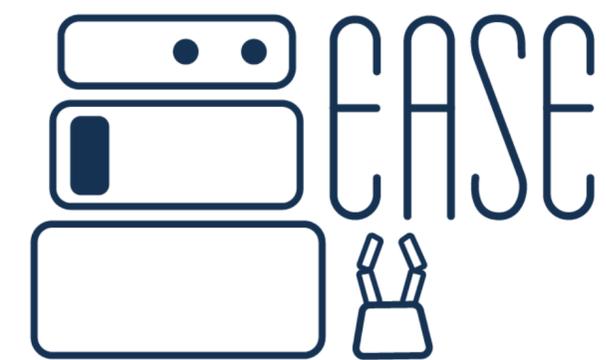




# Uncertain Physics for Robot Simulation in Unreal

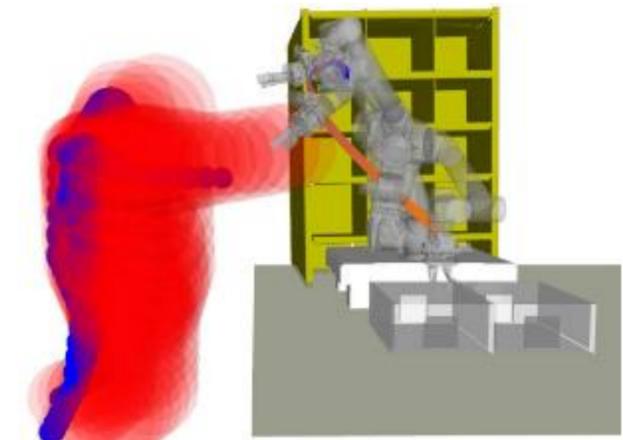
Hermann Meißenhelter, René Weller, Gabriel Zachmann  
University of Bremen, Germany



Everyday Activity  
Science &  
Engineering



- Our knowledge about the world is incomplete or uncertain (sensors are unreliable)
- State-of-the-art physics engines are deterministic
- Taking uncertainty into account for prospection
  - Sampling of uncertainty
  - Requires much computational time
  - Need for efficient algorithms
- Embedded in research project EASE

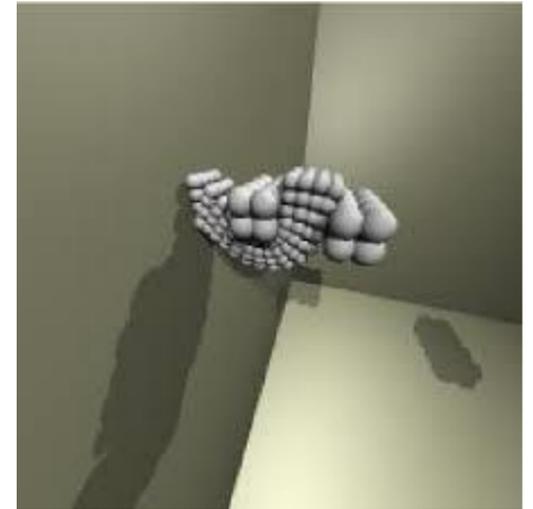


Probabilistic CD[Park18]

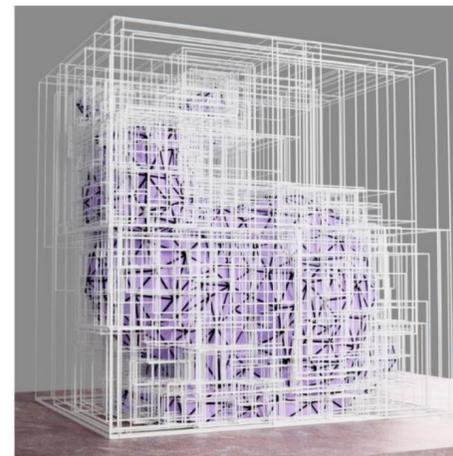


EASE: Everyday kitchen tasks, from setting the table to cooking and loading the dishwasher, handled by robots

- Extended Kalman filter [Sorenson85]
- Control and exploration of animations [Twigg07][Goel22]
- Methods for physics-based animation:
  - Penalty [Terzopoulos87][Tang12]
  - Impulse [Mirtich96]
  - Constraint [Macklin16]
- Collision detection (CD)
  - Bounding Volume Hierarchies (BVH) [Zachmann98]
  - Grid-based methods [Teschner03]
  - Sphere packings [Weller10]



Penalty[Jansson01]

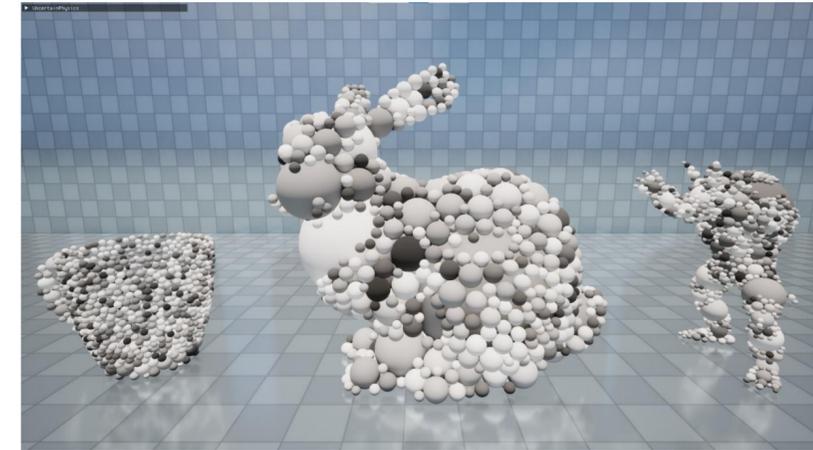


BVH[Chitalu20]



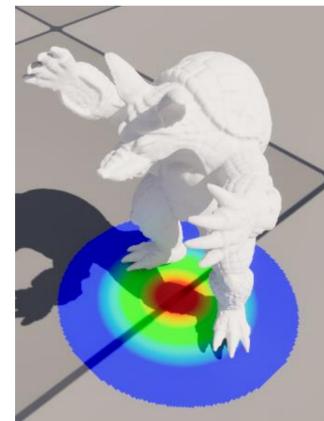
Sphere Packing - Armadillo

- Sphere Packings are used for collision detection
- Our approach works with Penalty and Impulse
- We model positional uncertainty as isotropic Gaussian



Sphere Packing & Tested models

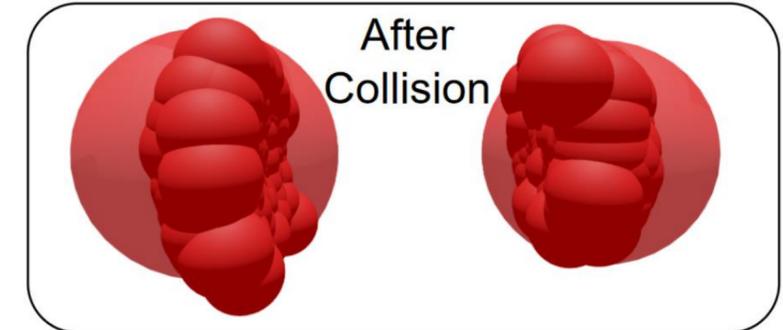
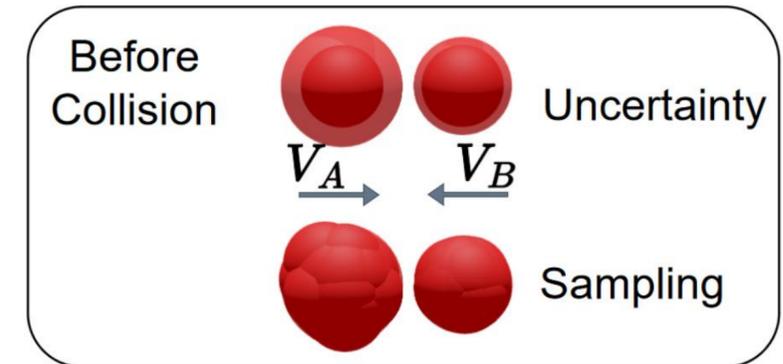
- We explore two approaches to propagate uncertainty forward
  - Geometrically & physically motivated
  - Linearization of collision resolution



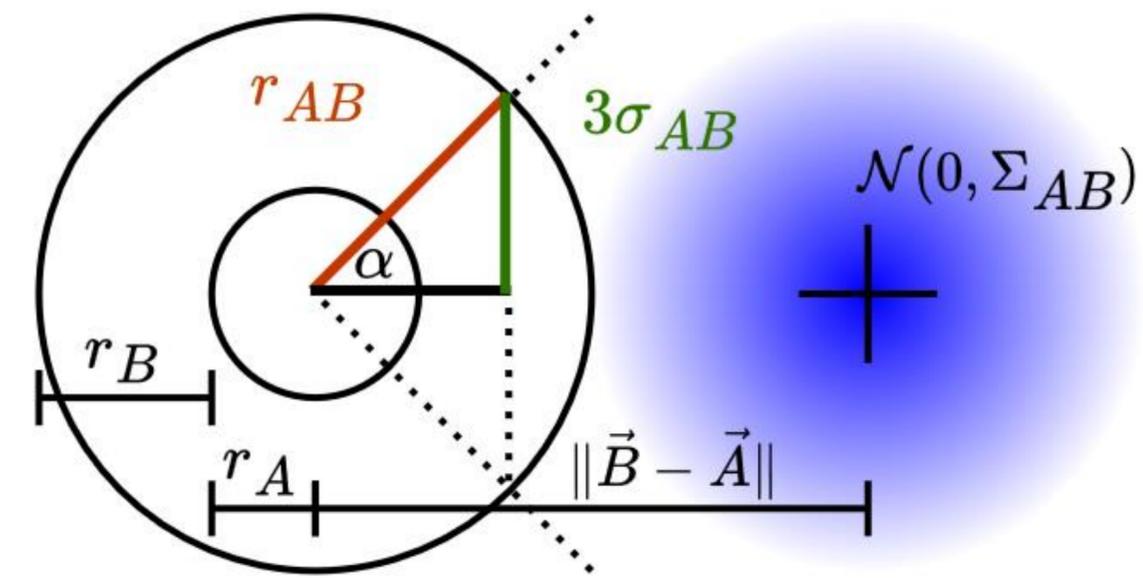
Positional Uncertainty – Isotropic Gaussian

# Simulation with Uncertainty

- Directional uncertainty of force/velocity
  - For penalty and impulse (tangent space)
- Integration
  - Geometric approach: physically motivated
  - Linearization: similar to Kalman
- Clamp uncertainty growth to velocity

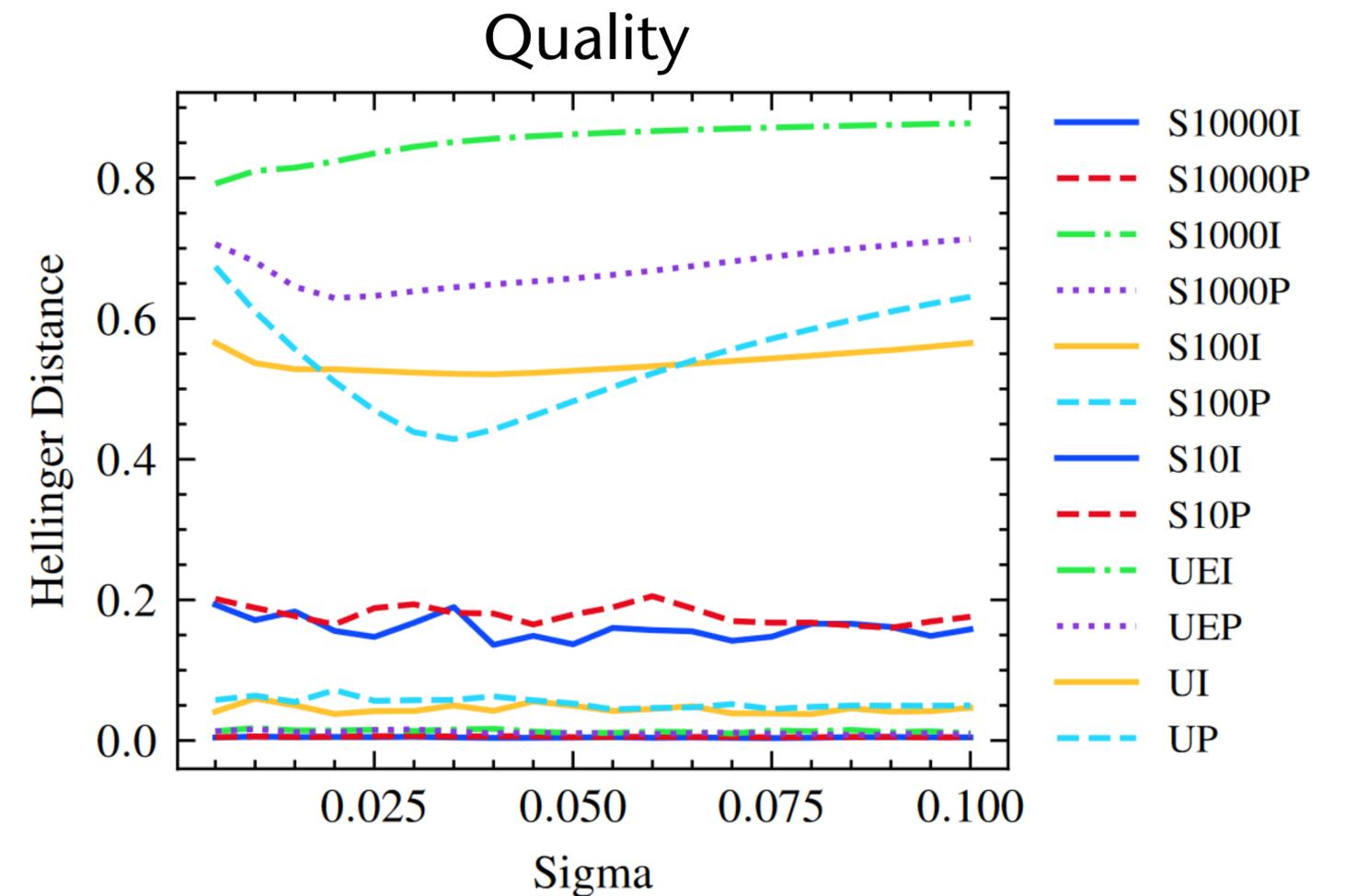
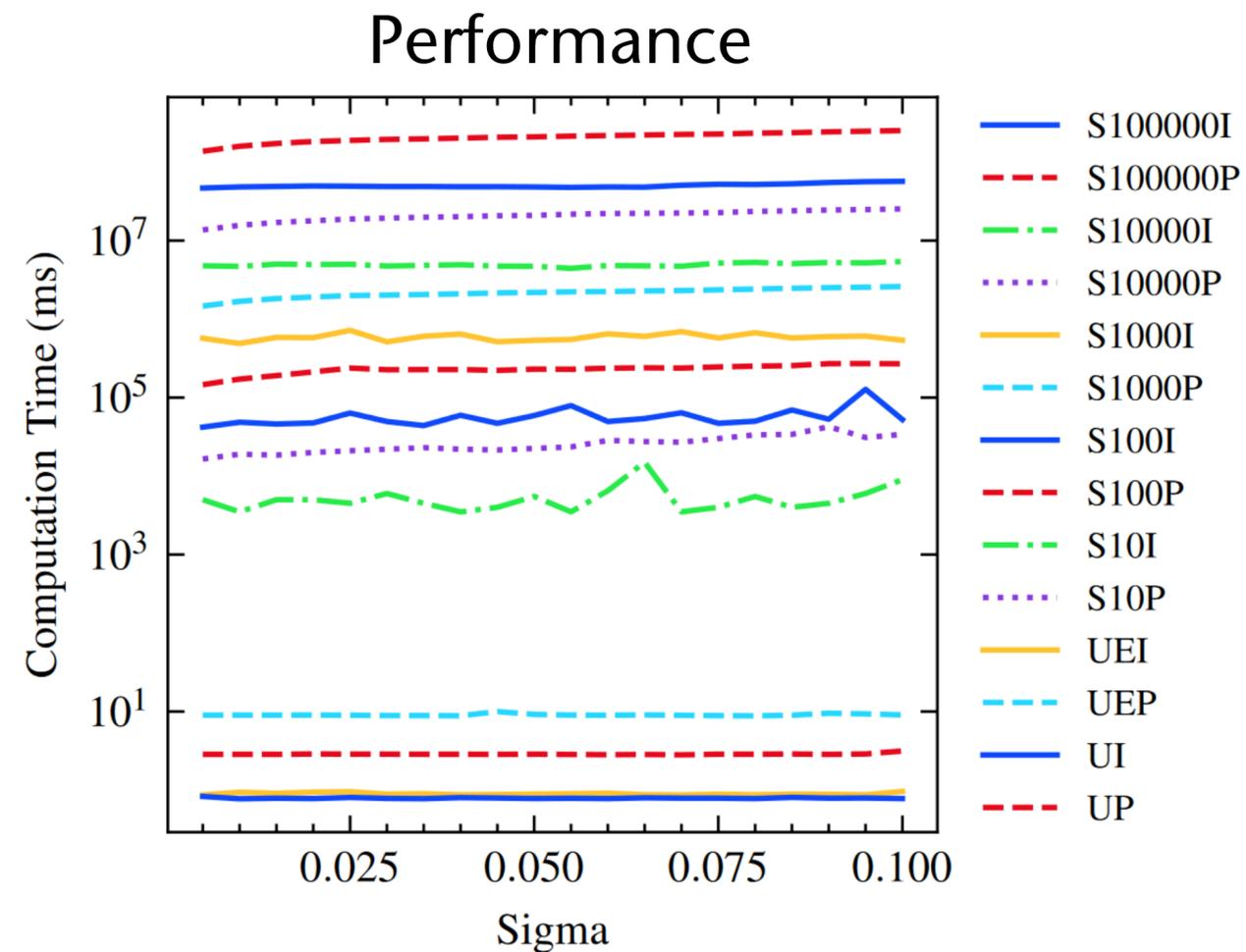


Directional Uncertainty



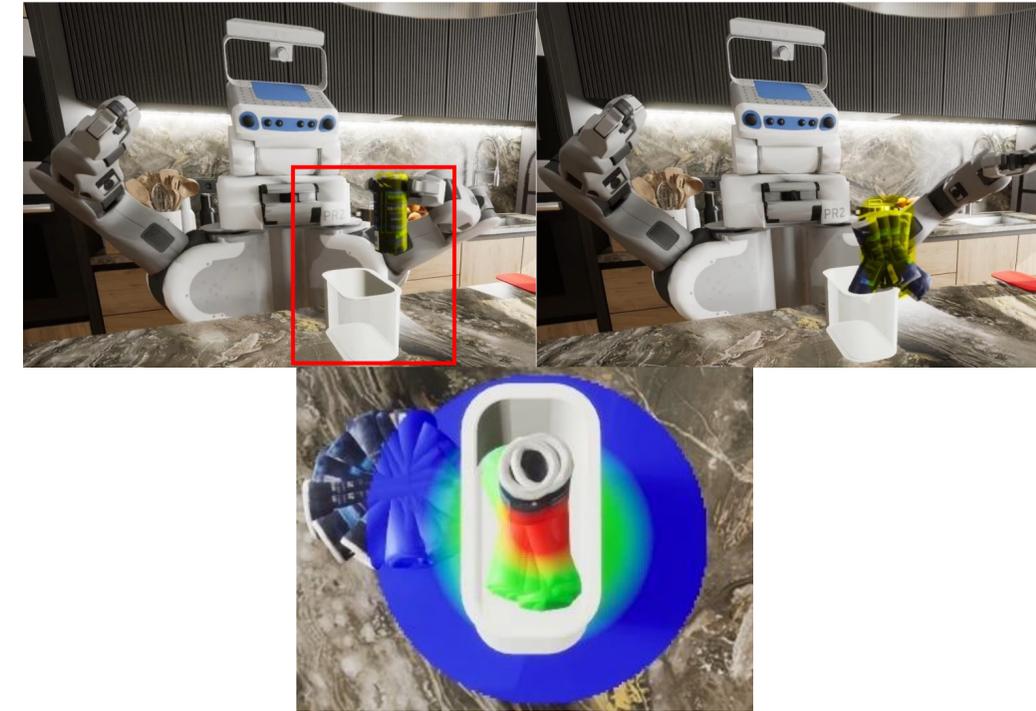
Geometric Approximation

- We let different objects collide: Armadillo, Bunny, Cup
- With different initial conditions: sigma, number of spheres, method
  - 100k samples act as ground truth



# Conclusion and Future Work

- Up to 3-4 magnitudes faster
  - Moderate similarity with sampling on average
  - Integrated into Unreal Engine
  - Use cases: prediction, physical reasoning
- 
- Currently, we experimented with non-isotropic Gaussian and rotational uncertainty
  - We plan to experiment with multi-modal distributions



## Uncertain Physics for Robot Simulation in a Game Engine

Hermann Meißenhelter<sup>1</sup> René Weller<sup>1</sup> Gabriel Zachmann<sup>1</sup>

*<sup>1</sup>University of Bremen*

{meissenhelter, weller, zach}@cs.uni-bremen.de