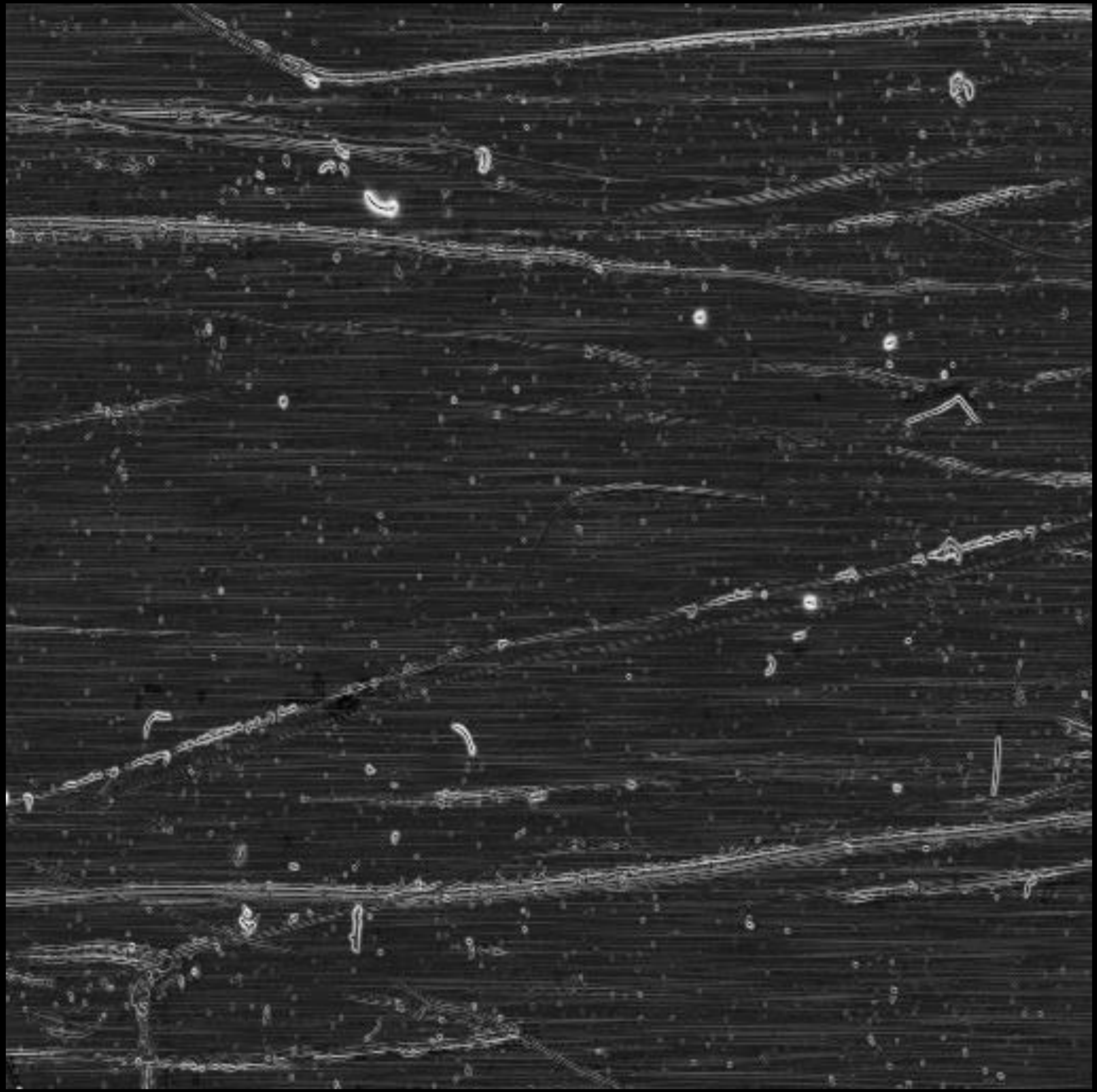
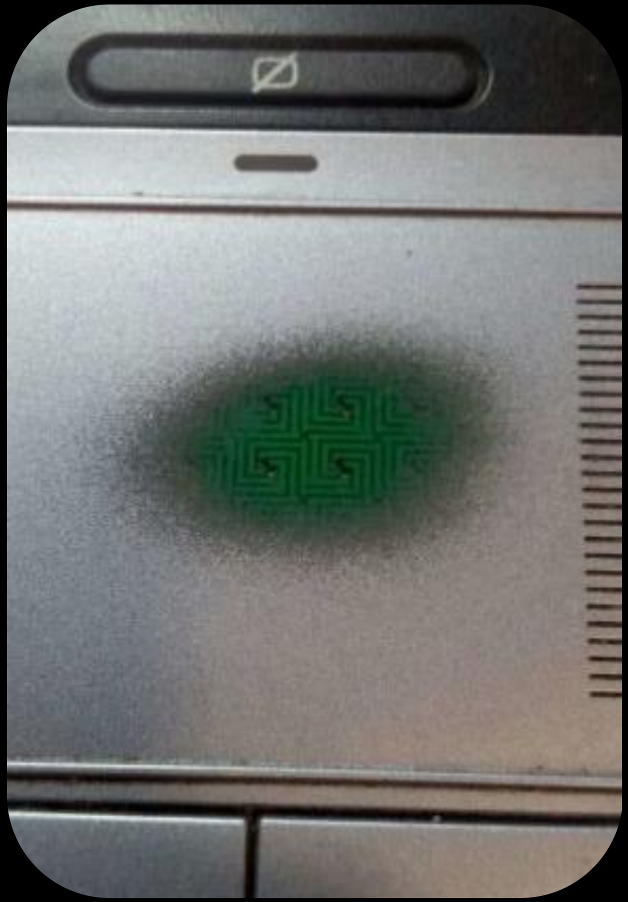
WHERE TO WEAR?

Antoine Boucher
Sheldon Andrews

ÉTS





EVERY SURFACE HAS A BIOGRAPHY WRITTEN BY FRICTIONAL CONTACT

TIME

Floor, surface, wall

PATTERN

trace lines of lasagna pan
and mixing bowl

REPETITION

men's vs women's bathroom use
at an engineering school

WHY SHOULD WE CARE?

Gaming & Rendering

Creation of believable **visuals** for immersion without endless manual effort

Robotics & Mechanical

Ensures adaptability of manipulation tools

Machine Failure Predictions

Health & Maintenance

Prevention strategies of high frictional area

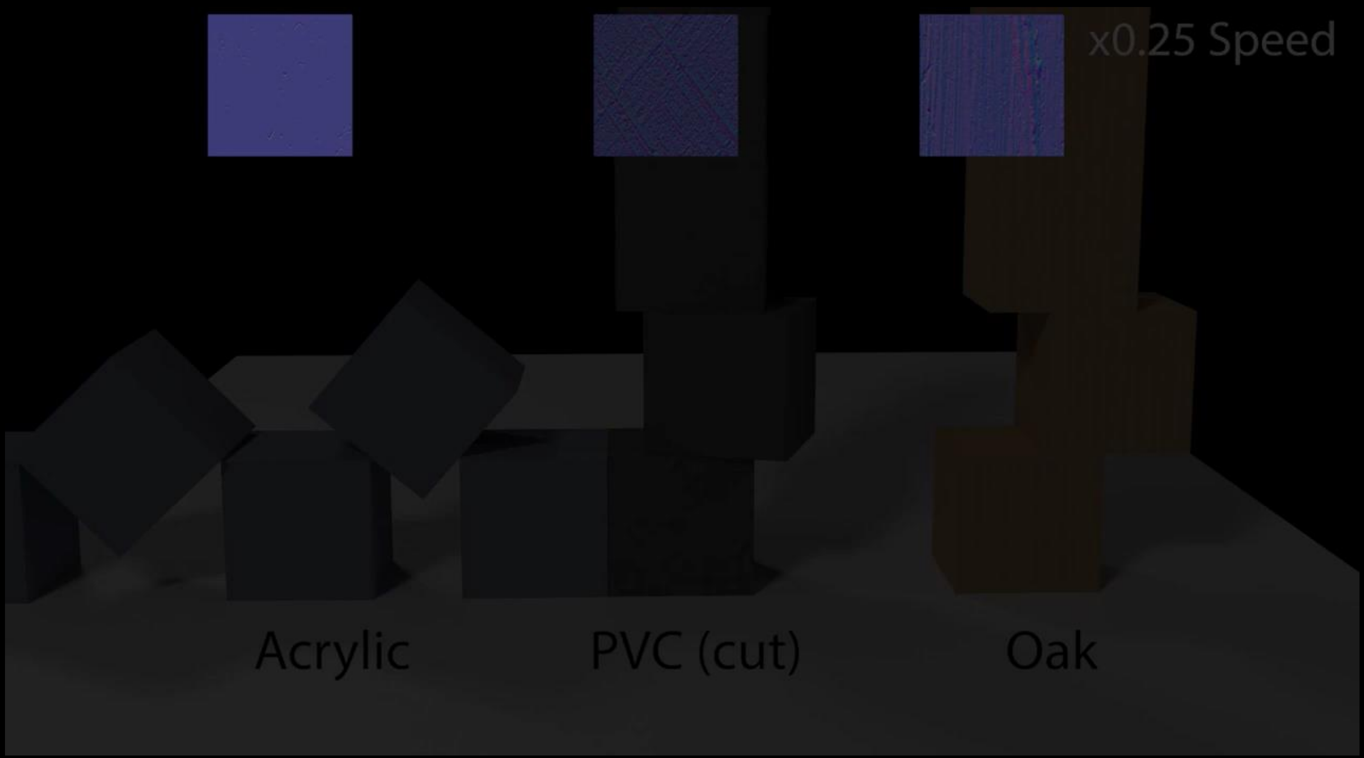
PREVIOUS WORKS

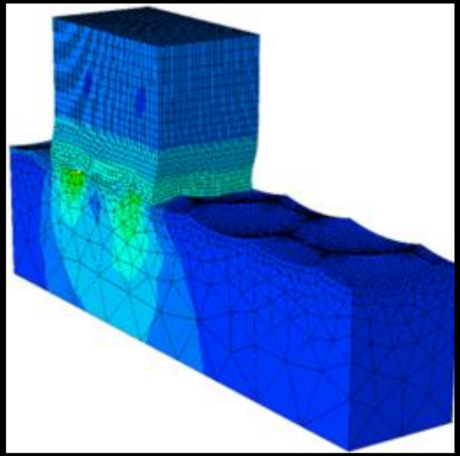
Texture friction

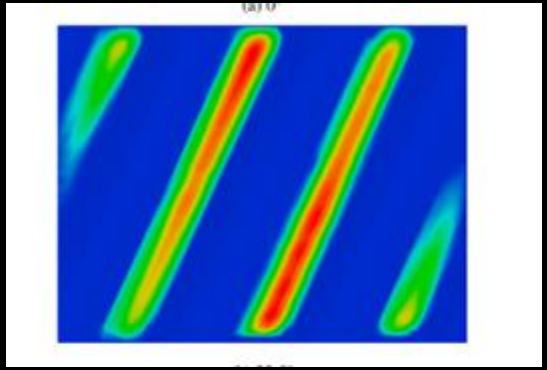
(*S Andrews, L Nassif, K Erleben, PG Kry, 2021*)

Simulation of wear & friction properties of micro surfaces

(Schewe, Wilbuer, & Menzel, 2021)

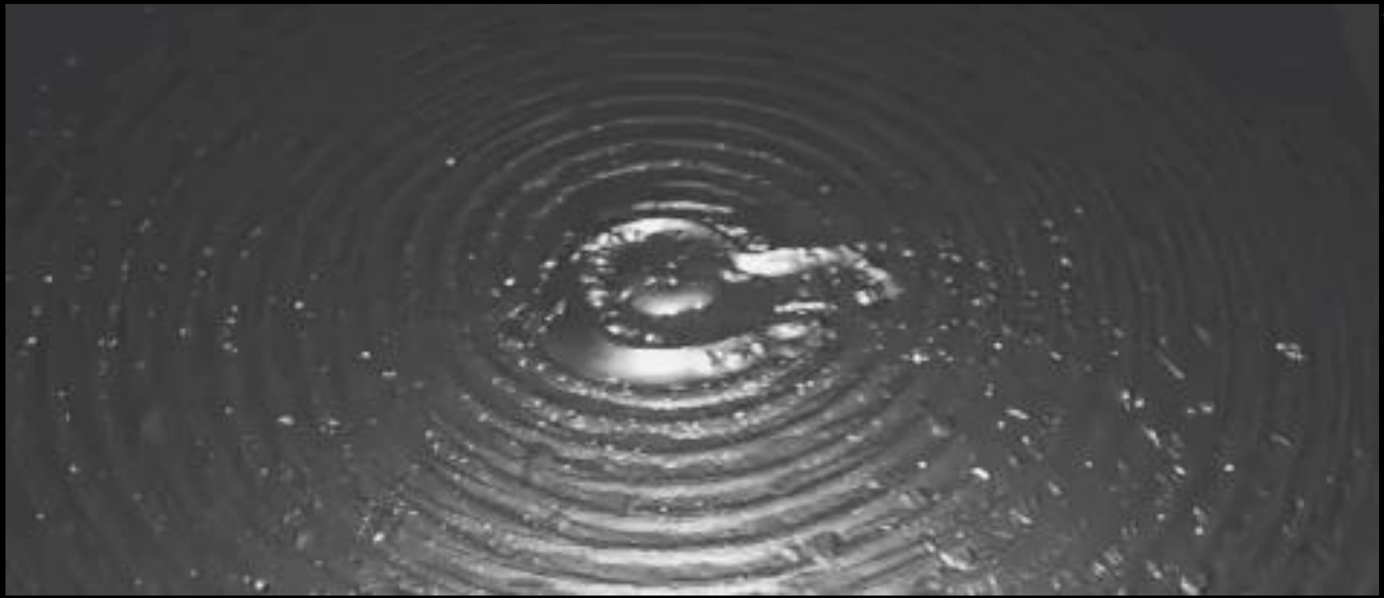




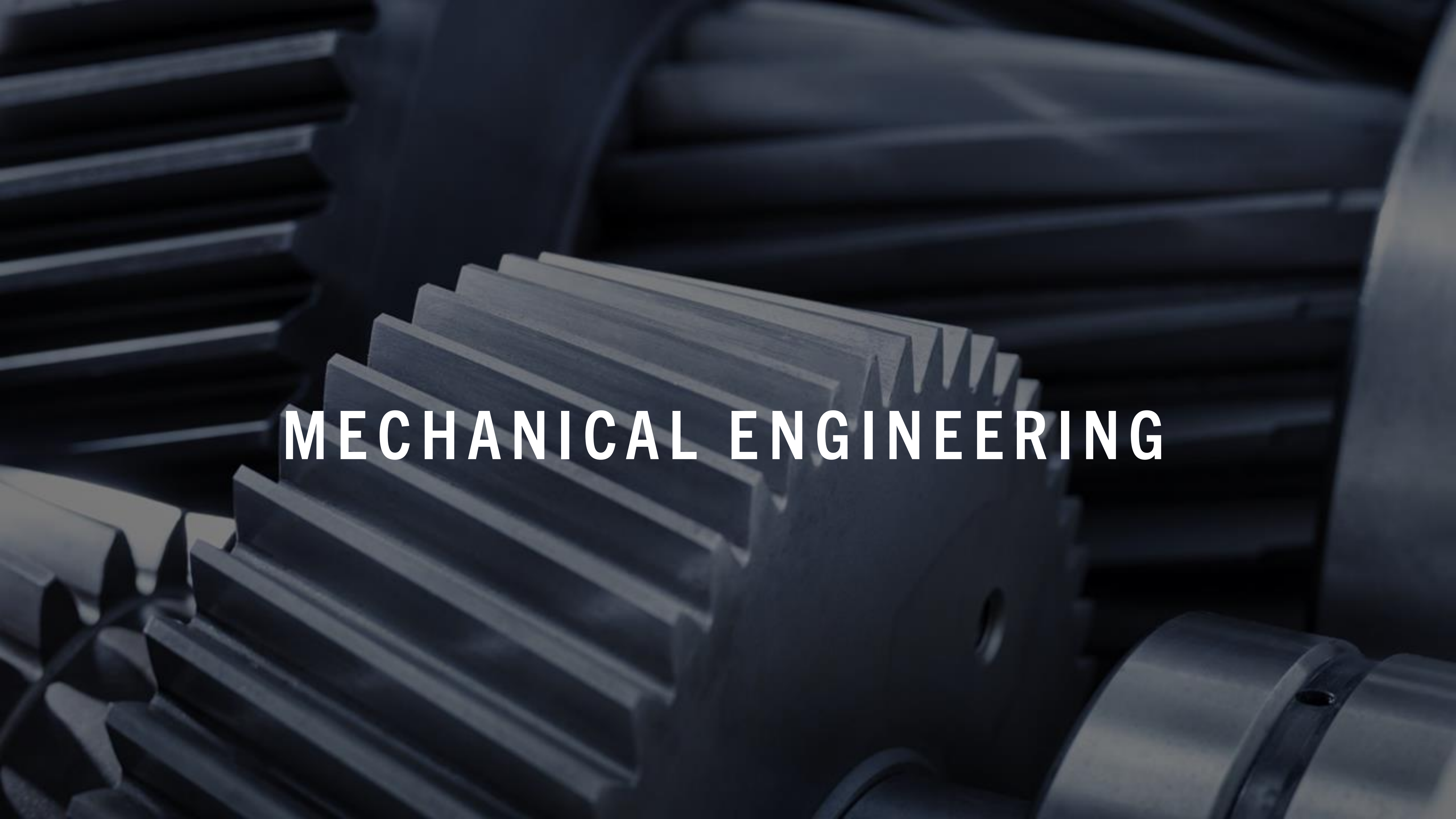


GOALS

- Predicting wear-induced visual changes in real-time
- Texture friction surface on changes



MECHANICAL ENGINEERING



ARCHARD'S LAW

$$V = \frac{k \cdot F \cdot s}{H}$$

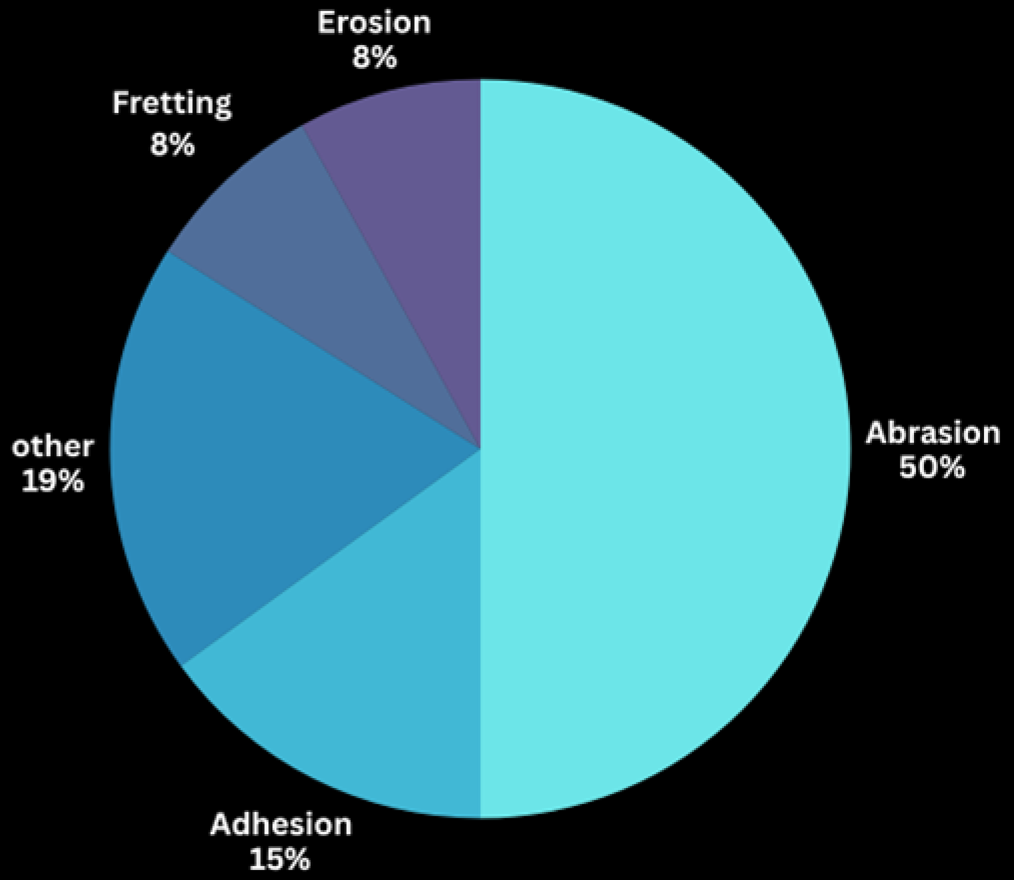
$V = \text{Wear volume } (\text{m}^3)$,

$k = \text{Dimensional wear coefficient } (\text{m}^3/(\text{N} \cdot \text{m}))$,

$F = \text{Normal load } (\text{N})$,

$s = \text{Sliding distance } (\text{m})$,

$H = \text{Hardness } (\text{Pa})$.



Progressive loss of material from a solid surface due to mechanical action.

The law predicts how much material is worn away during sliding contact. (Archard. 1953)

Estimated distribution of industrial wear mechanisms (Eyre, 1976).

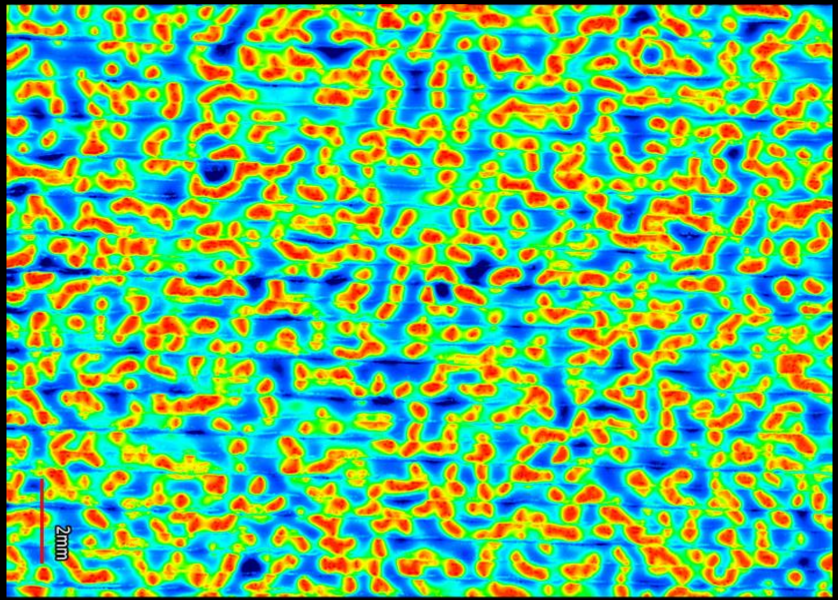
ENERGY-BASED WEAR LAW

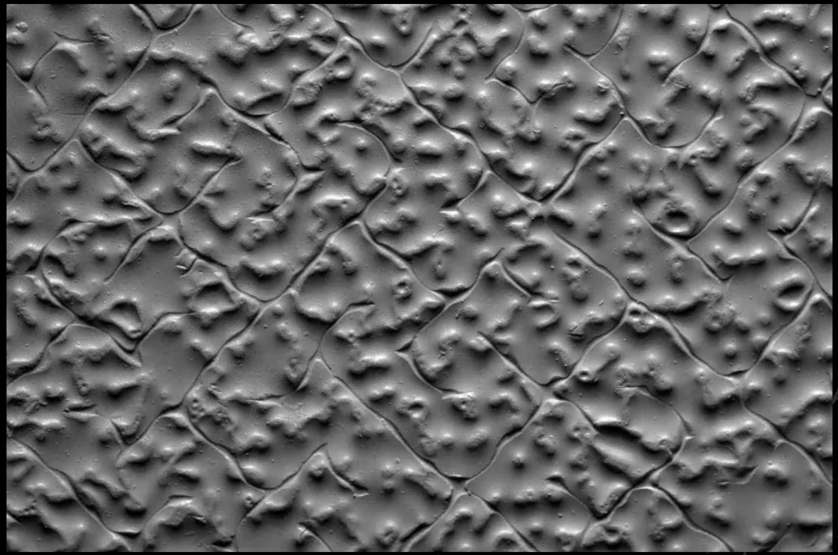
$$h_{\text{total}} = \sum_{i=1}^{n_t} k_e \, \tau_i \, v_i \, \Delta t_i$$

$$\begin{aligned} h_{\text{total}} &= \text{Total accumulated wear depth (m)}, \\ k_e &= \text{Energetic wear coefficient } (\text{m}^3/\text{J}), \\ \tau_i &= \text{Tangential traction at time step } i \text{ (Pa)}, \\ v_i &= \text{Tangential velocity at time step } i \text{ (m/s)}, \\ \Delta t_i &= \text{Duration of time step } i \text{ (s)}, \\ n_t &= \text{Number of time steps.} \end{aligned}$$

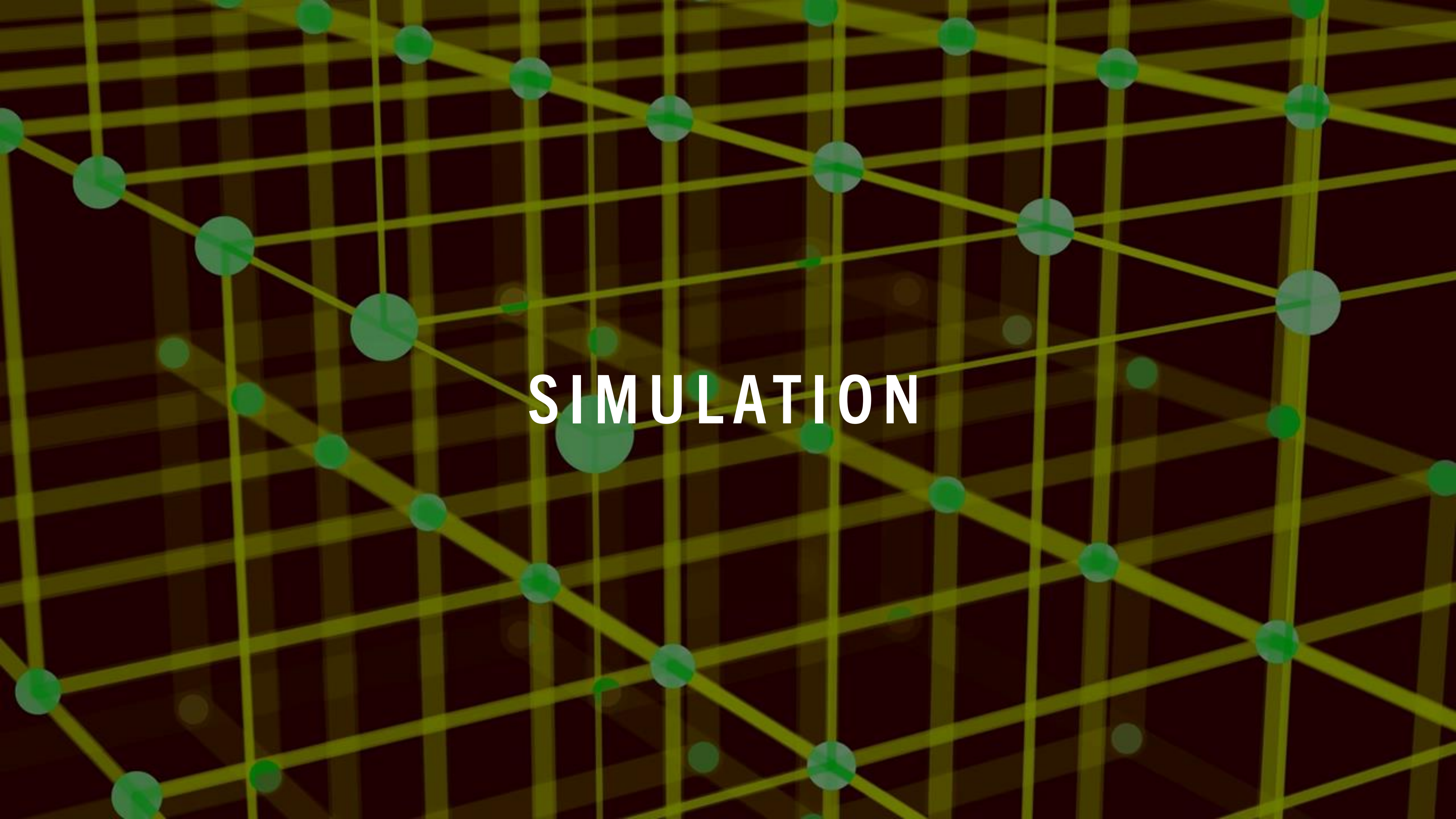
Frictional energy dissipation at contact

(Zmitrowicz, 2006) (Schewe, Wilbuer, & Menzel, 2021)



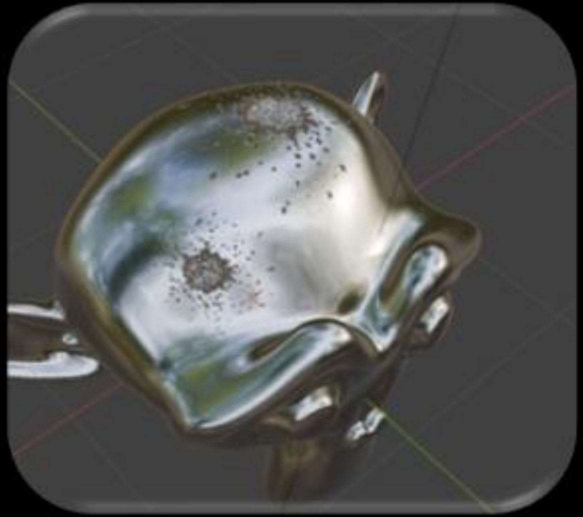


SIMULATION



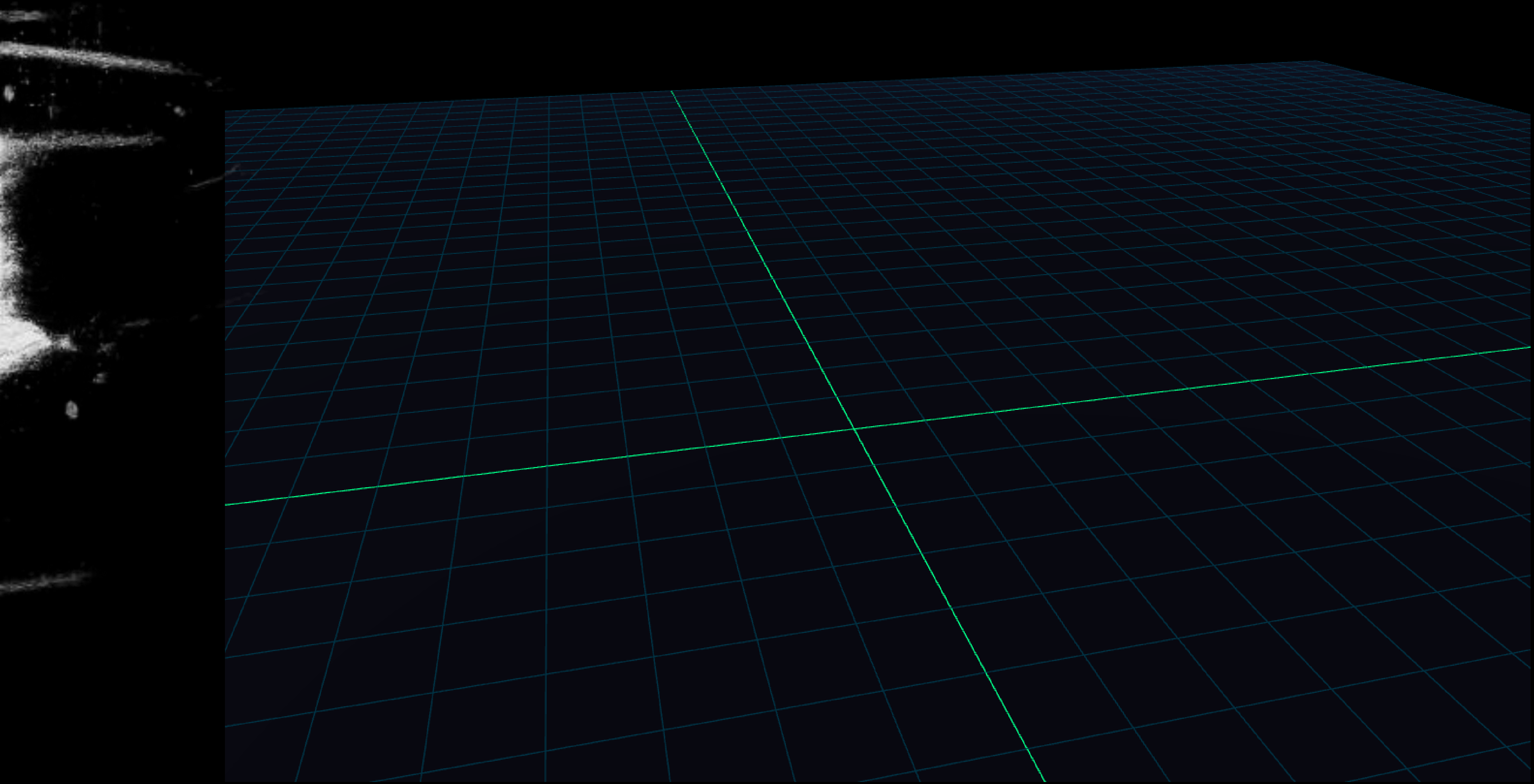
GRAPHICS

- Impact Wear
  - Isotropic Impact

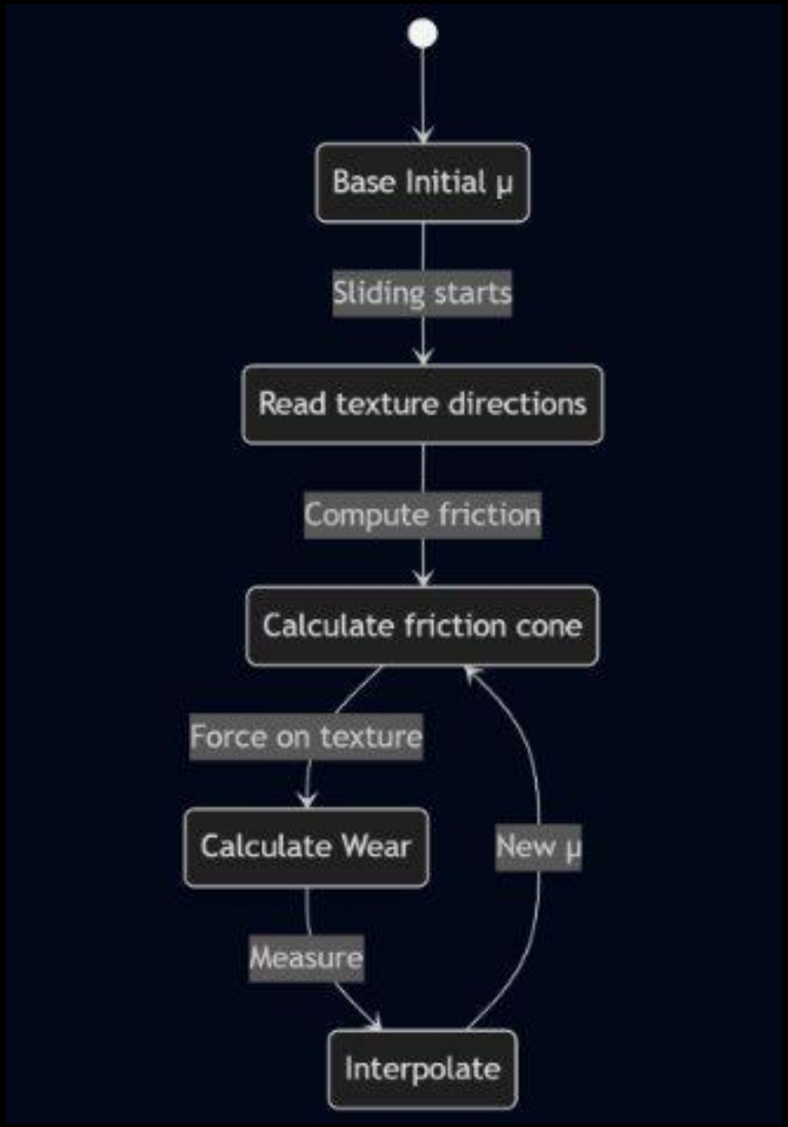


- Sliding Wear
  - Anisotropic Scratches
  - Directional fields on the tangent space

- Edge Wear
  - Noise
  - Exposed contours



PIPELINE


Base Initial μ
Sliding starts
Read texture directions
Compute friction
Calculate friction cone
Force on texture
Calculate Wear
New μ
Measure
Interpolate

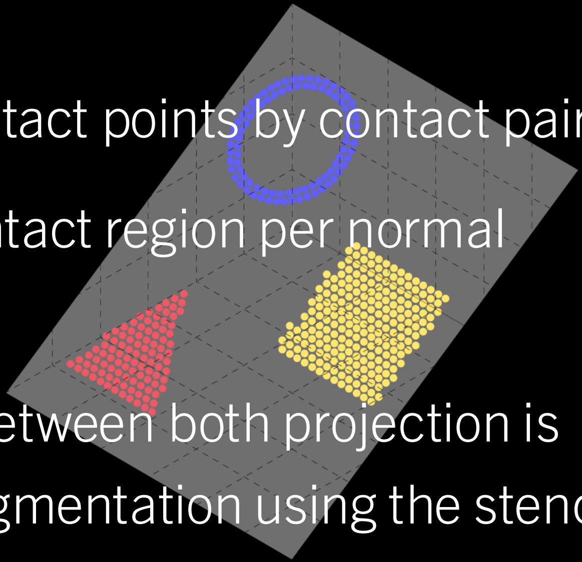
WHAT DO WE NEED ?

- Hardness
- Contact area
- Tangential Velocity
- Tangential Traction
- Directionality
- Normal maps

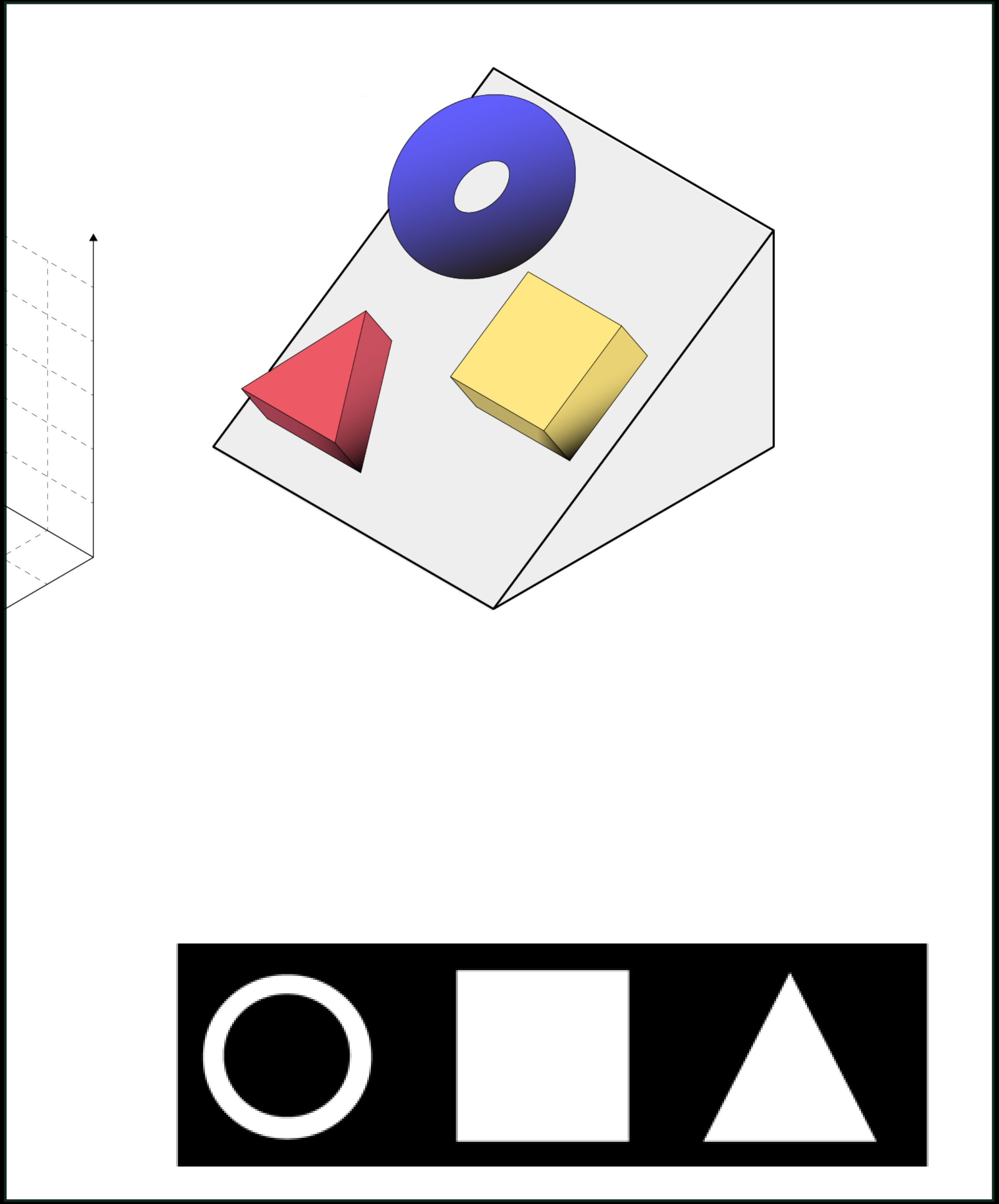
HARDNESS

- Each body has a base and texture **hardness.**
- On contact, **compare hardness** of both colliders.
- **Only the softer surface** accumulates wear.

CONTACT MASK



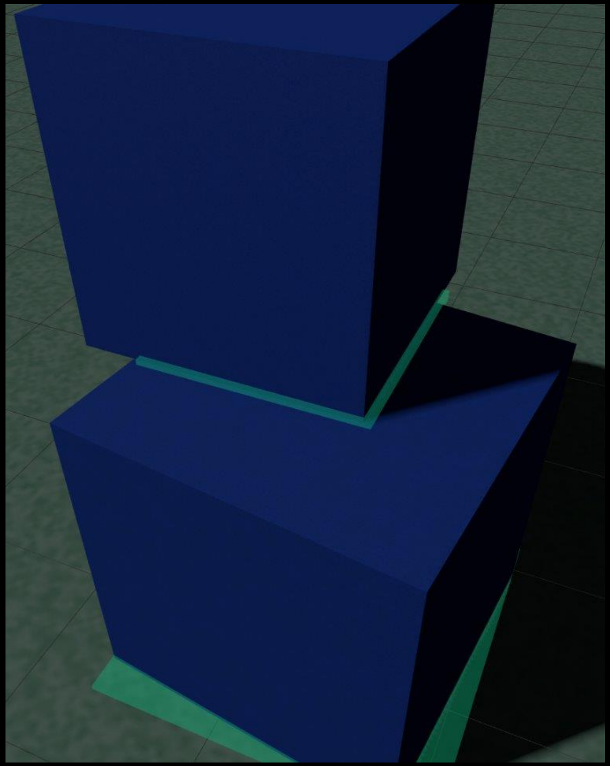
- Collect contact points by contact pair.
- Cluster contact region per normal direction
- Intersect between both projection is contact segmentation using the stencil buffer
- Get a 2D slice of the contact plane and place orthographic volume



ORTHOGRAPHIC VOLUME

AABB/KDOP

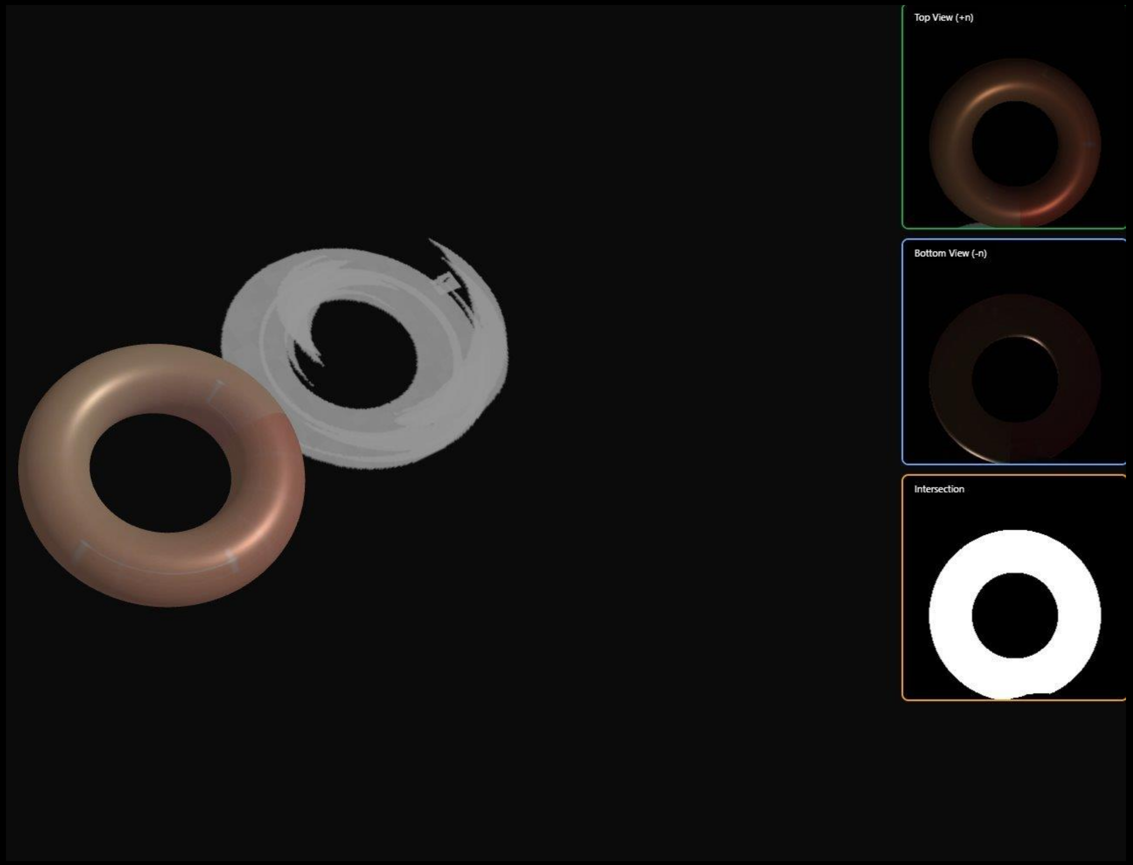
OMBB



INTEGRATE INTO TEXTURE

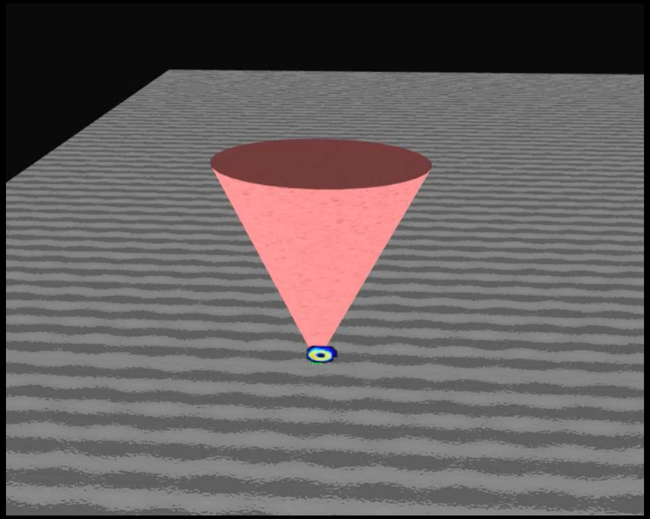
UV Selection

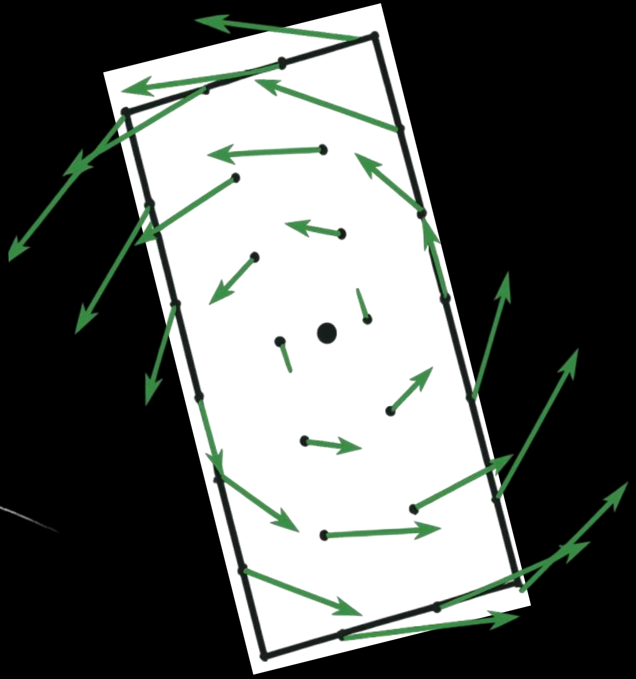
Masking

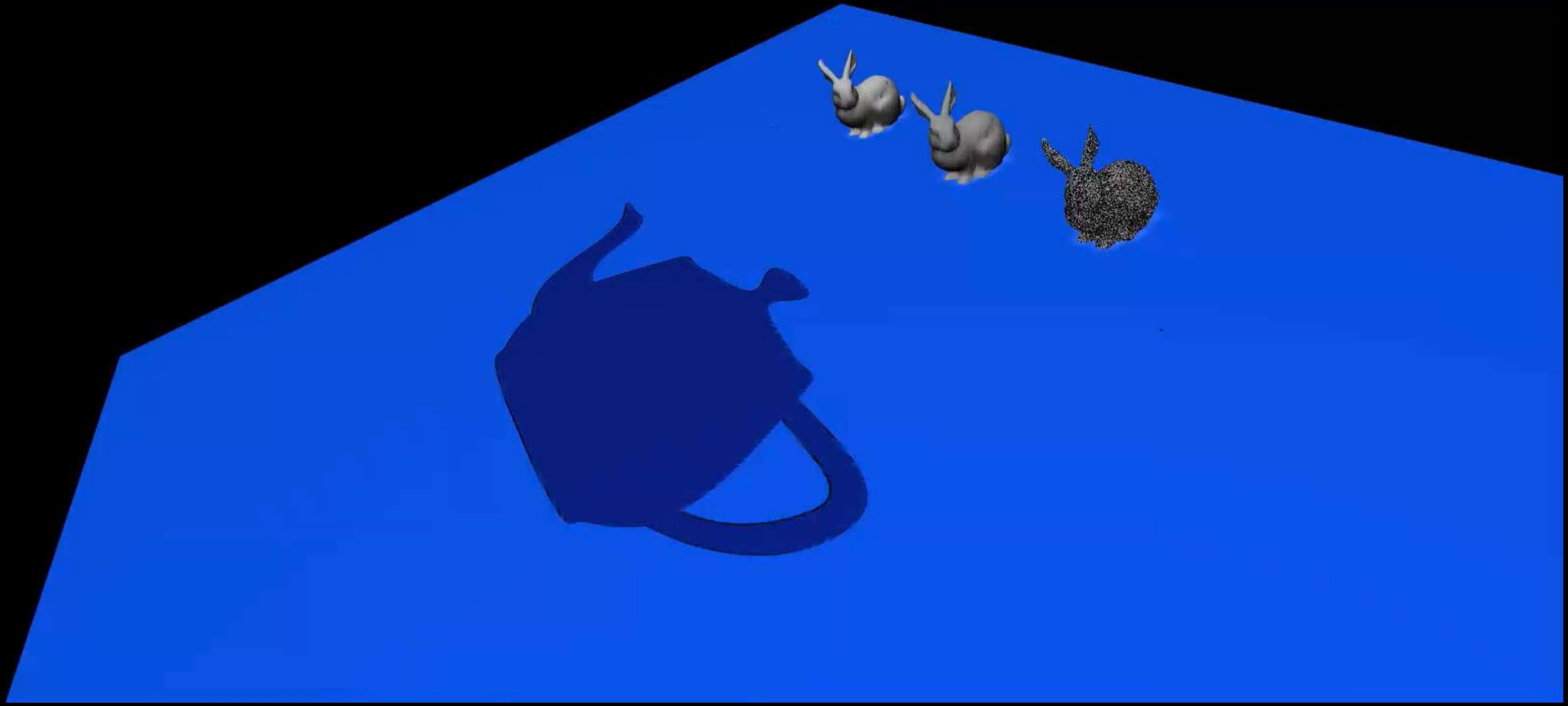


TANGENTIAL VELOCITY

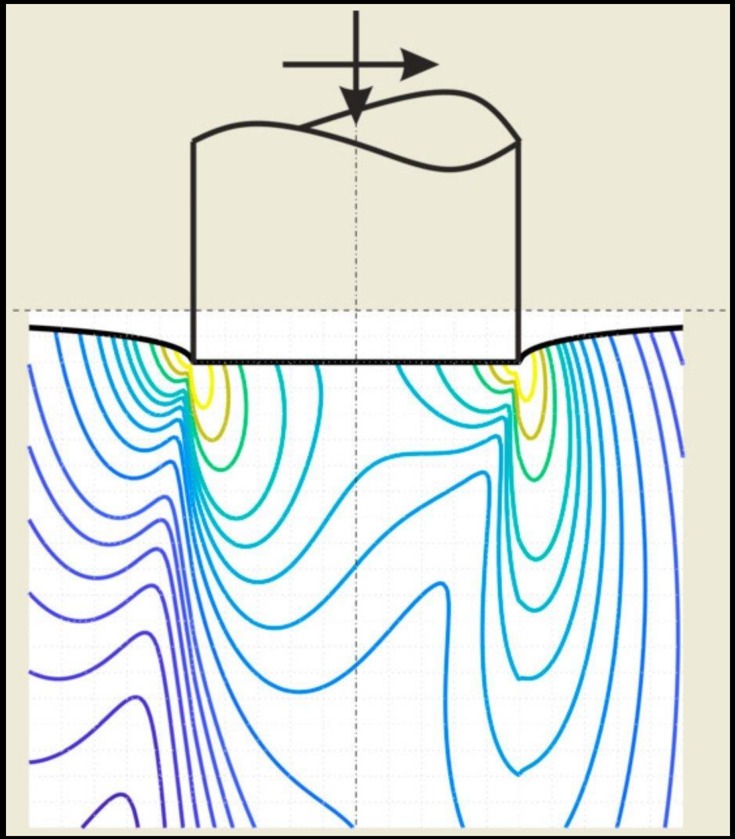
- Compute **Velocity Field**
  - Combines translational and rotational motion.
- Project to **Tangent Plane**
  - Normal to project to the plane
- Calculate **Sliding Distance**
  - Contact mask to accumulate displacement







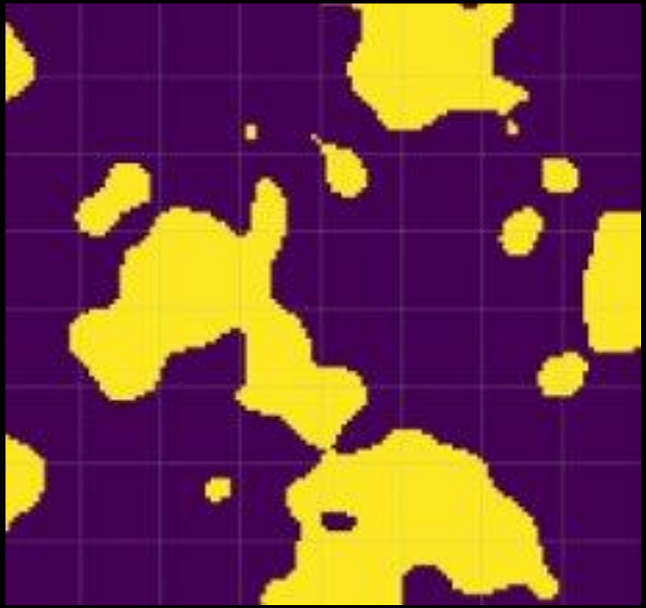
TANGENTIAL TRACTION

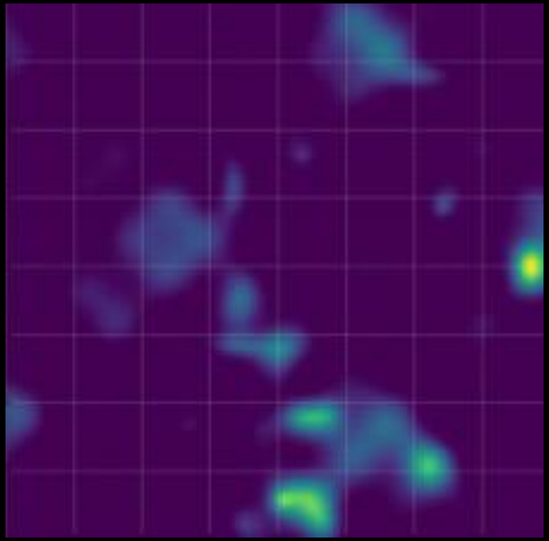


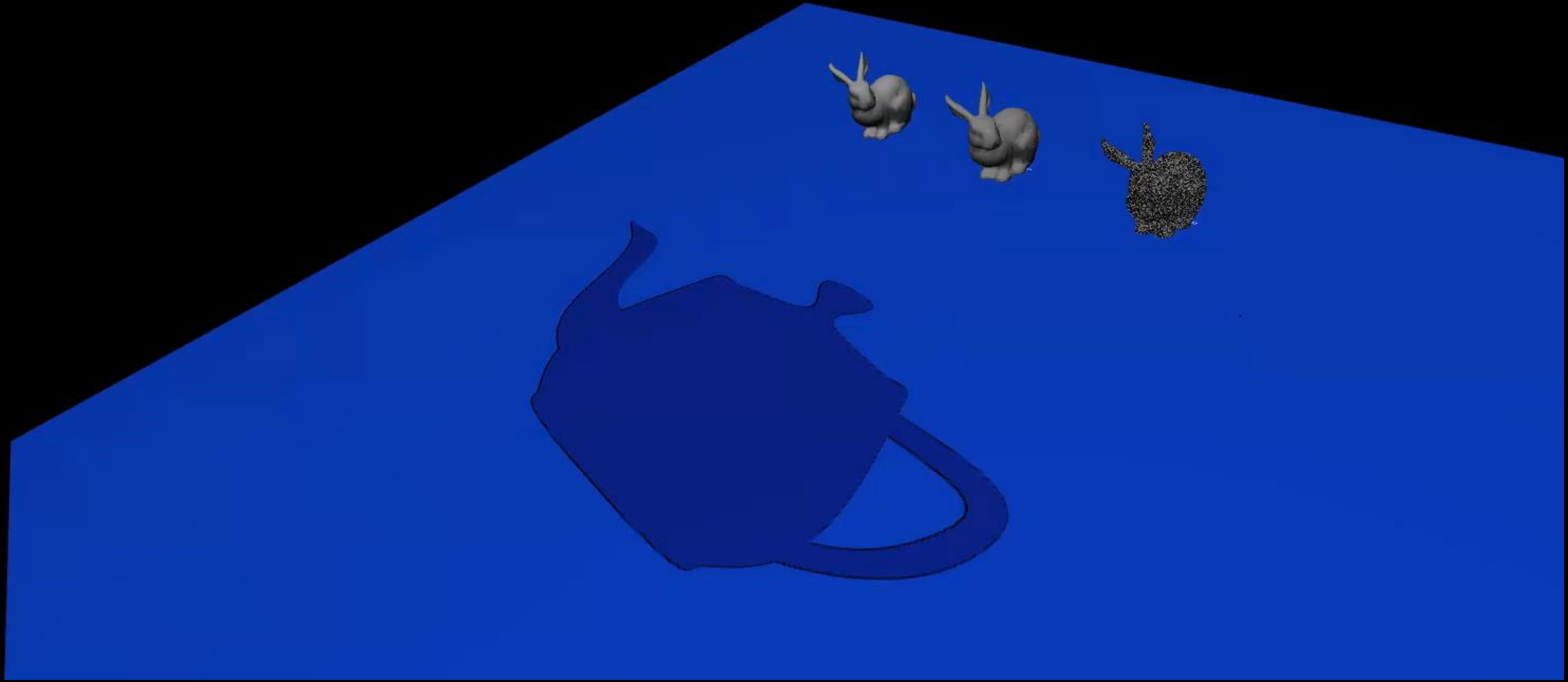
- Calculate **Traction**
  - Normal force and friction coefficient
- Project to **Tangent Plane**
  - Use the contact normal to project to the plane
- Calculate the **Wear**
  - Use the velocity and the traction to calculate the wear

TEXTURE INFORMATION

- Penetration and Normal Stiffness of maps on Hertzian Contact



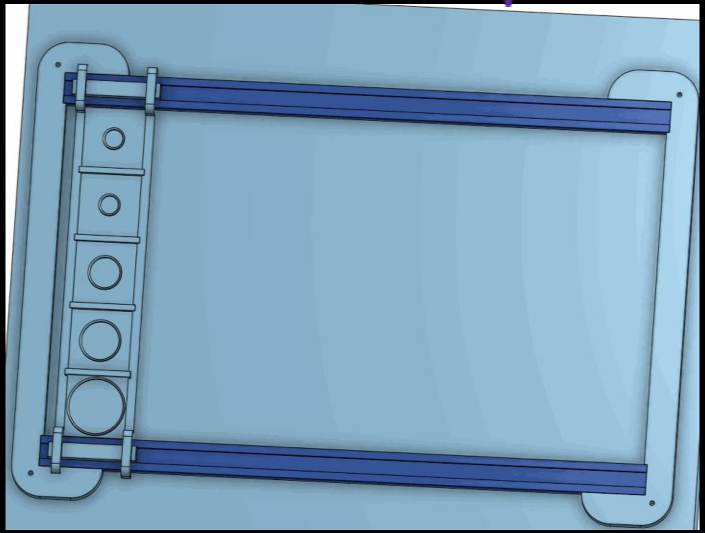


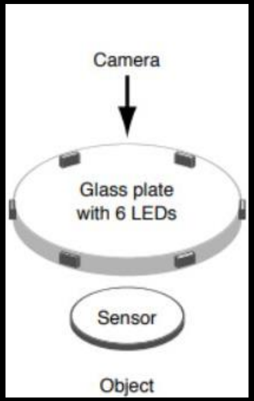


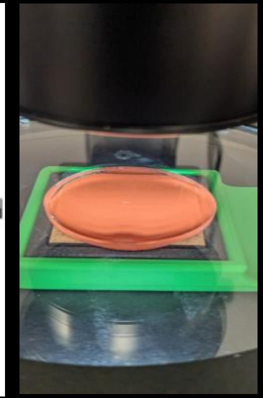
CAPTURE

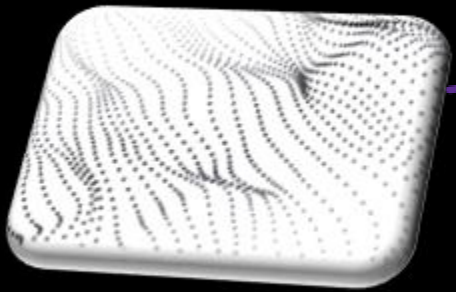
Linear motion with abrasive on varying material samples.

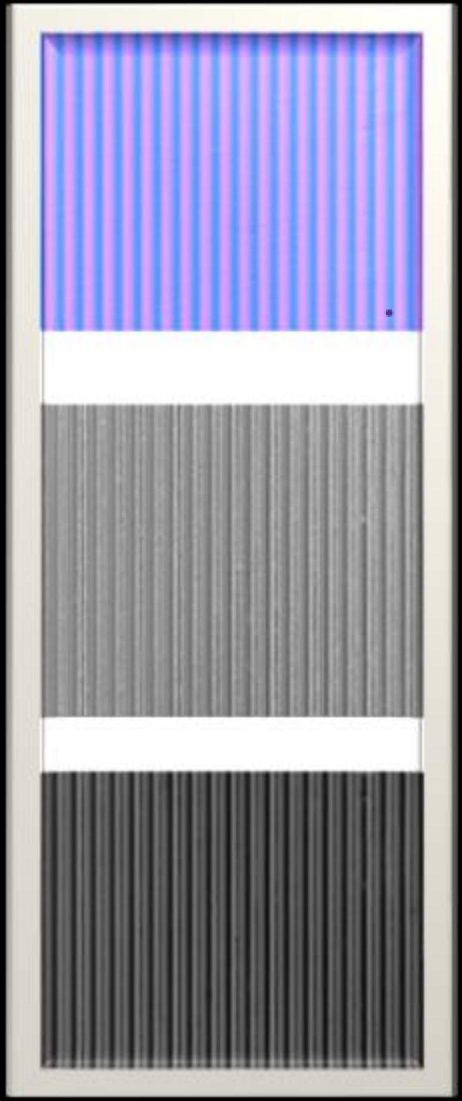
Using the **GelSight** system





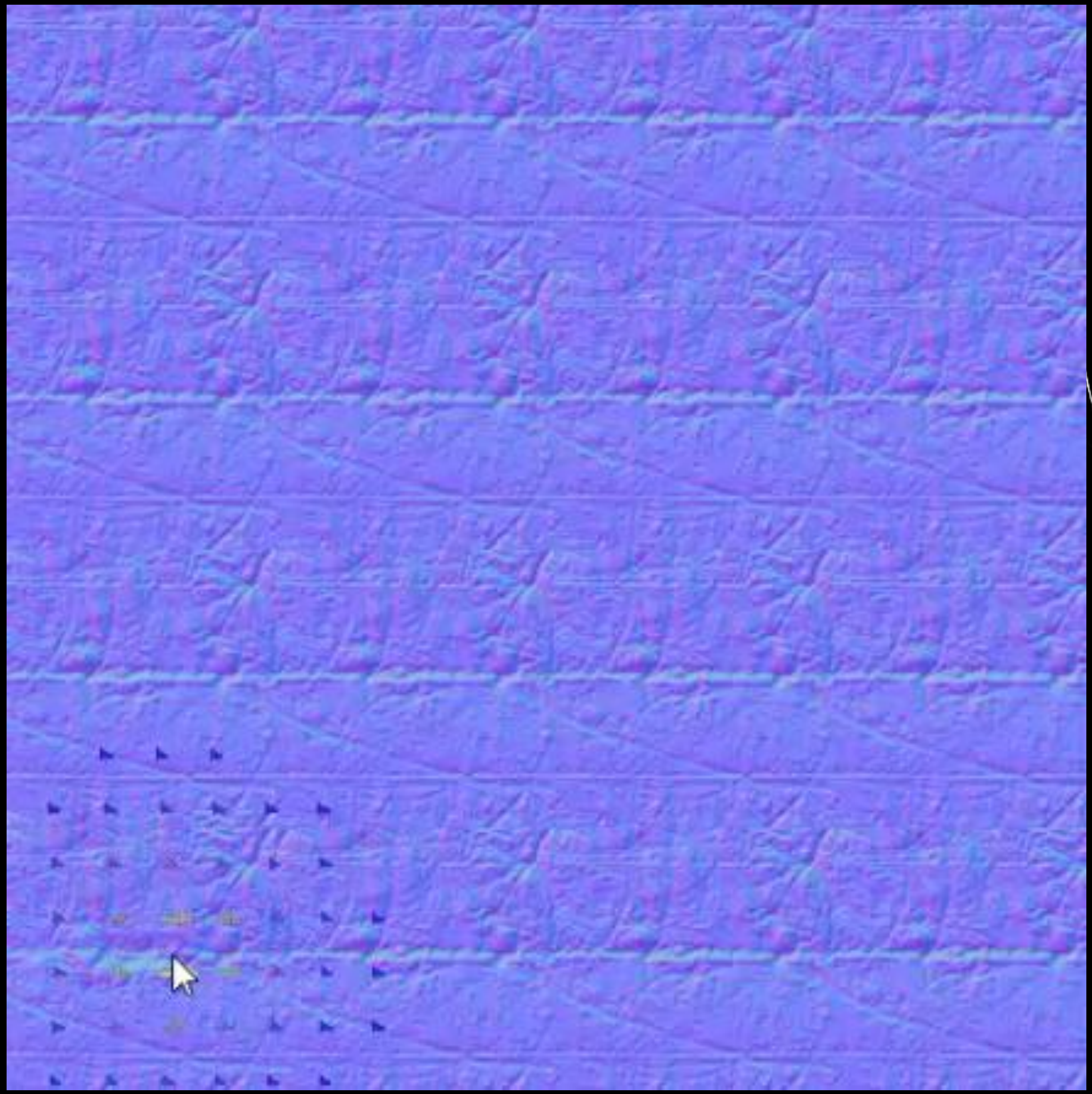






ATLAS INTERPOLATION

- Using Materials Atlas of wear states
- Tangent-aware interpolation smooth step with using quaternion representations on the geodesic of normal maps



CONCLUSION

- Having a simple, general, and easy-to-compute method that gives control over the appearance, but has the issue limitation of working with UV
- Engineer can have fast feedback on high-friction interactions simple simulator
- The story of energy, friction, and time