An Approach of Instigating 3D City Model in Urban Air Pollution Modelling for Sustainable Urban Development in Malaysia

Uznir Ujang[a], Alias Abdul Rahman[a] and François Anton[b]

[a] 3D GIS Research Lab, UTM, Malaysia
[b] The National Space Institute, DTU, Denmark

Commission No. 8:
Spatial Planning and Development - Planning and Managing Urbanization

Outline

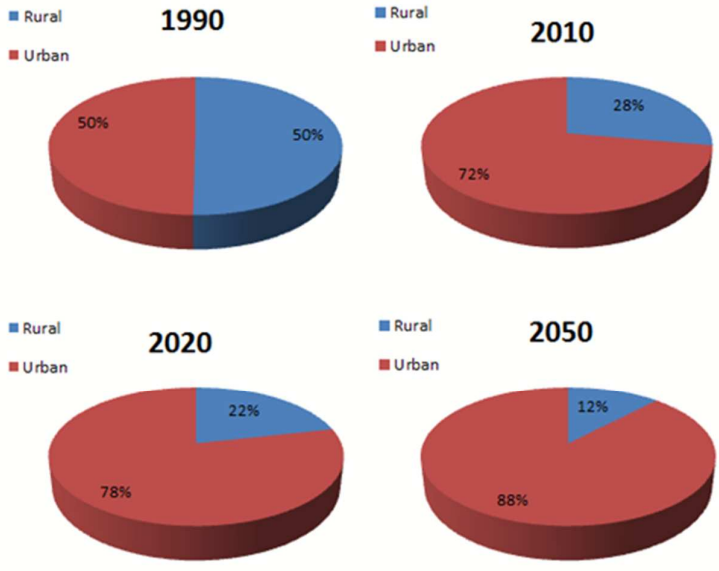
- Introduction
- Developments in 3D City Modelling
- Data Constellation Mechanism
- Analysis & Results
- Summary

Introduction

- Urbanization process gives impacts in a range of economic, political, social, cultural, and environmental.
- Based on current and previous research, negative impacts on the environment are more taking into place with poor development process and planning.
- The urbanization process can be seen since 1950's, when the world's population increases to triple in 25 years.

Urbanization

Country	Year	Total Population (Thousand)	Rural	Urban
Malaysia	1950	6110	4866	1244
Malaysia	1955	7000	5361	1639
Malaysia	1960	8140	5975	2165
Malaysia	1965	9502	6660	2842
Malaysia	1970	10853	7222	3631
Malaysia	1975	12258	7642	4615
Malaysia	1980	13763	7977	5787
Malaysia	1985	15677	8482	7195
Malaysia	1990	18103	9089	9014
Malaysia	1995	20594	9126	11468
Malaysia	2000	23274	8849	14424
Malaysia	2005	25653	8308	17345
Malaysia	2010	27920	7770	20150
Malaysia	2015	30047	7287	22760
Malaysia	2020	32020	6889	25130
Malaysia	2025	33769	6582	27187
Malaysia	2030	35270	6276	28994
Malaysia	2035	36622	5938	30684
Malaysia	2040	37819	5578	32241
Malaysia	2045	38830	5201	33629
Malaysia	2050	39631	4815	34816



Annual percentage of Malaysia's urban population (Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat)

Sustainable Urban Development

- Realizing these challenges, major cities tend to minimize the negative effects and building the benefits (Yue Ray, 2011, Dayaratne, 2010, Fang et al., 2009).
- Sustainable urban environment in developing urban spaces that meet the standard for future generations and fulfil current development needs.
- The Rio Declaration on Environment and Development, Agenda 21 by the United Nations, stated:

Principle 1: "Human beings are at the center of concern for sustainable development. They are entitled to a healthy and productive live in harmony with nature."

Sustainable Urban Development

- In the current 10th Malaysia's Plan, Thrust 4: "To Improve the Standards and Sustainability of Quality of Life" shows that Malaysia be present in positioning its part towards The Rio Declaration on Environment and Development, Agenda 21.
- For land use - National Physical Plan (NPP) and National Urbanization Policies (NUP);
- Climate change - National Policies on Climate Change and Road Map for Reduction of GHG Emissions;
- Green technology - National Green Technologies Policy

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

Sustainable Urban Development

- However, moving towards sustainable development for urban spaces is not an easy task.
- Despite the fact that policies regarding on the sustainable development are present, but to manage spaces with rapid development, active industrialization and high traffic volumes form a different scenario for the administration.
- Malaysian Meteorological Department monitors 22 air pollution monitoring stations.
- Department of Environment Malaysia only has 15 continuous air quality monitoring stations.

MET Malaysia

Location of Air Pollution Monitoring Stations by Meteorological Department, Malaysia

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

DoE Malaysia

Location of Continuous Air Quality Monitoring Stations by Department of Environment, Malaysia

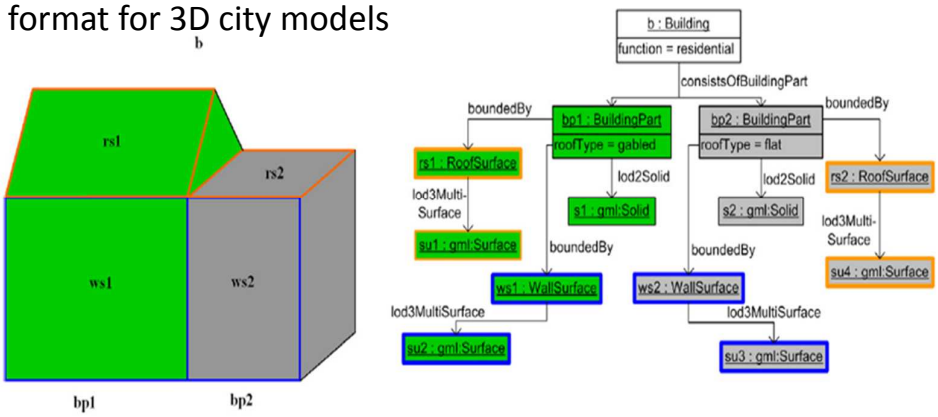
Air Pollution Modeling

- Urban air pollution dispersion modelling is one of the ways to upkeep the air quality monitoring in urban areas.
- Furthermore it will assist decision makers or planners in designing urban areas to meet the standard of sustainable cities.
- In this research, the highlights will be given onto the approach and performance issues of implementing 3D city model for urban air dispersion model.

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

Developments in 3D City Modelling

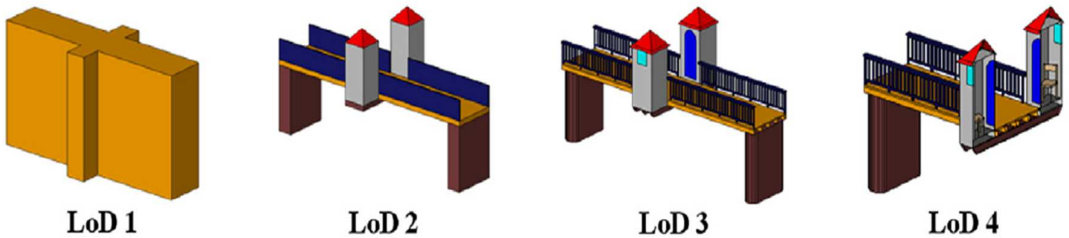
- ESRI (CityEngine), Bentley (Bentley's Map V8i) and Google (Google Earth) offer users the capability to create, visualize and measure for applications of 3D cities embedded in their product.
- City Geography Markup Language (CityGML) is an example of an exchange standard format for 3D city models



LoD2 building illustration: CityGML feature structure as UML instance diagram

CityGML Exchange Format

- An open standard for 3D city and landscape modeling that is recognized by the Open Geospatial Consortium (OGC) and the ISO TC211.
- Urban and landscape planning, 3D cadasters, environmental simulations, mobile telecommunications, disaster management, vehicle navigation, training simulators and mobile robotics.
- CityGML is an open data model and XML-based format for the storage and exchange of virtual 3D city models and it is implemented as an application schema for the Geography Markup Language version 3.1.1 (GML3).



LoD 1 LoD 2 LoD 3 LoD 4

Storage Issues

- However, CityGML requires 3.12KB size of memory disk storage for a building (102 lines of tags and elements in XML structure).

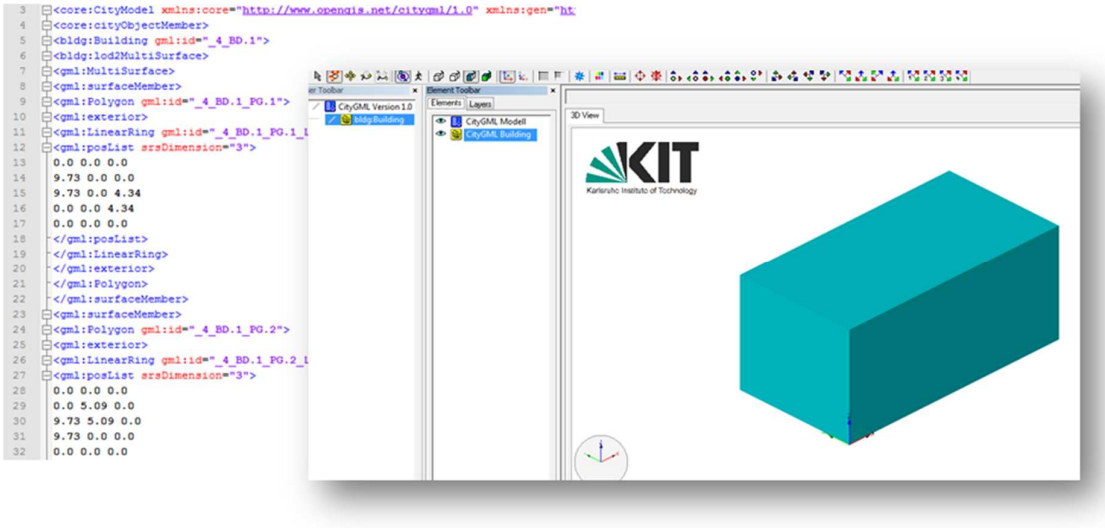


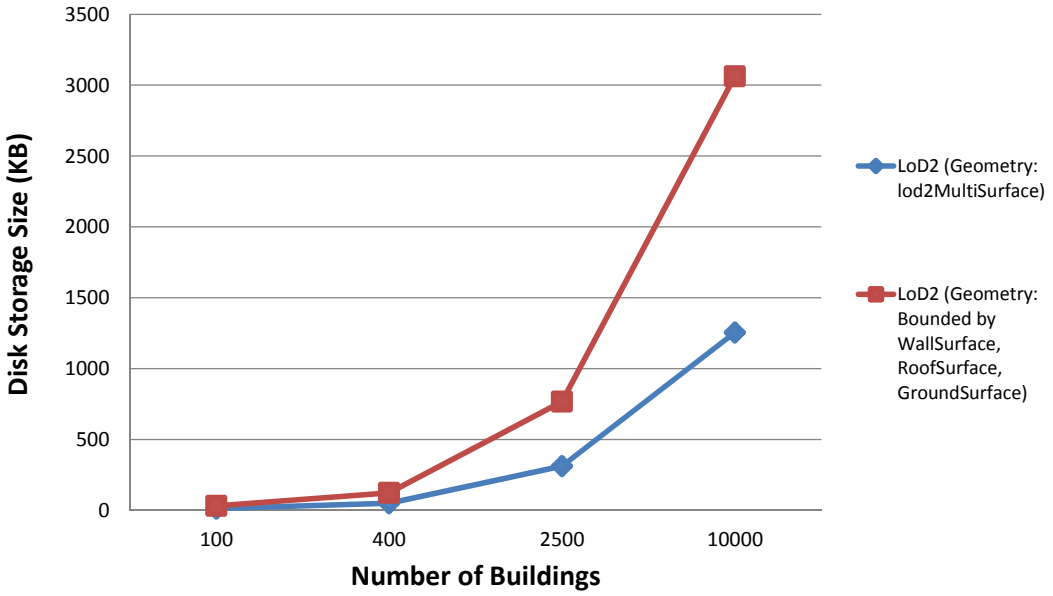
Table 1: CityGML Size (in KB) and number of lines comparison between different numbers of buildings

Number of Buildings	Total	Size (KB)	Number of Lines
2 x 2	4	17	708
10 x 10	100	394	17,412
20 x 20	400	1,592	69,612
50 x 50	2,500	10,084	435,012

- Retrieving information from CityGML data, the mechanism requires an XML tag list searching. Comparison in Table 1 shows a total line of tags for each category for a number of buildings.

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

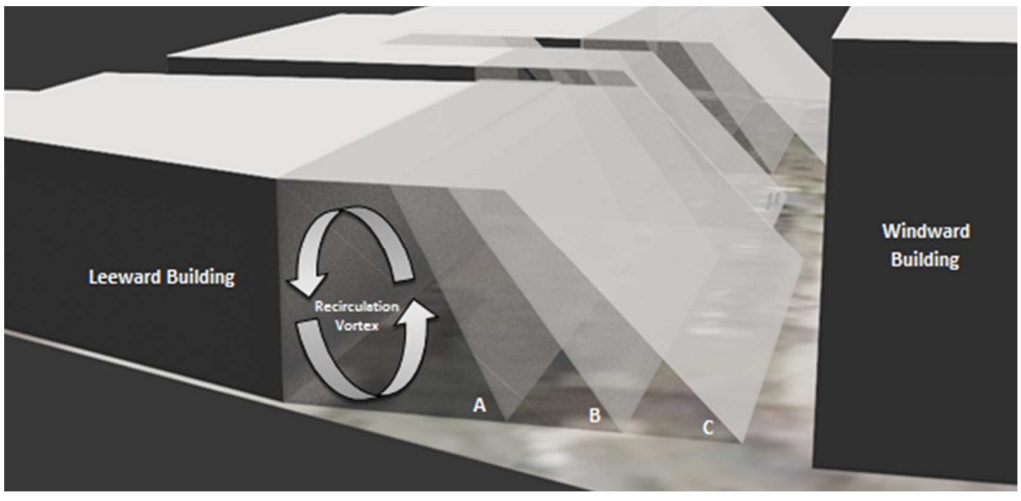
Disk Storage Comparison



Disk storage comparison between two LoD2 categories

Data Constellation Mechanism

- The data constellation mechanism by using spatial indexing for 3D city model data is proposed. The data will be stored in a more structured way for implementation.
- Providing common spatial topology information such as 3D adjacency and nearest neighbor queries.



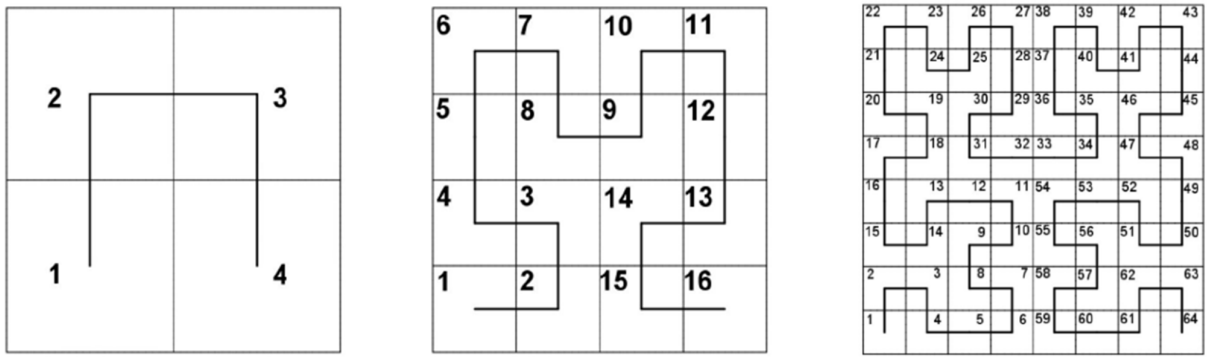
XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

Spatial Indexing

- Spatial indexing is a technique to optimize query processing in spatial database by organizing records in memory space.
- Query performance is increased especially when dealing with many rows in a table.

Hilbert's Curve

- Hilbert Space Filling Curve could be described as an underlying grid, an N x N array of cells where $N = 2^n$. Hilbert's enumeration of the squares is shown in the figure for n = 1, 2 and 3.



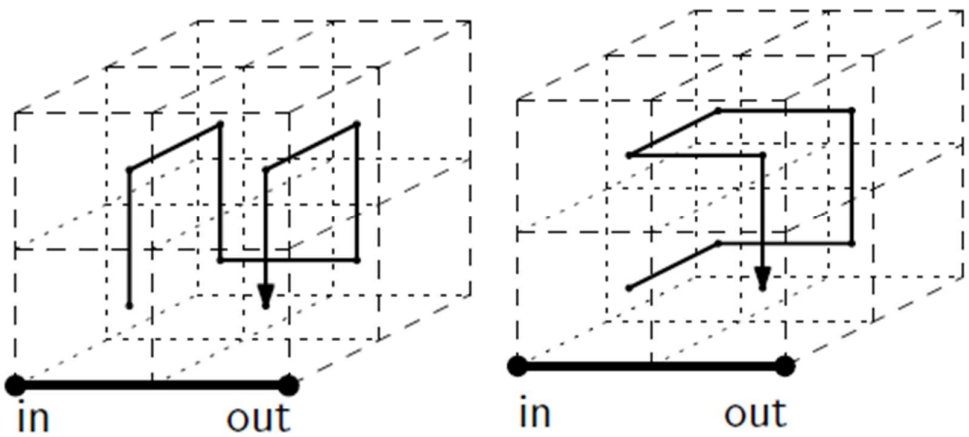
The first three stages in generating Hilbert's curve

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

3D Hilbert's Curve

- In this research we proposed a 3D Hilbert's curve with the rationalization of air pollution dispersion will not only move in horizontal direction but it will move vertically when the pollutant is trapped between buildings.

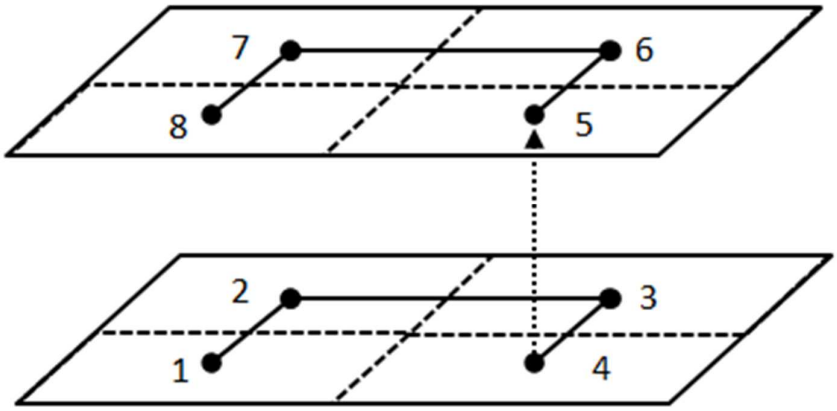
3D Hilbert's Curve



Possible approach of 3D Hilbert order where n = 2

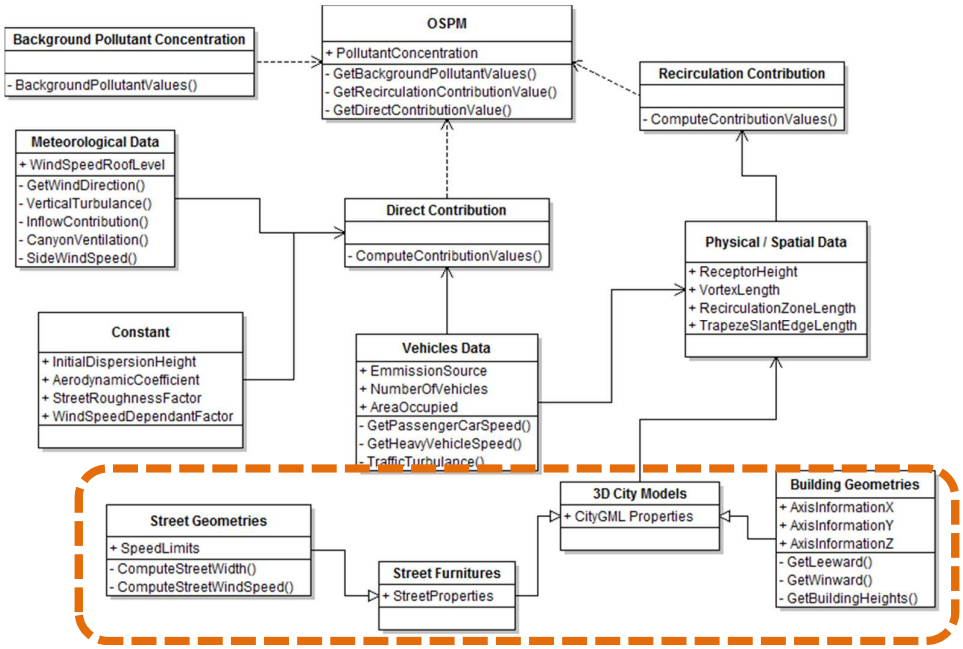
XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

3D Hilbert's Curve



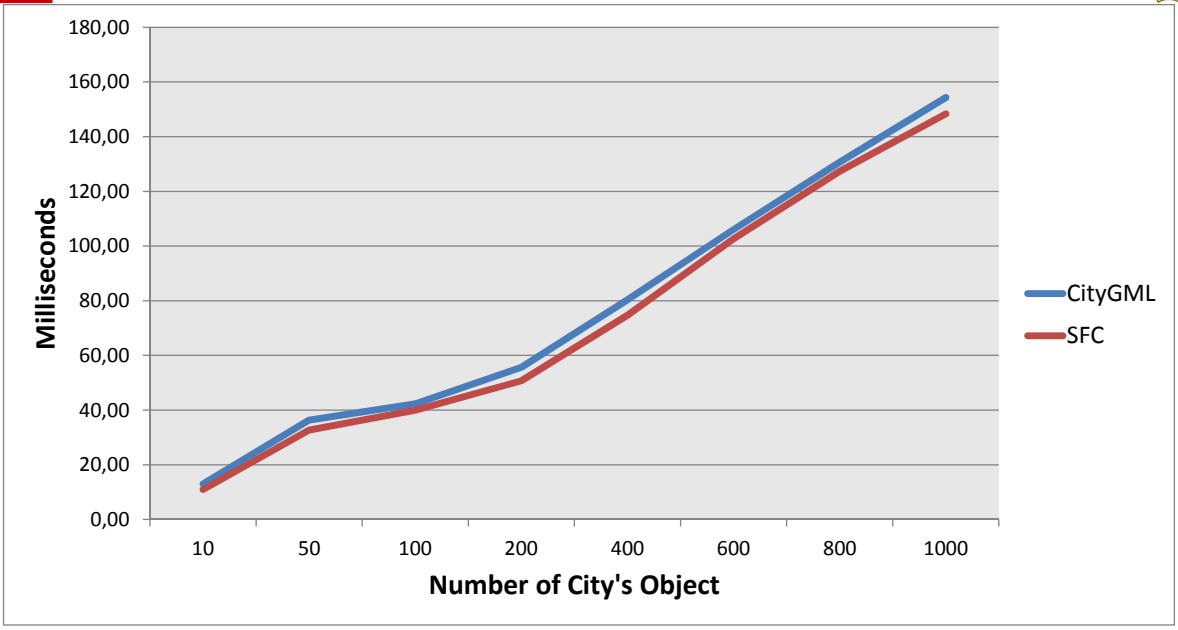
Implemented 3D Hilbert's Curve Order

Analysis & Results



The Unified Modelling Language (UML) for Air Dispersion Model with 3D City Model Integration

Single Object Search



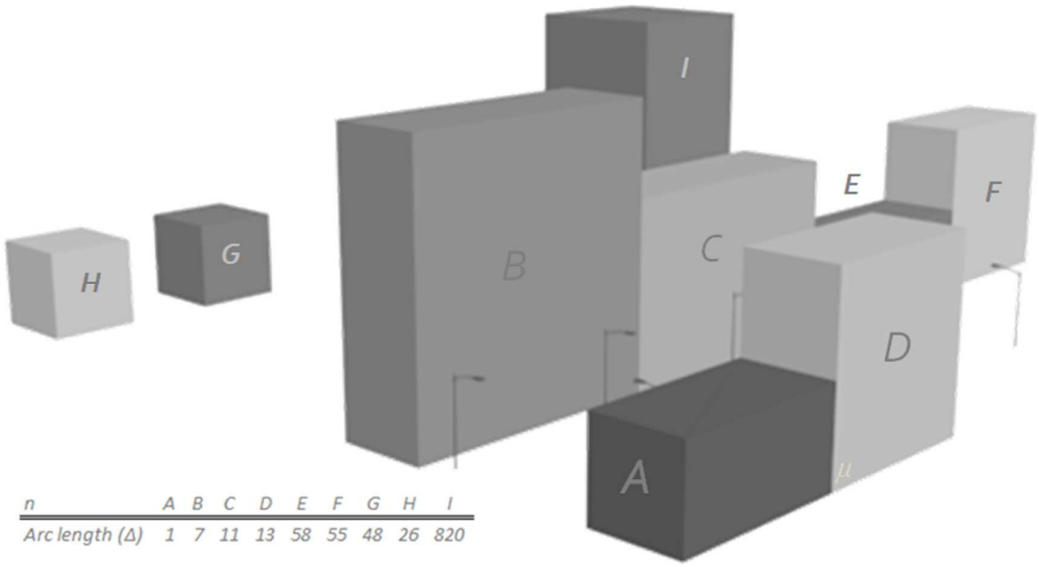
The "*single object search*" usually is implemented in cases where the user wants to identify a single object from the 3D city model data. For an example in air pollution modelling, search based on leeward or windward building names or ID.

Neighbor Information

- The advantage of space-filling curve operations can be seen in the consistency between neighboring pixels.
- The adjacencies between spatial objects were conserved and retrievable.
- Identifies objects that are located "near" to interest building.
- Since the Hilbert's curve is organized into the 1 dimensional structure, finding the nearest building to a specific building (*n*) is by way of finding the nearest arc length to *n*.
- The bigger the difference (Δ) of arc length will identify the object's distance from *n*.

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

Hilbert's Curve: Arc Length

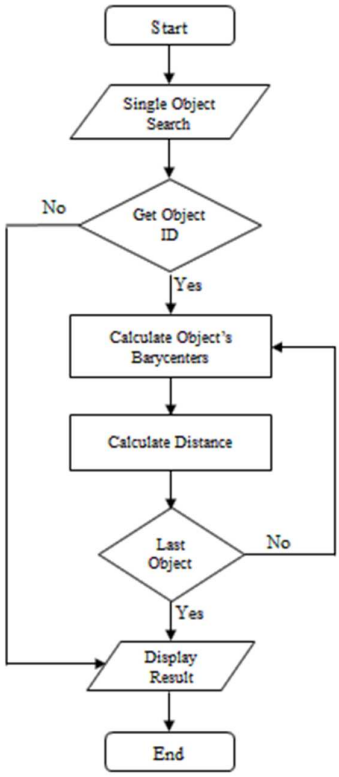


The nearest arc lengths (Δ) from city object A are B, C and D respectively

Nearest Object Search

- Another experiment conducted in this research is to test the performance in data retrieval time for finding the nearest object from the target object.
- The *"nearest object from target* search" is meant for queries like finding the adjacent buildings or building that affected from vehicle emissions.
- Result shows the queries performed and measured for finding the nearest building to the target building.

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014



Flowcharts for finding the nearest object for:

(a) CityGML data and
(b) with 3D Hilbert's curve implementation.

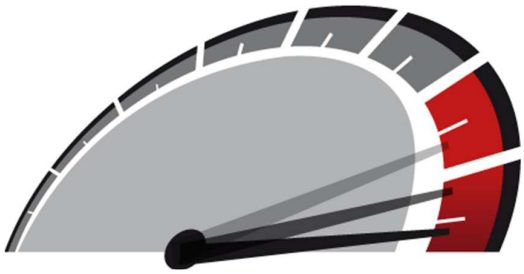
Target Object's ID	Nearest Object's ID	Time (milliseconds)		
		CityGML	Hilbert's Curve	Elapsed (%)
46	*56*	22	1	95.5
440	*540*	24	1	95.8
445	*545*	25	1	96.0
498	*598*	25	1	96.0
571	*539*	28	1	96.4
704	*800*	27	2	92.6
799	*753*	29	2	93.1
816	*817*	32	2	93.8
883	*884*	30	2	93.3
900	*804*	32	3	90.6
928	*963*	31	2	93.5
952	*951*	34	2	94.1
Average		28	2	94.2

Data retrieval time for nearest object from target search

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

Results

- On average Hilbert's curve implementation boost up more than **90% faster** compared to 3D city model data.
- It shows that 3D Hilbert's curve in 3D city model capable in organizing data in a more efficient way.
- Hence, Hilbert's curve implementation in large scale of data sets will optimize the data retrieval time while preserving the nearest neighbor information which is significant in geo-spatial analysis.



Summary

- In this research, we have demonstrated the 3D Hilbert's curve in 3D city model for optimizing query performance.
- From the test, we could see that the implementation of Hilbert's curve method gives advantages in fast acquiring and information retrieval for 3D city model data.
- The advantages of Hilbert's curve in preserving neighbouring information can be benefited for 3D city model application for air dispersion modelling.

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

Summary

- However, further studies need to be deliberated. This research only focused on buildings as the 3D city object.
- Since 3D city objects are becoming more sophisticated, therefore other relationship between city objects are needed.
- Experiment on street furniture and any other objects included in 3D city model should be implemented.

Acknowledgement

- Major funding for this research was provided by the Ministry of Education Malaysia and partially funded by the Malaysian Peninsula Land Surveyors Board (LJT).

KEMENTERIAN PENDIDIKAN MALAYSIA

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

Thank you for your attention!