



Contact Manifolds

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Executive Summary

- ④ Constraint solvers need contact points to prevent penetration.
- ④ We can use SAT to compute a contact manifold in one shot.
- ④ We can use GJK to build up a contact manifold point-by-point.



Contact

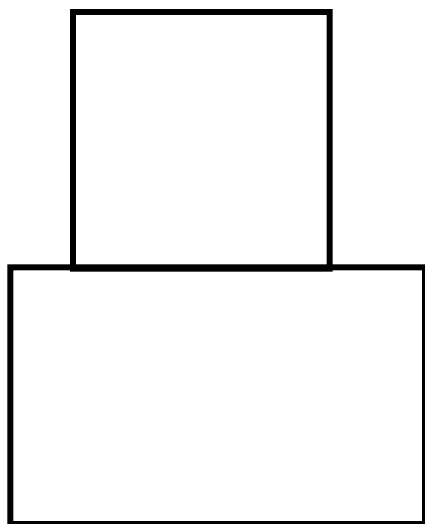
- ③ Contact occurs when two shapes touch.
- ③ We model contact to prevent penetration and to simulate friction.
- ③ Modeling contact requires some geometry and a lot of *finesse*.



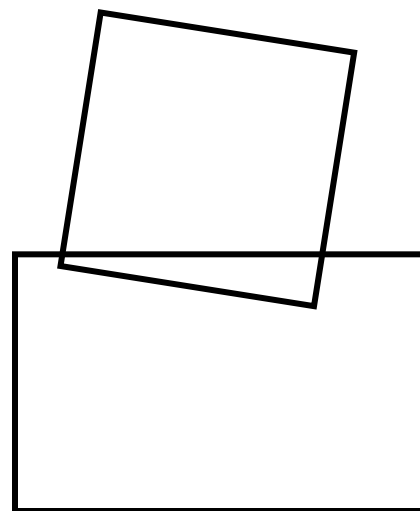
Contact Manifolds

- ④ For convex polyhedra, a contact manifold is ideally a single point, a line segment, or a convex polygon.
- ④ For general convex 3D shapes, the contact manifold is a convex 2D shape.
- ④ Did I mention overlap?

Overlap Happens



What we want.



What we get.

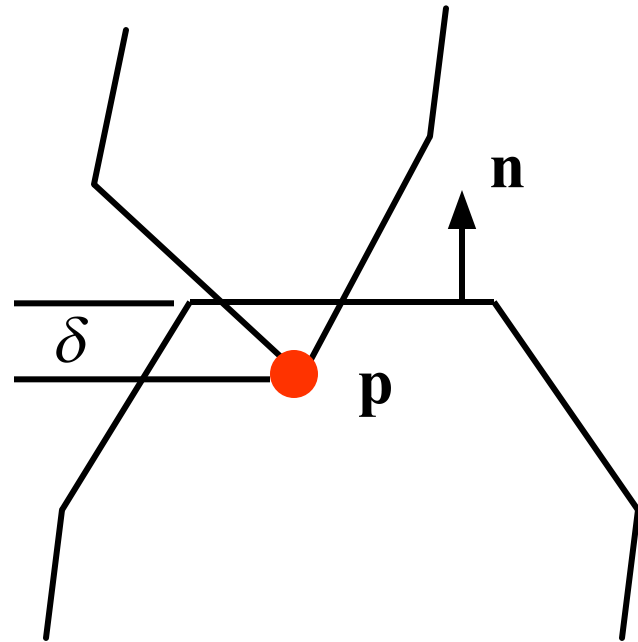


Approximate Manifolds

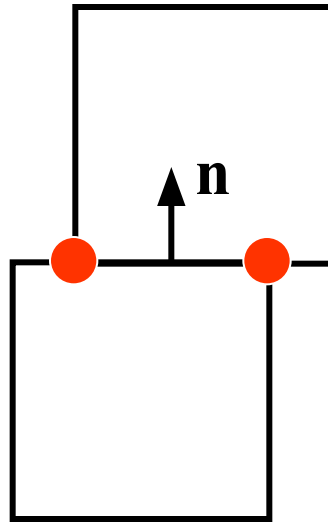
- ④ We use a collection of *contact points* to approximate the contact manifold.
- ④ Our goal is fast, stable, and plausible simulation.
- ④ In this sense, computing good manifolds is an art.

Contact Points

- ④ Position
- ④ Normal
- ④ Penetration
- ④ Contact ID



Example Manifold



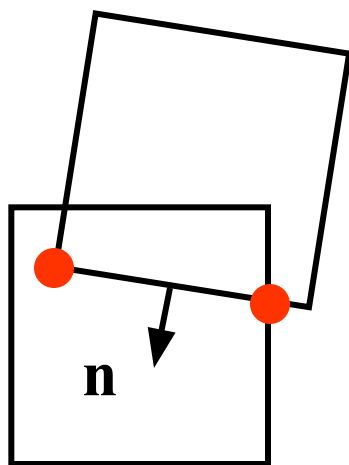
Two points and a common normal



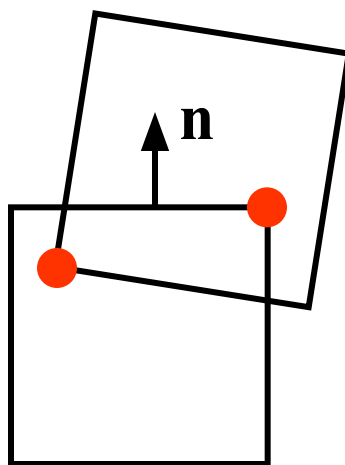
Contact Manifold Quality

- ③ When objects penetrate significantly the contact manifold is fuzzy.
- ③ Contact solvers like coherence.
- ③ Be consistent from step-to-step.

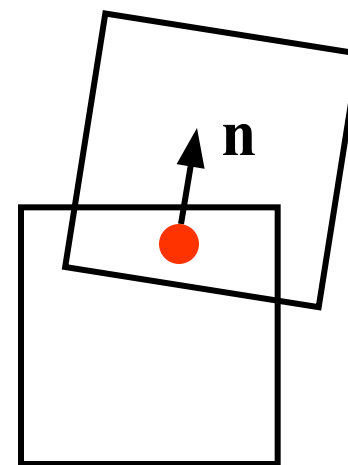
Fuzziness



manifold 1

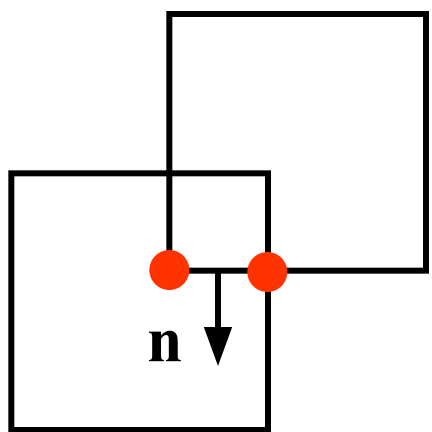


manifold 2

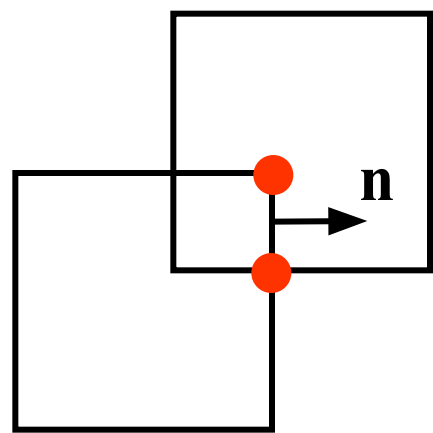


manifold 3

Extreme Fuzziness



manifold 1



manifold 2

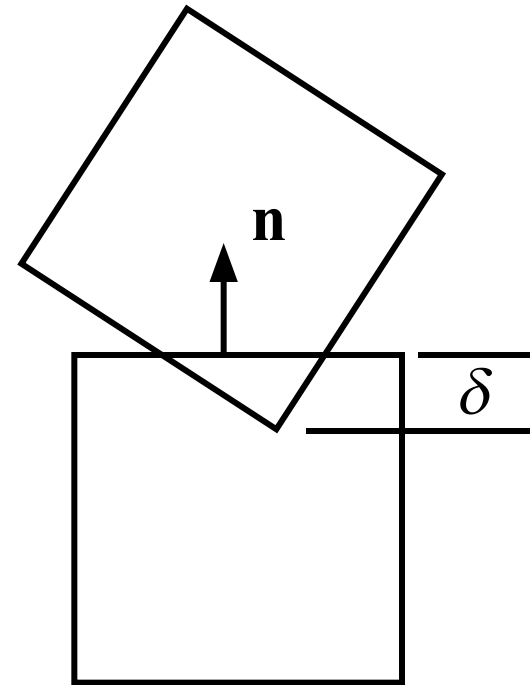


Using the SAT

- ④ Mainly useful for convex polyhedra (boxes, triangles, etc).
- ④ Find the axis of minimum penetration.
- ④ For edge-edge contact, find the midpoint.
- ④ For face contact, use Sutherland-Hodgeman clipping.

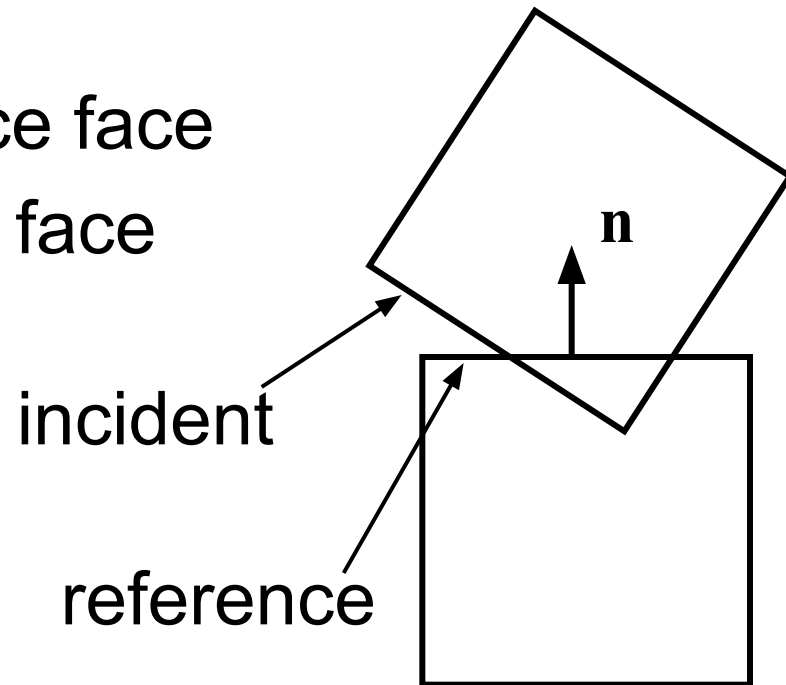
Example: 2D Box-Box SAT

- First find the separating axis with the minimum penetration.
- In 2D the separating axis is a face normal.



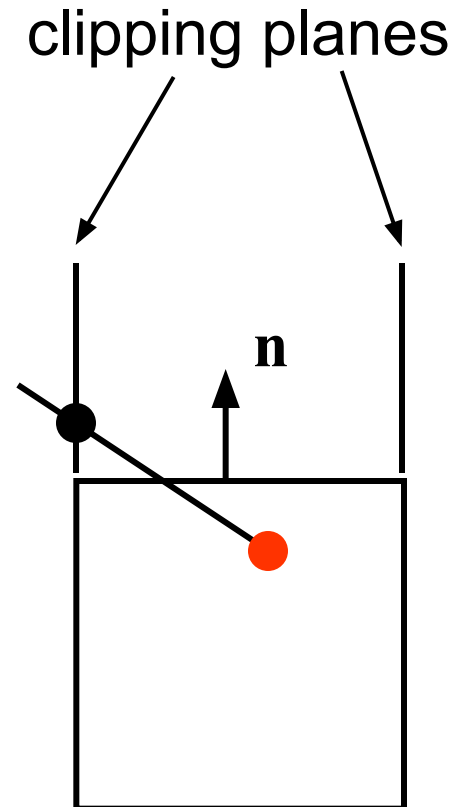
Box-Box Clipping Setup

- Identify reference face
- Identify incident face



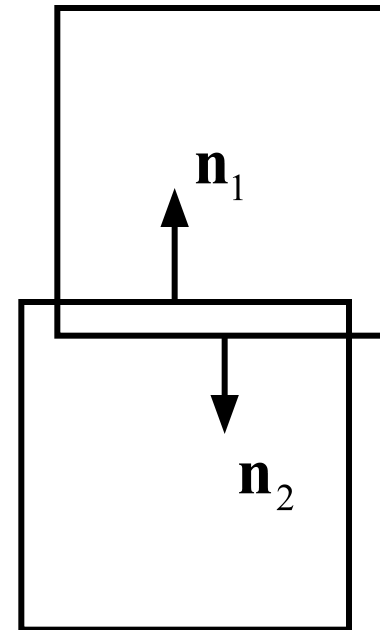
Box-Box Clipping

- Clip incident face against reference face side planes (but not the reference face).
- Consider clip points with positive penetration.



Feature Flip-Flop

- Which normal is the min separating axis?
- Apply weightings to prefer one axis over another.
- Improved coherence.





Coherence

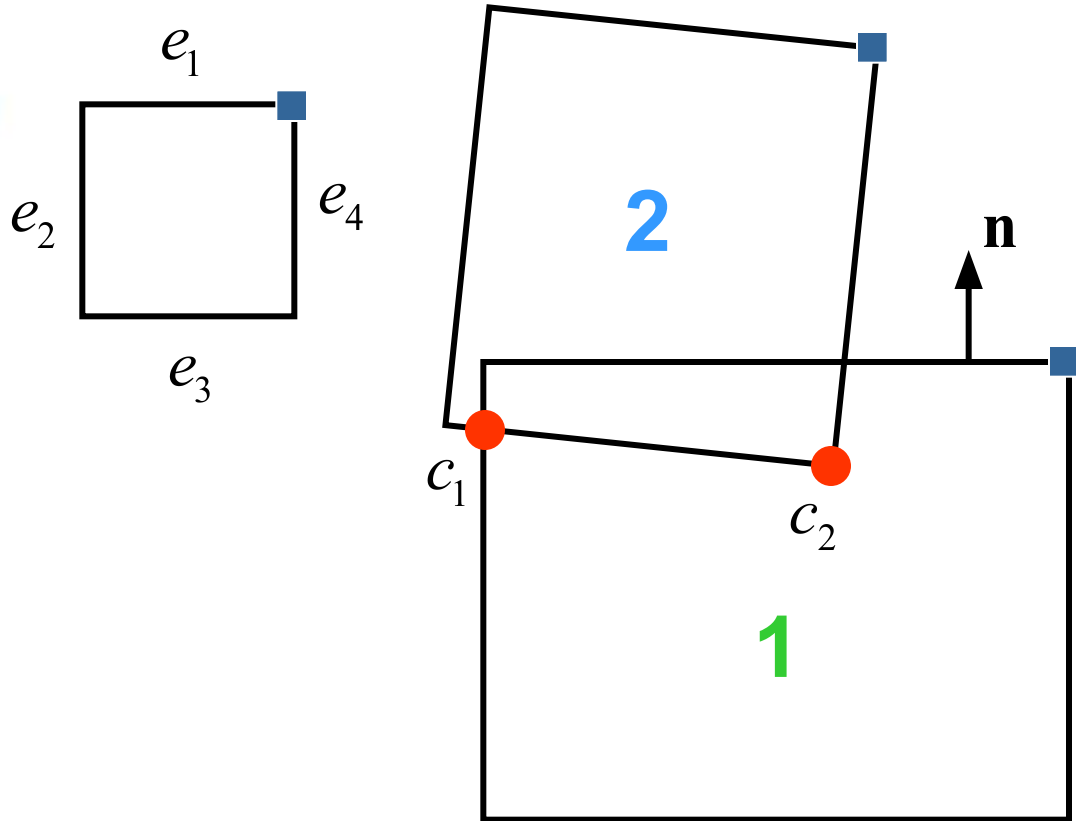
- ④ Apply old force/impulse solution at the beginning of the step.
- ④ Fewer iterations and greater stability.
- ④ We need a way to match old and new contacts.



Feature-Based Contact Points

- ④ Each contact point is the result of clipping.
- ④ It is the junction of two different edges.
- ④ An edge may come from either box.
- ④ Store the two edge numbers with each contact point – this is the Contact ID.

Contact Point IDs



- c_1
- box 1 edge 2
- box 2 edge 3
- c_2
- box 2 edge 3
- box 2 edge 4



GJK Contact Points

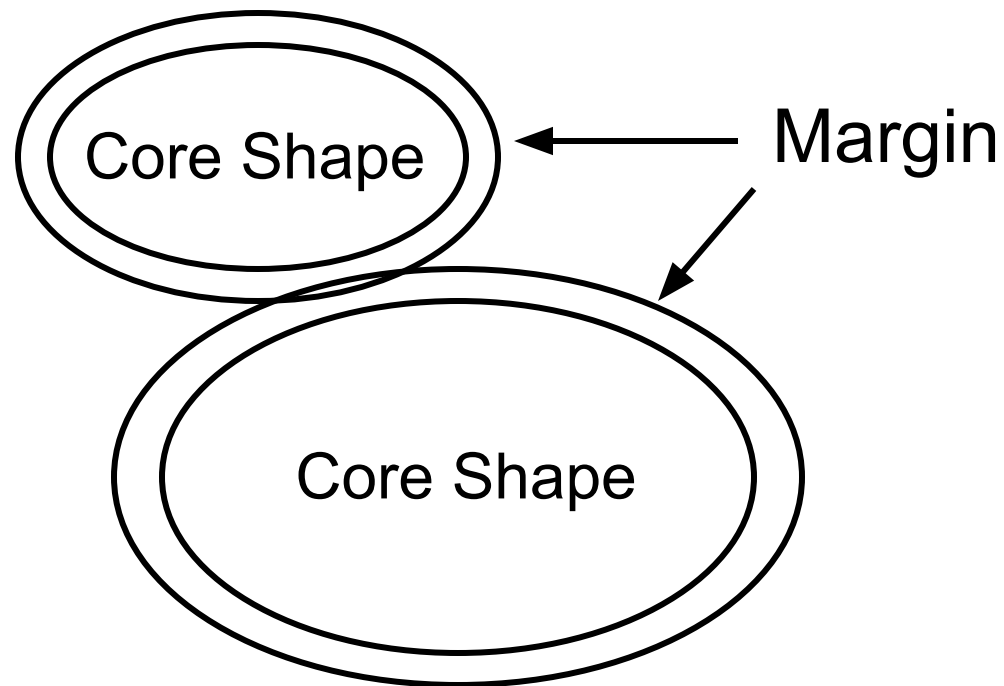
- ④ Three cases:
 - No contact
 - Shallow contact
 - Deep contact



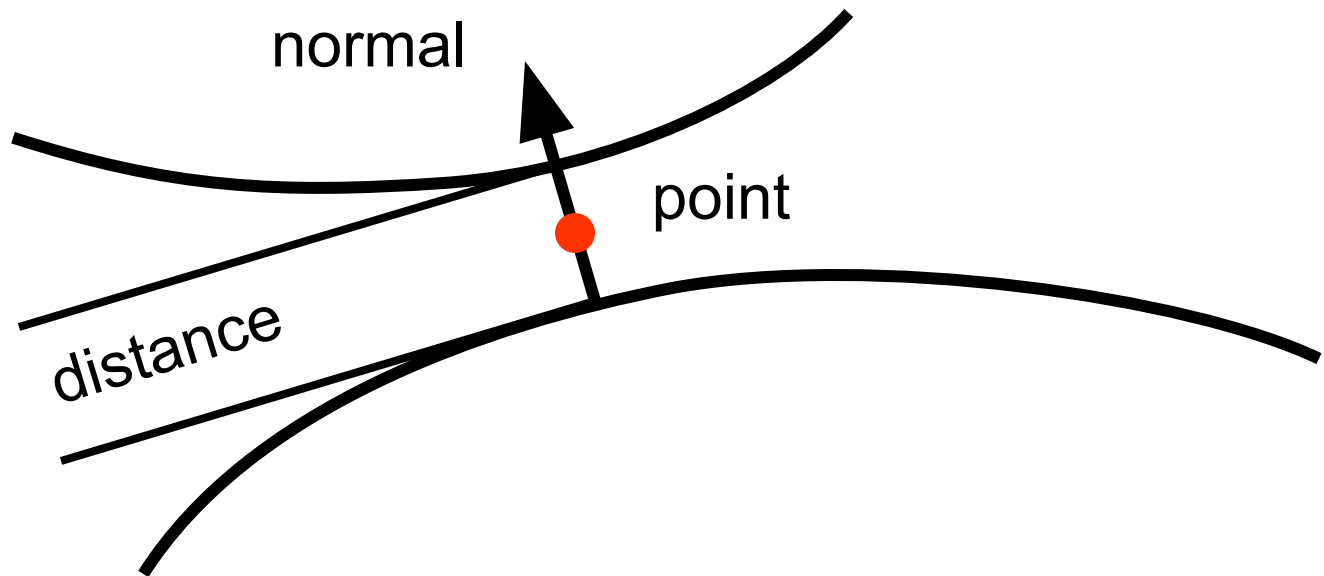
GJK Shallow Contact

- ④ The support points are scaled up by a small margin to detect contact.
- ④ Compute the closest points (no margin).
- ④ This gives the position and normal.
- ④ The penetration is the margin minus the true distance.

GJK Contact Margins

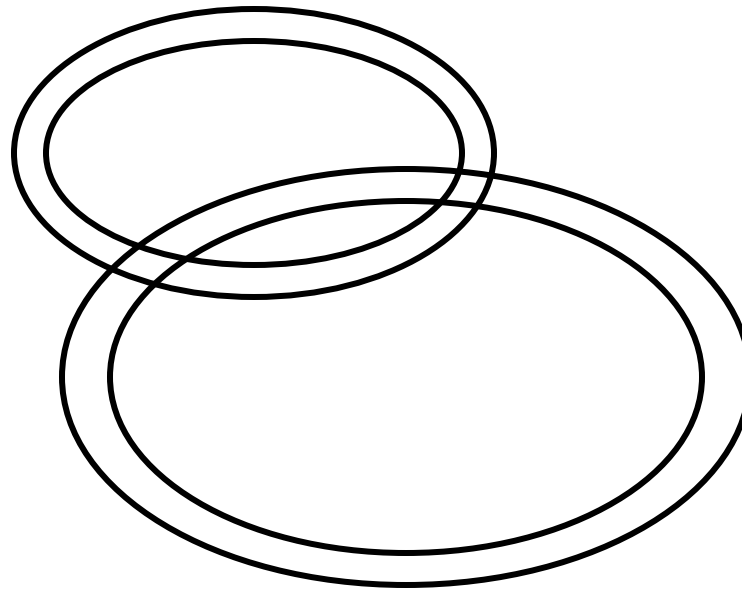


GJK Contact Point





GJK Deep Contact



An awkward encounter ...



Deep Contact

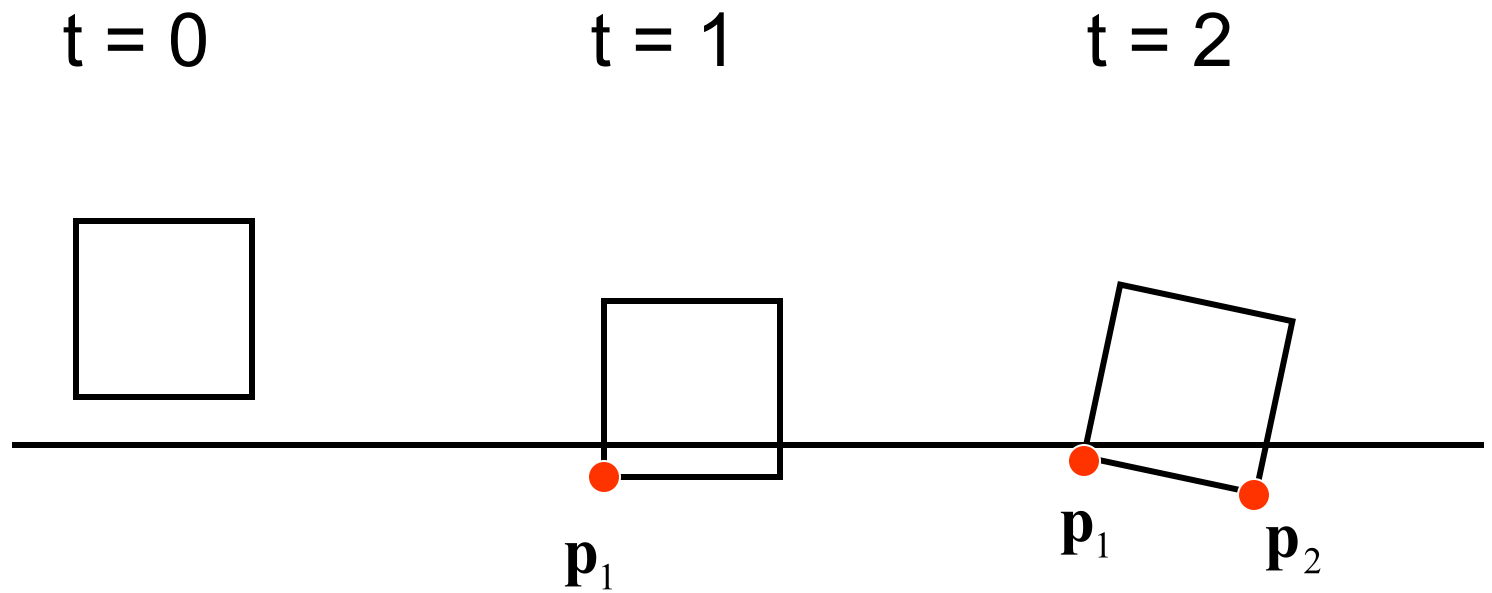
- ④ Use some *other* algorithm.
- ④ It will be slower than GJK, but it won't last long.
- ④ SAT, EPA, brute force.
- ④ Read Gino's book to learn EPA.



GJK Manifolds

- ④ GJK only gives one contact point at a time.
- ④ We hold on to and *treasure* each contact point.
- ④ Build a manifold over several time steps.
- ④ This automatically provides coherence.

Building the Manifold





Manifold Persistence

- ④ Track the points in each body.
- ④ If the points move too far apart, dismiss them.
- ④ This is bad for sliding.
- ④ Use Contact IDs?



Adding New Points

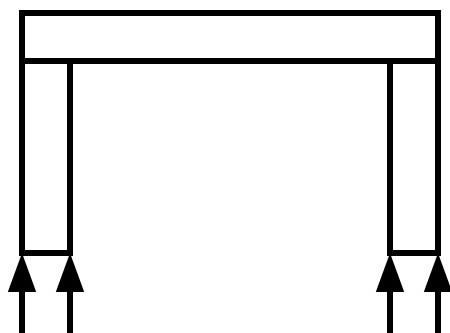
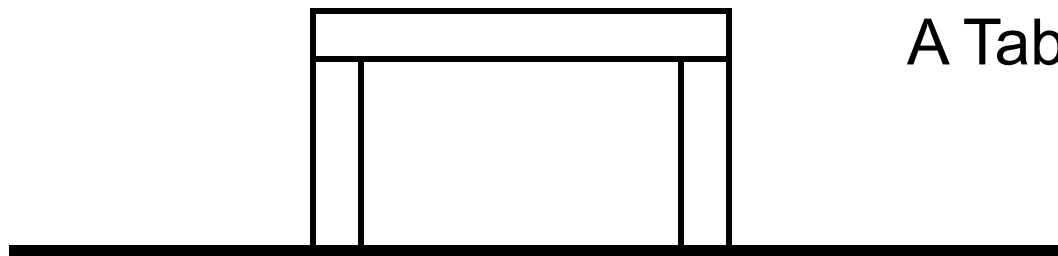
- ④ Keep a minimal set of points per manifold (e.g. 4 points).
- ④ Reject new points that are too *close* to old points.



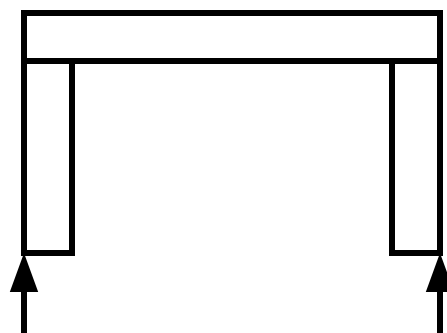
Manifold Reduction

- ④ This applies to one-shot and incremental manifolds.
- ④ We want to keep the minimum number of contact points for a stable simulation.
- ④ This improves performance drastically.

Example Reduction



Before



After



Further Reading

- ④ <http://www.gphysics.com/downloads/>
- ④ <http://www.continuousphysics.com>
- ④ Collision Detection in Interactive 3D Environments by Gino van den Bergen
- ④ Fast Contact Reduction for Dynamics Simulation by Adam Moravanszky and Pierre Terdiman in Game Programming Gems 4.