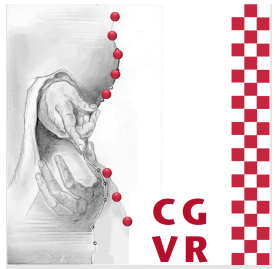

Collision Detection Based on Fuzzy Scene Subdivision

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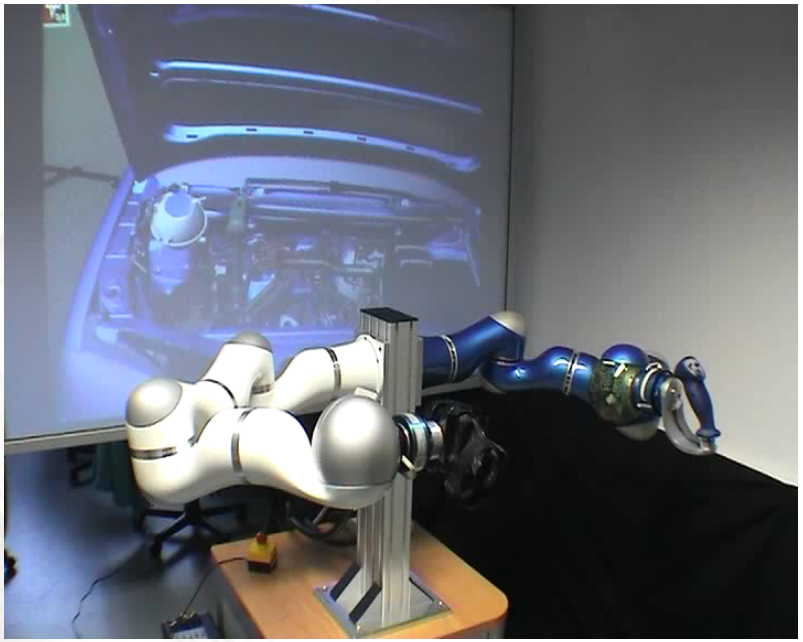
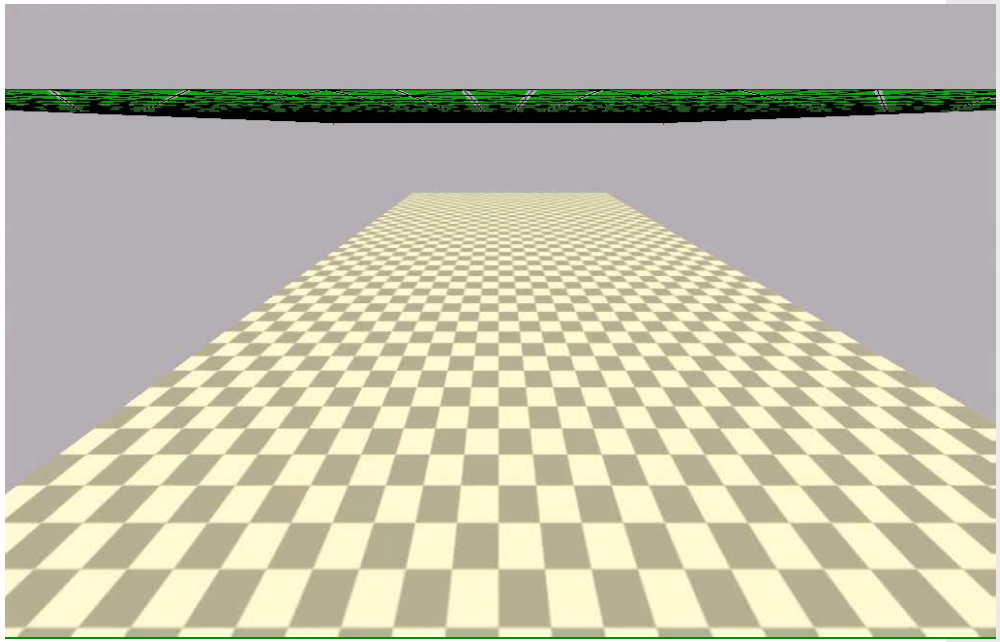
Motivation for Collision Detection





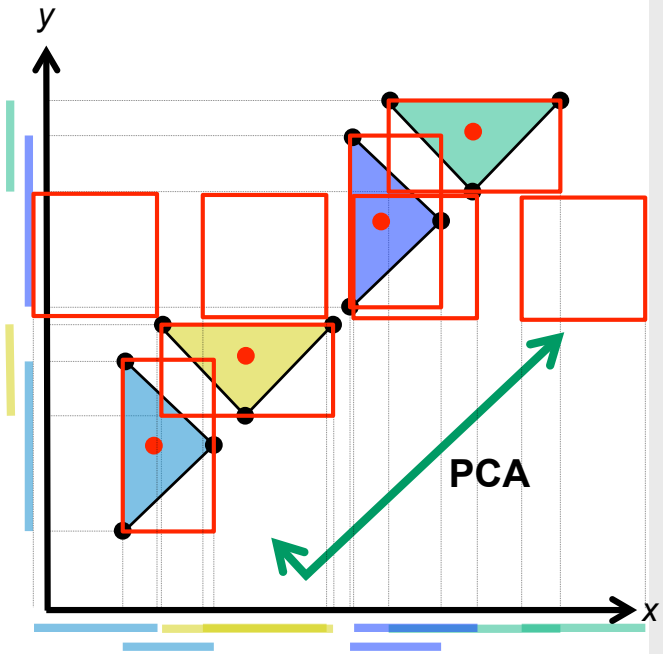
- Make virtual environments realistic
- Basic component of video games, robotics, medical applications, etc.
- Collision detection is bottleneck in many applications

Previous Work

- Algorithm for proximity queries between a closed rigid object and an arbitrary mesh [Morvan 2008]
  - Sampled distance field of rigid object over arbitrary mesh
  - Drawback: one object has to be a rigid body
- Hybrid CPU/GPU technique based on spatial subdivision [Pabst 2010]
  - Prune away non-colliding parts of scene by using an adapted spatial subdivision method
- GPU-based streaming algorithm for collision detection [Tang 2011]
  - Use BVH as culling technique
  - Cannot be easily extended to use more than one GPU

PCA-based Sweep-Plane Technique

- 1D sweep-plane approach
  - BBox spans an interval on axis
- Sorting intervals
  - Identify possible colliding BBoxes

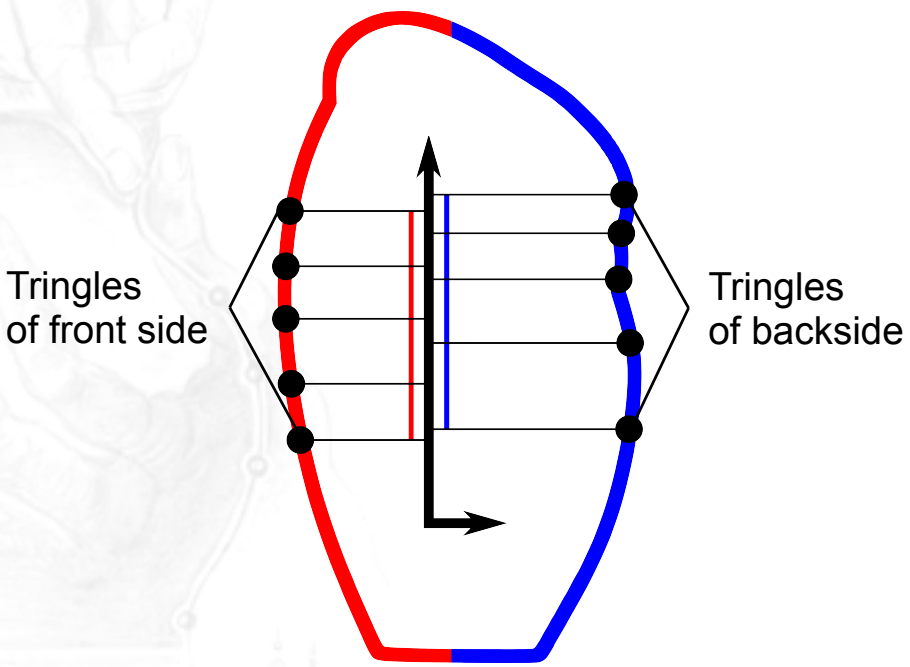


- Minimize potentially colliding BBoxes
- Best sweep direction separate primitives as much as possible
- Best sweep direction:
  - Compute the **Principal Component Analysis (PCA)**

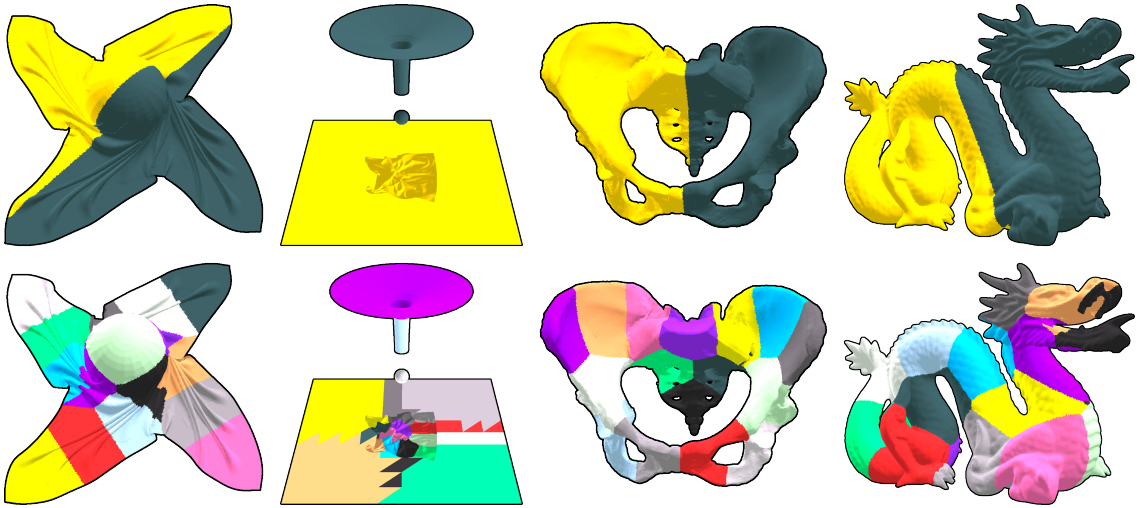
Scene Subdivision Using Fuzzy C-Means

Problem:

- Sweep-plane step → dimensional reduction → false positives
  - Primitives of *front side* and primitives of *backside* identified as potentially colliding pairs



Scene Subdivision Using Fuzzy C-Means



Solution:

- Subdivide scene into components using *clustering* algorithm
- Primitives on border need to be on two (or more) clusters → fuzzy clustering
- Run incrementally → reuse results from previous step → Fuzzy C-Means

Our Algorithm

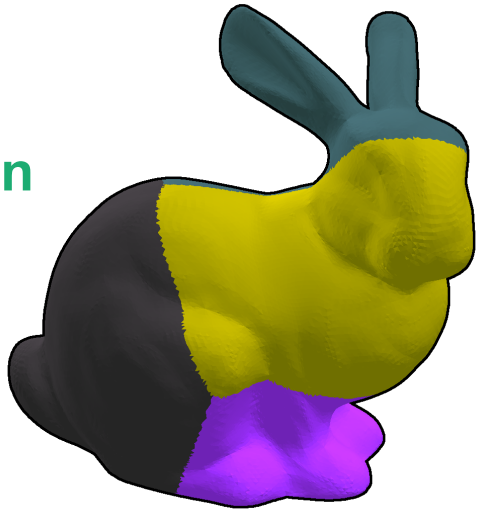
Fuzzy C-means GPU-based Collision Detection

Input: primitives of all objects

Output: intersecting pairs of primitives

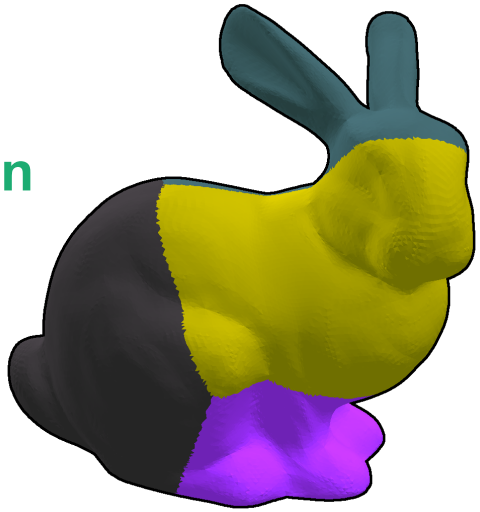
Subdivide scene into c clusters using fuzzy C-means

for all clusters **do in parallel**



Our Algorithm

Fuzzy C-means GPU-based Collision Detection



Input: primitives of all objects

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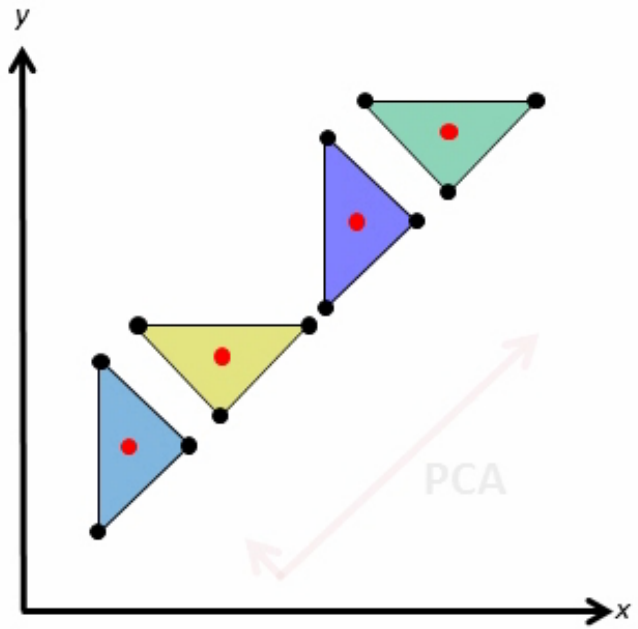
Subdivide scene into c clusters using fuzzy C-means

for all clusters **do in parallel**

compute and apply PCA

sort AABBs along longest principle axis

collect all overlapping intervals



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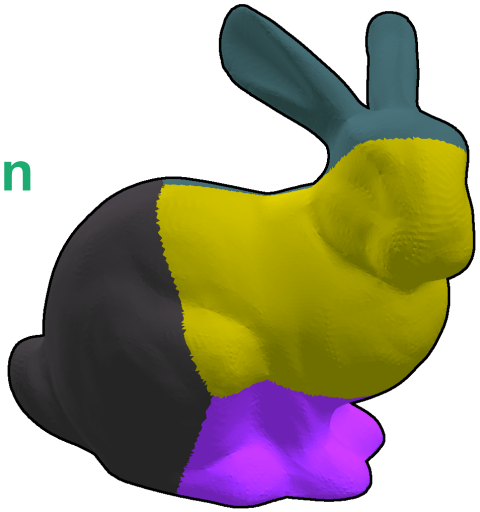

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Subdivide scene into c clusters using fuzzy C-means

for all clusters **do in parallel**

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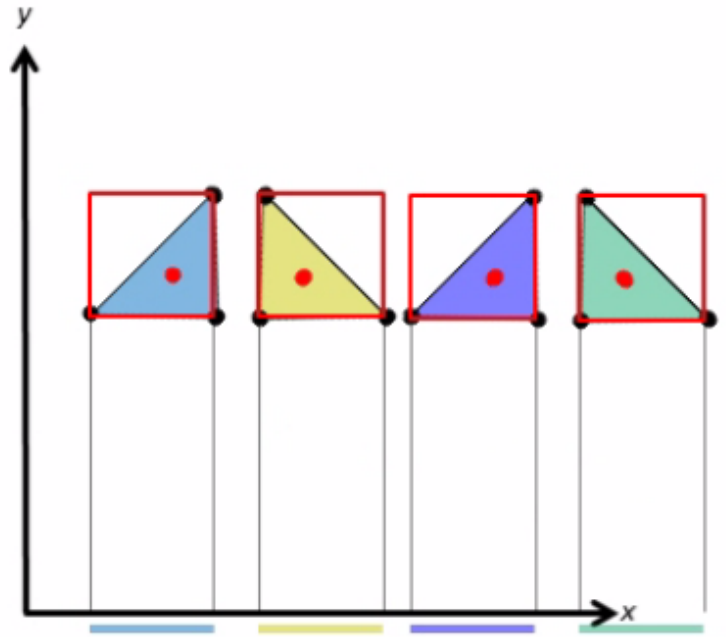
collect all overlapping intervals

for all overlapping intervals **do in parallel**

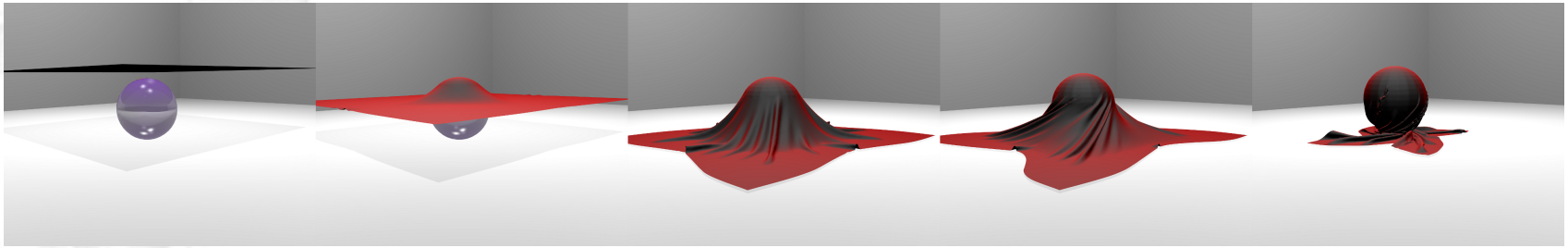
if AABB intersect along y-axis **then**

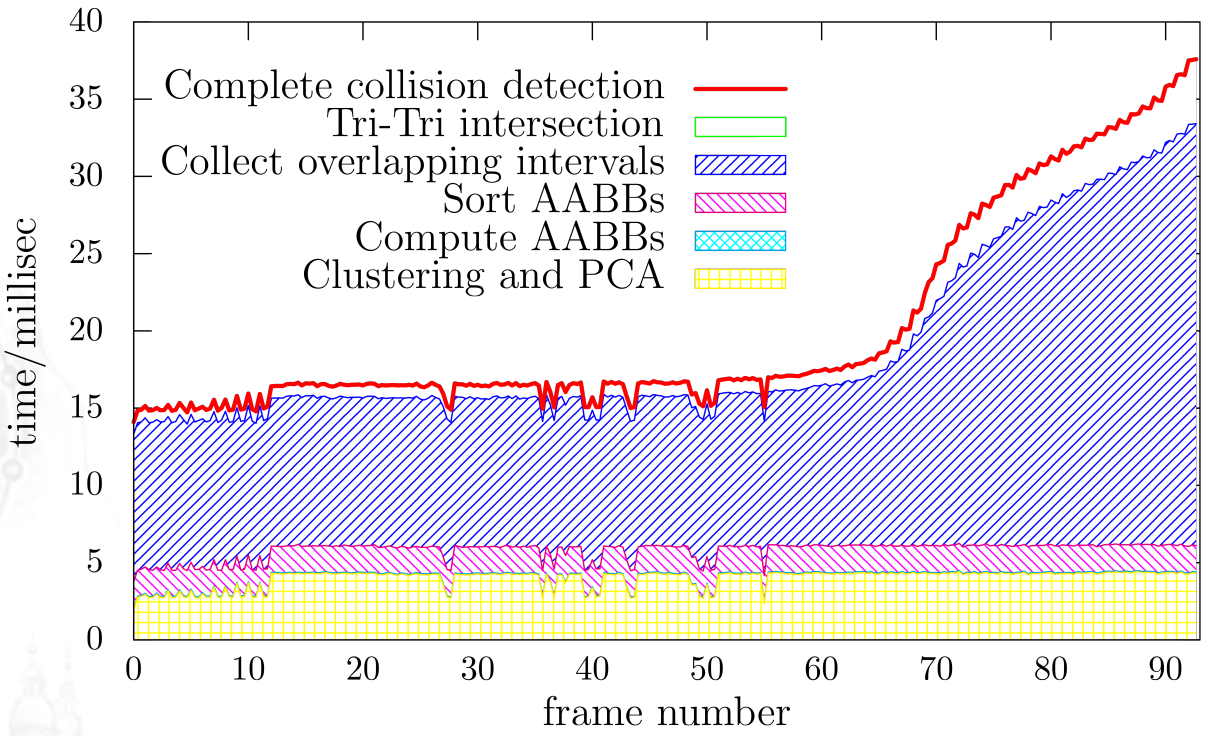
do primitive-primitive intersection test



Results: Cloth on Ball Benchmark

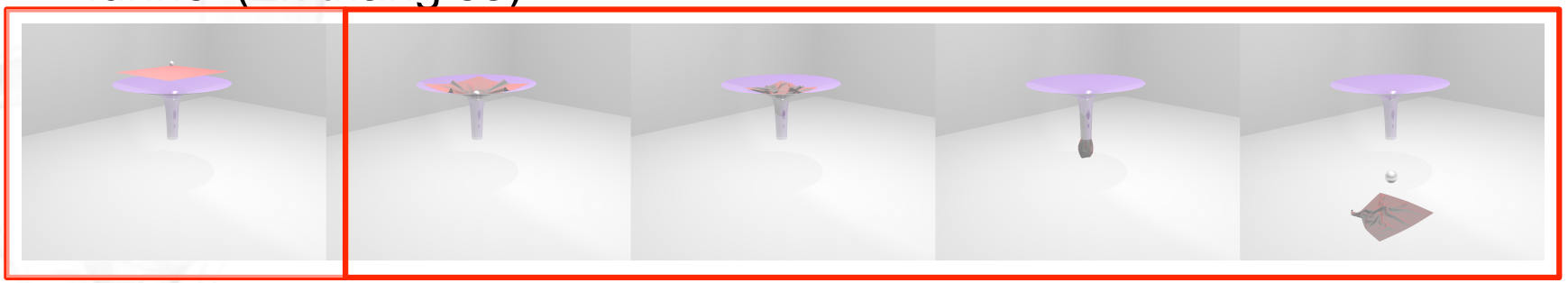
- Cloth (92k triangles) drops down on a rotating ball (760 triangles)

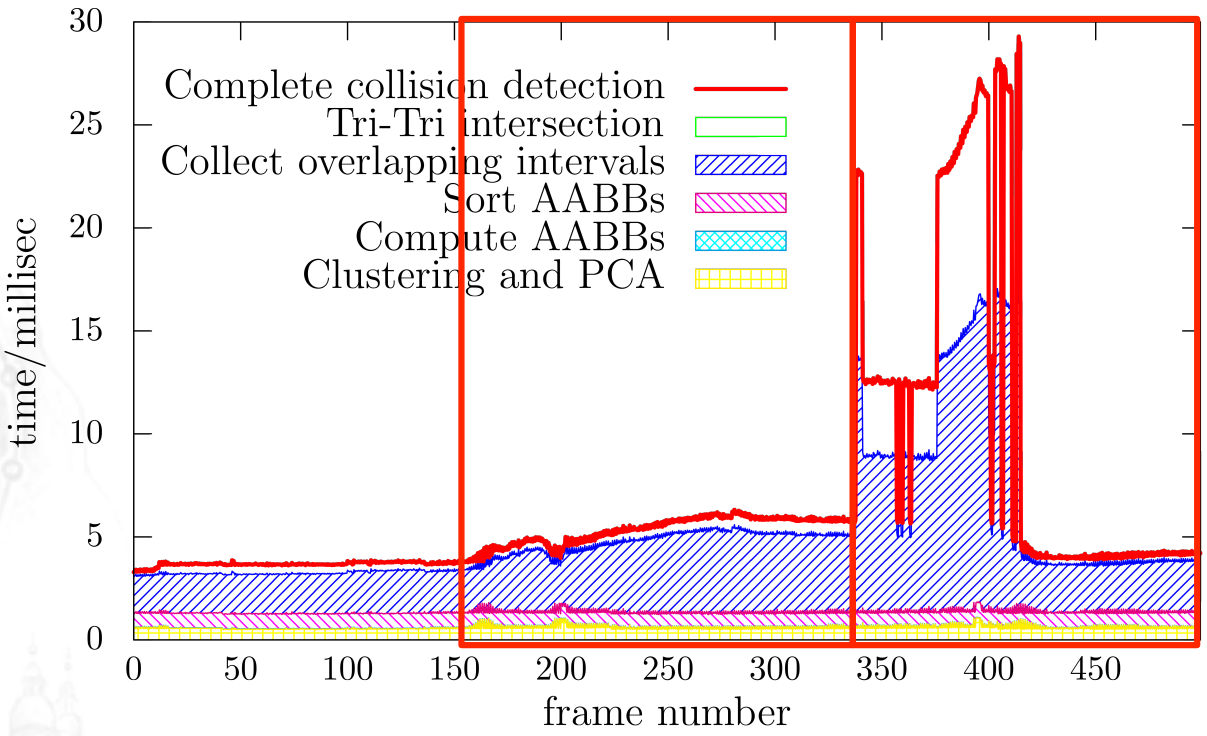




Results: Funnel Benchmark

- Ball (1.7k triangles) passes a cloth (14.4k triangles) through a funnel (2k triangles)





Conclusions and Future Work

- Completely GPU-based fast and accurate collision detection algorithm
- Broad phase and narrow phase within one single framework
- Our approach is easier to implement than many other collision detection algorithm
- We can compute external and self-collisions within one computation step
- We can handle scenes with 95k triangles in ~22*ms*

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- Completely GPU-based fast and accurate collision detection algorithm
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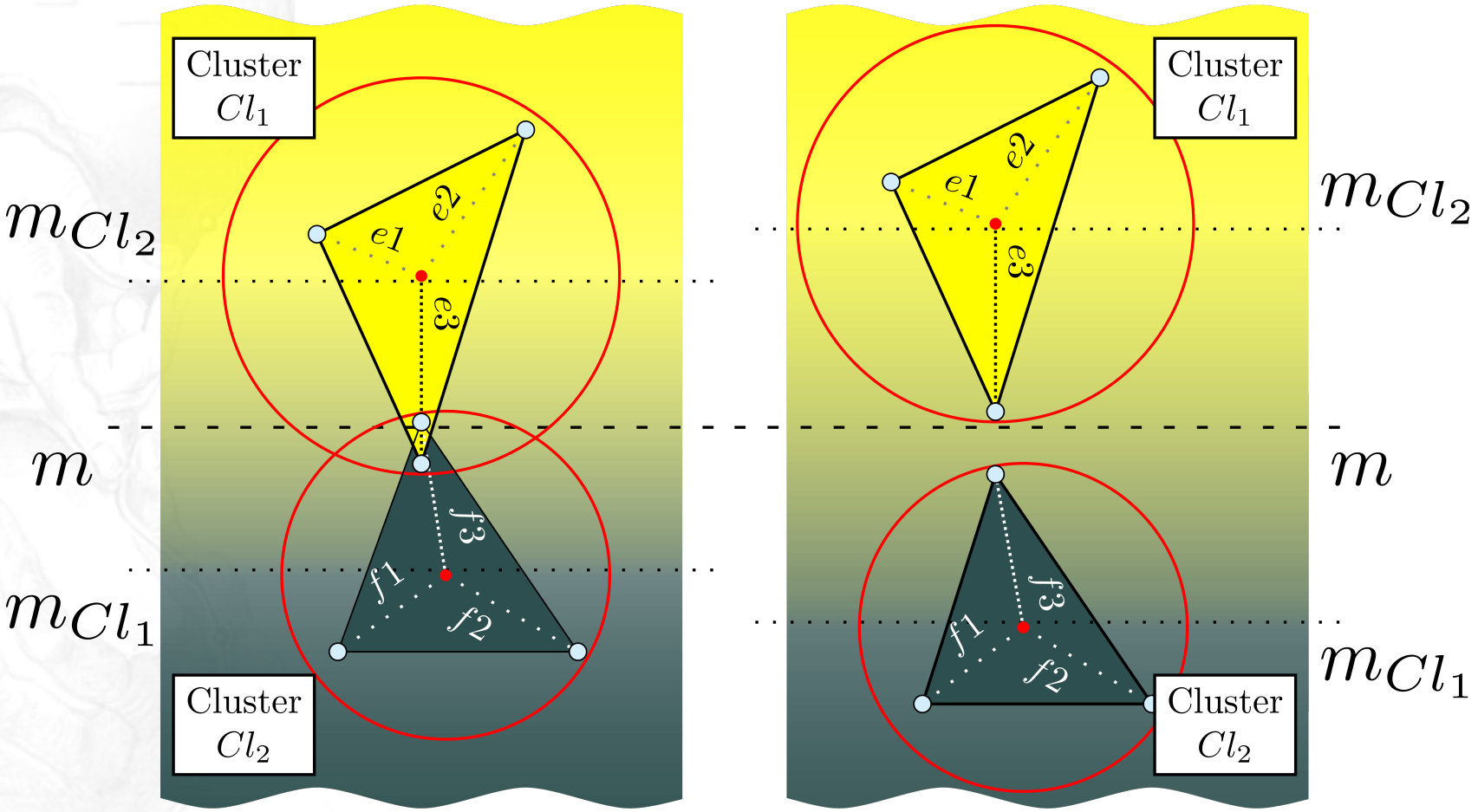
- Our approach is easier to implement than many other collision detection algorithm
- We can compute external and self-collisions within one computation step
- We can handle scenes with 95k triangles in ~22*ms*
- Improving the PCA process → reduce number of false positives
- Virtual subdivision for extremely large triangles
- Extend to perform other proximity queries


Cluster
Cl_1
m_{Cl_2}
$e2$
$e1$
$e3$
m
$f3$
$f1$
$f2$
m_{Cl_1}
Cluster
Cl_2
Cluster
Cl_1
m_{Cl_2}
$e2$
$e1$
$e3$
m
$f3$
$f1$
$f2$
m_{Cl_1}
Cluster
Cl_2

Bench.	Our	CSt.	Pab	HP	MC
Cl. On Ball	20.24	18.6	36.6	23.2	32.5
Funnel	6.53	4.4	6.7	-	-

- Timings include both external and self-collision detection
- CStreams (CSt.) – GPU-based streaming algorithm for collision detection
- Pab. – a hybrid CPU-GPU collision detection technique based on spatial subdivision
- HP – a hybrid CPU-GPU parallel continuous collision detection
- MC – a multi-core collision detection algorithm running on a 16 core PC

Position	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	
Bounding Box ID (Start/End)	S_A	S_C	S_B	E_C	E_A	E_B	S_D	E_D	$\cdots$
Type (Start/End)	1	1	1	0	0	0	1	0	$\cdots$
prefix sum of Type (pT)	0	1	2	3	3	3	3	4	$\cdots$

Triangle ID	*A*	*B*	*C*	*D*
Start position (S)	0	2	1	6
End position (E)	4	5	3	7

Triangle ID	*A*	*B*	*C*	*D*	
$pT[E] - pT[S] - 1$	$3-0-1$	$3-2-1$	$3-1-1$	$4-3-1$	
number Threads	2	0	1	0	$= 3$