



# Compression Techniques for 3D SDI

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## Outline

- Introduction
- Background of the problem
- The motivation
- Some compression techniques
- The methodology
- Concluding remarks

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## Introduction - what is compression?



- Lossless compression
  - Identical result (compressed data is identical after decompression)
  - Without degrading data quality
  - Reversible process
  - Examples: gzip and winzip
  - Suitable for any text file e.g. XML file

## Introduction - what is compression?



- Lossy compression
  - Degrading data quality
  - Compressed data quality is still acceptable
  - Compressed data normally not reversible (unless archiving is available)
  - Example: 24-bit bmp -> jpg
  - Commonly found in image compression, music compression, floating number compression (quantization), etc.

## Introduction - why compression?

- Limitations
  - Limited bandwidth (large files and geometries)
  - Limited processing power (small device processor)
  - Limited resources (storage, graphic rendering)
- Advantages
  - Require lesser storage
  - Faster transmission / transferring
  - Low bandwidth consumption
  - Reduce redundancies


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## 

- Disadvantages
  - Lossy compression reduces quality of data
  - Lossless compression sometimes require lengthy decompression process
  - Require more processes (decompression when retrieving)
- Summary
  - Optimization is required to obtain the best in terms of compression rate and retrieval speed

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## Background of the problem

  
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- Redundancies are found in meshes coordinate storage scheme (Deering, 1995)
- CityGML for a large city normally exceeds several Gigabytes (GB) (Mao, 2010)
- Bandwidth and resources limitations are common in mobile devices (Coors, 2007) & (Goetz, 2010)
- Specific compression algorithm may achieve 90% compression rate than a 60% - 70% common gzip compression (Goetz, 2010)

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## The motivation

  
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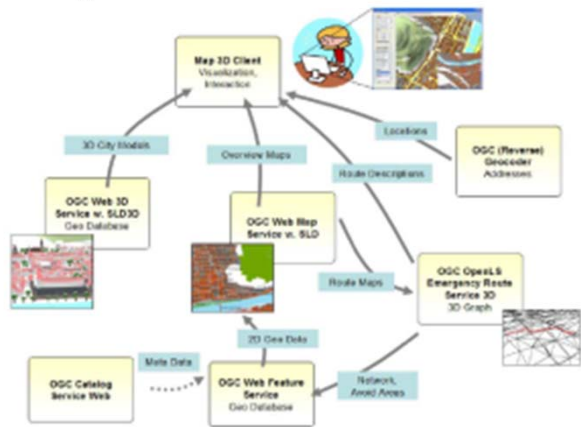
- Various textual compressions library are available for general XML compression, but not specifically for GIS usage (e.g. Xmill, Xgrind, Xpress, XCQ).
- CityGML contents overhead generally > 60% for LOD3
- Better result is achievable by employing lossless compression on coordinates, leveraging the advantages of available textual compression library, e.g. LZMA or Gzip Algorithm / Fast Infoset (FI)

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## Example of 3D SDI




- Heidelberg 3D SDI

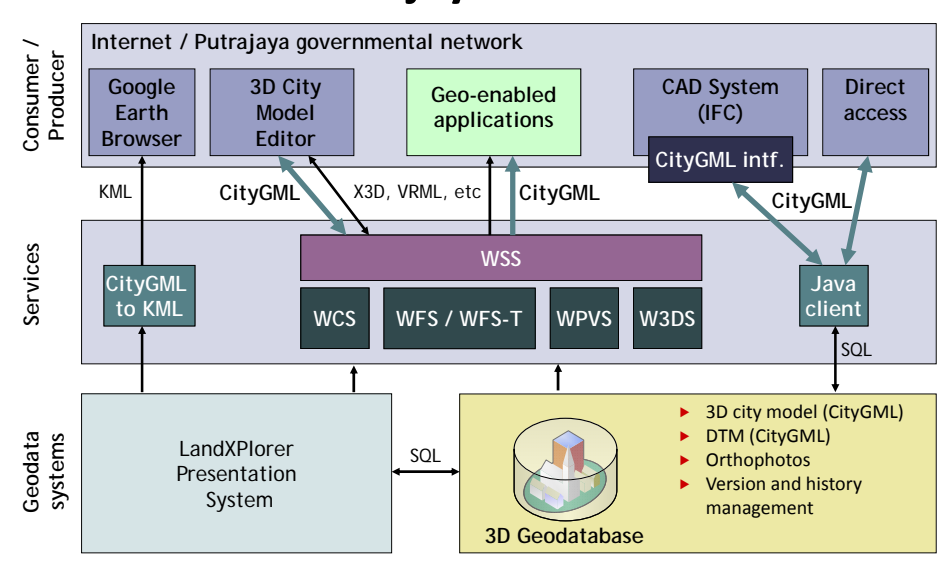


(Basanow et. al, 2007)

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## Putrajaya 3D SDI



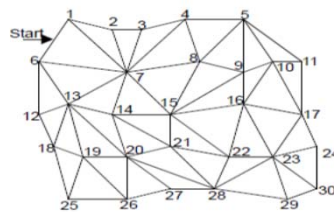


T. Kolbe (2010)

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## Geometry / Connectivity Compression

## Generalized Triangle Meshes



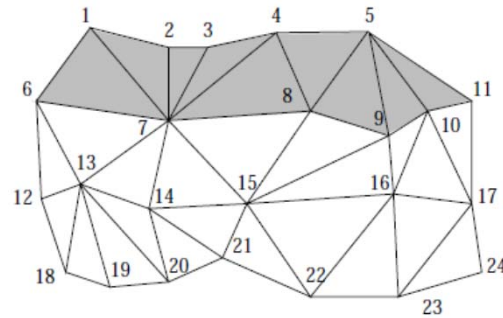
Generalized Triangle Strip:  
 R6, O1, O7, O2, O3, M4, M8, O5, O9, O10, M11,  
 M17, M18, M9, O15, O8, O7, M14, O13, M6,  
 O12, M18, M19, M20, M14, O21, O15, O22, O16,  
 O23, O17, O24, M30, M29, M28, M22, O21, M20,  
 M27, O26, M19, O25, O18

Generalized Triangle Mesh:  
 R6p, O1, O7p, O2, O3, M4, M8p, O5, O9p, O10, M11,  
 M17p, M16p, M-3, O15p, O-5, O6, M14p, O13p, M-9,  
 O12, M18p, M19p, M20p, M-5, O21p, O-7, O22p, O-9,  
 O23, O-10, O-7, M30, M29, M28, M-1, O-2, M-3,  
 M27, O26, M-4, O25, O-5

Legend:  
 First letter: R = Restart, O = Replace Oldest, M = Replace  $M_i$   
 Trailing "p" = push into mesh buffer  
 Number is vertex number, -number is mesh buffer reference  
 where -1 is most recent pushed vertex.

(Deering, 1995)

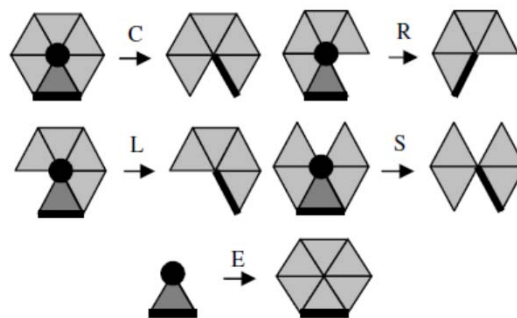
## Triangle Strip Decomposition




vertex chain	vertex list	vertex degree
$C^0$	$\langle 1, 2, 3, 4, 5 \rangle$	$\langle 0, 0, 0, 0, 0 \rangle$
$C^1$	$\langle 6, 7, 8, 9, 10, 11 \rangle$	$\langle 1, 4, 2, 1, 1, 1 \rangle$
$C^2$	$\langle 12, 13, 14, 15, 16, 17 \rangle$	$\langle 1, 2, 1, 3, 2, 2 \rangle$
$C^3$	$\langle 18, 19, 20, 21, 22, 23, 24 \rangle$	$\langle 2, 1, 2, 2, 2, 2, 1 \rangle$

(Park et al, 1999)

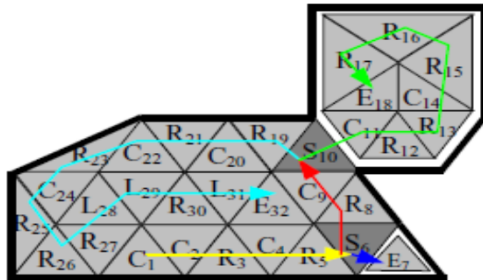
## EdgeBreaker



(Rossignac, 1999)



## EdgeBreaker (cont.)



↑

(Rossignac, 1999)

Output: CCRCSERCSCRRRCRRRERC RCRCRRLLR L

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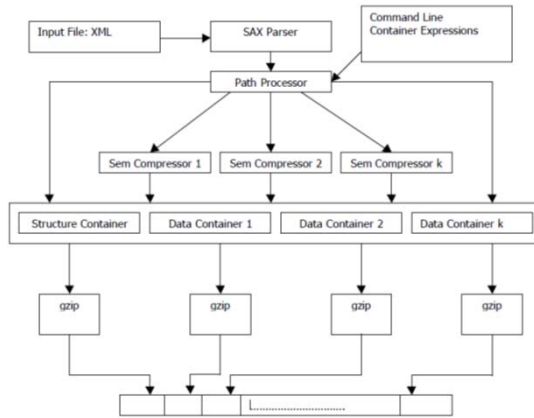
## XML / Textual Compression

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## XMill



(Liefke et al, 1999)

### Description

#### Advantages:

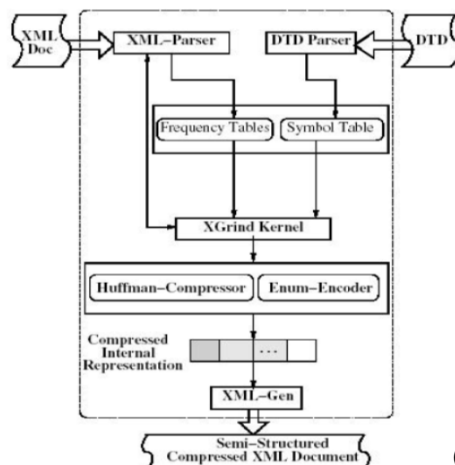
- Separate container for data and structure
- Path scanner

#### Limitations:

- No Coordinate Component
- No indexing for tag
- Gzip as the main compressor



## XGrind



(Tolani et al, 2002)

### Description

#### Advantages:

- DTD Parser
- Statistic collected

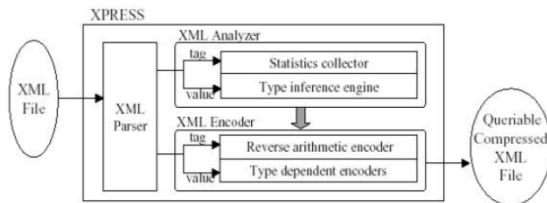
#### Limitations:

- No coordinate component
- No indexing for tag



# Xpress

## Description



(Min et al, 2003)

### Advantages:

- Analyzer that provides type inference capability, statistic collector
- Encoding on type-dependent
- Query-able

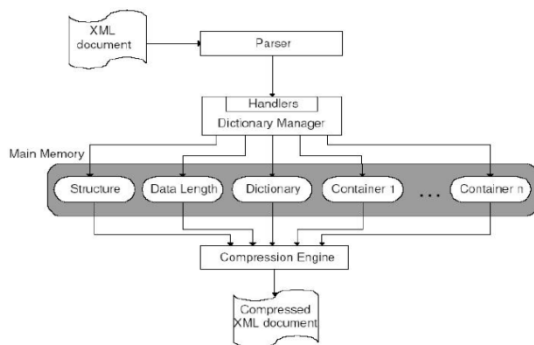
### Limitations:

- No Coordinate Component (Redundancy is expected)
- No indexing for tag



# XComp

## Description




(Li et al, 2003)

### Advantages:

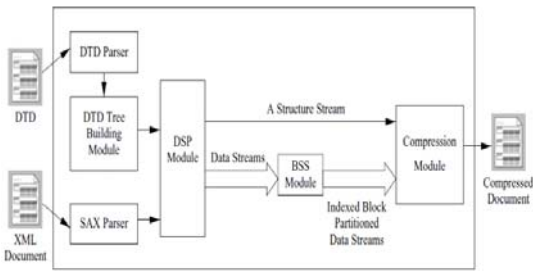
- DTD Parser
- Separate container for data and structure

### Limitations:

- No Coordinate Component
- No indexing for tag
- Query-able: NO



## XCQ



(Ng et al, 2006)

### Description

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**Advantages:**

- DTD Parser
- Indexing
- Blocks differentiating Structure Stream and Data Stream

**Summary:**

- Effective
- Geometry and connectivity component could be embedded

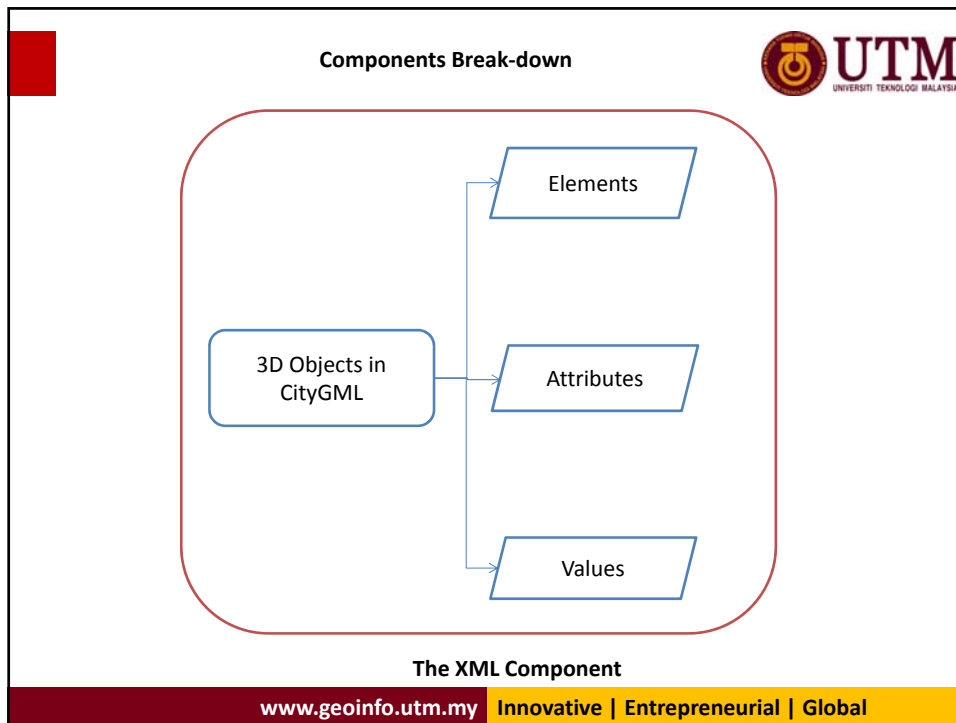
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## The methodology

- Using XML compression technique to scan CityGML
- Detect redundancies and perform data mapping as well as data referencing
- URIs (unique resource identifier) are used to maintain connectivity (Xlink)
- Coordinates are scanned and quantized
- Gzip the scanned document at final stage

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### CityGML Structure (Putrajaya 3D Building)

```

<CityModel xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.citygml.org/1.0/
http://www.citygml.org/citygml/1/0/0/CityGML.xsd http://www.opengis.net/citygml/appearance/1.0
http://schemas.opengis.net/citygml/appearance/1.0/appearance.xsd" xmlns="http://www.citygml.org/citygml/1/0/0"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xAL="urn:oasis:names:tc:ciq:xsdschema:xAL:2.0" xmlns:app="urn:oasis:names:tc:ciq:xsdschema:app:1.0">
  <gml:name>Final_6_1.xml</gml:name>
  <cityObjectMember>
    <Building>
      <gml:name>Commercial_Building(306)</gml:name>
      <usage>1150;Business_Building</usage>
      <measuredHeight uom="urn:ogc:def:uom:UCUM::m">80.35</measuredHeight>
      <storeysAboveGround>15</storeysAboveGround>
      <storeysBelowGround>2</storeysBelowGround>
      <doubleAttribute name="StoreyHeightsAboveGround">
        <value>72.85</value>
      </doubleAttribute>
      <doubleAttribute name="StoreyHeightsBelowGround">
        <value>7.5</value>
      </doubleAttribute>
      <lod3Solid>
        <gml:Solid>
          <gml:exterior>
            <gml:CompositeSurface gml:id="ID-326C4951-E5A4-4646-BC9C-461C04B0323">
              <gml:surfaceMember>
                <gml:Polygon gml:id="ID-70B85218-2C90-48ED-BDE0-B0B65BFCE0A2">
                  <gml:exterior>
                    <gml:LinearRing gml:id="ID-133D3875-911B-436A-B259-9EE8A6E1AFD4">
  
```

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The diagram illustrates the relationship between Element Tags, Name, Path / Depth, and Path-Expression. It includes an XML snippet and a list of path expressions.

**Element Tags** (dashed box) points to **Name** (oval). **generates** (text) points to **Path / Depth** (oval). **Path / Depth** points to **Path-Expression** (text box).

**Path-Expression** (List):

- 1:CityModel
- 2:CityModel/gml:name
- 3:CityModel/cityObjectMember
- 4:CityModel/cityObjectMember /Building
- 5:CityModel/cityObjectMember /Building/gml:name
- 6:CityModel/cityObjectMember /Building/usage
- 7: ....

**XML Snippet:**

```

CityModel xmlns:xsi="http://www.xml.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.citygml.org/2008/05/citygml http://www.citygml.org/2008/05/citygml.xsd" http://www.opengis.net/2.0/ogml:Appearance?_lang=en
xmlns:citygml="http://www.xml.org/2001/XMLSchema" xmlns:citygml="urn:ogis:names:citygml:schema:2.0" xmlns:xsi="http://www.xml.org/2001/XMLSchema"
<gml:name?final_0_1_xml:gml:name>
<citygml:cityObjectMember>
<Building>
<gml:name?Commercial_Building?gml:name>
<usage?Usage?Building?usage>
<measureHeight name="urn:ogis:del:usage:2008:05/measureHeight"
<storeysAboveGround?2?storeysAboveGround>
<storeysBelowGround?2?storeysBelowGround>
<doubleAttribute name="StoreysAboveGround"
<value?2.85?value>
</doubleAttribute>
<doubleAttribute name="StoreysBelowGround"
<value?2.85?value>
</doubleAttribute>
<clouds?lid>
<gml:center?center>
<gml:CompositeSurface gml:id="ID-324C951-E5A4-NA4-829C-NA1C04080232"?
<gml:surfaceMember>
<gml:Polygon gml:id="ID-78085210-2C10-4EE0-80E0-80B450FCE062"?
<gml:center?center>
<gml:LinearRing gml:id="ID-12030075-9110-4340-8259-9E1804E10034"?
    
```

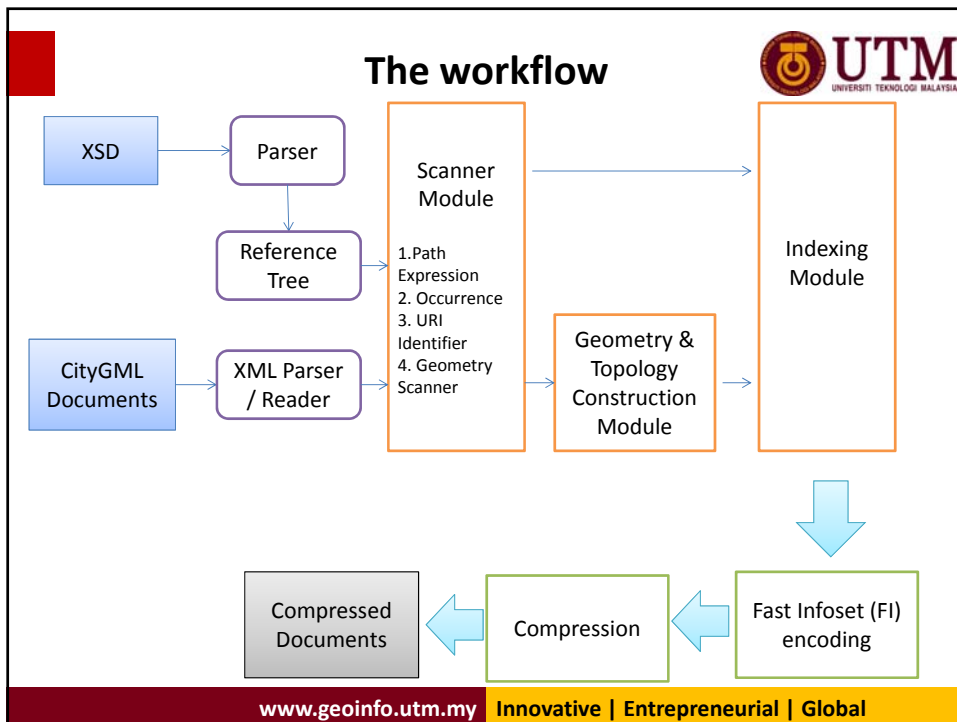
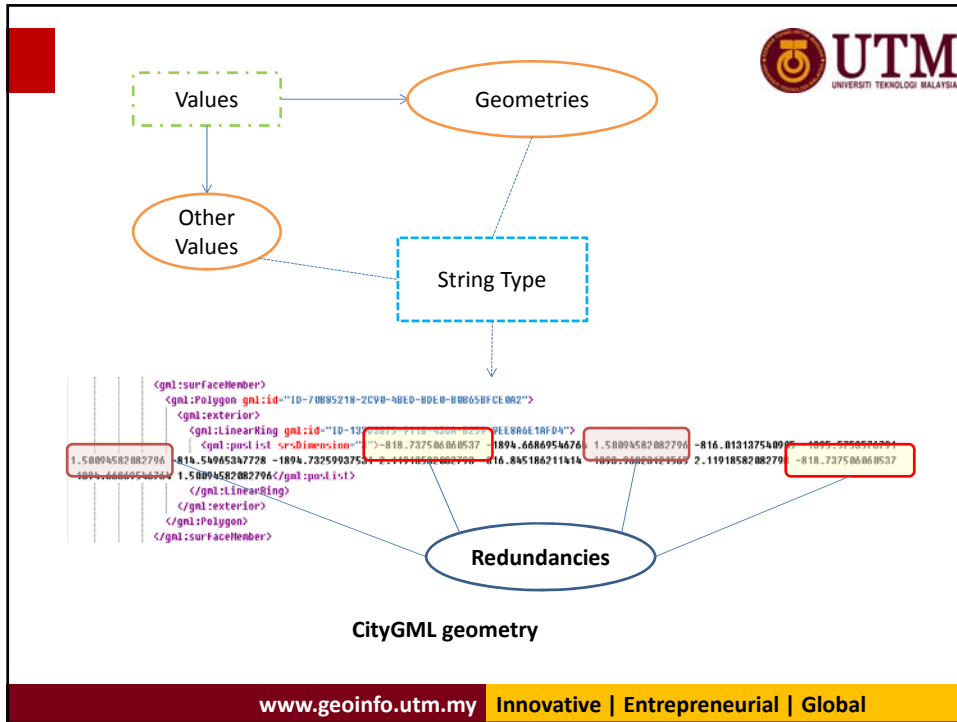
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**CityGML Attributes**

The diagram shows the relationship between Attributes, Name, ValueType, URI, Date, Double, Integer, and String.

**Attributes** (dashed box) points to **Name** (oval). **Attributes** points to **ValueType** (oval). **ValueType** points to **URI** (oval), **Date** (oval), **Double** (oval), **Integer** (oval), and **String** (oval).

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## Advantages & applications



- Scanned data can be used for small devices for visualization
- Web service component
- Scanned document is a compact version, smaller in size after decoded / decompressed, and lossless type
- The framework enable implementation of different compression techniques
- Future development ensure external referenced files (texture images) are packaged within an archive

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## URI relationship (generated document)




```

<?xml version="1.0" encoding="utf-8" ?>
<urlList>
<URI parent="0" index="1">ID-000016A8-218A-45E9-B229-019BB2E64A90</URI>
<URI parent="5149" index="2">ID-00042F19-94F2-450E-884F-0457A868691E</URI>
<URI parent="9161" index="3">ID-000438C3-E34E-4253-944F-4E84C525F3</URI>
<URI parent="1" index="4">ID-000610B4-ADE6-461D-8D9C-E6D42256043C</URI>
<URI parent="4625" index="5">ID-000663E0-F13A-40F3-A742-925E1194B0D9</URI>
<URI parent="1" index="6">ID-0007AFC4-3D5B-488B-848C-E6B0542164E1</URI>
<URI parent="16482" index="7">ID-0008025A-8120-4E6E-91E7-9E84660032D</URI>
<URI parent="1" index="8">ID-00097034-122E-4070-A4B8-5949B7CF3964</URI>
<URI parent="7341" index="9">ID-000A9581-1949-403D-9ADD-BED46FF24BF8</URI>
<URI parent="1" index="10">ID-000B44C-4984-41E2-8209-63CF040892D9</URI>
<URI parent="16264" index="11">ID-000FCBDE-50CE-40A8-A53E-FCDD2498D3B</URI>
<URI parent="1" index="12">ID-001FFABC-CDC4-4111-8A25-2293396F7934</URI>
<URI parent="10423" index="13">ID-002495B6-26A4-4237-9CC5-68A5639C0581</URI>
<URI parent="1" index="14">ID-002D39C3-3F3D-4829-90A1-7AA3E032F584</URI>
<URI parent="4225" index="15">ID-002E9EFA-BDCC-4AF3-B7B0-486C8D17A5D</URI>
<URI parent="1" index="16">ID-002F424F-2F2B-4FBF-9C79-117E2643B64</URI>
<URI parent="943" index="17">ID-0030E46E-E6A8-4B07-9290-854D6E793EAB</URI>
<URI parent="1" index="18">ID-003188BC-D6C3-499C-985C-C8B6D40DF5</URI>
<URI parent="14503" index="19">ID-003C9A4-6B2A-48F9-AECE-F0F567647EA</URI>
<URI parent="1" index="20">ID-00379E6E-B84B-415A-B3E9-AEBD2D1F0271</URI>
<URI parent="1796" index="21">ID-0037C04E-28FB-4E16-A751-1782E24D6C8A</URI>
<URI parent="1" index="22">ID-0037E3A1-8022-4E29-8D08-72D0A05C46D</URI>
<URI parent="11319" index="23">ID-003B498F-3C06-4455-BCC8-862173AE932D</URI>
<URI parent="1" index="24">ID-003D5189-B3B2-4745-9823-796B0658E893</URI>
<URI parent="11557" index="25">ID-003FB61A-748E-4186-ACB8-CD91868D1AC3</URI>
<URI parent="1" index="26">ID-004AC4CC-A4FF-4327-92E6-724ECCB4442</URI>
<URI parent="4000" index="27">ID-004C92C3-EA9E-490A-BB05-A03CBE9E052F</URI>
<URI parent="1" index="28">ID-0053DA2A-DA7E-4F1B-B131-B5CA4924C703</URI>
<URI parent="2842" index="29">ID-005721DA-1096-43A6-99EF-BF005601E37</URI>
<URI parent="1" index="30">ID-005DAA90-9FF0-4677-8243-BEFOAF18SF03</URI>
<URI parent="1247" index="31">ID-0062E46D-ED39-4E2- AE3D- D53FC76944D5</URI>
<URI parent="1" index="32">ID-006313DC-D99F-4C07-B39D-5B673759541E</URI>
<URI parent="11269" index="33">ID-006A3E82-C00F-4FA6-A285-26709211B344</URI>
<URI parent="1" index="34">ID-006AE054-4487-40FC-A642-DC48A8EF2A8F</URI>

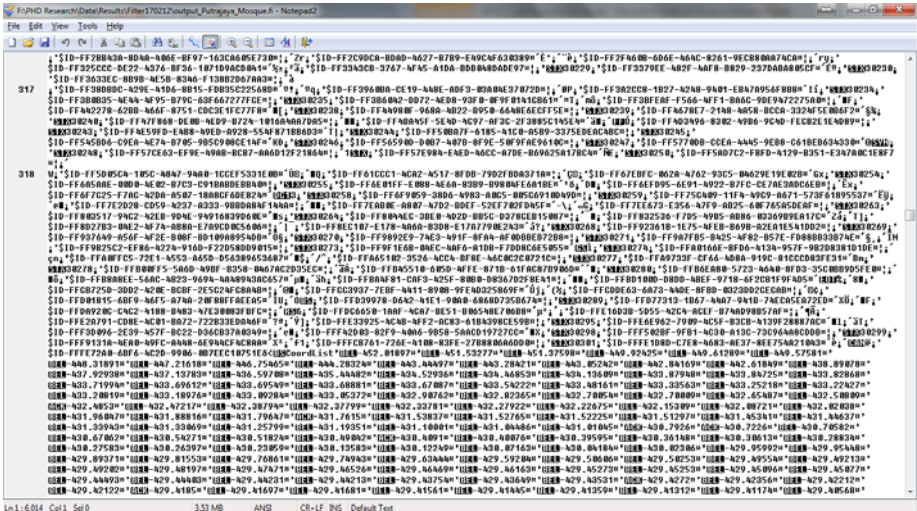
```

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# Encoded Document




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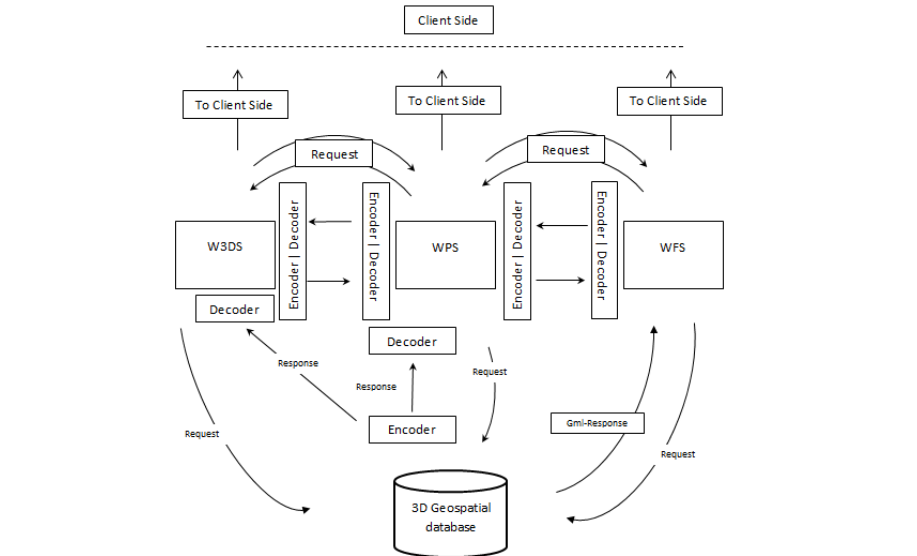


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## The Proposed Compression for Putrajaya 3D SDI





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## Concluding remarks

- We intend to make use of XMill compression technique for XML-based files within the Putrajaya 3DSDI case study
- Encoded document will be packaged as an archive for textures
- Javascript decoder for common browser / cross platform mobile
- Server side implementation for web service data transfer

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## That's all, thank you!

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