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Controlling the contact levels of detail for fast and precise haptic collision detection

Key words: Collision detection; Haptic rendering; Bounding sphere; Clustering; Contact levels of detail

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Motivation/Main ideas

➢ Motivation

Creating bounding spheres in respect to the contact levels of detail (CLOD), which can fit objects while maintaining the balance between high speed and precision of haptic collision detection.

➢ Main ideas

Summary of our method for collision detection	
Method	Specification
Bounding Spheres formation	Creating sphere • Find centroids • Generate central axis • Produce centers of spheres
	Creating sphere • Discard meaningless centers • Cluster centers through single-link clustering
Two-level collision detection	Fast detection of sphere • Calculate the distance • Check for overlap
	Precise detection in sphere • Project the haptic pointer • Take outer product and inner product of vectors • Check distance

Method : Bounding sphere formation

Finding centroids

Clustering centers

Creating bounding spheres

Method : Two-level collision detection

1. Fast detection of sphere

```
1. GPU: for each sphere_i do
2.       difference = hapticCursor.pos−sphere_i.pos
3.       distance = difference.length
4.       sumOfRadius = hapticCursor.radius+sphere_i.radius
5.       if distance < sumOfRadius then
6.             collision detected
7.       end if
8. end for
```

2. Precise detection in sphere

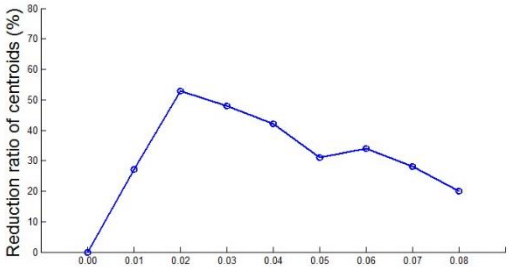
```
13. for each triangle_i do
14.       for each triangle_j do
15.             isPositive = true
16.             vector_1 = (vertex_a, vertex_b)
17.             vector_2 = (vertex_a, vertex_c)
18.             vector_3 = (vertex_a, T)
19.             crossResult_1 = vector_1 × vector_3
20.             crossResult_2 = vector_3 × vector_2
21.             if (crossResult_1 · crossResult_2) < 0 then
22.                   isPositive = false
23.                   break
24.             end if
25.       end for
26.       if isPositive then
27.             index = i
28.             break
29.       end if
30. end for
```

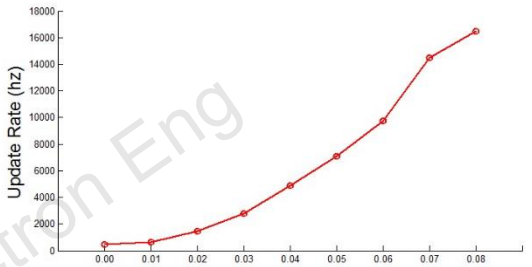
Method : Contact levels of detail

Contact levels of detail controlled by variable distances (*d*=0–0.11) of single-link clustering, where *d* indicates the side length of the clustering cube, and the numbers in the parentheses denote the number of spheres.

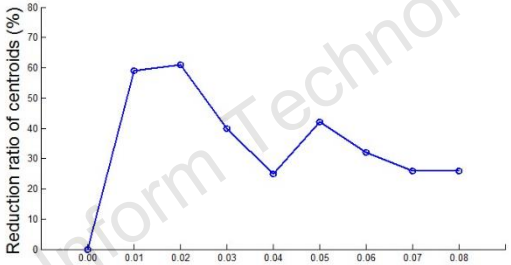
Major result(I)

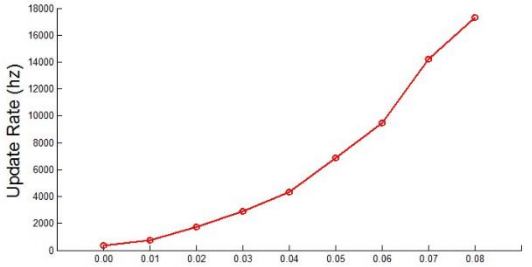
Reduction ratio for tooth.
(a) Step reduction ratio.
(b) Update rate.



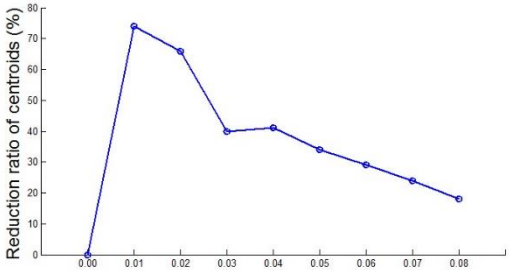


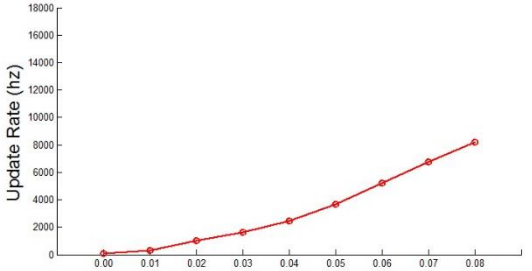
Reduction ratio for clover.
(a) Step reduction ratio.
(b) Update rate.



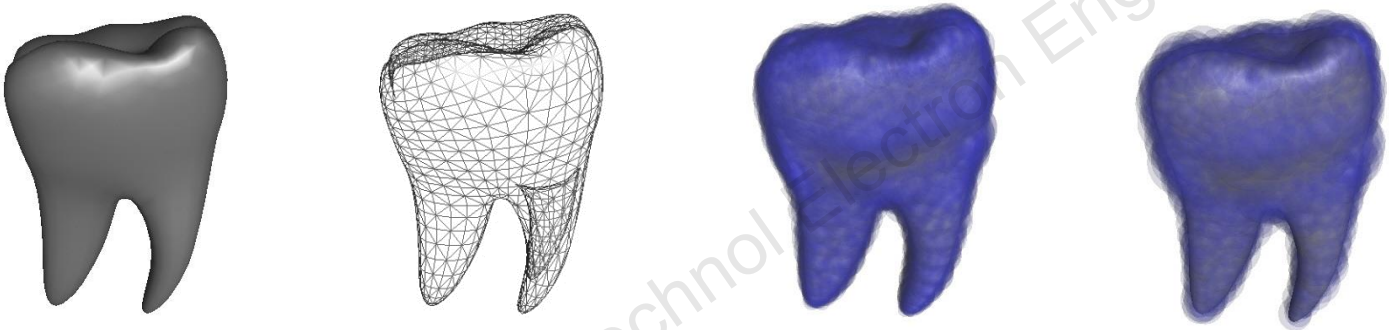


Reduction ratio for hat.
(a) Step reduction ratio.
(b) Update rate.





Major result(II)



(a) (b) (c) (d)

Depiction of a tooth.

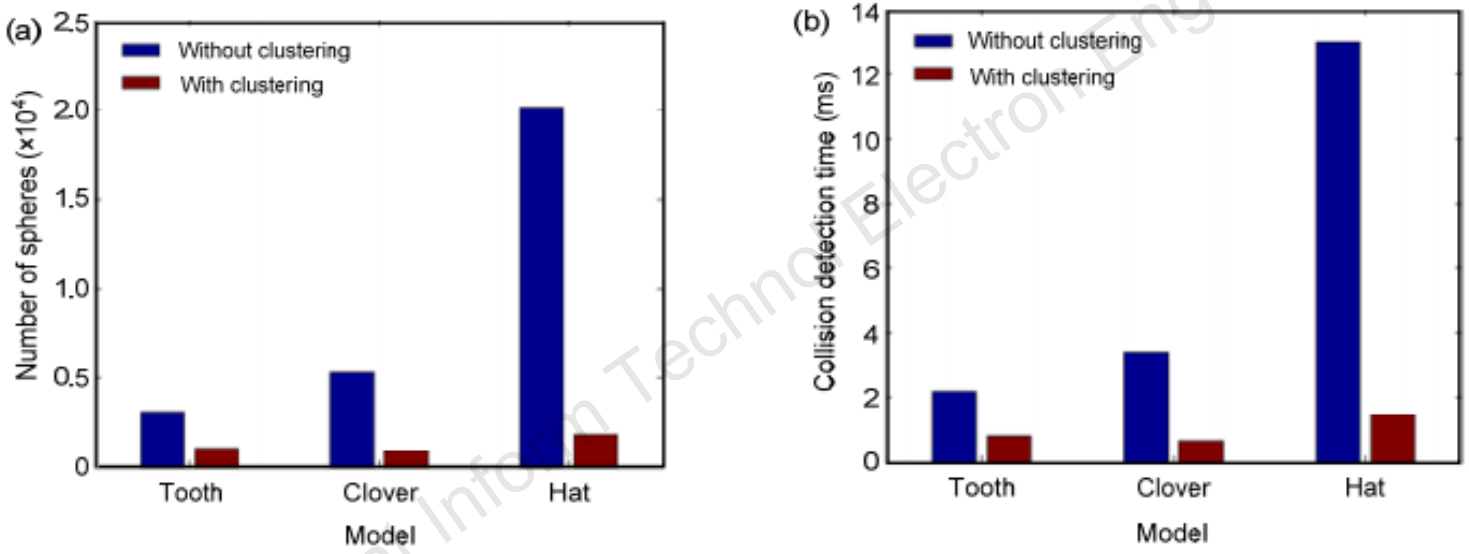
(a) Model.

(b) Polygons.

(c) Bounding spheres without clustering.

(d) Bounding spheres with the optimal clustering distance of 0.02.

Major result(IV)



Performance comparison.

(a) Number of spheres without and with clustering (clustering distance = 0.02).

(b) Comparison of collision detection time without and with clustering (clustering distance = 0.02).

Conclusions

- Fast enough for haptic rendering, using spherical structure for bounding volume.
- Precise enough to the voxel level.
- Variable clustering distances for controllable CLOD.
- Less overhead for maintaining bounding sphere hierarchy.
- Smaller radii of bounding spheres using centroids of triangular polygons.