Digital Reality:
Understanding the World with AI

Philipp Slusallek

German Research Center for Artificial Intelligence (DFKI)
Saarland University, Computer Graphics Lab (UdS-CGL)

Saarland Informatics Campus
slusallek@dfki.de

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
  - 24 research areas, 9 competence centers, 8 living labs
  - More than 1100 research staff & support
  - Revenues of >73 M€ in 2020 (58 M€ in 2019, 50 M€ in 2018)
  - More than 90 spin-offs

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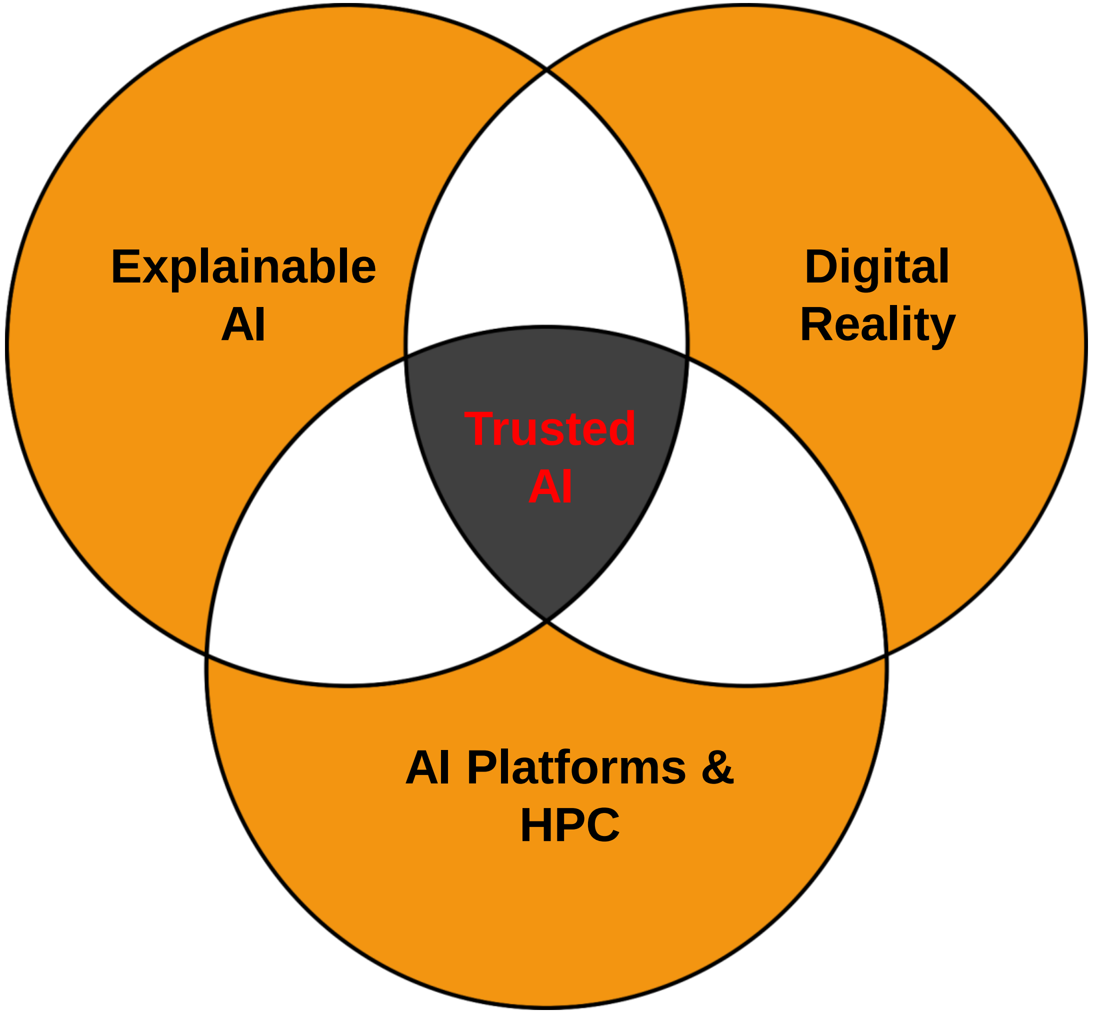
DFKI-ASR: Agents and Simulated Reality

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?*

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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

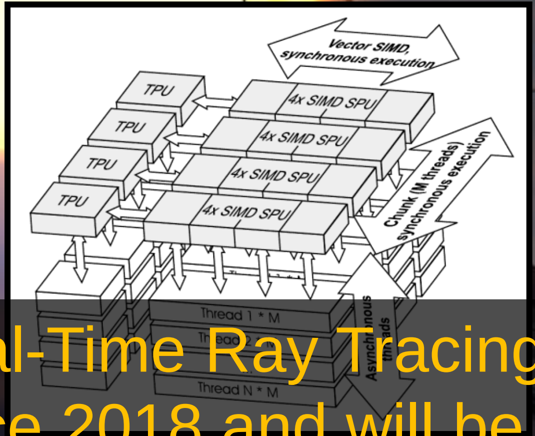
Physically-Based Image Synthesis with Real-Time Ray Tracing

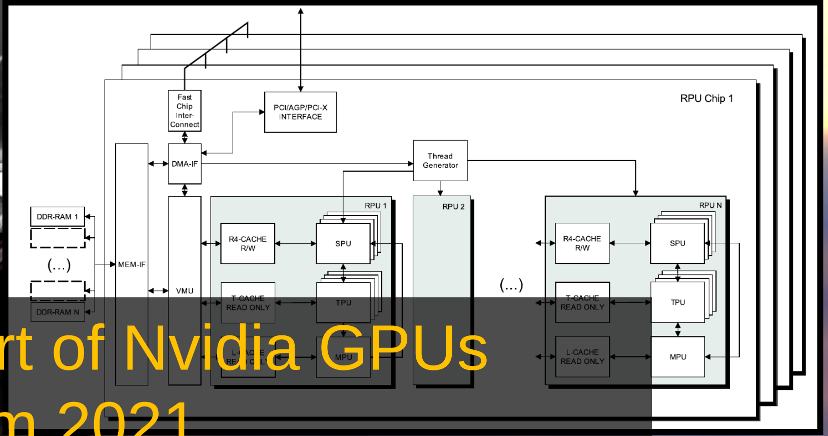
Technical Oscar, Feb 2021

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

Custom Ray Tracing Processor [Siggraph'05]

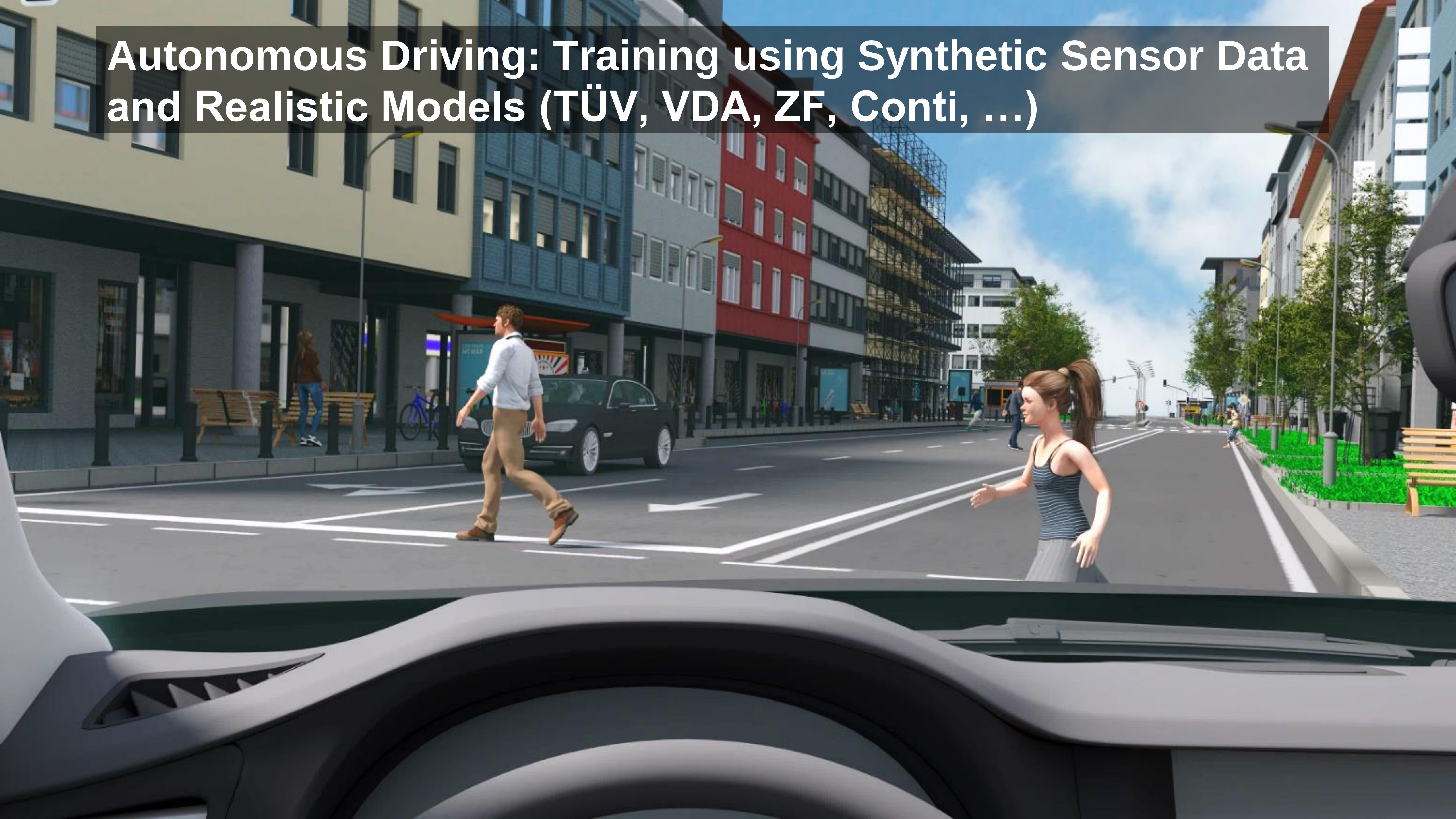
In EVERY GPU starting 2021





Real-Time Ray Tracing Hardware is part of Nvidia GPUs since 2018 and will be for all others from 2021

Autonomous Driving: Training using Synthetic Sensor Data and Realistic Models (TÜV, VDA, ZF, Conti, …)



AI & Models of the World

Models & AI:
Relationship Between Humans and AI

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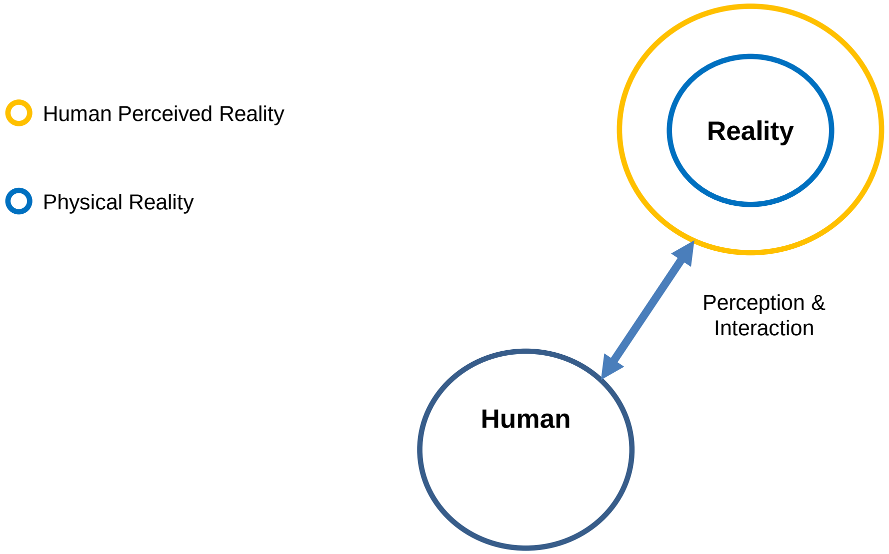
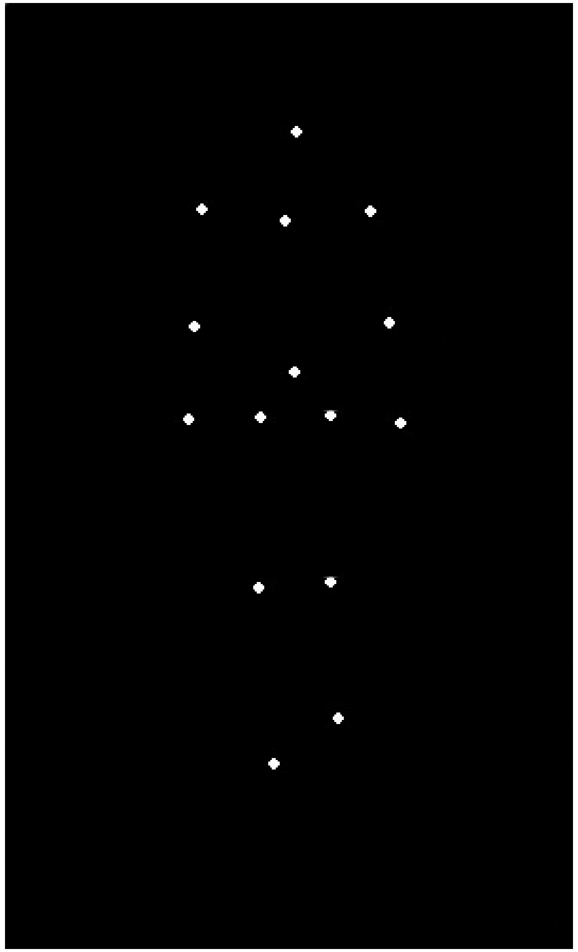
Models & AI:
Relationship Between Humans and AI





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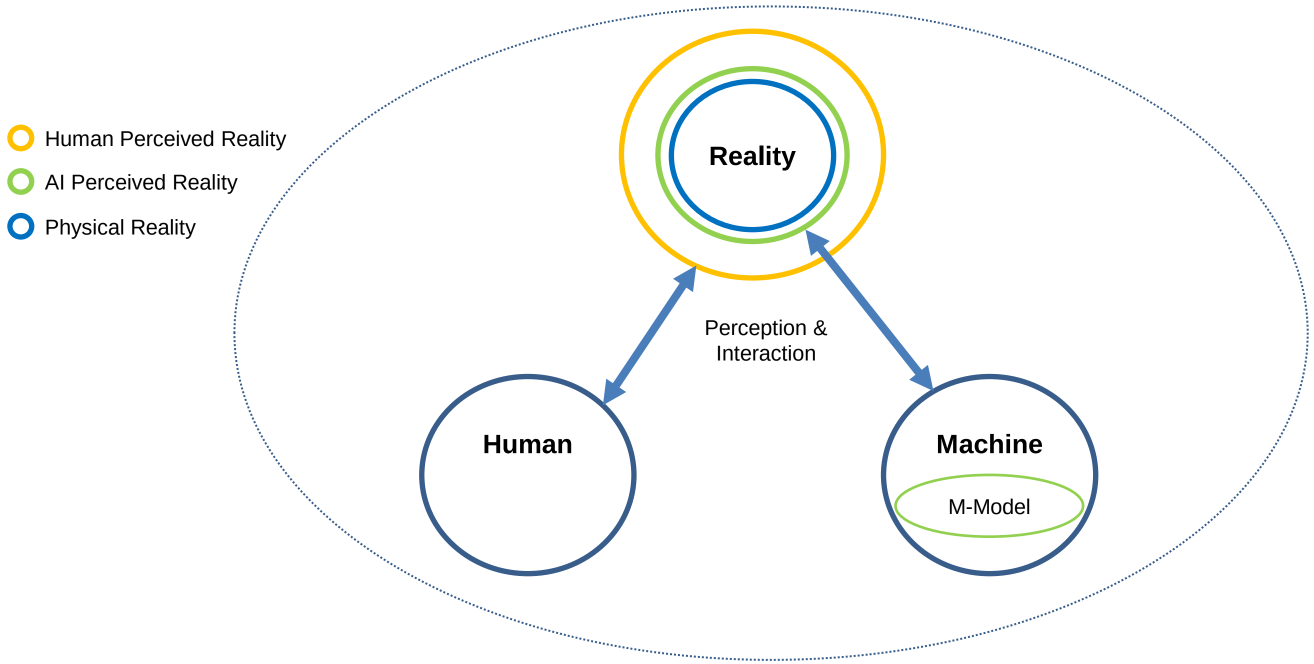
Relationship Between Humans and AI



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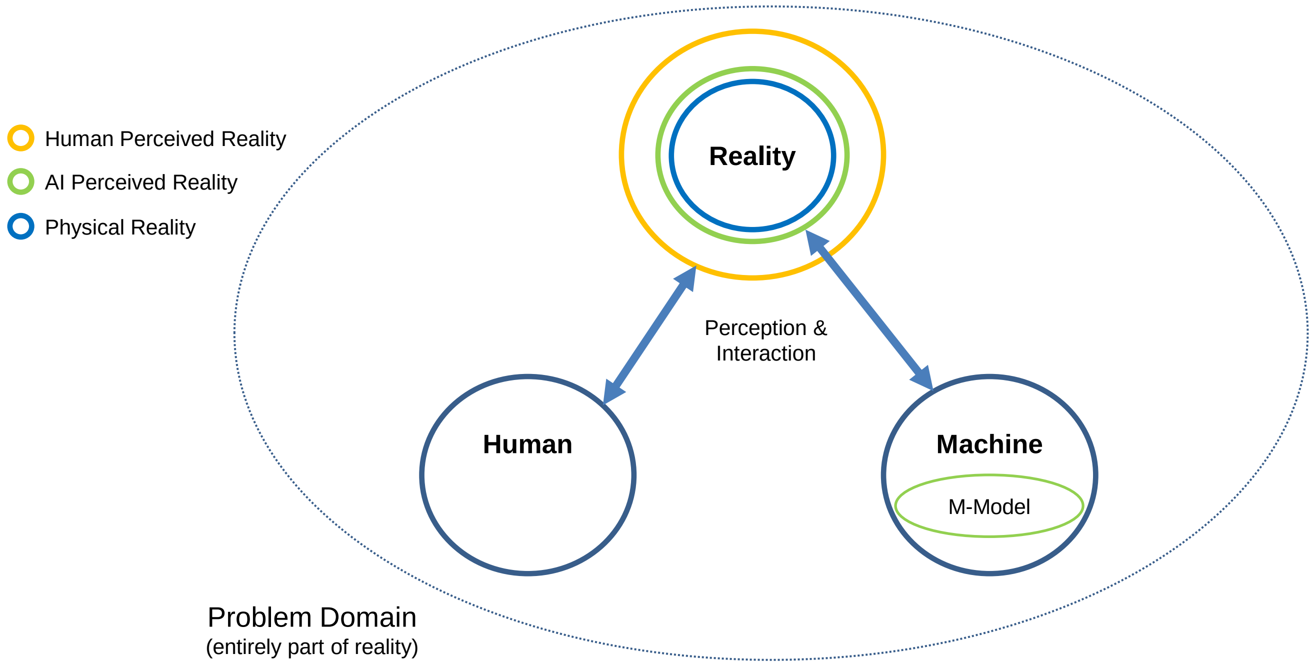

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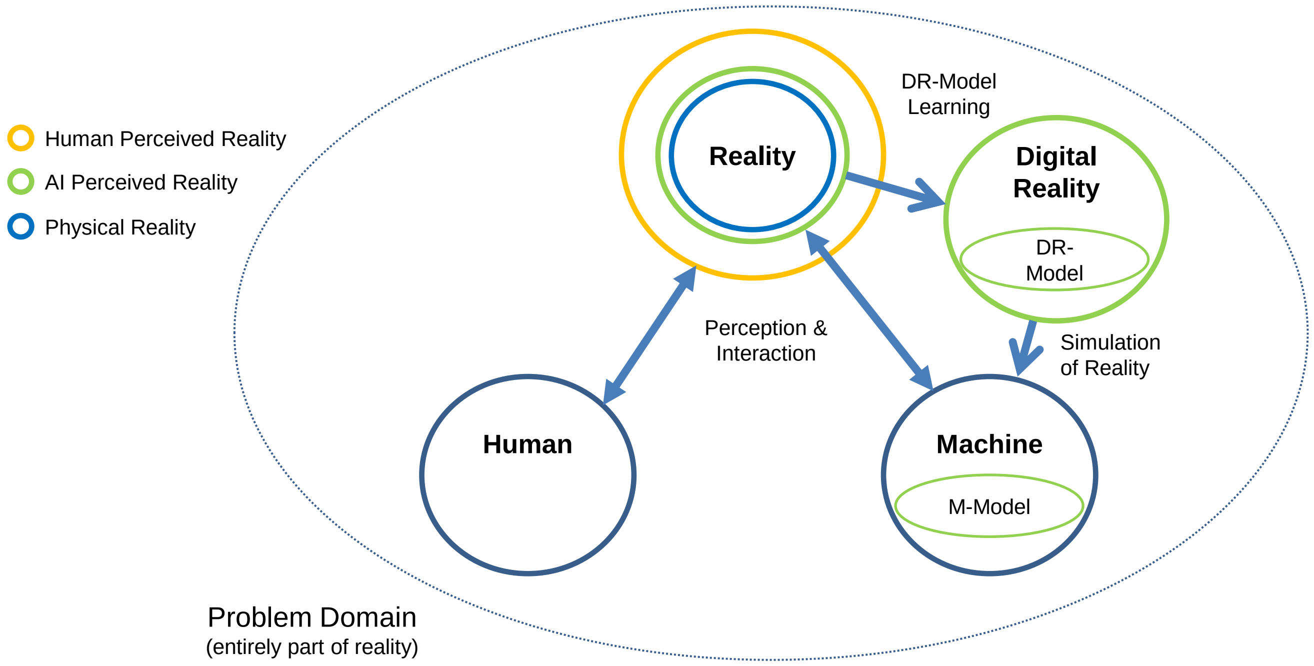

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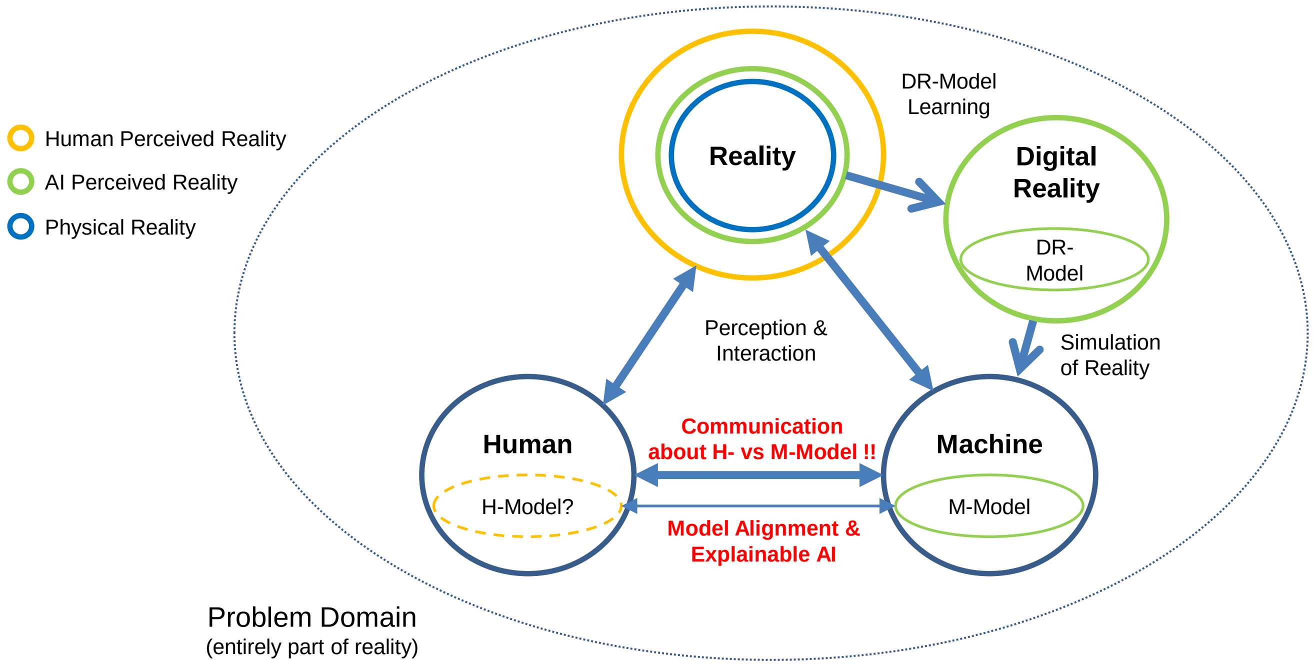

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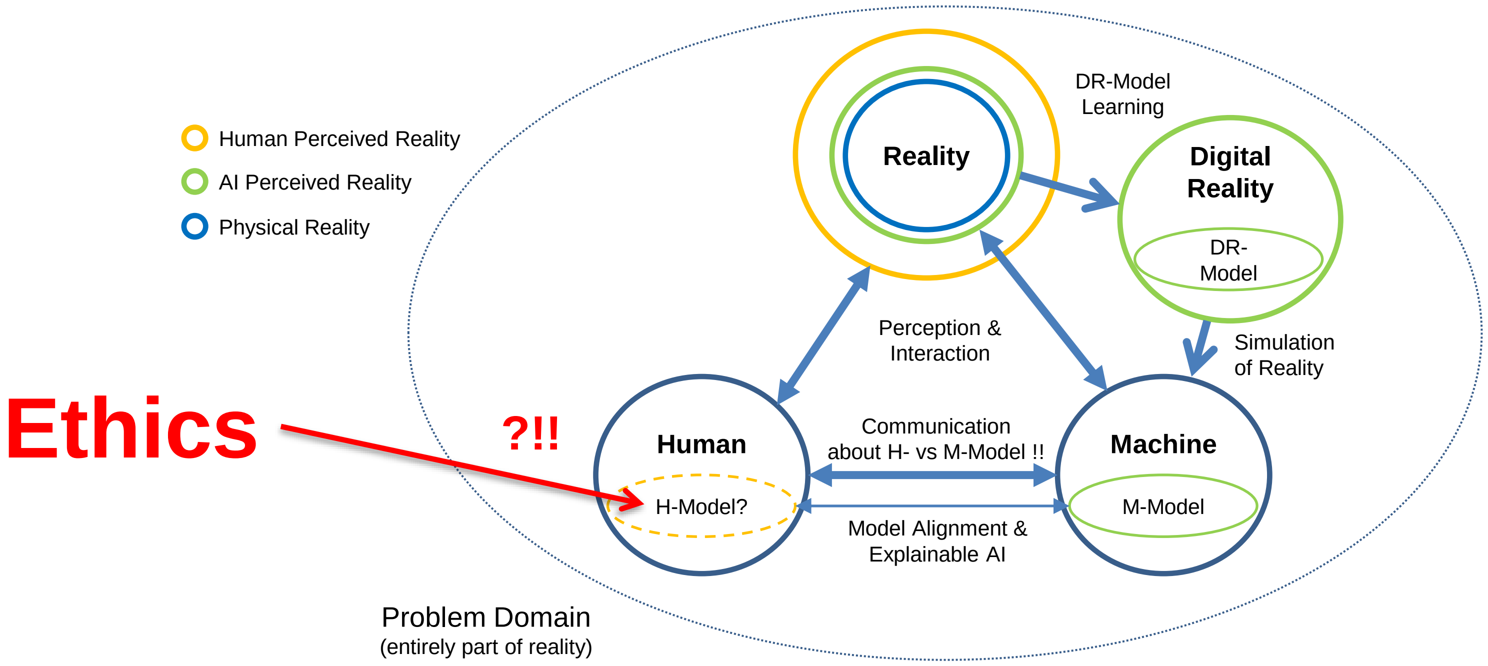
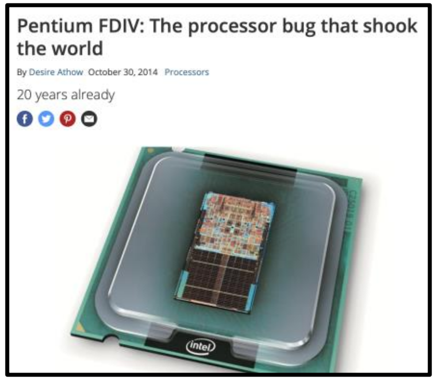


Digital Reality

State of AI

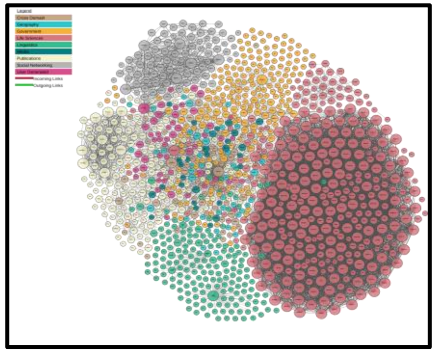
- **Success stories**
  - HW Verification, Knowledge Graphs, Search & Optimization, …
  - Perception: Vision, Speech, …
  - Game playing: Chess, Go, video games, …
  - Some complex tasks: translation, autonomous driving, …
- **Amazing progress in recent years**
  - Most visible due to Deep Neural Networks (DNNs)
  - Focus shifting to hybrid/neuro-symbolic/neuro-explicit approaches
- **Still many fundamental challenges**
  - With severe consequences to the practical use of AI

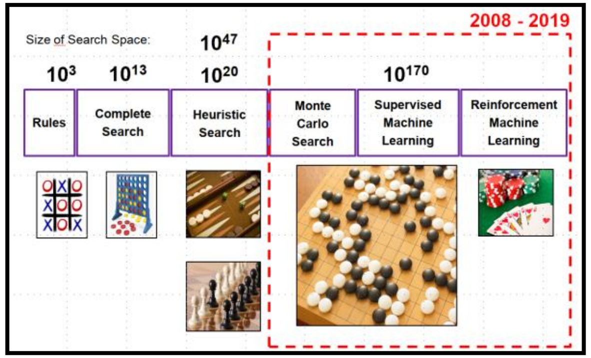


Pentium FDIV: The processor bug that shook the world

By Desire Athow October 30, 2014 Processors

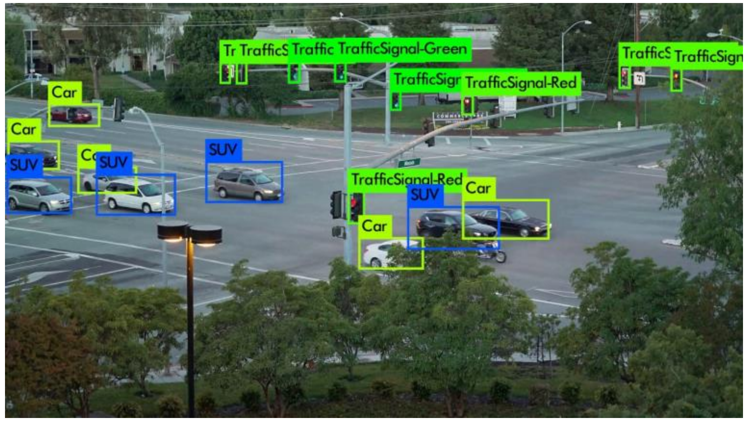
20 years already



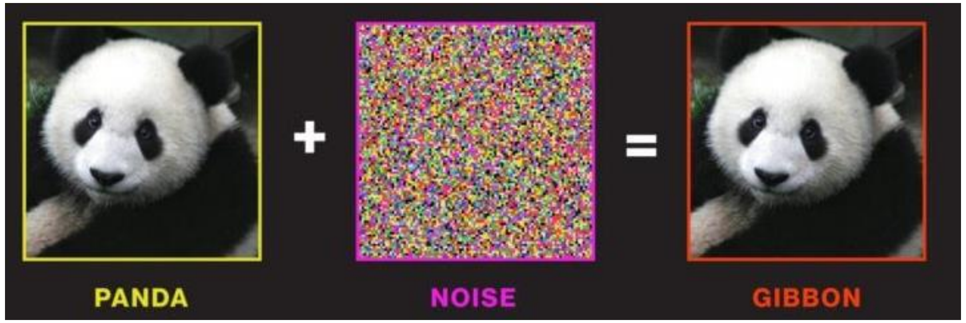


Fundamental Challenges: Functionality vs. Robustness

- AI/DL is highly capable already …

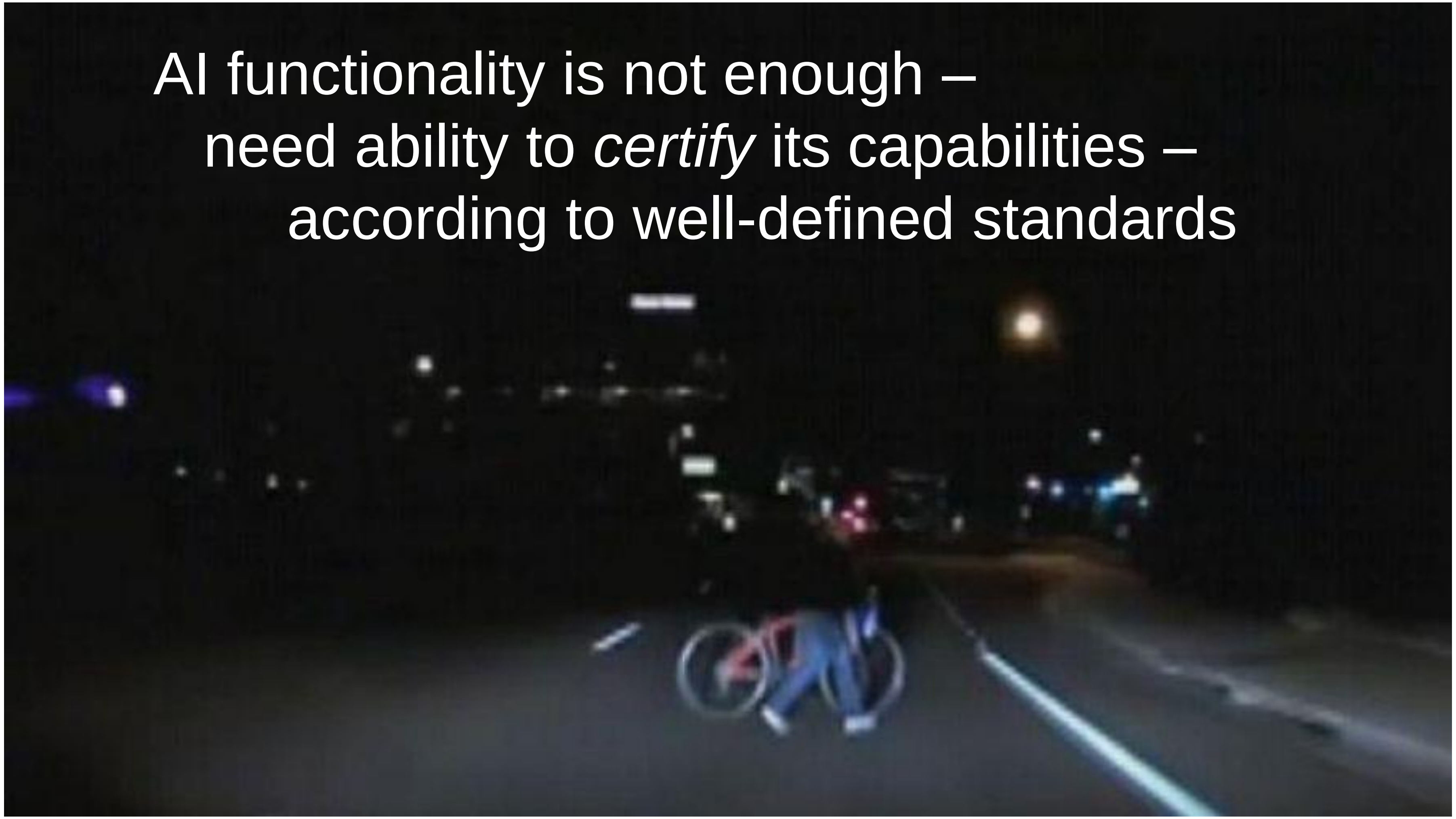


- … but we often cannot guarantee basic functionality



Achieving Trusted AI via Digital Reality

AI functionality is not enough –
need ability to *certify* its capabilities –
according to well-defined standards



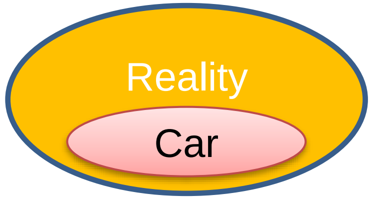
Autonomous Systems: The Problem

- **Our World is extremely complex**
  - Geometry/Shape, Appearance, Motion, Weather, Environment, …
- **Systems must make accurate and reliable decisions**
  - Especially in ***Critical Situations***
  - Increasingly making use of (deep) machine learning
- **But learning for critical situations is essentially impossible**
  - Often little (good) data even for “normal” situations
  - Critical situations rarely happen in reality – per definition!
  - Extremely high-dimensional models

➔**Goal: Scalable Learning from *synthetic* input data**
  - Continuous benchmarking & validation (“Virtual Crash-Test“)

Reality

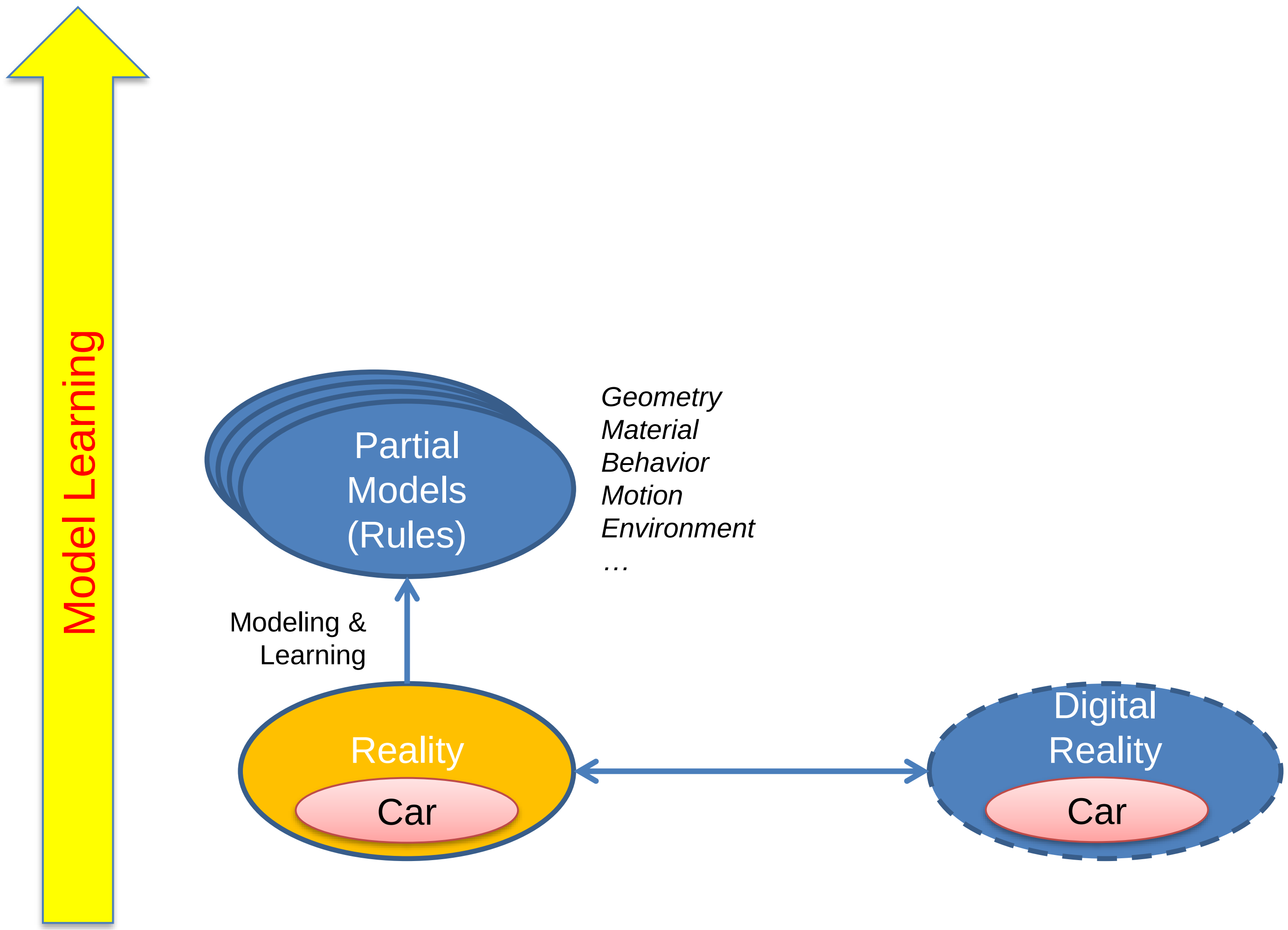
- **Training and Validation in Reality**
  - E.g. driving millions of miles to gather data
  - Difficult, costly, and non-scalable



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 Optimize and Certify AI



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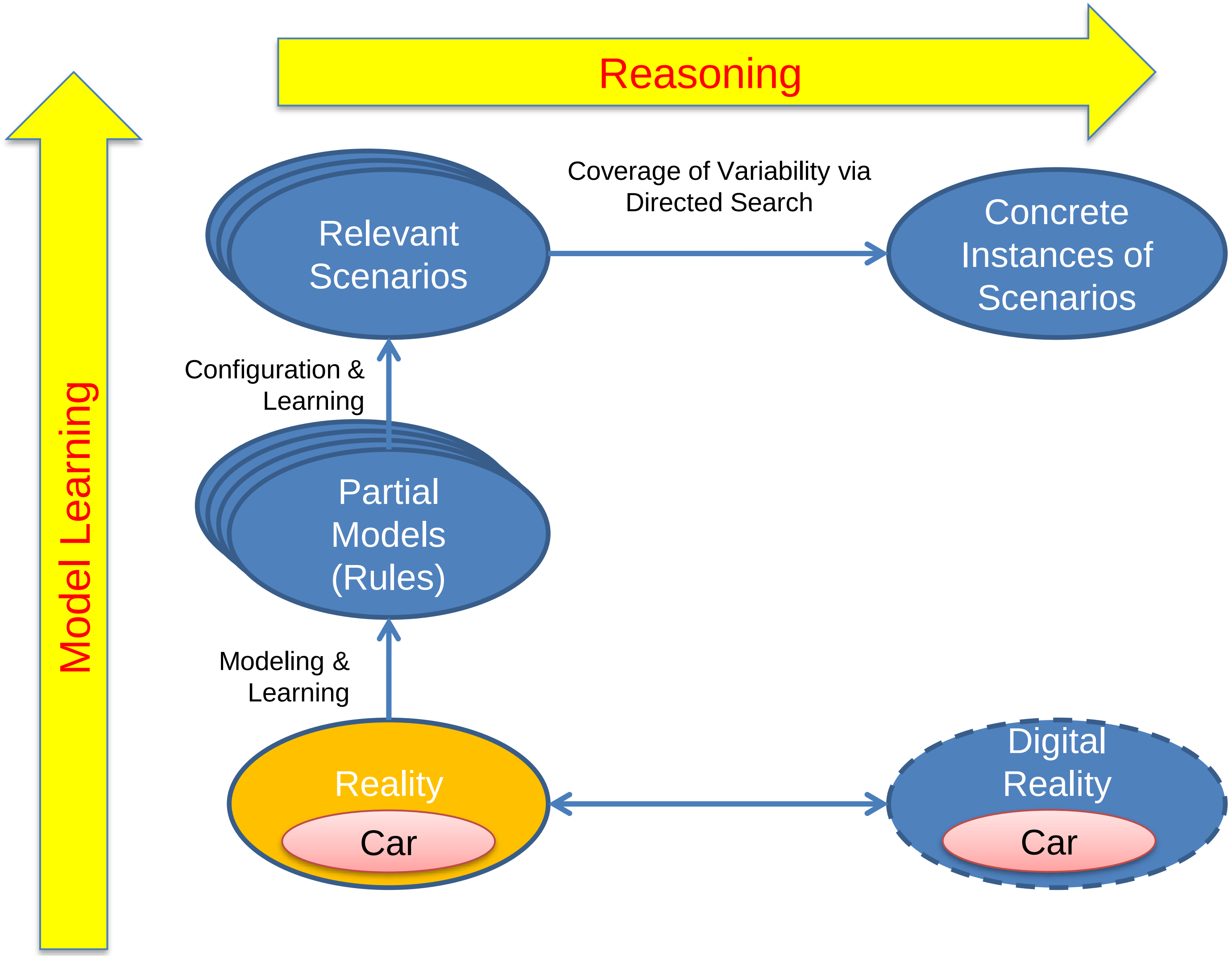

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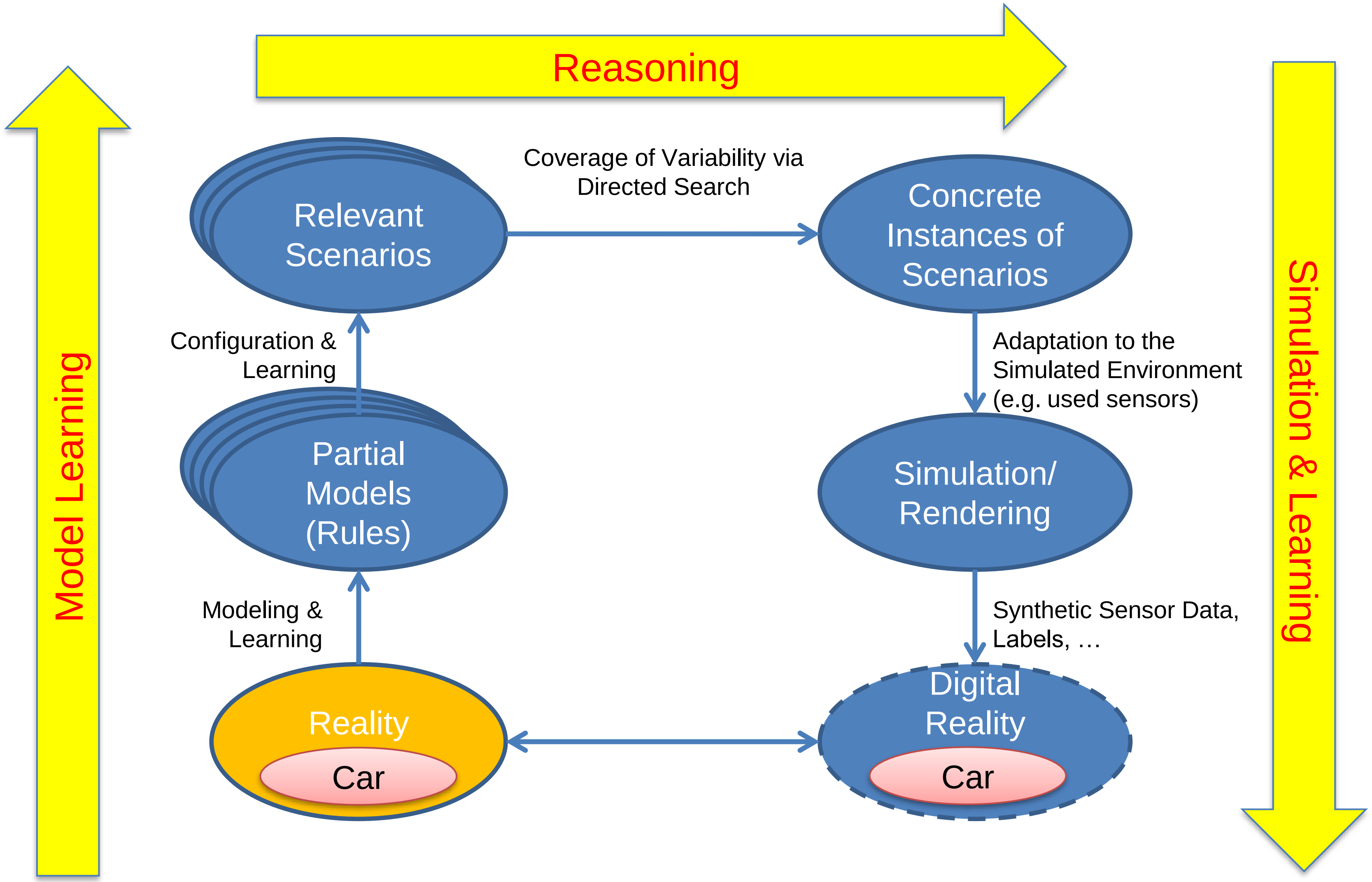

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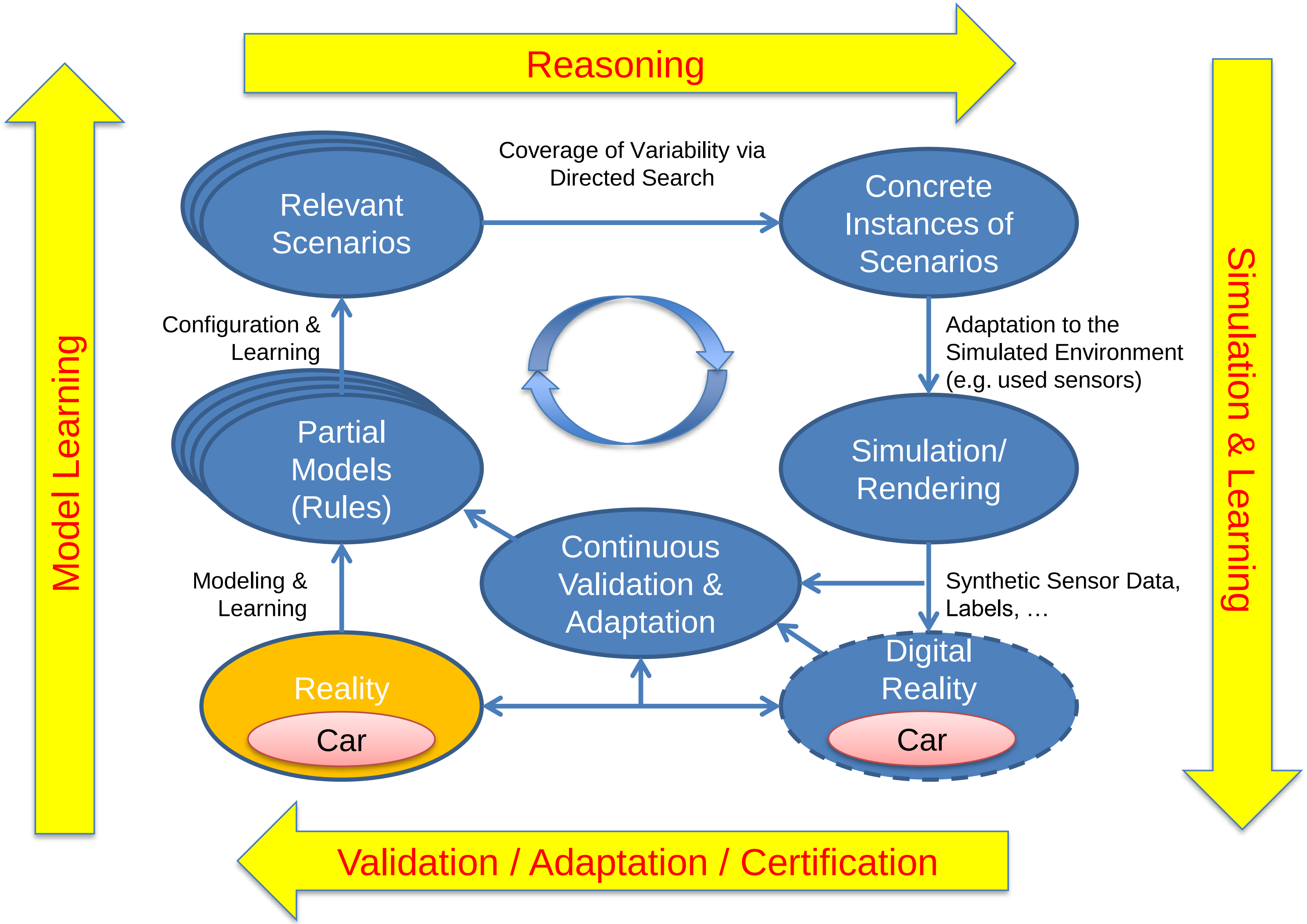

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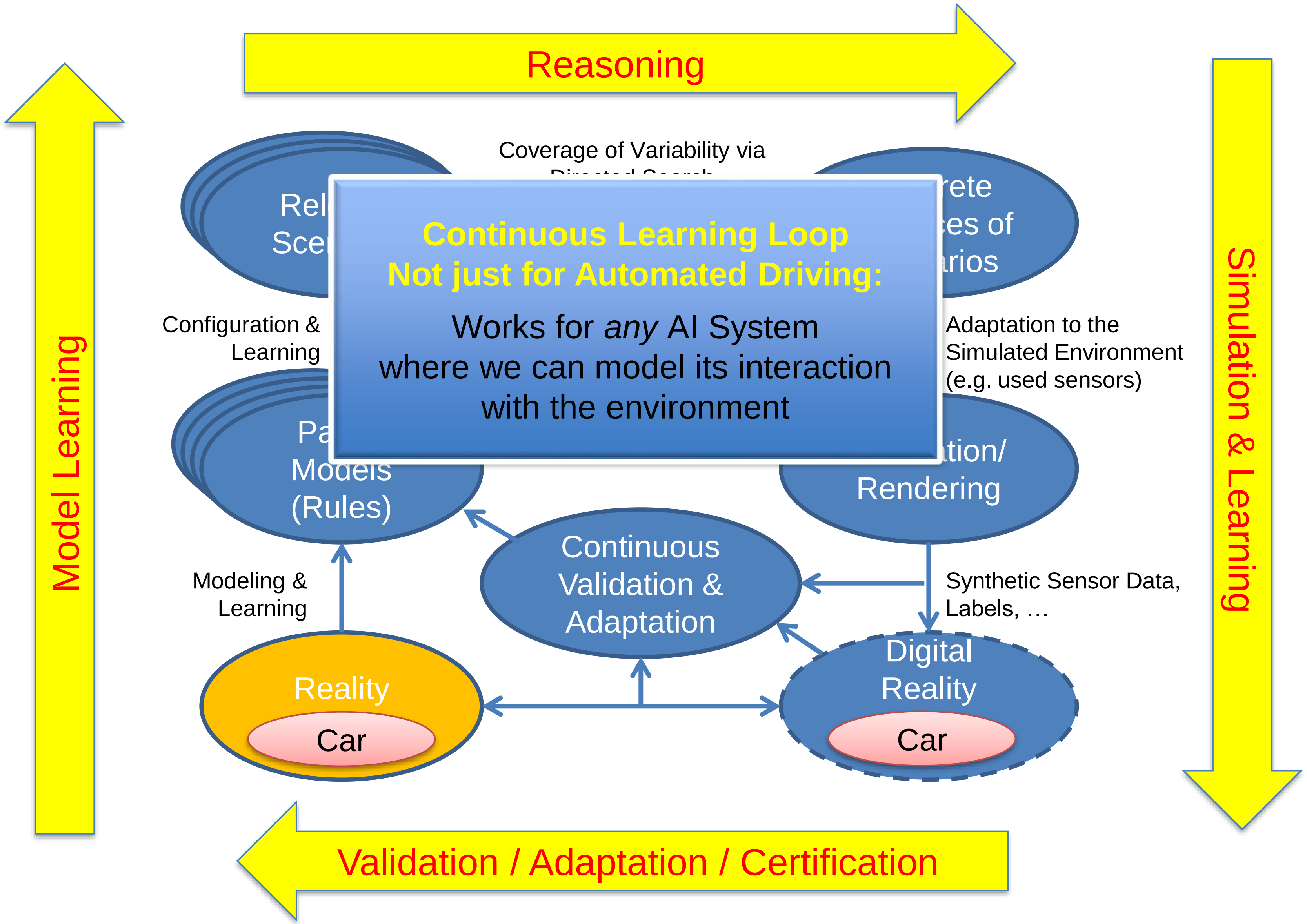
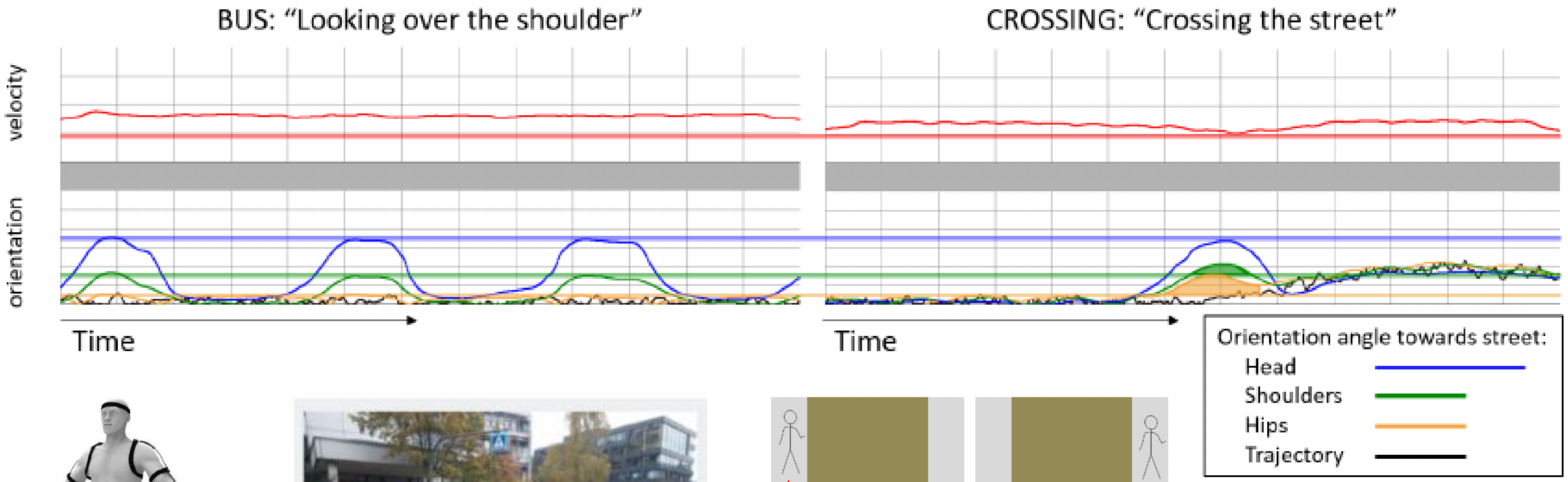


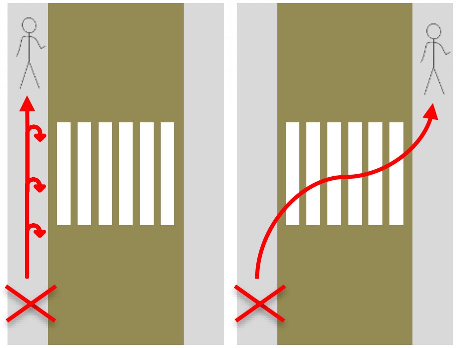
Continuous Learning Loop
Not just for Automated Driving:

Works for *any* AI System
where we can model its interaction
with the environment

Challenge: Pedestrian Motion

- **Characterizing Pedestrian Motion**
  - Clear motion differences when crossing the street



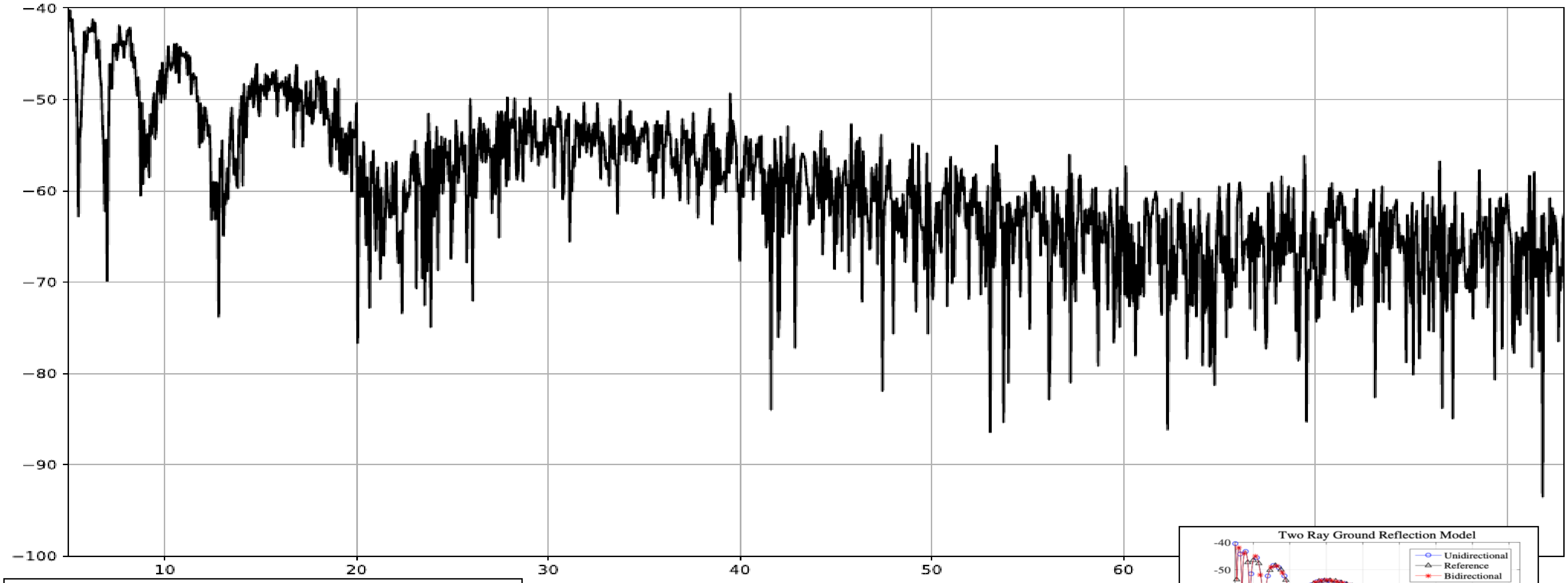


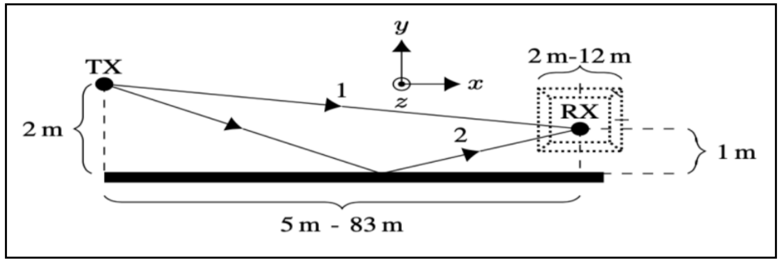
Bus Crossing

Challenge: Better Simulation (e.g. Radar Rendering)

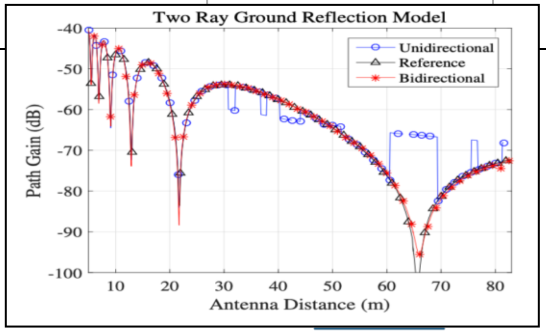
- **Key Differences**
  - Longer wavelength: Geometric optics (rays) not sufficient
  - Need for *some* wave optics
    - Interference of multi-path interactions (coherent radiation, GO/PO)
    - Need for polarization and phase information
    - Diffraction from rough surfaces and edges
  - Highly different goals
    - Optical: Focus on *diffuse* effects (+ some highlights, reflections, etc.)
    - Radar: Focus on *specular* transport only (i.e. caustic paths)
- **Completely novel approach (beyond ray tracing)**
  - Using latest Monte-Carlo techniques (BiDir, MIS, VCM, …)
  - Using recent work on Path Guiding [Rath et al., Siggraph´19]
- **Bringing together radar & latest research on MC rendering**

Radar Simulation
Using Modern Monte-Carlo Algorithms





Path Tracing



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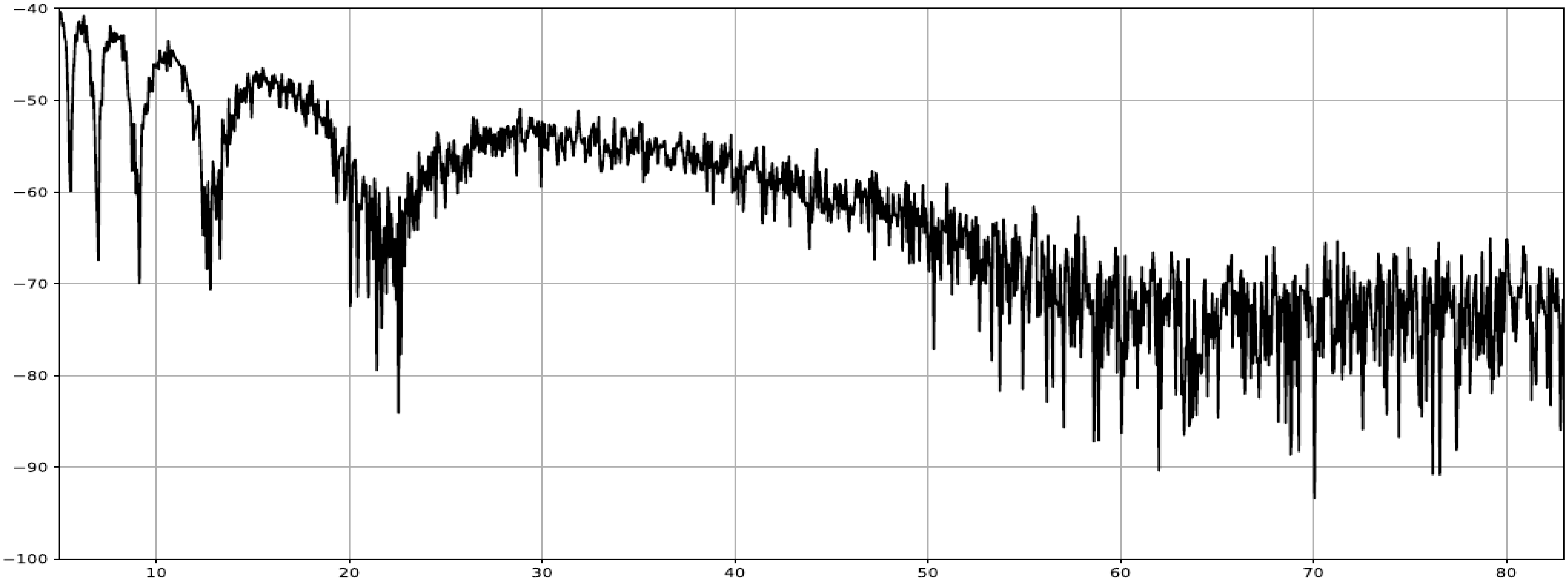
Radar Simulation
Using Modern Monte-Carlo Algorithms



Path Tracing + "Texture Filtering"

Radar Simulation
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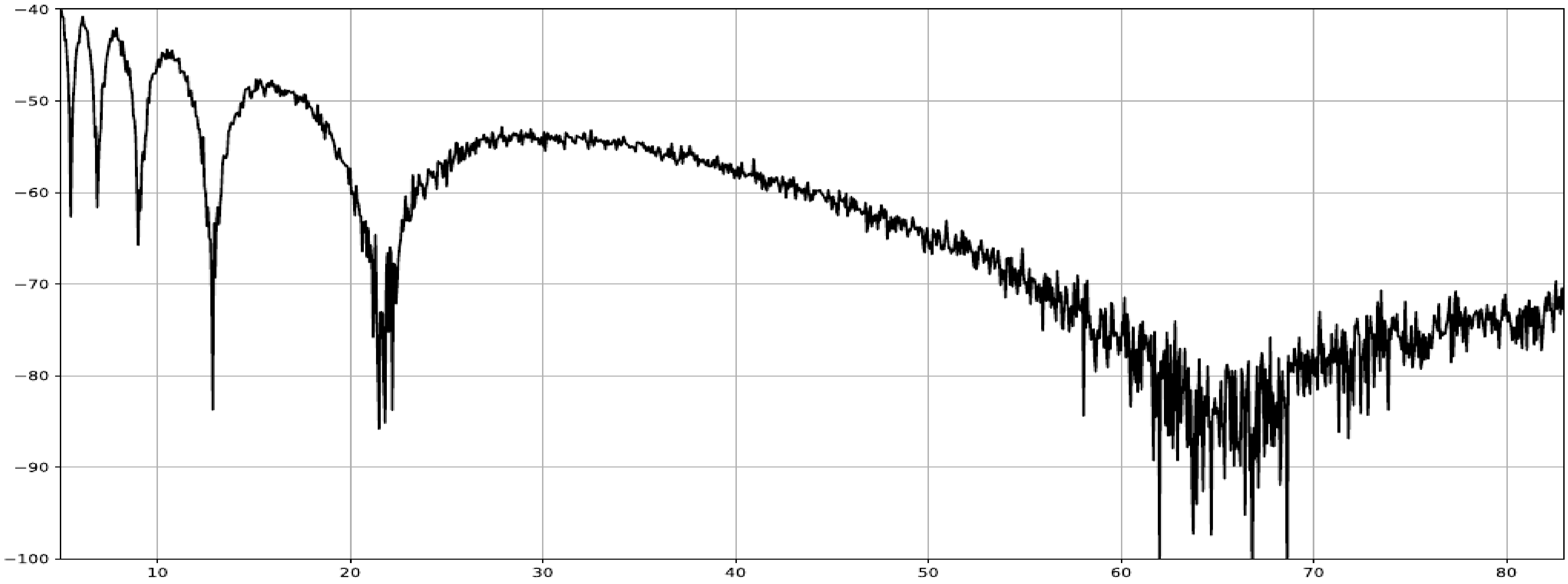
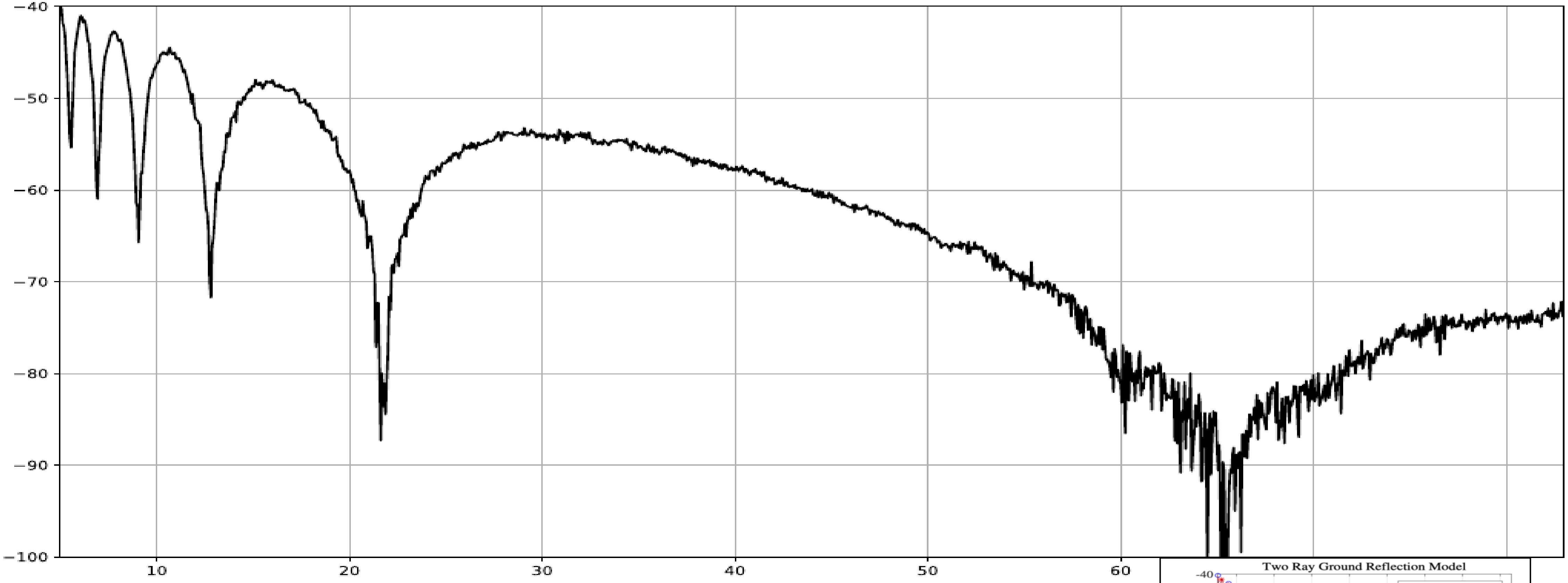
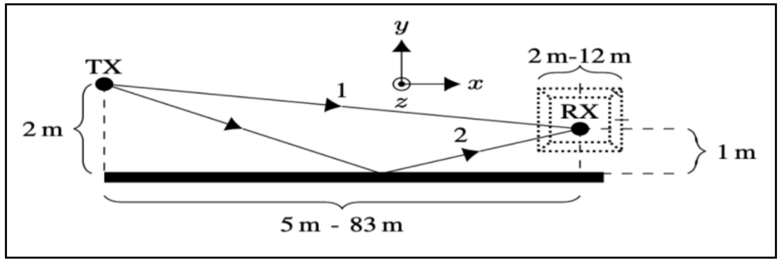


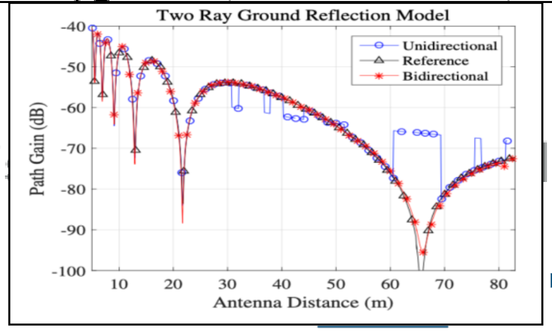
Path Tracing + "Texture Filtering" + Guiding

Radar Simulation
Using Modern Monte-Carlo Algorithms





Filtering" + Guiding + Low Di



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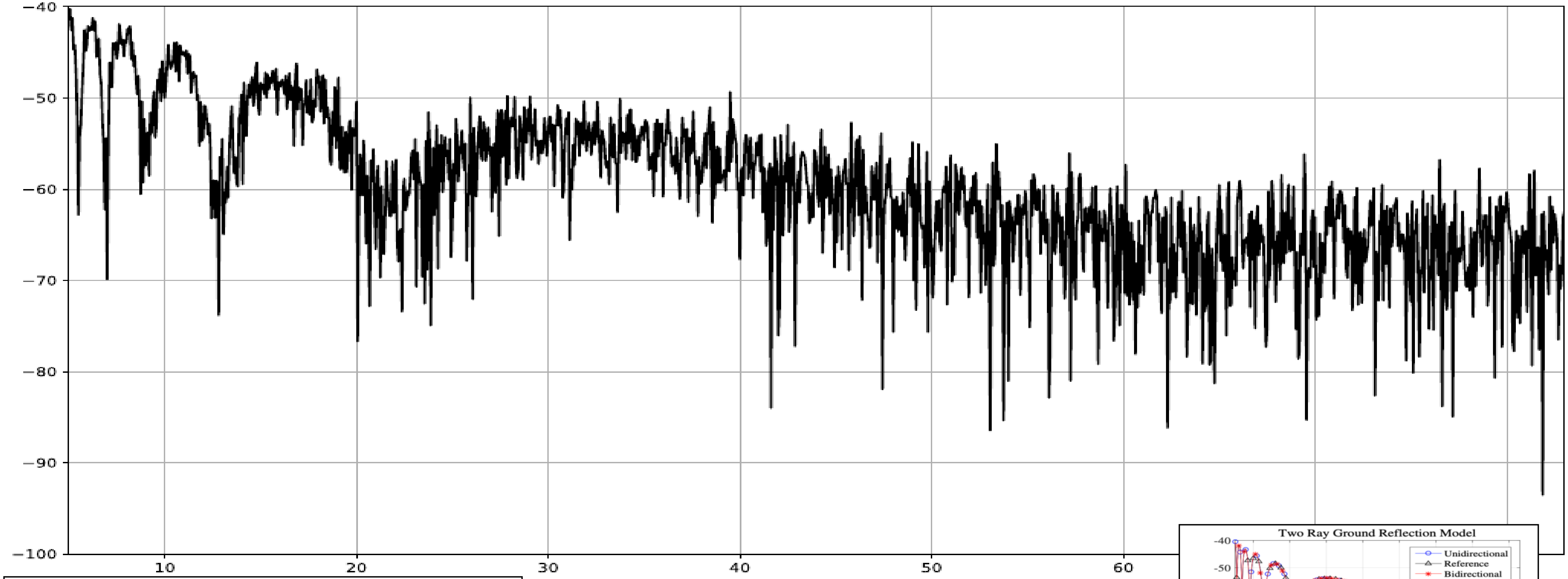
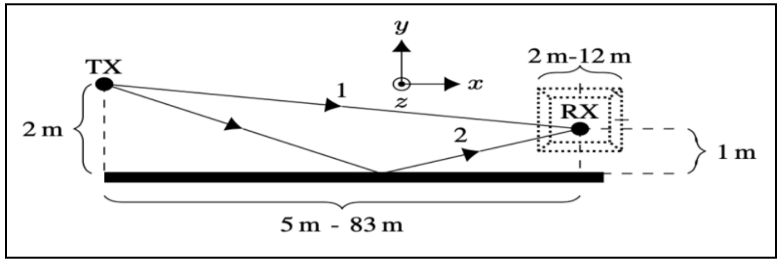
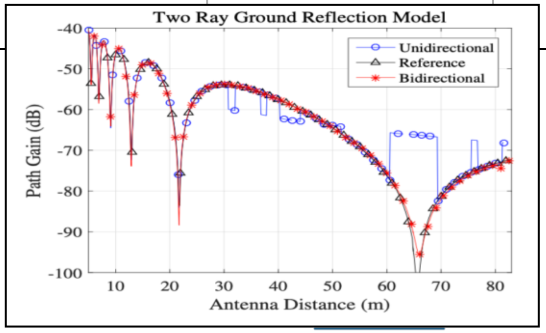




Path Tracing



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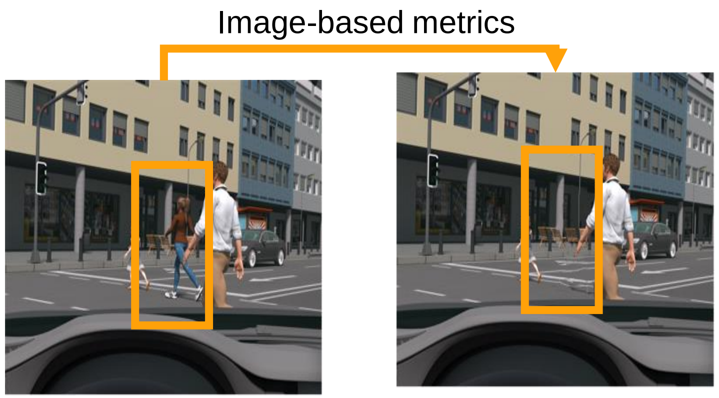
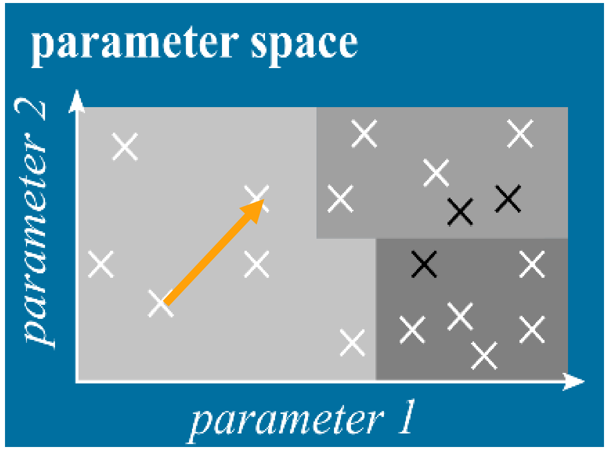
Synthetic Training Data Generation: Parameter Space Characterization

- **Goal: Need a metric for similarity of configurations**
  - Based on samples from high-dimensional parameter space
- **Allows for applying Monte-Carlo sampling approaches**
  - e.g. importance sampling
  - Provides statistical confidence and relevance of samples
- **Towards more semantically meaningful measures**
  - Class boundaries, input from NN, …





Challenge: Verification ~~versus~~ and Validation

- **Verification (Top-Down)**
  - Strict formal models and exact mathematical proofs
  - But: Limited expressiveness and complexity

Find path between both worlds, e.g.

- Identifying potential critical situations
- Limiting the search space for testing

- **Validation (Bottom-Up)**
  - Rich and flexible models close to physical reality
  - But: No completeness and only statistical results

Take-Aways

- **Digital Reality as a fundamental tool in AI**
  - Modeling, simulation, and leaning even in complex environments
  - **Learning and reasoning via feedback loop (e.g. RL)**
  - **Key element for future AI systems**
- **Continuous Learning Loop using Synthetic and Real Data**
  - Needed to achieve Validation and Certification of AI systems
  - **Validation & Certification required to establish trust in AI systems (Trusted AI)**
  - **Needs significant HPC resources for simulations and AI**
- **Big Challenges Ahead**
  - Many promising partial results already – but largely islands
  - **Requires closer collaboration of industry & academia**
  - **CLAIRE: Towards large-scale European initiative (“CERN for AI”, https://claire-ai.org)**

Thank you very much for your attention !

Human Centric AI.

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