

CELL COMPLEXES TOPOLOGICAL LINKS FOR BUILDINGS IN CITYGML

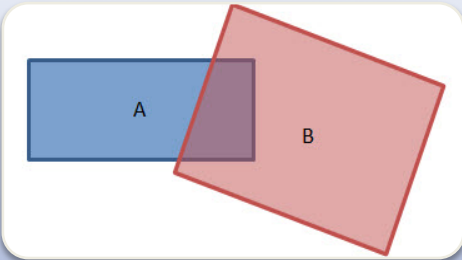
Authors:

Syahiirah Salleh, Uznir Ujang, Suhaibah Azri & Tan Liat Choon

*Department of Geoinformation,
Faculty of Built Environment and Surveying,
Universiti Teknologi Malaysia,
Johor, Malaysia.*

3D Geoinfo Conference, October 1-2, Delft 2018

Introduction



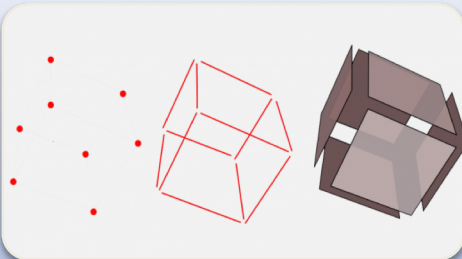
Topological Information

- Describe connectivity information between buildings (Krämer & Huhnt, 2009)
- Comprehensive connectivity information is required to support 3D exploratory analyses (Isikdag et al., 2013; Moser et al., 2010; Ellul, 2007)



CityGML

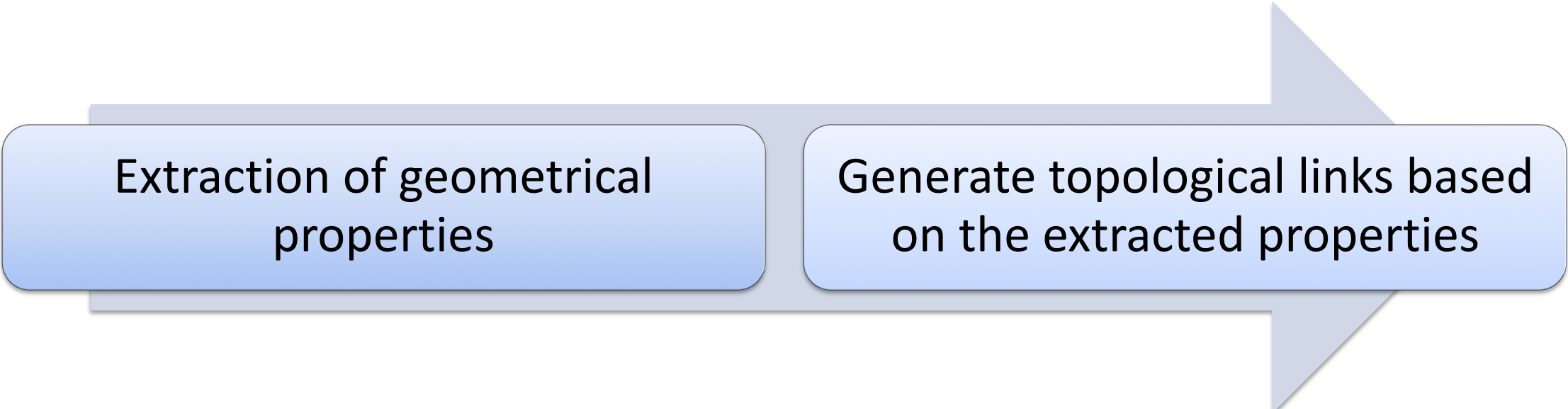
- XML links or “XLink” mechanism relates explicitly stored objects (Kolbe, 2009)
- No maintenance of relationships between 0D, 1D, and 2D primitives (Ghawana & Zlatanova, 2012)
- Neighbouring buildings often modelled using separate (“invisible”) surfaces to facilitate efficient and consistent visualisation (Gröger et al., 2005)



Cell Complexes Topological Links

- Clear storage of topological information in a topological data structure is preferable for extraction of connectivity information (Boguslawski et al., 2011)
- Traverse via decomposed lower dimension primitives such as 0D points, 1D lines and 2D surfaces to make up a 3D object while preserving connectivity information

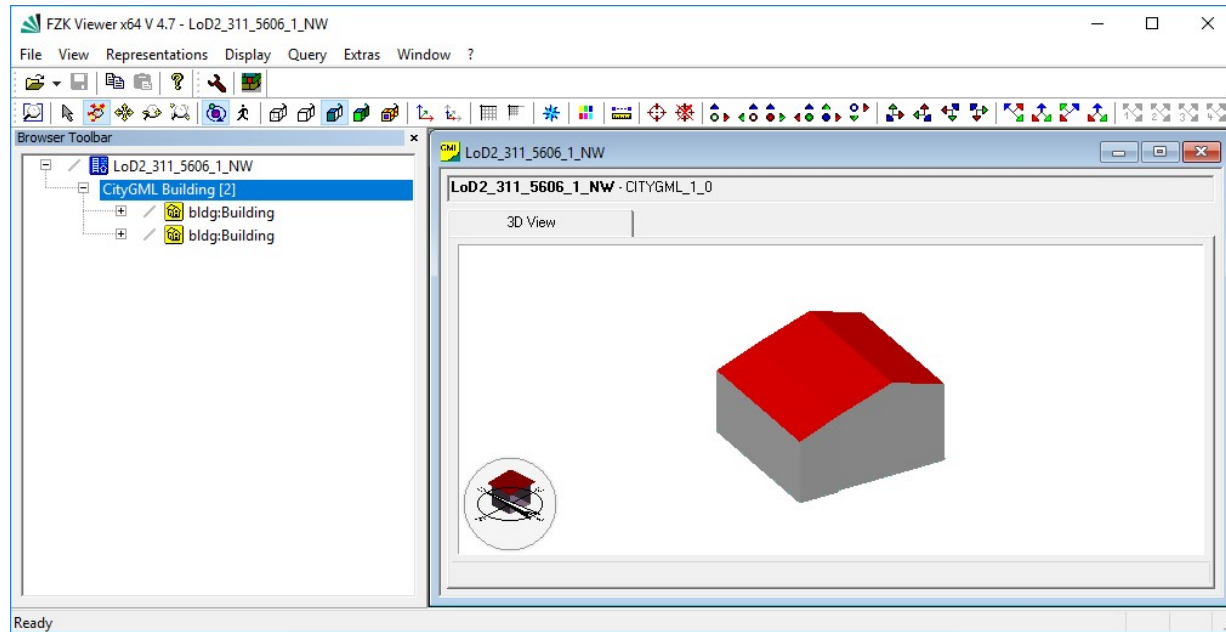
Methodology



Extraction of geometrical
properties

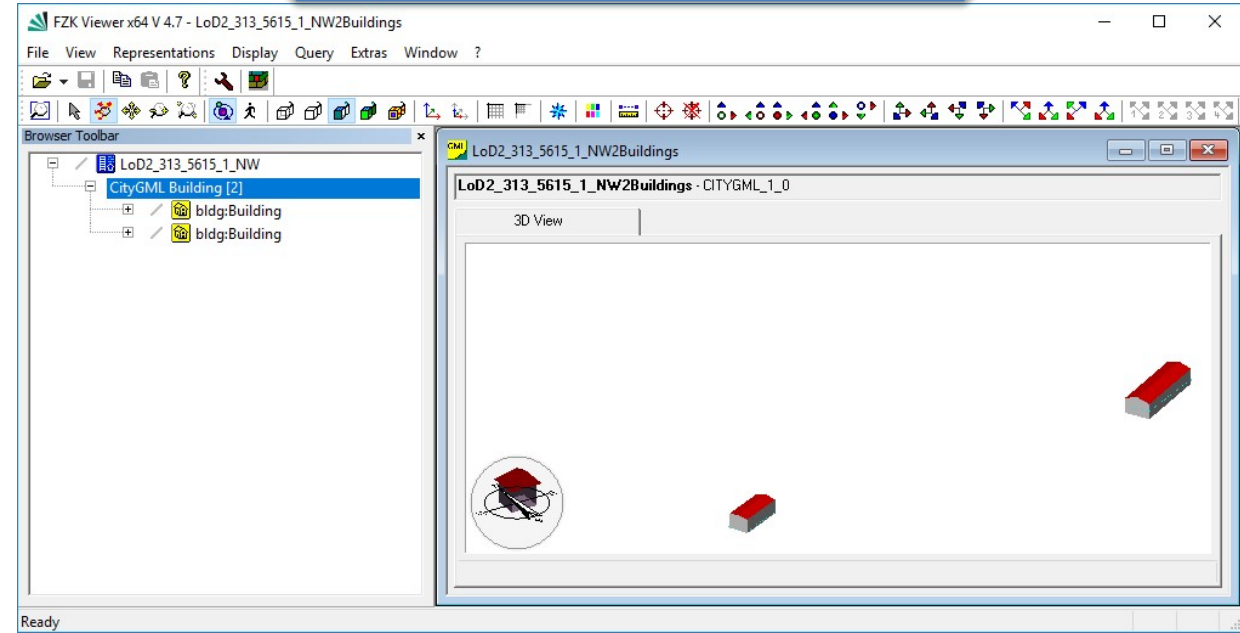
Generate topological links based
on the extracted properties

CityGML Datasets



Dataset A: Two
connected buildings

Dataset B: Two
disjointed buildings



**The CityGML datasets used in this study were obtained freely from Nordrhein-Westfalen Open Data*

Extraction of Geometric Properties

CityGML Extractor Tools

File About Help

Polygon ID: "GUID_1439827406056_1021004_2_6"

Linear Ring ID: "GUID_1439827406056_1021004_2_6_0_"

Point:	5	311949.492	5606352.601	309.595
Point:	13	311954.561	5606351.235	309.624
Point:	16	311952.027	5606351.918	310.456

Roof Surface ID: "UUID_3082ab26-124e-4853-8c02-1ab3fd06fda"

Polygon ID: "GUID_1439827406056_1021004_2_7"

Linear Ring ID: "GUID_1439827406056_1021004_2_7_0_"

Point:	2	311951.342	5606359.492	309.595
Point:	5	311949.492	5606352.601	309.595
Point:	16	311952.027	5606351.918	310.456
Point:	15	311953.877	5606358.814	310.456

Roof Surface ID: "UUID_7e95fcef-7900-40bf-a99e-c97cfff9ab2"

Polygon ID: "GUID_1439827406056_1021004_2_8"

Linear Ring ID: "GUID_1439827406056_1021004_2_8_0_"

Point:	13	311954.561	5606351.235	309.624
Point:	11	311956.412	5606358.136	309.624
Point:	15	311953.877	5606358.814	310.456
Point:	16	311952.027	5606351.918	310.456

Ground Surface ID: "UUID_d7f08624-4326-4281-b4a0-8ccae2afe326"

Polygon ID: "GUID_1439827406056_1021004_2_0"

Linear Ring ID: "GUID_1439827406056_1021004_2_0_0_"

Point:	10	311949.492	5606352.601	305.84
Point:	9	311951.342	5606359.492	305.84
Point:	12	311956.412	5606358.136	305.84
Point:	14	311954.561	5606351.235	305.84

Number of building(s): 2
 Number of building part(s): 0
 Number of surfaces of building(s): 15

Dataset A:

- 2 Buildings
- 15 Surfaces
- 16 Nodes

CityGML Extractor Tools

File About Help

Polygon ID: "GUID_1439827406056_1100214_2_6"

Linear Ring ID: "GUID_1439827406056_1100214_2_6_0_"

Point:	11	313177.113	5615994.494	330.411
Point:	17	313179.751	5615989.933	330.411
Point:	20	313178.432	5615992.214	331.218

Roof Surface ID: "UUID_b034e5c6-734a-4c0f-97a7-efd4931e35bc"

Polygon ID: "GUID_1439827406056_1100214_2_7"

Linear Ring ID: "GUID_1439827406056_1100214_2_7_0_"

Point:	12	313191.402	5616002.562	330.411
Point:	11	313177.113	5615994.494	330.411
Point:	20	313178.432	5615992.214	331.218
Point:	19	313192.695	5616000.258	331.218

Roof Surface ID: "UUID_a50756e0-2753-45de-8df2-dfde3a58df91"

Polygon ID: "GUID_1439827406056_1100214_2_8"

Linear Ring ID: "GUID_1439827406056_1100214_2_8_0_"

Point:	17	313179.751	5615989.933	330.411
Point:	15	313193.988	5615997.954	330.411
Point:	19	313192.695	5616000.258	331.218
Point:	20	313178.432	5615992.214	331.218

Ground Surface ID: "UUID_37cf9ed-54f4-4273-ae5c-efef3a77b25"

Polygon ID: "GUID_1439827406056_1100214_2_0"

Linear Ring ID: "GUID_1439827406056_1100214_2_0_0_"

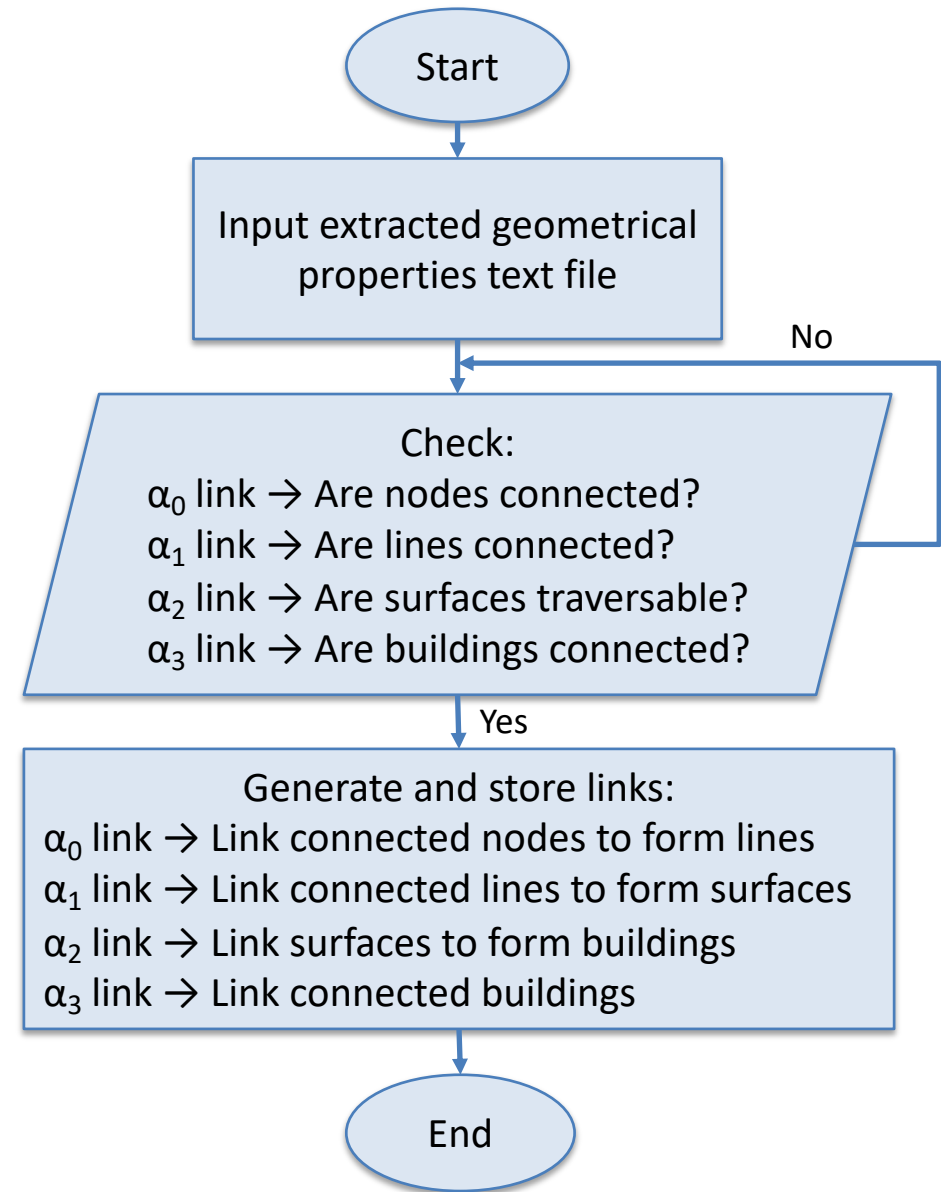
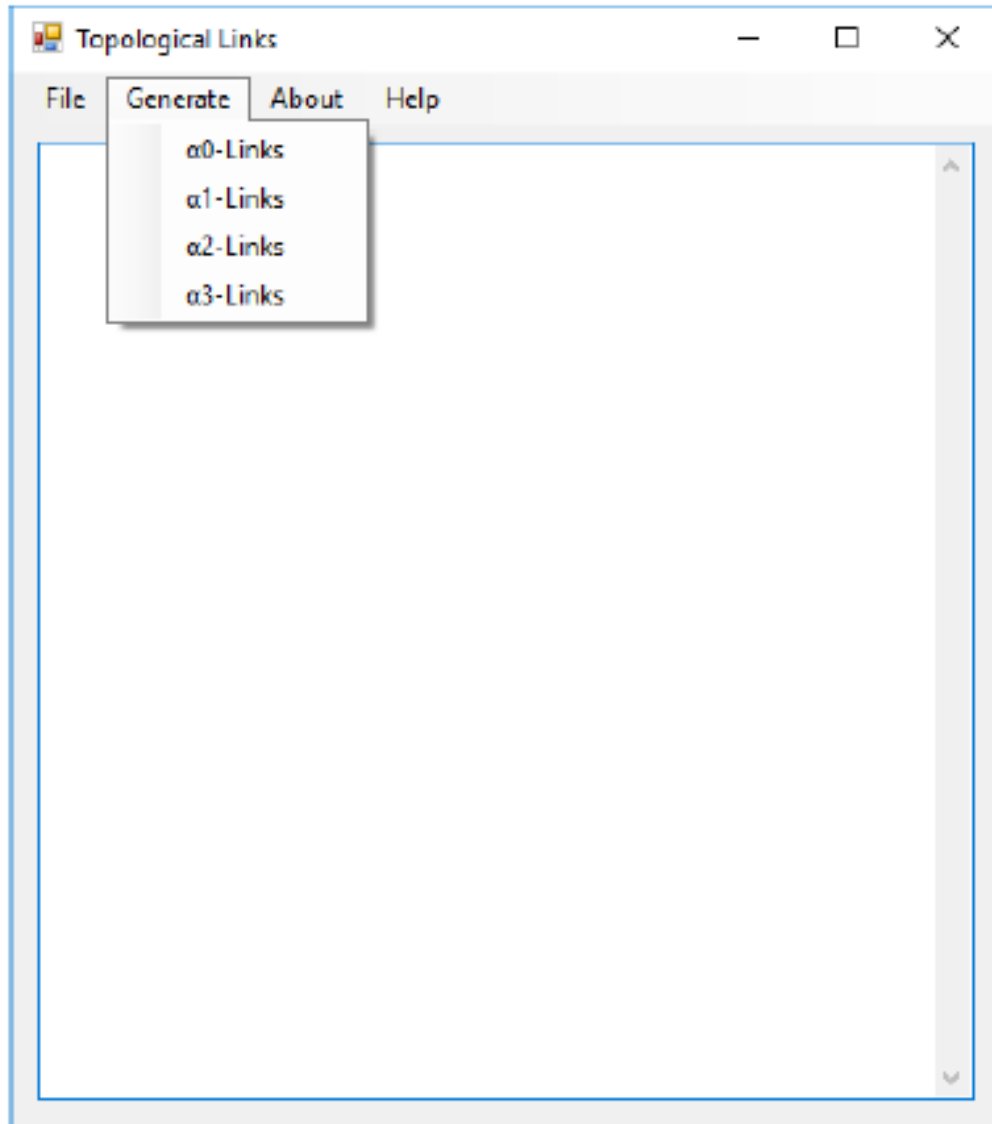
Point:	14	313177.113	5615994.494	327.082
Point:	13	313191.402	5616002.562	327.082
Point:	16	313193.988	5615997.954	327.082
Point:	18	313179.751	5615989.933	327.082

Number of building(s): 2
 Number of building part(s): 0
 Number of surfaces of building(s): 18

Dataset B:

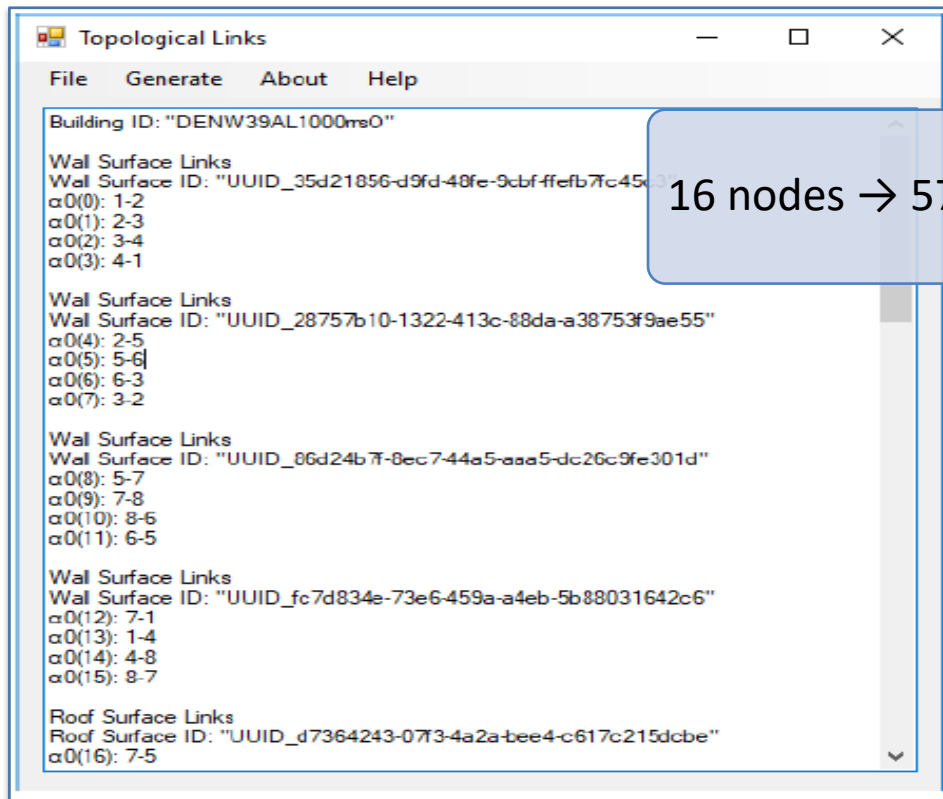
- 2 Buildings
- 18 Surfaces
- 20 Nodes

Generating Topological Links

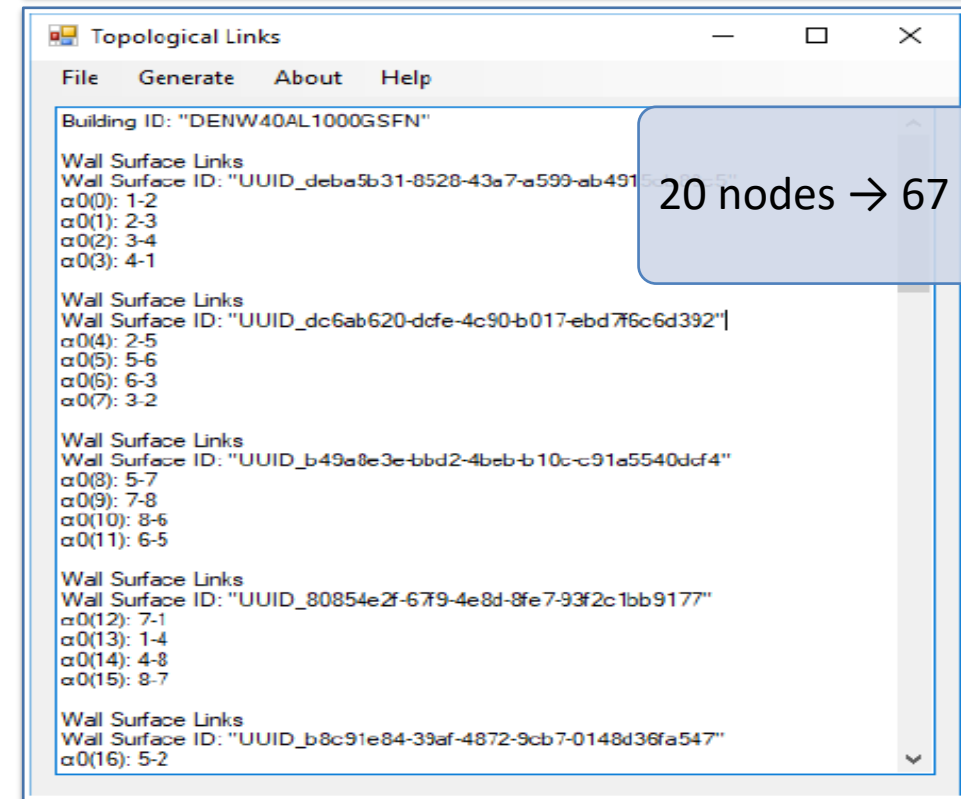


Results (1D α_0 links)

a_0 Links for Dataset A



α_0 Links for Dataset B



Results (2D α_1 links)

α_1 Links for Dataset A

```

Topological Links
File Generate About Help

Building ID: "DENW39AL1000msO"

Wall Surface Links
Wall Surface ID: "UUID_35d21856-d9fd-48fe-9cbf-feb77c4d4e55"
 $\alpha_1(0)$ :  $\alpha_0(0)$  -  $\alpha_0(1)$  -  $\alpha_0(2)$  -  $\alpha_0(3)$  -  $\alpha_0(0)$ 

Wall Surface Links
Wall Surface ID: "UUID_28757b10-1322-413c-88da-a38753f9ae55"
 $\alpha_1(1)$ :  $\alpha_0(4)$  -  $\alpha_0(5)$  -  $\alpha_0(6)$  -  $\alpha_0(7)$  -  $\alpha_0(4)$ 

Wall Surface Links
Wall Surface ID: "UUID_86d24b7f-8ec7-44a5-aaa5-dc26c9fe301d"
 $\alpha_1(2)$ :  $\alpha_0(8)$  -  $\alpha_0(9)$  -  $\alpha_0(10)$  -  $\alpha_0(11)$  -  $\alpha_0(8)$ 

Wall Surface Links
Wall Surface ID: "UUID_fc7d834e-73e6-459a-a4eb-5b88031642c6"
 $\alpha_1(3)$ :  $\alpha_0(12)$  -  $\alpha_0(13)$  -  $\alpha_0(14)$  -  $\alpha_0(15)$  -  $\alpha_0(12)$ 

Roof Surface Links
Roof Surface ID: "UUID_d7364243-07f3-4a2a-bee4-c617c215dcbe"
 $\alpha_1(4)$ :  $\alpha_0(16)$  -  $\alpha_0(17)$  -  $\alpha_0(18)$  -  $\alpha_0(19)$  -  $\alpha_0(16)$ 

Ground Surface Links
Ground Surface ID: "UUID_3ecc583d-4508-44d5-ad93-c33f6151e952"
 $\alpha_1(5)$ :  $\alpha_0(20)$  -  $\alpha_0(21)$  -  $\alpha_0(22)$  -  $\alpha_0(23)$  -  $\alpha_0(20)$ 

Building ID: "DENW39AL1000mH4"

Wall Surface Links
Wall Surface ID: "UUID_0b0d1c8d-a43d-4c52-a6ce-cd0ac7f0368c"
 $\alpha_1(6)$ :  $\alpha_0(24)$  -  $\alpha_0(25)$  -  $\alpha_0(26)$  -  $\alpha_0(27)$  -  $\alpha_0(24)$ 

Wall Surface Links
  
```

57 α_0 links \rightarrow 15 α_1 links

α_1 Links for Dataset B

```

Topological Links
File Generate About Help

Building ID: "DENW40AL1000GSFN"

Wall Surface Links
Wall Surface ID: "UUID_deba5b31-8528-43a7-a599-ab0c0b88c55"
 $\alpha_1(0)$ :  $\alpha_0(0)$  -  $\alpha_0(1)$  -  $\alpha_0(2)$  -  $\alpha_0(3)$  -  $\alpha_0(0)$ 

Wall Surface Links
Wall Surface ID: "UUID_dc6ab620-dcfe-4c90-b017-ebd7f6c6d392"
 $\alpha_1(1)$ :  $\alpha_0(4)$  -  $\alpha_0(5)$  -  $\alpha_0(6)$  -  $\alpha_0(7)$  -  $\alpha_0(4)$ 

Wall Surface Links
Wall Surface ID: "UUID_b49a8e3e-bbd2-4beb-b10c-c91a5540dcf4"
 $\alpha_1(2)$ :  $\alpha_0(8)$  -  $\alpha_0(9)$  -  $\alpha_0(10)$  -  $\alpha_0(11)$  -  $\alpha_0(8)$ 

Wall Surface Links
Wall Surface ID: "UUID_80854e2f-67f9-4e8d-8fe7-93f2c1bb9177"
 $\alpha_1(3)$ :  $\alpha_0(12)$  -  $\alpha_0(13)$  -  $\alpha_0(14)$  -  $\alpha_0(15)$  -  $\alpha_0(12)$ 

Wall Surface Links
Wall Surface ID: "UUID_b8c91c84-39af-4872-9cb7-0148d36fa547"
 $\alpha_1(4)$ :  $\alpha_0(16)$  -  $\alpha_0(17)$  -  $\alpha_0(18)$  -  $\alpha_0(16)$ 

Wall Surface Links
Wall Surface ID: "UUID_0724c4ee-5ab8-4b1f-bb71-f37e5c630d4c"
 $\alpha_1(5)$ :  $\alpha_0(19)$  -  $\alpha_0(20)$  -  $\alpha_0(21)$  -  $\alpha_0(19)$ 

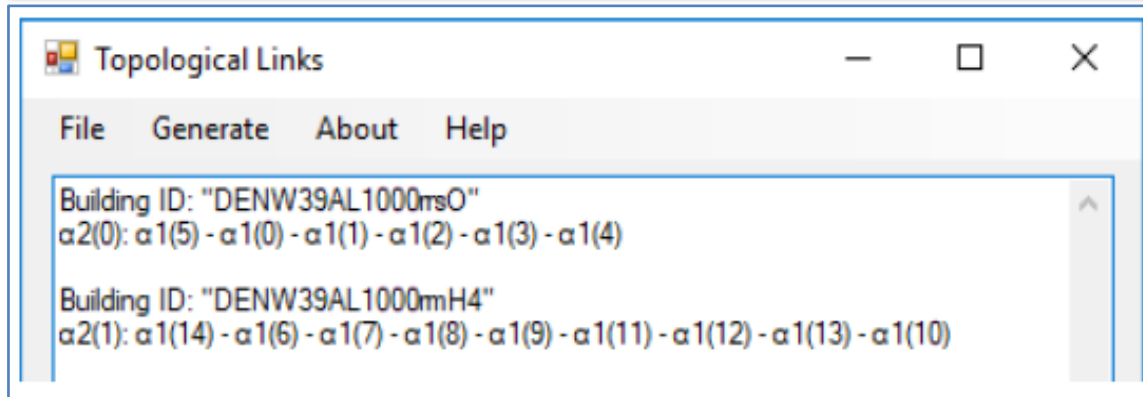
Roof Surface Links
Roof Surface ID: "UUID_4a7a543b-4f47-476d-bae6-12f6abb33747"
 $\alpha_1(6)$ :  $\alpha_0(22)$  -  $\alpha_0(23)$  -  $\alpha_0(24)$  -  $\alpha_0(25)$  -  $\alpha_0(22)$ 

Roof Surface Links
Roof Surface ID: "UUID_f0059410-d318-40b7-ab24-2b797544f342"
 $\alpha_1(7)$ :  $\alpha_0(26)$  -  $\alpha_0(27)$  -  $\alpha_0(28)$  -  $\alpha_0(29)$  -  $\alpha_0(26)$ 
  
```

67 α_0 links \rightarrow 18 α_1 links

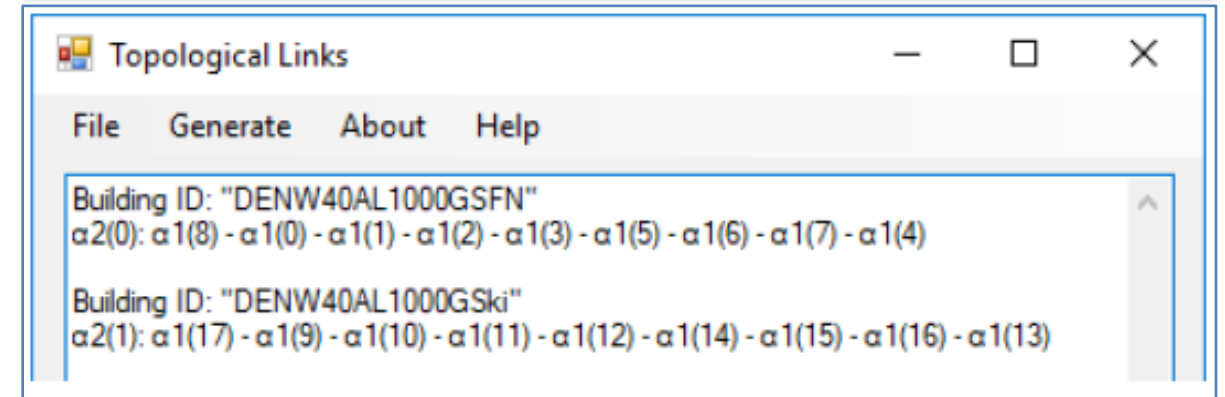
Results (3D α_2 links)

α_2 Links for Dataset A



15 α_1 links \rightarrow 2 α_2 links

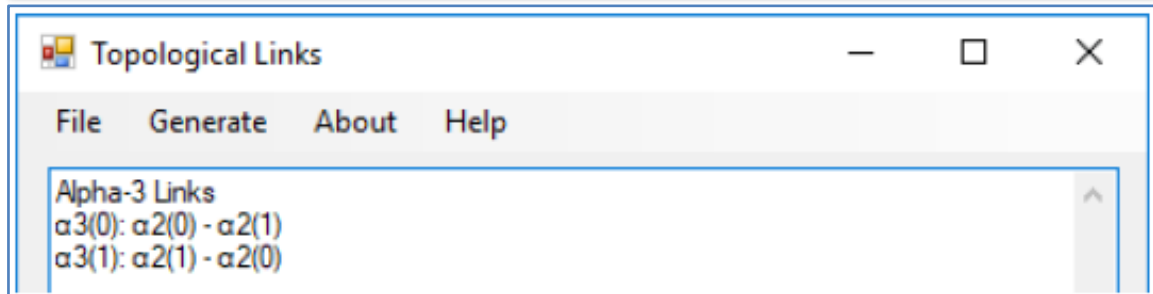
α_2 Links for Dataset B



18 α_1 links \rightarrow 2 α_2 links

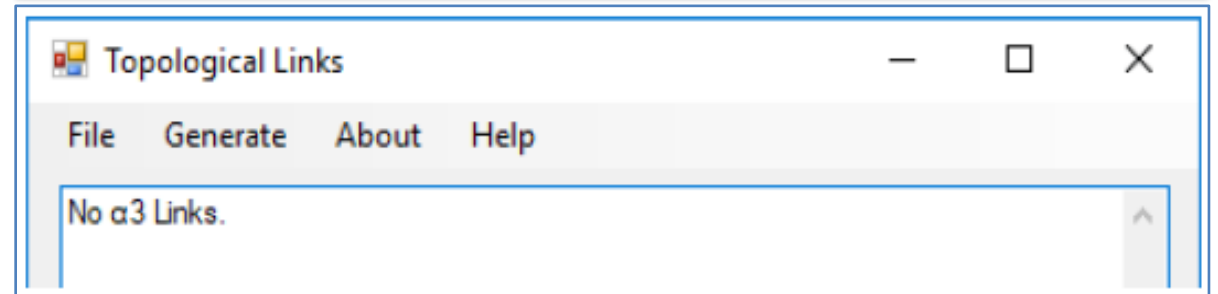
Results (α_3 links)

α_3 Links for Dataset A



2 α_2 links \rightarrow 2 α_3 links

α_3 Links for Dataset B



No connected buildings

The α_3 links describe the connection between the buildings of Dataset A which could not be referenced in CityGML due to being connected via an “invisible” face.

Conclusion

Dataset A: 2 connected buildings
Dataset B: 2 disjointed buildings

Cell
Complexes
Topological
Links

4
Topological
Links

α_0 link: 0D nodes to 1D lines
 α_1 link: 1D lines to 2D surfaces
 α_2 link: 2D surfaces to 3D volumes
 α_3 link: connections between 3D volumes

Dataset A: 57 α_0 links to 2 α_2 links
Dataset B: 67 α_0 links to 2 α_2 links

Decrease
in number
of links

Preserve
topological
properties

Simple and compact
One α_2 link per building
Describe how surfaces are connected (via an “invisible” face)
Allows navigation through topological links

Future Research

- n -dimensional case study
- 3D Smart Cities
- BIM
- Urban Pollutions (multi-dimensional)
- Visual Positioning System (VPS) Integration (local positioning)

Acknowledgements

- The CityGML datasets used in this study were obtained freely from Nordrhein-Westfalen Open Data.
- The CityGML viewer used in this study is the FZK Viewer developed by Karlsruhe Institute of Technology.
- This work is supported by the UTM Research University Grant, Vot Q.J.130000.2527.15H49 and Vot Q.J.130000.2527.11H78.

Thank you

Syahiirah Salleh: syahiirahsalleh78@gmail.com

Dr. Uznir Ujang: mduznir@utm.my