

Papers I Have Loved

Casey Muratori
Molly Rocket, Inc.

PAPERS I HAVE LOVED

Casey Muratori
Molly Rocket, Inc.

< Speed

0.25

0.5

✓ Normal

1.25

1.5

Z 

< Speed

0.25

0.5

Normal

1.25

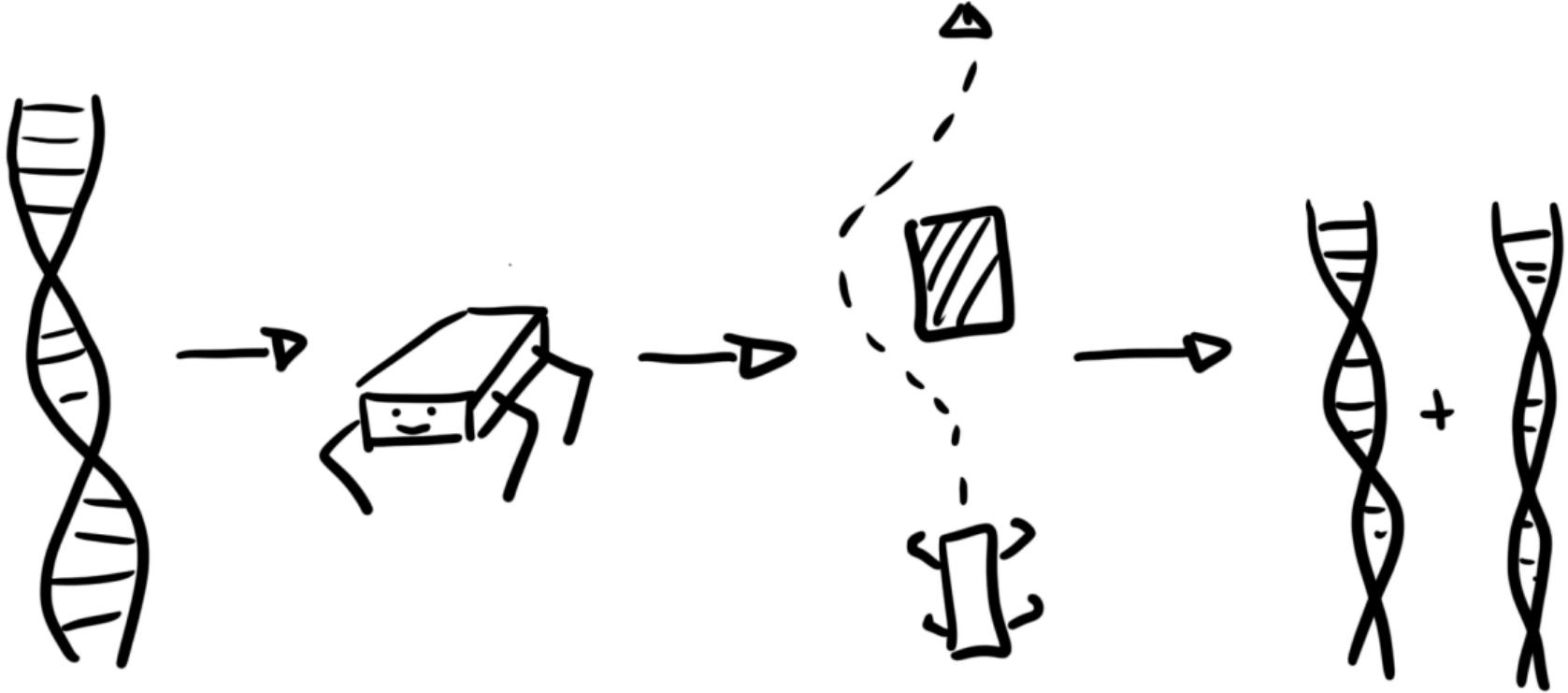
1.5

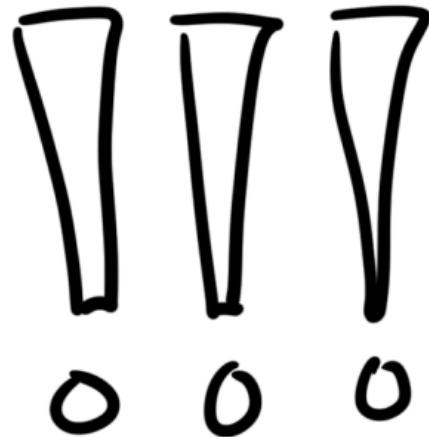
✓ Z 

1996

Evolving Virtual Creatures

Karl Sims





CM-5

32 CPUS

~3 HOURS



CM-5

32 CPUS

~3 HOURS

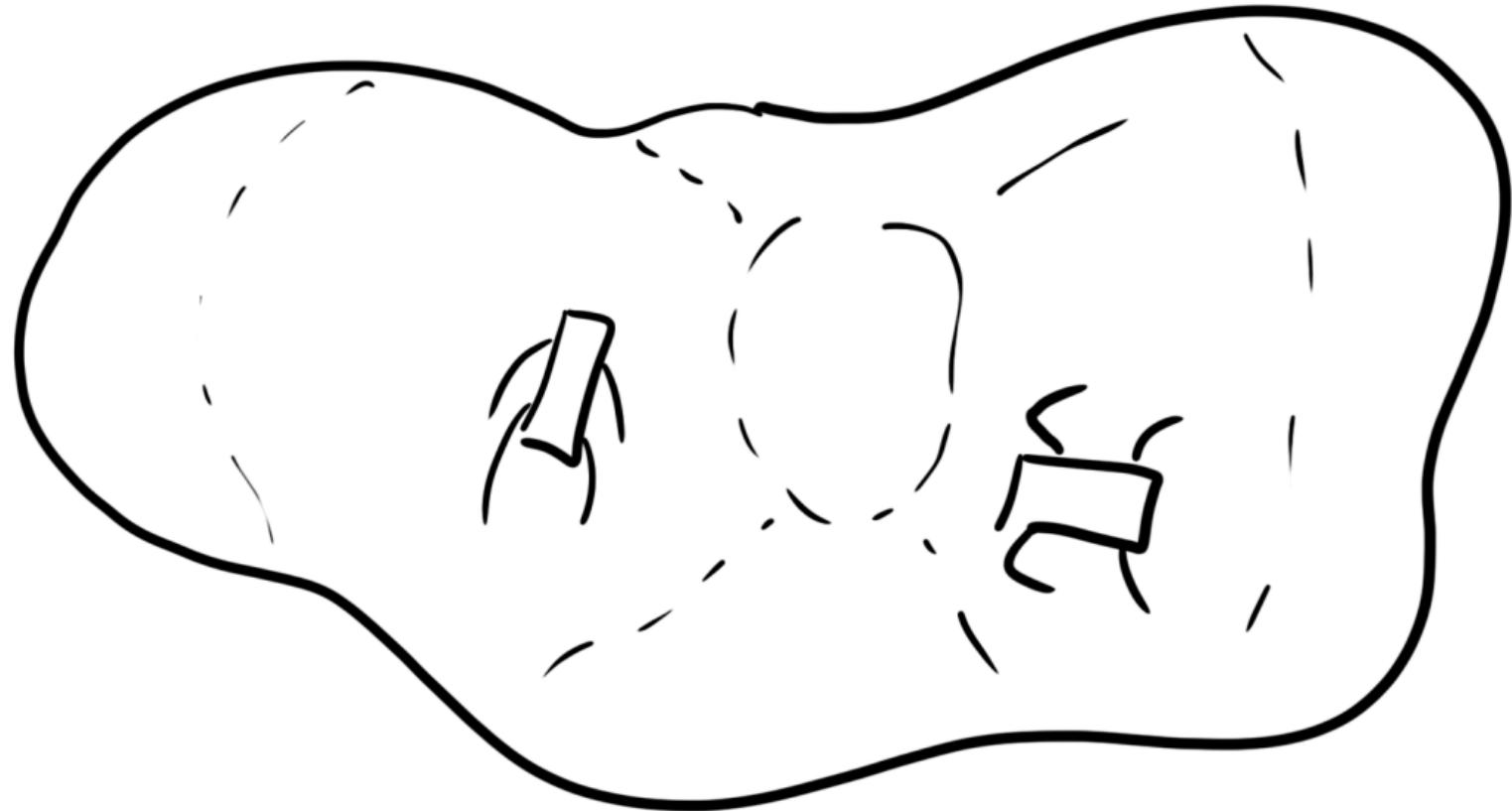


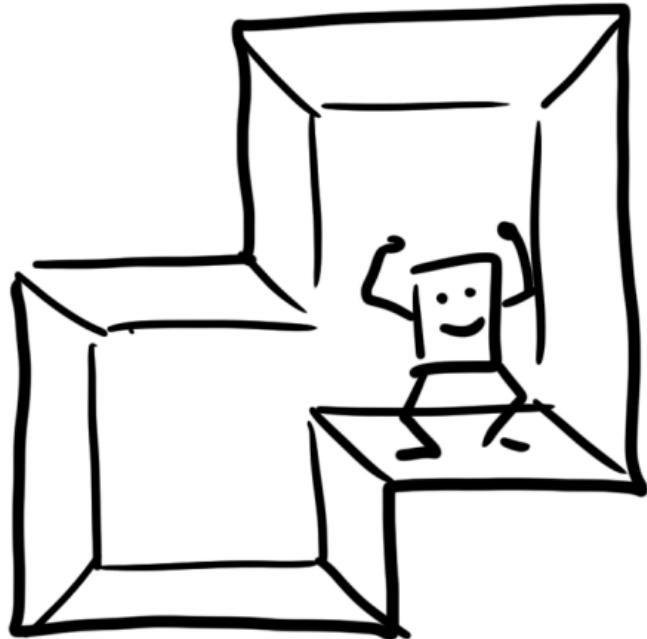
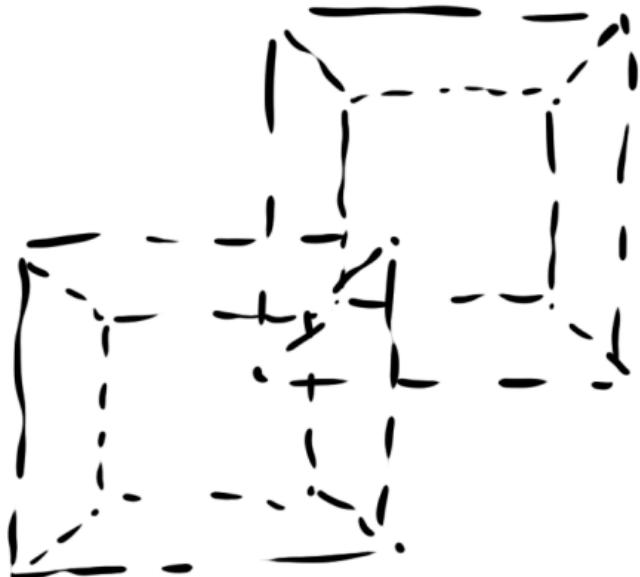
PC

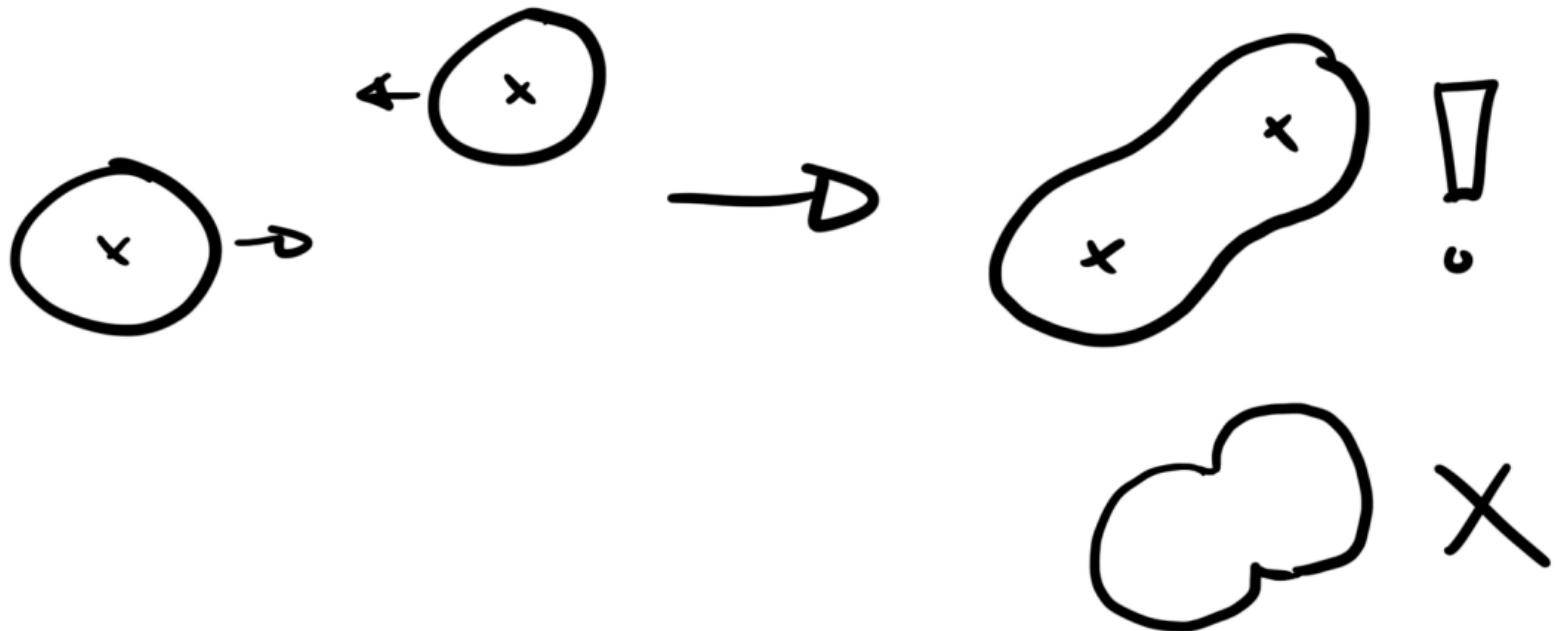
1 CPU
(120 mHz!)

10 SECONDS?



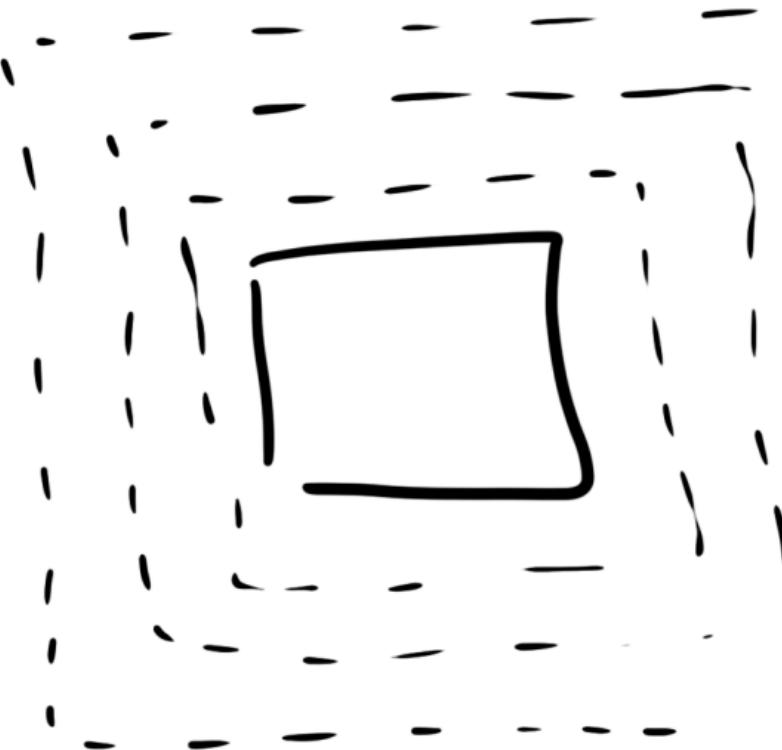
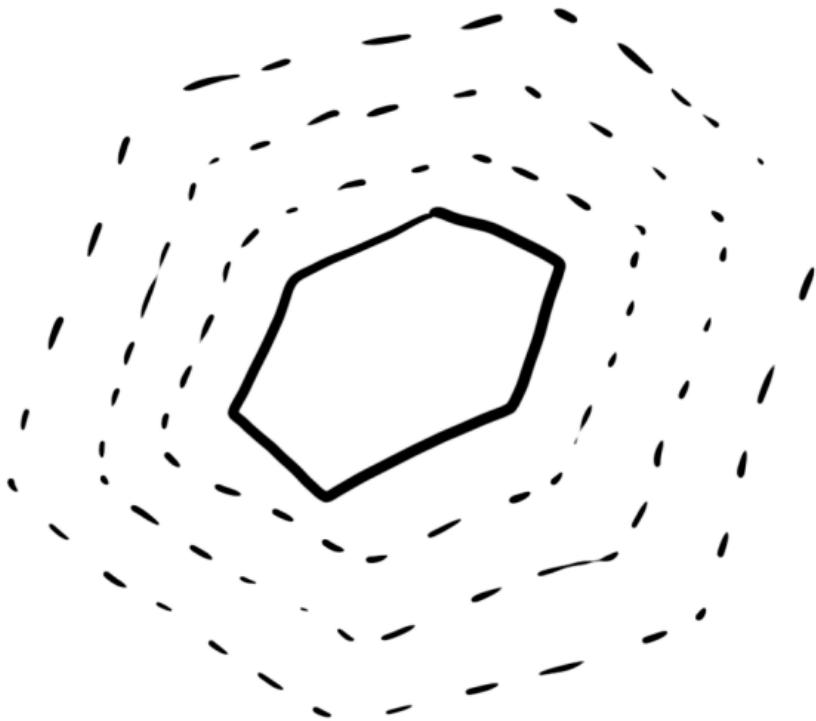


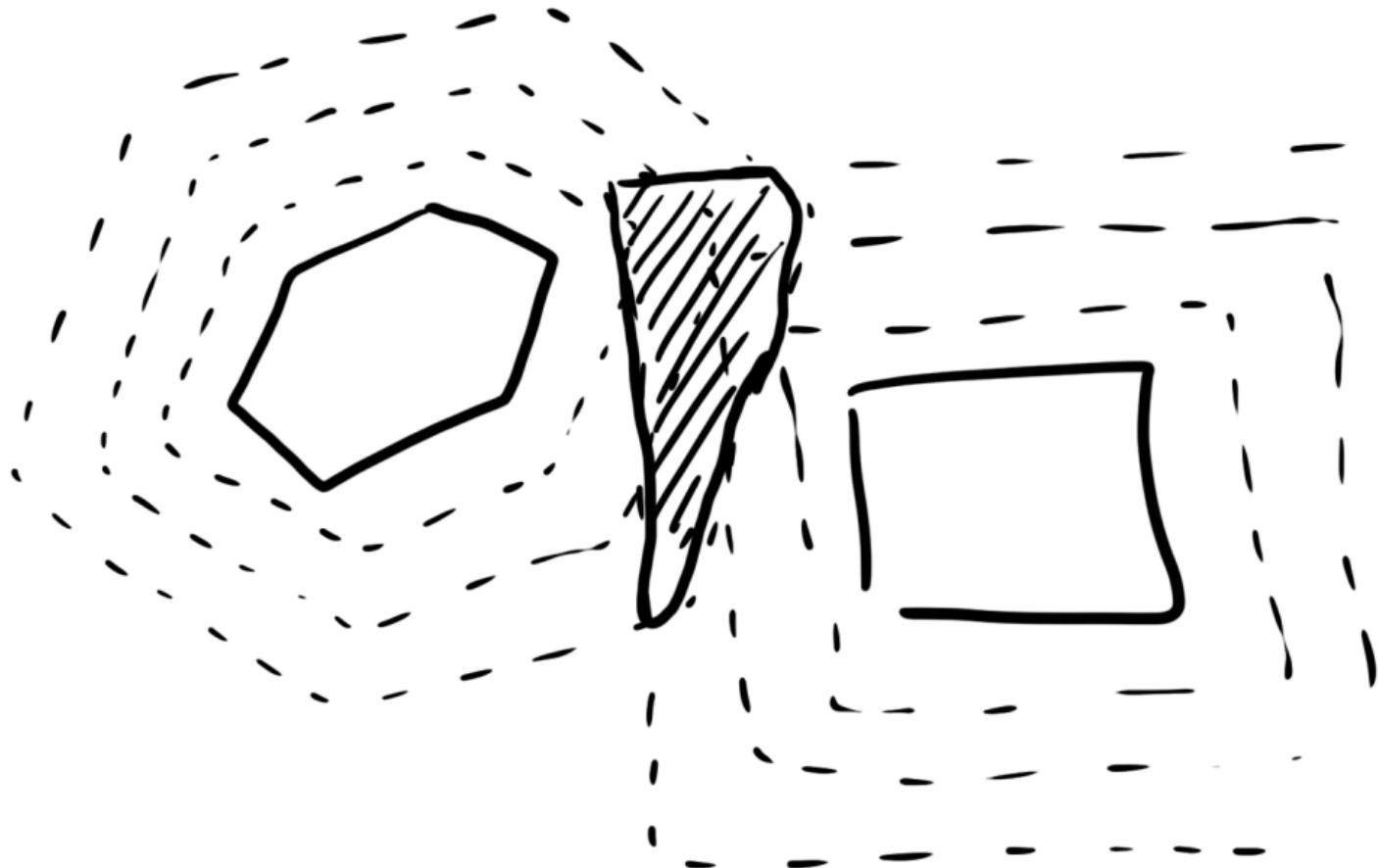


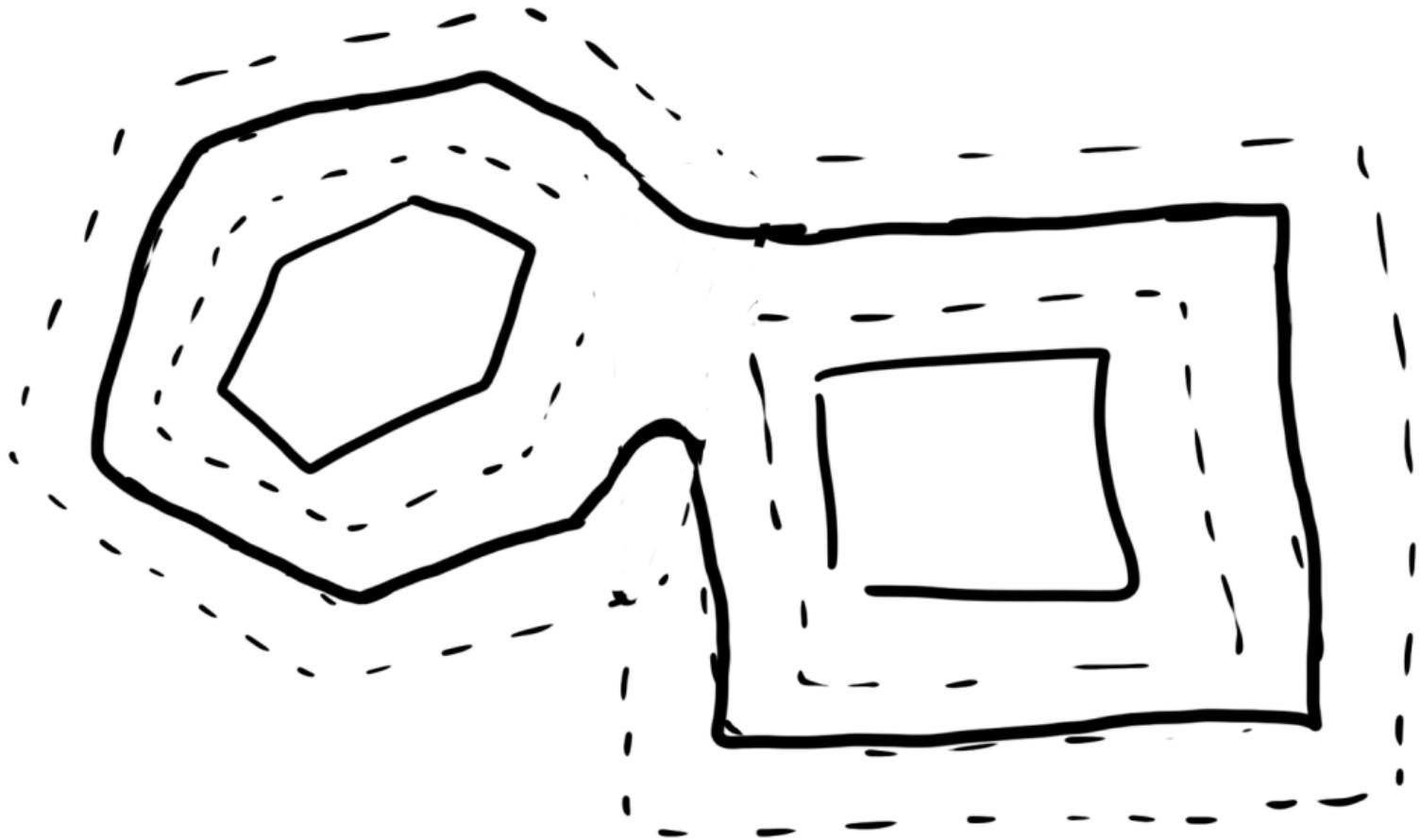


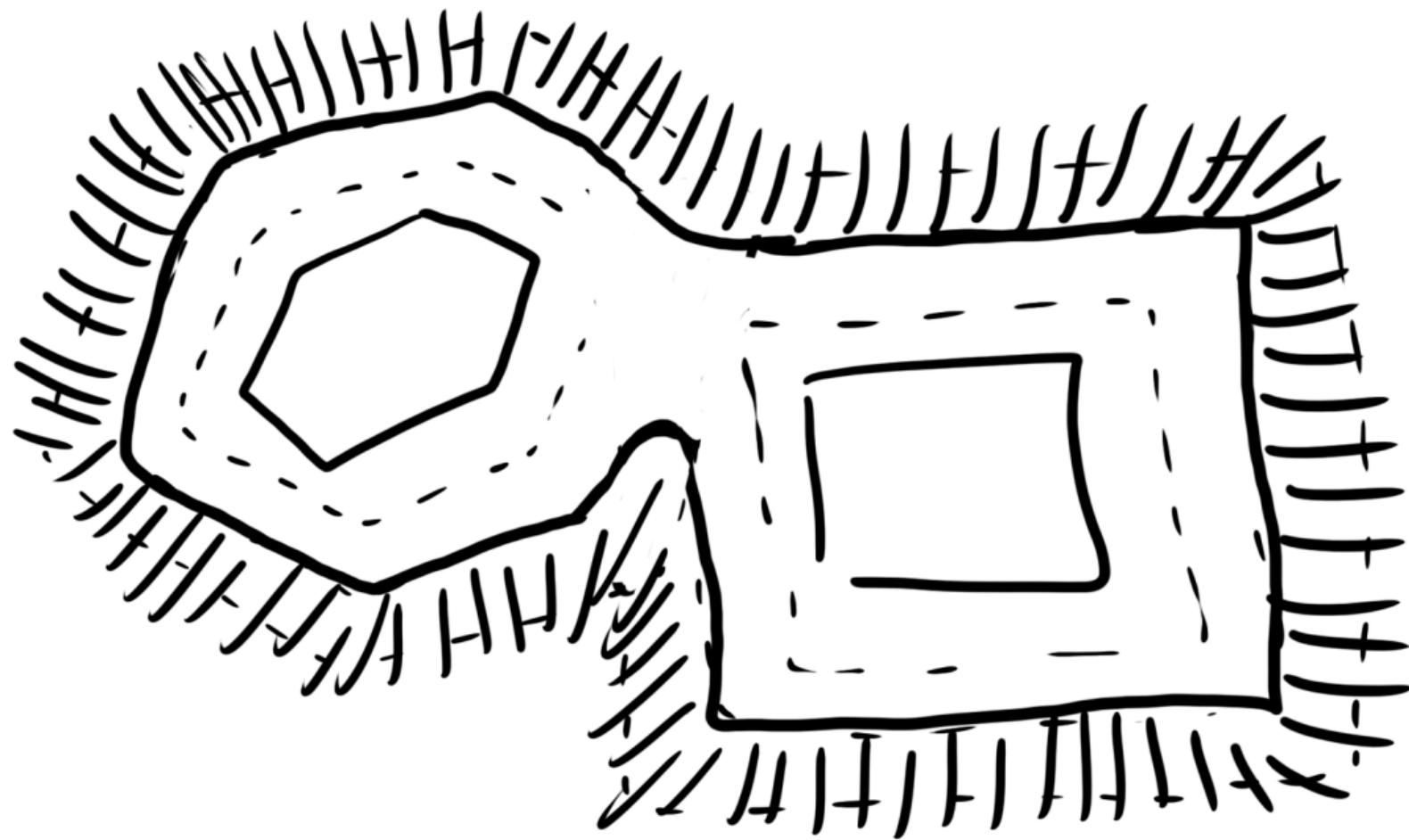


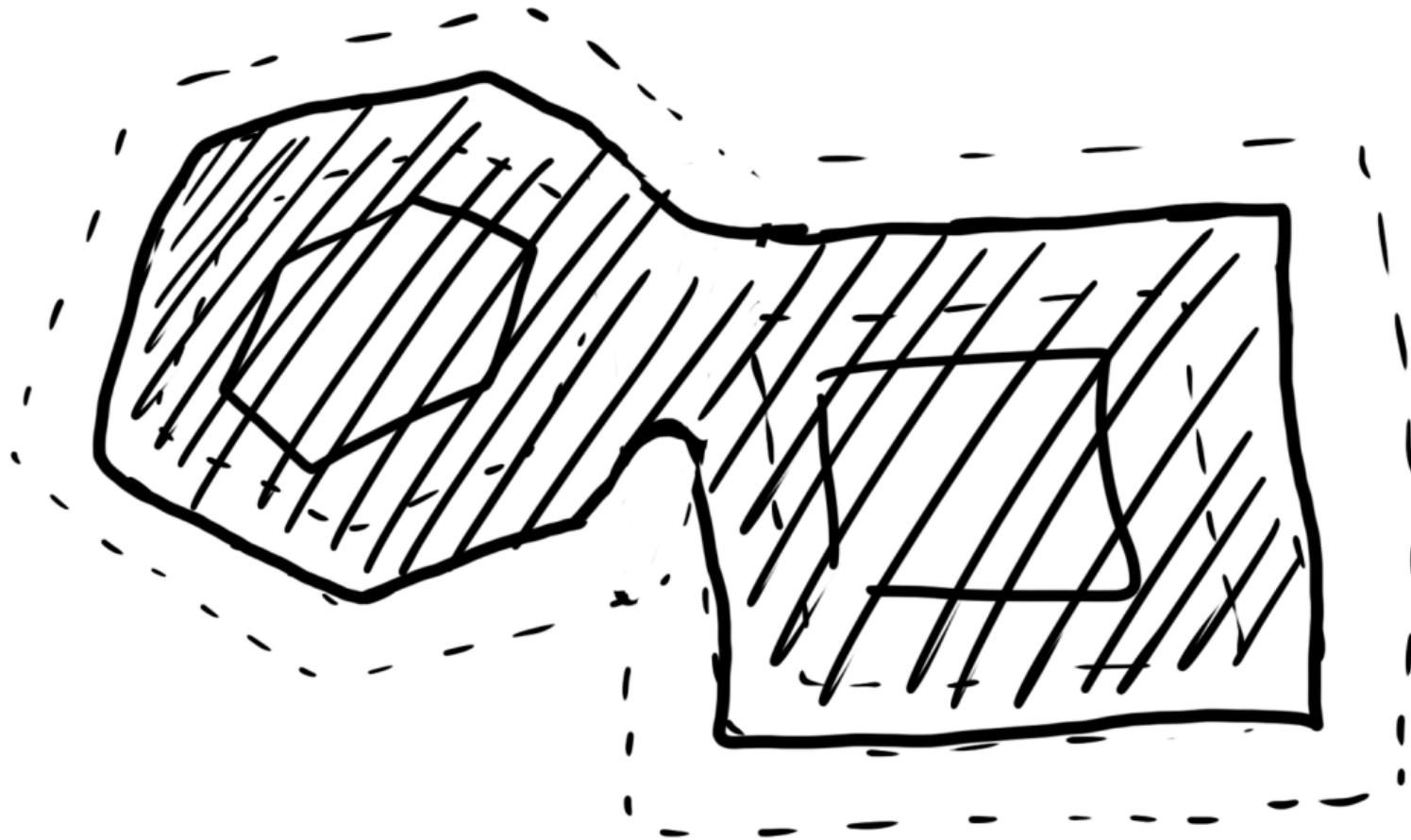
Implicit
Surfaces

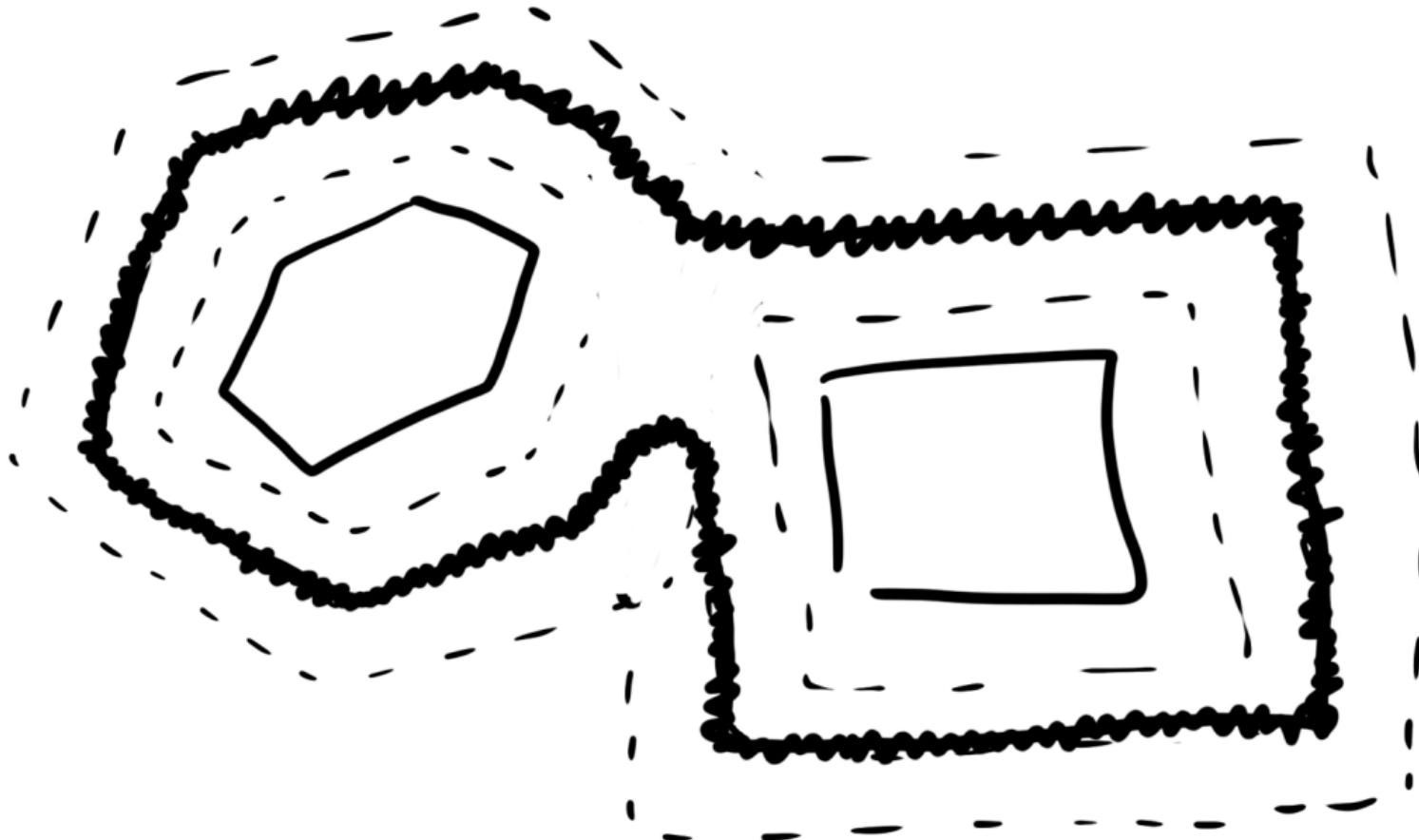












$$f(x, y, z) \rightarrow R$$

$$R = 37,12$$

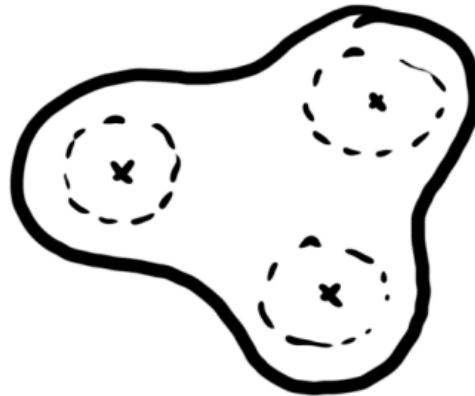
$$f(x, y, z) - 37,12 = 0$$

$f(x, y, z) = 0 \rightarrow \text{surface}$

$f(x, y, z) > 0 \rightarrow \text{inside}$

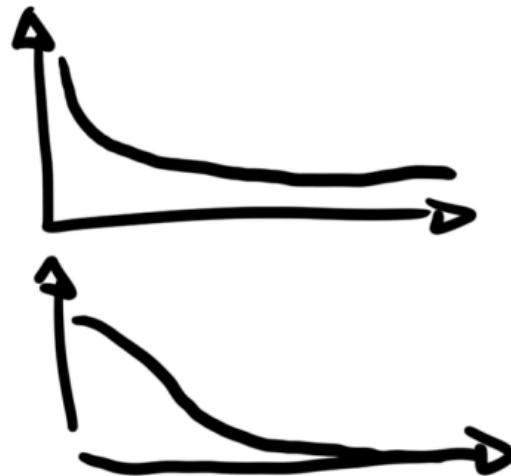
$f(x, y, z) < 0 \rightarrow \text{outside}$

Metaballs



$$f(x, y, z) = \frac{1}{\text{distance}}$$

$$f(x, y, z) = \text{something else} \therefore$$



STEP 1: $\sum f(x, y, z)$

STEP 2: ? ? ? ?
.....

STEP 3: ISOSurface¹
(or ISOcontour)

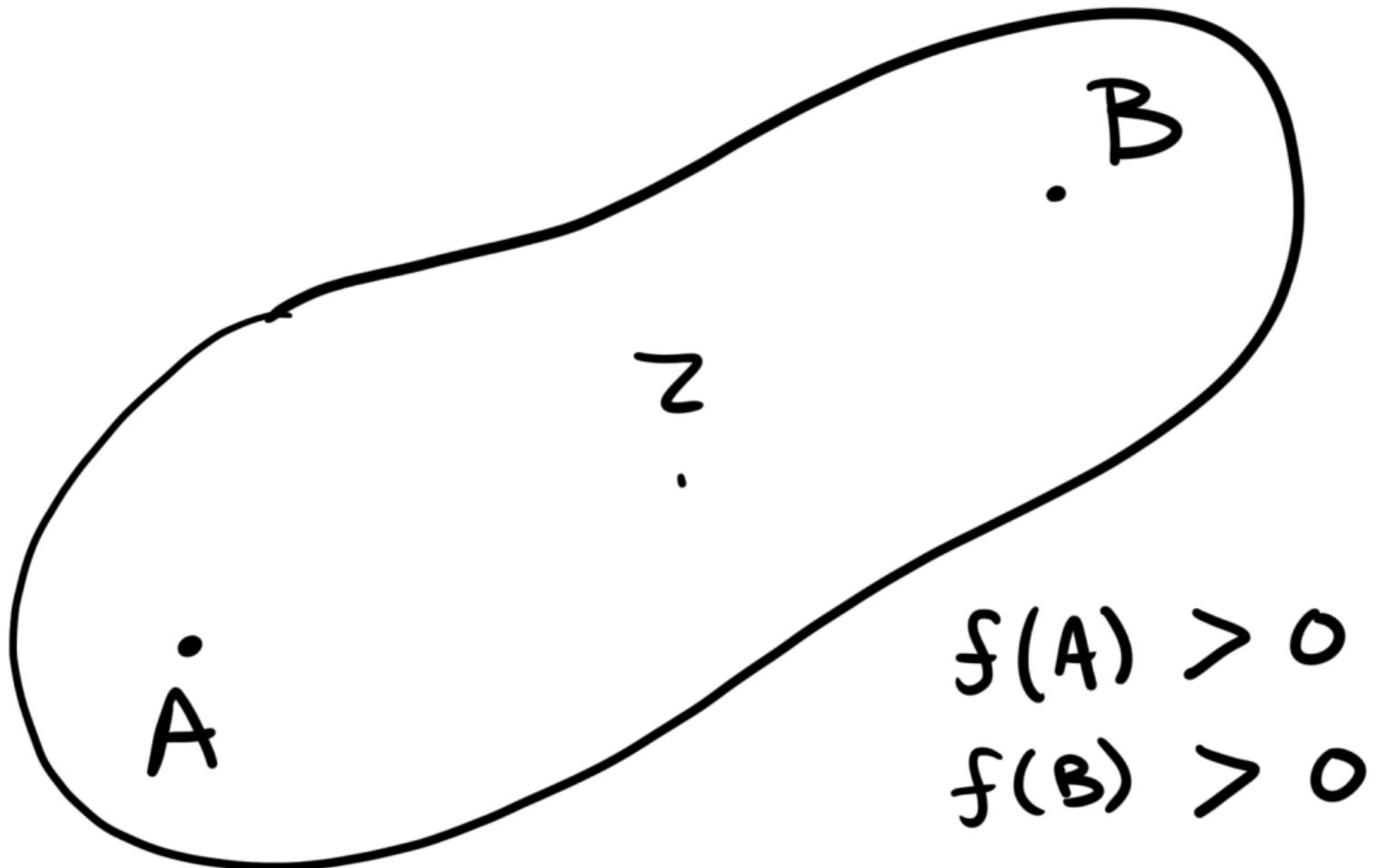
MARCHING CUBES:
A HIGH RESOLUTION
3D SURFACE RECONSTRUCTION ALG.

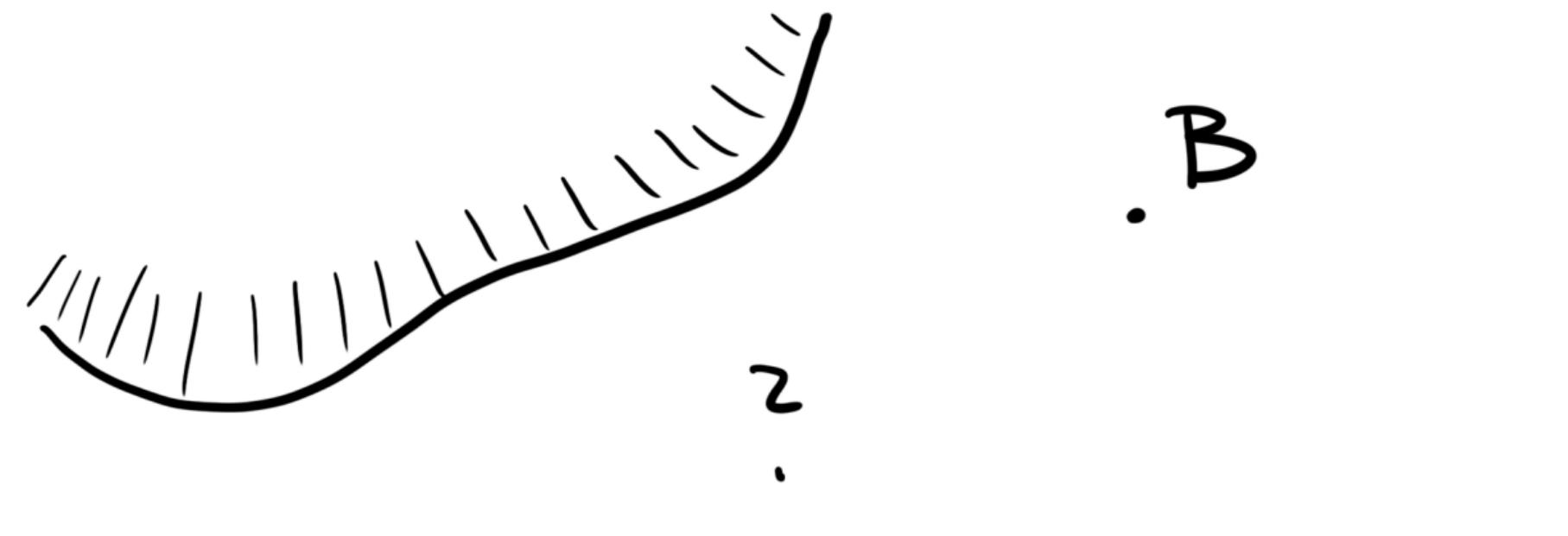
LORENSEN ⚡ CUNI

• A

$$f(A) = a$$
$$f(B) = b$$

• B



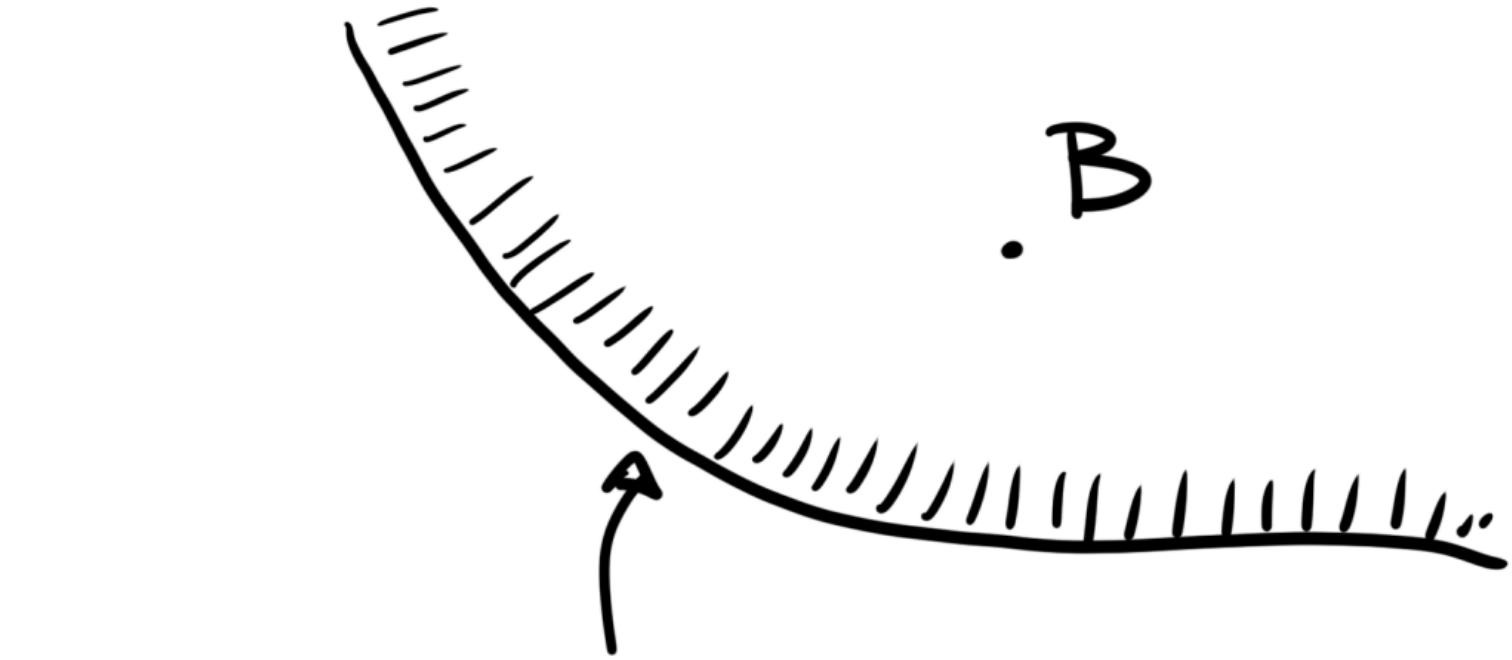


A

?

B

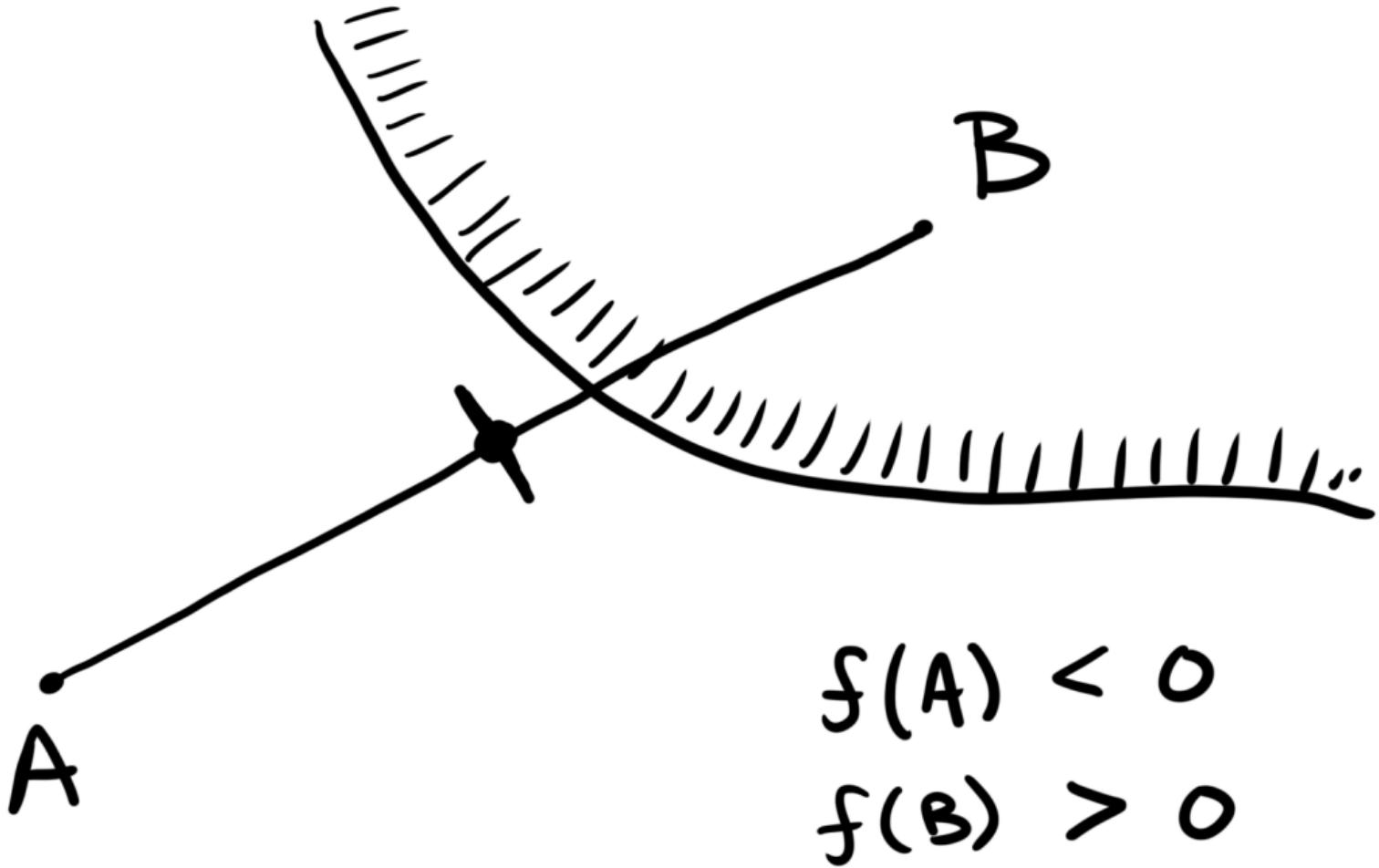
$$f(A) < 0$$
$$f(B) < 0$$

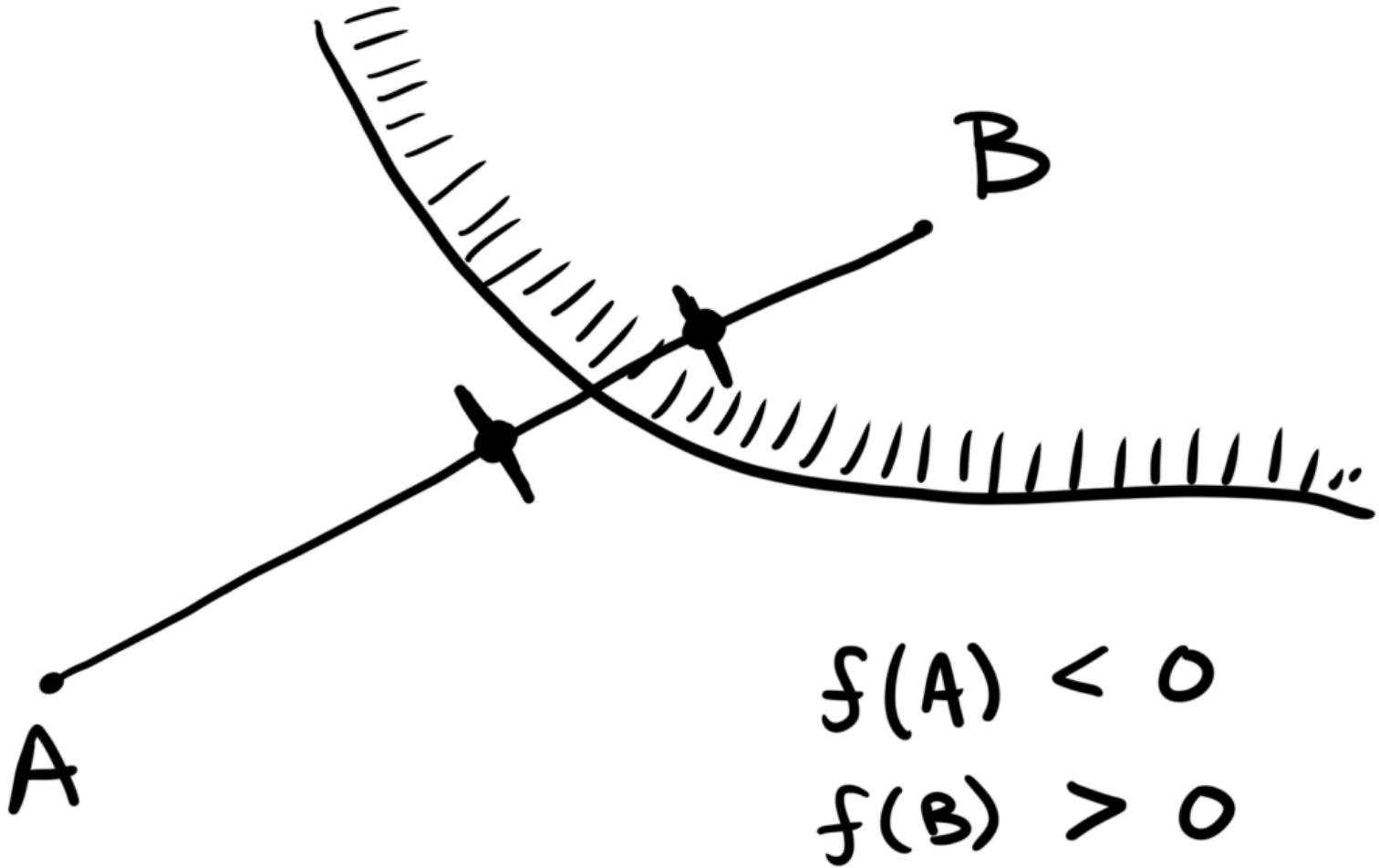


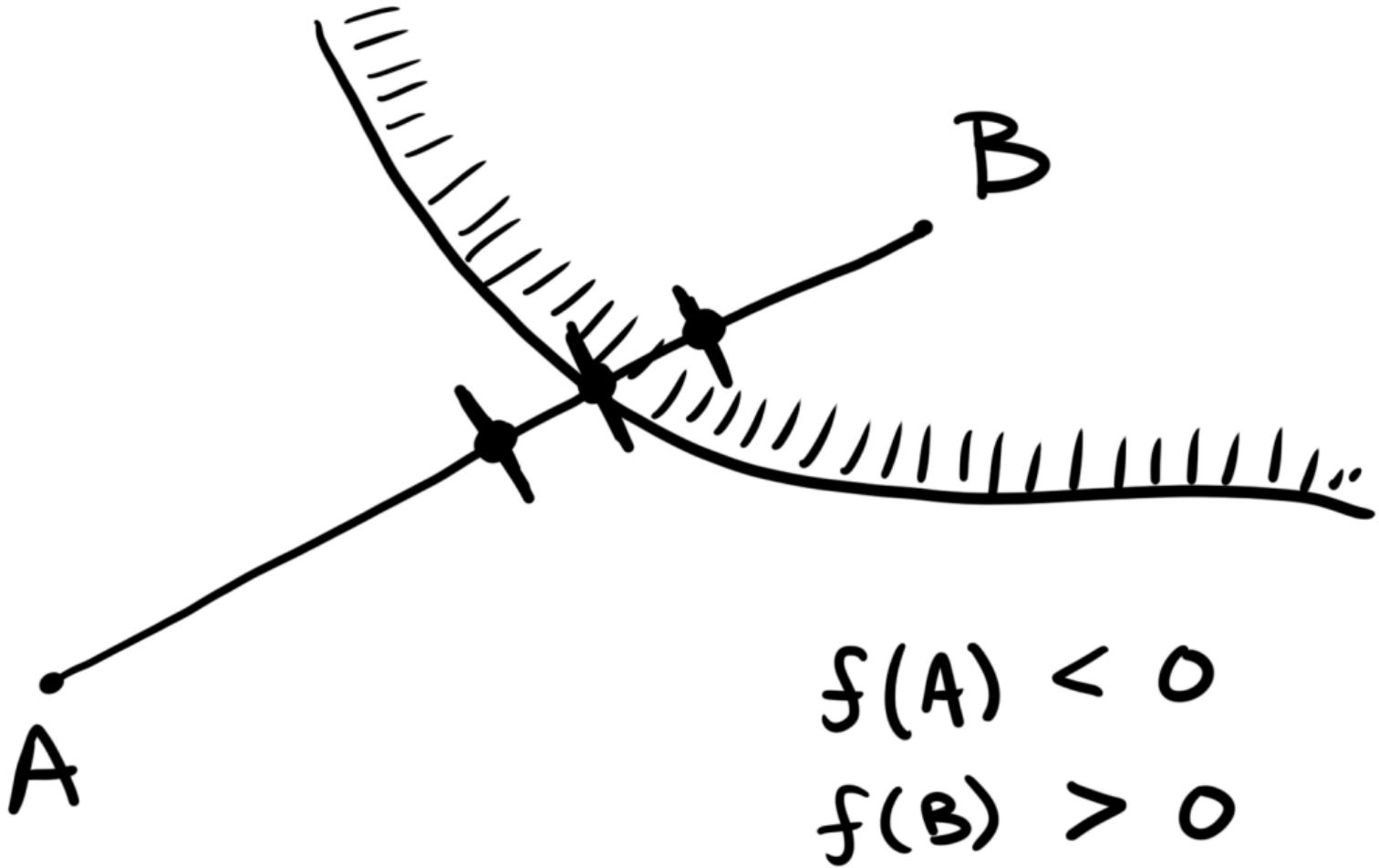
• A

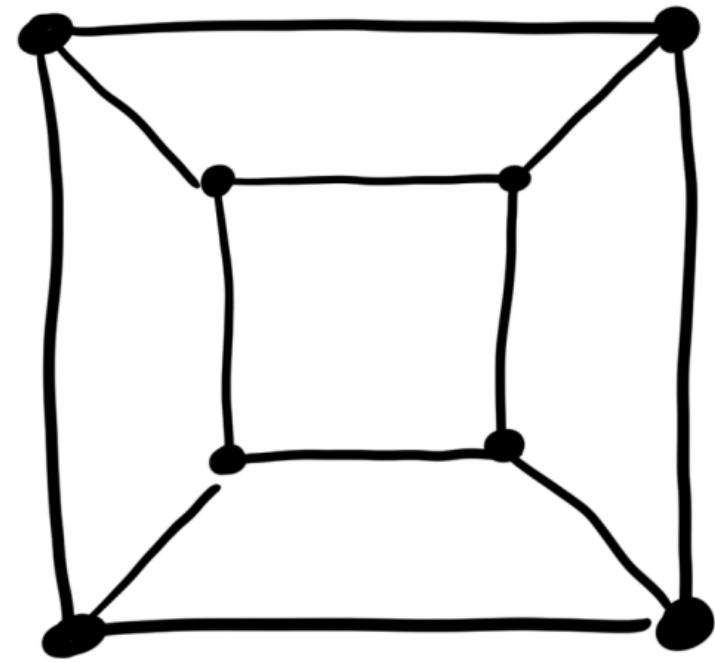
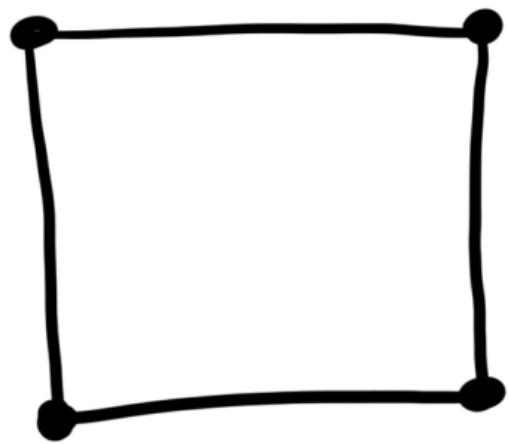
!

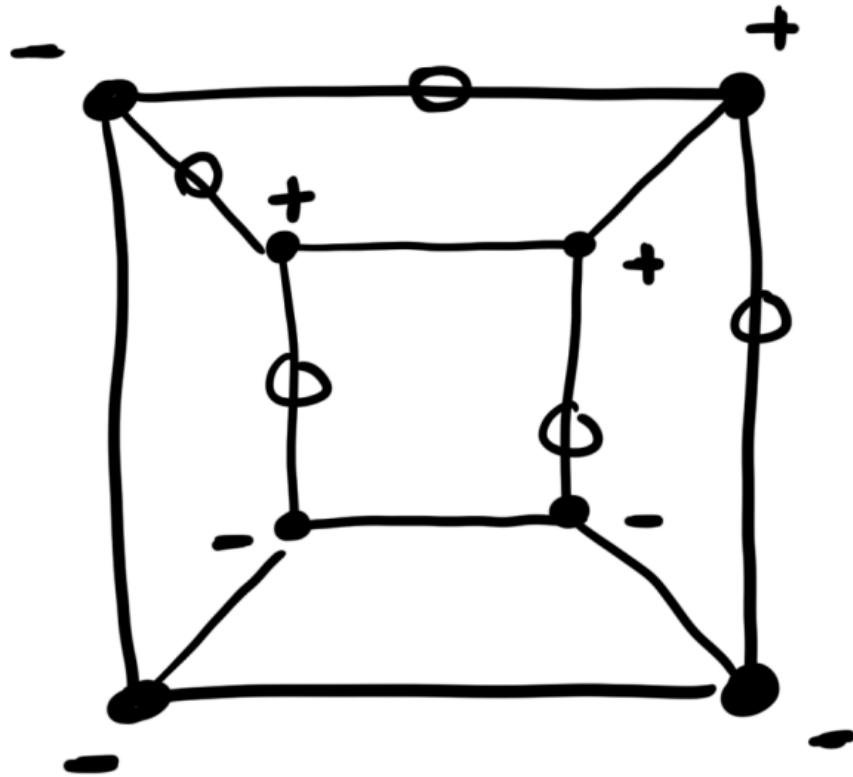
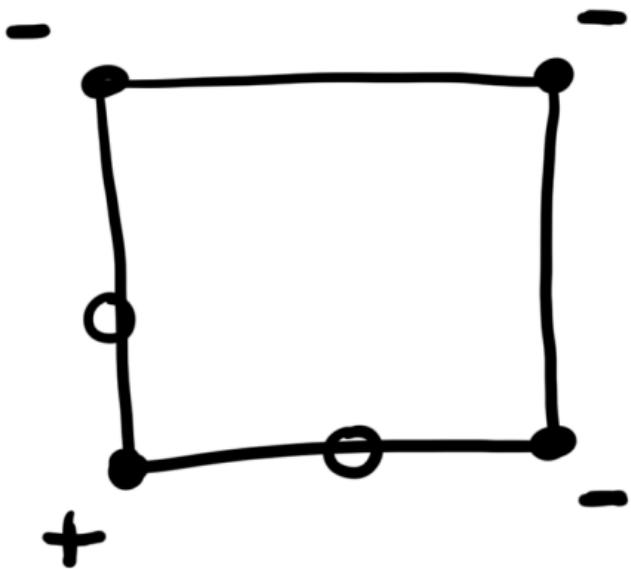
$$\begin{aligned}f(A) &< 0 \\f(B) &> 0\end{aligned}$$

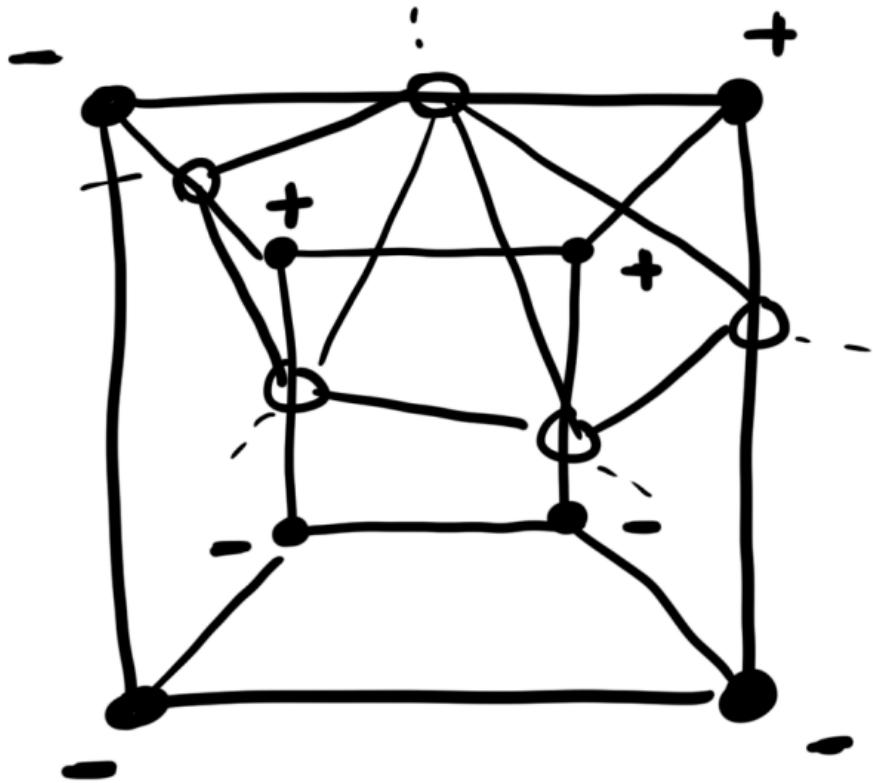
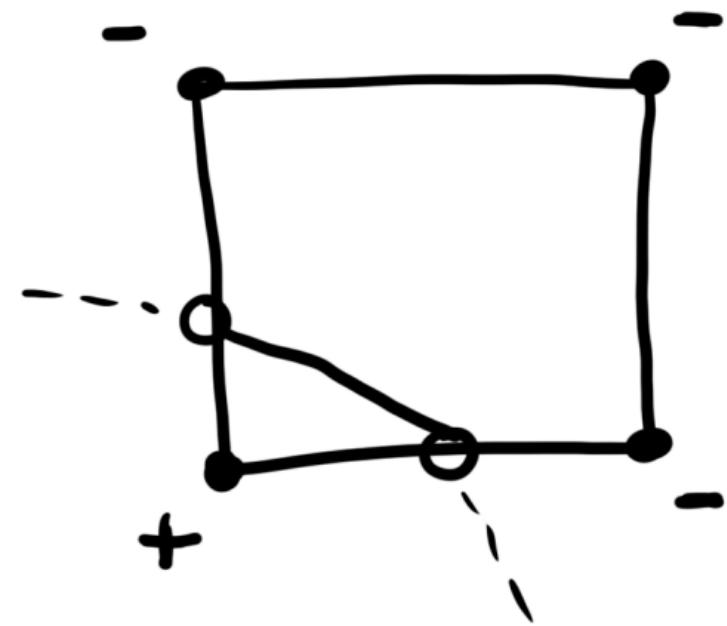


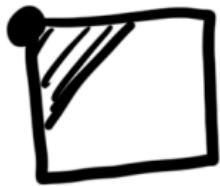












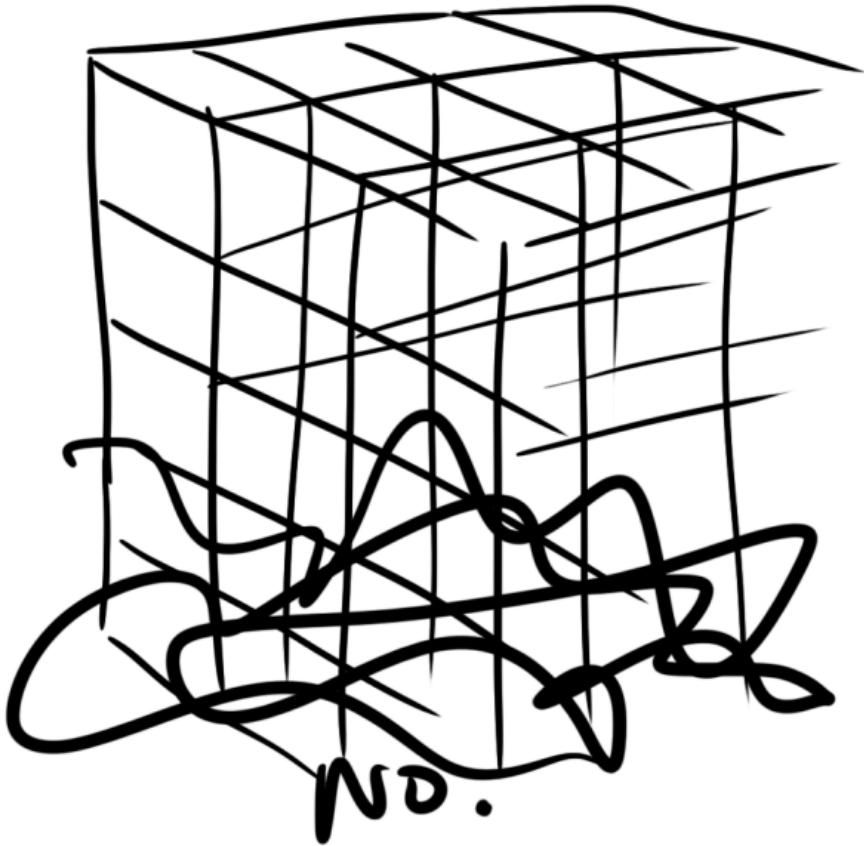
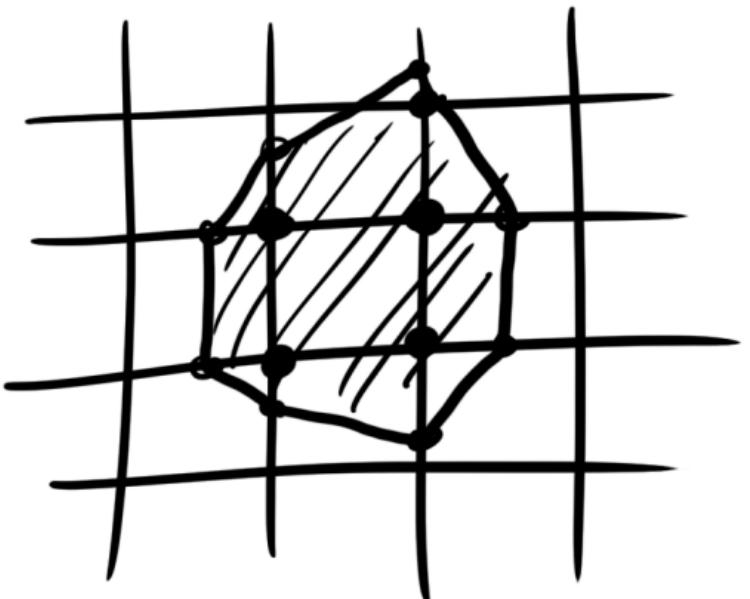
4 POINTS

$$2^4 = 16 \text{ entries}$$



8 POINTS

$$2^8 = 256 \text{ entries}$$



1999

ROTATION

z z z
· · ·

$$\begin{vmatrix} X_x & Y_x & Z_x \\ X_y & Y_y & Z_y \\ X_z & Y_z & Z_z \end{vmatrix}$$

Quaternions

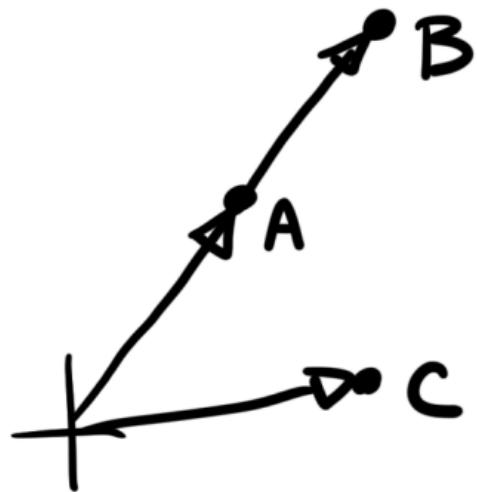
Shoemake

$$a + bi$$

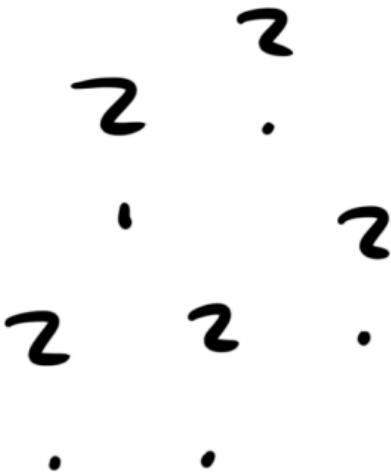
$$\omega + xi + yj + zk$$

$$|x, y, z, \omega|$$

2D



4D



William

Alexander

A then B \rightarrow C

B then A \rightarrow D

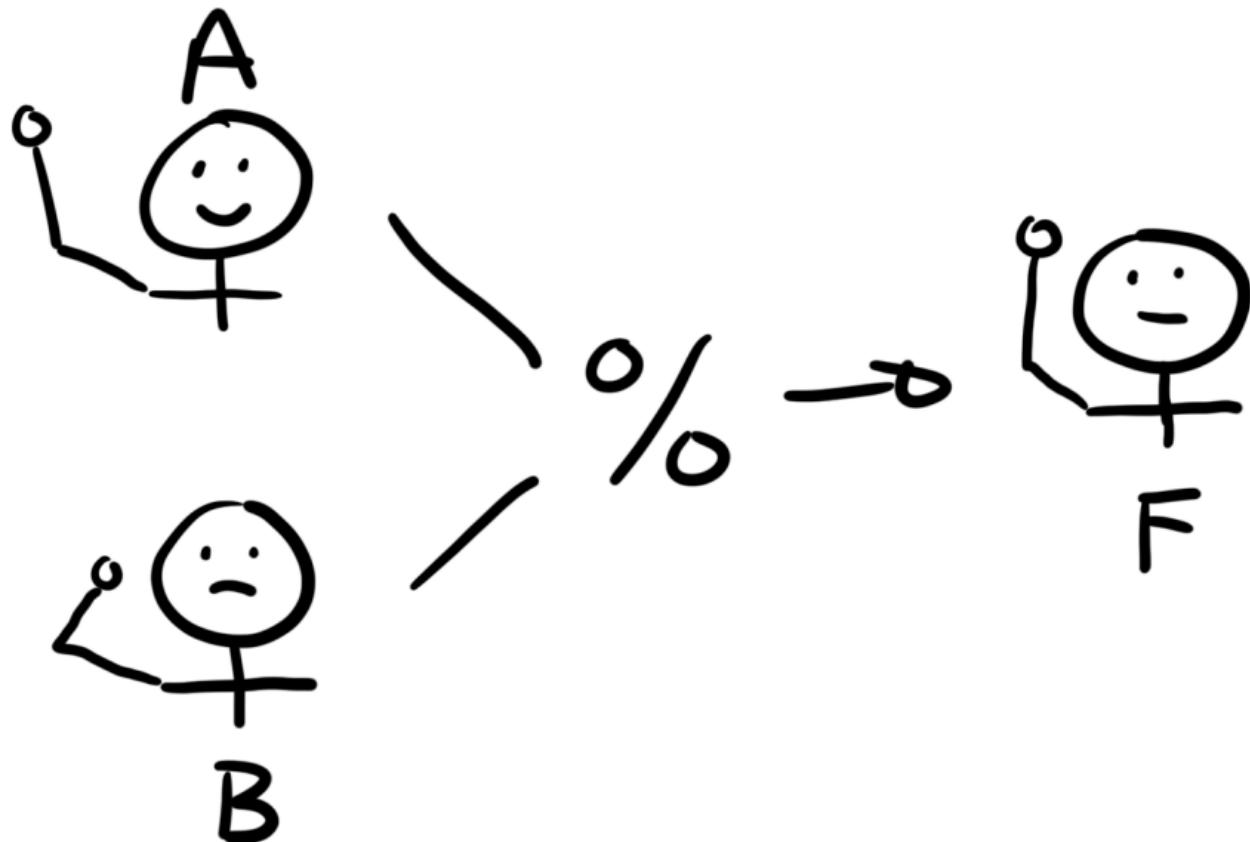
Does not commute!!

3D ROTATIONS: A then B

MATRICES: A·B

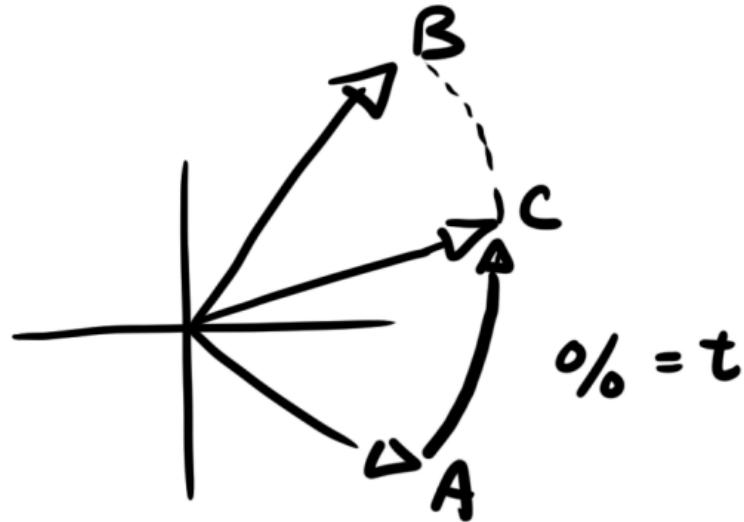
QUATERNIONS: A·B

$$(A \otimes B, B \otimes A)$$



$$f(A, t, B) = C$$

$\%$



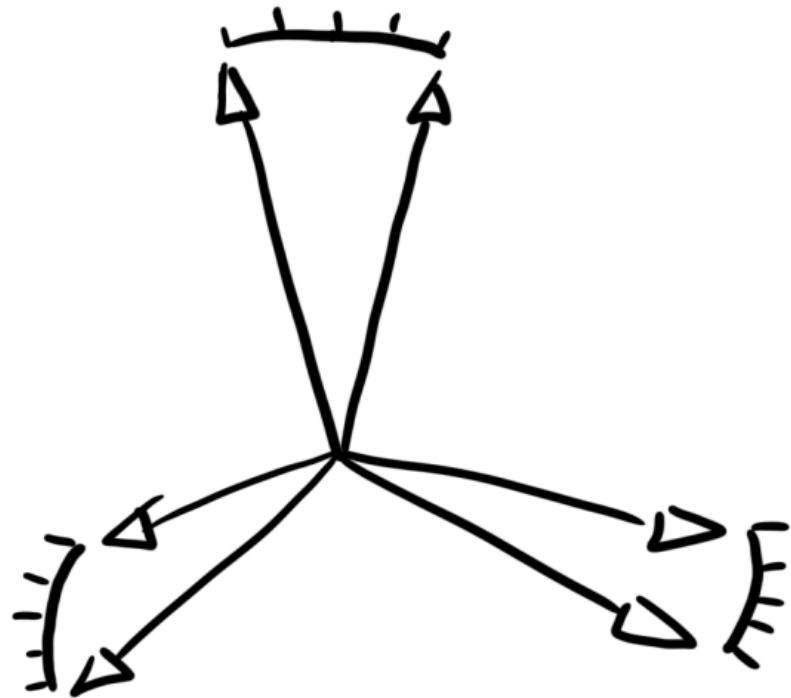
“SLERP”

$f(A, t, B)$

$f(A, B, C, D, \dots) ?$

2001

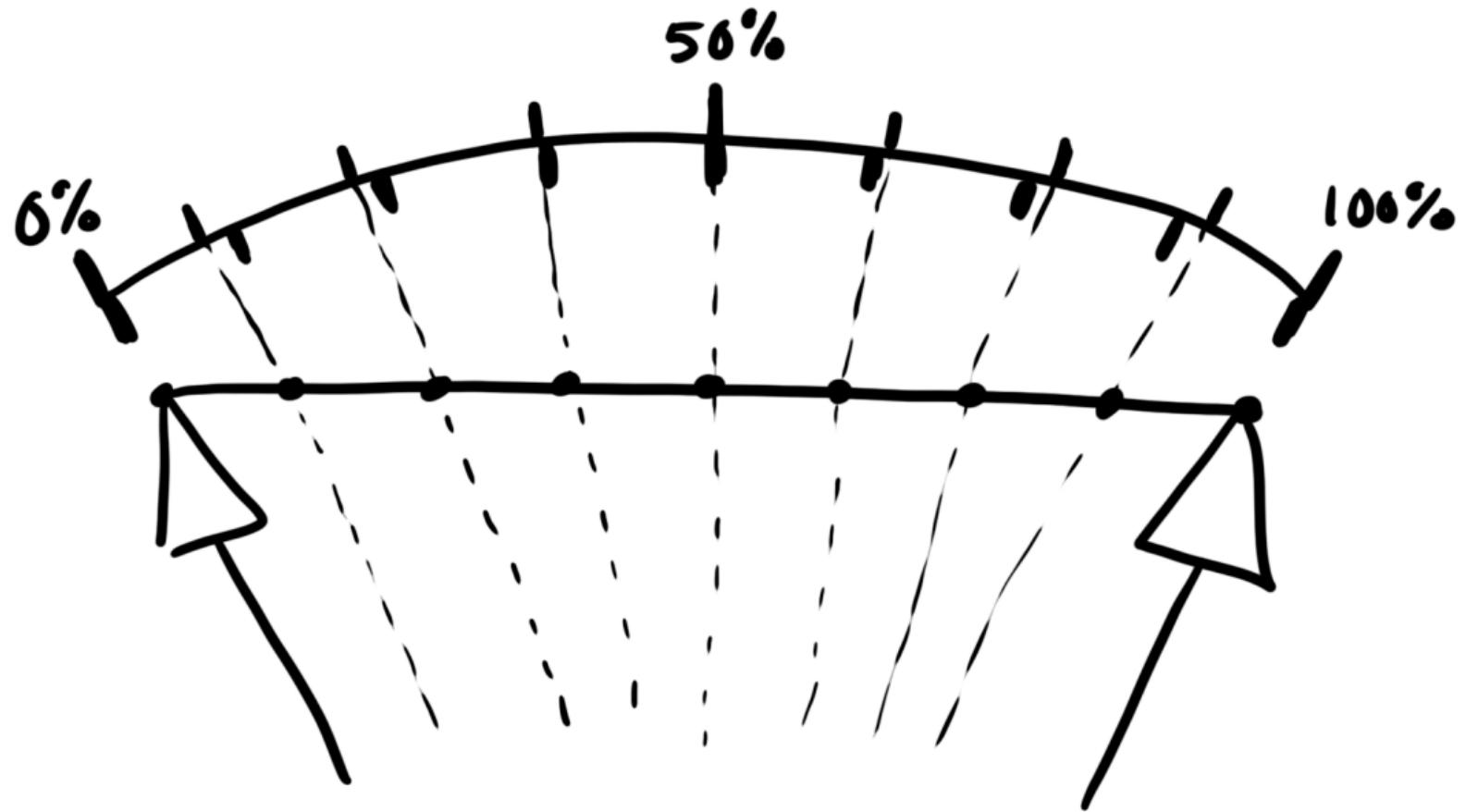
z z z z z z z z z z



- 1) MATRICES
- 2) EXPONENTIAL MAP
- 3) SLERP
- 4) LERP



- n-way blending
- faster z-way blending
- Splines
- least-squares fitting
- etc., etc.



MATRICES

$$\sin \theta$$

$$\cos \theta$$

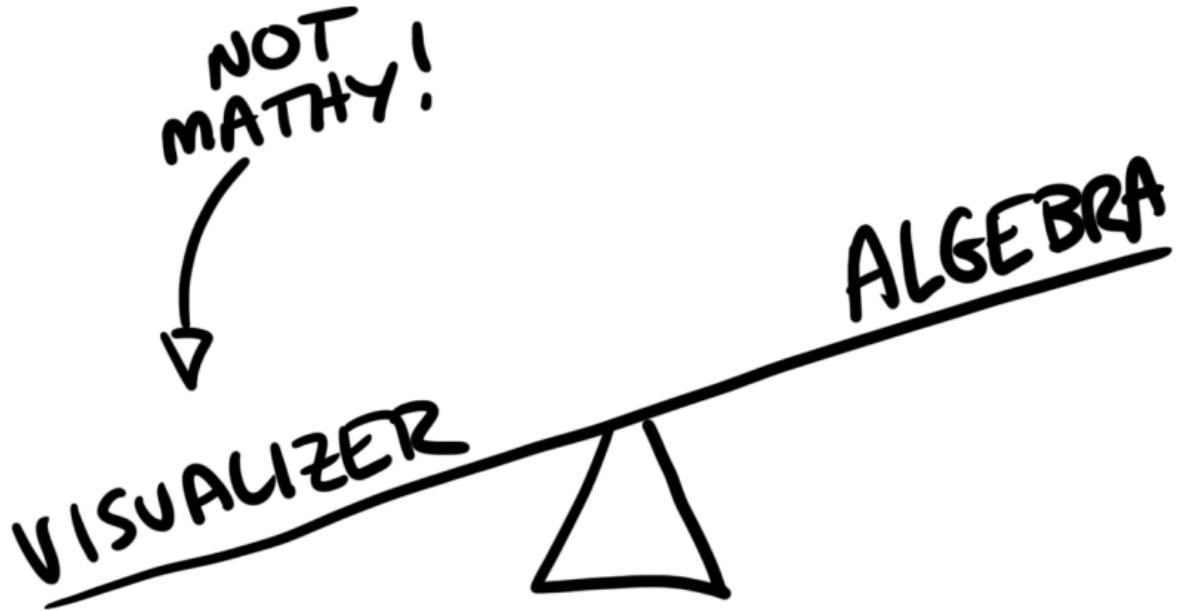
QUATERNIONS

$$\sin \frac{\theta}{2}$$

$$\cos \frac{\theta}{2}$$


DUMBEST = BEST

(in this case ;)

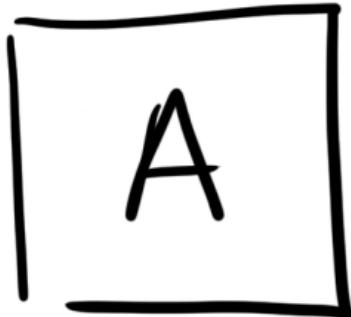


2003

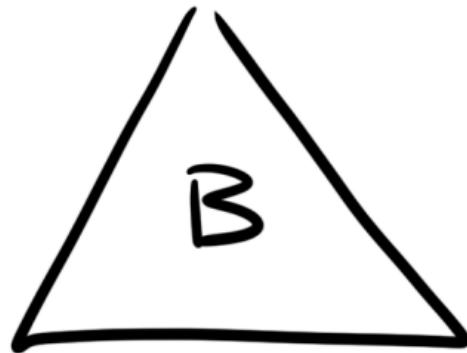
A FAST PROCEDURE
FOR COMPUTING THE DISTANCE
BETWEEN COMPLEX OBJECTS
IN THREE-DIMENSIONAL SPACE

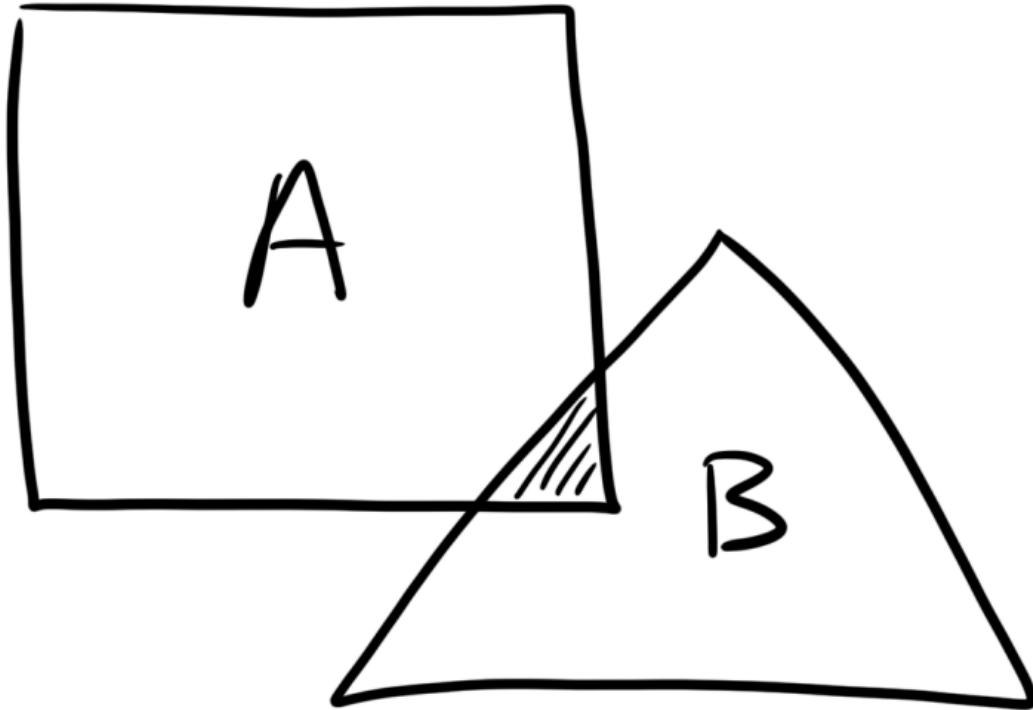
GILBERT, JOHNSON, & KEERTHI

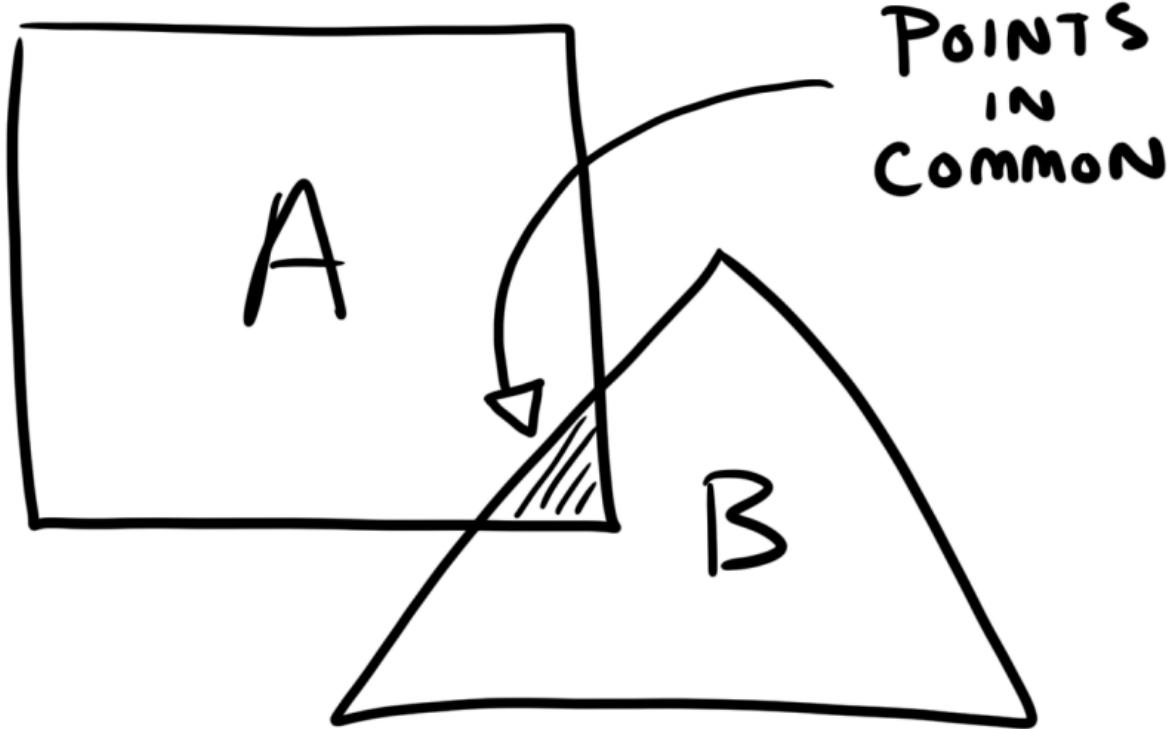
FULL
BANANACAKES



z -







If A intersects B ,

$$a = b$$

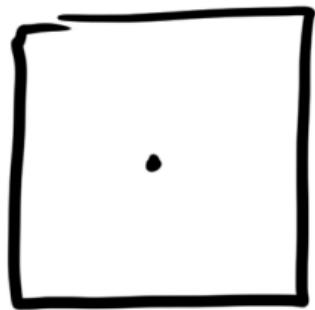
$$a \in A$$

$$\boxed{a - b = \emptyset}$$

$$b \in B$$

MINKOWSKI

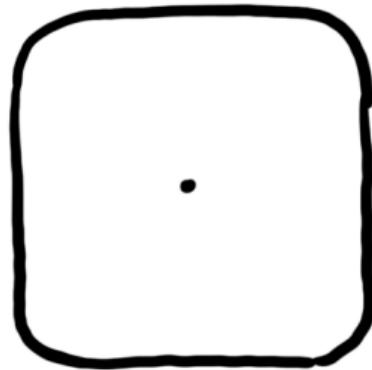
Sum

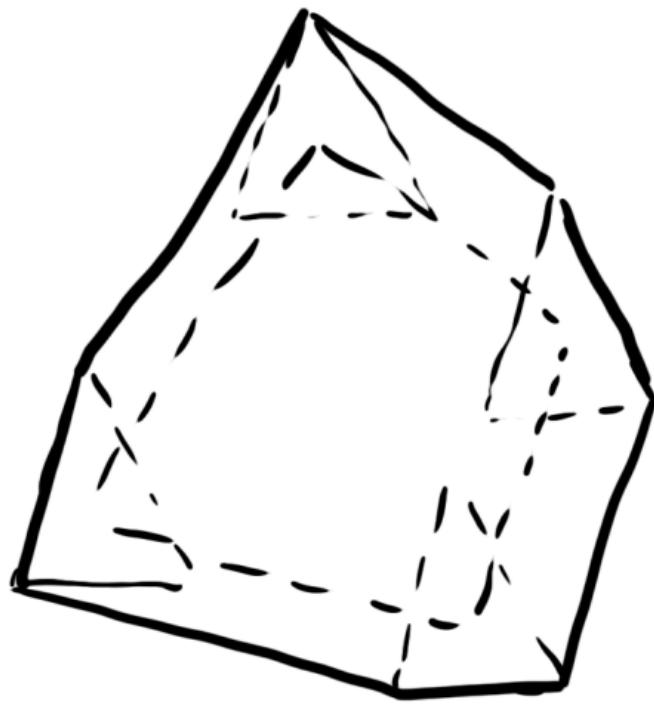
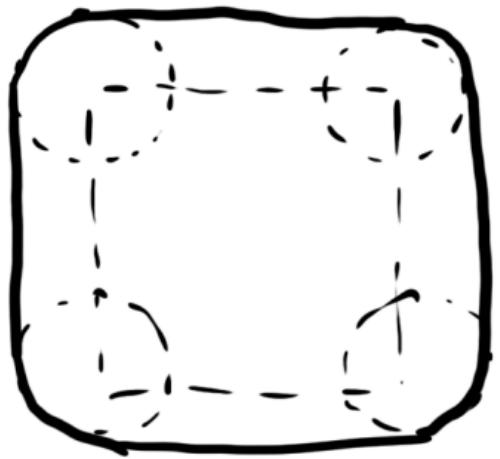


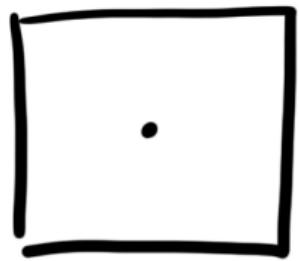
+



=



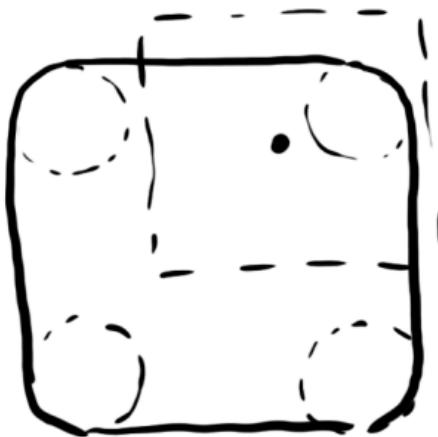




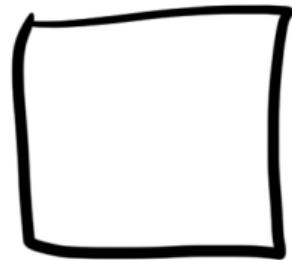
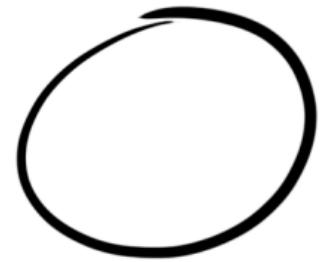
+



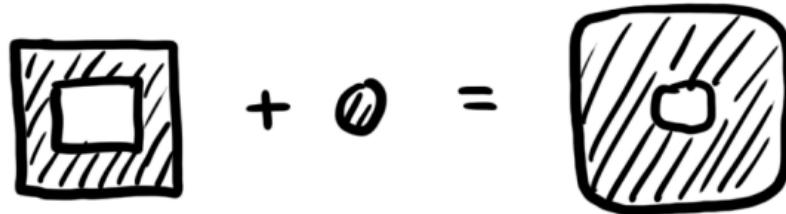
=



$$\begin{array}{c} \square \\ \cdot \quad - \quad \cdot \quad \circ \end{array} \quad \left. \right\} = \quad \boxed{\begin{array}{c} \square \\ \cdot \quad + \quad \circ \end{array}} \quad \begin{array}{l} \text{SUM'S} \\ \text{ORIGIN} \end{array}$$

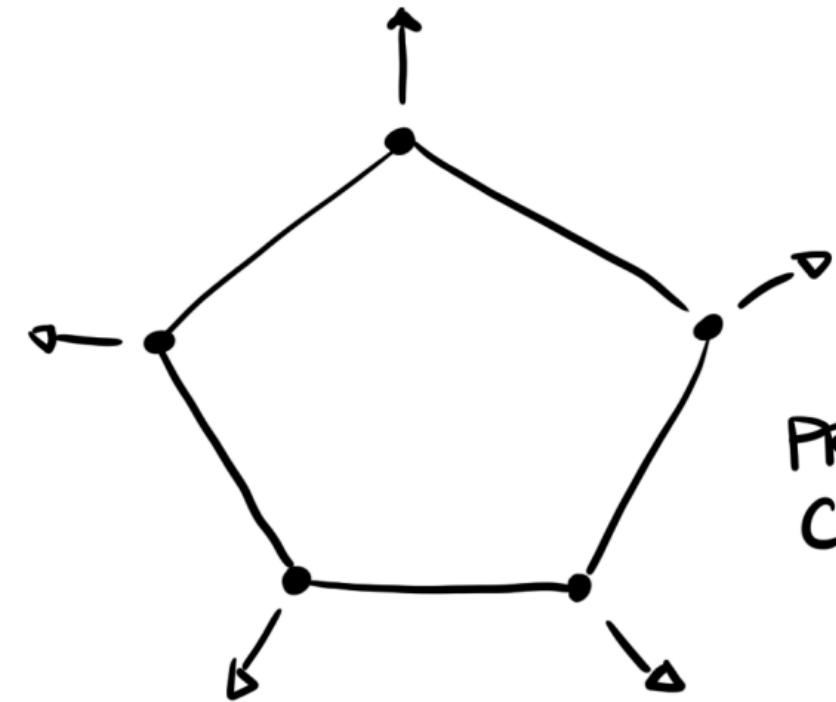


CONCAVE :

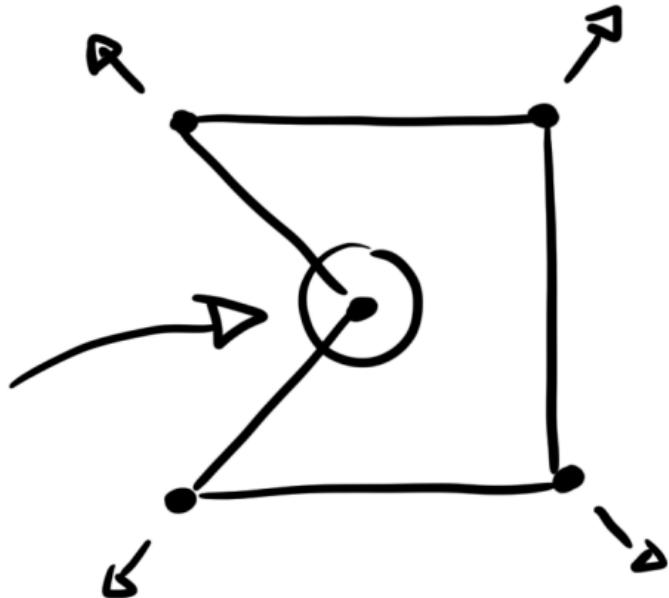


CONVEX :

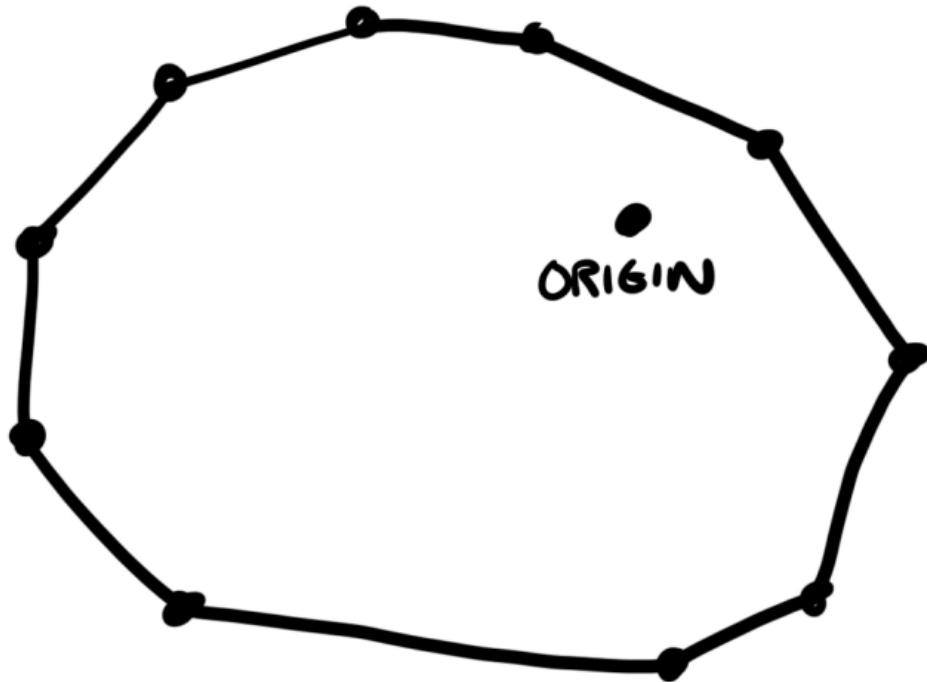


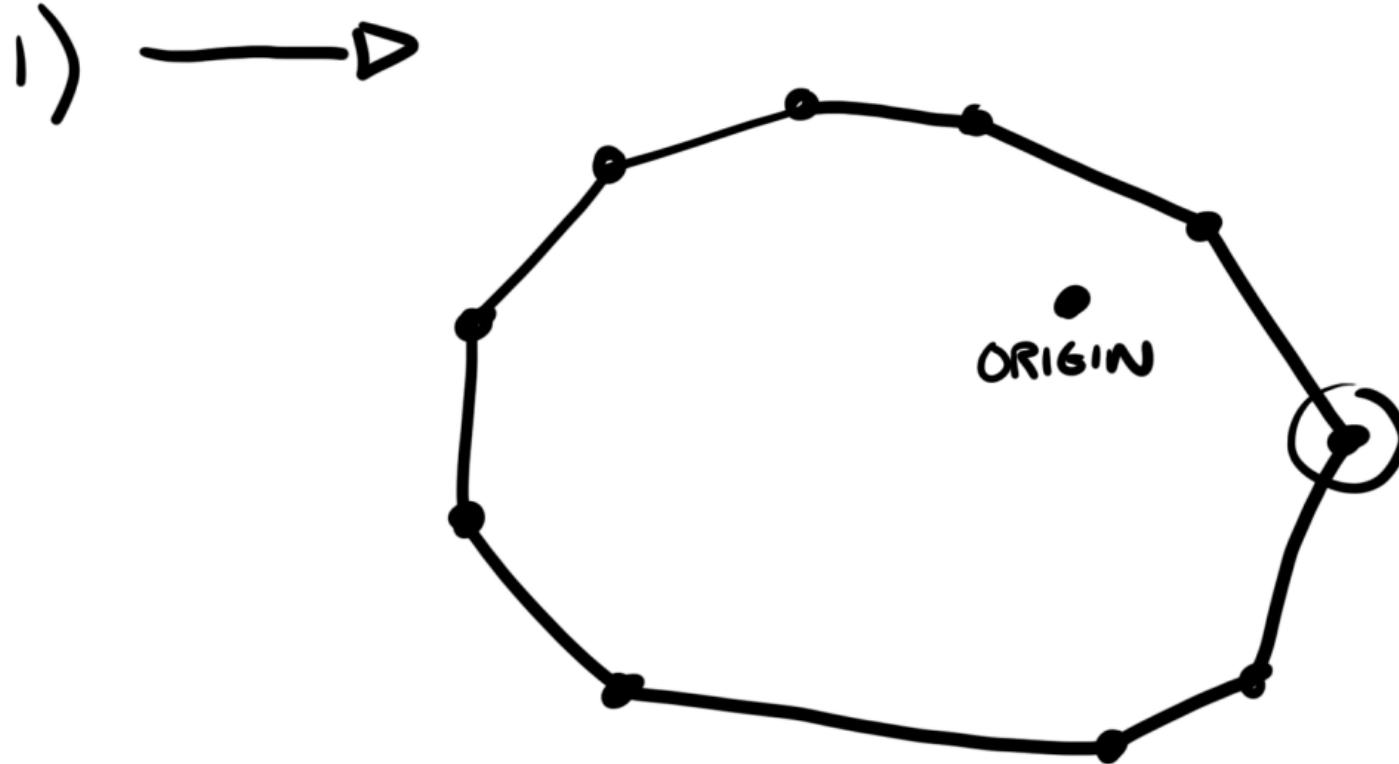


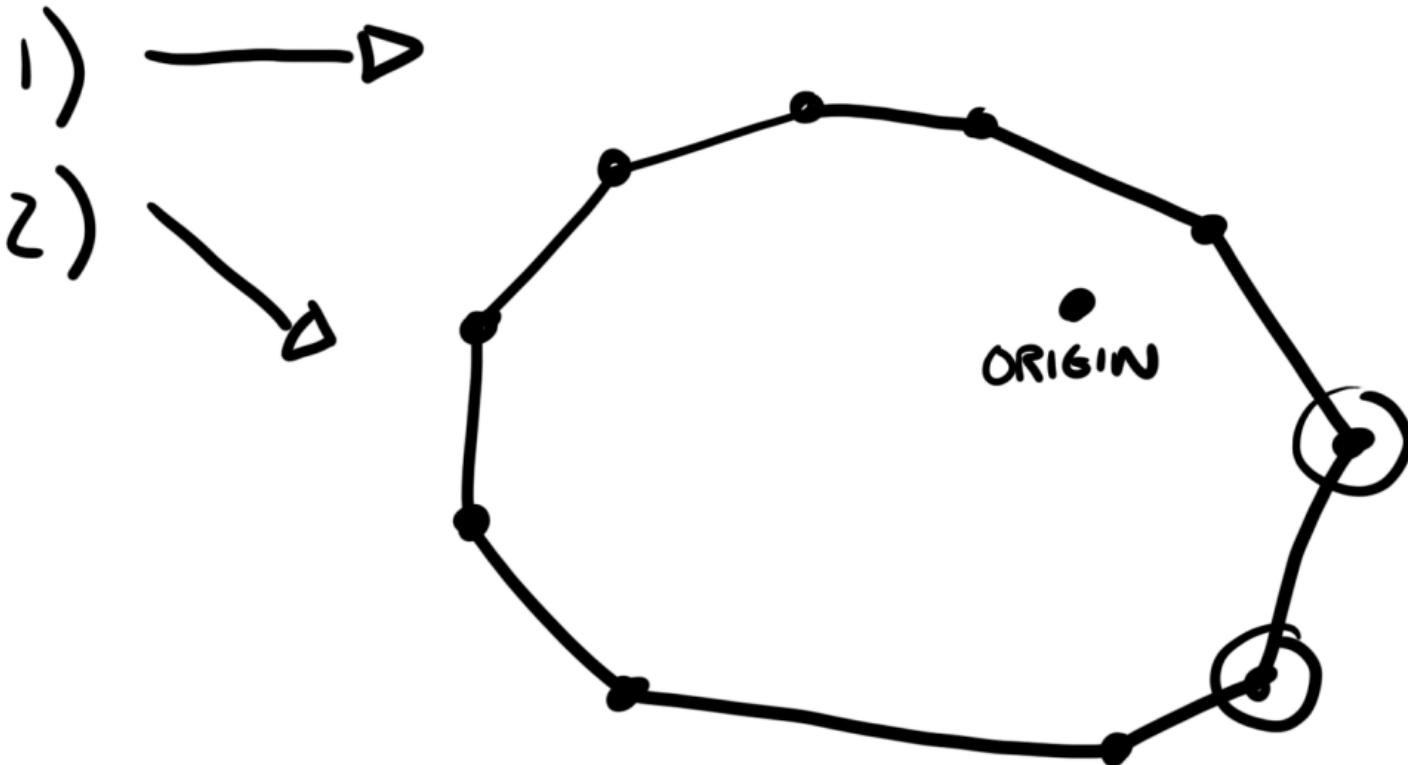
PROBLEM
CHILD

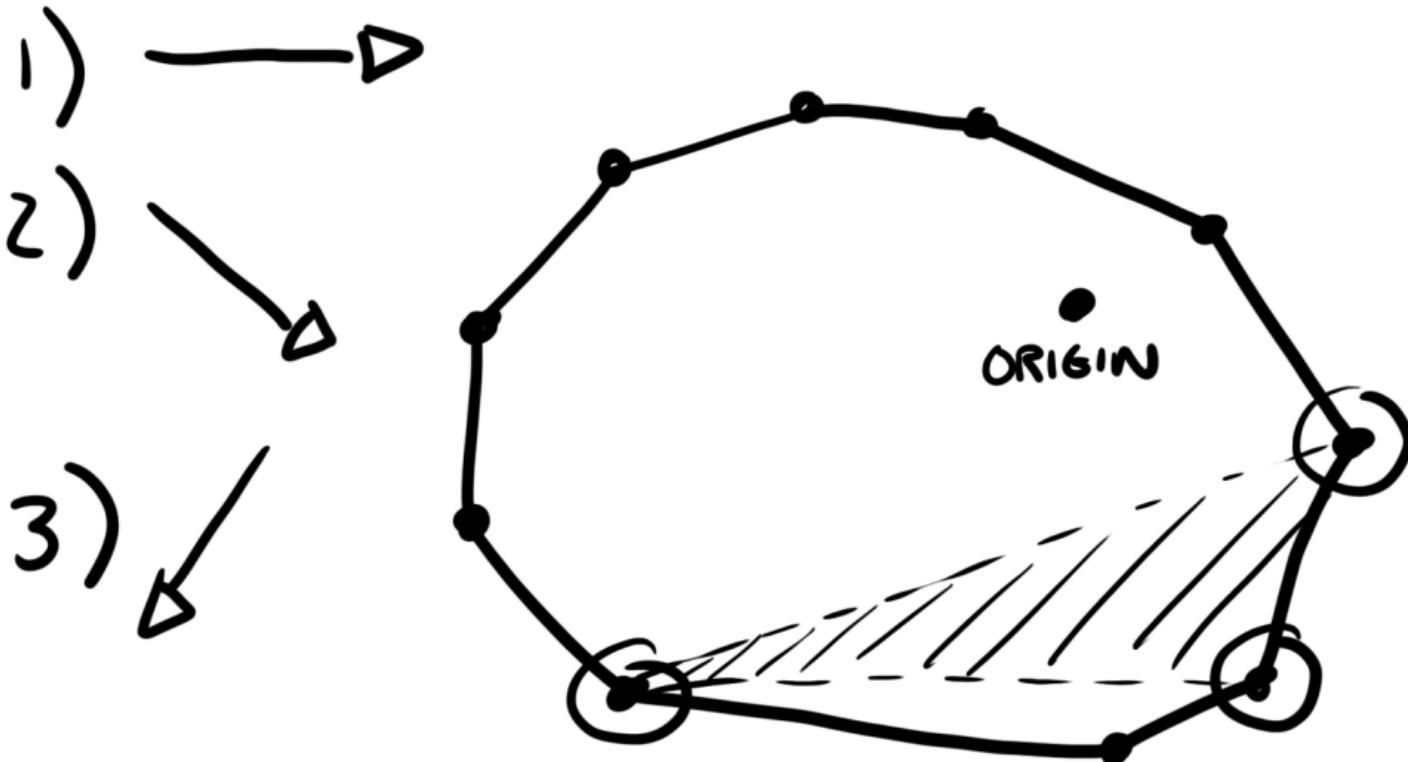


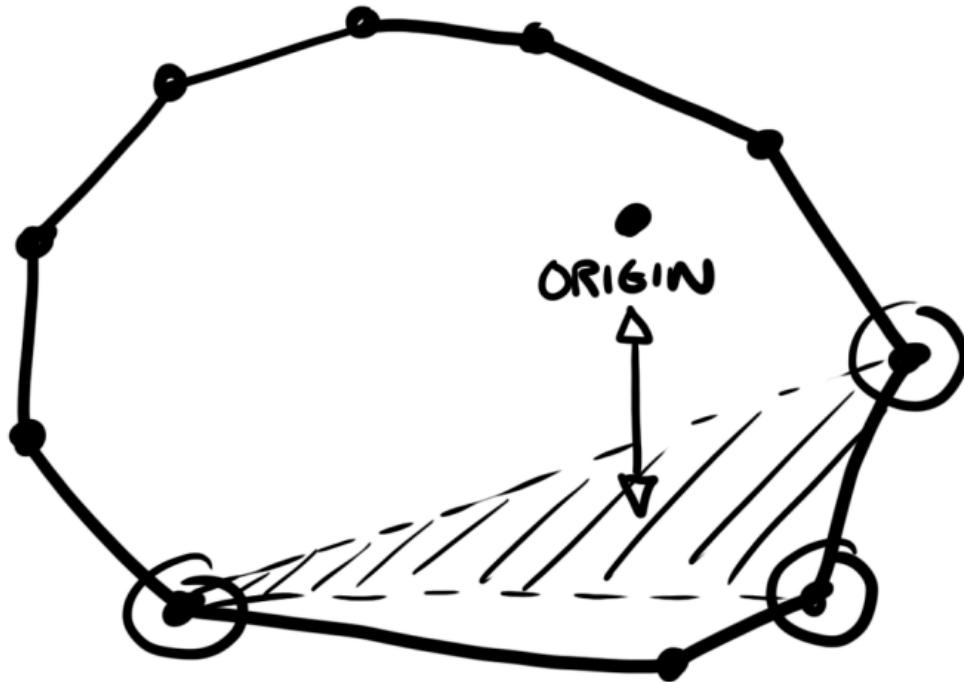
WHO
CARES?



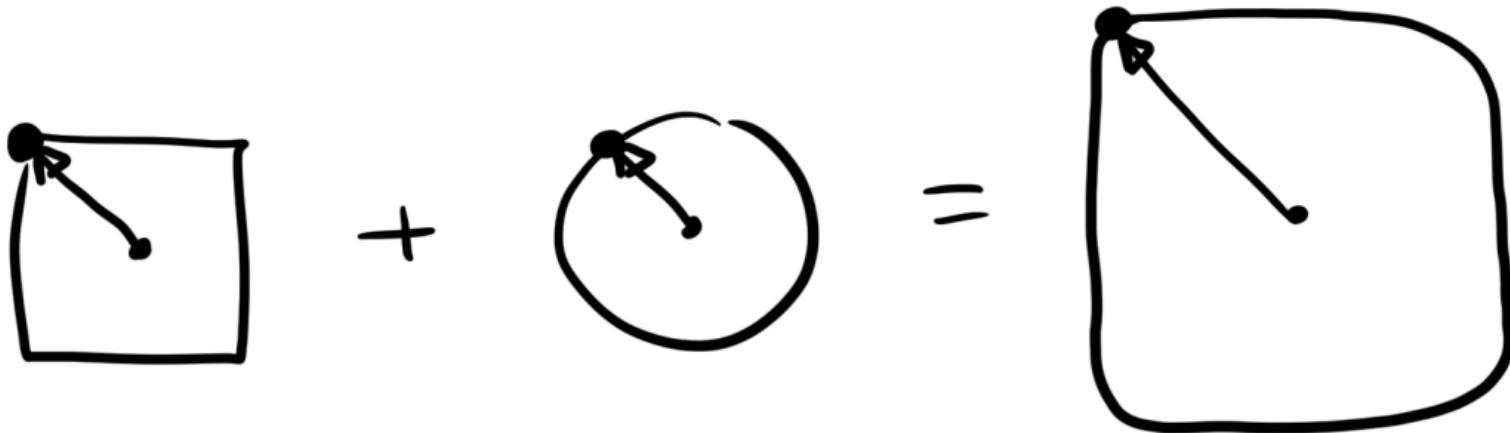


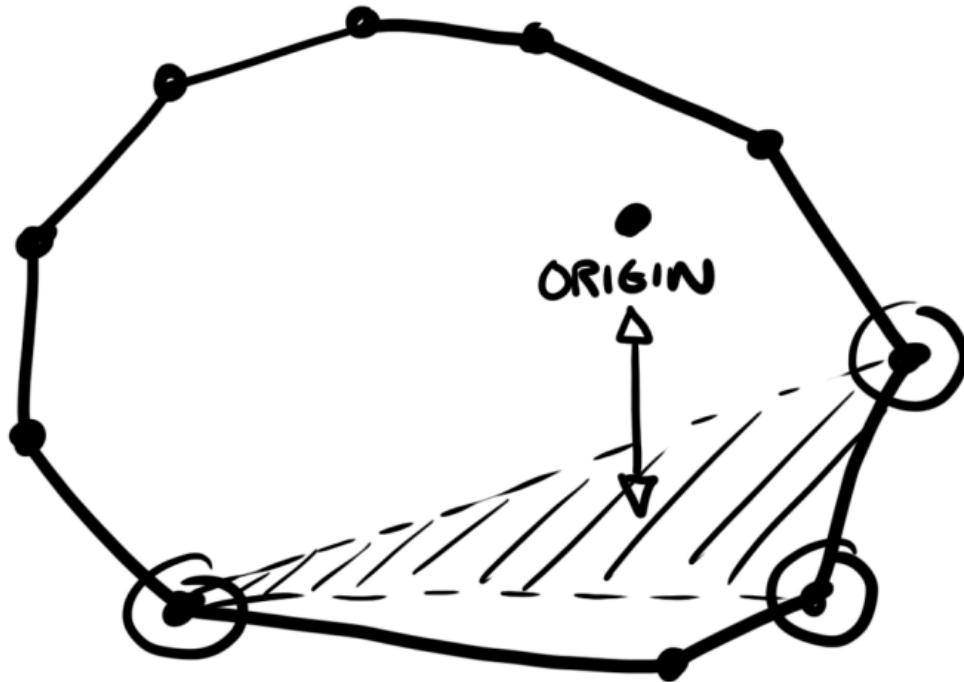






SUPPORT FUNCTION

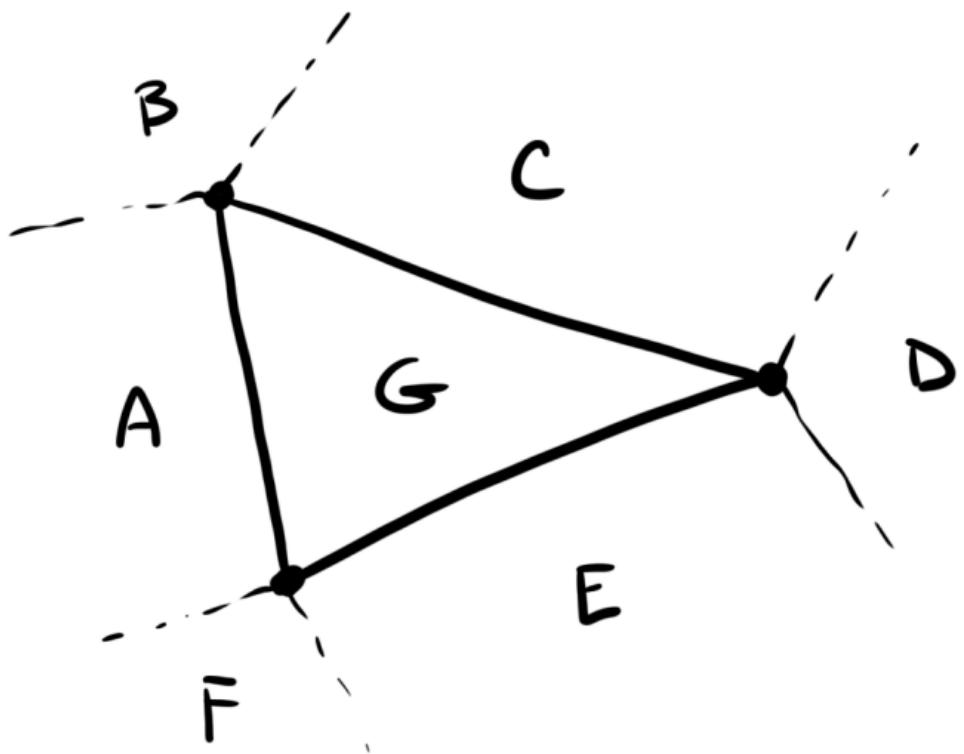




JAY STELLY

VALVE SOFTWARE

"VORONOI REGION"



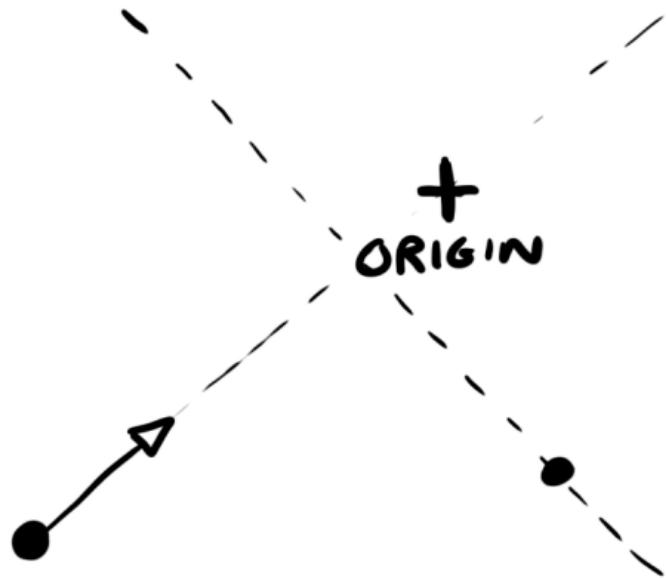
$\text{Support}(\text{dir}) \rightarrow p \text{ on sum's}$
 surface

1) any support direction (↙)

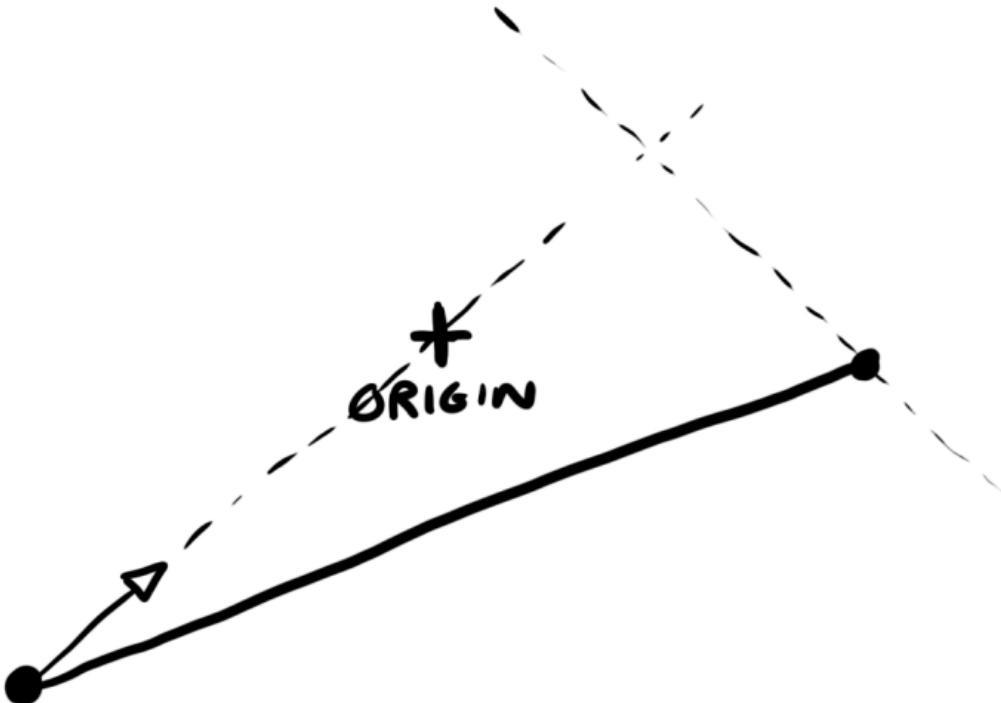
+
ORIGIN



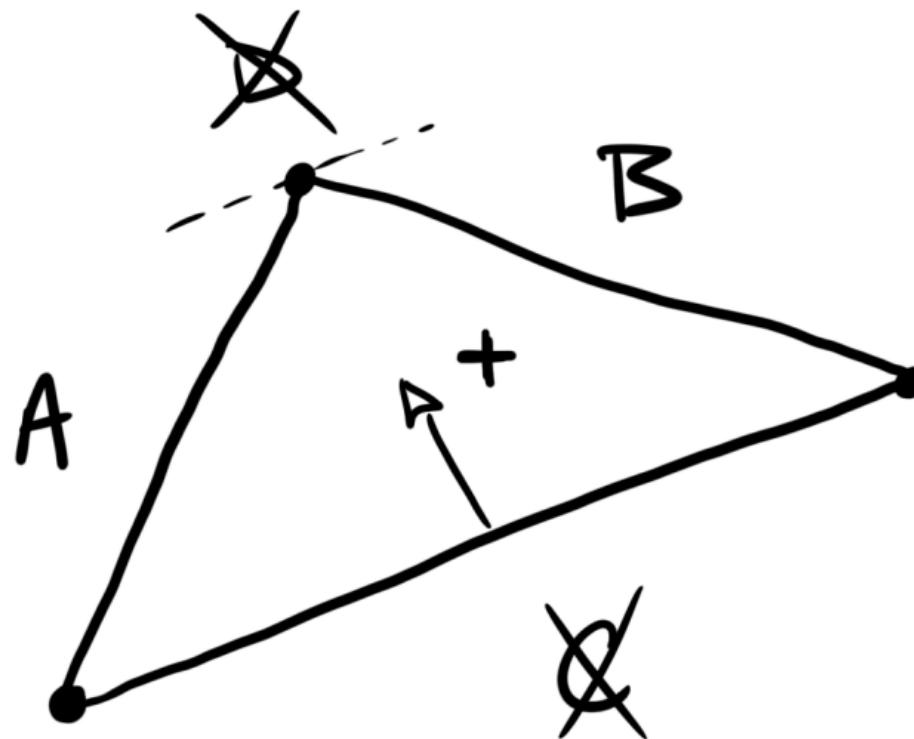
z) origin direction



z) origin direction



3) perpendicular toward origin

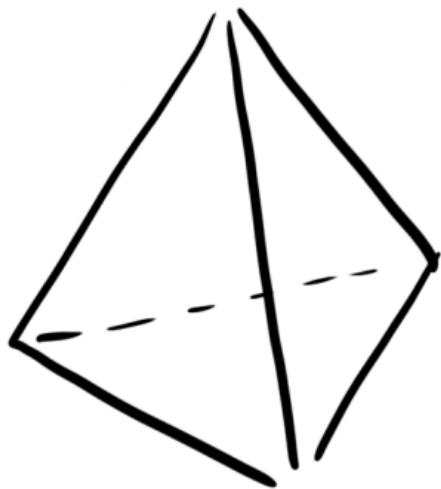


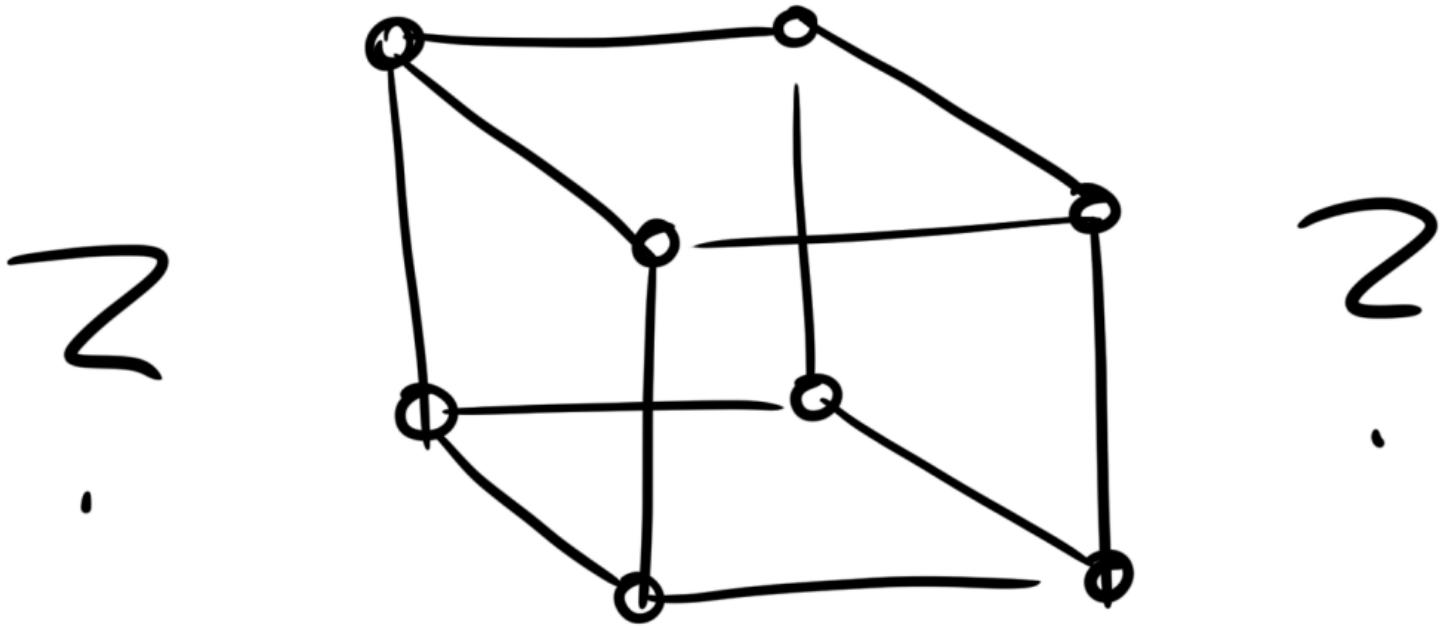
THAT'S
GJK!

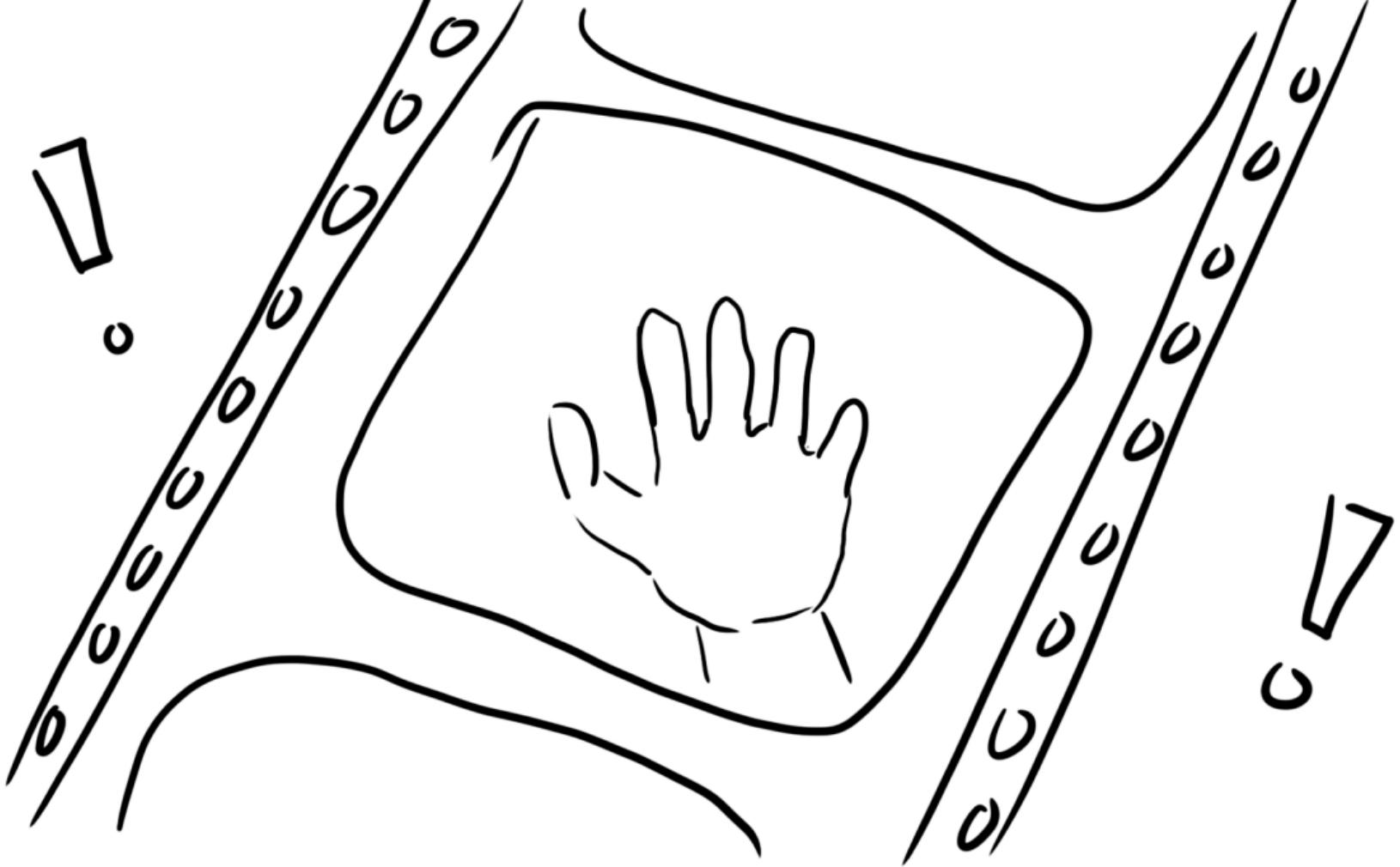
ANY CONVEX SUM!



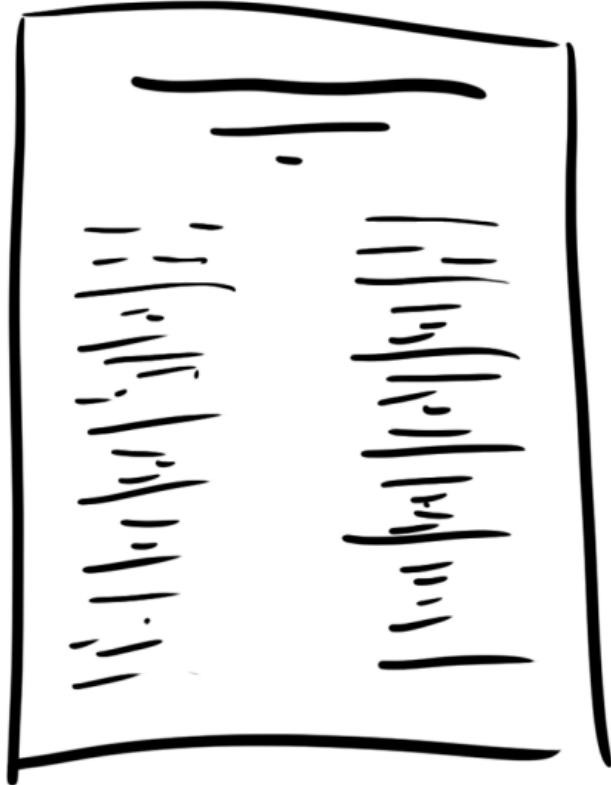
3D!







THE
WITNESS



Casey Muratori
Molly Rocket, Inc.

@cmuratori

molly1935.com
handmadehero.org