Representing three-dimensional topography in a DBMS with a star-based data structure

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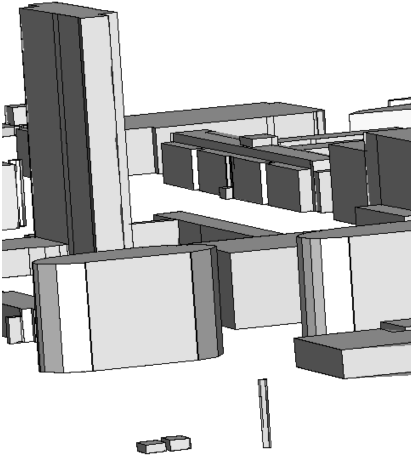
3D GeoInfo 2012 (Québec City, Canada)
2012–06–16

Representing and storing 3D topography

Our options:

1. *b-rep* (CityGML, 3D FDS)
2. CSG (IFC)
3. tetrahedralisation (TEN)



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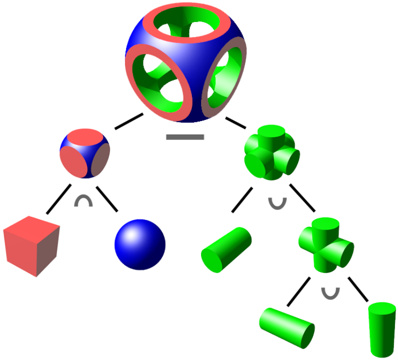

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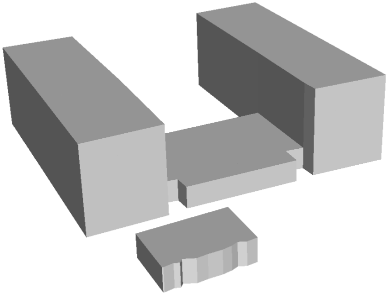

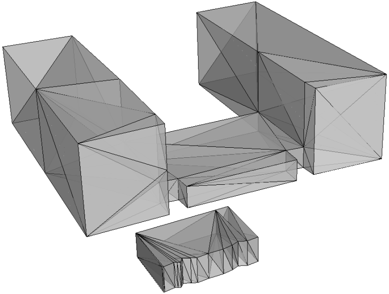

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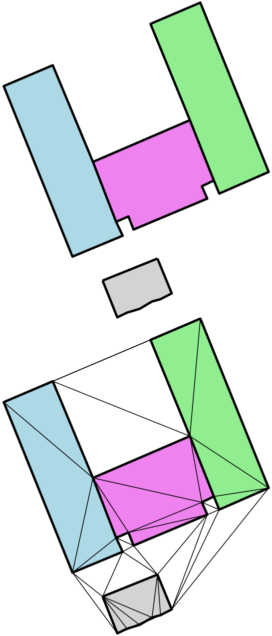
Constrained Delaunay tetrahedralisation (or TEN)

Advantages:

1. storage is simplified
2. spatial analysis is efficient
3. features can be represented
4. robust implementation
5. spatial relations between unconnected features explicitly stored



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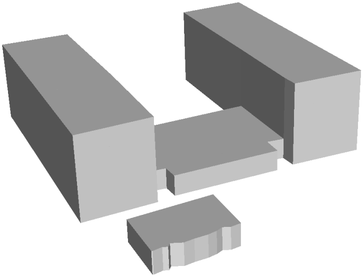

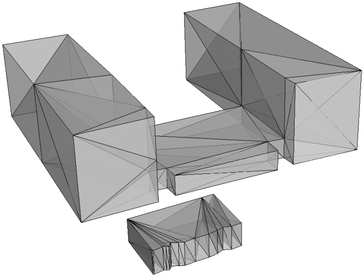

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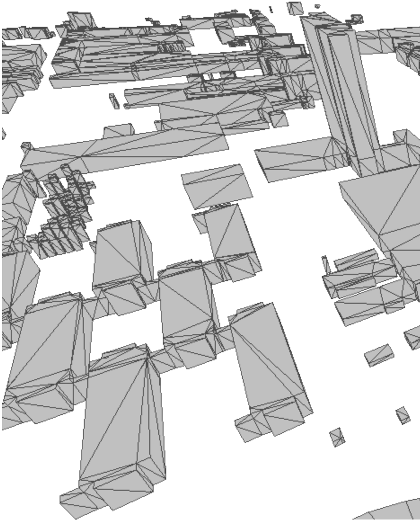

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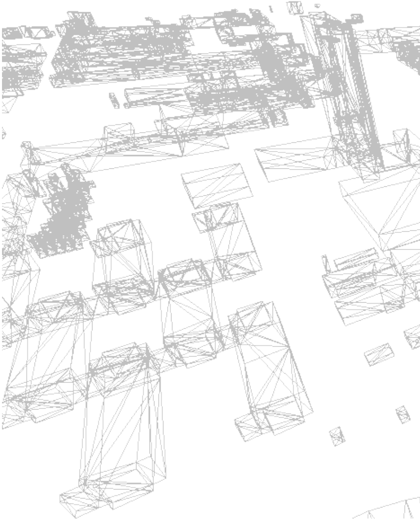

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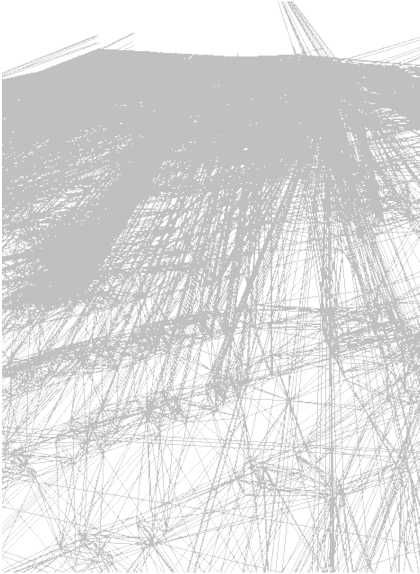


But...

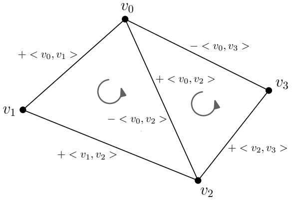
"An additional disadvantage of TEN is its much larger database size compared with other representations."

– S. Zlatanova *et al.* (2004)

Penninga (2008): Efficient storage is possible

Only vertices and tetrahedra are stored:

- akin to Simple Features
- 4 IDs per tetrahedron
- only 20% more storage than Oracle Spatial*

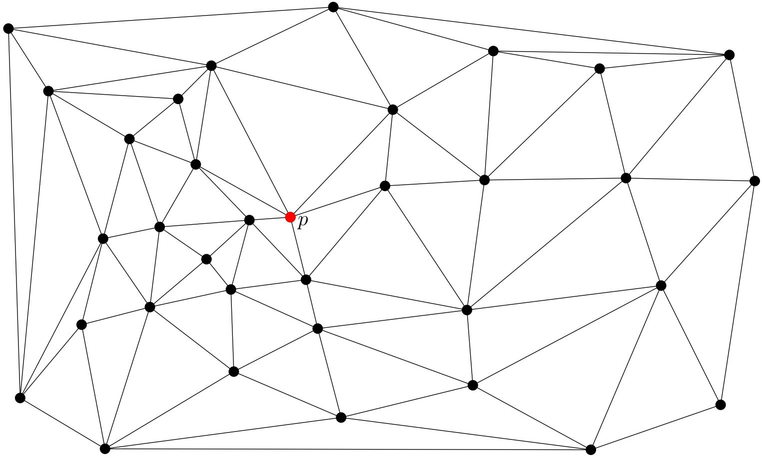


$$\partial C_2 = \partial S_{21} + \partial S_{22} = (< v_1, v_2 > - < v_0, v_2 > + < v_0, v_1 >) + (< v_2, v_3 > - < v_0, v_3 > + < v_0, v_2 >) = < v_1, v_2 > + < v_0, v_1 > + < v_2, v_3 > - < v_0, v_3 >$$

But...

- structure *not* topological
- spatial index should be added (e.g. R-tree)

Our approach: storing *stars* in a 2D triangulation



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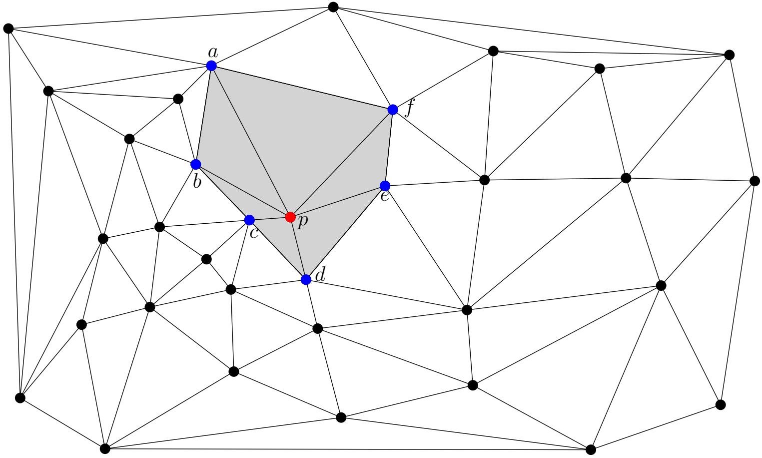

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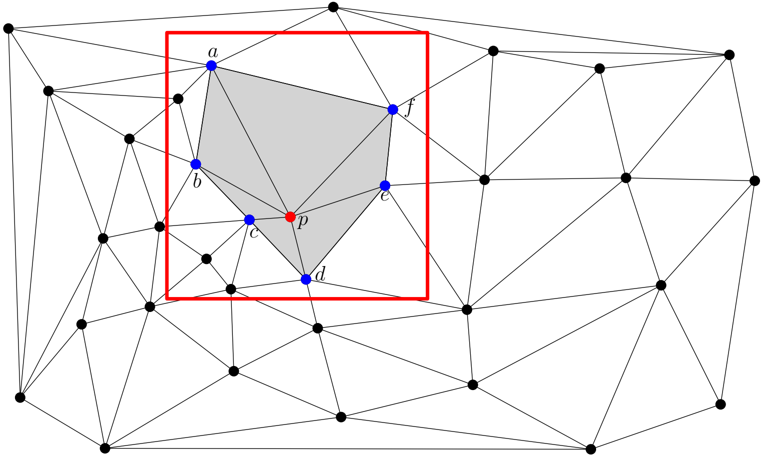

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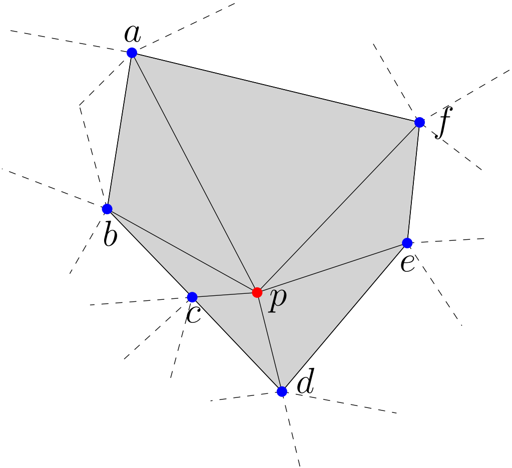
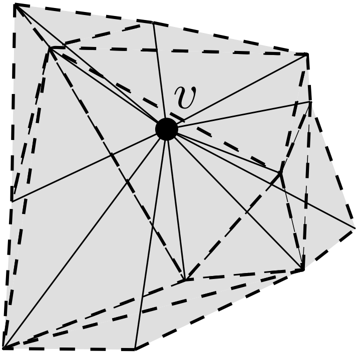
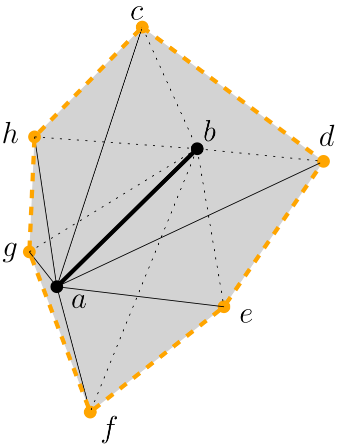


$$star(p) = abcdef$$

A *star* in 3D in a tetrahedralisation

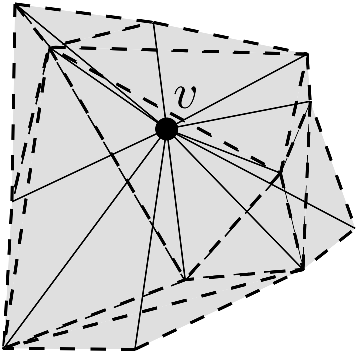


star for a vertex



star for an edge

A *star* in 3D in a tetrahedralisation



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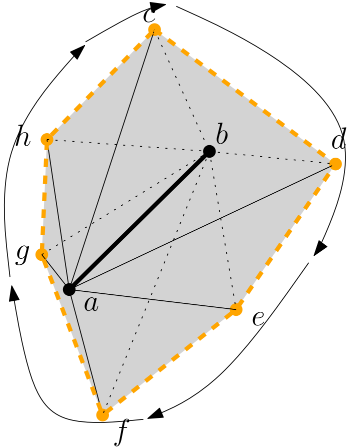
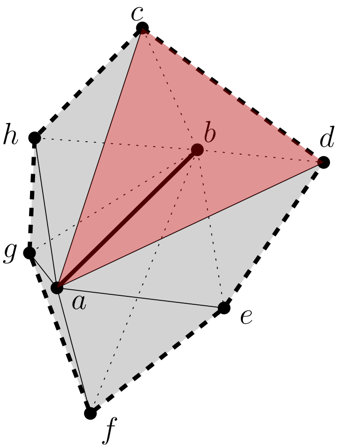


star for an edge

The *star* of an edge in 3D

$star(ab) = cdefgh$



- $abcd$ = one tetra

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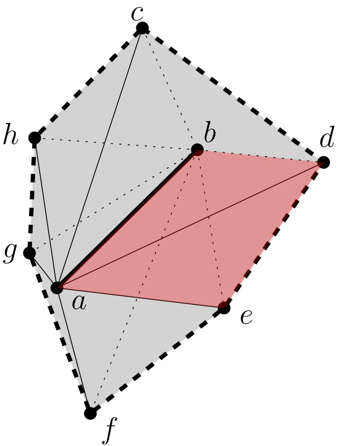

- $abcd$ = one tetra
- $abde$ = another tetra

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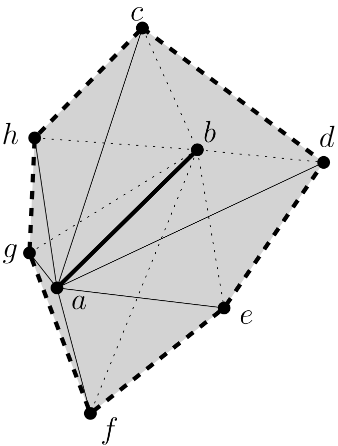

- *abcd* = one tetra
- *abde* = another tetra
- *abcd* and *abde* are adjacent

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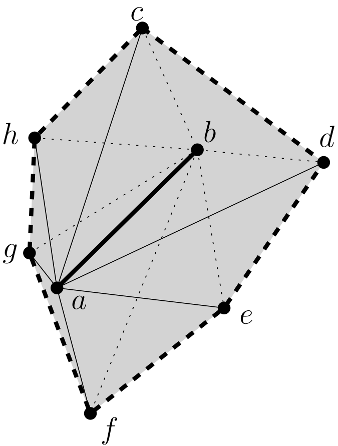
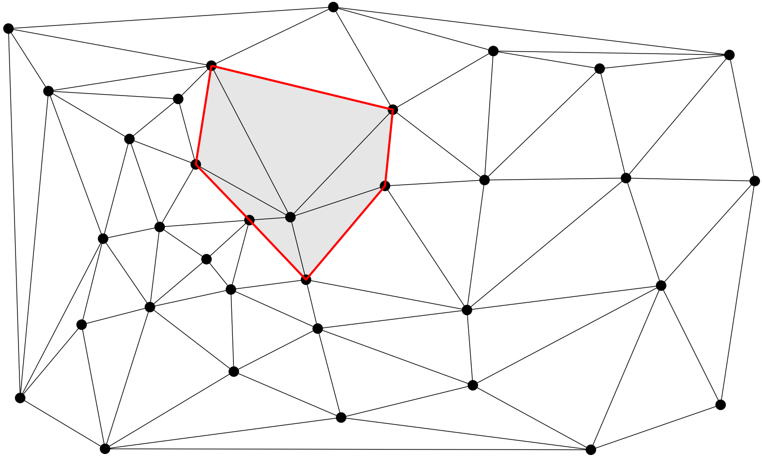


- *abcd* = one tetra
- *abde* = another tetra
- *abcd* and *abde* are adjacent
- each tetra is in 6 edges

Every star is stored → implicit triangles



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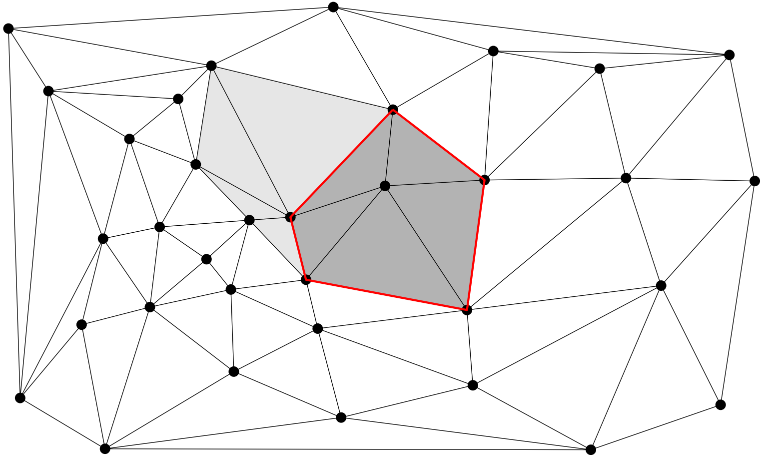

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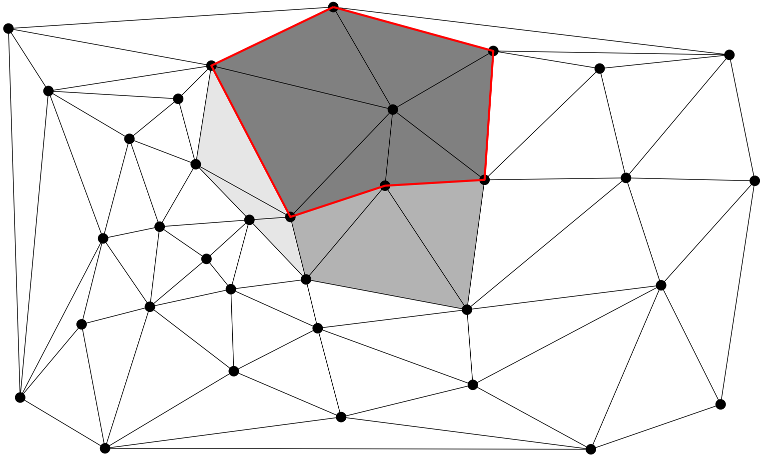

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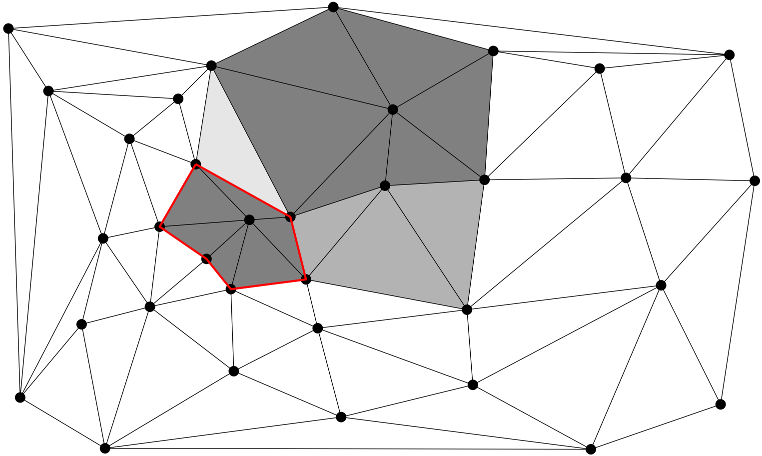
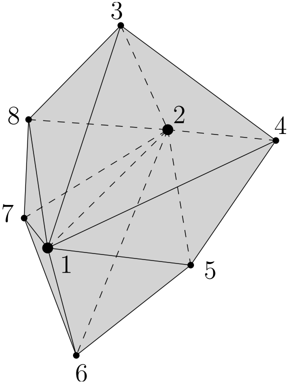


Compression = storing only *representative* edges

- $|E| \cong (7/6)|T|$
- using smart idea of Blandford *et al.* (2005)
- representative edge = both vertex labels are either odd or even
- half of edges will be stored
- each triangle and each tetra must be in at least 1 star
- only 3 labels per tetra on average—Penninga (2008) needs 4



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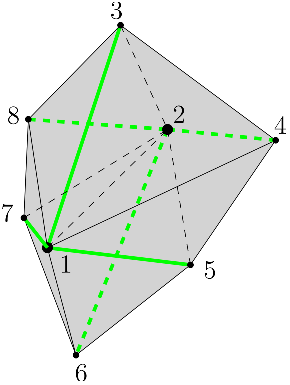


DBMS storage = easy and efficient

Vertex table

id	x	y	z
1	5.0	2.5	6.0
2	5.0	11.5	6.0
3	5.0	6.0	12.0
...	...	...	...
8	1.0	6.0	8.0

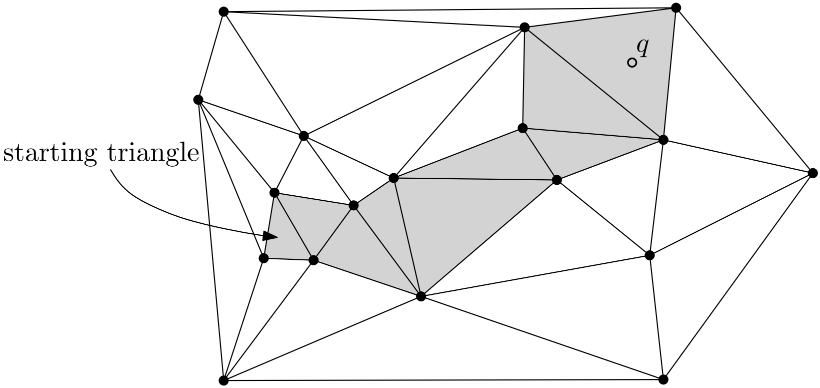
Representative edge table

start	end	star[]
2	4	$\{\emptyset, 3, 1, 5\}$
5	7	$\{6, 1, 2\}$
1	7	$\{\emptyset, 8, 2, 5, 6\}$
1	5	$\{\emptyset, 6, 7, 2, 4\}$
...	...	...
1	3	$\{\emptyset, 4, 2, 8\}$

PostgreSQL table

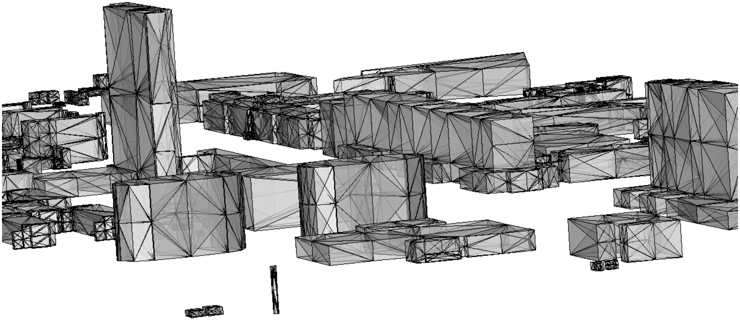
```
-- Vertex table
CREATE TABLE pgtet_vertex (
    gid bigint,
    x numeric,
    y numeric,
    z numeric
);
ALTER TABLE pgtet_vertex ADD PRIMARY KEY (gid);

-- Edge table
CREATE TABLE pgtet_edge (
    start bigint,
    end bigint,
    link bigint[] -- array of integers
);
ALTER TABLE pgtet_edge ADD PRIMARY KEY (from_gid, to_gid);
```

No auxiliary R-tree index needed: “walking” is used



(Can be made efficient [MSZ99])

Experiments with the TU Delft campus dataset



input 3D model		CDT				star
vertices	constraints	vertices	edges	triangles	tetrahedra	representative edge
5 978	3 982	6 938	56 291	95 420	47 707	25 697

Experiments with the TU Delft campus dataset

Some facts and statistics:

- 370 solids (building's footprints extruded)
- 1000 vertices added by the tetrahedralisation
- 20% compacter than Penninga's (or than Simple Features)
- average size of a star = 4.9 (min = 3; max = 28)

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Thanks for your attention

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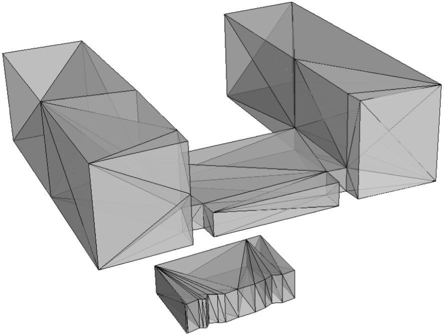

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