Vario-scale data server in a web service context

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Section GIS Technology

TU Delft
Delft University of Technology

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2. Background tGAP structure
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5. Conclusions

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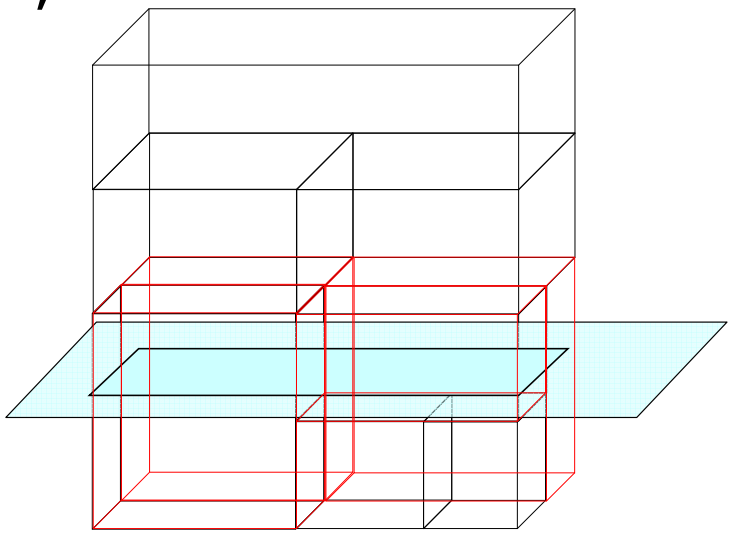
1. Introduction

- Multi-scale databases: often multiple representation
  drawbacks: redundancy, fixed levels of detail
- Scaleless data structures: single representation with additional structure to access at any level of detail

- Often also spatial organization (clustering/indexing)
- Progressive transfer: keep sending more details (compare to raster formats: data pyramids, wavelets)

1. Generalized Area Partitioning-tree (GAP-tree) history

- In normal GAP-tree (van Oosterom 1993) areas are stored as independent polygons, drawback (computed) redundancy
- Vermeij et al.'03 proposed topological GAP-tree: edges and faces (with importance range, consider as height), reduced redundancy between neighbors



- Still some redundancy left: coordinates in higher level edge also present in lower (more detailed) level edges

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1. tGAP structure (GAP-face tree + GAP-edge forest)

- Also coordinate redundancy between edges at different aggregation levels is removed
- Throughout remainder of presentation examples of the tGAP-structure (creation and use) will be shown
- Creation of the tGAP-tree is shown in pairs of steps
  1. removal of least important face (merge face)
  2. removal of edges, merge of edges (BLG-tree)

1. Proposed solution: tGAP structure

- Variable scale: infinite amount of levels
- Base level with most detailed geometry/topology
- Create links/structure on top

- Only theory → validate
- Last year at Autocarto 2005, presentation was concluded with question: What is the price of non-redundancy, that is, the many references?

- Test and implement structure

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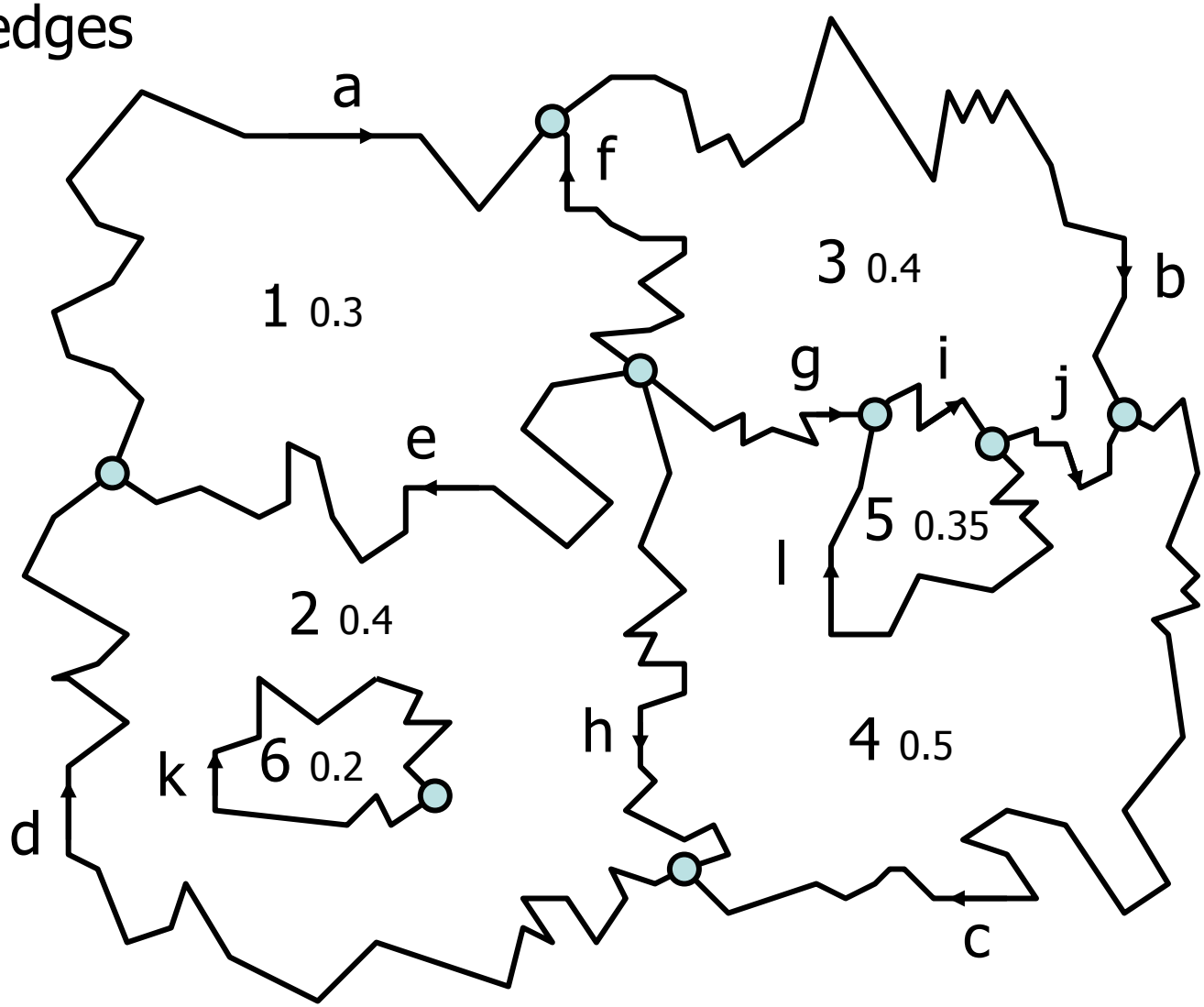
edges



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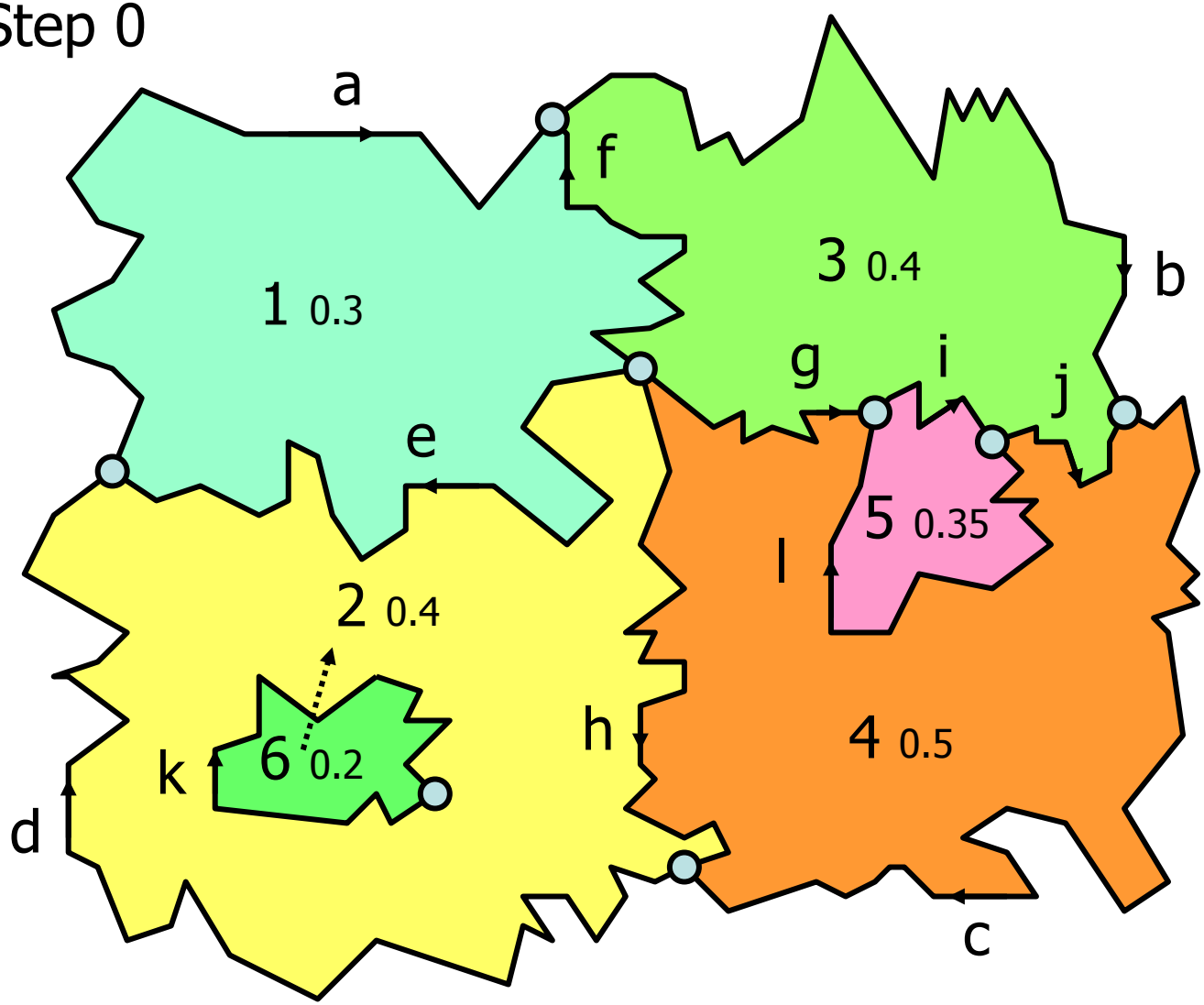
Step 0



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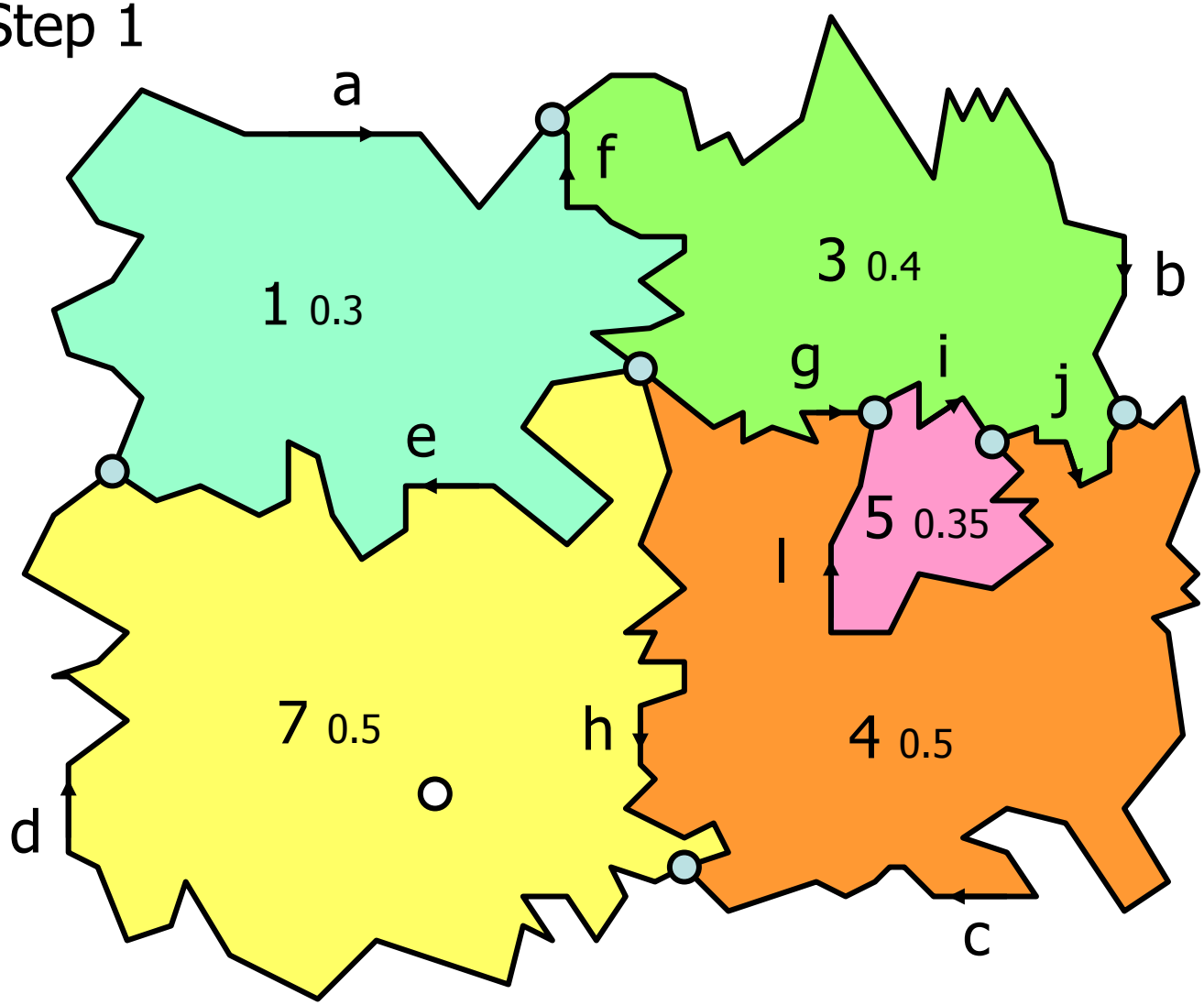
Step 1



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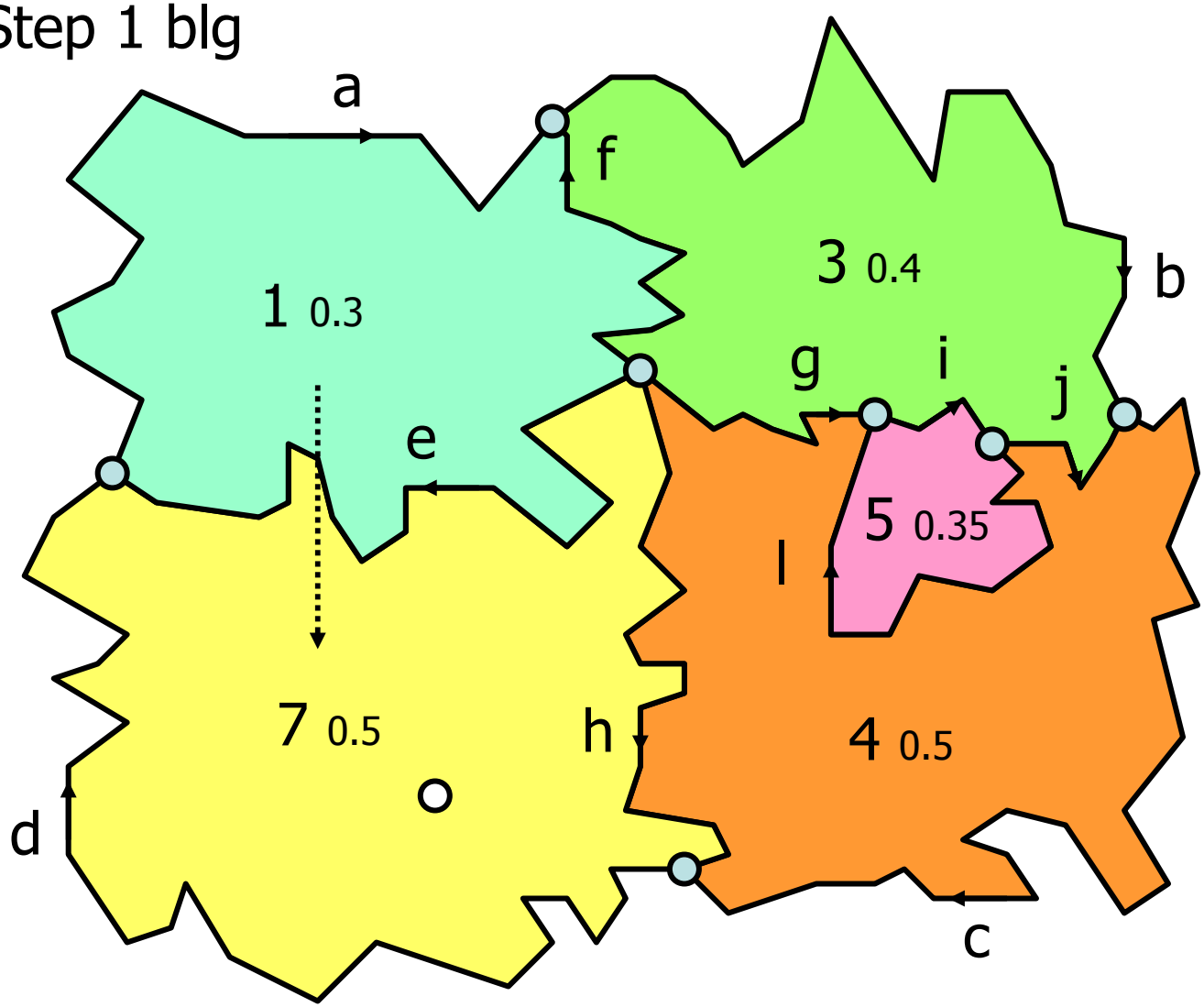
Step 1 blg



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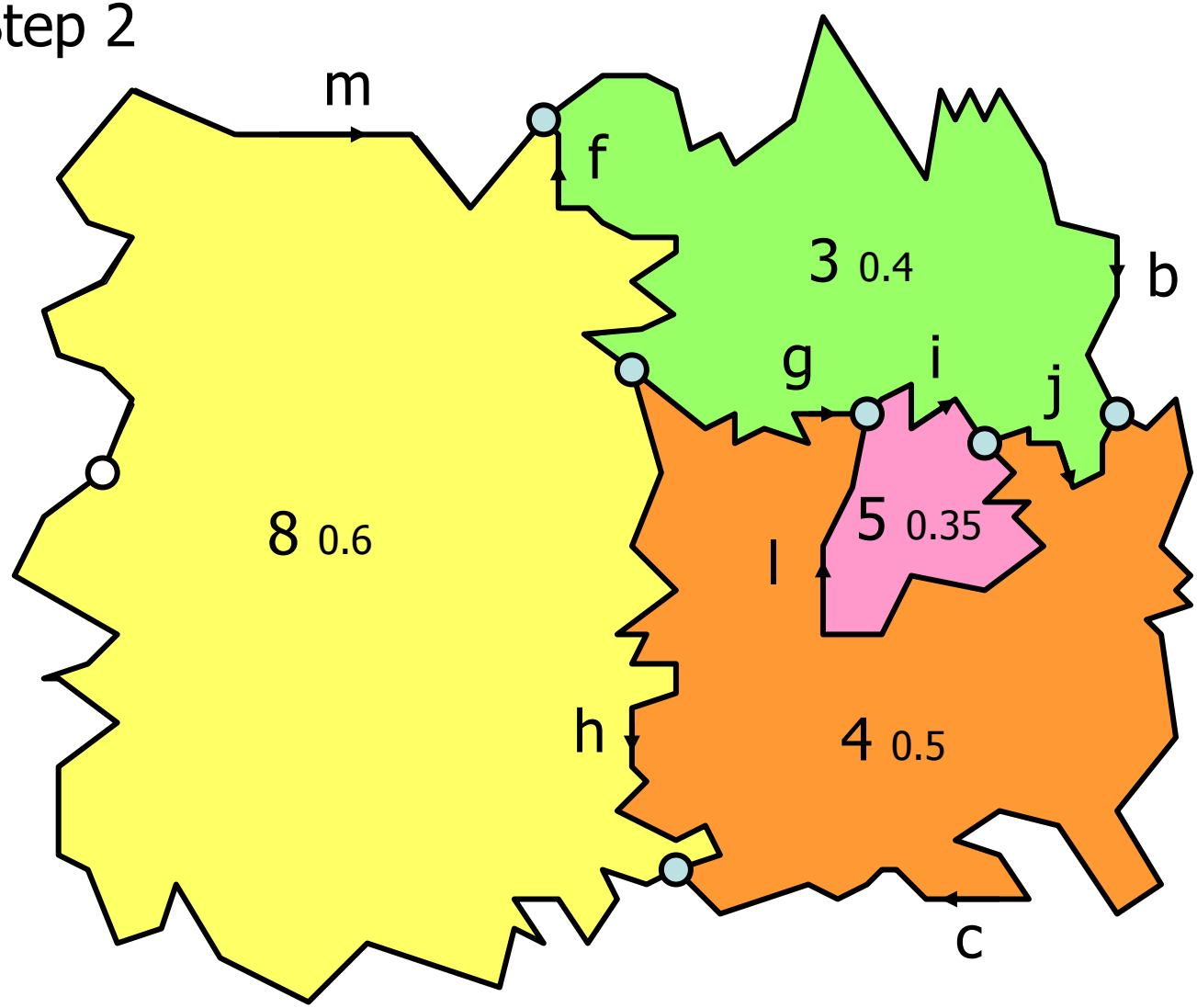
Step 2



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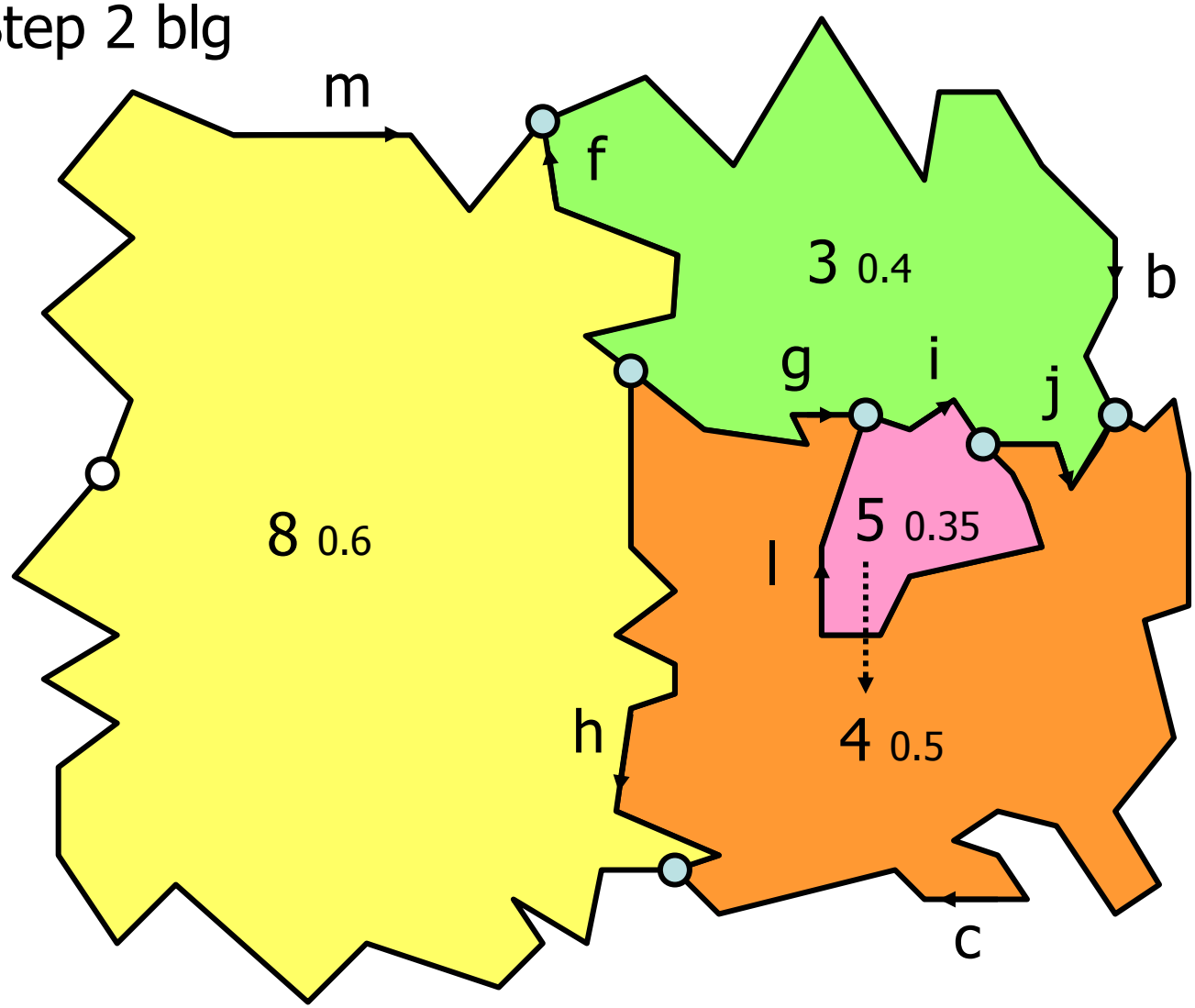
Step 2 blg



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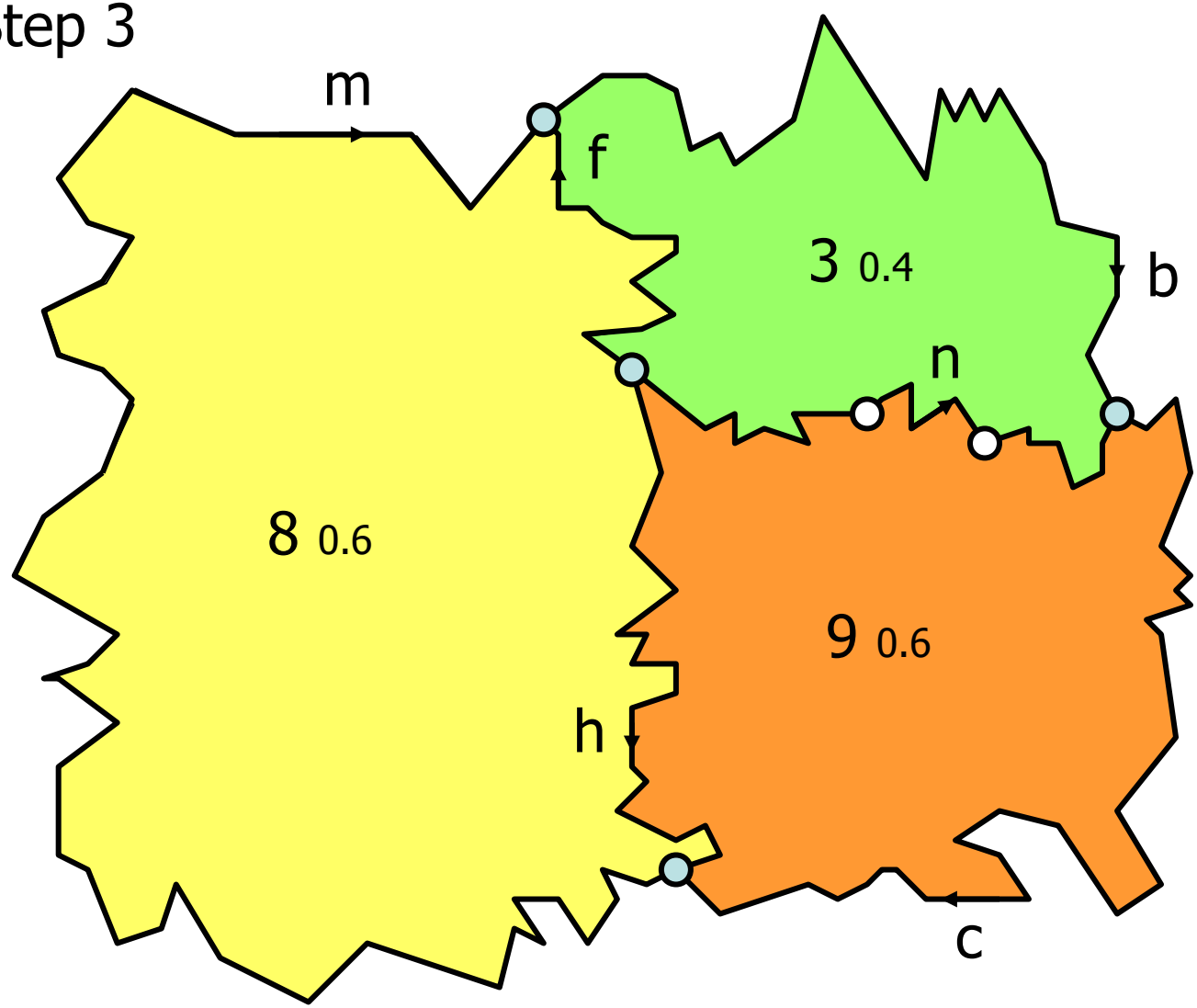
Step 3



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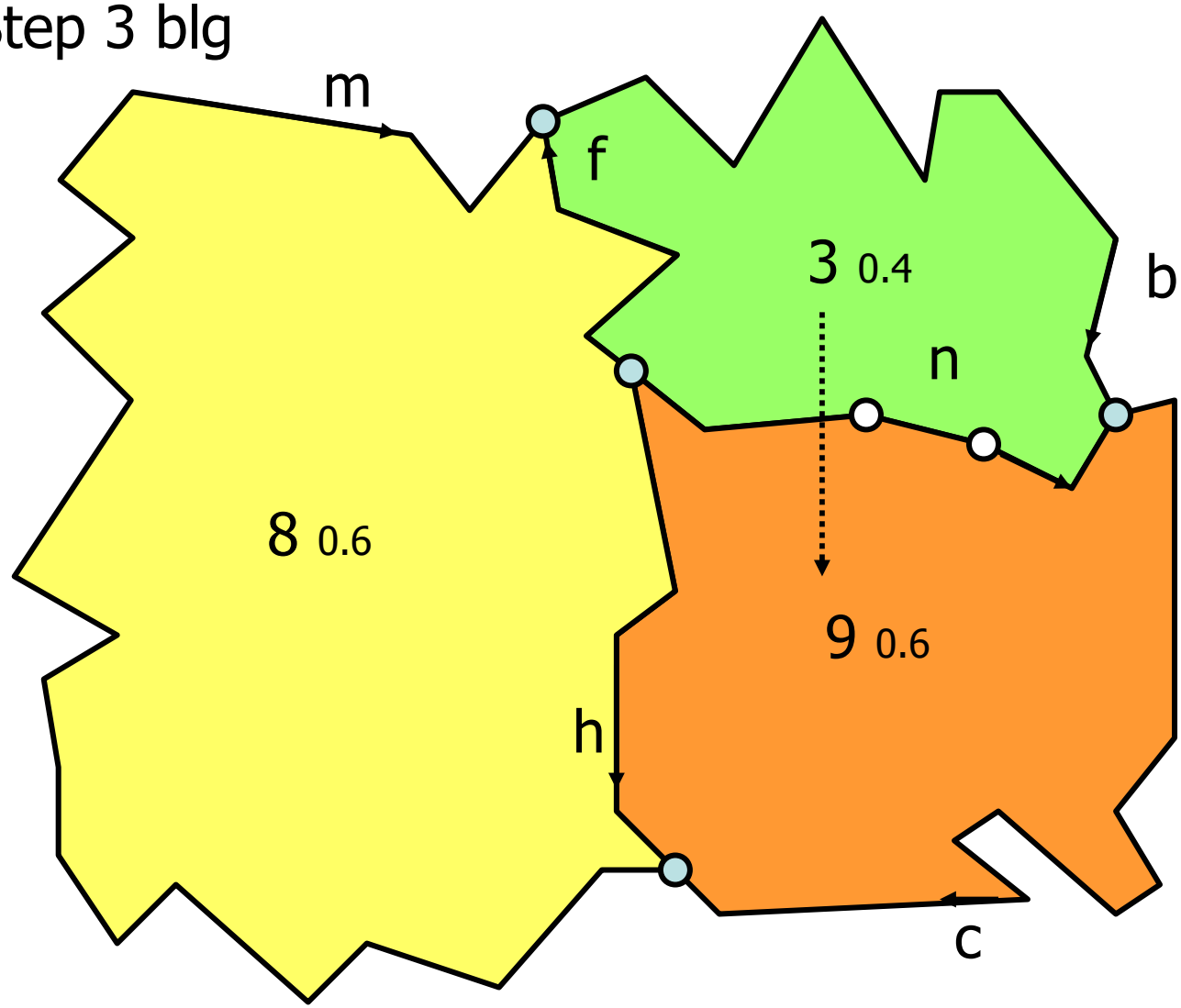
Step 3 blg



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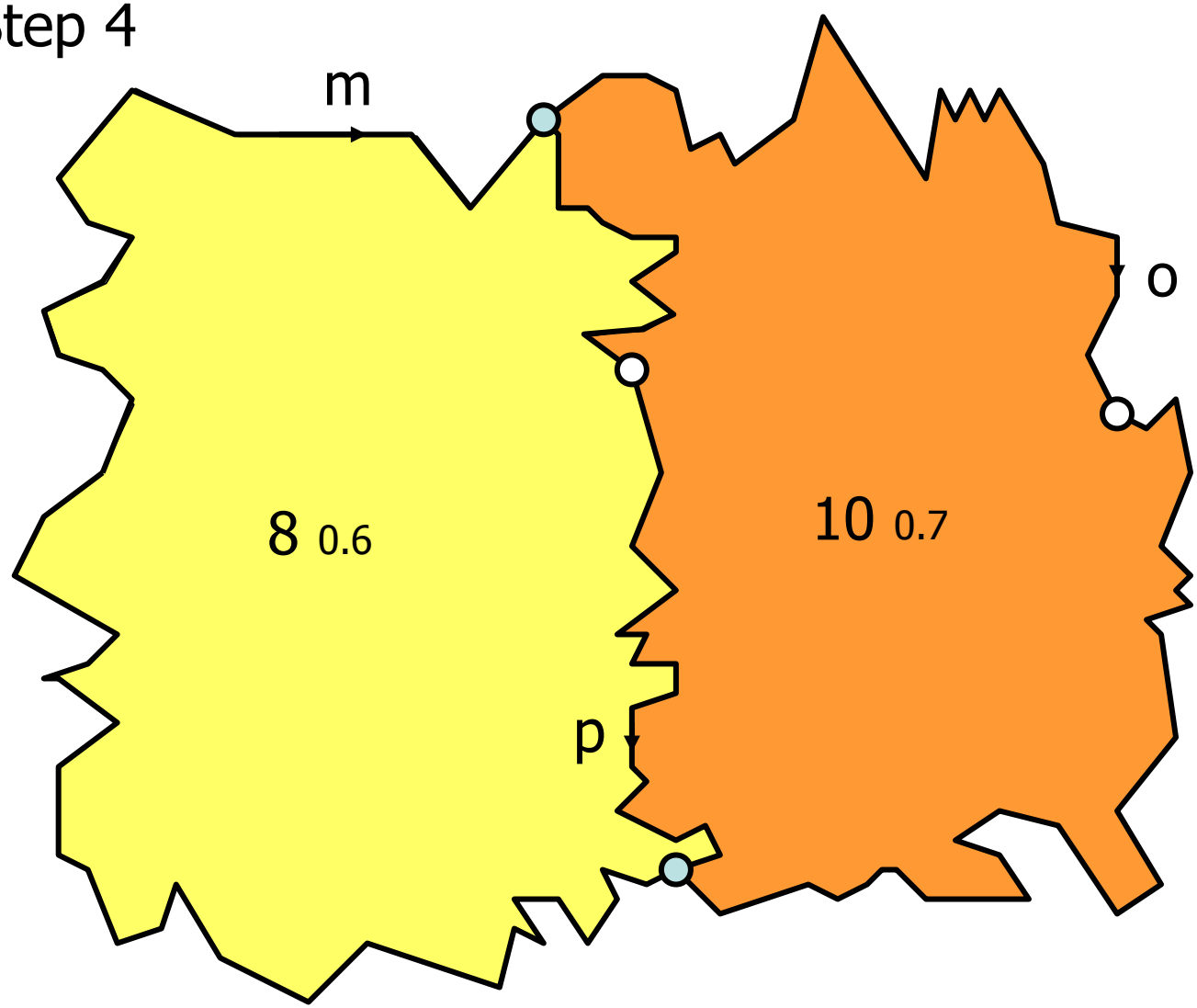
Step 4



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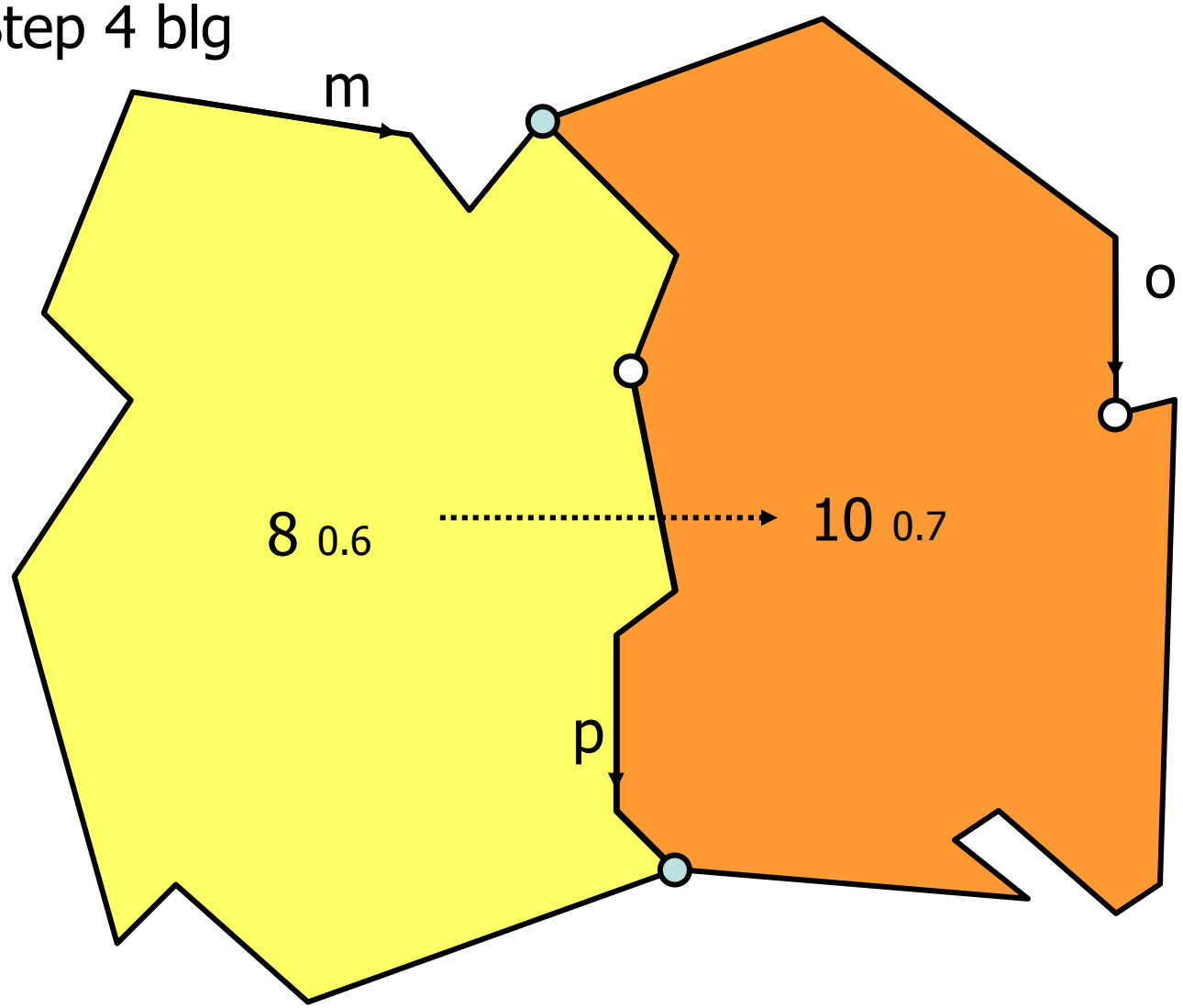
Step 4 blg



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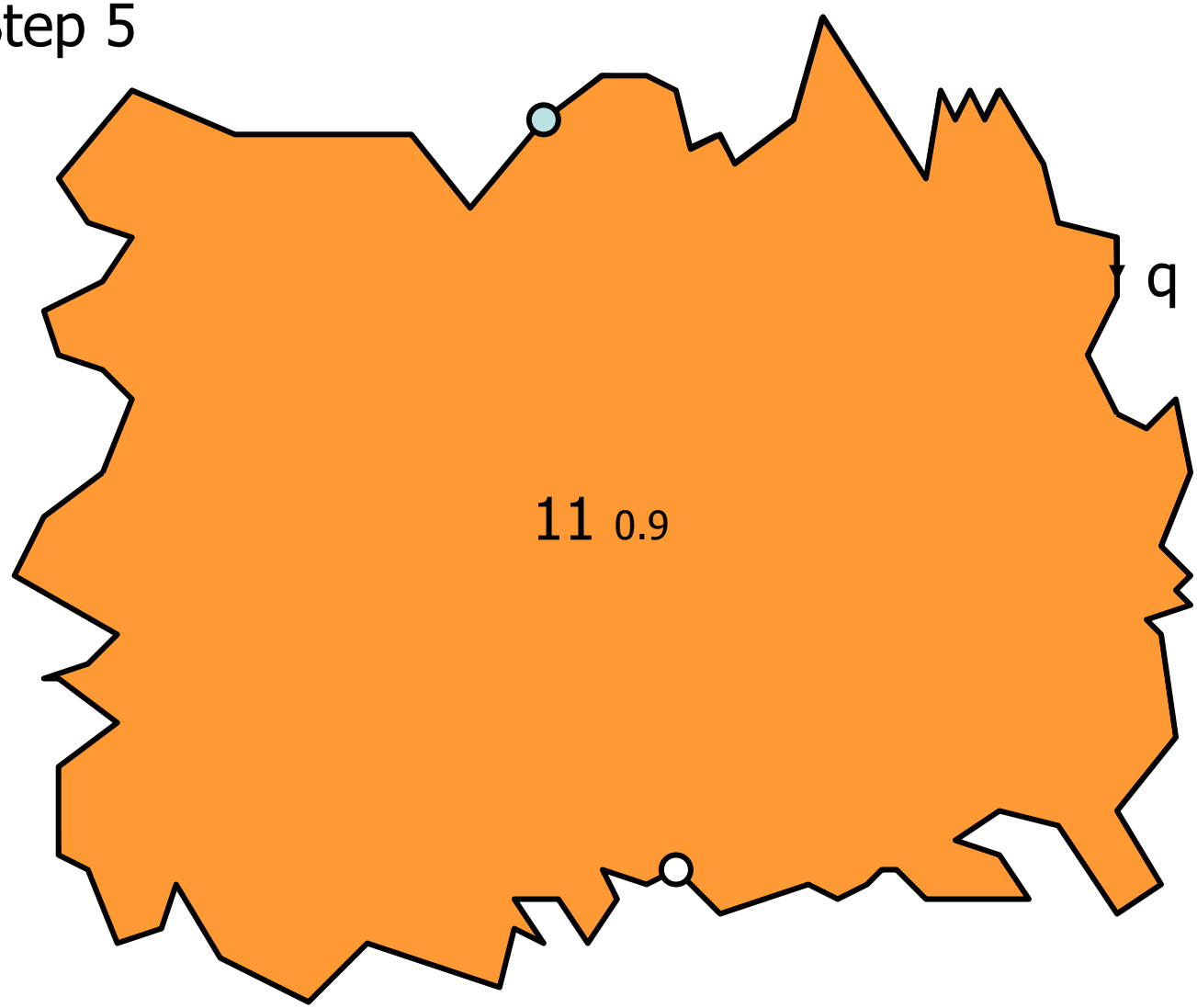
Step 5



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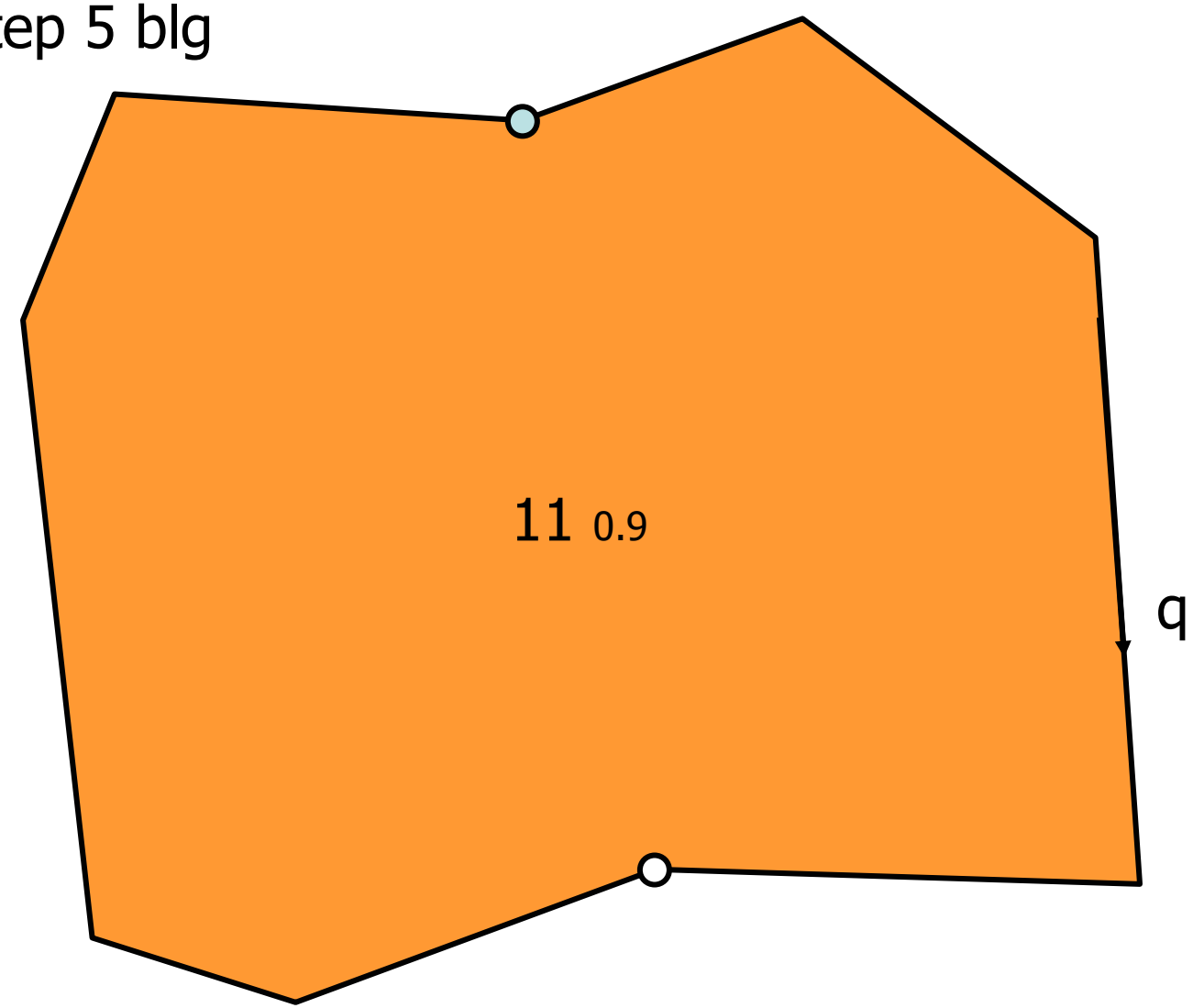
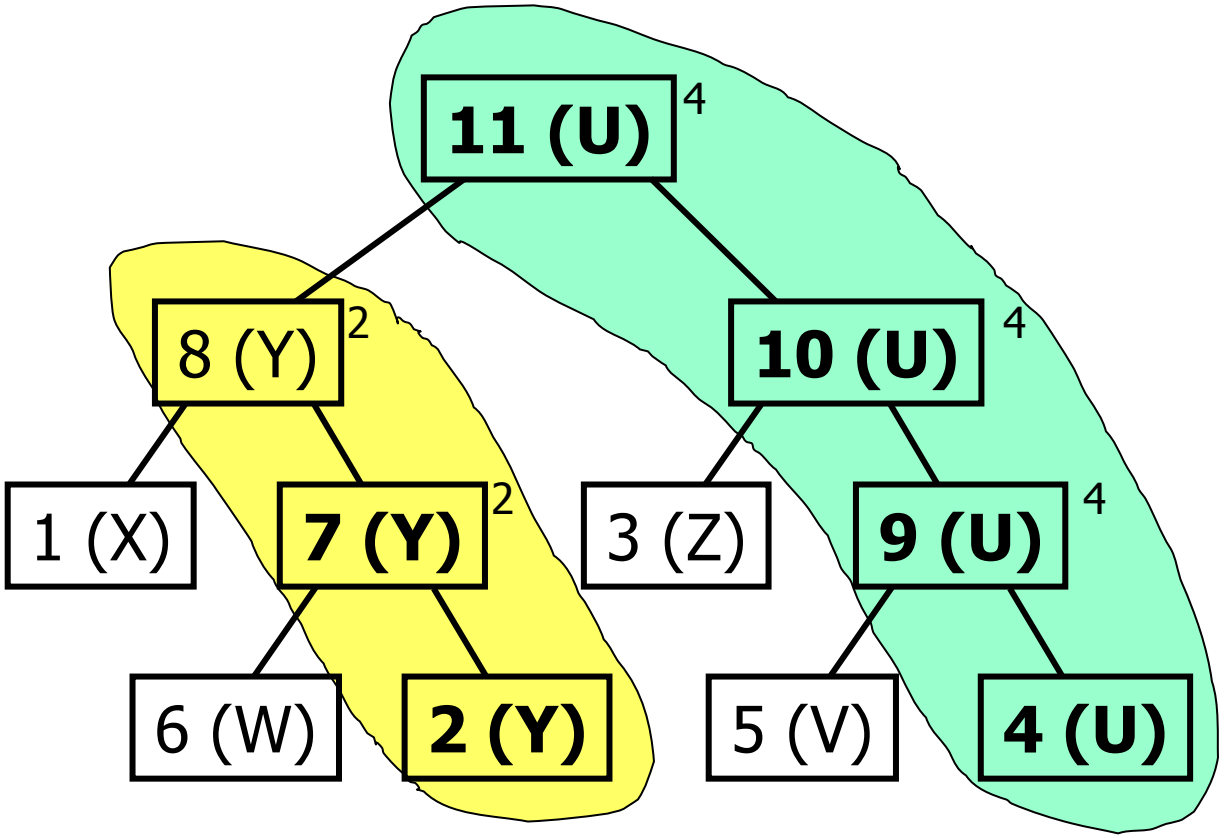
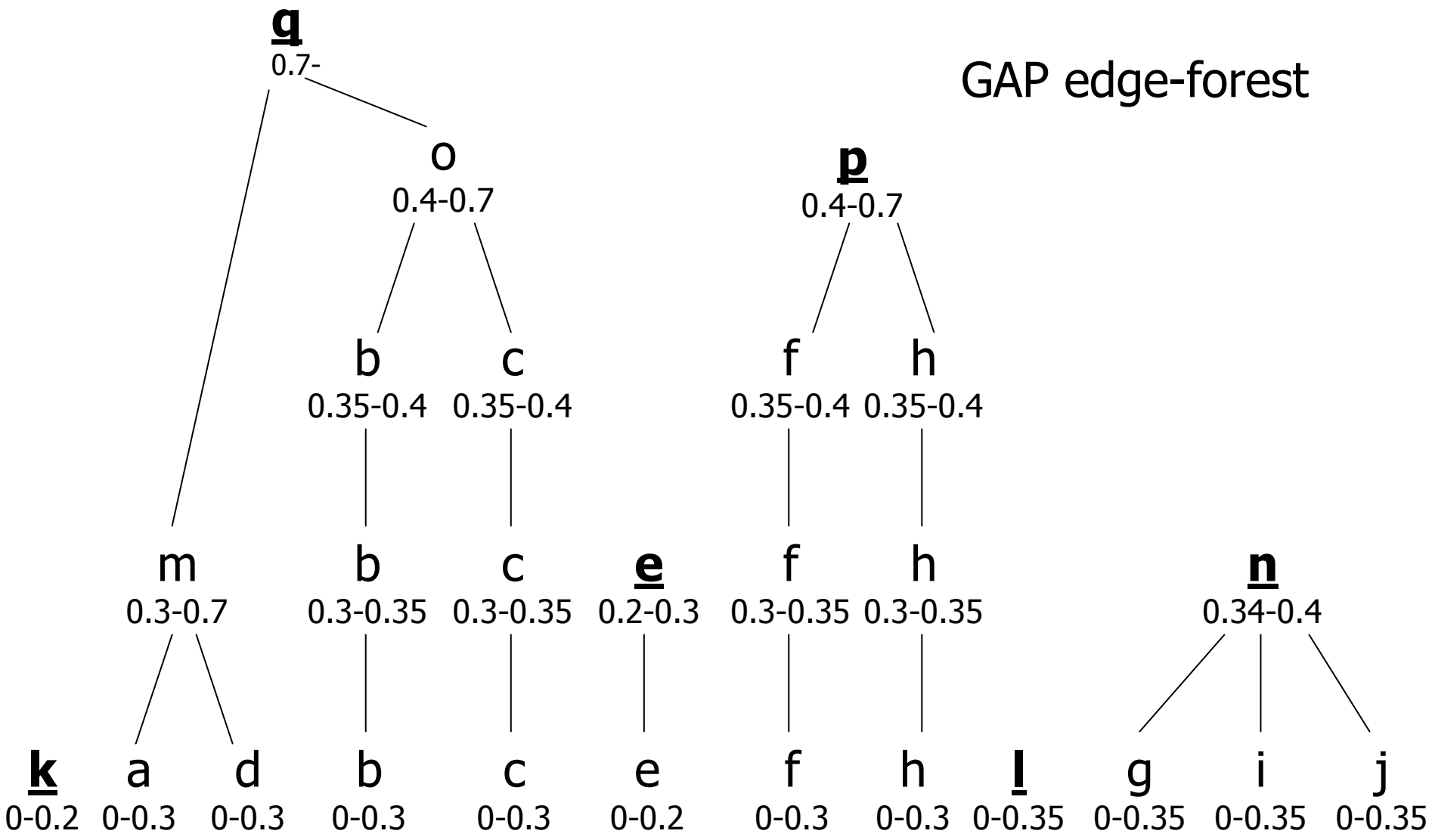
Step 5 blg



GAP face-tree



GAP edge-forest



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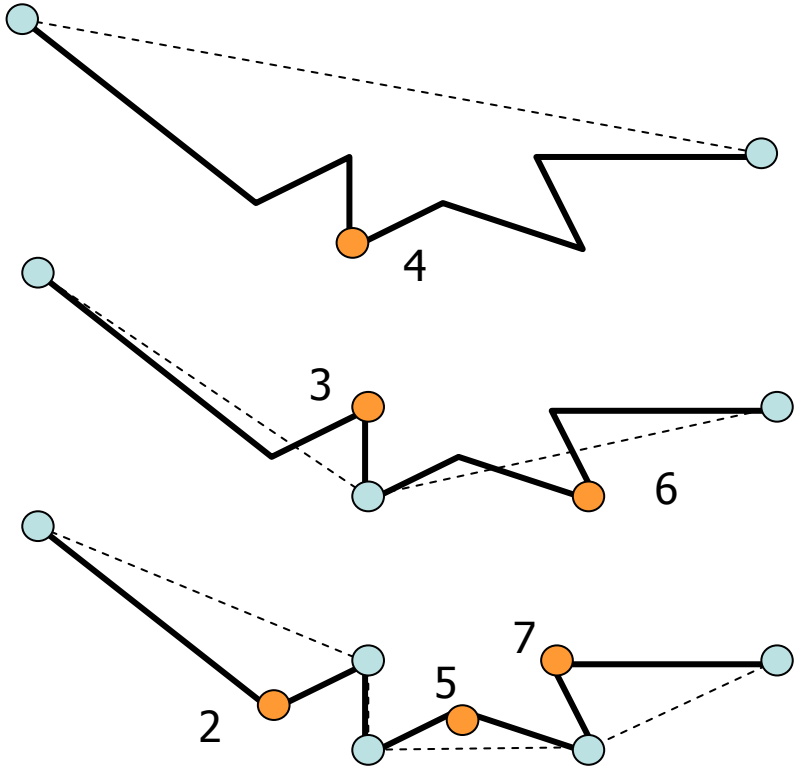
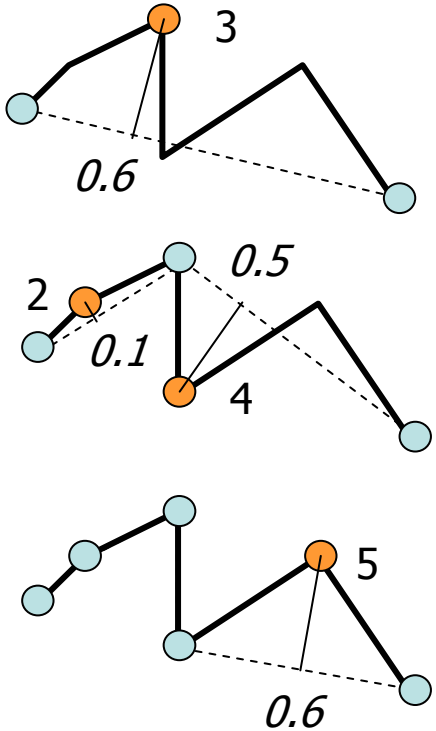
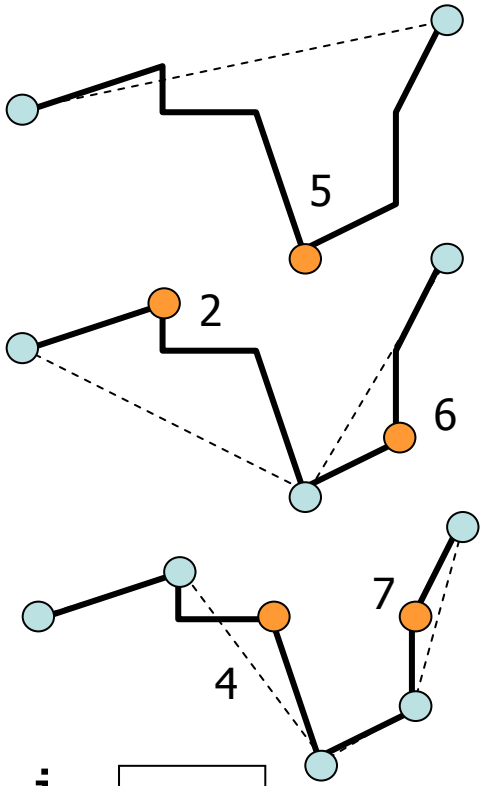
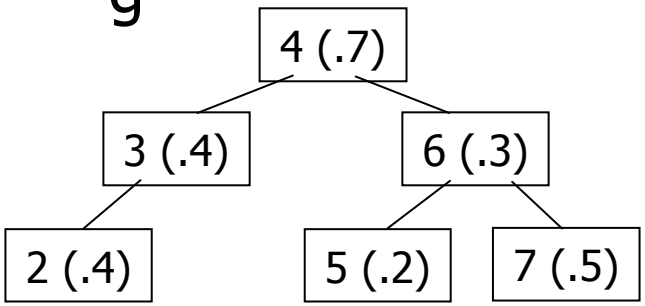

4
3
6
2
5
7

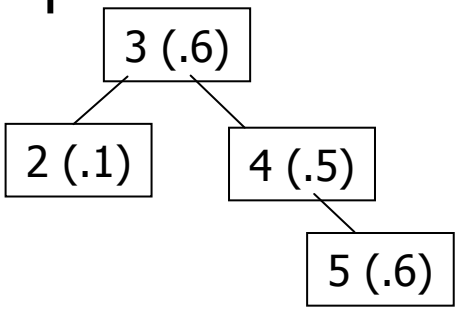

3
0.6
2
0.5
0.1
4
5
0.6


5
2
6
7
4

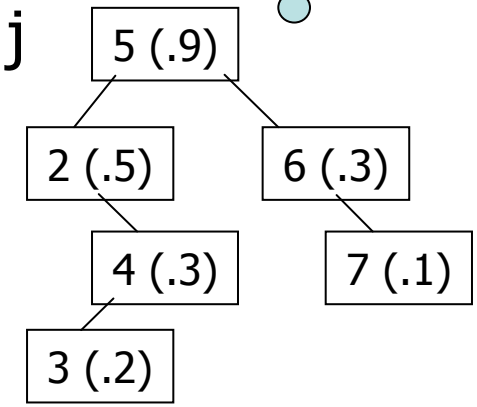
g


4 (.7)
3 (.4)
6 (.3)
2 (.4)
5 (.2)
7 (.5)

i


3 (.6)
2 (.1)
4 (.5)
5 (.6)

j


5 (.9)
2 (.5)
6 (.3)
4 (.3)
7 (.1)
3 (.2)

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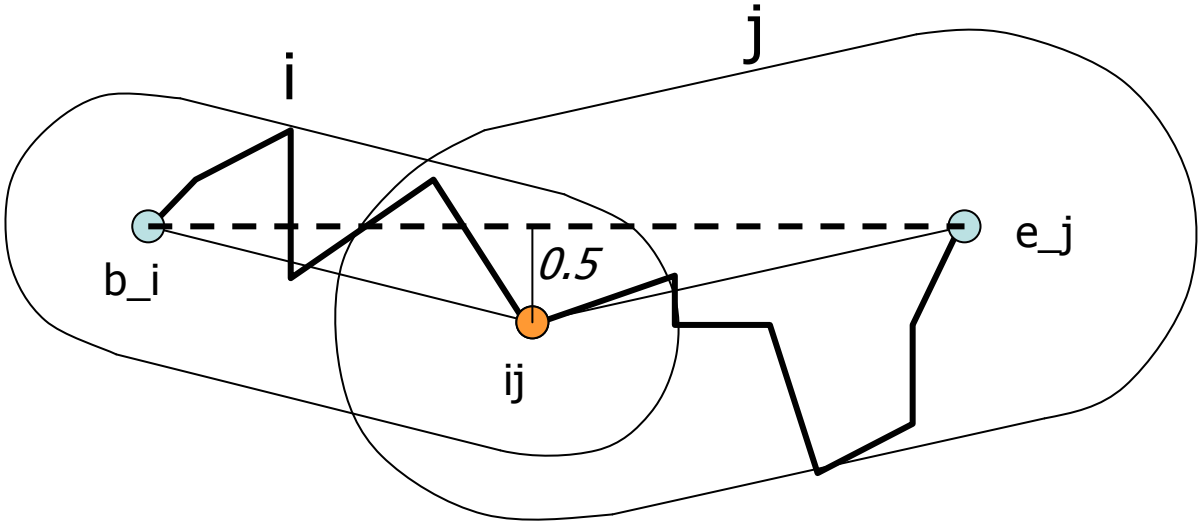
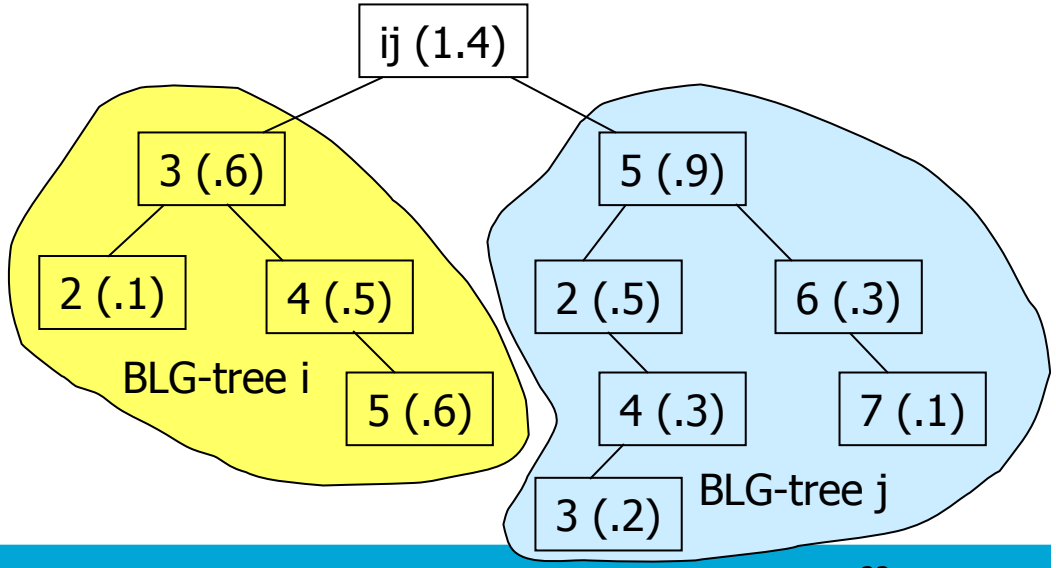
Join BLG-tree's
of edges i and j



err_ij=dist(point(ij), line(b_i,e_j))
+ max(err_i, err_j)=

0.5+0.9=1.4



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3. First implementation

- Object-relational model
- Spatial data types available (incl. BLG-tree polyline)
- Tables for tgap_face, tgap_edge, and tgap_blg
- Heavy use of views (and functions) to avoid redundant storage, but to provide 'easy access'
- Functional index (3D R-tree: 2D box+imp range)

- Different from earlier 'theory'
  1. tgap_node table added (last redundancy+BLG-tree)
  2. No winged edge, only left/right refs (less storage)
  3. Signed references when merging BLG-trees

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3: tGAP structure: combination of structures

- Uses topology
- Stores results of Generalization
- Suitable for Area Partitioning

GAP face tree	allow face selection
GAP edge forest	allow line selection
BLG tree	allow line simplification
3D R-tree	allow fast selection

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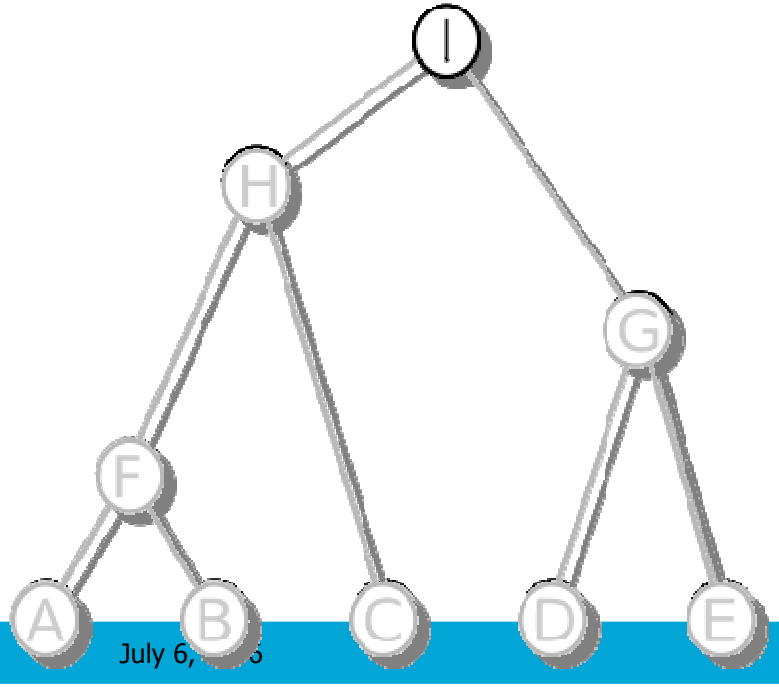
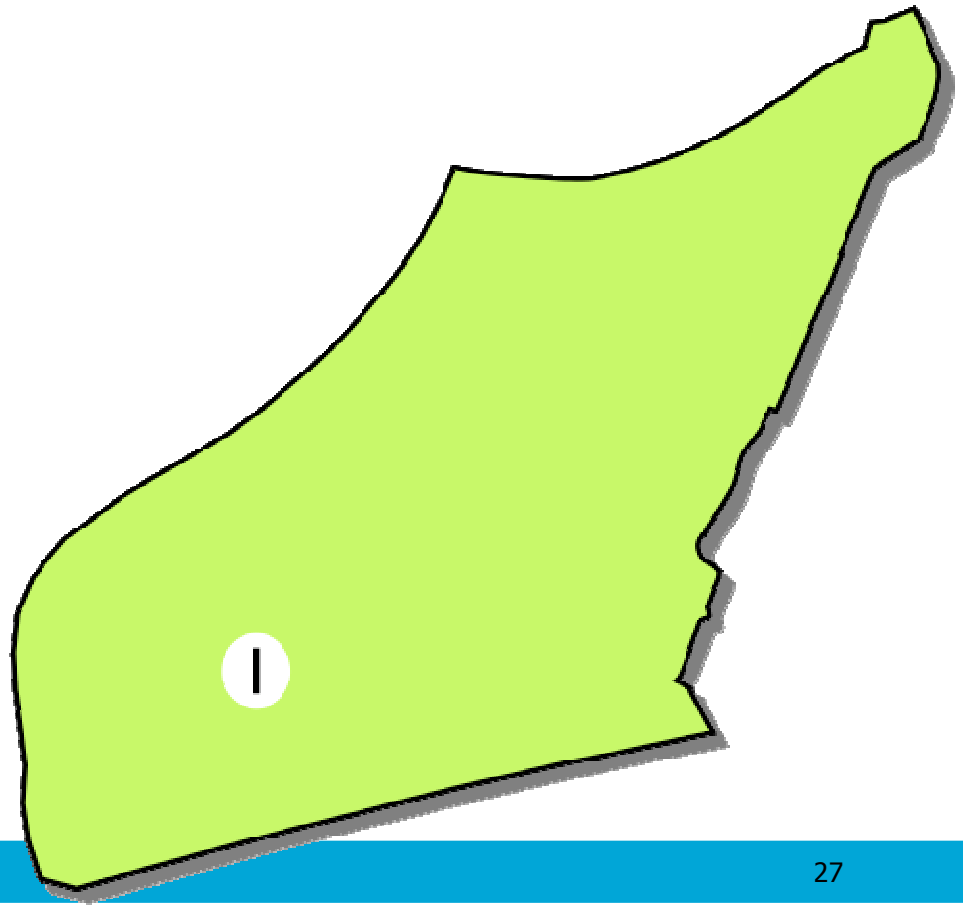
3. Constructing GAP face tree





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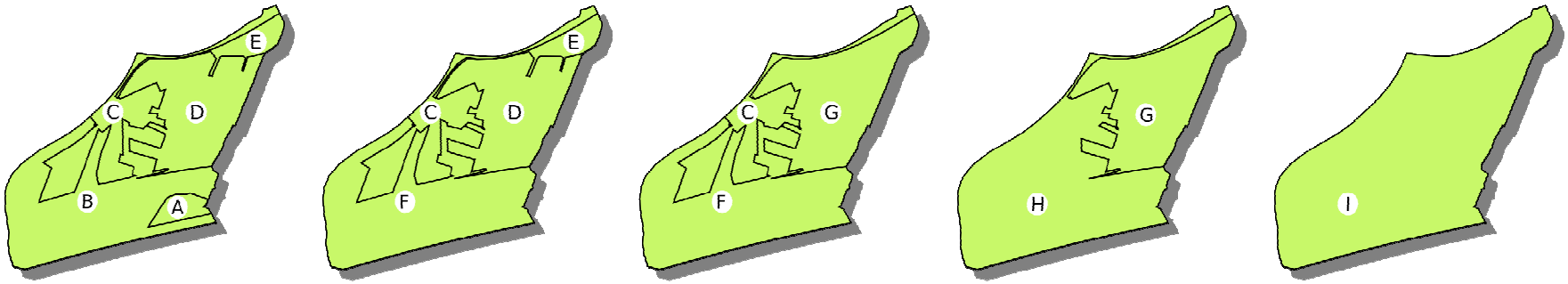
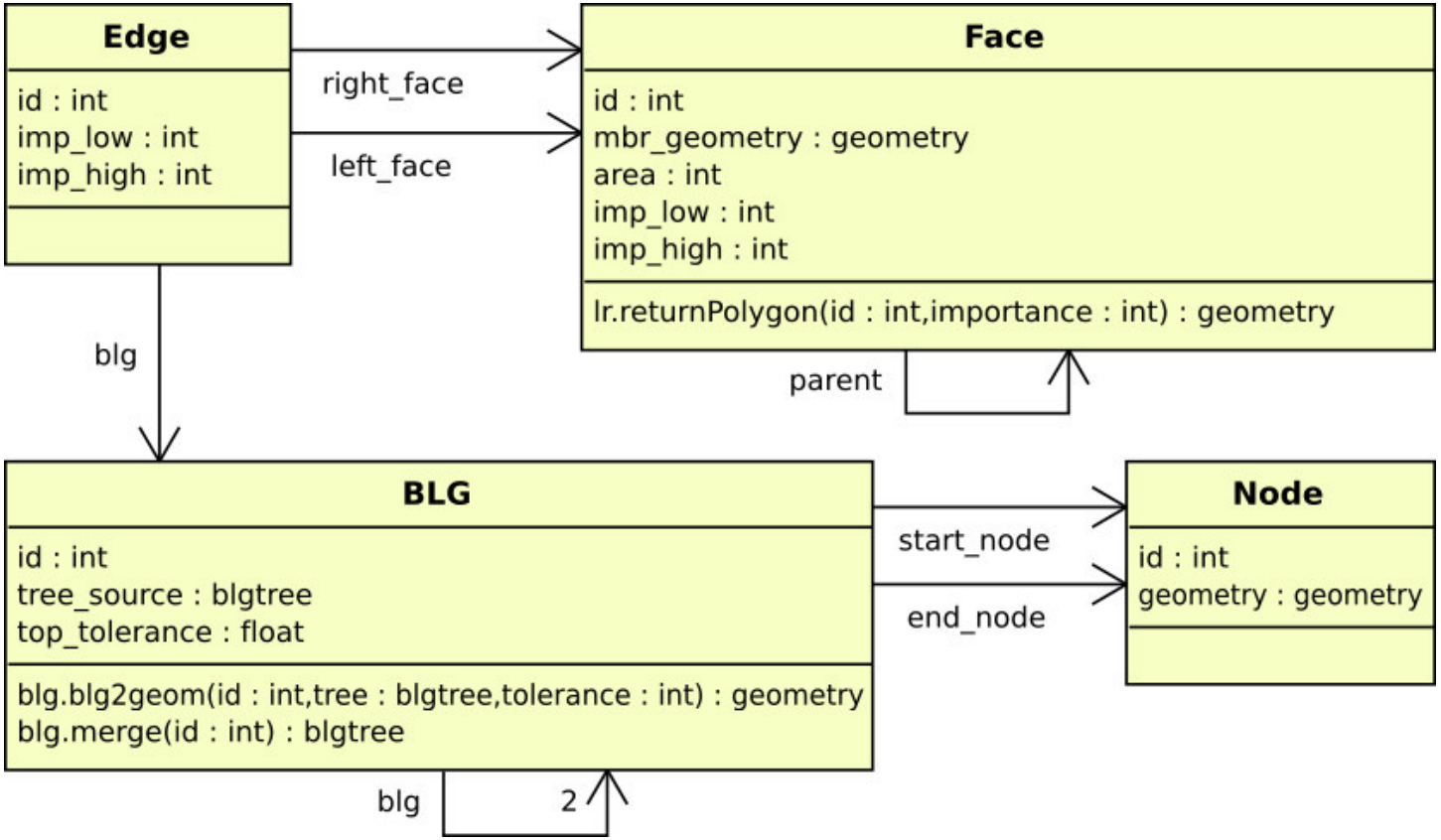


face id	imp l	imp h	area	mbr	parent
A	0	1	...	x_l, y_l, x_h, y_h	F
B	0	1	...	x_l, y_l, x_h, y_h	F
C	0	3	...	x_l, y_l, x_h, y_h	H
D	0	2	...	x_l, y_l, x_h, y_h	G
E	0	2	...	x_l, y_l, x_h, y_h	G
F	1	3	A+B	$A \cup B$	H
G	1	4	D+E	$D \cup E$	I
H	1	4	F+C	$F \cup C$	I
I	1	5	H+G	$H \cup G$	-

3. UML class diagram tGAP structure



3. tGAP storage requirements

- Several test datasets (small/medium/large): cadastral and topographic data (1:1.000-1:10.000)
- Plain (base scale) polygon storage 82 Mb
- Lean topology (base scale storage) 107 Mb (fact 1.3, note that Oracle spatial topology requires fact 3.0)
- Current tGAP (vario scale storage) 491 Mb (fact 6.0)

	#face/ Mb	*#edge/ Mb*	*#blg/ Mb*	*#node/ Mb*	*Total Mb*
Basic topology	170.368/ 2	418.530/ 94	-/ 0	281.216/ 11	107
tGAP structure	340.735/ 56	7.113.680/ 291	658.219/ 133	281.216/ 11	491

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3. tGAP storage improvements

- tgap_face: less attributes; area, mbr, perhaps parent..
- tgap_edge 'explodes': 17 times more than base edges, many versions of same edge (at different imp levels). However only few attributes change left, right, imp → all versions of edge in same record+varray's for variable attributes
- tgap_blg: implicit BLG-tree or even polyline
- tgap_blg: separate table for leaf and non leaf records

- Expected size mean and lean tGAP: factor 3

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3. tGAP initial visualization: polygons at arbitrary scale in Google Earth

1. DBMS Server: Oracle spatial with tGAP as discussed → Polygons generated for arbitrary importance and tolerance (BLG-tree)
2. Middleware (Apache web server + Python, GDAL): coord transf, KML → Polygons transformed
3. Frontend: Google Earth → Polygons visualized

- Communication:
  - 2←→3: HTTP get/KML and
  - 1←→2: OCI (query, result set)

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Image © 2006 GeoContent
Image © 2006 TerraMetrics
Google
Pointer 51°48'40.85" N 5°15'16.88" E
Streaming 100%
Eye alt 54.37 mi

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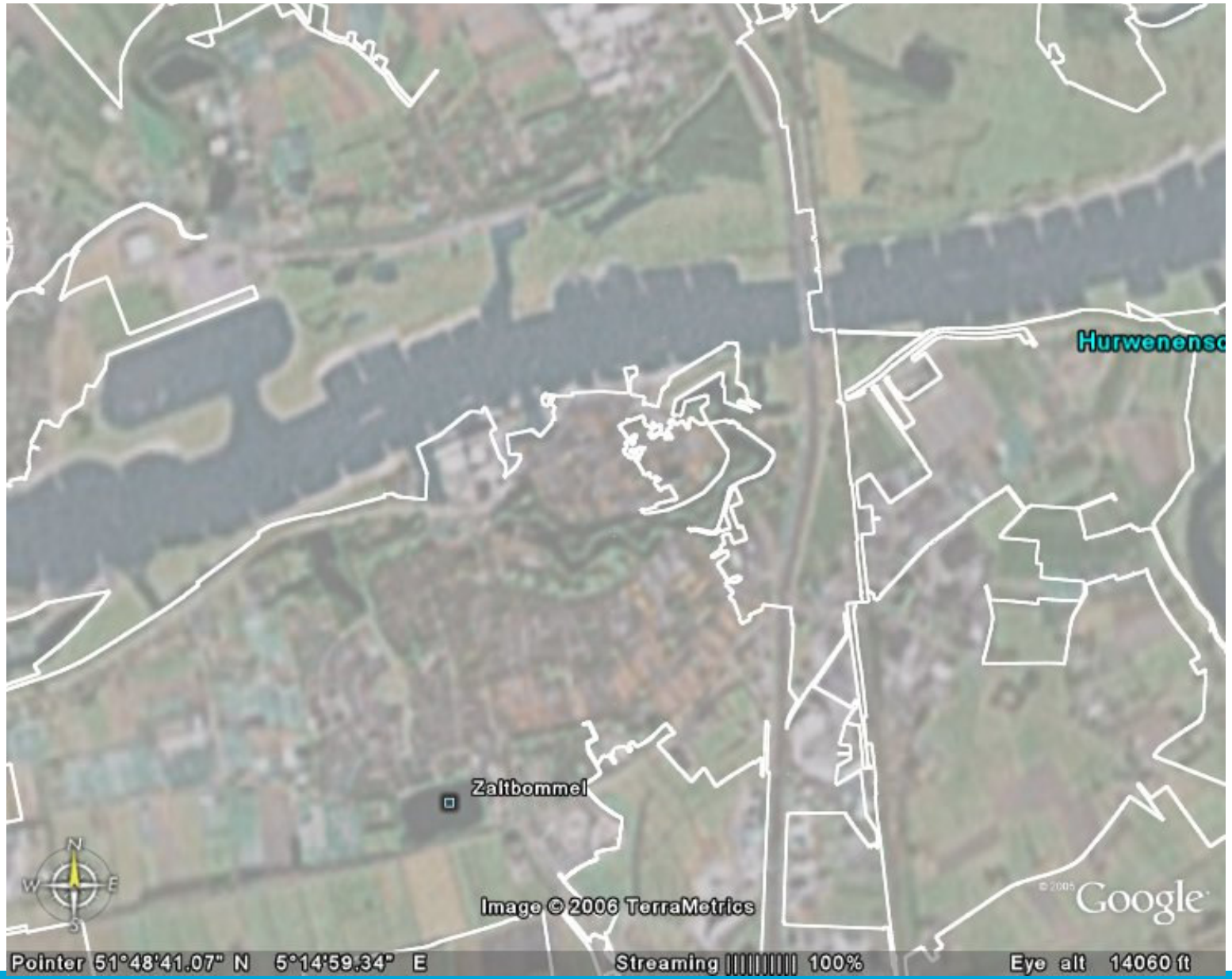
Hurwenensc
Zaltbommel
N
W
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S
Image © 2006 TerraMetrics
© 2005 Google
Pointer 51°48'41.07" N 5°14'59.34" E
Streaming 100%
Eye alt 14060 ft

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Image © 2006 TerraMetrics
©2005 Google
Pointer 51°48'49.00" N 5°15'06.88" E
Streaming 100%
Eye alt 5483 ft

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Image © 2006 TerraMetrics
©2005 Google
Pointer 51°48'40.95" N 5°15'17.50" E
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Eye alt 1478 ft

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4. Polygons or structure?

- Current implementation has focus on server
- Client gets only polygons:
  1. No topology structure
  2. No progressive refinement

- Polygons are requested for every wanted scale (importance)
- Improvements for progressive transfer:
  1. Send importance range polygons (sorted) → smart client
  2. Send tGAP structure → needs smarter client (tGAP aware)

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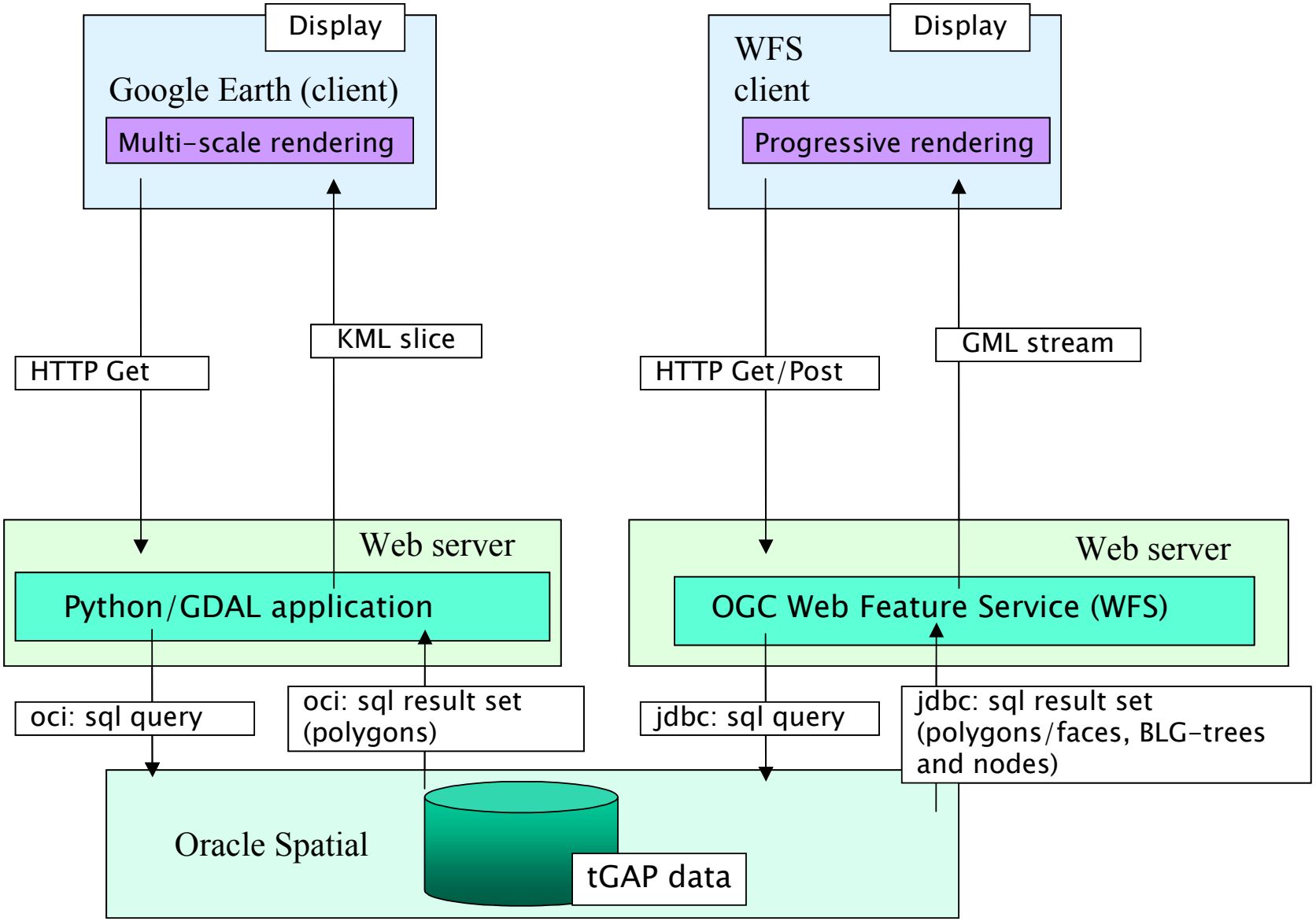
Display
Google Earth (client)
Multi-scale rendering
Display
WFS
client
Progressive rendering
HTTP Get
KML slice
HTTP Get/Post
GML stream
Web server
Python/GDAL application
Web server
OGC Web Feature Service (WFS)
oci: sql query
oci: sql result set
(polygons)
jdbc: sql query
jdbc: sql result set
(polygons/faces, BLG-trees
and nodes)
Oracle Spatial
tGAP data

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4. Streaming of importance range (and first compared with a cut)

- A cut (or slice) of single importance

```
select face_id as id, '101' as impLevel,
  RETURN_POLYGON(face_id, 101) as geom
from tgap_face
where imp_low <= 101 and 101 < imp_high;
```

- A ordered range of importance values

```
select face_id as id, imp_high-1 as impLevel,
  imp_low, imp_high,
  RETURN_POLYGON(face_id,imp_high-1) as geom
from tgap_face
where imp_high > 90
order by imp_high desc;
```


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4. Smart client for polygon range

- Alternatives:
  - Render step by step: start with most coarse polygon, then replace it by its two children. Repeat this step when receiving more detailed polygons.
  - Collect polygons for a while and render at a number of larger steps (and morph between steps).
  - Wait until everything has arrived and draw at appropriate scale
- The cached range (imp) of polygons can also be used at client side for (smart) zooming.
- Note no topology used and also no line simplification

4. Extension to OGC/ISO WFS

- It is possible to specify imp range in Filter part of GetFeature request and using ogc:SortBy
- Not ideal because it is not clear that this is about scale, streaming, progressive transfer/refinement
- Deeper integration in WFS (called WFS-R):
  1. GetCapabilities should indicate if server supports progressive refinement
  2. Reporting of the min and max imp of a theme
  3. New request type GetFeatureByImportance

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4. Example WFS-R request

```
<wfs:GetFeatureByImportance service="WFS"
 version="1.0.0" outputFormat="GML2" ...>
 <wfs:Query typeName='tgap_face' minImp='5' maxImp=`8'>
  <ogc:Filter>
   <ogc:BBOX>
    <ogc:PropertyName>geom</ogc:PropertyName>
    <gml:Box srsName="…epsg.xml#28992">
     <gml:coordinates>
      136931,416574 139382,418904
     </gml:coordinates>
    </gml:Box>
   </ogc:BBOX>
  </ogc:Filter>
  <ogc:SortBy>gdmc:imp_high D</ogc:SortBy>
 </wfs:Query>
</wfs:GetFeatureByImportance>
```


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5. Conclusions, main results

- First time ever non-redundant geometry scaleless data structure has been implemented (based on topology)
- tGAP is well suited for web environment:
  1. No geometric processing at client side
  2. Supports progressive refinement (several levels)
- The class importance values and classes compatibility matrix are crucial for quality of the structure
- Views can be used for 'dumb' clients (non-tGAP-aware)

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5. Conclusion: progressive refinement based on tGAP structure

- Server starts sending most important nodes in GAP face-tree/edge-forest (in selected search rectangle)
- Client builds partial copy of GAP/BLG-structure
  → can be used to display coarse impression
  → every (x) seconds this structure is redisplayed
- Server keeps on sending more data and GAP/BLG-structure at client is growing (with more details)
- Possible stop criteria:
  1. 1000 objects (meaningful info density on screen)
  2. Required imp level is reached (with tolerance value)
  3. User interrupts the client

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5. Conclusions, improvements

- Generalization is application (task) dependent
  → more than 1 tGAP structure on same base topol (compare to multiple indices on same table)
- 'Bug': different edges of narrow features may cross when generalizing → avoid this during creation by tests (and state corresponding correct imp/tol value)
- Benchmarks have to be performed with alternatives (multiple-representation approaches and redundant scaleless approaches)
- Two important test client environments:
  1. Desktop GIS
  2. Distributed Web GIS

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5. Conclusions, further enhancements

- Data editing (at most detailed level), local propagation to higher levels, dynamic structures
- Support for non-area objects (Reactive-tree for index):
  1. Points: own table with importance range
  2. Lines: same but now with reference to BLG-repr.
  3. Also combine 2 less important lines in 1 (e.g. after removal of least important branch)
- Change from area to line (or point) representation at certain moment. Similar to normal GAP-face tree when face is removed, but now at same time it is introduced in point or line table (with link).

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