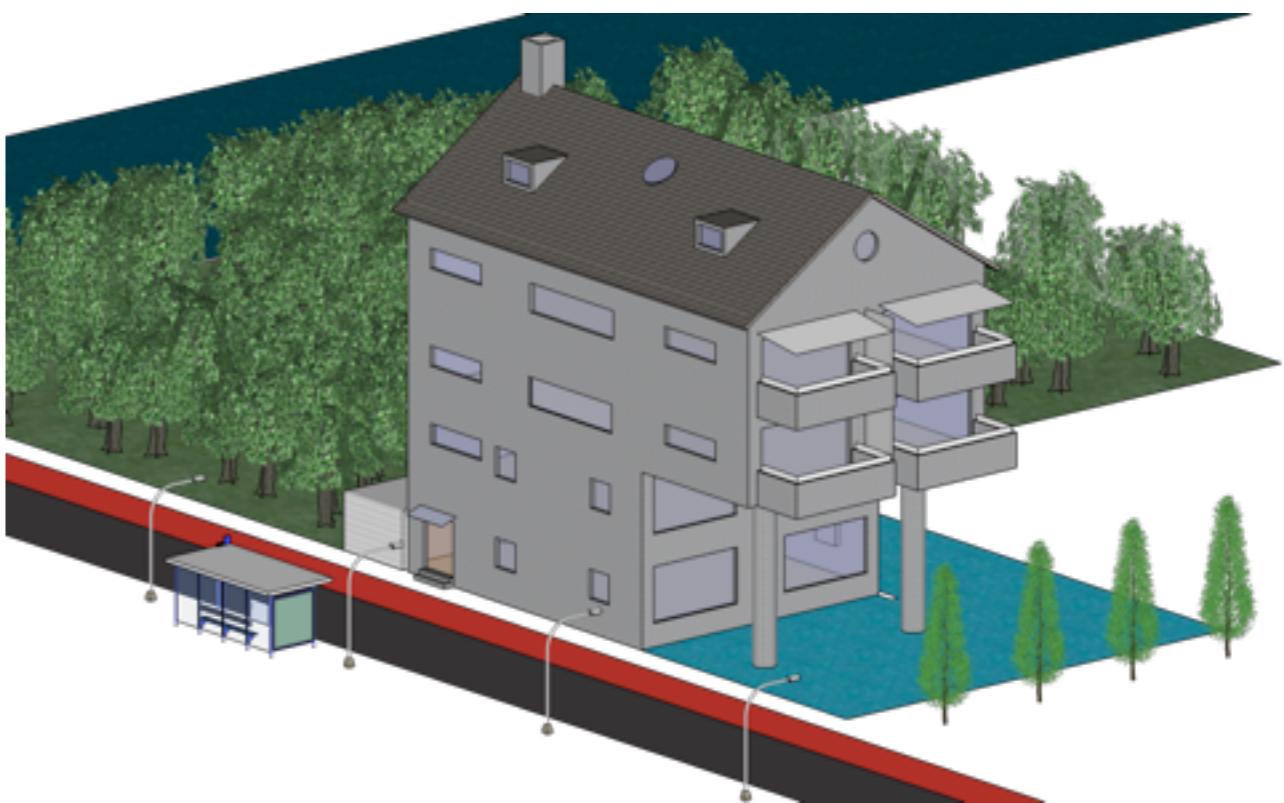
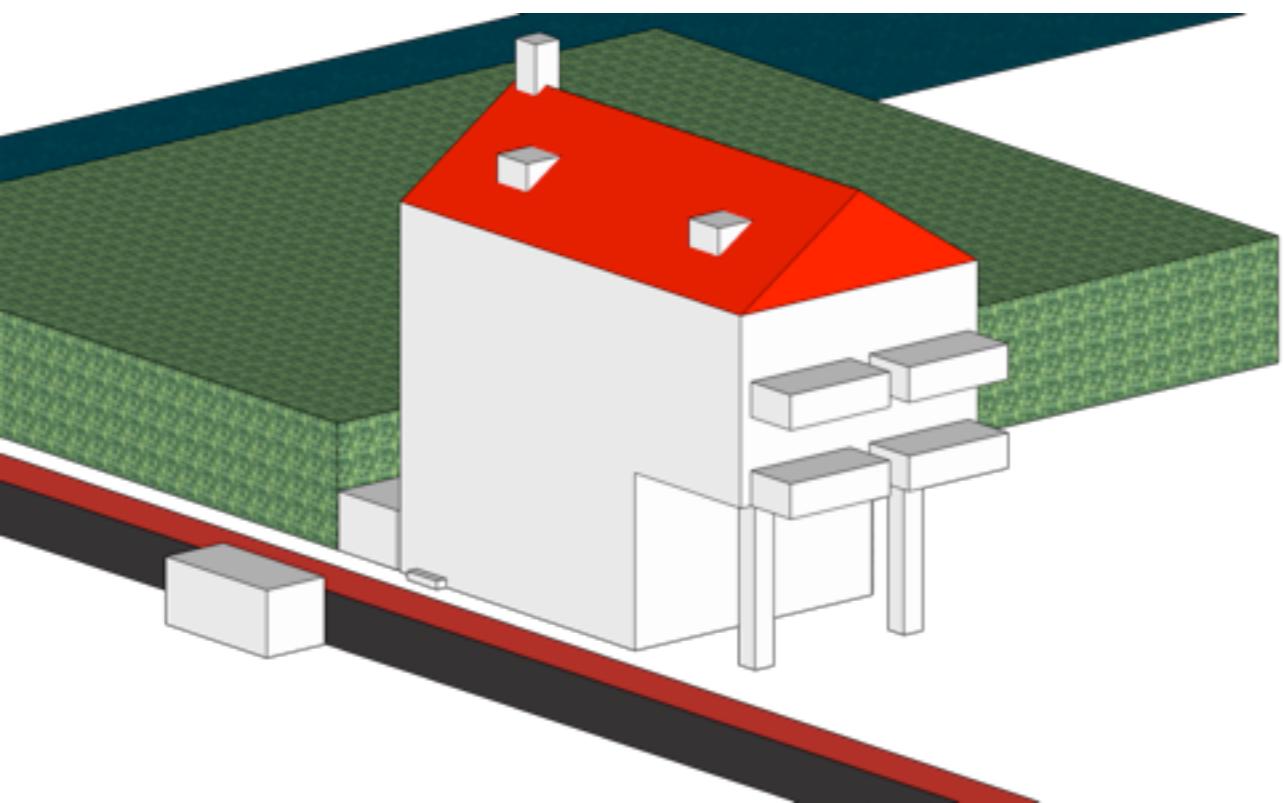
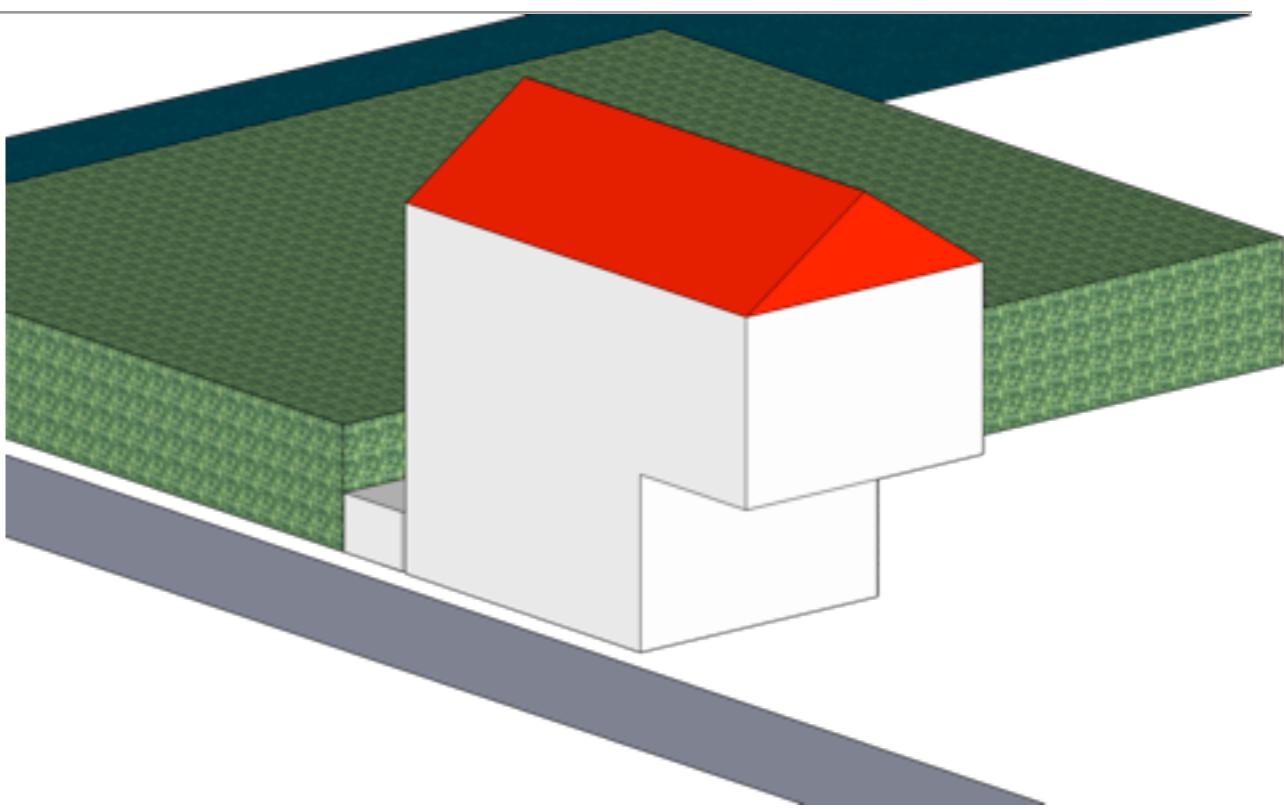
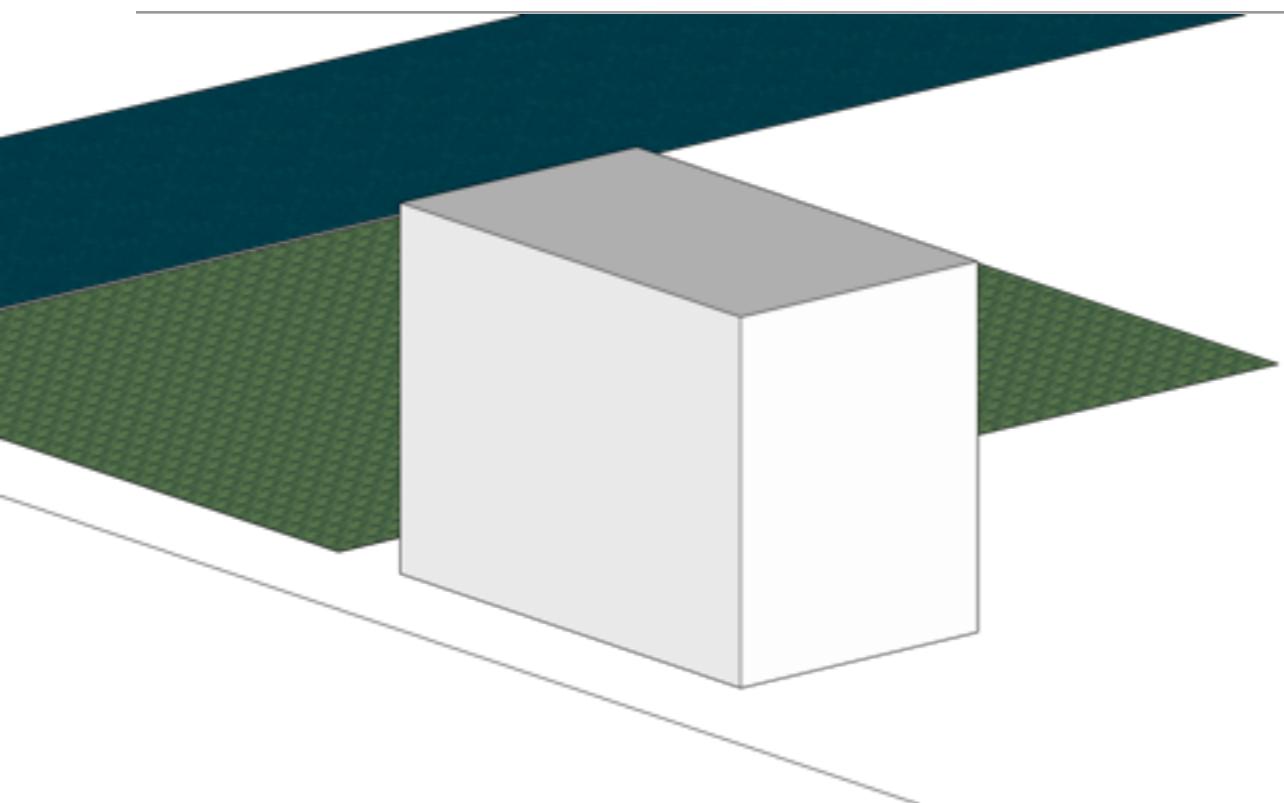


Extrusion of n D objects using generalised maps

Ken Arroyo Ohori

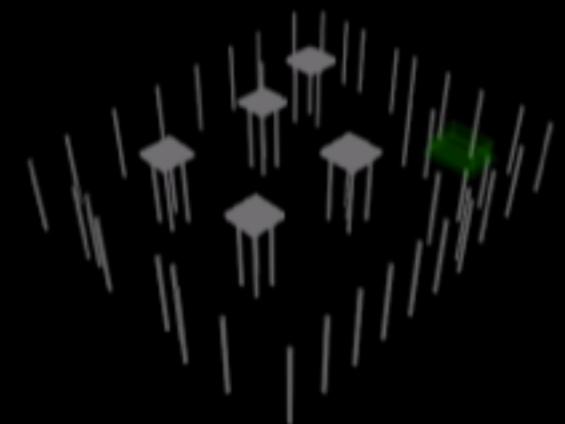
9th Dutch Computational Geometry Day
October 24, 2013

From multiple representation to higher dimensional GIS

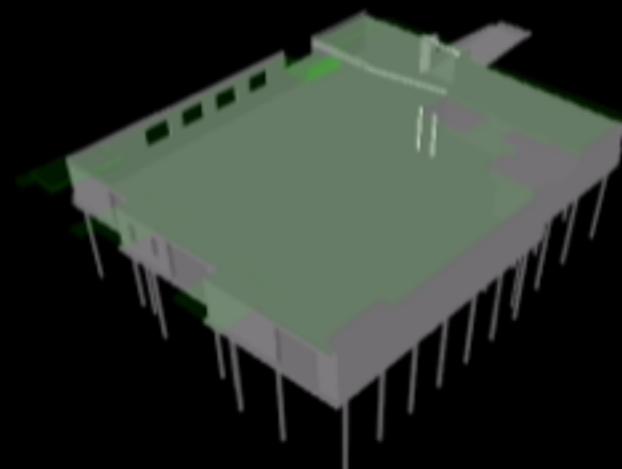


From multiple representation to higher dimensional GIS

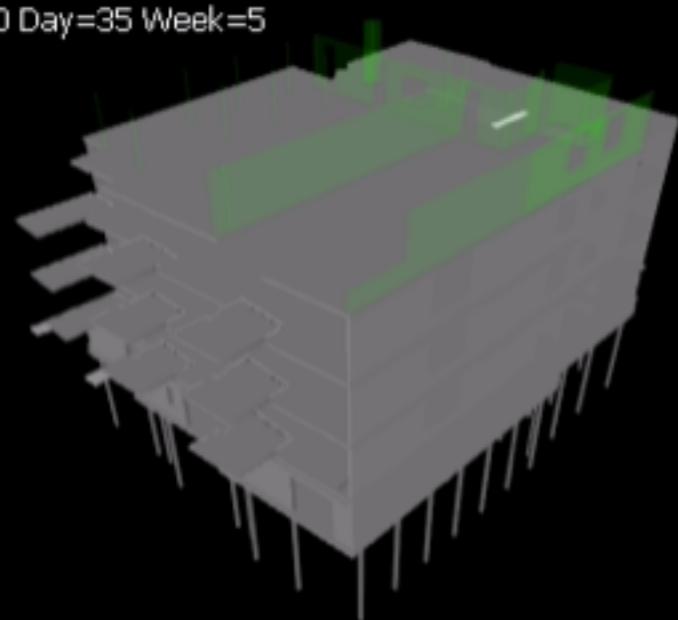
g 5:31:12 31-8-2010 Day=14 Week=2



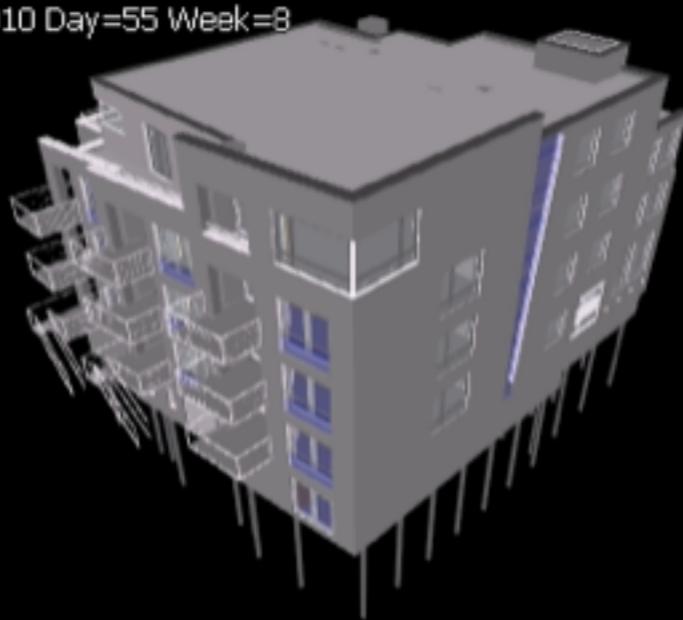
dinsdag 3:50:24 7-9-2010 Day=21 Week=3



g 19:55:12 21-9-2010 Day=35 Week=5

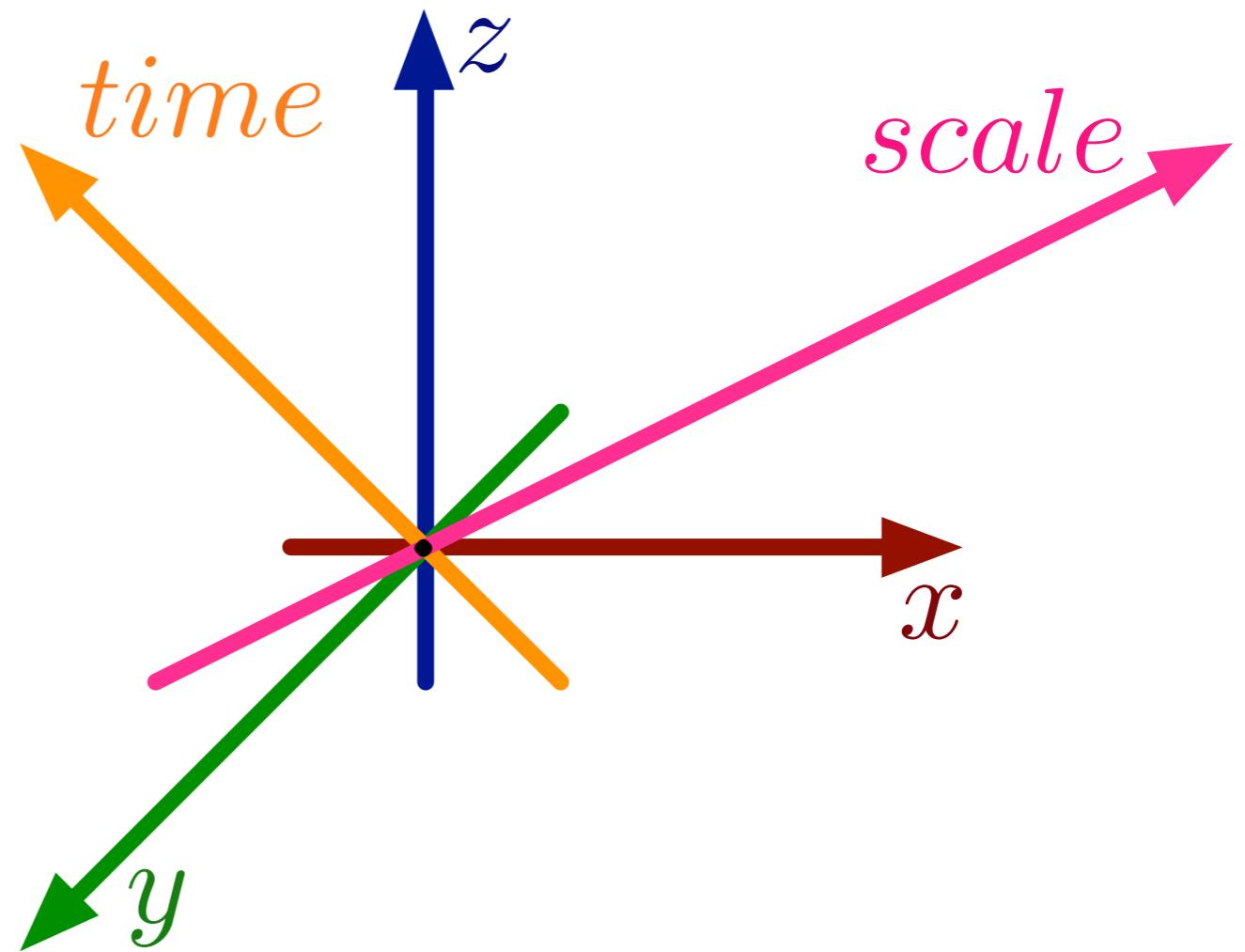


maandag 0:00:00 11-10-2010 Day=55 Week=8



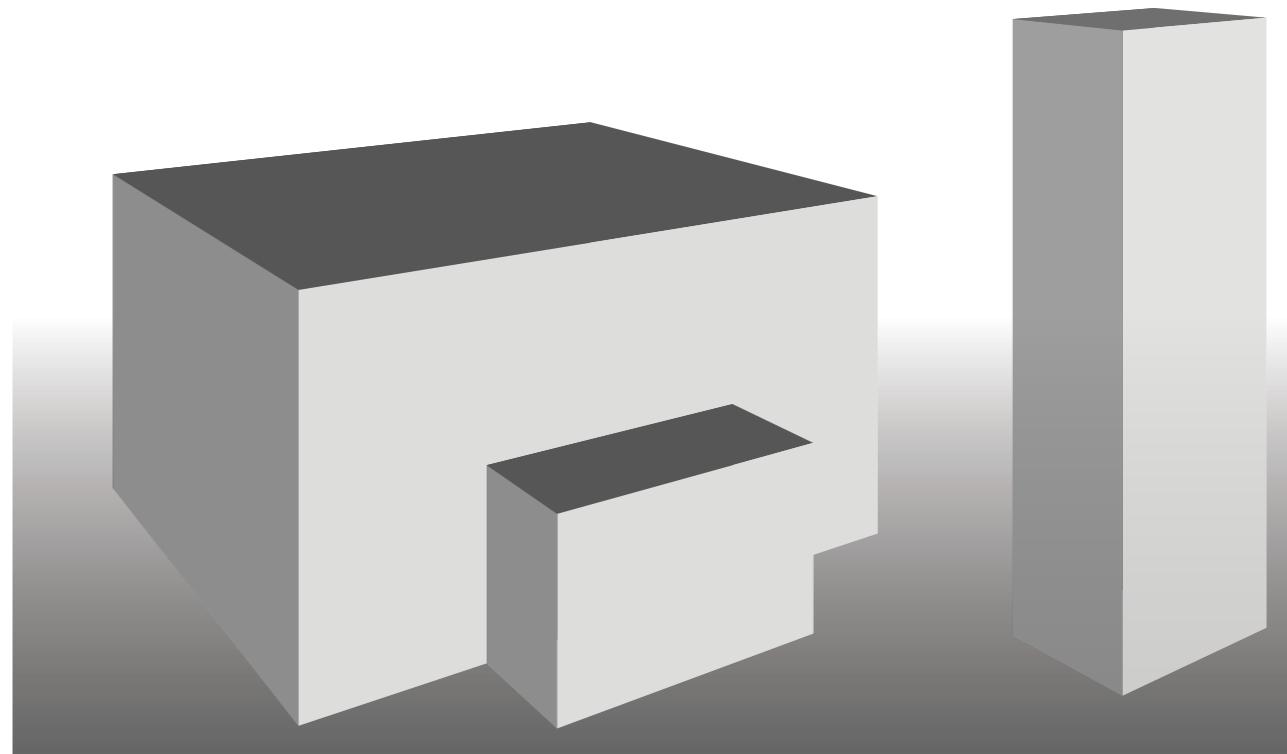
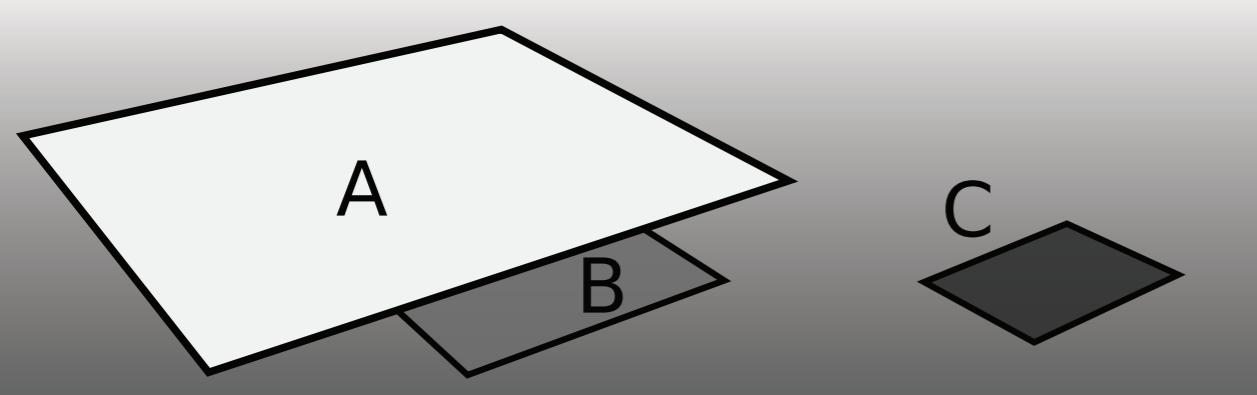
From multiple representation to higher dimensional GIS

- Powerful representation
- Conceptually easy but new techniques are needed



2D to 3D extrusion

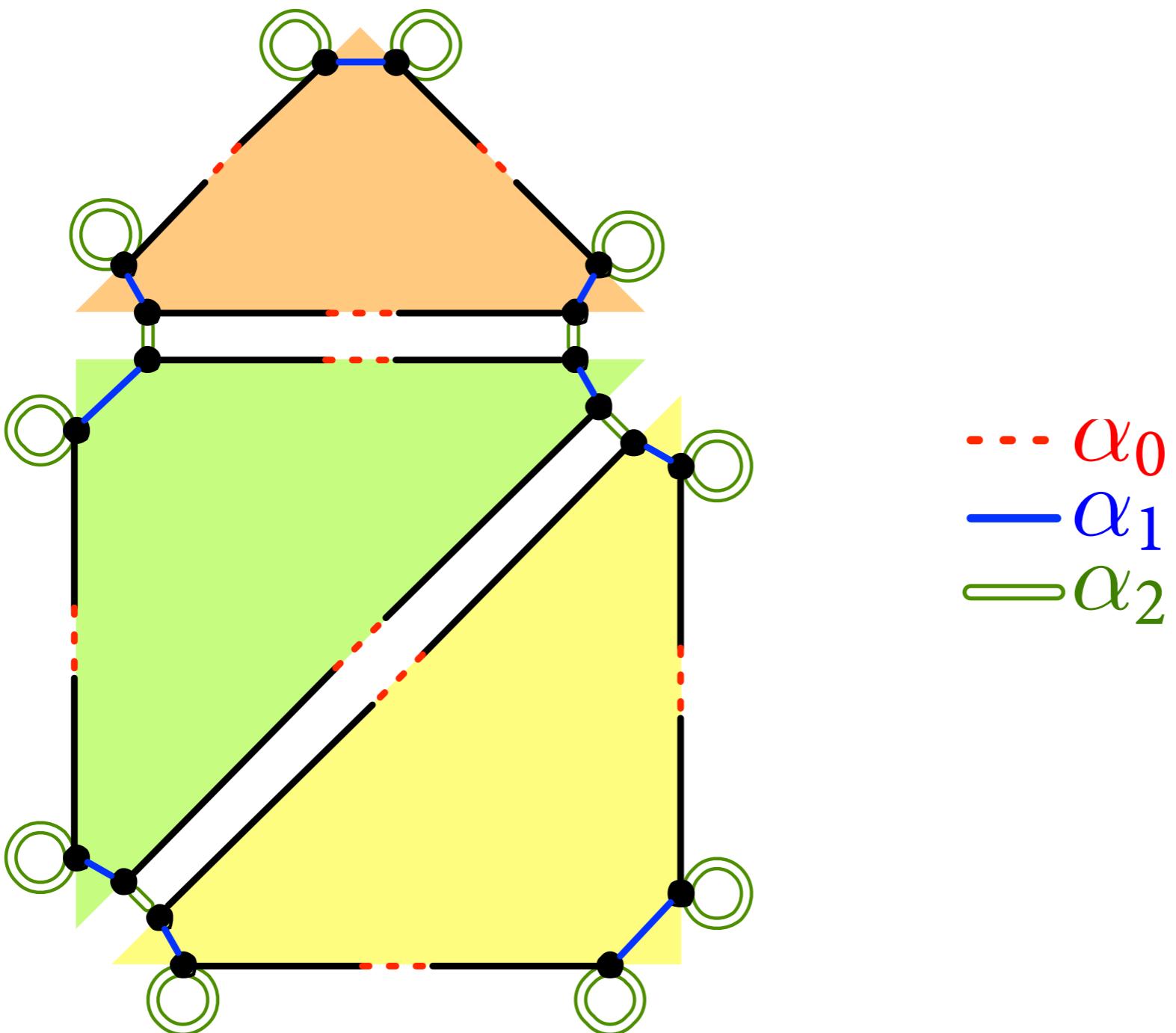
- 2D footprint + height → 3D



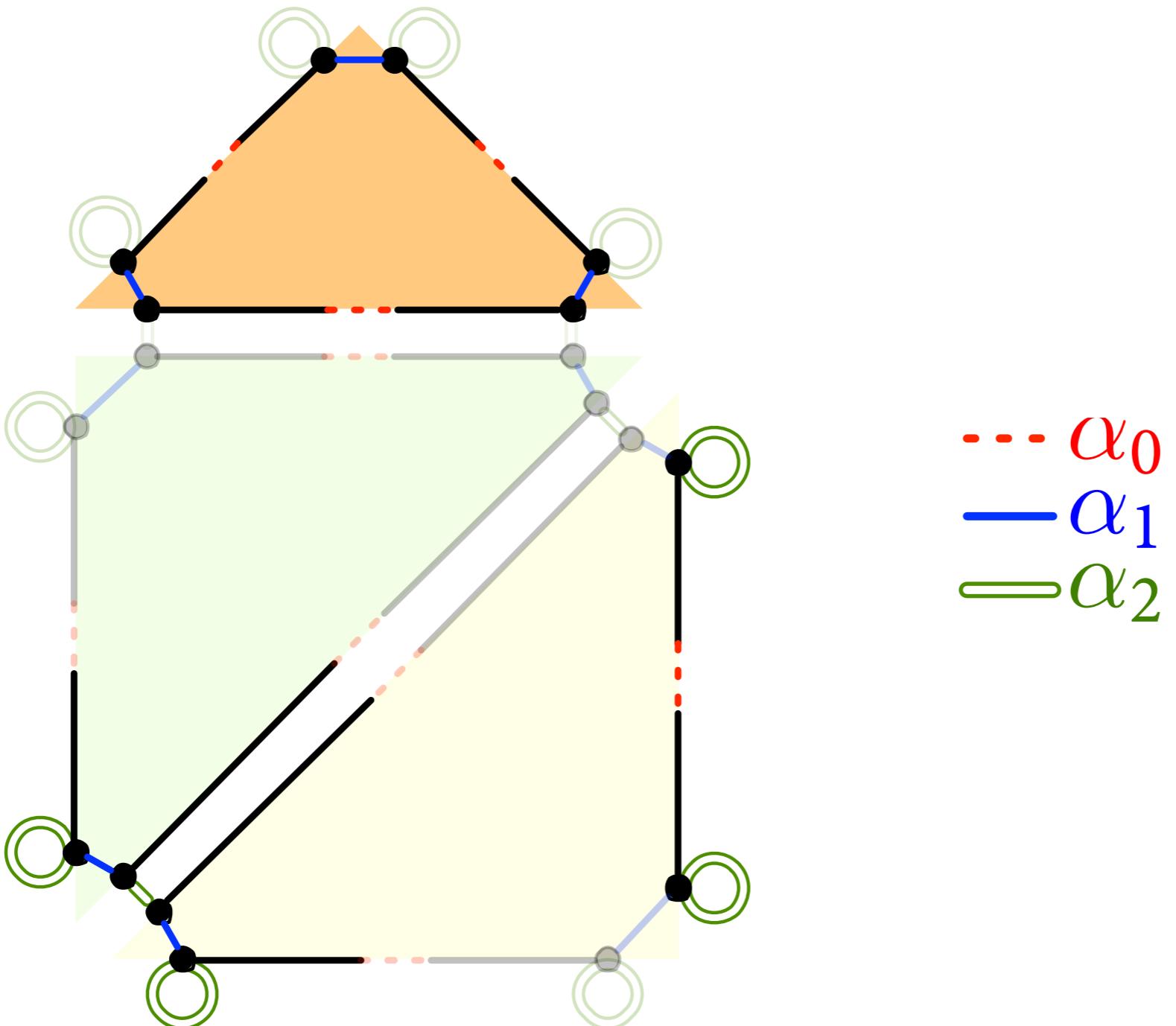
n D extrusion

n D cell complex + range $\rightarrow (n+1)$ D

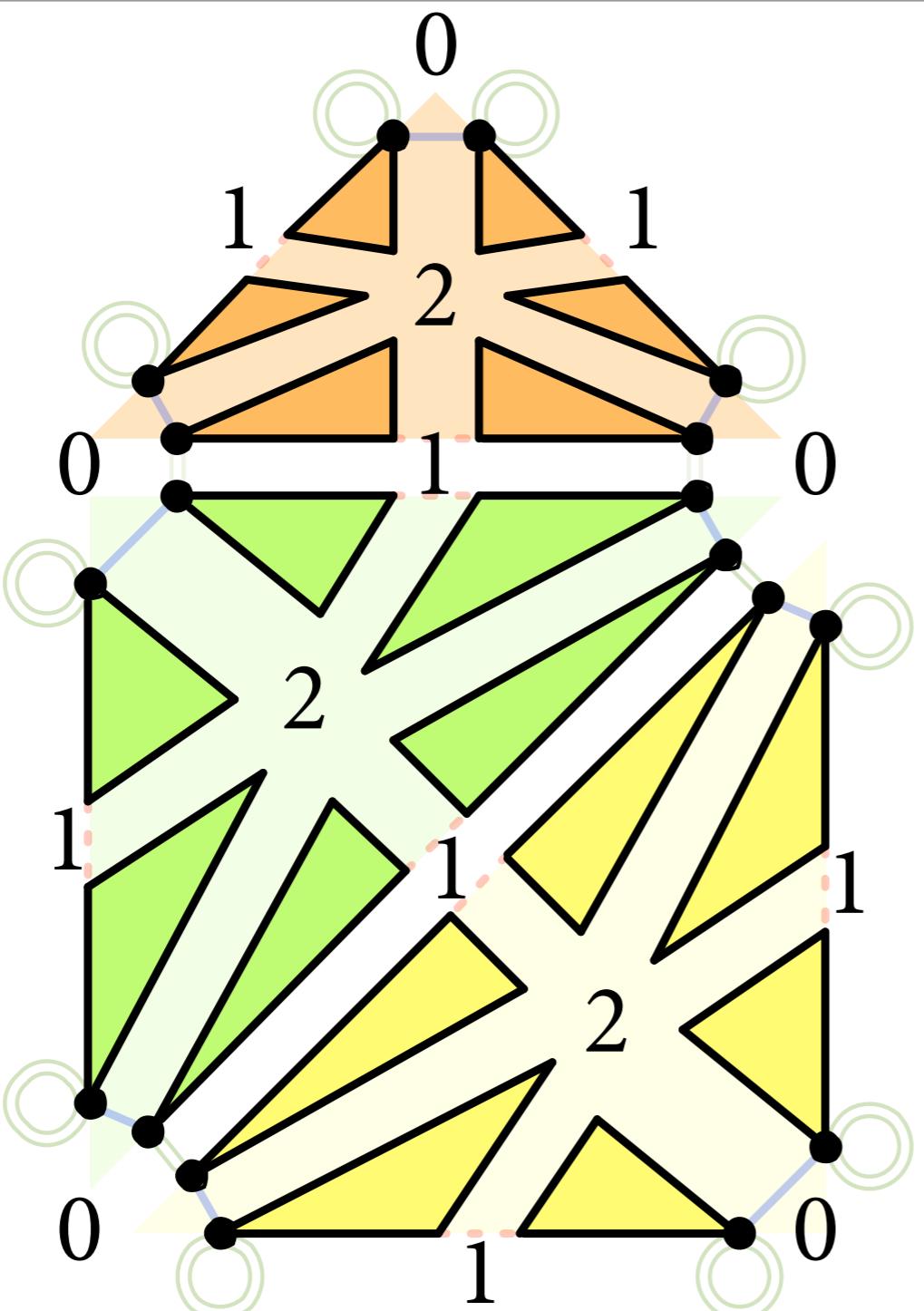
Generalised maps



Generalised maps



Generalised maps



Generalised maps

```
struct Dart {  
    Dart *involutions[n+1];  
    Embeddings *embeddings[n+1];  
};  
  
struct Embedding {  
    Dart *referenceDart;  
    Embedding *holes[];  
    int dimension;  
    ...  
    float red, green, blue;  
};  
  
struct PointEmbedding : Embedding {  
    float x, y, z;  
};
```

Extrusion

Algorithm 1: EMBEDDINGS EXTRUSION

Input : $E, [r_{\min}, r_{\max}]$
Output: E' , base , top , ex
foreach $e \in E$ **do**

$\text{base}(e), \text{top}(e), \text{ex}(e) \leftarrow e$
if $e.\text{dimension} = 0$ **then**

- Append r_{\min} to $\text{base}(e)$'s coordinates
- Append r_{\max} to $\text{top}(e)$'s coordinates

 $\text{ex}(e).\text{dimension} \leftarrow \text{ex}(e).\text{dimension} + 1$

Put $\text{base}(e)$, $\text{top}(e)$ and $\text{ex}(e)$ in E'

Extrusion

Algorithm 2: GMAPEXTRUSION

Input : $G = (D, \alpha_0, \alpha_1, \dots, \alpha_{n-1}), E, E', base, top, ex, e, e'$
Output: $G' = (D', \alpha'_0, \alpha'_1, \dots, \alpha'_n)$

for $dim \leftarrow n$ **to** 0 **do**

- GMAPLAYER**($G, G', dim, 1, last, E, E', e, e', base, ex$)
- $last \leftarrow cur$

for $dim \leftarrow 0$ **to** n **do**

- GMAPLAYER**($G, G', dim, 0, last, E, E', e, e', top, ex$)
- $last \leftarrow cur$

Extrusion

Algorithm 3: GMAPLAYER

Input : $G = (D, \alpha_0, \alpha_1, \dots, \alpha_{n-1})$, $G' = (D', \alpha'_0, \alpha'_1, \dots, \alpha'_n)$,
 $dim, offset, last, E, E', e, e', el, ex$

Output: $G' = (D', \alpha'_0, \alpha'_1, \dots, \alpha'_n)$, $last, cur, e'$

foreach $d \in D$ **do**

| $cur(d) \leftarrow$ new dart

| Put $cur(d)$ in D'

foreach $d \in D$ **do**

| **for** $inv \leftarrow 0$ **to** $dim - 1$ **do**

| | $\alpha'_{inv}(cur(d)) \leftarrow cur(\alpha_{inv}(d))$

| | $\alpha'_{dim+offset}(cur(d)) \leftarrow last(d)$

| | $\alpha'_{dim+offset}(last(d)) \leftarrow cur(d)$

| **for** $inv \leftarrow dim + 2$ **to** n **do**

| | $\alpha'_{inv}(cur(d)) \leftarrow cur(\alpha_{inv-1}(d))$

| **for** $emb \leftarrow 0$ **to** dim **do**

| | $e'_{emb}(cur(d)) \leftarrow el(e_{emb}(d))$

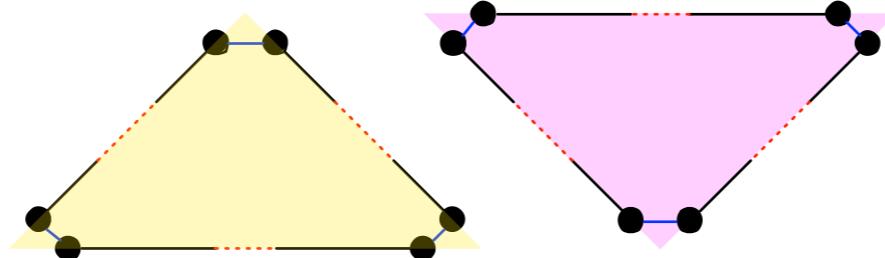
| **for** $emb \leftarrow dim + 1$ **to** n **do**

| | $e'_{emb}(cur(d)) \leftarrow ex(e_{emb-1}(d))$

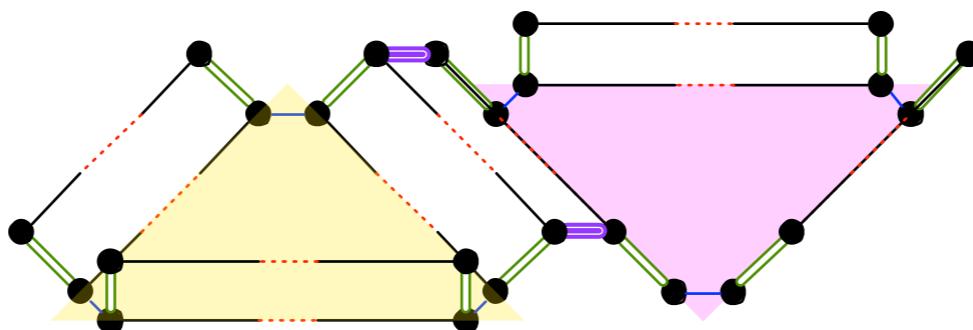
Extrusion

dim	alpha1	alpha2	alpha3	alpha4	e0	e1	e2	e3	e4
4	switch edge	switch face	switch volume	↓↑	e0-	e1-	e2-	e3-	e4-
3	switch edge	switch face	↓↑	switch volume	e0-	e1-	e2-	e3-	e3x
2	switch edge	↓↑			e0-	e1-	e2-	e2x	e3x
1	↓↑	switch edge	switch face	switch volume	e0-	e1-	e1x	e2x	e3x
0			switch face	switch volume	e0-	e0x	e1x	e2x	e3x
0	↓↑	↓↑	switch face	switch volume	e0+	e0x	e1x	e2x	e3x
1			switch face	switch volume	e0+	e1+	e1x	e2x	e3x
2	switch edge	↓↑	↓↑	switch volume	e0+	e1+	e2+	e2x	e3x
3	switch edge	switch face		e0+	e1+	e2+	e3+	e3x	
4	switch edge	switch face	switch volume	↓↑	e0+	e1+	e2+	e3+	e4+

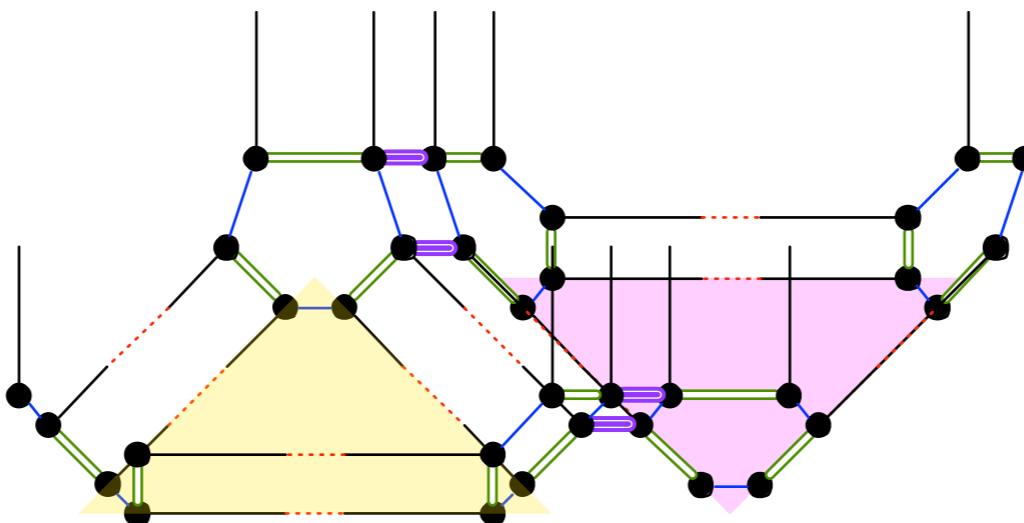
Extrusion



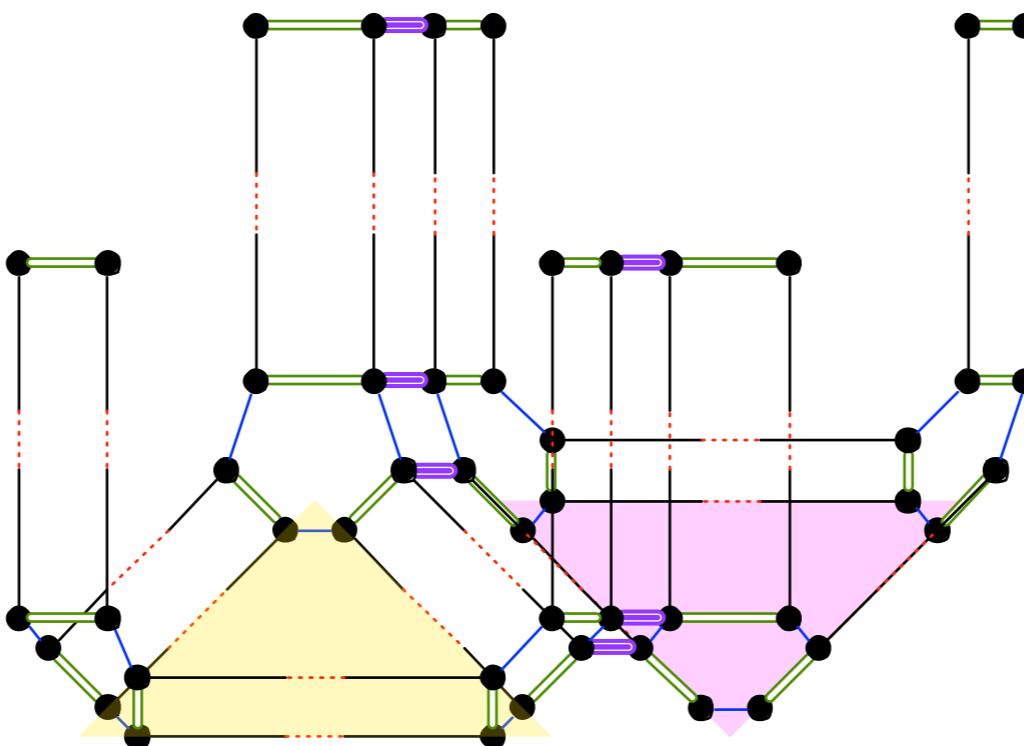
Extrusion



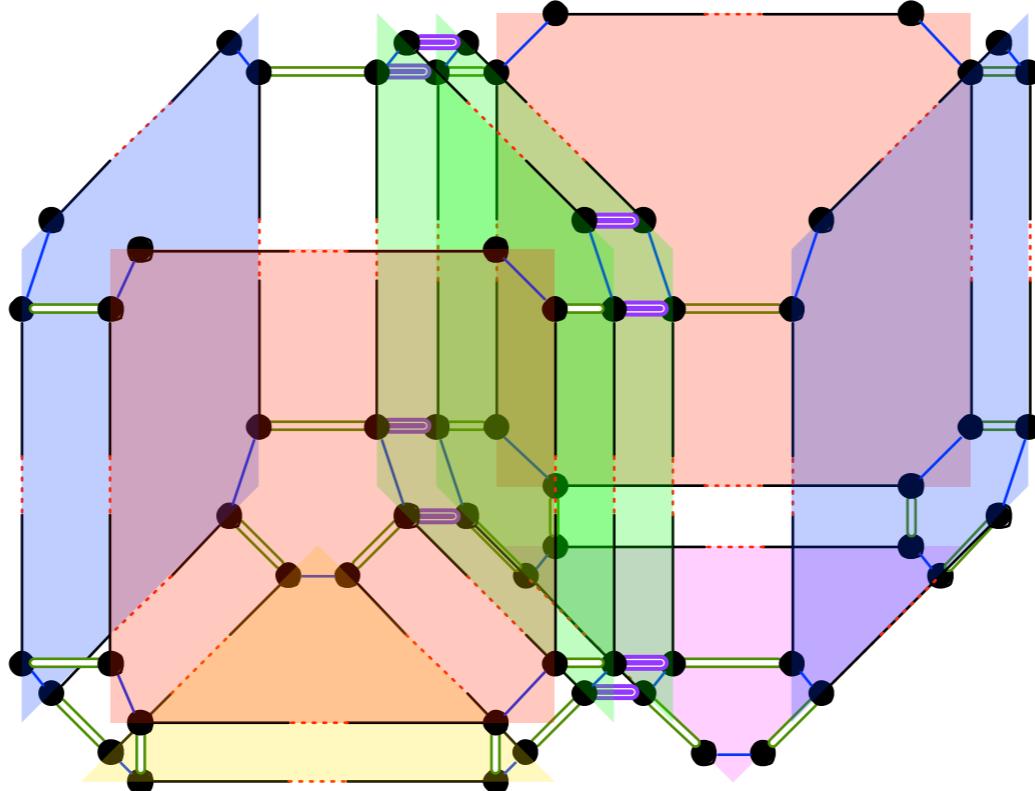
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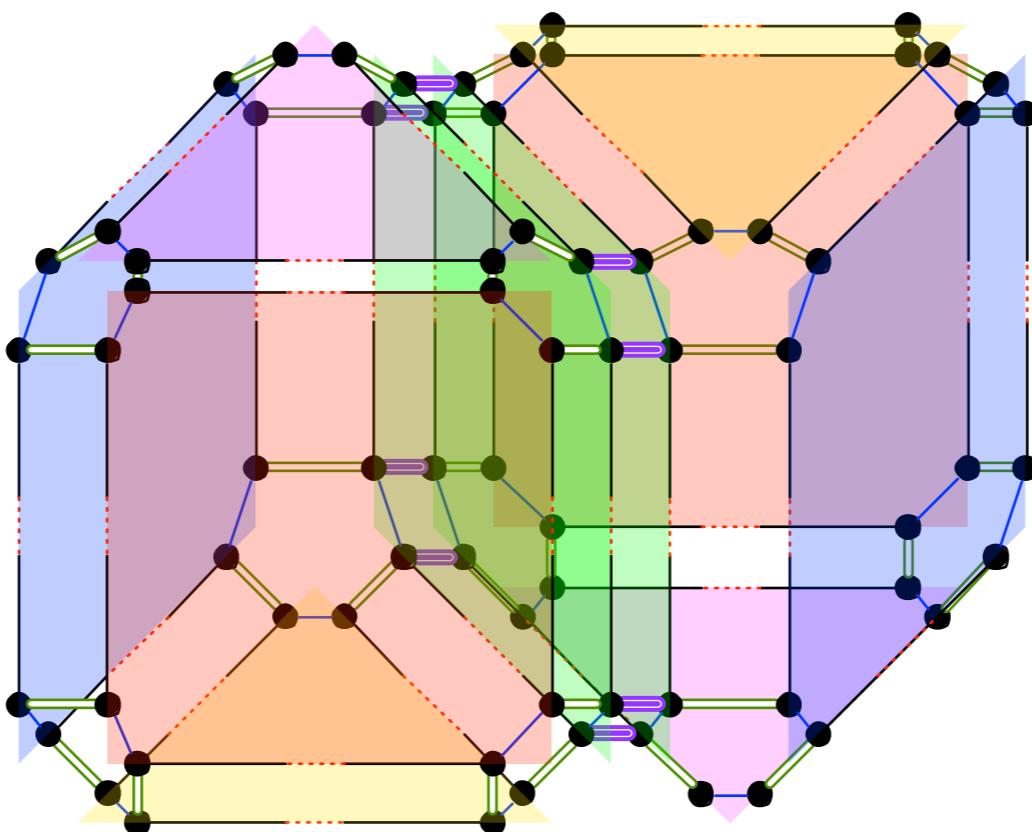
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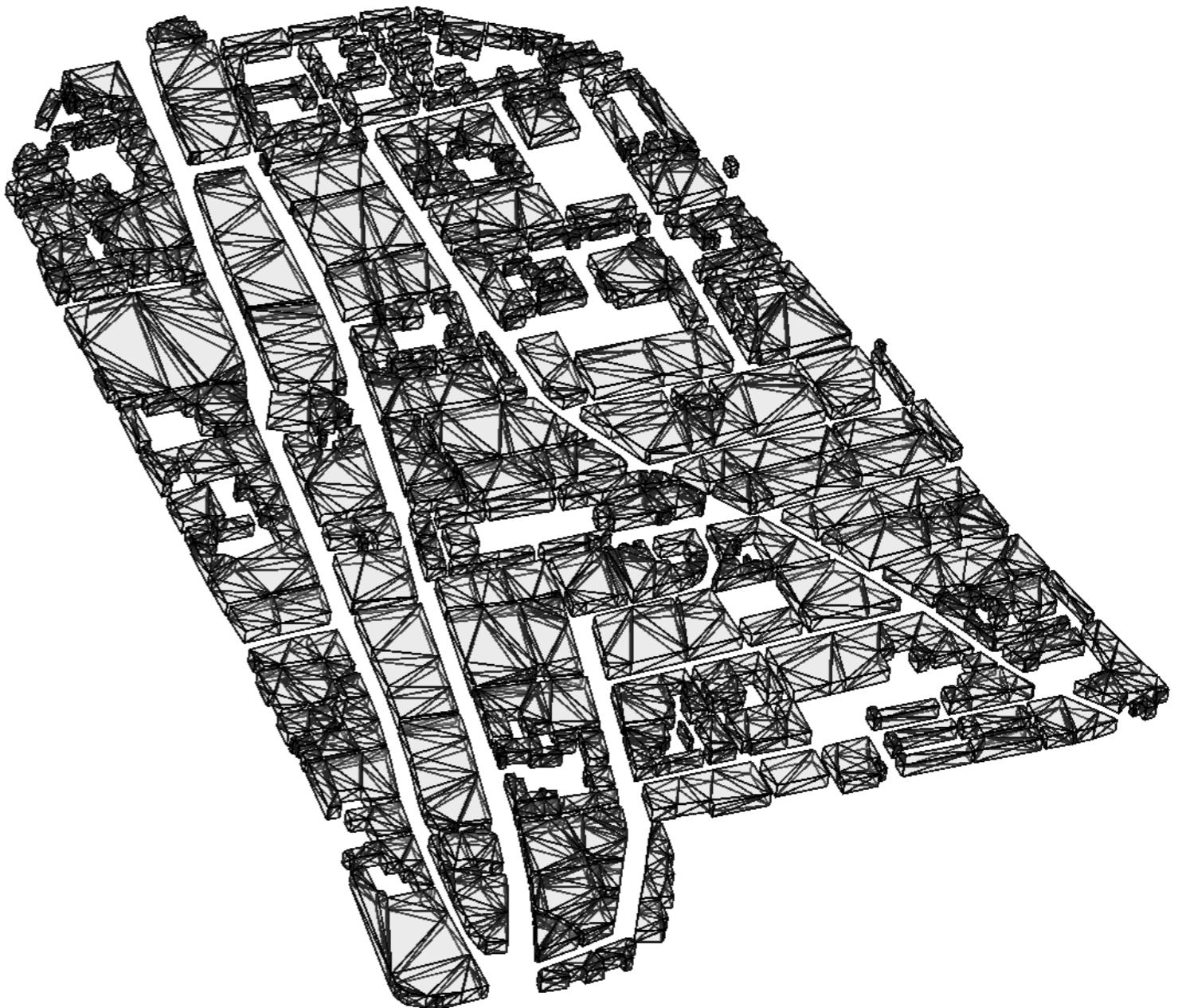
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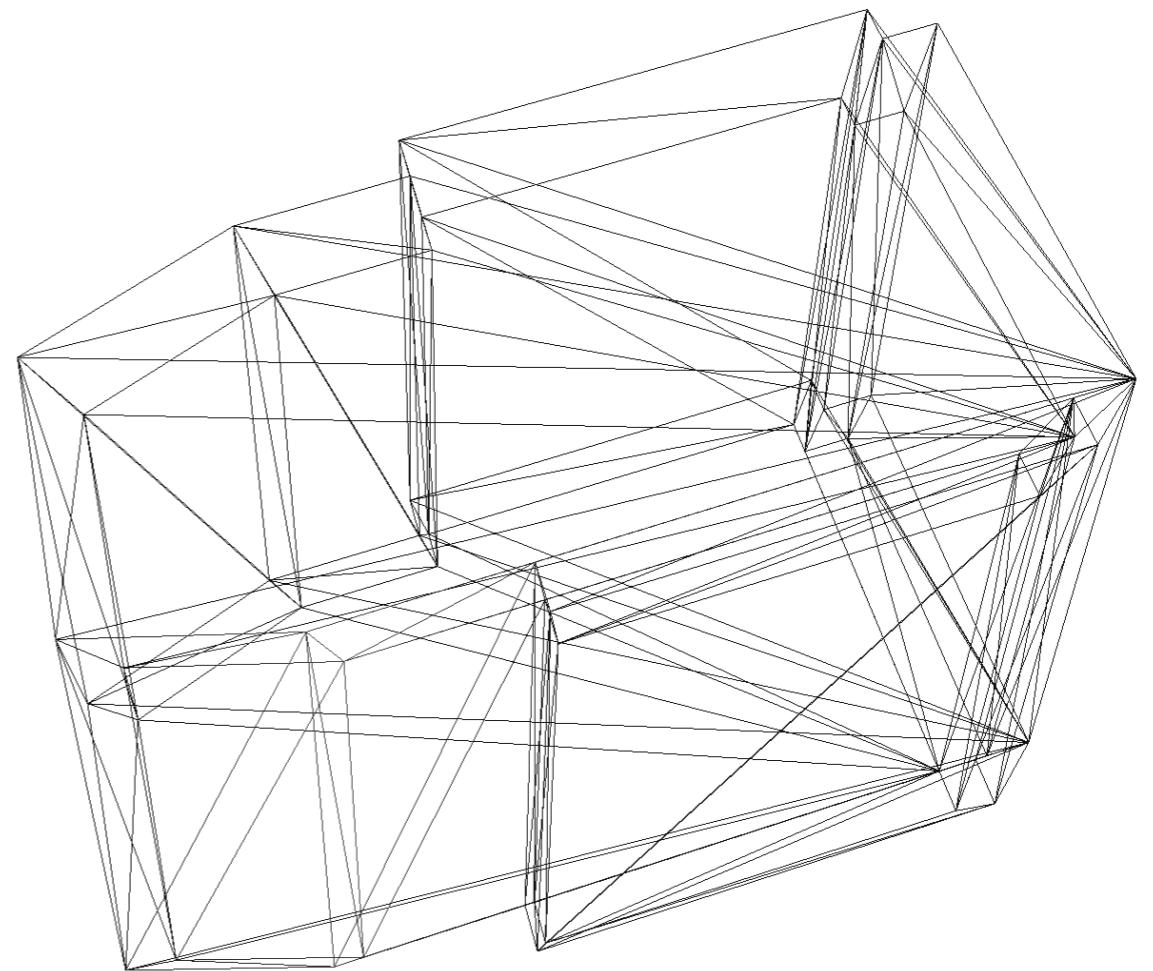
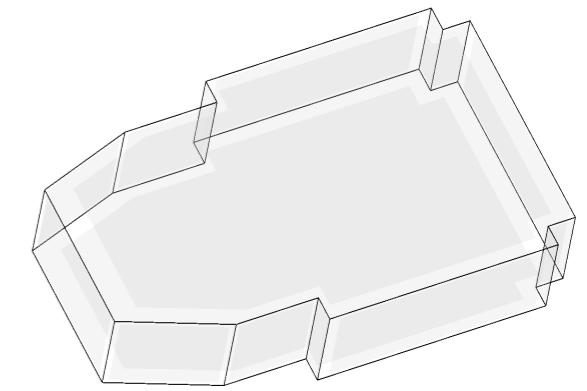
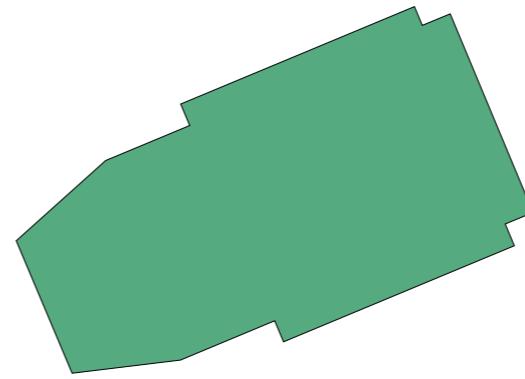
Extrusion



Experiments



Experiments



Conclusions

- Works in any dimension
- Deals with geometry and topology
- Optimal assuming constant time access to dart maps
 - $O(n)$ with n darts

~~Future~~ current work

- Extension to combinatorial maps
- Implementation with CGAL Combinatorial Maps
- Extrusion to different ranges per object
- Larger datasets

Thank you!

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