(Volume-preserving) Soft Object Denting

Blender Script

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Motivation

Soft object denting

Problem and Motivation

Consider: soft object deformation in response to another (hard) object.

E.g.: A soft ball is grabbed and squished by a hand.

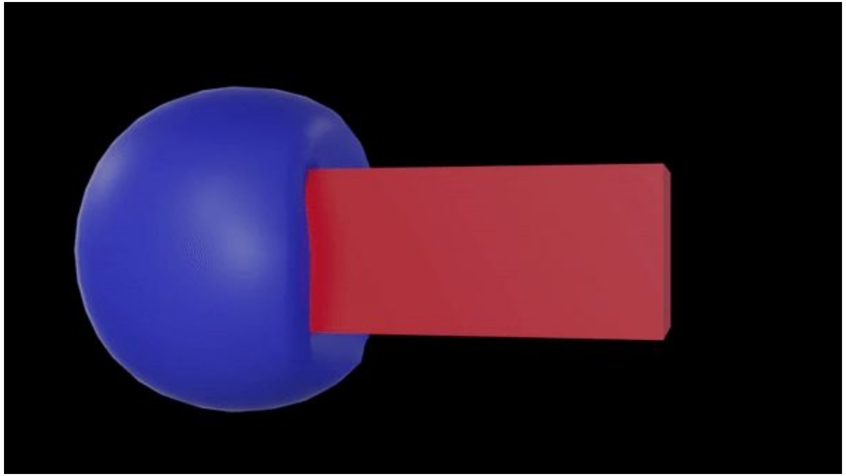
- Area underneath the fingers is pushed down.
- Additional sink-in around this area (depending on plasticity/elasticity)
- Displaced volume is added to the rest (depending on internal pressure)

Materials science terms: Elastic modulus, Poisson’s ratio

Existing Solutions (in Blender)

Sculpting:

+ Allows full artistic expression
- Requires a lot of time and work
- Not adaptable to changes
- Results may vary

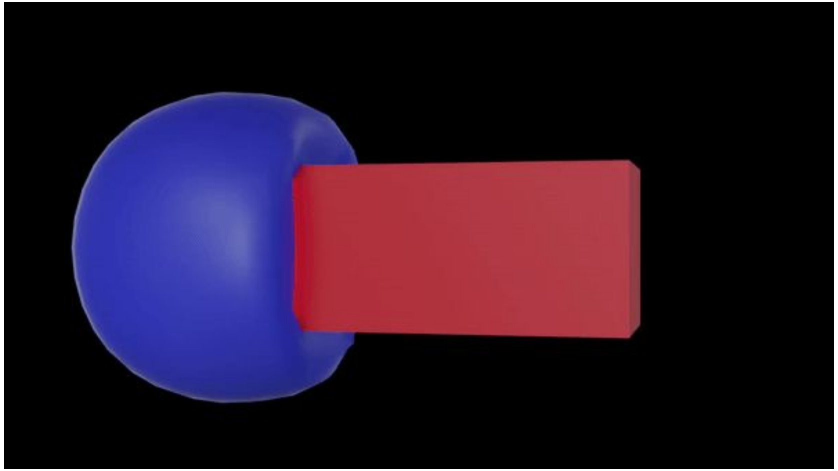


Work: 5 minutes

Existing Solutions (in Blender)

Softbody simulation

+ Physically accurate (more or less)
+ Automatically updates
- Requires animation (depends on time)
- Hard to control (depends on many parameters)
- Sometimes too realistic for artistic expression
- Not volume preserving (without changing the mesh)

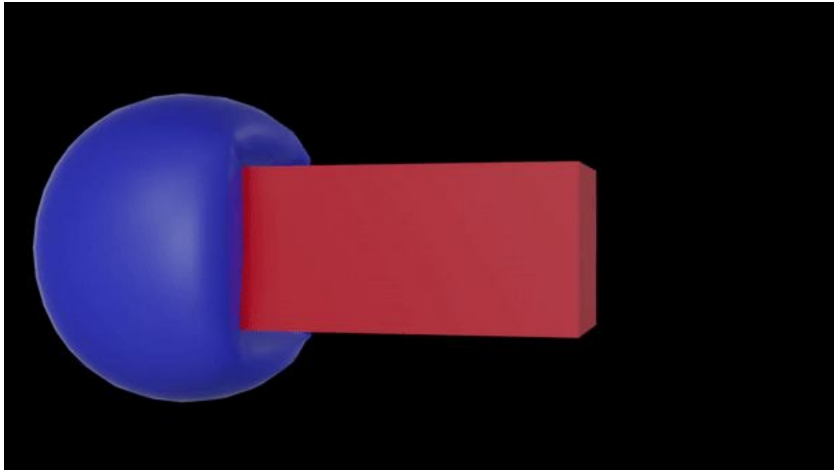


Work: 5 minutes

Existing Solutions (in Blender)

Cloth simulation

- Similar to Softbody
- Better volume control through pressure…
- …but even harder to control overall



Work: 5 minutes

Existing Solutions (in Blender)

Dynamic Paint:

+ Relatively quick to use
+ Automatically updates
- Requires animation (to some extent)
- Only displaces (no volume preservation)
- Can cause artifacts

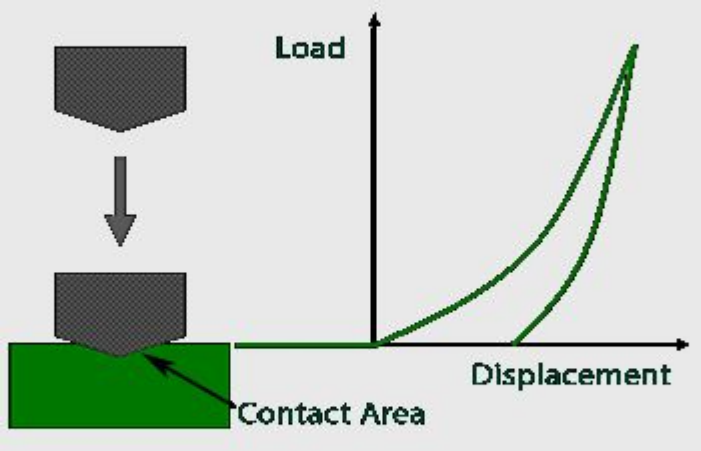
Boolean:

+ Displacement is quite exact
- Only displaces (no volume preservation)
- Creates additional geometry
- Either destructive, or otherwise problematic

Theory

Indentation

- Normally based on various material factors
- The material resists indentation to a certain extent
- Research focused on deformation *over time*



Source: https://www.nanoscience.com/techniques/mechanical-testing/

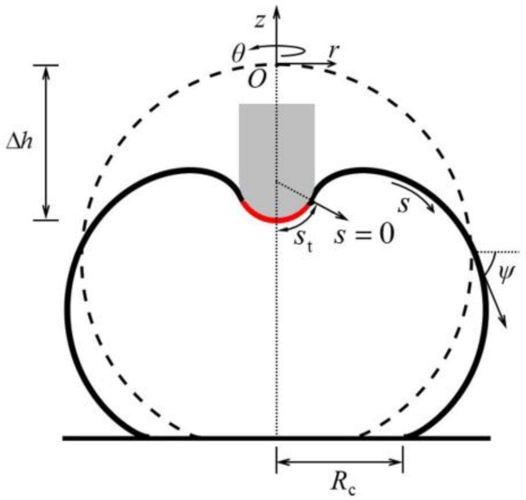
Sink-in

- Depends on plasticity/elasticity of the material
- For most materials, it is either sloped downwards (elastic), or linear (plastic/rigid)

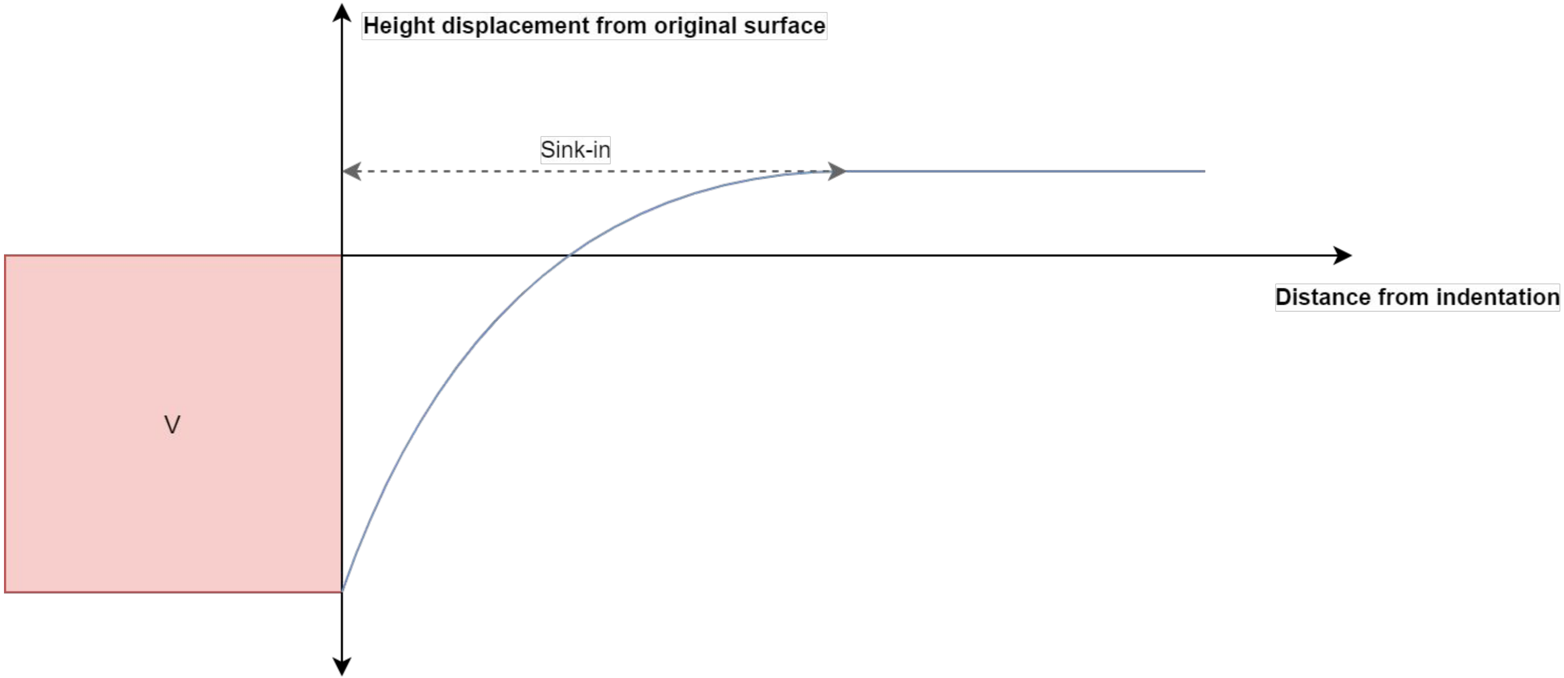
Source: Instrumented Indentation Testing (2000)

Volume distribution

- Not common in research
- Depends on internal pressure



Source: Finite Indentation of Pressurized Elastic Fluid Nanovesicles by a Rigid Cylindrical Indenter (2019)



The combined deformation would look something like this (2D)

Implementation

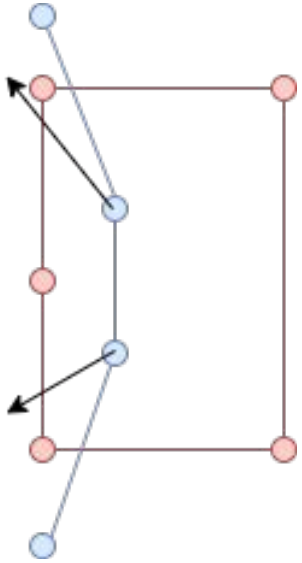
This Implementation...

- Preserves volume (approximate)
- Is not based on time (one-click solution)
- Does not add additional geometry
- Tries to keep artifacts to a minimum
- Has parameters to control artistic (not physical) properties
- Works non-destructively on shape keys (can be animated)

... is a Blender addon!

Part I a: Pushing in

1. Find all soft object vertices inside the hard object
2. For each vertex inside:
    1. Find some average displacement direction depending on the surrounding hard object vertices
    2. Get the closest surface point on the hard object surface along this direction
    3. Put the vertex on this point (+ some optional, additional displacement)



We save the total displacement amount for later.

Part II: Sink-in function

- Creating a function f(x) which can describe everything from a smooth to a linear falloff

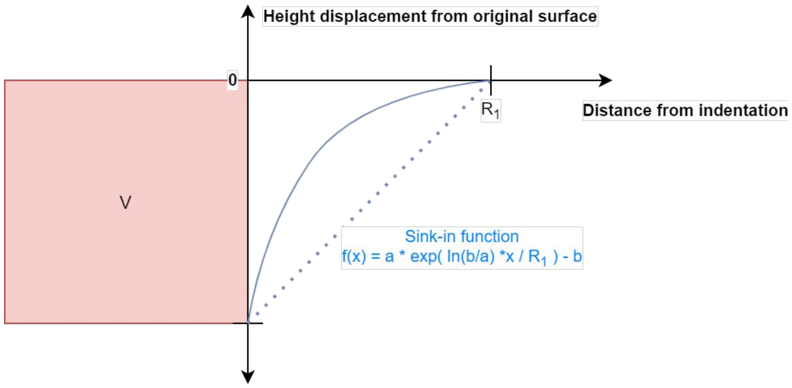
$$f(x) = a * \exp(\ln(\frac{b}{a}) * \frac{x}{R_1} - b$$

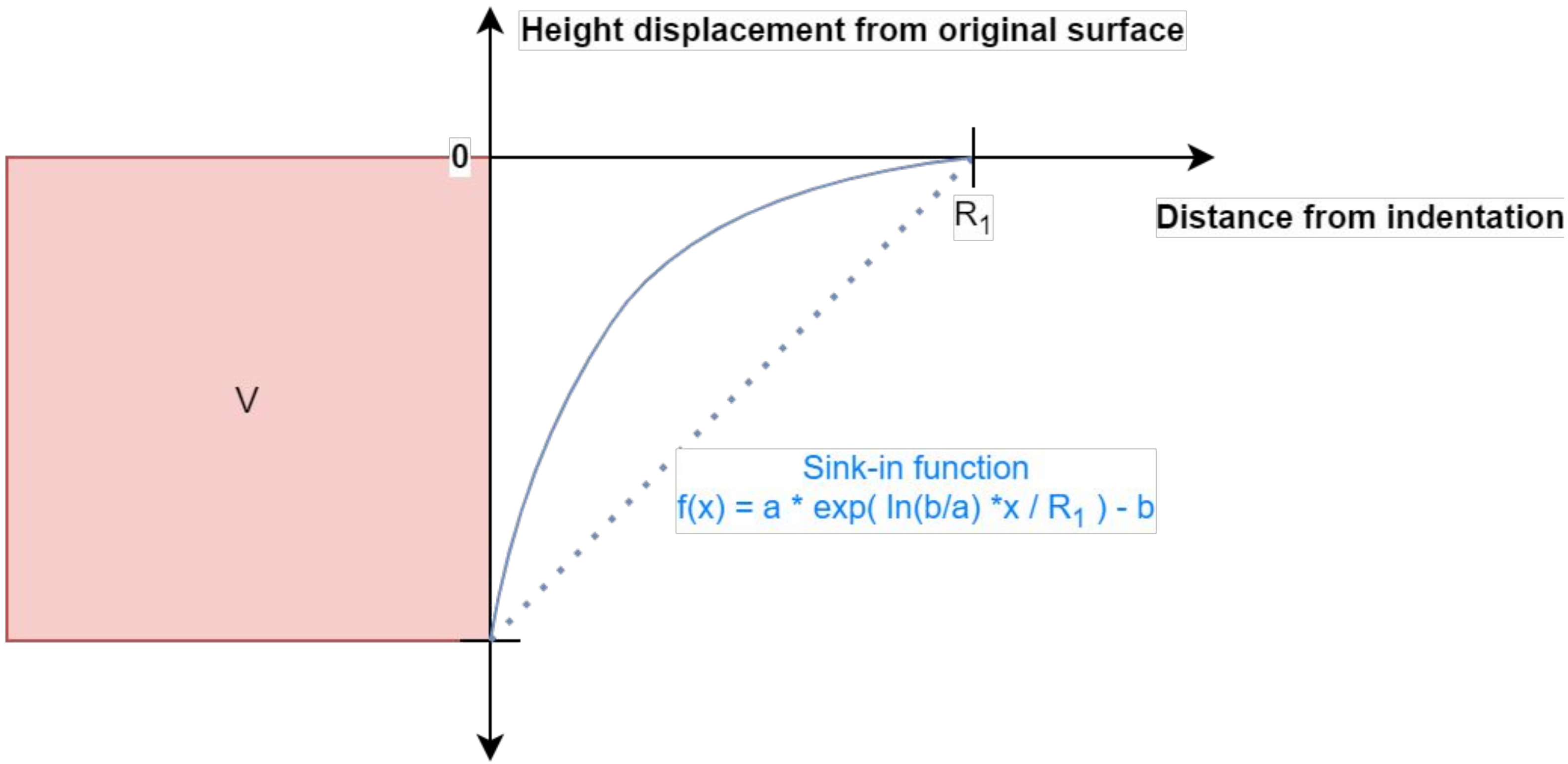
for $a = 1 + b$, b > 0 and $R_1 > 0$

$b \to 0$: curvature increases

$b \to \infty$: approximately linear

$R_1 = \sqrt{D}$ describes the range of the sink-in for indentation depth D





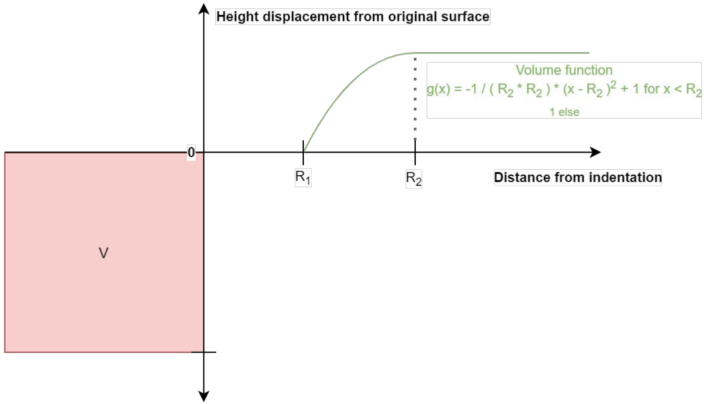
Sink-in function f(x)

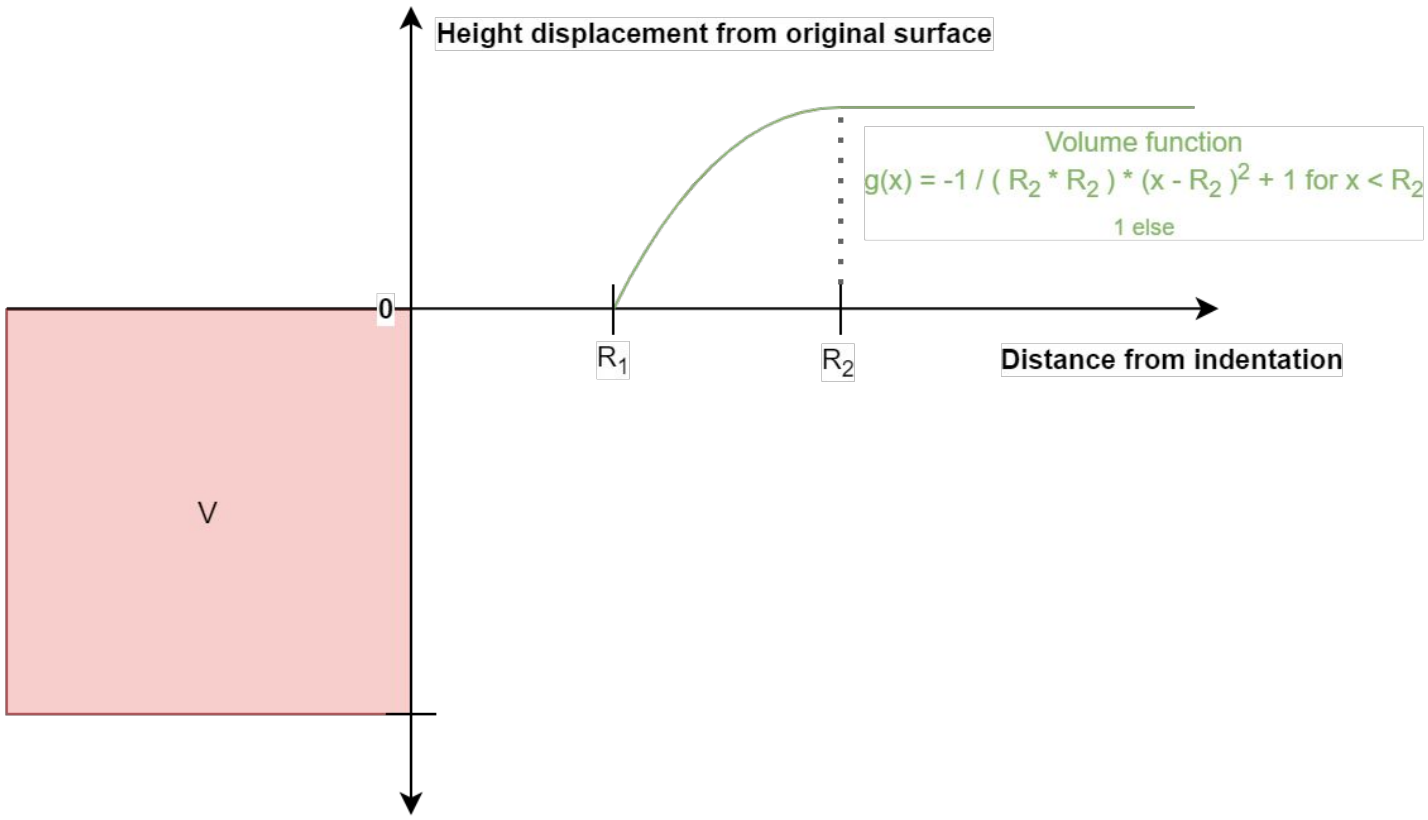
Part III: Volume function

- A simple half-parabola which leads into a constant distribution

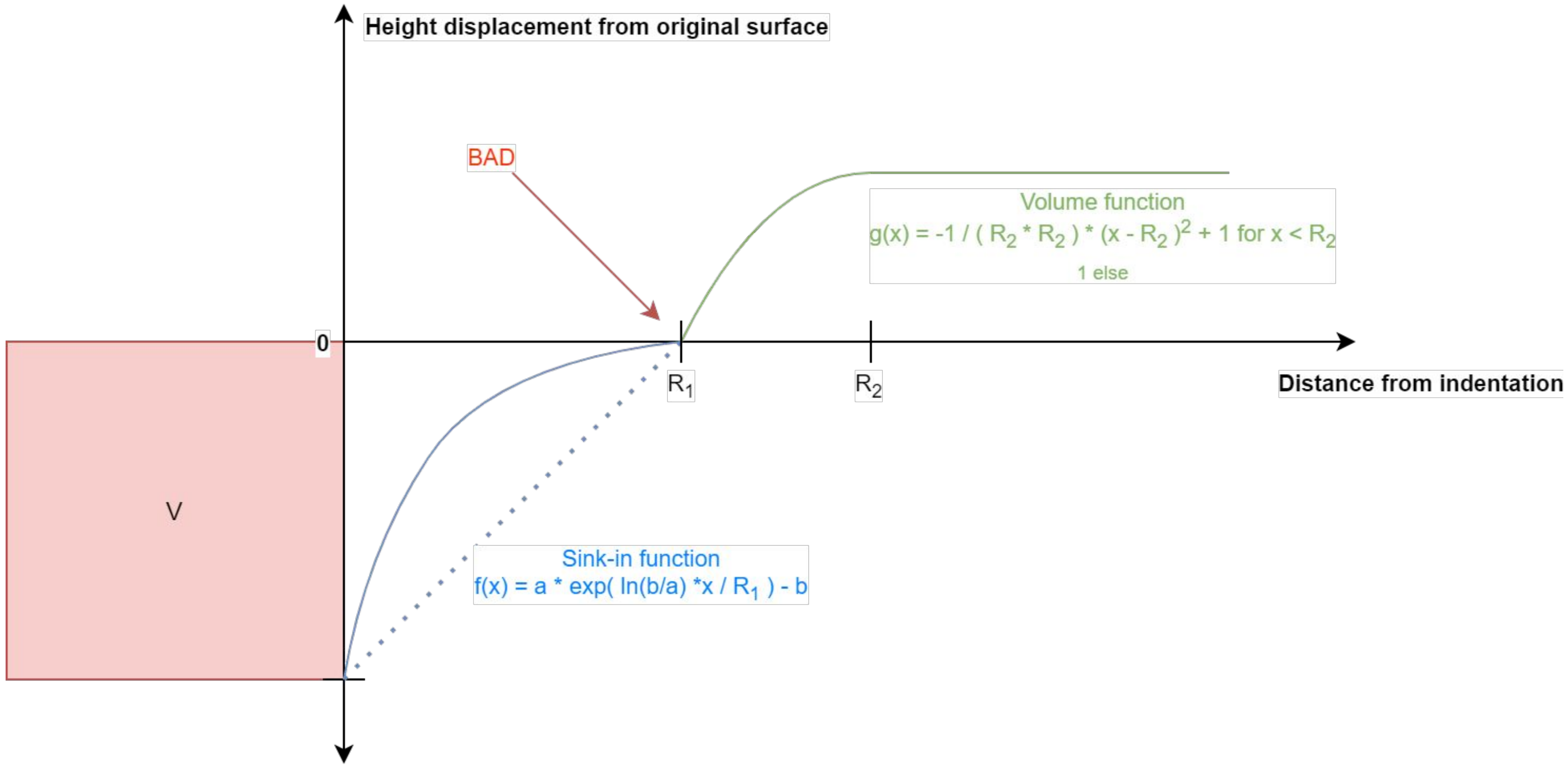
$$g(x) = \begin{cases} -\frac{1}{R_2^2} * (x - R_2)^2 + 1, & \text{if } x < R_2 \\ 1, & \text{otherwise} \end{cases}$$

$R_2 > 0$ describes the range of the volume ramping up to a constant level

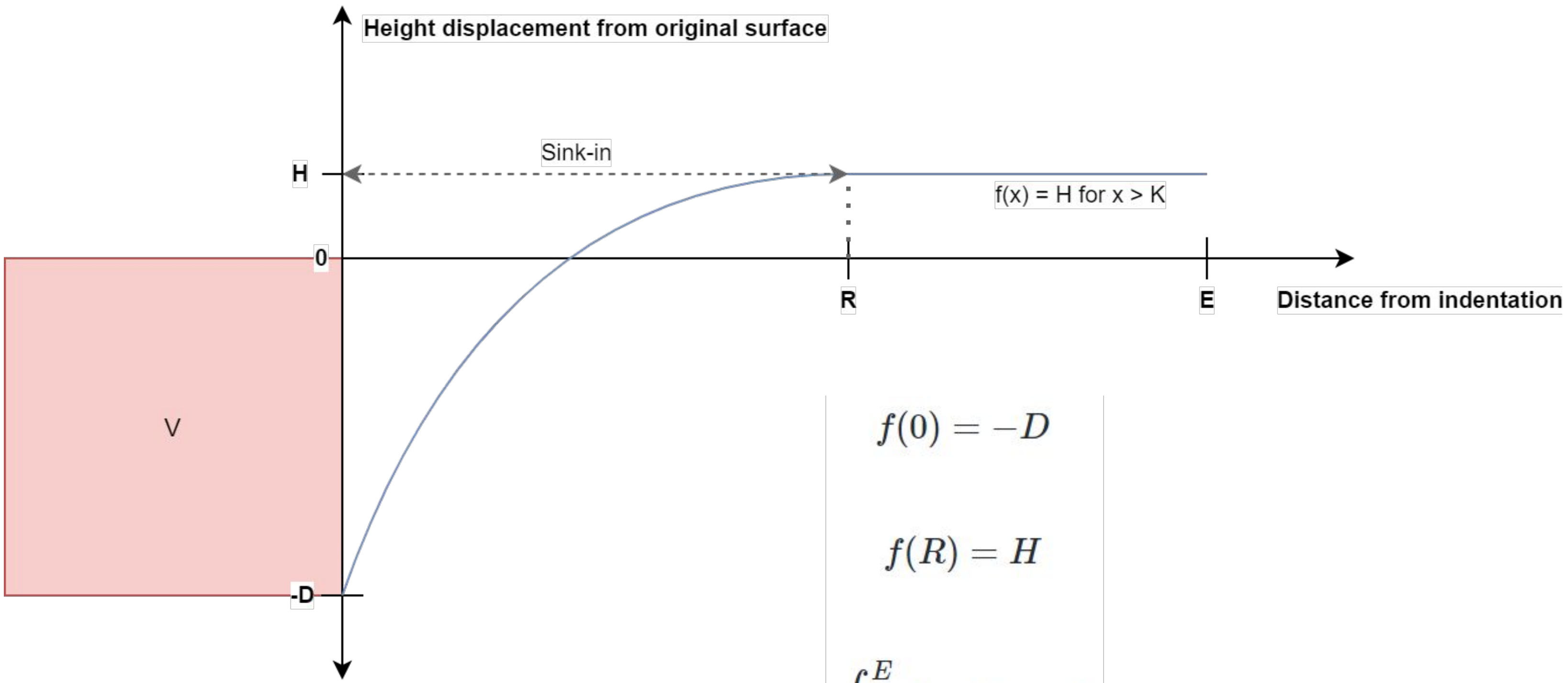




Volume function g(x)



Combining the functions…



$$f(0) = -D$$

$$f(R) = H$$

$$\int_0^E f(x)\,dx = V$$

R, V, D, and E are known. H is not.

Creating a single, combined function

One function to rule them all

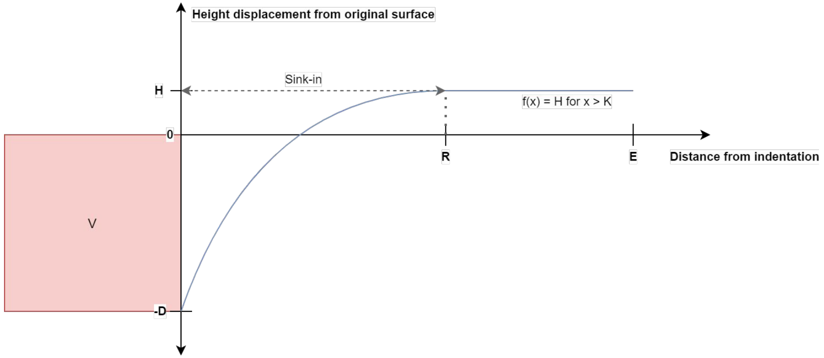
$$f(x) = \begin{cases} a * (x - R)^2 + c & \text{if } x < R \\ -D + a * R, & \text{otherwise} \end{cases}$$

for

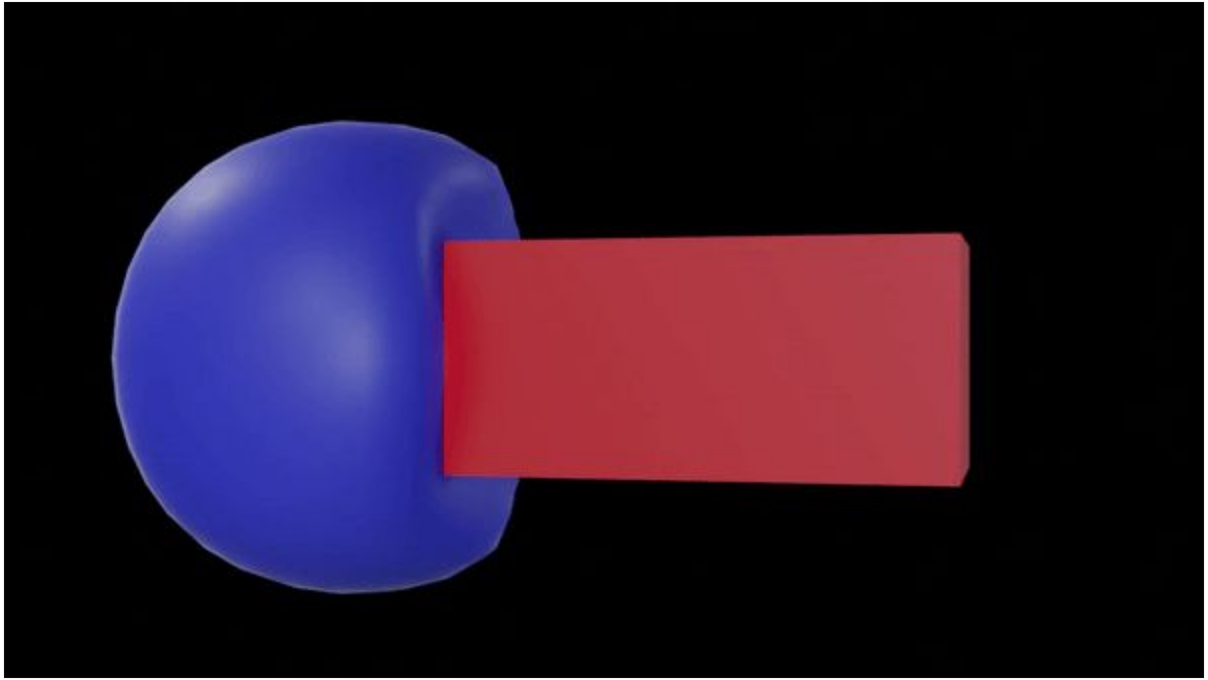
$$a = (V + D * E) * \frac{1}{\frac{R^3}{3} - 2 * R^2 + R * E}$$

and $c = -D + a * R$

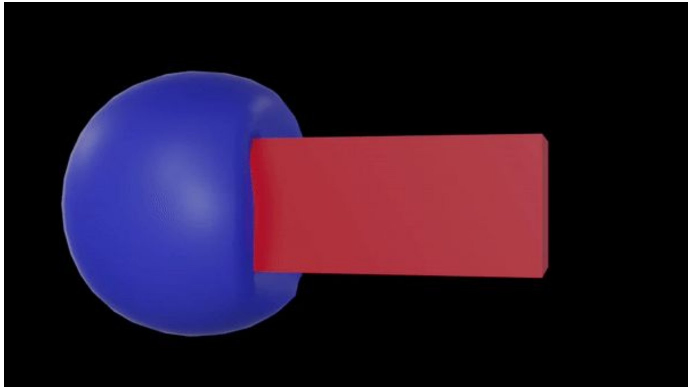
With $R = \sqrt{D}$ the sink-in range, D the displace depth, V the displaced volume (estimate), E the maximum distance of any vertex to the indentation area



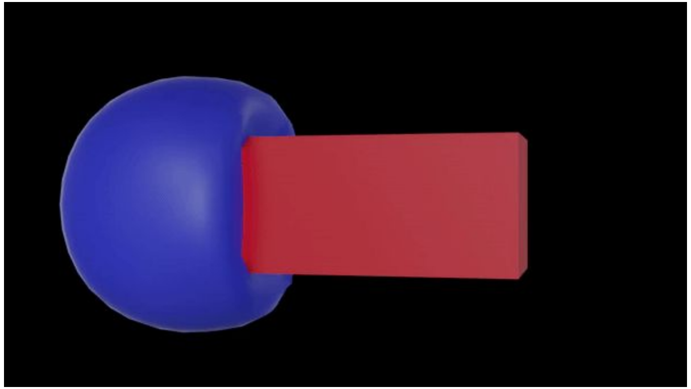
Results



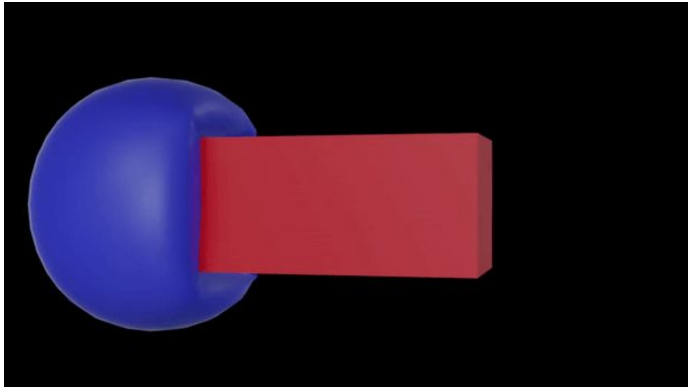
Work: 1 second (10 seconds for animating shape keys)



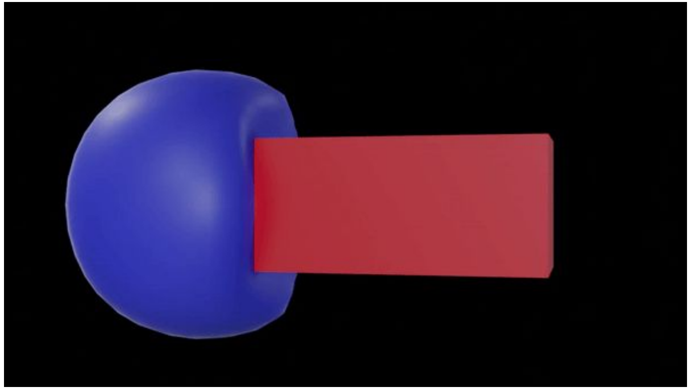
Sculpting



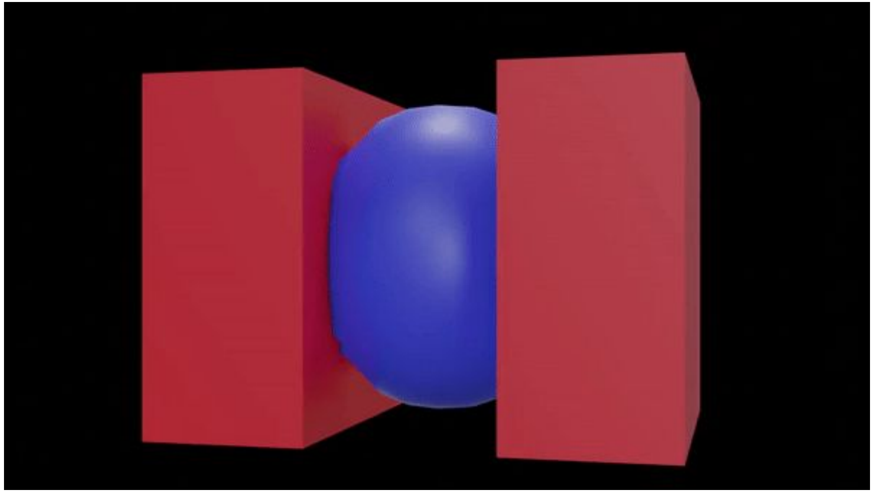
Softbody simulation



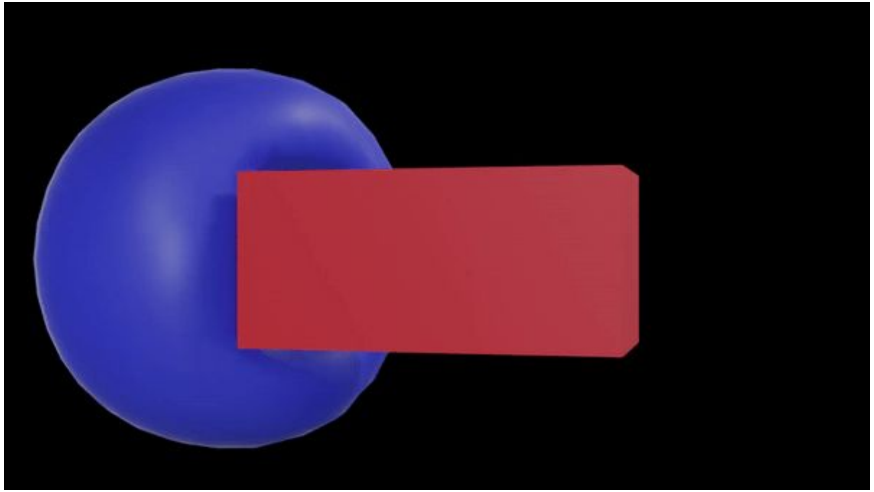
Cloth simulation



My solution



Multiple deformations

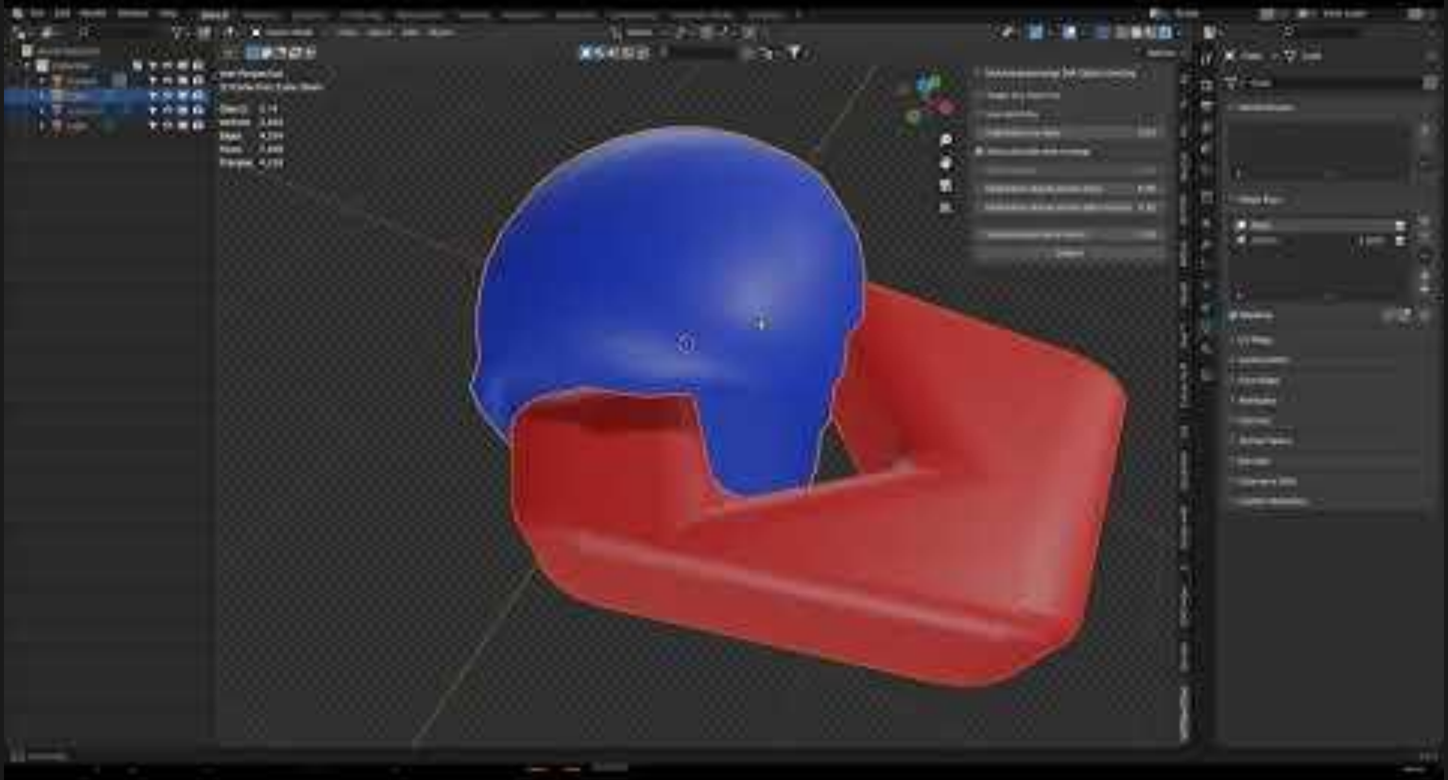


80% Volume preservation

And it can do more!

Video Demo

https://www.youtube.com/watch?v=taOCVPt3nzI&t=102s



Challenges

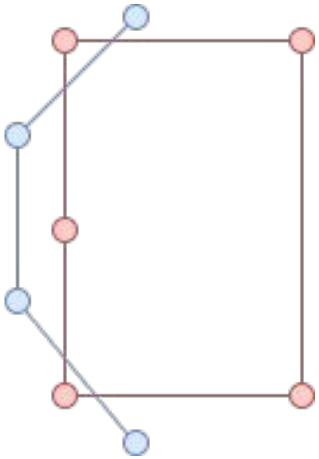
Current Problems

1. Because pushing in (Part I) is based on overlapping **vertices**, faces/edges may still overlap.

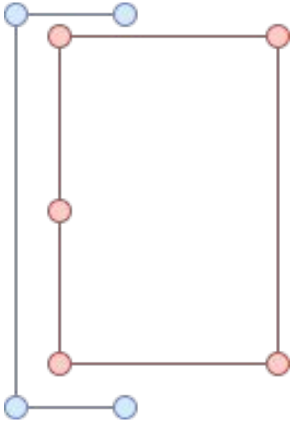
   Two ways to fix this:

   a. Easy: Also displace vertices around the initial area (already done to some extent through sink-in)

   b. Hard (but better): First try to find defining features of the hard object (convex hull + 1° planar decimate) and displace verts onto those, then continue as normal.



We want this:



Current Problems

2. Can only handle one overlap/indentation area at the time

   How to fix this:

   Isolate the impact/overlap areas and work with them separately (can also be done with multiple hard objects)

   These “islands” then need to be associated with each other

Questions?