-Based Image Synthesis with Real-Time Ray Tracing

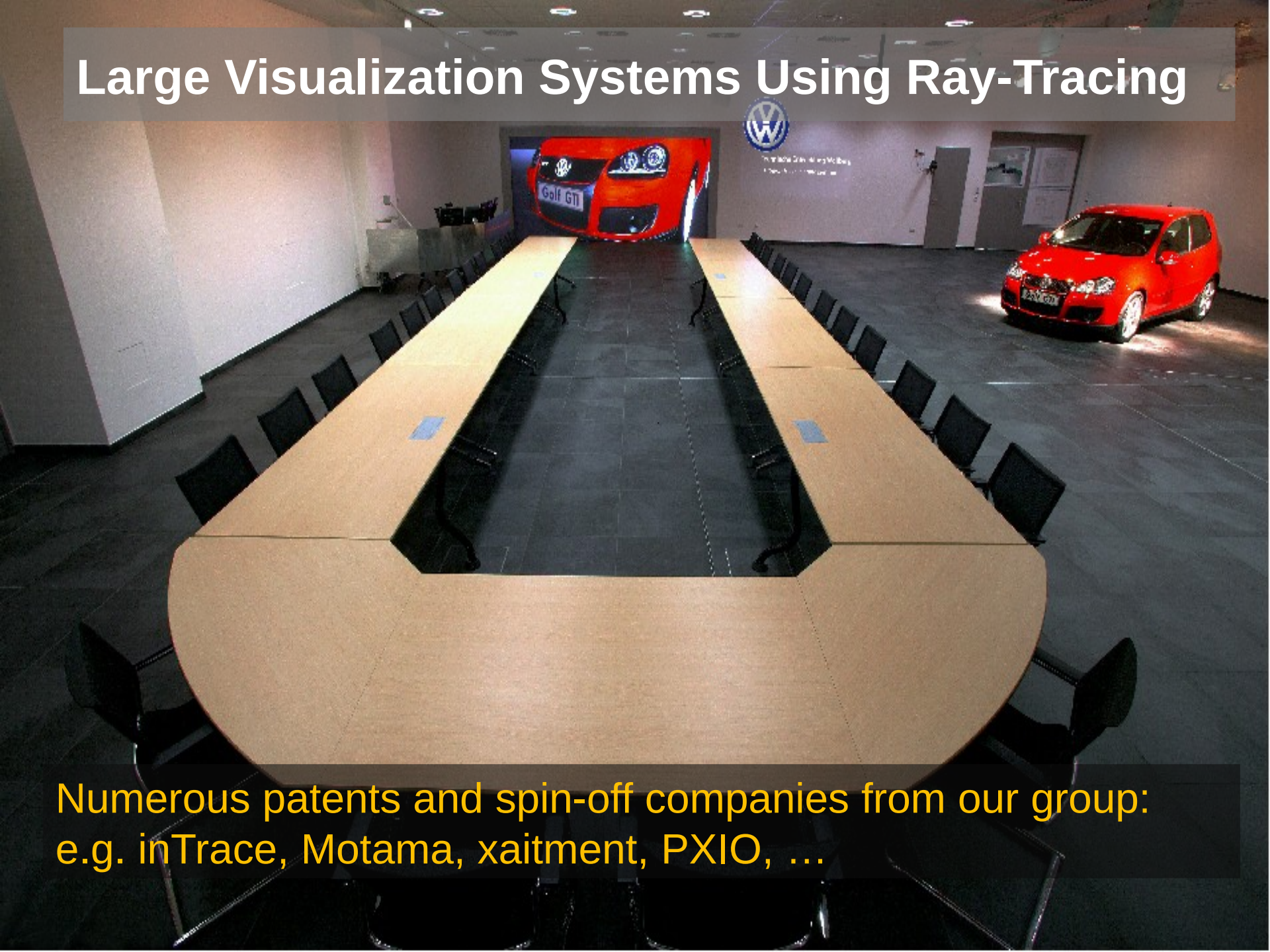


Key product offered now by all major HW vendors:
e.g. Intel (Embree), Nvidia (OptiX), AMD (Radeon Rays) , …

Efficient Simulation of Illumination: Light Propagation and Sensor Models

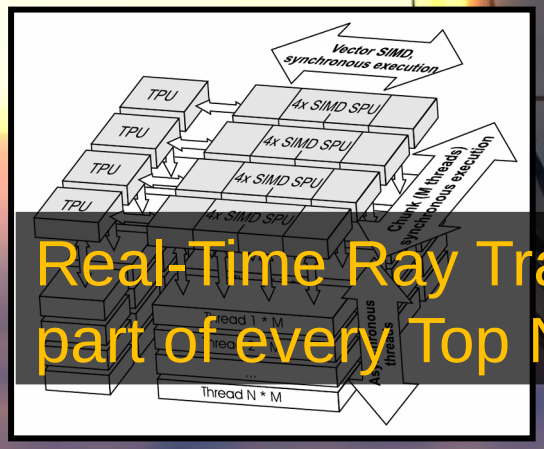
VCM now part of most commercial renders:
e.g. RenderMan, V-Ray, Corona, …

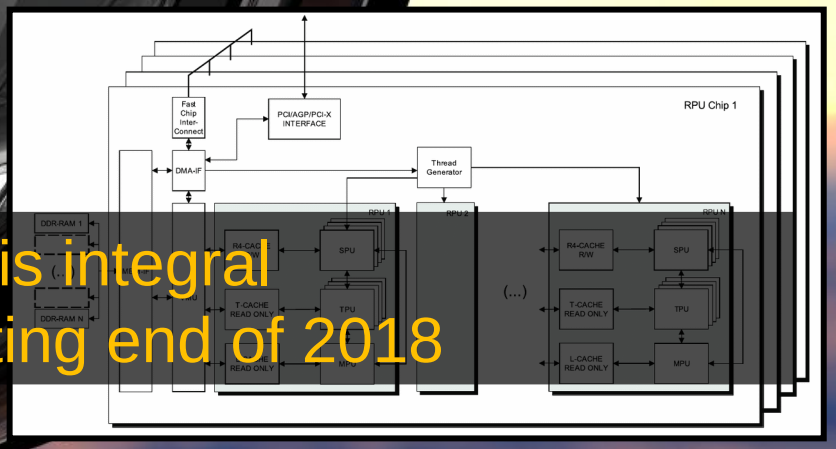
Large Visualization Systems Using Ray-Tracing



Numerous patents and spin-off companies from our group:
e.g. inTrace, Motama, xaitment, PXIO, …

Custom Ray Tracing Processor [Siggraph'05]

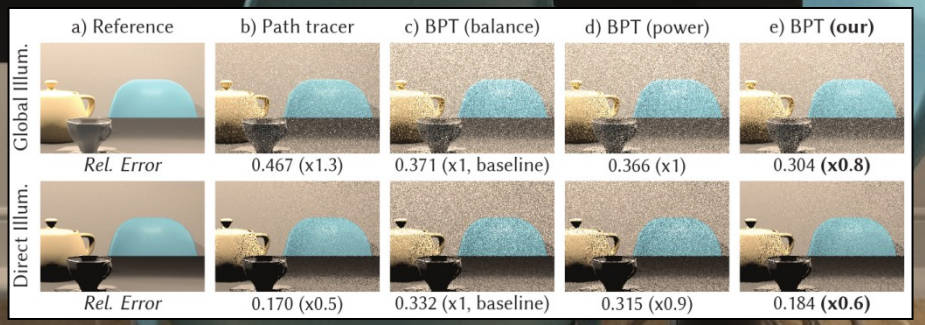




Real-Time Ray Tracing Hardware is integral part of every Top Nvidia GPU starting end of 2018

Fundamental Research in Computer Graphics, High-Performance Computing/Graphics, and AI

Three Siggraph papers in 2019 alone!



AnyDSL Compiler Framework

Computer Vision DSL | **Physics DSL** | **Ray Tracing DSL** | **Parallel Runtime DSL** | **…**

Developer

Layered DSLs

Impala Language & Unified Program Representation

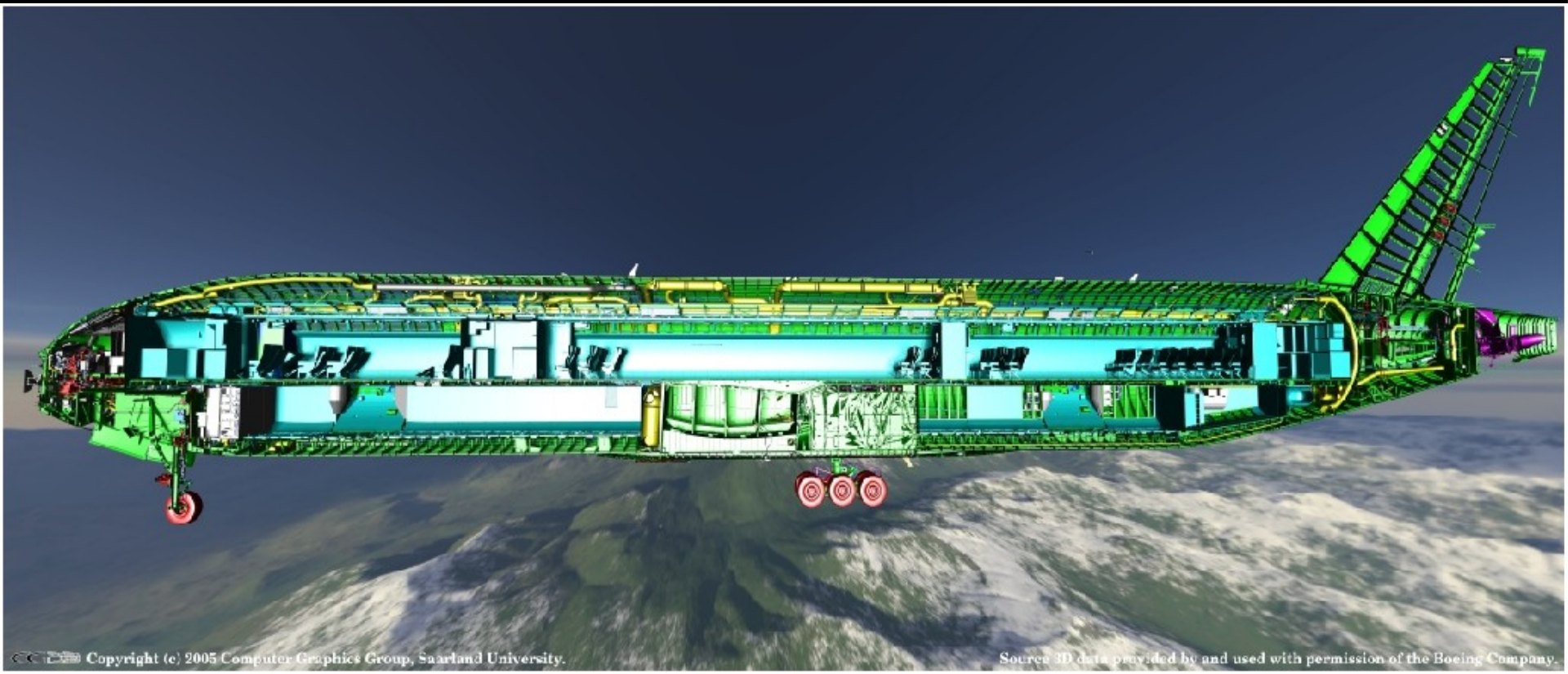
AnyDSL Compiler Framework (Thorin)

Various Backends (via LLVM)

CPUs | GPUs | FPGAs | Accels

GIS and Geo Visualization

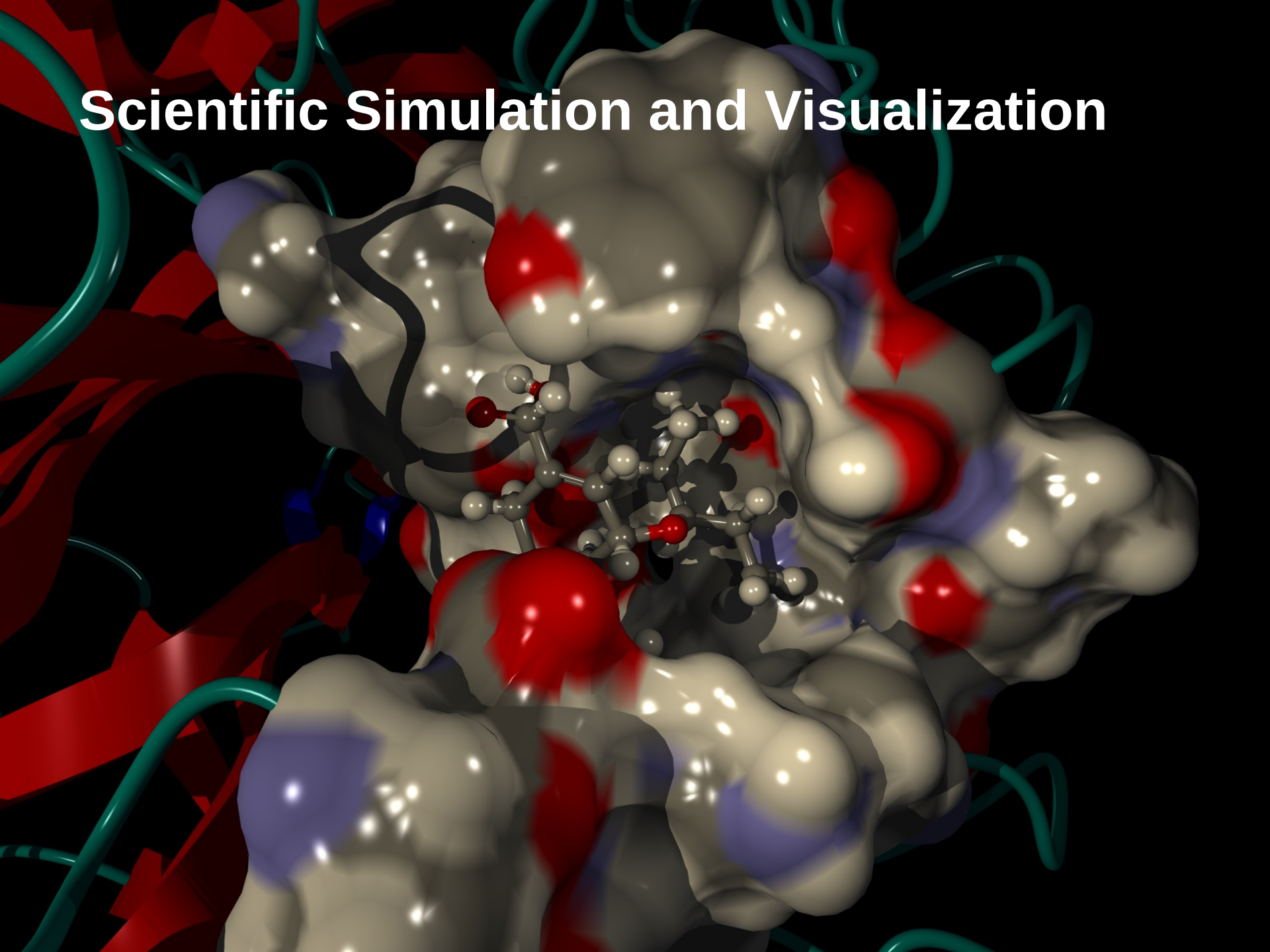
Visualization of Large CAD Models



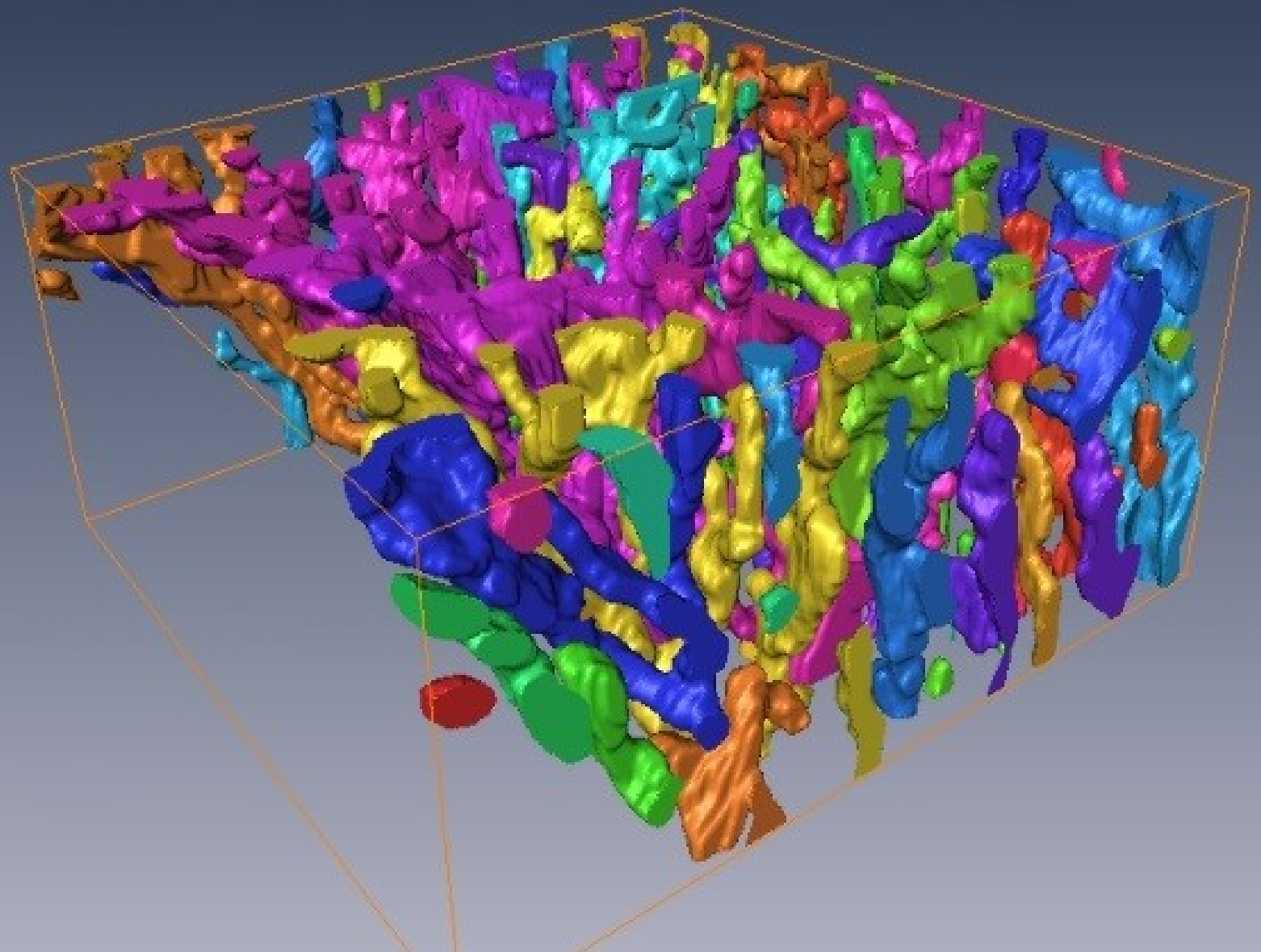
Real-Time Photorealistic Rendering on Film Sets

Display as a Service (DaaS, now Pxio GmbH): Distributed Visualization on the Internet

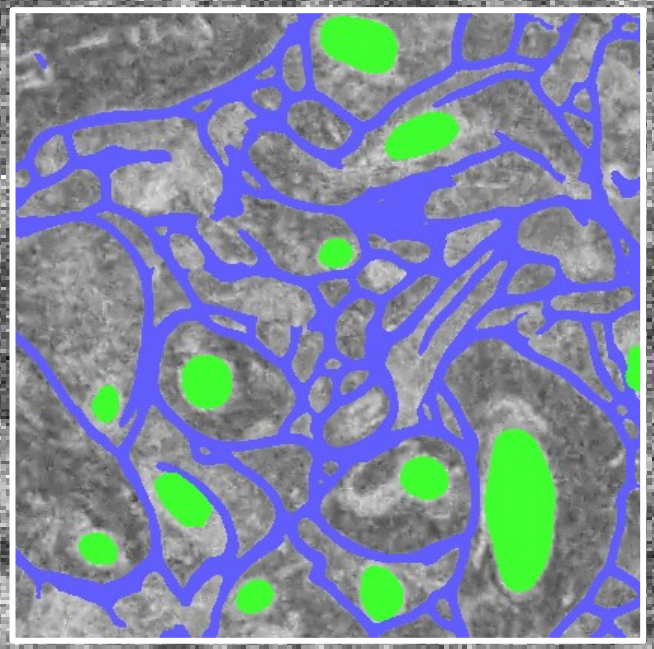
Scientific Simulation and Visualization

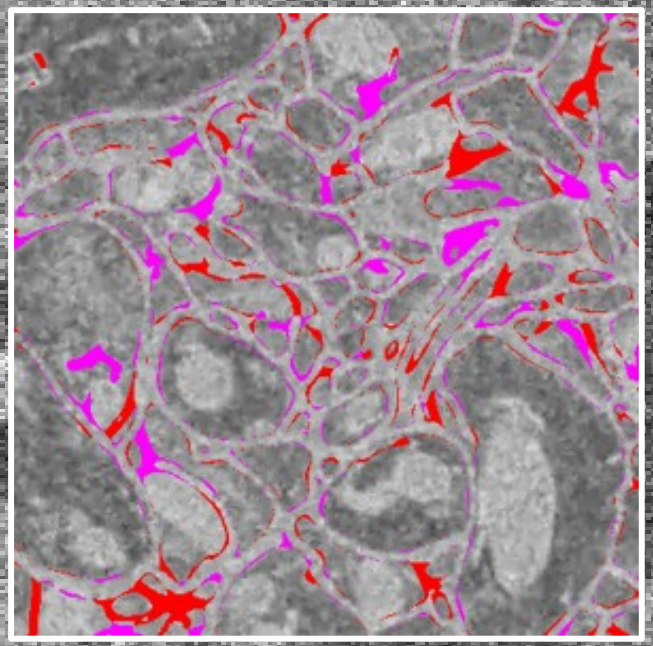


Material Science: Understanding & Predicting Effects of 3D Structures Across Scales



Efficient Acquisition of Imaging Data using AI (e.g. for Connectomics with EM)





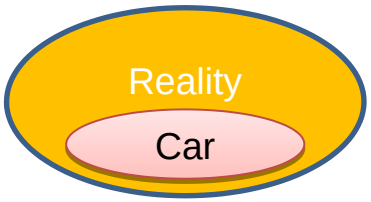
Intelligent Human Simulation, e.g. in Production Environments (Daimler, ...)

Collaborative Robotics and Simulated Reality (VW, Airbus, …)

Autonomous Driving: Training using Synthetic Sensor Data (TÜV, …)

Reality

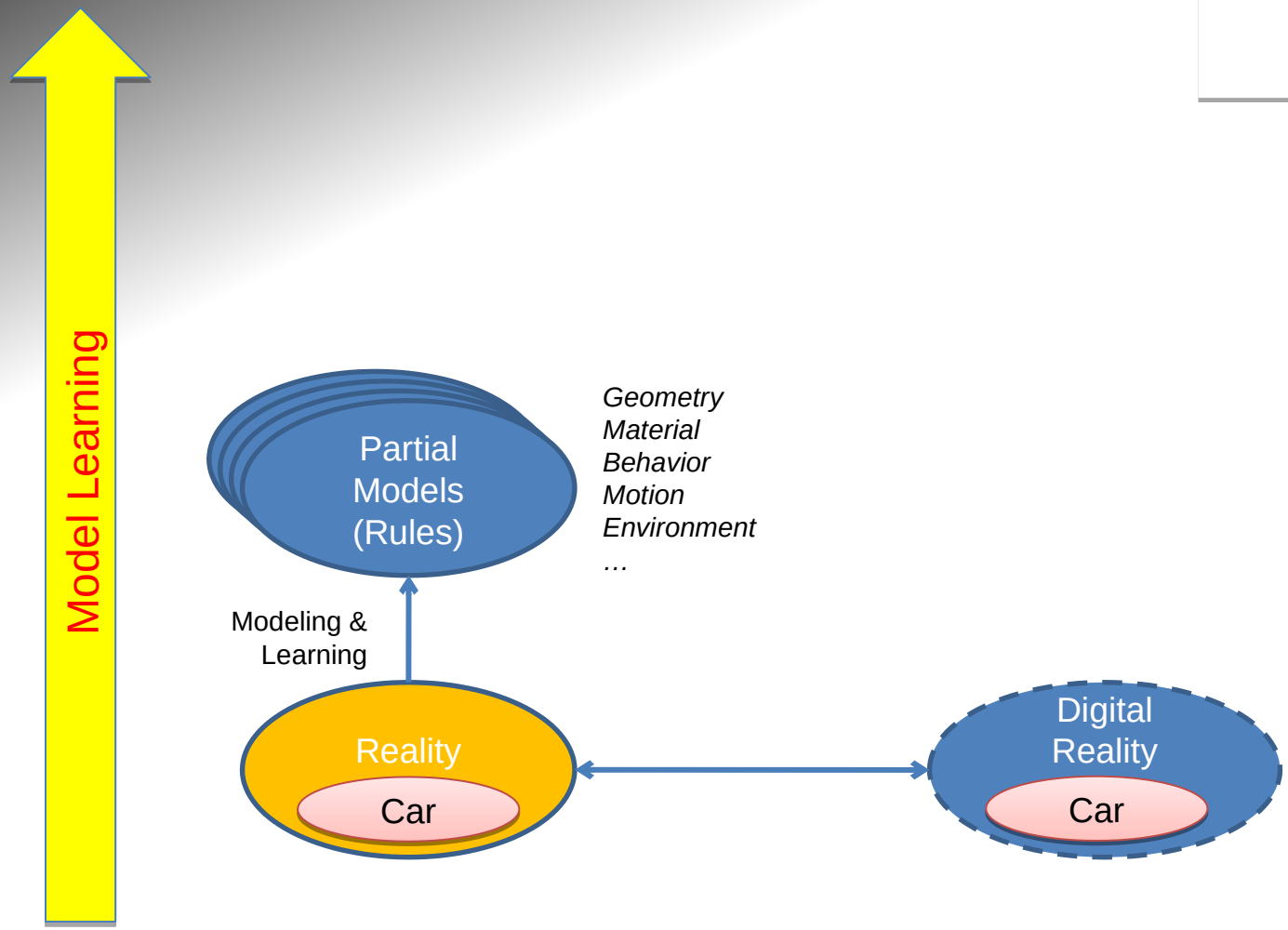
- **Training and Validation in Reality**
  - E.g. driving millions of miles to gather data
  - Difficult, costly, and non-scalable



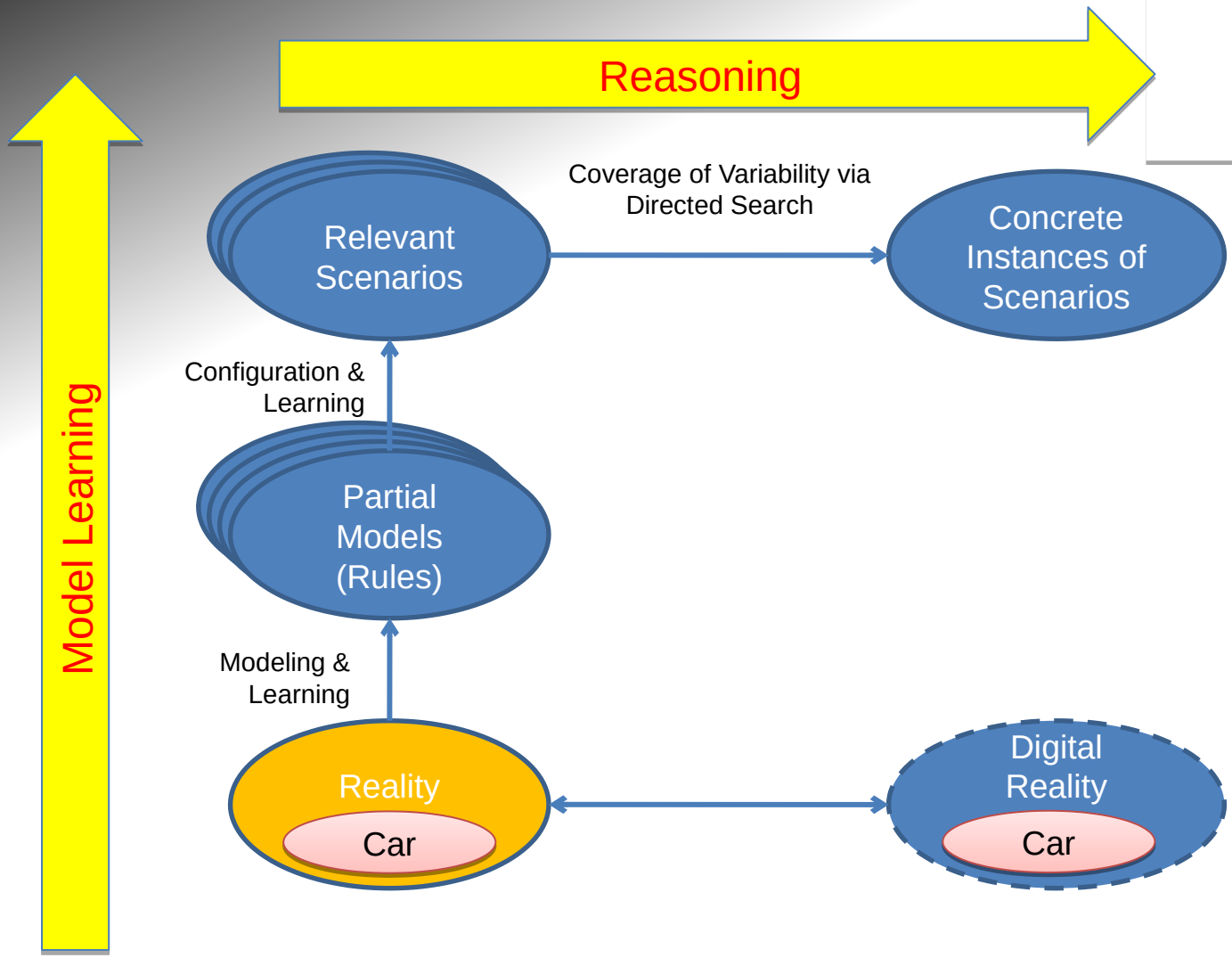
Digital Reality

- **Training and Validation in the *Digital Reality***
  - Arbitrarily scalable (given the right platform)
  - But: Where to get the models and the training data from?

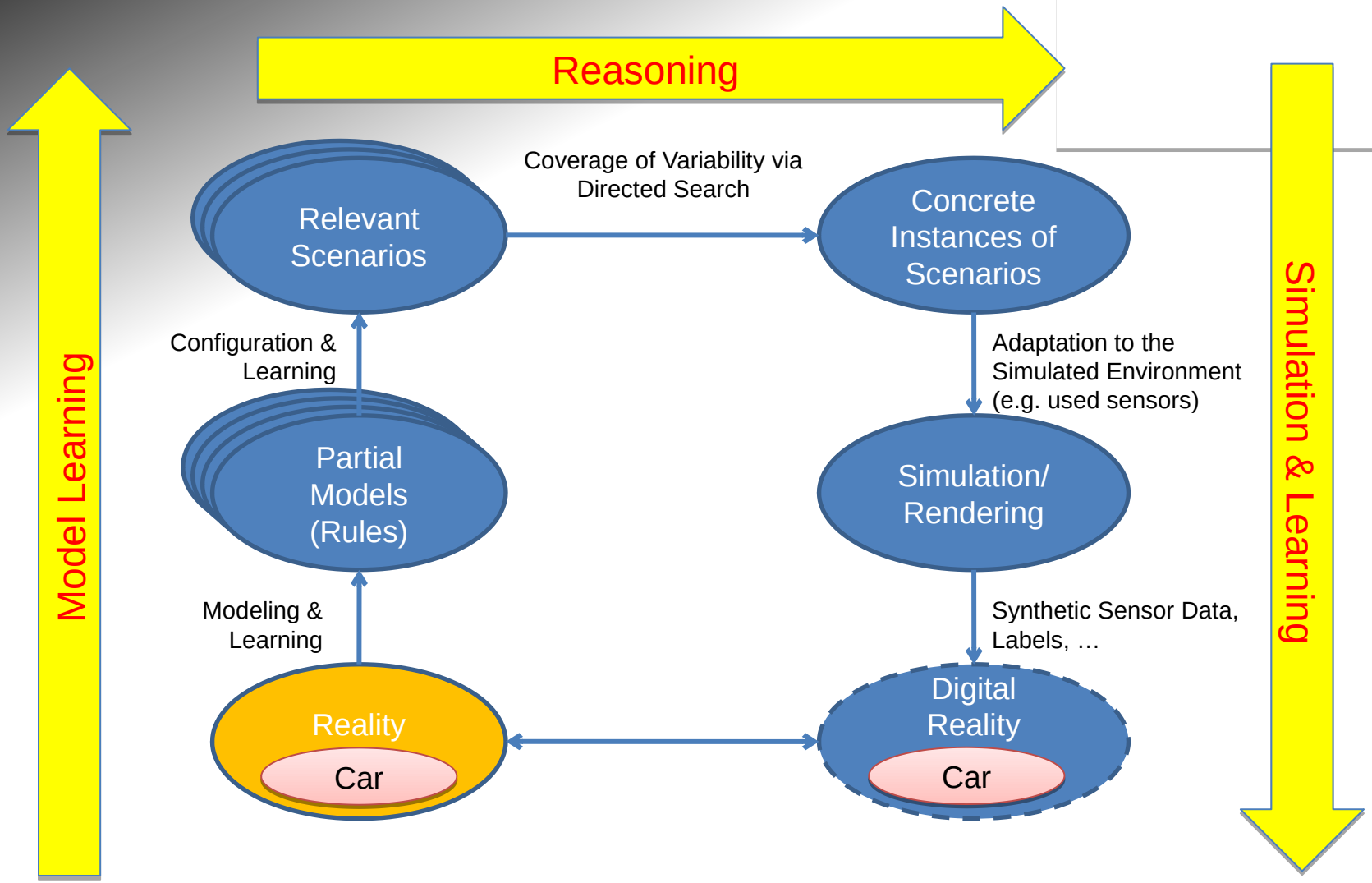
Digital Reality: AI to Safeguard AI



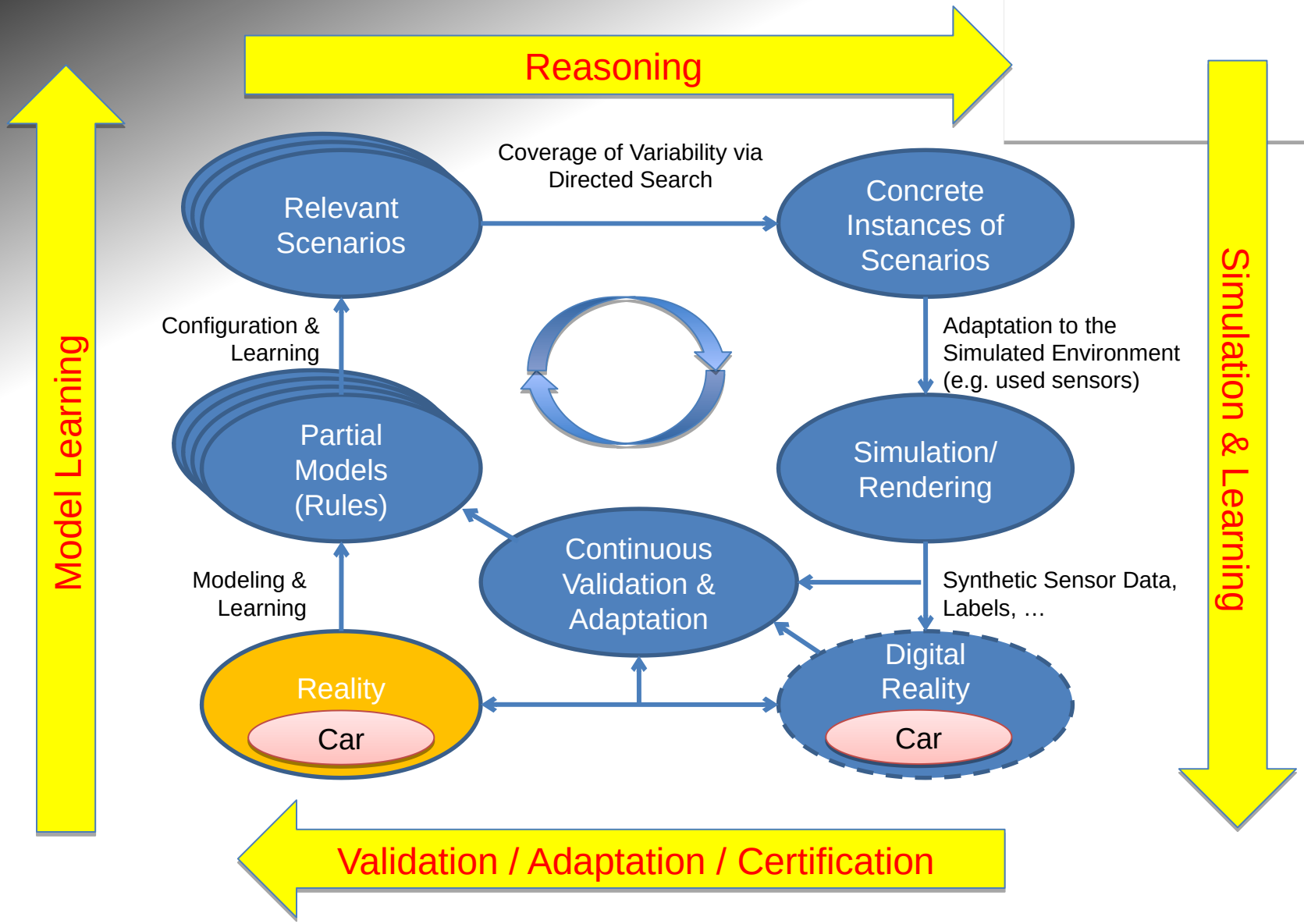
Digital Reality: AI to Safeguard AI



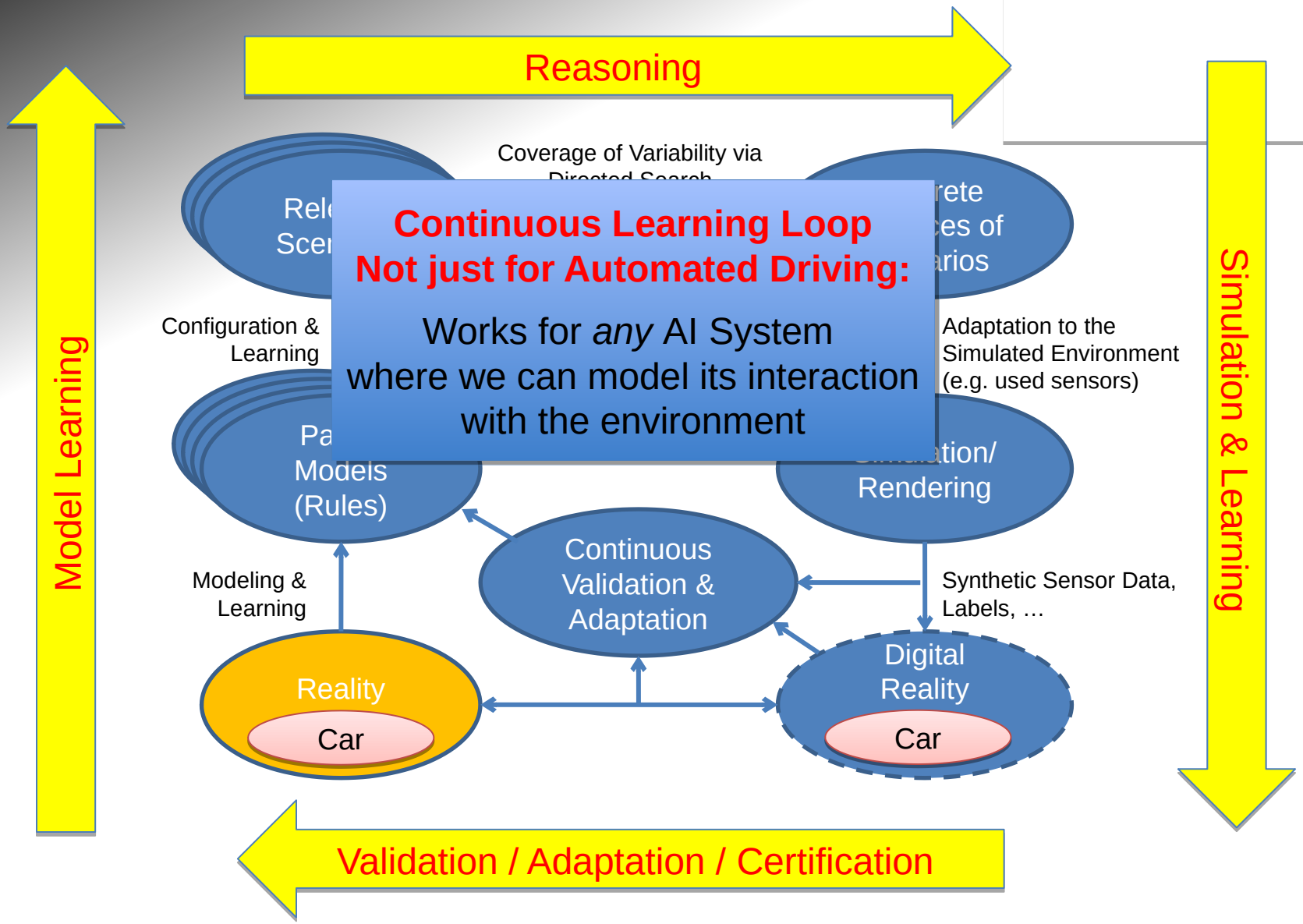
Digital Reality: AI to Safeguard AI



Digital Reality: AI to Certify AI



Digital Reality: AI to Certify AI



Wrap-Up

- **Computer Graphics**
  - Rendering, Modeling, Visualization, Animation, Imaging, …
- **Young, dynamic area**
  - “Everything is possible” mentality
  - Progress driven by research & technology
  - Flexible transfer between research and industry
- **Big industry !**
  - Intel, Nvidia, AMD, Imagination, ARM, …
  - Automotive, aerospace, engineering, …
  - Entertainment: games, film, TV, animations, ...
- **Innovation areas**
  - Digital Reality, Visualization, Industrie-4.0, Big Data, Smart Cities, …
- **Interdisciplinary field**
  - Relations to mathematics, physics, engineering, psychology, art, entertainment, …