UK 3DGIS Special Interest Group

UCL

Towards a True 3D GIS

Dr Claire Ellul

University College London

About me ..

- Lecturer in GIS at University College London
- PhD looked a performance of 3D queries in Oracle Spatial
- Specialise in 3D GIS, and also spatial data management
- Founder and Chair of the AGI 3D Special Interest Group
  - https://www.linkedin.com/groups?mostRecent=&gid=7467823

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Overview

- What is 3D GIS and why do we need it?
- Is there data, and can we store and share it?
- What analysis options exist?
- How can we present the results?
- Next Steps …

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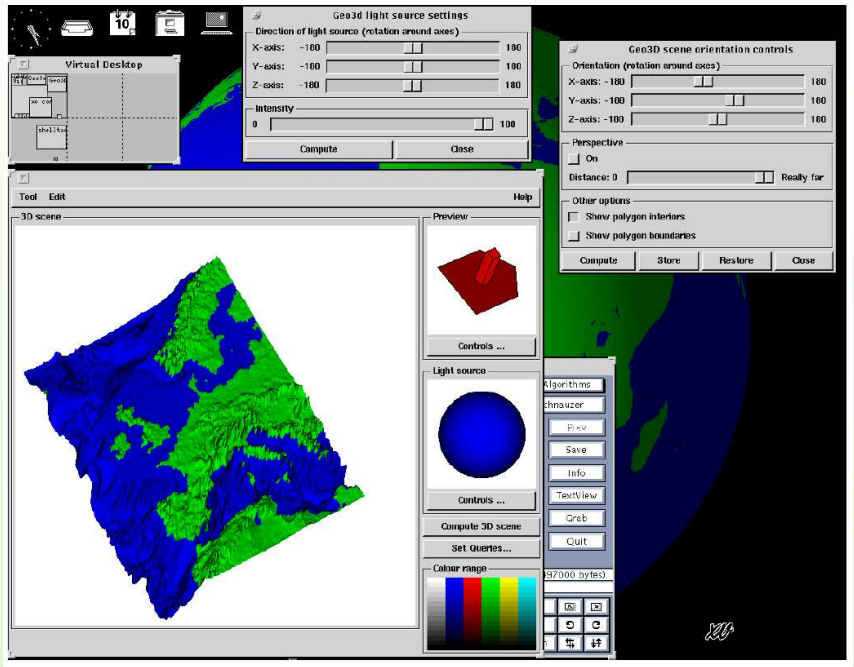
What is 3D GIS?

- 3D GIS has been around a while
- But mainstream 3D GIS does not exist – why?
  - Applications?
  - Functionality?
    - Data Creation and Storage
    - Analysis
    - Presentation



VAN OOSTEROM, P, VERTEGAAL, W, VAN HEKKEN, M, 1994, Integrated 3D Modelling within a GIS, *Proceedings of Advanced Geographic Data Modelling (AGDM),* Delft, The Netherlands

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What is 3D GIS?

- Dimensions
  - 2.5D – x, y and 1 height value (z)
  - 3D – x, y and multiple height values for the same x, y points
  - 3D GIS deals with solid 3D objects – **i.e. those that enclose a volume**
    - NB: Talking about Vector GIS
- Operations
  - Data capture and edit
  - Data quality validation
  - Visualisation
  - Metric and topological analysis
    - Proximity (buffer, distance)
    - Area and Volume
    - Intersection, within, contains
  - Thematic mapping
  - Interpolation and statistical analysis

Integrating the 3D Geometry and the Information System

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Why do we need 3D GIS?

- The first question to ask …
  - Do we really need 3D GIS?
  - Are there situations where:
    - 2D GIS really doesn't provide the functionality we need
    - 2D GIS provides the functionality but with quite a bit of 'fudging'

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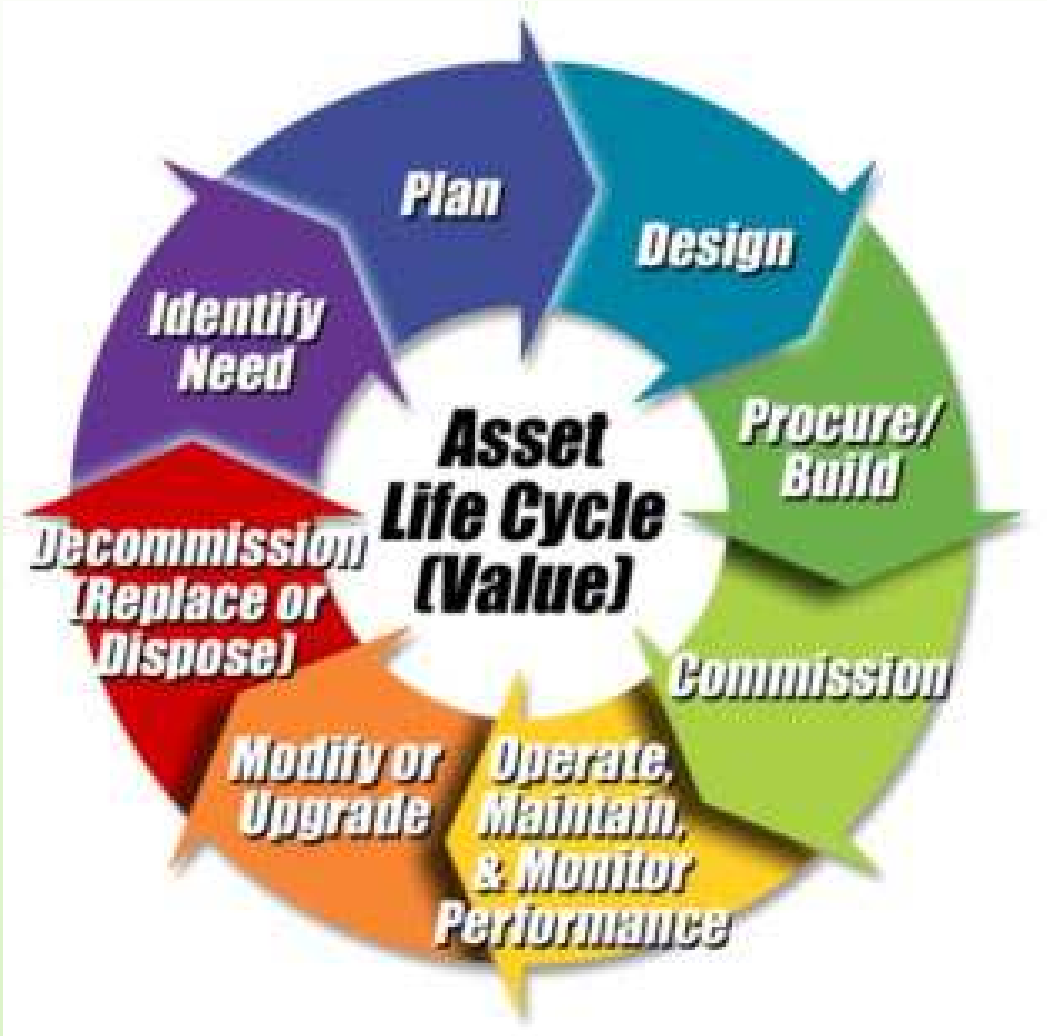
Case Study – The Built Environment Lifecycle



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Case Study 1 – Planning and Construction

http://www.skyscrapercity.com/showthread.php?t=1067687

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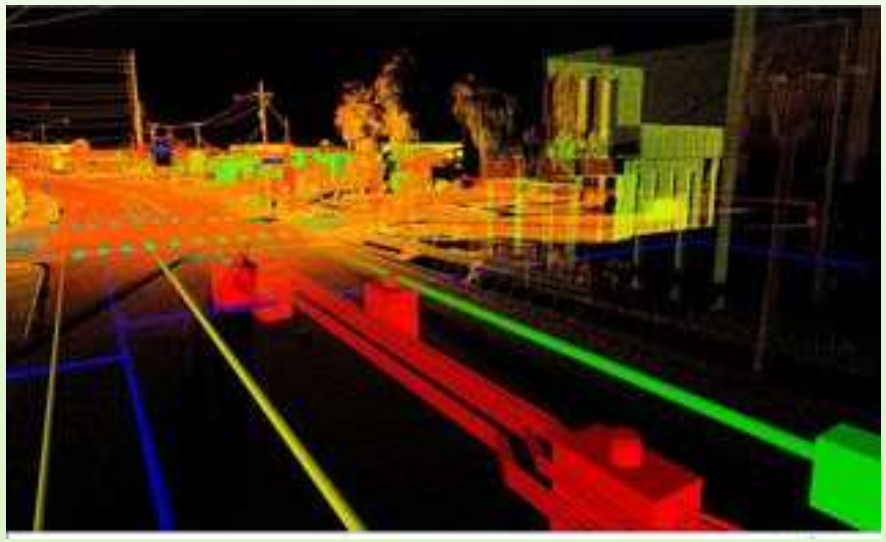
Case Study 1 – Planning and Construction



http://geospatial.blogs.com/geospatial/digital_cities/page/2/
http://www.thisoldhouse.com/toh/article/0,,1206502,00.html

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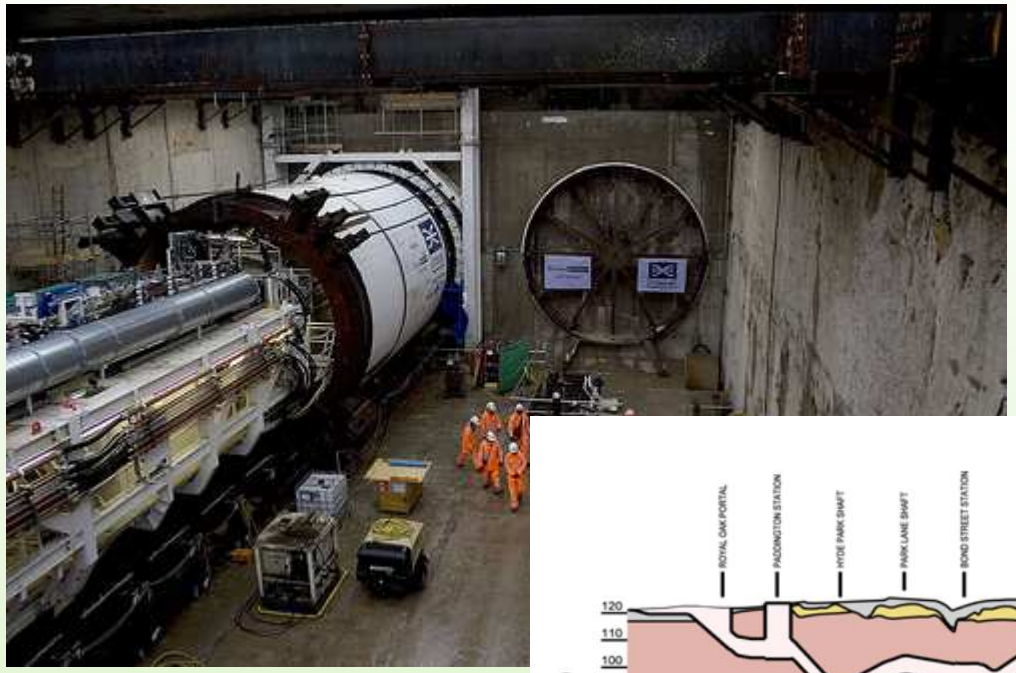
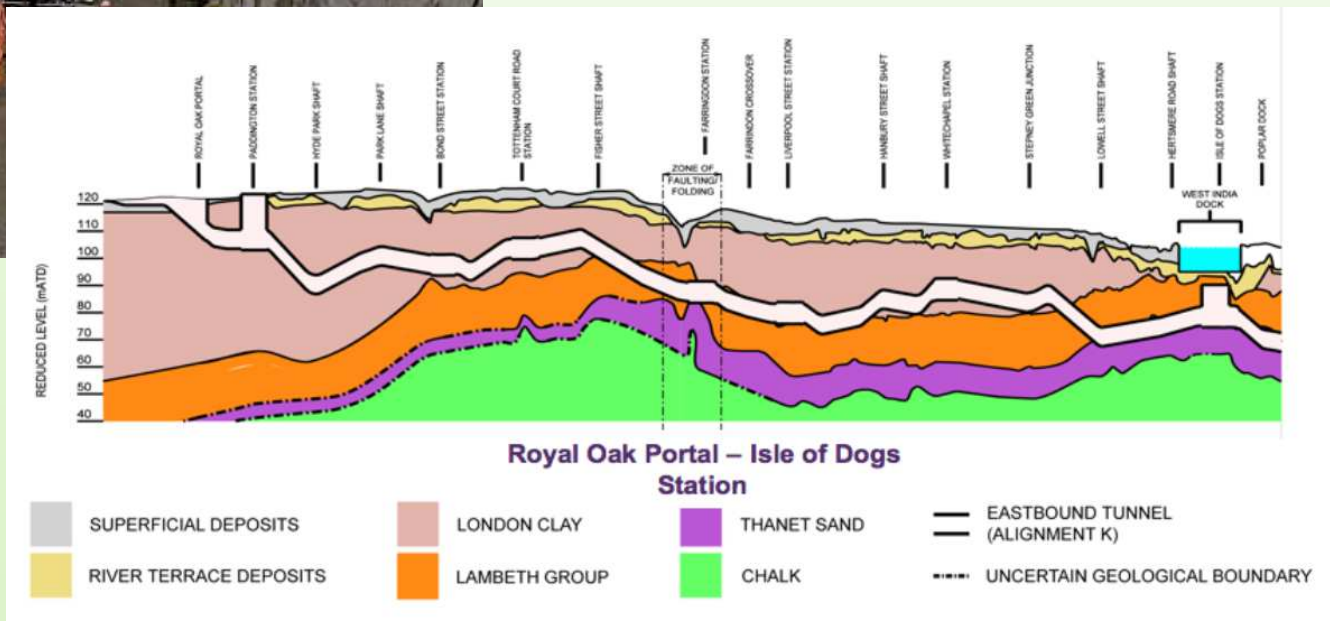
Case Study 1 – Planning and Construction





http://www.ianvisits.co.uk/blog/2012/12/19/photos-the-crossrail-tunnel-portal-at-plumste

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Case Study 1 – Planning and Construction

http://www.ajgroupinternational.com/construction-2/construction-material/

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Case Study 2 – Operation and Maintenance

http://www.topfliteloftconversions.co.uk/planning-a-loft-conversion-let-your-neighbours-know/

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Case Study 2 – Operation and Maintenance

http://forums.digitalspy.co.uk/showthread.php?t=1761849
http://www.allaboutmoney.com/debt-advice/news/incidents-of-council-tax-debt-up-by-27-pc-0-5649.htm

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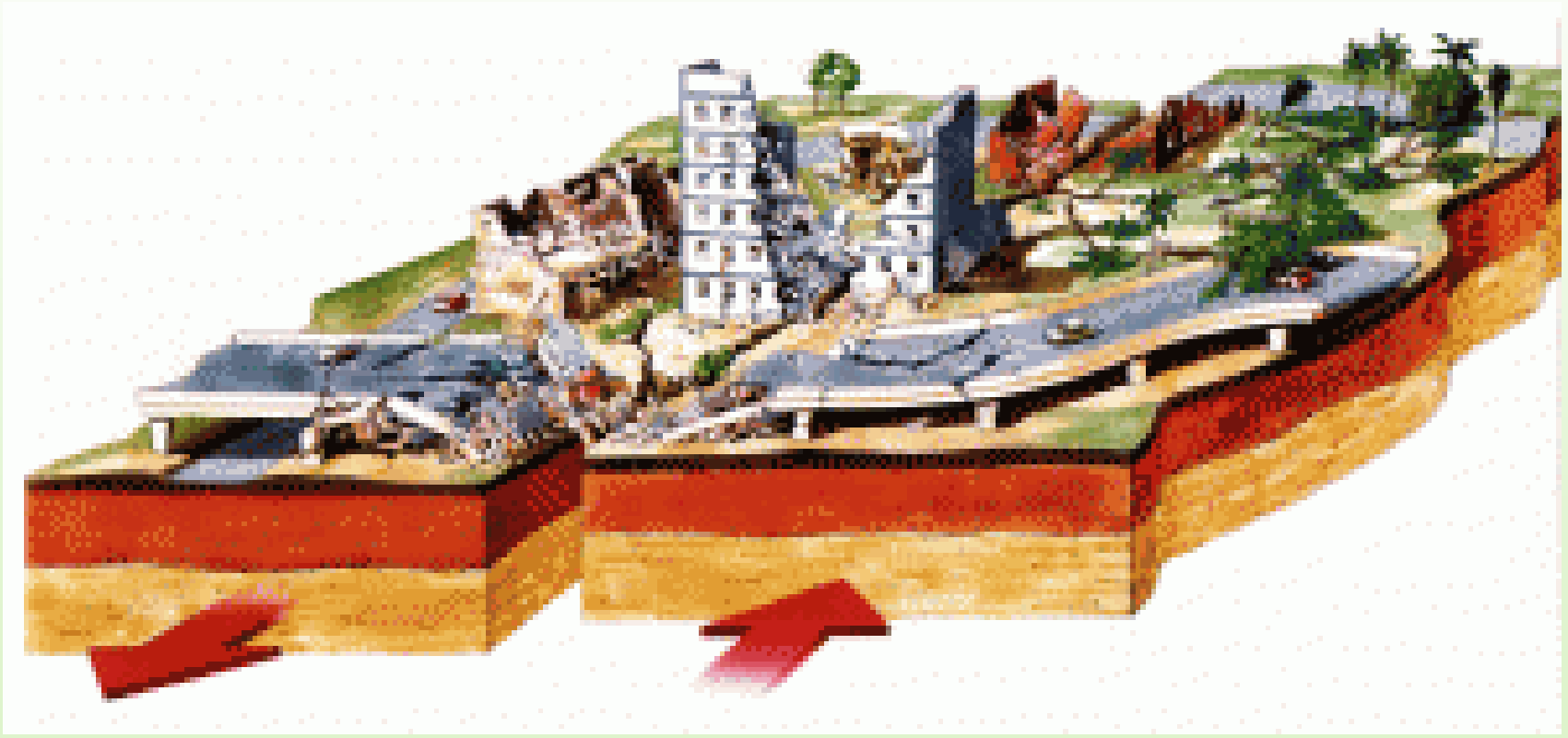
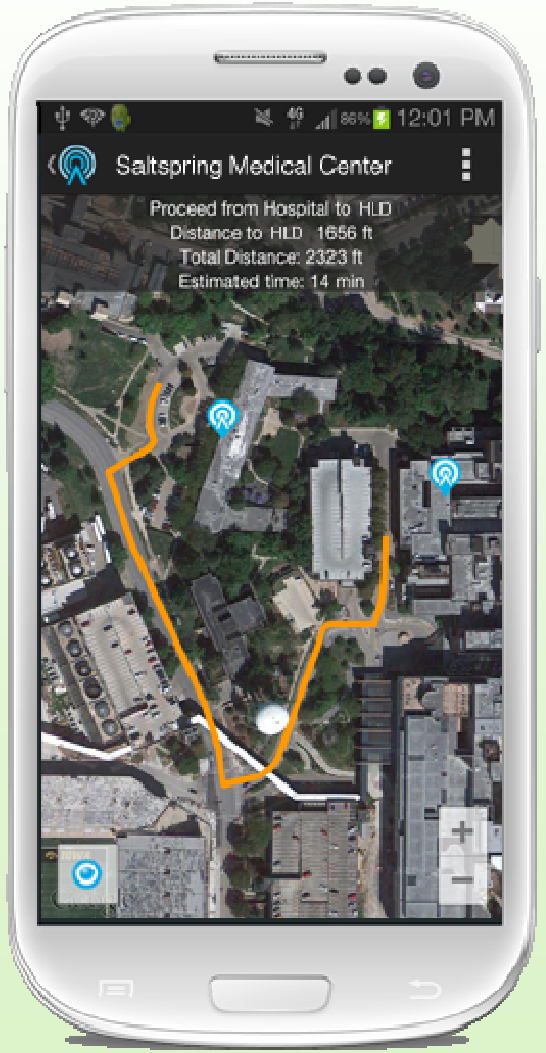
Case Study 2 – Operation and Maintenance



http://scientificallyspeaking.edublogs.org/2012/09/24/get-involved-young-ones/

Case Study 2 – Operation and Maintenance



http://www.wifarer.com/hospitals

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Case Study 3 – Decommissioning

- http://www.findlocales.com/bangalore/bcontacts/all/details/1248/an-yarab-traders.html

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- Is there data, and can we store and share it?
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3D Data Sources

- Extrusion of 2D Datasets
- Manual Data Capture
- Point Cloud Sources
    - LiDAR and Laser Scanning (Kinect, PhotoSynth)
- Computer Aided Design
- Photogrammetry
- Crowd Sourcing
  – OSM Buildings + @ViziCities Height App

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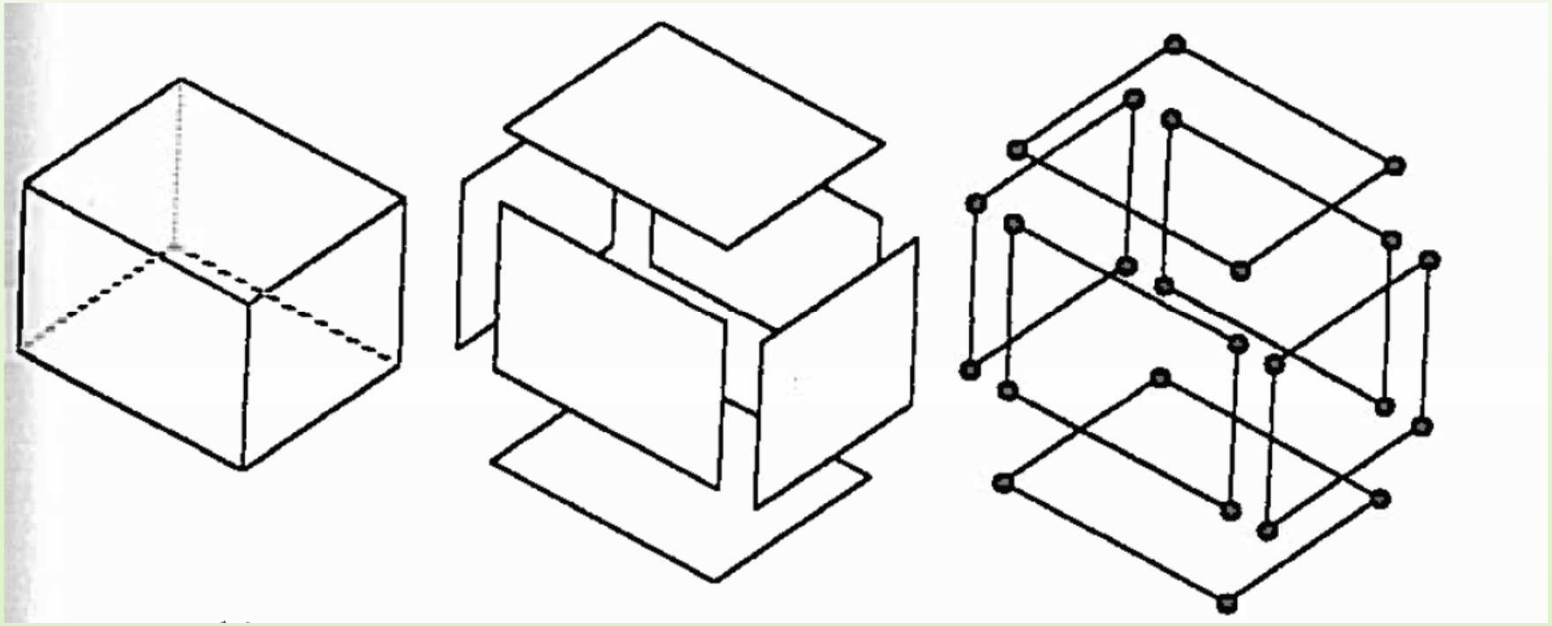
Creating 3D Data In SQL

- In PostGIS, 3D data is stored using a Boundary-Representation Structure
  - i.e. only the ‘shell’ of the 3D object is stored



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Creating 3D Data In SQL

- Insert into buildings (geom) values (ST_GEOMFROMTEXT('POINT(0 0 3)',27700));
- Insert into buildings (geom) values (ST_GEOMFROMTEXT('LINESTRING(0 0 0,1 0 0,1 1 2)',27700));

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Creating 3D Data In SQL

- Insert into buildings (geom) values (ST_GEOMFROMTEXT('POLYGON((1 1 3, 1 2 3,2 2 3, 2 1 3, 1 1 3))',27700));

- Insert into buildings(geom) values (ST_GEOMFROMTEXT('MULTIPOLYGON(((5 5 5, 5 6 5, 6 6 5, 6 5 5, 5 5 5)), ((5 5 5, 5 6 5, 5 6 6, 5 5 6, 5 5 5)))',27700));

Creating 3D Data In SQL

- Insert into buildings (geom) values (ST_GEOMFROMTEXT('POLYHEDRALSURFACE(((0 0 0, 0 1 0, 1 1 0, 1 0 0, 0 0 0)), ((0 0 0, 0 0 1, 0 1 1, 0 1 0, 0 0 0)),((0 0 0, 1 0 0, 1 0 1, 0 0 1, 0 0 0)), ((0 0 1, 1 0 1, 1 1 1, 0 1 1, 0 0 1)),((1 0 0, 1 1 0, 1 1 1, 1 0 1, 1 0 0)),((1 1 0, 0 1 0, 0 1 1, 1 1 1, 1 1 0)))',27700));

Creating 3D Data In SQL

SELECT ST_ASTEXT(geom) FROM buildings

- "POINT Z (0 0 3)"
- "LINESTRING Z (0 0 0,1 0 0,1 1 2)"
- "MULTIPOLYGON Z (((5 5 5, 5 6 5, 6 6 5, 6 5 5, 5 5 5)), ((5 5 5, 5 6 5, 5 6 6, 5 5 6, 5 5 5)))"
- "POLYGON Z ((1 1 3,1 2 3,2 2 3,2 1 3,1 1 3))"
- "POLYHEDRALSURFACE Z (((0 0 0,0 1 0,1 1 0,1 0 0,0 0 0)),((0 0 0,0 0 1,0 1 1,0 1 0,0 0 0)),((0 0 0,1 0 0,1 0 1,0 0 1,0 0 0)),((0 0 1,1 0 1,1 1 1,0 1 1,0 0 1)),((1 0 0,1 1 0,1 1 1,1 0 1,1 0 0)),((1 1 0,0 1 0,0 0 1,1 1 1,1 1 0)))"

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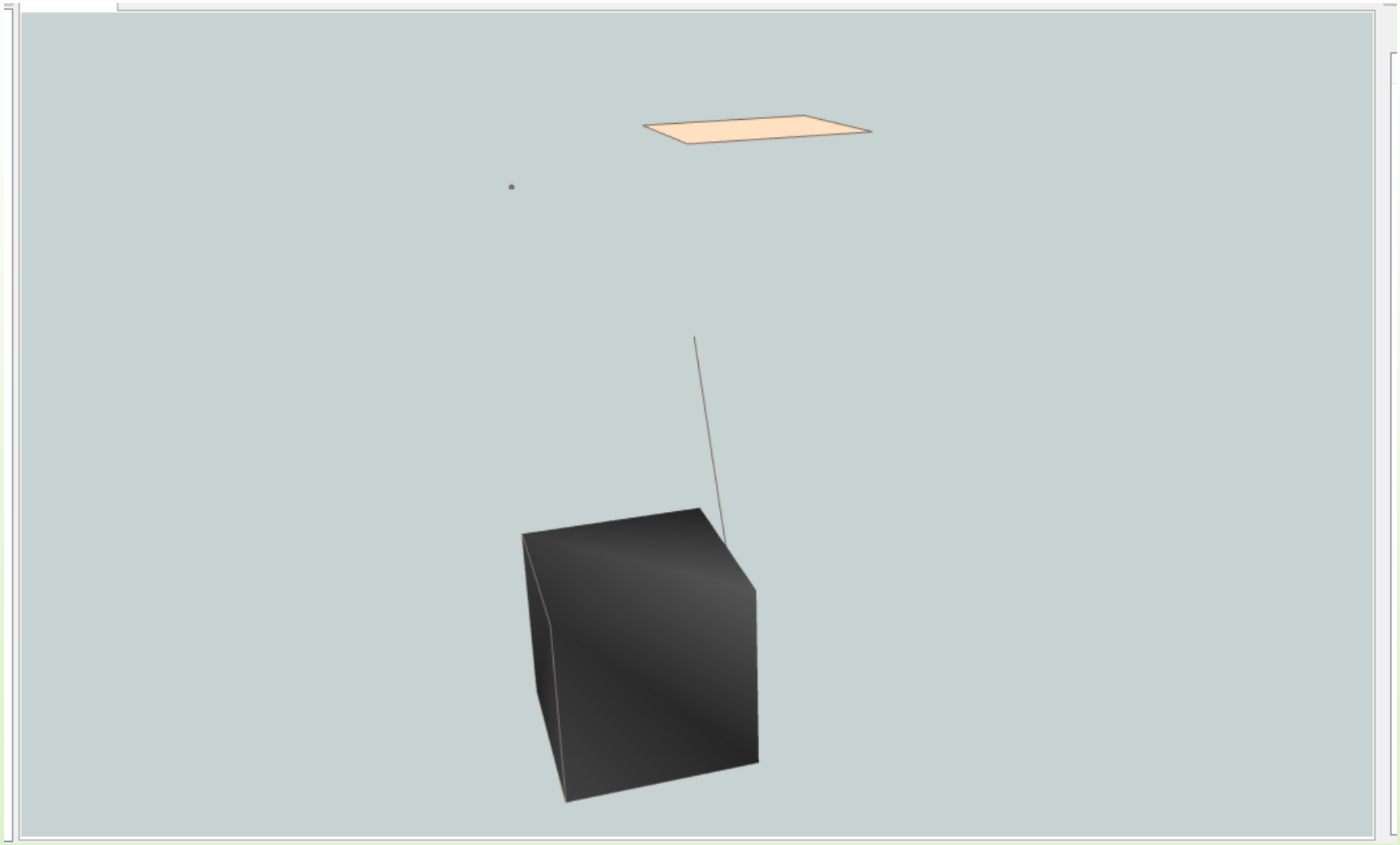

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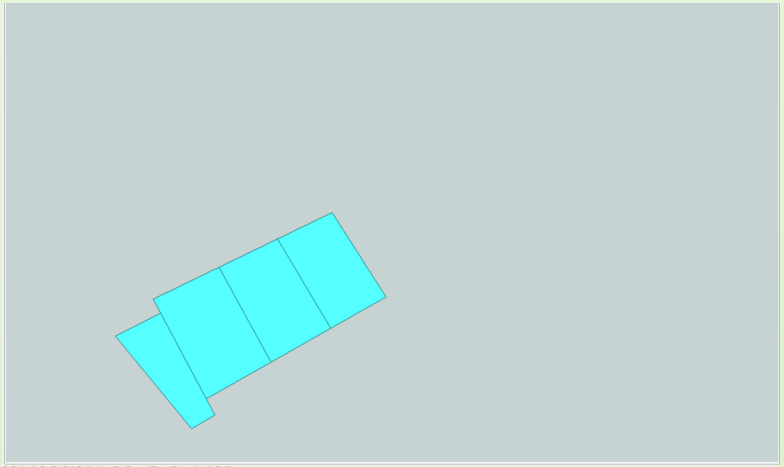
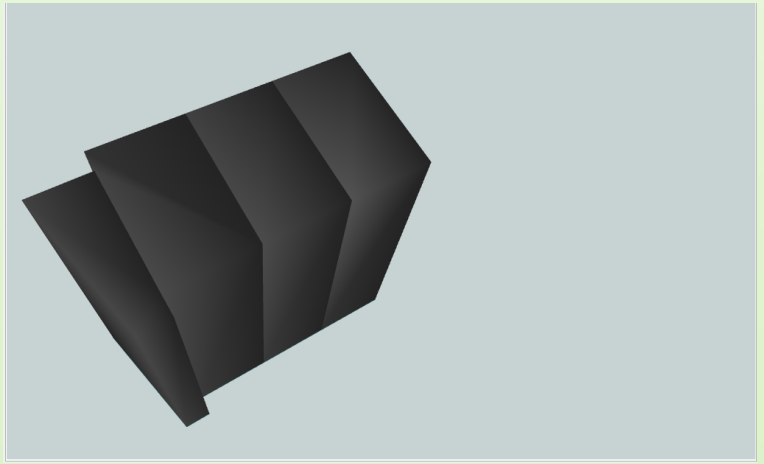
Creating 3D Data in PostGIS

- PostGIS (as of 2.1.0) now offers the ST_Extrude function
  - Extrude a surface to a related volume
  - Powerful as you can extrude along the X, Y, Z axis





"LINESTRING Z (529551.581430858 182210.067253863 11,529546.659619969 182206.683981214 11)"
"POLYHEDRALSURFACE Z (((529547.427963132 182207.29101935 11,529551.544609975 182210.120818988 11,529551.618251741 182210.013688738 11,529547.501604897 182207.1838891 11,529547.427963132 182207.29101935 11)),((529551.544609975 182210.120818988 11,529551.5446 (...)"
"LINESTRING Z (529551.581430858 182210.067253863 12.8665607354318,529546.659619969 182206.683981214 12.8665607354318)"
"POLYHEDRALSURFACE Z (((529546.622799086 182206.737546338 12.8665607354318,529546.622799086 182206.737546338 13.2255609278956,529551.544609975 182210.120818988 13.2255609278956,529551.544609975 182210.120818988 12.8665607354318,529546.622799086 182206.73754 (...)"
"LINESTRING Z (529551.581430858 182210.067253863 13.2255609278956,529546.659619969 182206.683981214 13.2255609278956)"
"POLYHEDRALSURFACE Z (((529546.622799086 182206.737546338 13.2255609278956,529546.622799086 182206.737546338 13.3265607354318,529551.544609975 182210.120818988 13.3265607354318,529551.544609975 182210.120818988 13.2255609278956,529546.622799086 182206.73754 (...)"

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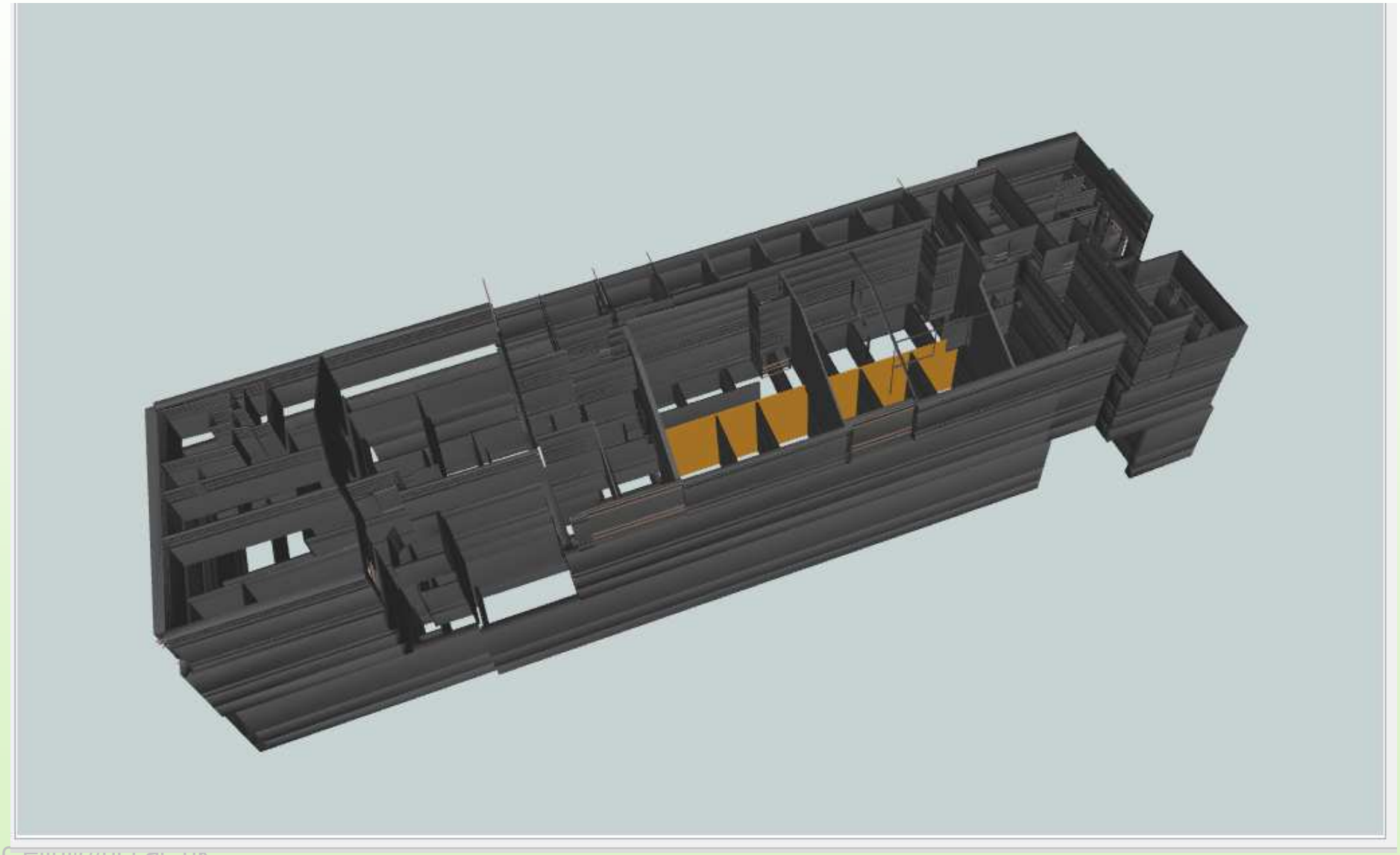

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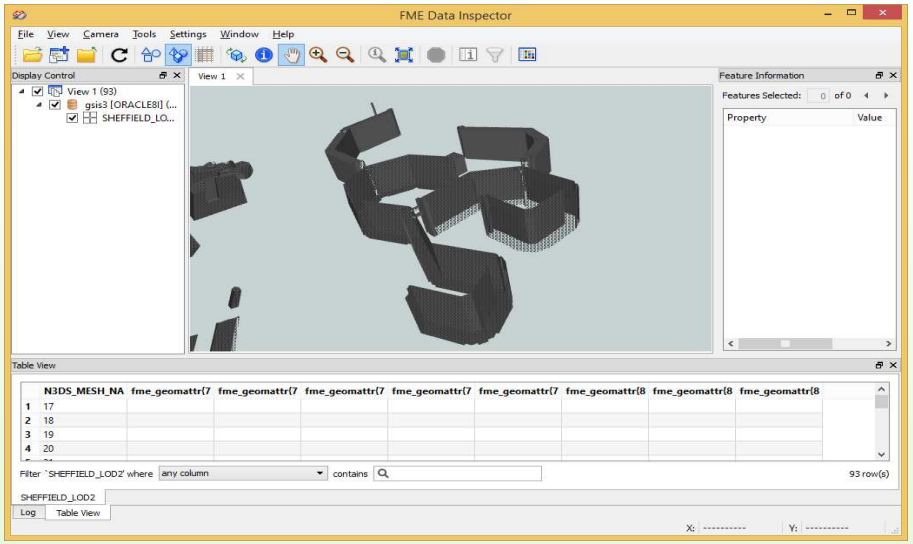
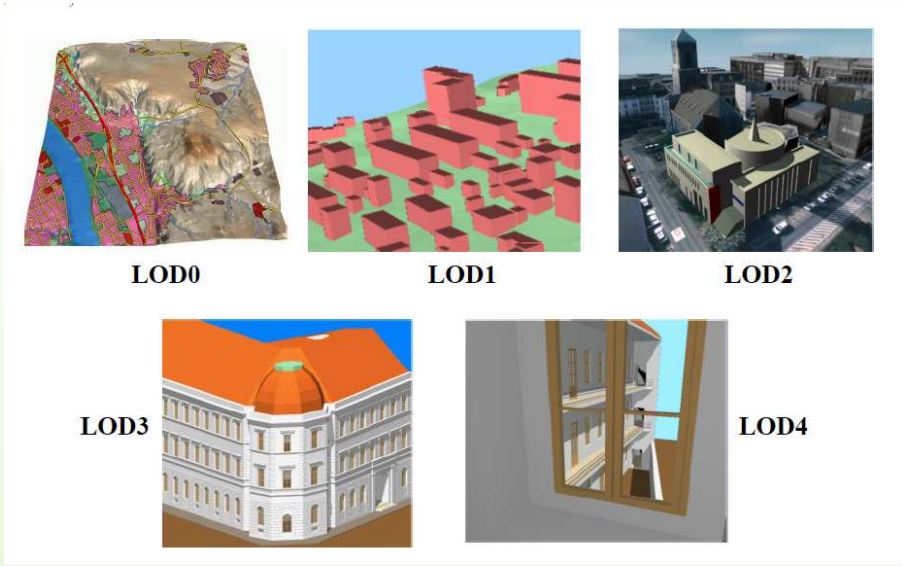
Sharing Data





- FME
  - General GIS Data Exchange
  - Offers 3D import/export into Oracle Spatial, **PostGIS**, IFC, Shape

- CityGML
  - XML based exchange format for 3D city data
  - OGC standard in 2008
  - Models both 3D vector data and the attributes associated with the data

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3D Analysis

- Focus on two types of GIS functionality
  - Metric (measurement)
  - Topological (relationships between objects)

- Assuming that for now functions such as 3D interpolation, 3D networking, 3D hotspot analysis etc. will be developed outside of the database ….

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3D Analysis - Metric Queries

ST_3DClosestPoint — Returns the 3-dimensional point on g1 that is closest to g2. This is the first point of the 3D shortest line.
ST_3DDistance — For geometry type Returns the 3-dimensional cartesian minimum distance (based on spatial ref) between two geometries in projected units.
ST_3DDWithin — For 3d (z) geometry type Returns true if two geometries 3d distance is within number of units.
ST_3DDFullyWithin — Returns true if all of the 3D geometries are within the specified distance of one another.
ST_3DIntersects — Returns TRUE if the Geometries "spatially intersect" in 3d - only for points and linestrings
ST_3DShortestLine - Returns the 3-dimensional shortest line between two geometries

3D Analysis - Metric Queries

ST_3DLongestLine — Returns the 3-dimensional longest line between two geometries
ST_3DMaxDistance — For geometry type Returns the 3-dimensional cartesian maximum distance (based on spatial ref) between two geometries in projected units.
ST_3DShortestLine — Returns the 3-dimensional shortest line between two geometries
ST_3DArea — Computes area of 3D geometries
ST_3DExtent - an aggregate function that returns the box3D bounding box that bounds rows of geometries.
ST_3DPerimeter - Returns the 3-dimensional perimeter of the geometry, if it is a polygon or multi-polygon.

Some functions require the SFCGAL Library to be installed – a wrapper around CGAL, the geometry functions library.

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Metric Queries

- Missing
  - ST_Volume
  - ST_SurfaceArea
  - Others?

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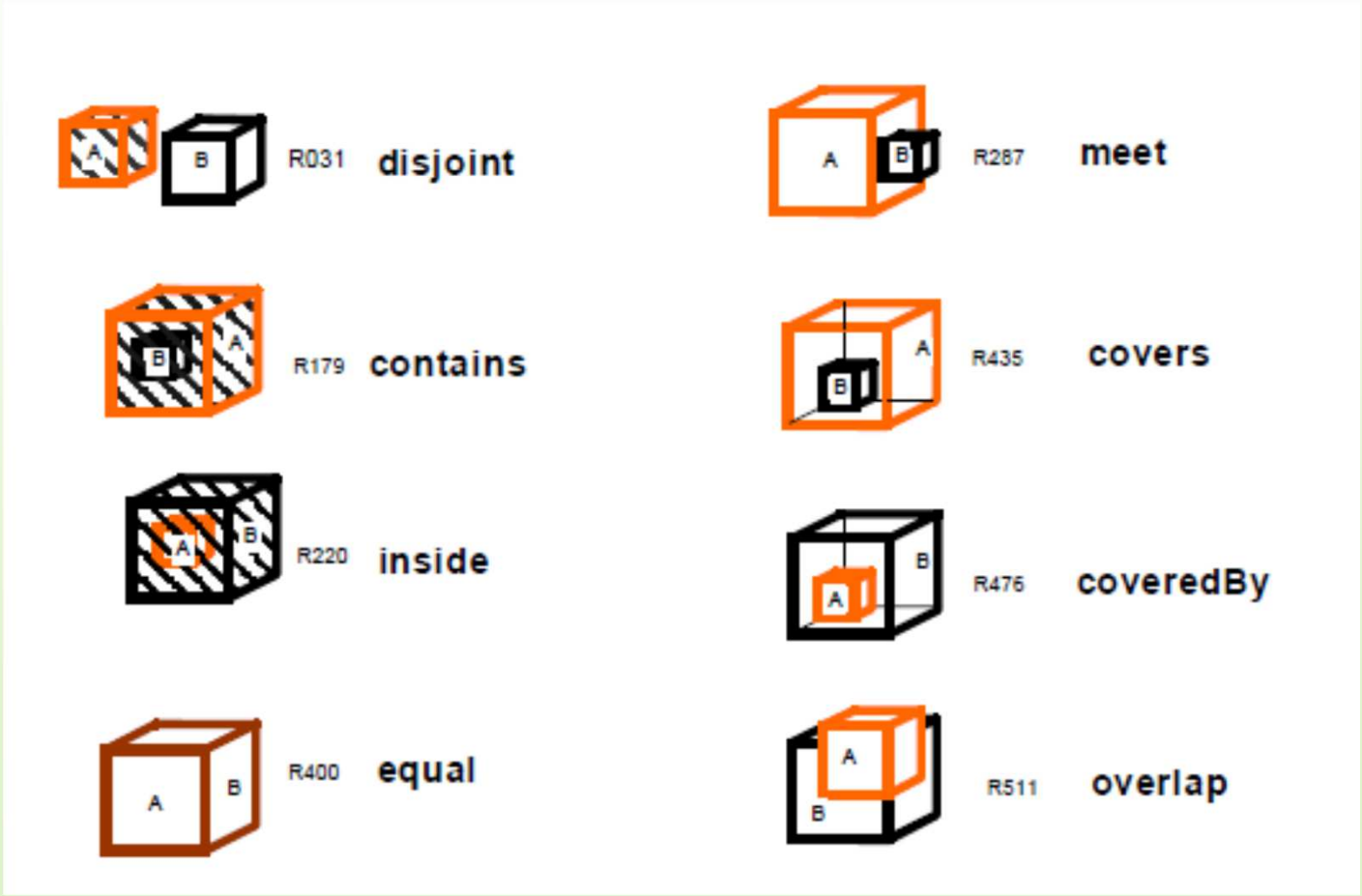
3D Analysis - Topological Queries



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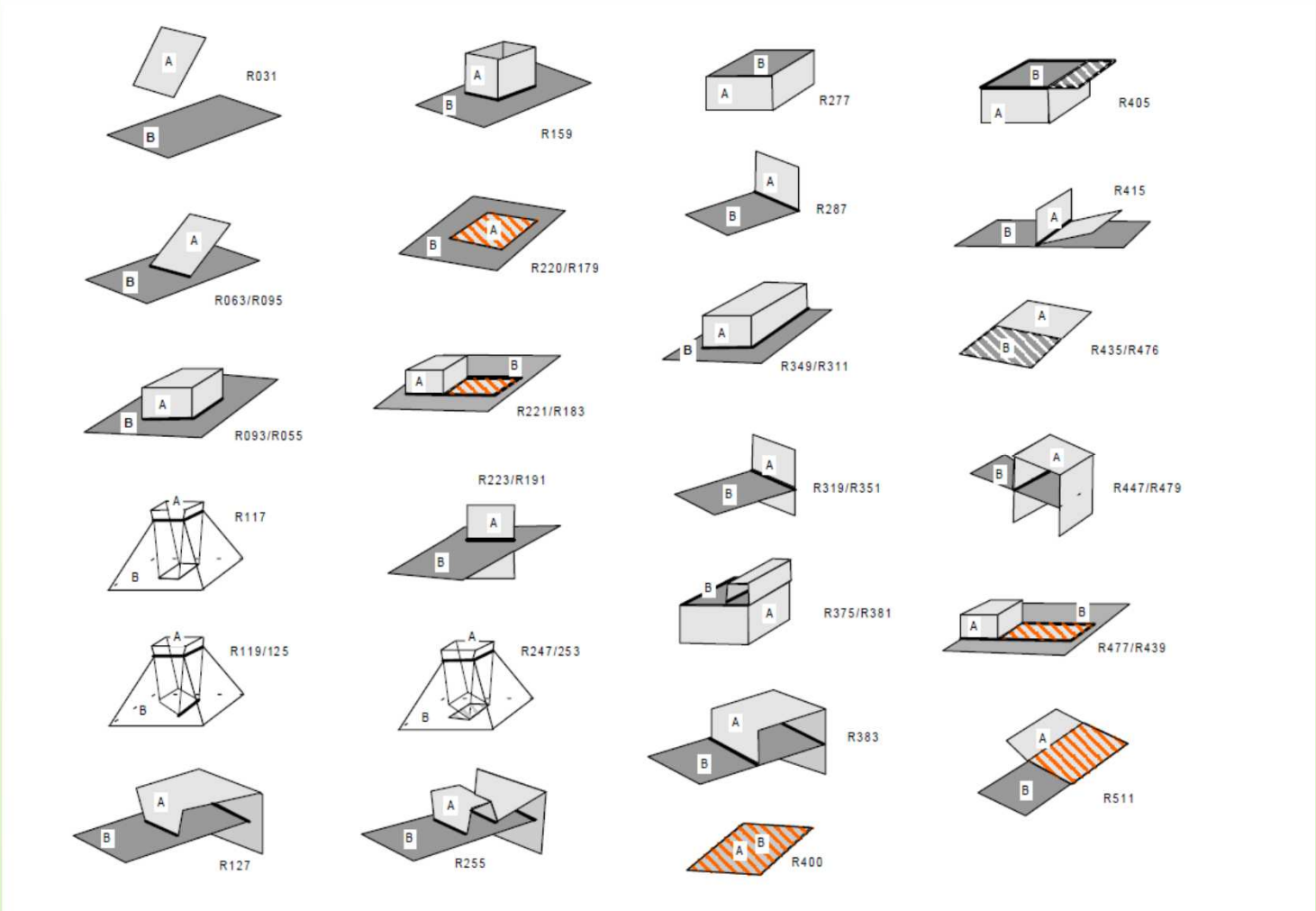
3D Analysis - Topological Queries



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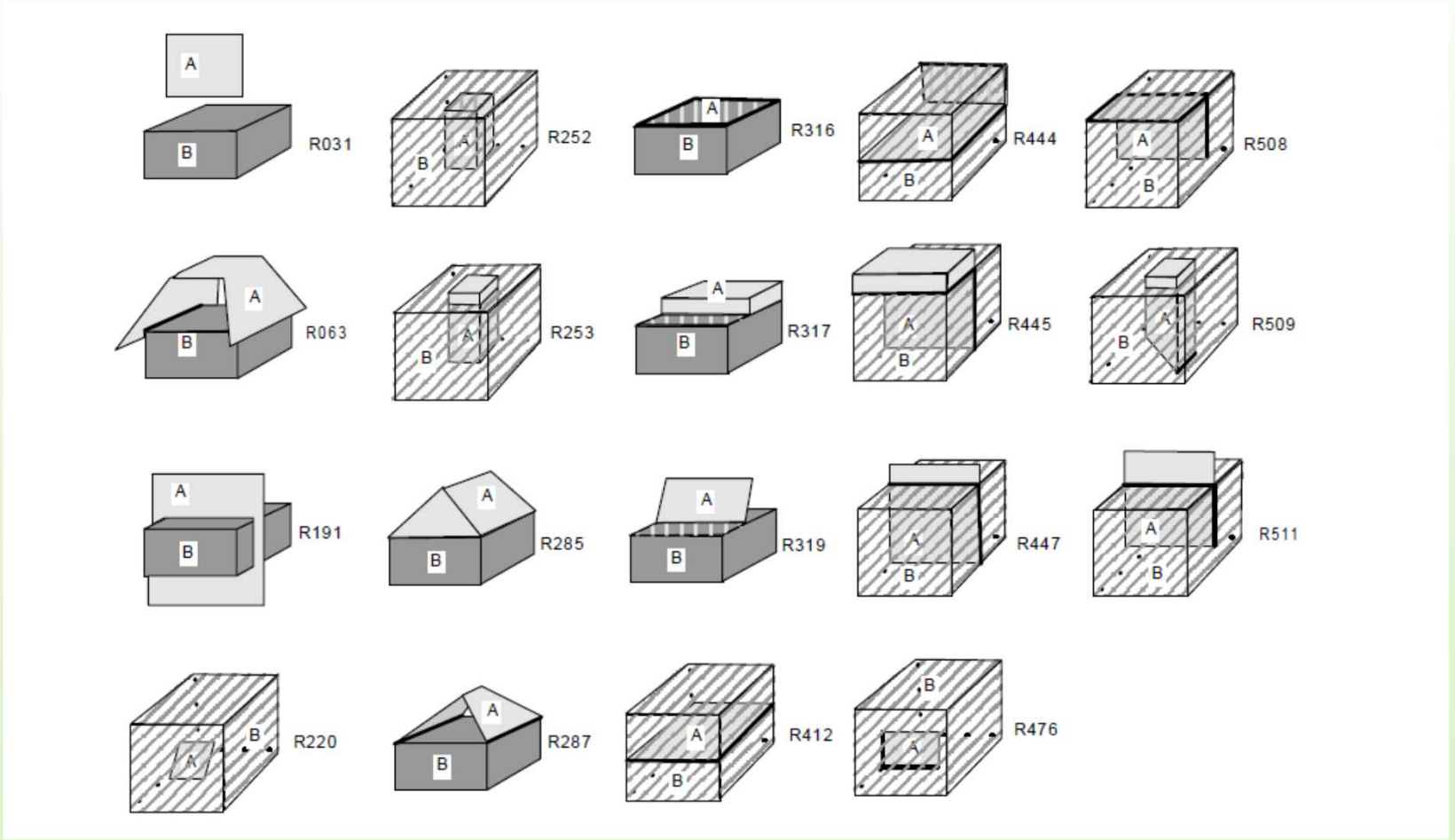
3D Analysis - Topological Queries



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3D Analysis - Topological Queries

ST_3DIntersects

- Returns TRUE if the Geometries "spatially intersect" in 3d - only for points and linestrings

ST_3DIntersection

- Perform 3D intersection and return the geometry (any geometry type)

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3D Analysis - Topological Queries

- Missing
  - ST_3DContains/Inside
  - ST_3DCovers/CoveredBy
  - ST_3DOverlap
  - ST_3DDisjoint
  - ST_3DMeet
- Others
  - ST_Union
  - ST_Difference

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3D Analysis

- PostGIS functions that support 3D
  - http://postgis.net/docs/manual-dev/PostGIS_Special_Functions_Index.html#PostGIS_3D_Functions

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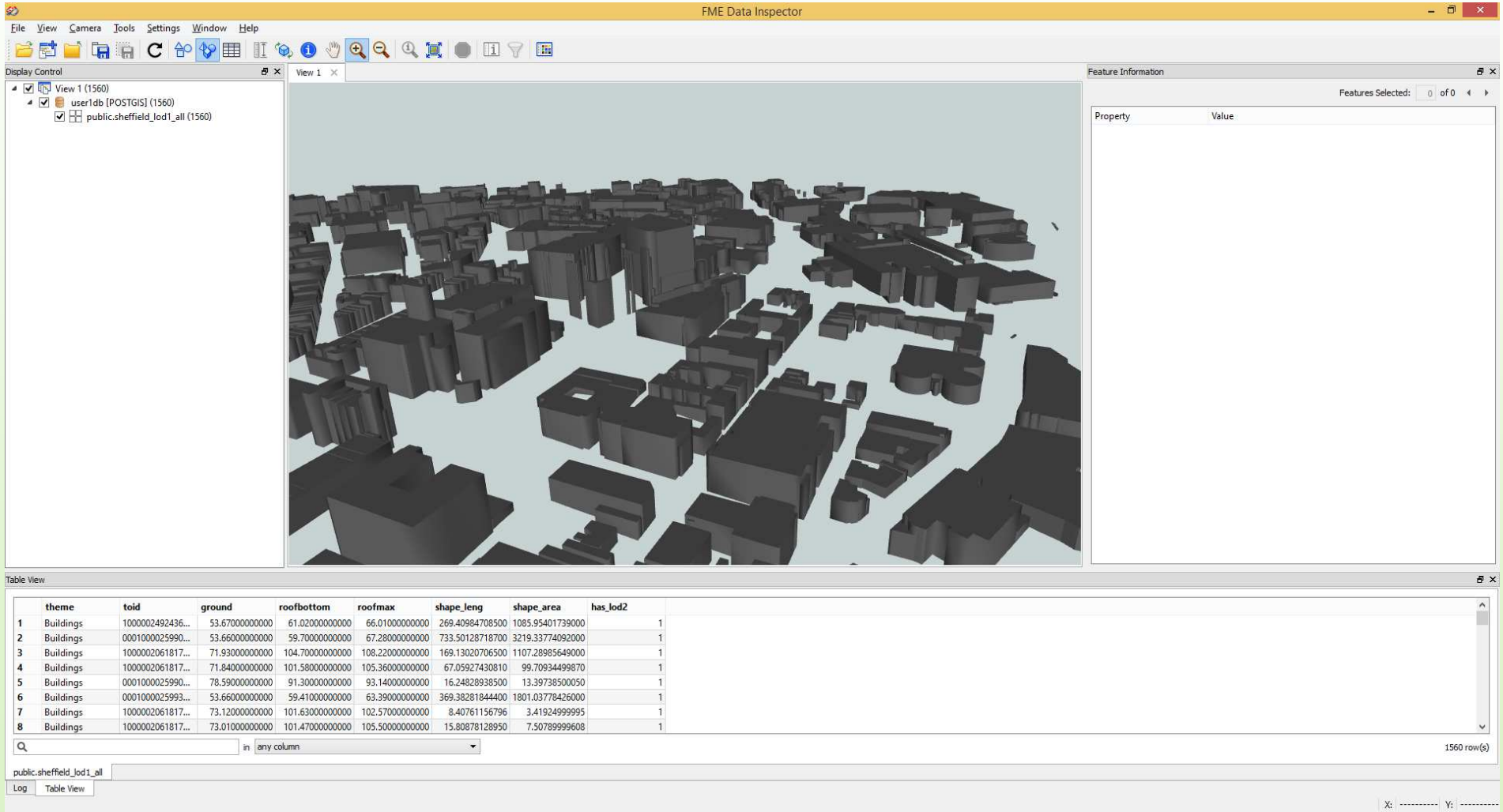
Presenting Data - FME



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Presenting Data – QGIS Threejs Plug In

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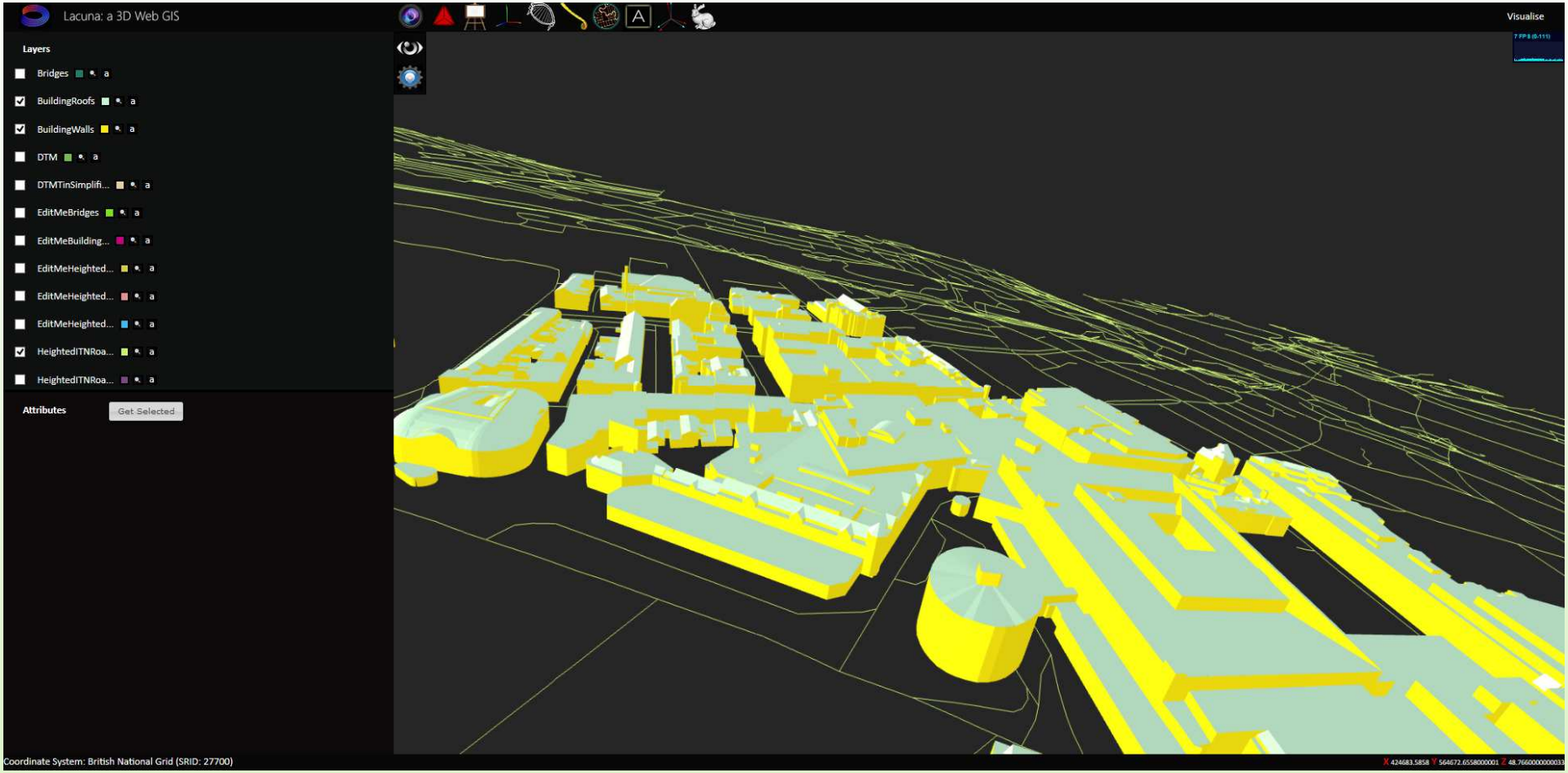
Presenting Data - Lacuna



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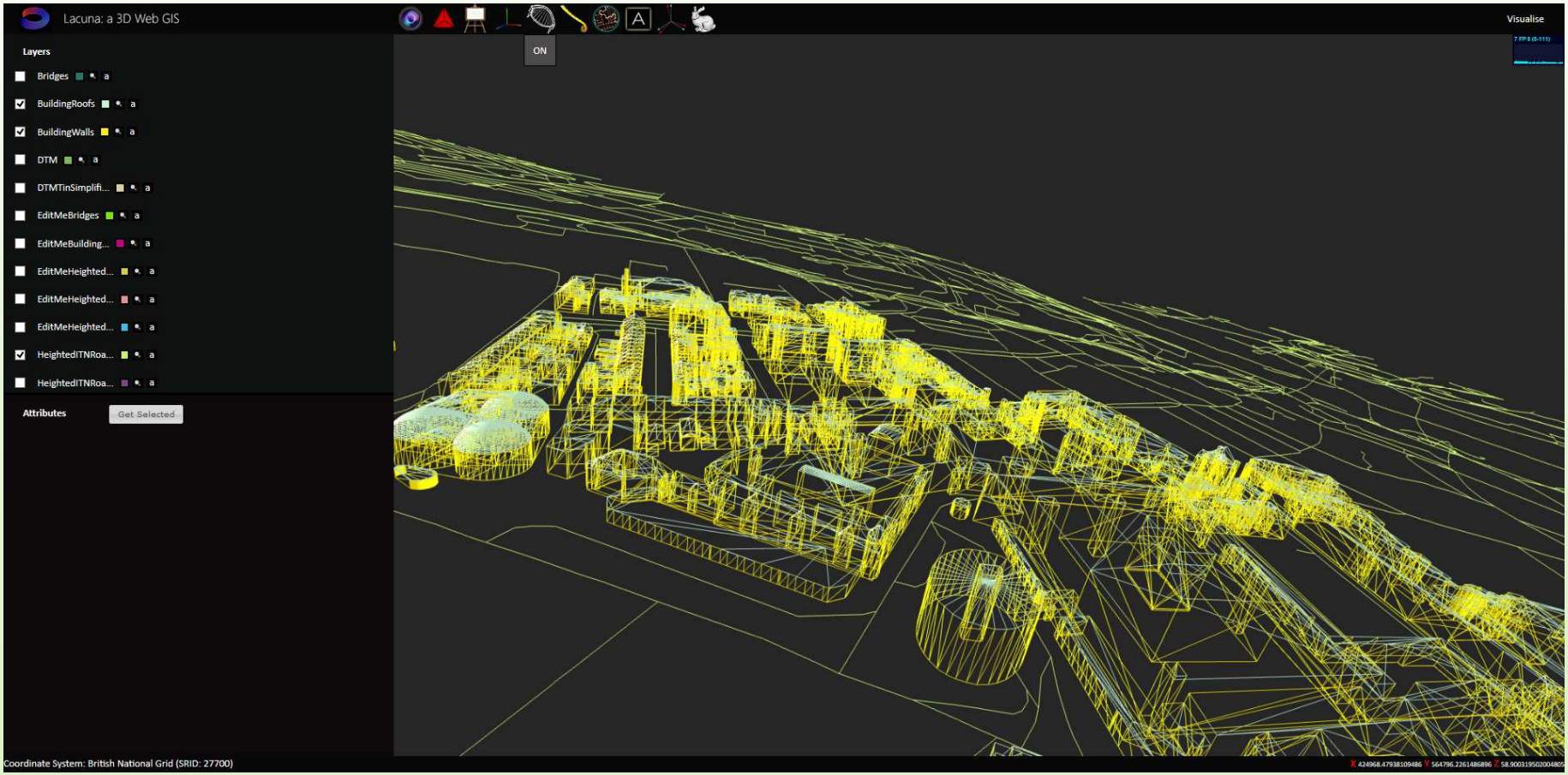
Presenting Data - Lacuna



Presenting Data - Lacuna

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Towards a True 3D GIS

- Encouraging Signs - Growth in 3D GIS Functionality
  - C. 2005
    - Arc scene in ArcGIS 8.3, Virtual London
    - Oracle supported 3D indexing but not solid features
    - 3D GIS is visualisation only, no IS
    - 3D GIS was 2.5D (surfaces, TINS)
  - C. 2010
    - Oracle supports 3D solids + some 3D functionality
    - Bentley Map links to Oracle 3D solids
    - ArcGIS 10 will support 3D editing
    - W3DS, City GML from OGC, Google Earth + Sketch-Up
  - C. 2013
    - MapInfo and Geomedia both have 3D Products
    - PostGIS supports 3D
    - ArcGIS + Oracle have extended their 3D functionality
    - OS establishing a 3D dataset

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Towards a True 3D GIS

- But still to be done (1):
  - Applications
    - Legacy of 2D
    - Do we need a “killer app” for 3D GIS?
    - Review of what is required
    - Editing 3D Data

- Is it the lack of tools or data that is driving the lack of implemented applications, or vice-versa?

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Towards a True 3D GIS

- But still to be done (2):
  - Data Creation and Storage
    - Sourcing, quality, integration of G and IS, roof structures
    - Generalisation and Levels of Detail
    - Detail versus performance on mobile devices
  - Analysis
    - Linking Information Systems for analysis and CAD for 3D geometry manipulation
    - Missing analytical functionality (especially topology)
  - Presentation
    - Paradigm shift from 2D to 3D
    - Standardisation of interfaces
    - Usability

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Towards a True 3D GIS

- There is a good opportunity for the PostGIS/FOSS community to fill the gaps!

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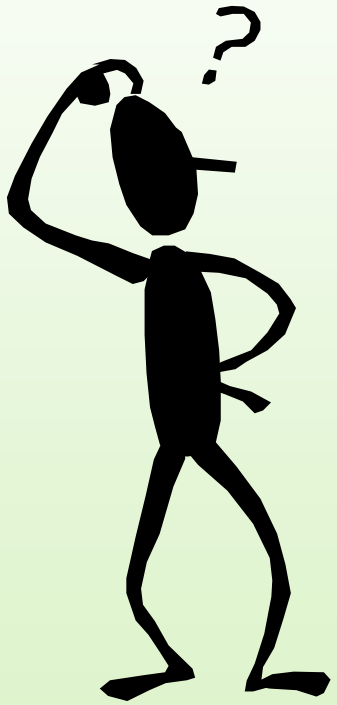
Any Questions?



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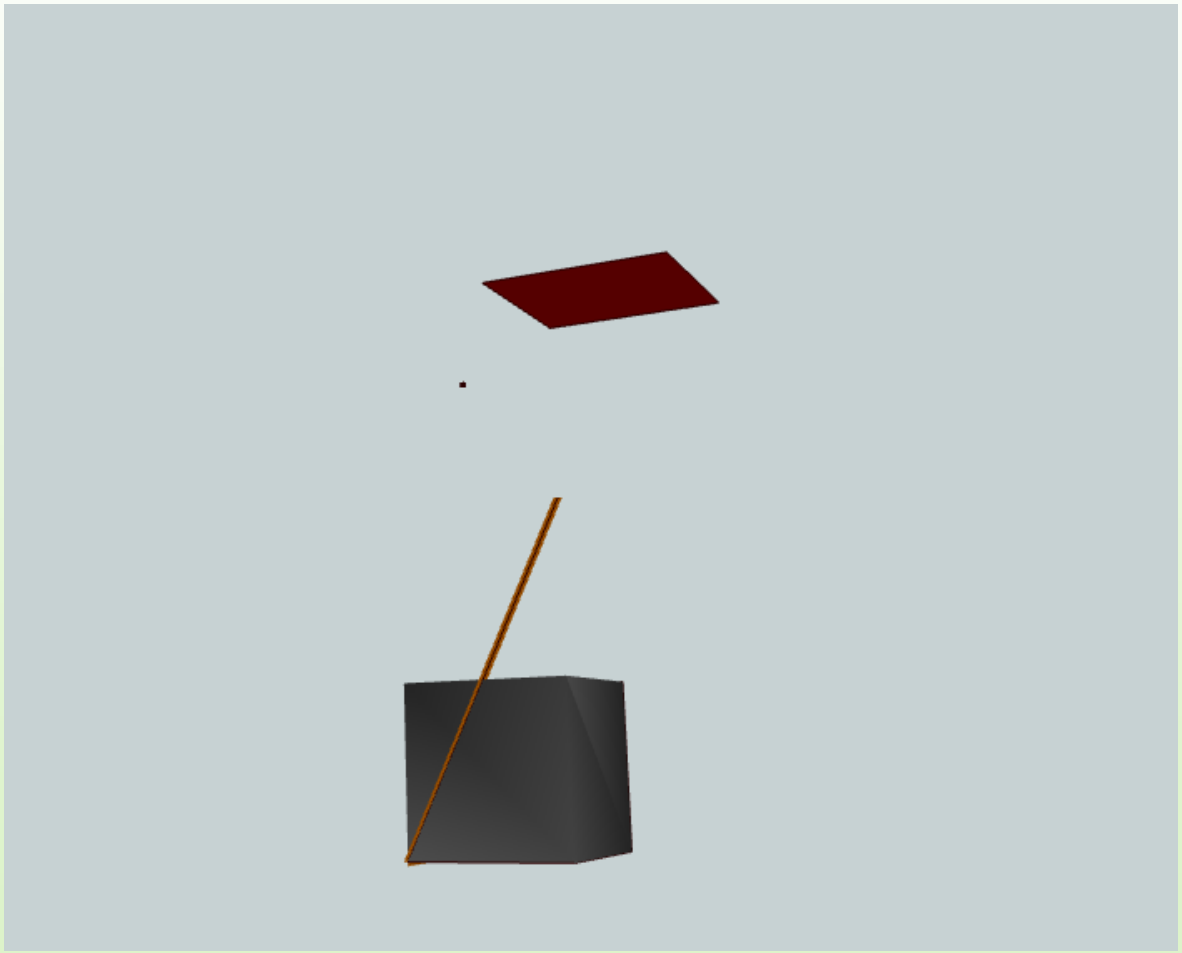
Overview

- What is 3D GIS?
  - What is missing
- PostGIS and 3D?
  - 3D Data storage
  - 3D Query functionality
- Visualising the 3D Data

Viewing the Results in FME



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Why do we need 3D GIS? - History, Tourism, Marketing

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Why do we need 3D GIS? – Cadastre/Property Ownership

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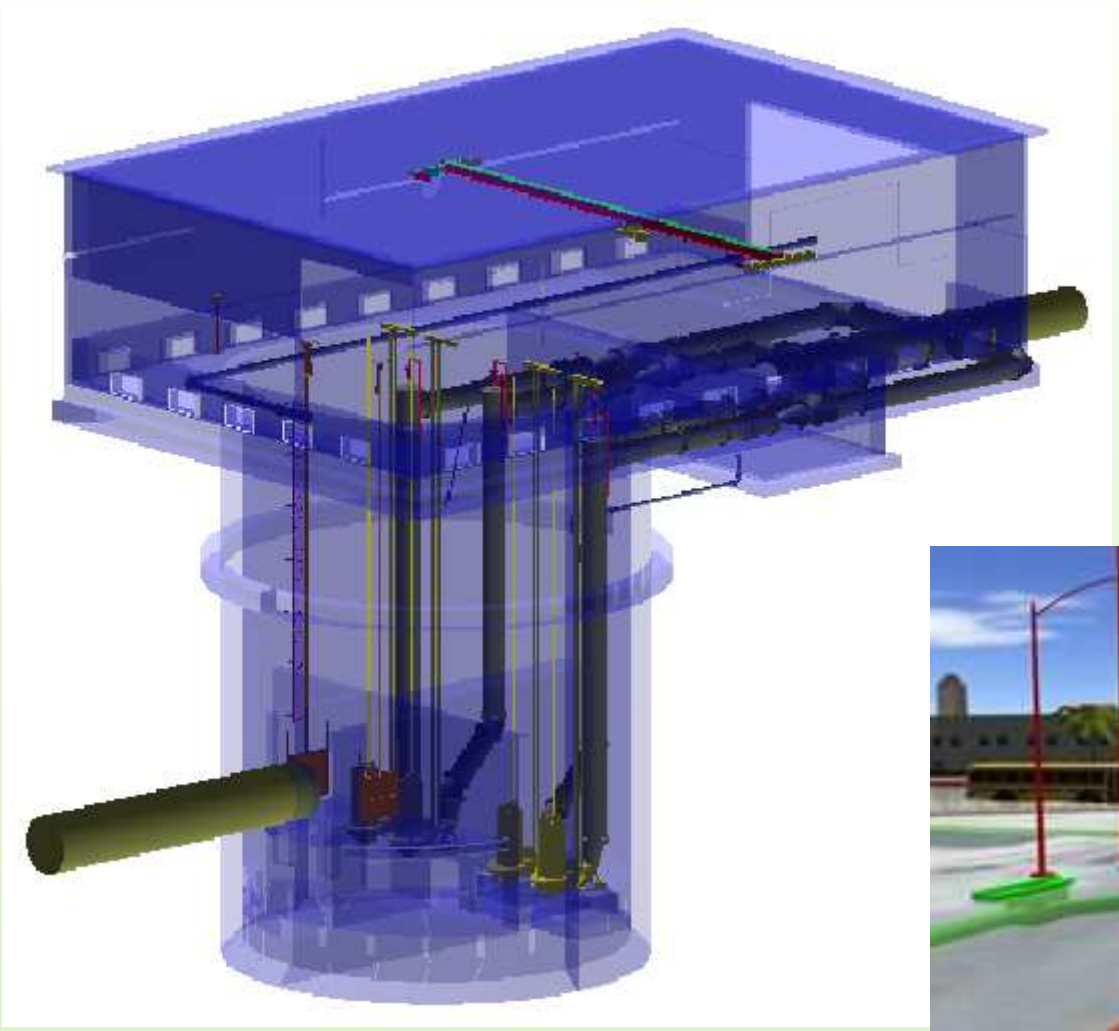
Why do we need 3D GIS? - Infrastructure



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Why do we need 3D GIS? - Energy

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Why do we need 3D GIS? – Air Quality and Noise

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Why do we need 3D GIS? - Heritage and Archaeology

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Case Study 1 – Planning and Construction

Questions:

- What will I see from my window? (evaluating a new construction) - use the BIM to position the user indoors create a view onto a 3D GIS/city model
- What do the community (GIS, addresses of locals) think of this design (BIM)?
- Construction supply chain monitoring –
  - Who stocks the required materials (GIS) and how can they be routed (GIS) to the appropriate area of a large site (BIM)?
  - How much do materials cost (GIS) and how much is needed and when (BIM)?
  - Can we ensure that the different trades are dispatched (GIS) to an appropriate area of the site when needed (BIM)?

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Case Study 1 – Planning and Construction

Questions:

- What is the cost of constructing this tunnel (GIS for geology/cost of getting people and machinery to site, BIM for the construction details)?
- What specification of pipe/cable do I need for this route (BIM), what substrate/geology is under the ground and will it support the pipe?
- Where is my current infrastructure located (GIS) and what different pipes, fire hydrants, water junctions, fibre junction boxes and other connection types do I have (BIM)?
- What is the likely power or water consumption of the building (BIM), and do the local utility companies have to do anything to improve their cables, pipes in the neighbourhood (GIS)?

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Case Study 1 – Planning and Construction

Questions:

- What is the likelihood of underground pipes or cables on this site (GIS) and how can we design the building to avoid them (BIM)?
- How can we mitigate noise (BIM) for neighbours (GIS) during construction?
- How can we ensure that the building has appropriate sound proofing (BIM) against traffic and other neighbourhood noise and pollution (GIS)?
- Do the current location and soil strength (GIS/geology) support the design of a multi-storey commercial building (BIM), e.g. if deep foundations (BIM) are required?

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Case Study 1 – Planning and Construction

Questions:

- Where is the best location for my new shopping centre/hospital (GIS, traffic, population demographics) and what layout (BIM) should the internal building have (size and shape of units, wards specialising in different health issues) to meet customer needs (GIS – e.g. health information, epidemiology, population demographics). What road improvements are needed (GIS) for my new facility?
  - Similarly – where should a university build a new campus (GIS, transport information ,distance/accessibility from old campus) and how should it be structured (BIM, labs and safety issues, classroom / lecture theatre sizes) based on intake (GIS, student population)
- What are the next door buildings (GIS) and how will they be impacted by the various phases of construction (BIM)?

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Case Study 1 – Planning and Construction

Questions:

- What are the predicted energy consumption and lighting requirements for the building (BIM for building design, GIS for external light model)?
- How will a building impact a neighbourhood and whether, for example, telephone or electricity cables can be seen from a specific window?
- What will the building (BIM) look like when situated in this neighbourhood (GIS, 3D city modelling)?
- Does the building meet environmental compliance, health and safety regulations (BIM)? Does the building meet planning rules – heigh, shadowing and so forth(GIS)?
- Where is a suitable site (GIS, available land, transport, roads, zoning) for my building (BIM – number of occupants, footprint, purpose) ?

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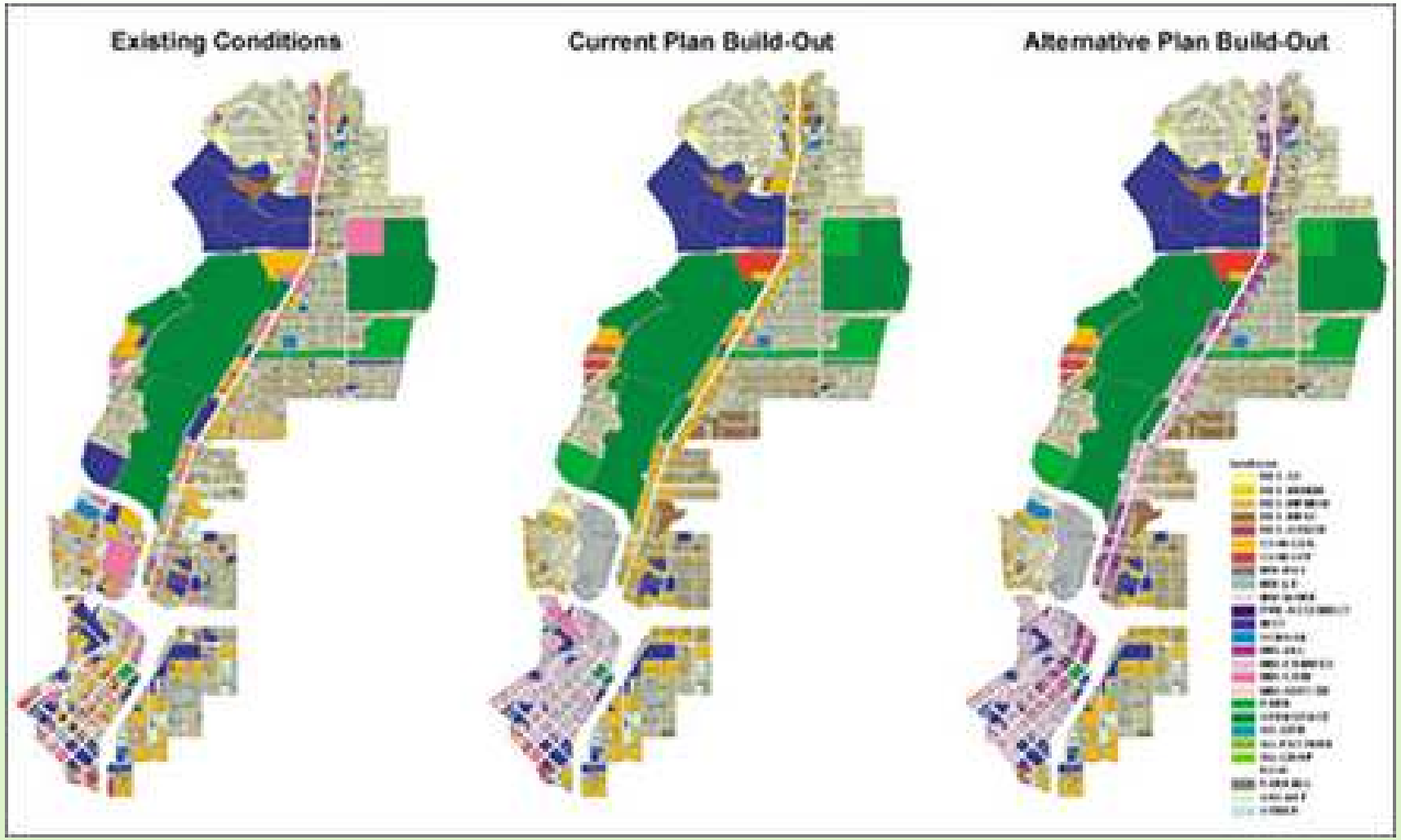
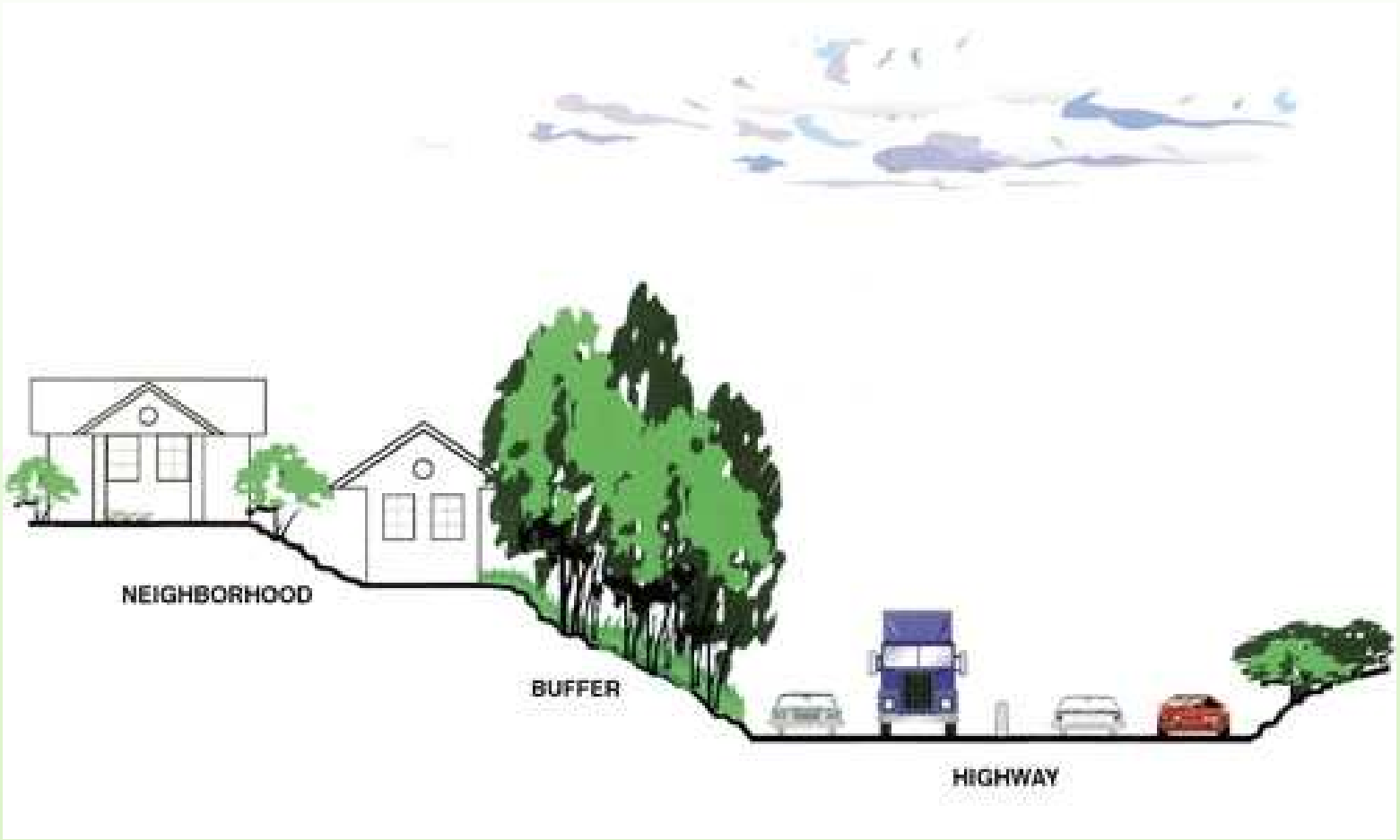
Case Study 1 – Planning and Construction



http://www.esri.com/industries/planning/business/support_systems

Case Study 1 – Planning and Construction



http://www.fhwa.dot.gov/environment/noise/noise_compatible_planning/federal_approach/land_use/qz06.cfm

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Case Study 2 – Operation and Maintenance

- Questions for Campus Emergency Management
  - Where are the students and staff (GIS/database for time-table information, BIM for room information)?
  - What is their fastest safe exit route avoiding hazards (BIM for indoor navigation, GIS for outdoor navigation)?

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Case Study 2 – Operation and Maintenance

- Questions for Insurance/Disaster Management
  - Will the building be impacted by the power cut caused by the disaster (GIS, utility network data) and how long will the generator for the building keep working (e.g. in a hospital) and do we have Uninterruptable Power Supplies for the main computers/machinery (BIM)?
  - Where, in the case of disaster, should we locate a field hospital – this requires identification of the most suitable location for a field hospital (GIS), combining knowledge of the buildings' suitability (internal layout, vulnerability to disaster, current configuration, BIM) with knowledge of the routes from the disaster zone to the new hospital (GIS)?

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Case Study 2 – Operation and Maintenance

- Questions for Insurance/Disaster Management:
  - What is the best place for fire safety equipment, fire doors and so forth? (BIM) and who is responsible for the regular checking of these (GIS/personnel management)
  - Emergency evacuation – from the BIM, which is the fastest route out of the building (perhaps taking into account lack of elevators, or blocked routes) and from the GIS, which is the fastest route out of the area, taking into account obstructions such as fallen trees.

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Case Study 2 – Operation and Maintenance

- Questions for Insurance/Disaster Management:
  - Is the building occupied at this time, and if so by whom (GIS/database derived from the building's address and residential/non-residential status)? Where are they likely to be in the building (offices, residential accommodation, BIM)?
  - What is the replacement cost of the contents of the building (fixtures, infrastructure etc. – BIM) and what is the risk of flooding, earthquake or other disaster (GIS/3D City Modelling). Are the defences suitable (flood defences, GIS, specific re-enforcing of the structure BIM) and are they cost effective?

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Case Study 2 – Operation and Maintenance

- Questions for Planning
  - What property tax should be charged on this building (BIM for number of bedrooms, facilities such as air conditioning, lifts, office space etc.) and GIS for zoning/location information?
  - Who owns the flying freehold on this building (BIM) and where do they currently live (GIS) (3D Cadastre)

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Case Study 2 – Operation and Maintenance

Questions:

- How can I link my indoor route network (BIM) to my outdoor route (GIS) and view them seamlessly on one device?
- What points of interest / navigation aids and directions are required indoors – e.g. door and floor numbers (BIM) and outdoors – e.g. street names and building names (GIS)?
- What scale/resolution should my network be for each part of this task (BIM, GIS)?

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Case Study 2 – Operation and Maintenance

Questions:

- What buildings are contained within a specific geographic area – from the GIS?
- Where are the entrance/exit doors of the building – BIM/CAD?
- What is the shortest route between the buildings – GIS -> network?
- What is the shortest route in the building – BIM -> network ?
- How do I ensure that my position is being correctly recorded using Wifi locations (BIM) and GPS (GIS)?
- How do I find the entrance/exit doors for the buildings (BIM/GIS)?

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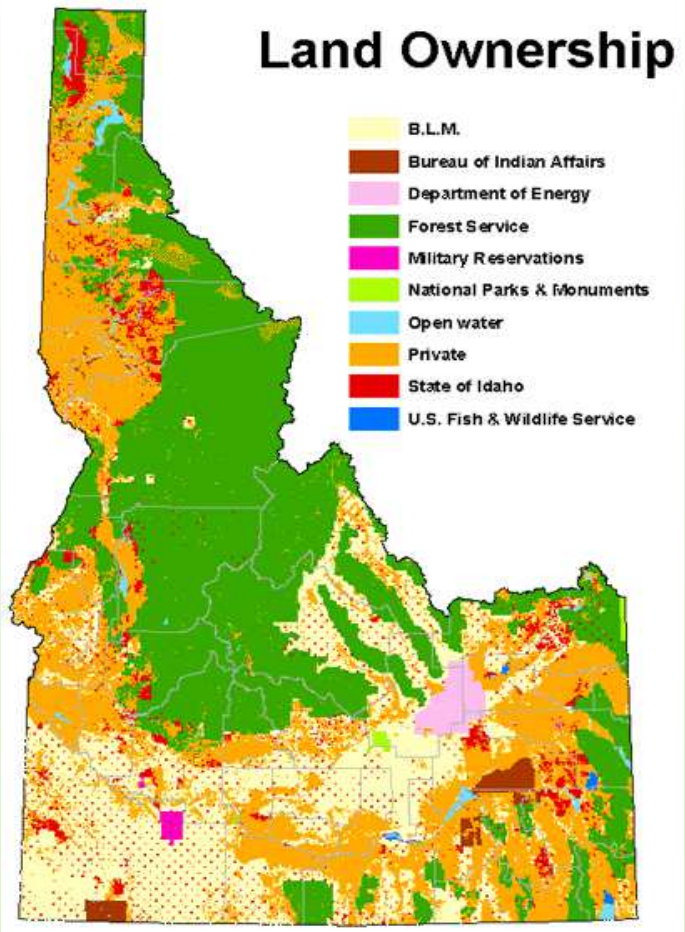
Case Study 1 – Planning and Construction



http://www.uidaho.edu/cnr/pag/idaho-land-ownership-map

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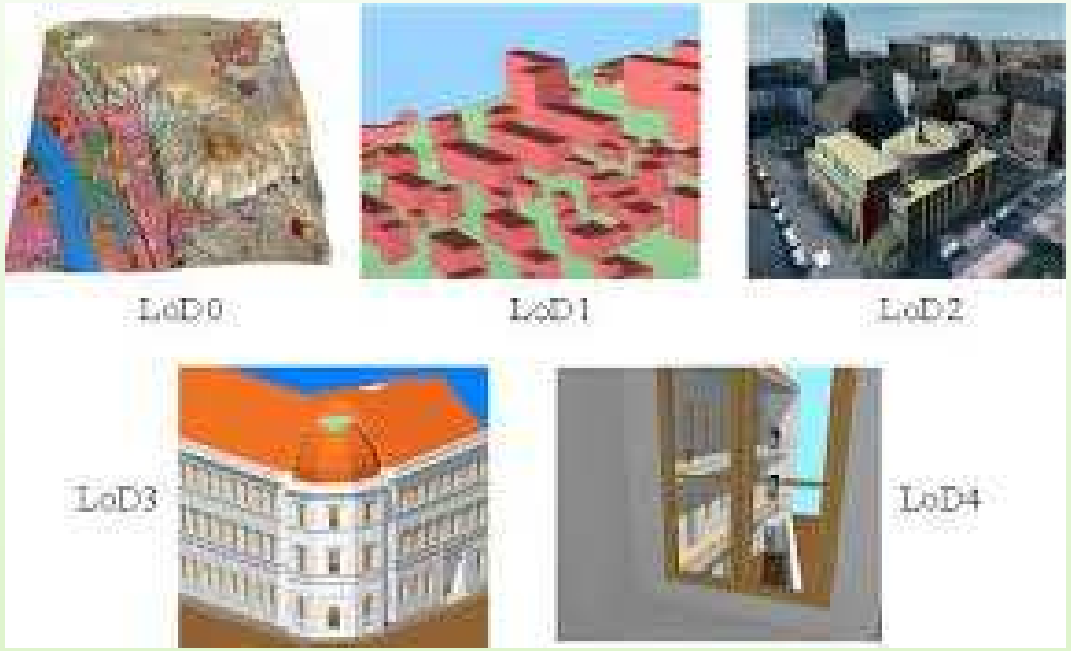
Integrating BIM and GIS

- CityGML
  - Defines 5 levels of detail:



http://www.directionsmag.com/images/newsletter/2006/06_22/LoD_lg.jpg

Structuring

- OGC W3DS – Web 3D services
  - A Web 3D Service (W3DS) is a portrayal service for three-dimensional Geodata
    - landscape models
    - city models
    - textured building models
    - vegetation object
    - street furniture
  - Builds on existing standards (e.g. WFS) but ..
    - Geodata is delivered as scenes that are comprised of display elements, optimized for efficient real time rendering at high frame rates
  - Currently a draft candidate standard with OGC, extensive work going on in relation to 3D Portrayal

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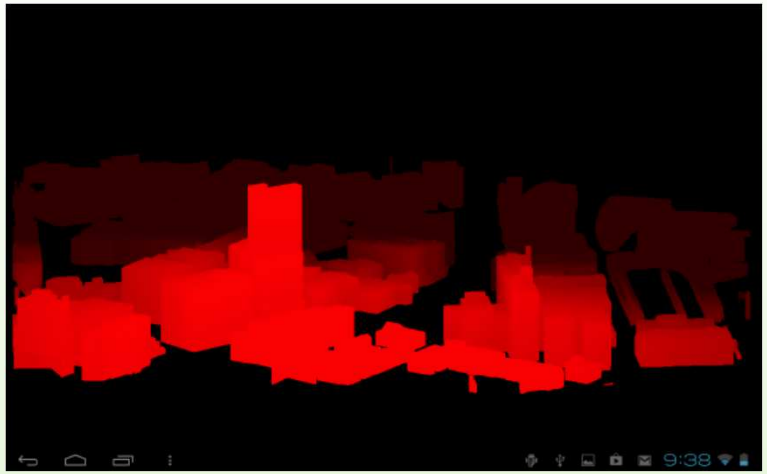
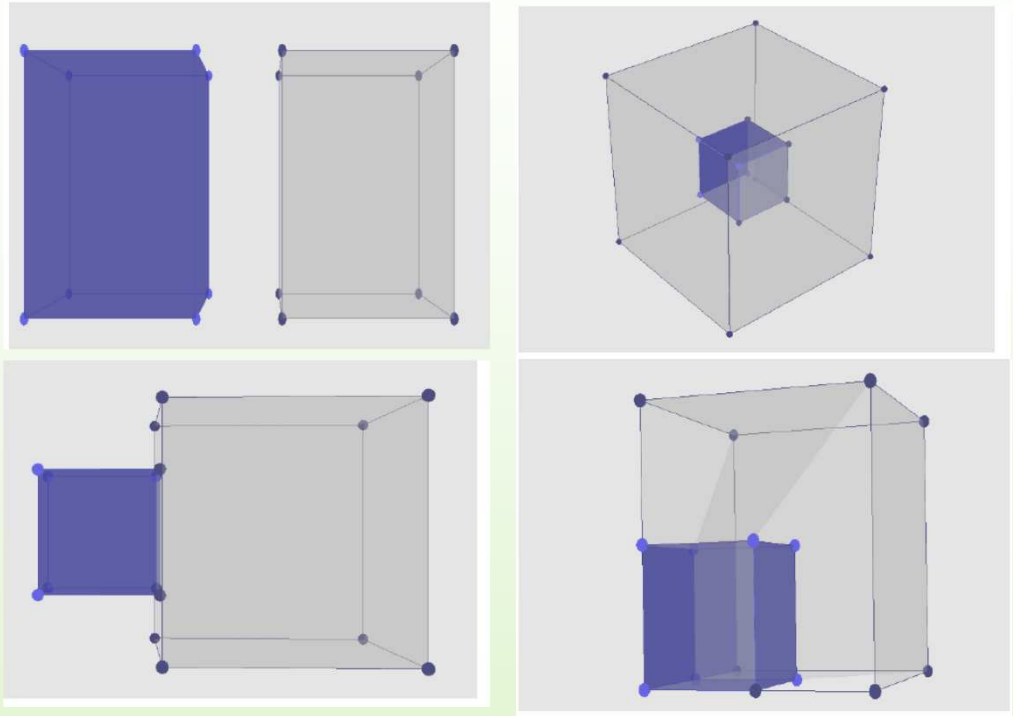
Structuring - Research





- How to efficiently transmit 3D data to mobile devices over low bandwidth @ UCL
- Do we need a separate topological data structure as well as ‘spaghetti’ 3D @ UCL

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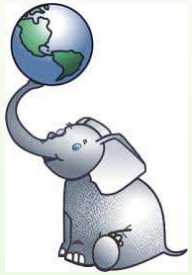
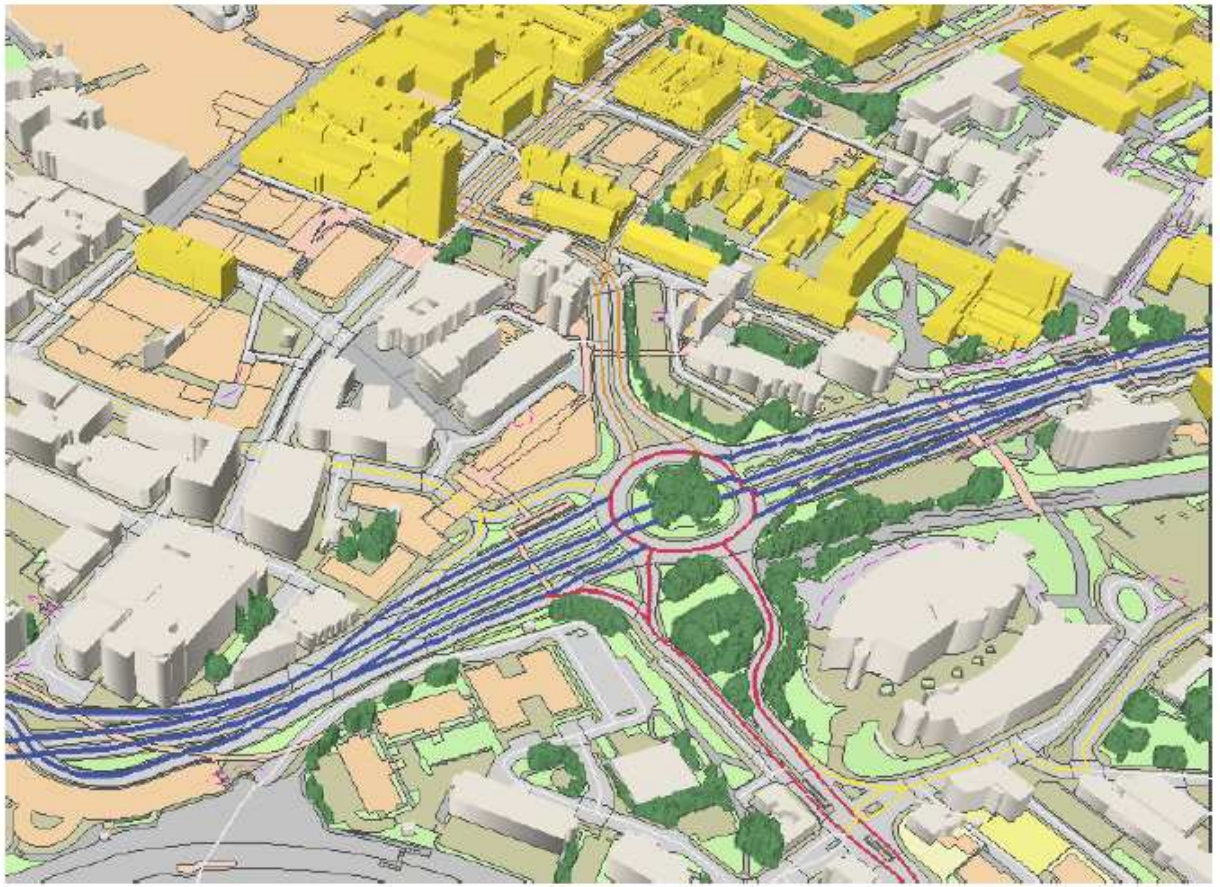
Manipulation and Analysis

ORACLE



Pitney Bowes
Business Insight
FORMERLY GROUP 1 SOFTWARE & MAPINFO

INTERGRAPH



Manipulation and Analysis - Research

- Some Questions
  - How to integrate sophisticated CAD geometry and the GIS understanding of Spatial Information and Analysis? (BIM?)
  - How to efficiently incorporate topological analysis?
    - Touch, Overlap, Covers/Covered By
  - The importance of time!

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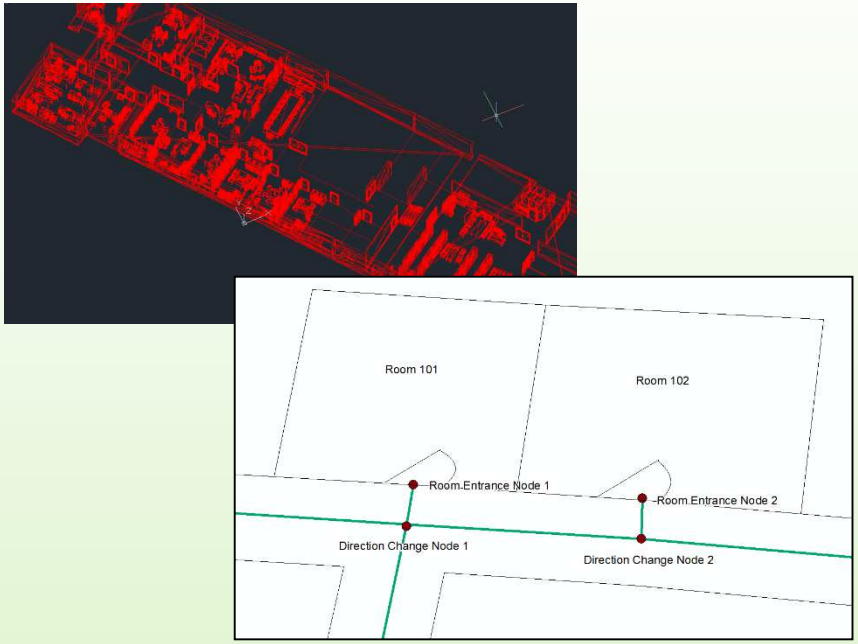
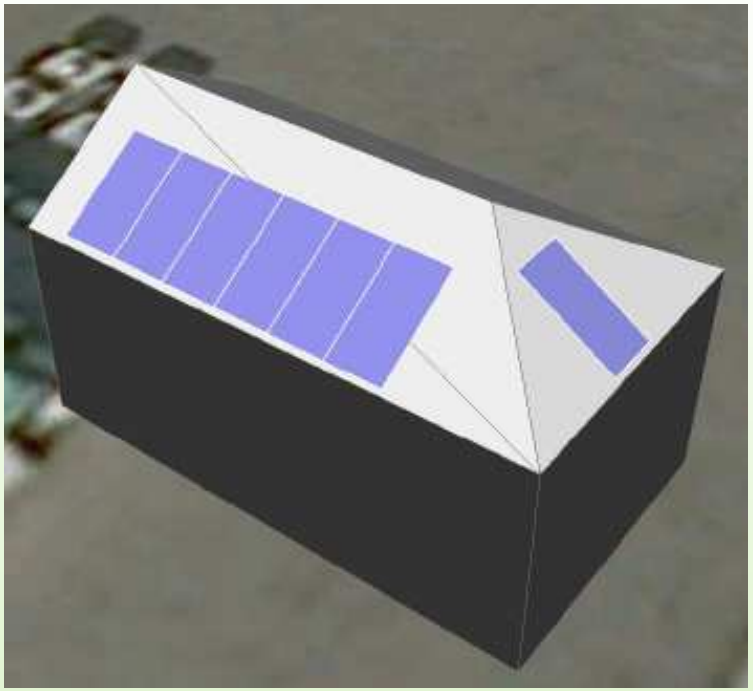
Manipulation and Analysis - Research



How to use 3D data in Oracle Spatial for Indoor Navigation @ UCL



Assessing suitability of 3D roof structures for Solar Panels @ UCL

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Overview

- Do we really need 3D GIS?
- What should a 3D GIS do?
  - Data
  - Structuring
  - Manipulation and Analysis
  - Presentation
- 3D GIS in PostGIS

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Presentation

- Data > Structuring > Manipulation & Analysis > **Presentation**
  - Can 3D datasets be displayed in a useful manner?
  - What interfaces/tools are offered?
  - Do concepts similar to 2D GIS exist?
    - Info tools?
    - Layers/themes?
    - Thematic mapping of different features?

Question 5: Can we visualise 3D data in a usable and useful fashion?

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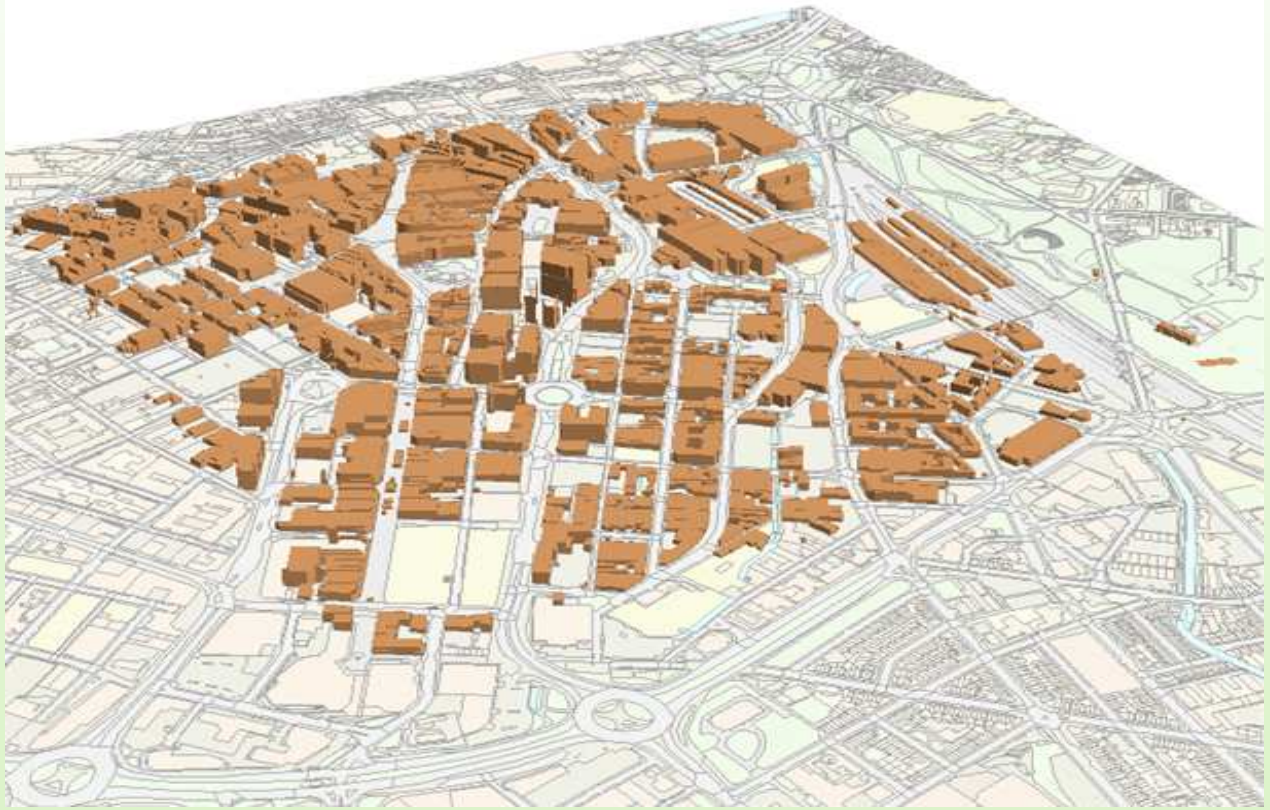
ESRI ArcScene



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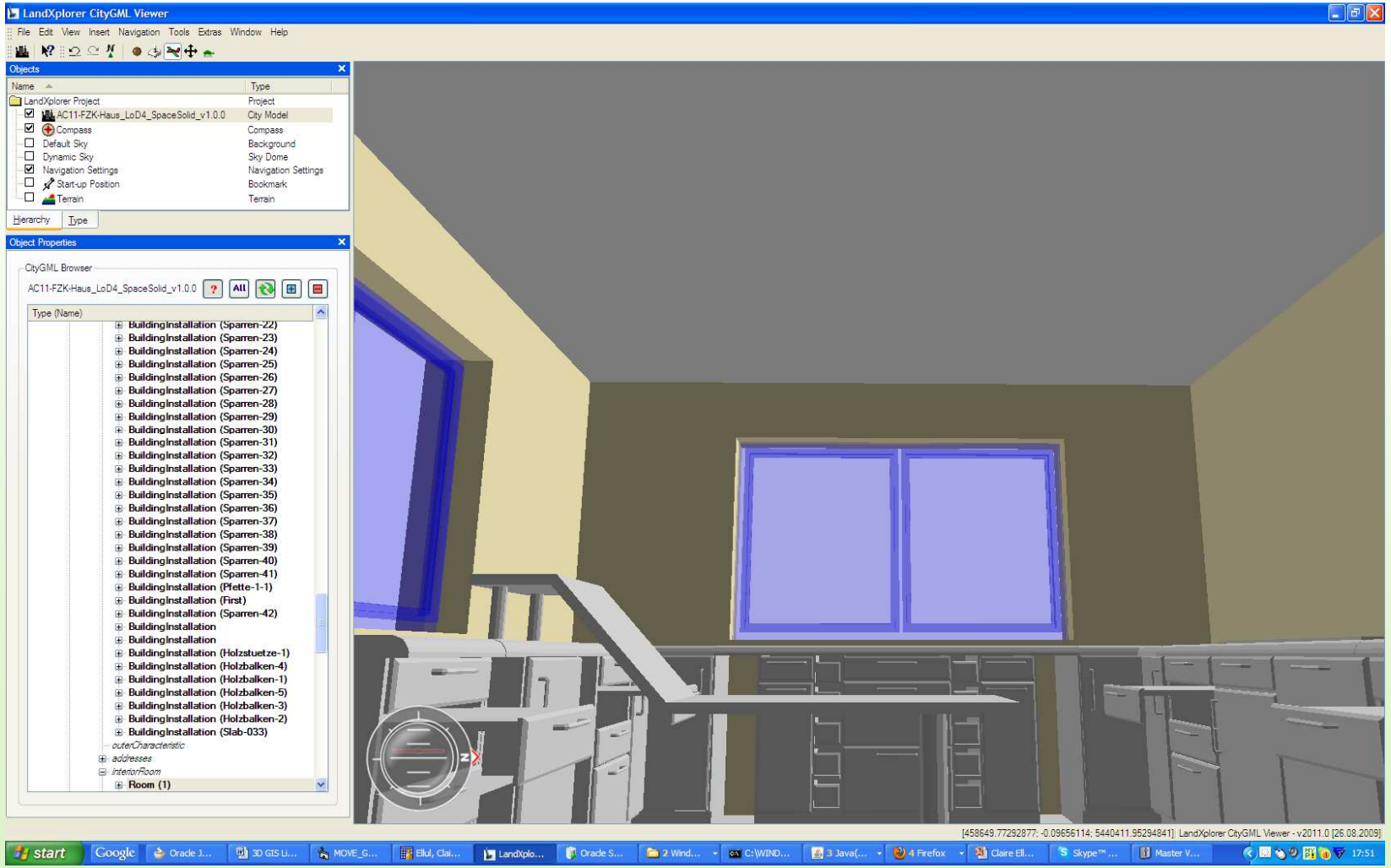
LandXplorer City GML viewer



Viewer: LandXplorer City GML, from Autodesk (http://www.3dgeo.de/citygml.aspx Accessed 10th March 2010
Data: Sample CityGML dataset, Level 4, from http://www.citygml.org/1539/ Accessed 1st March 2010

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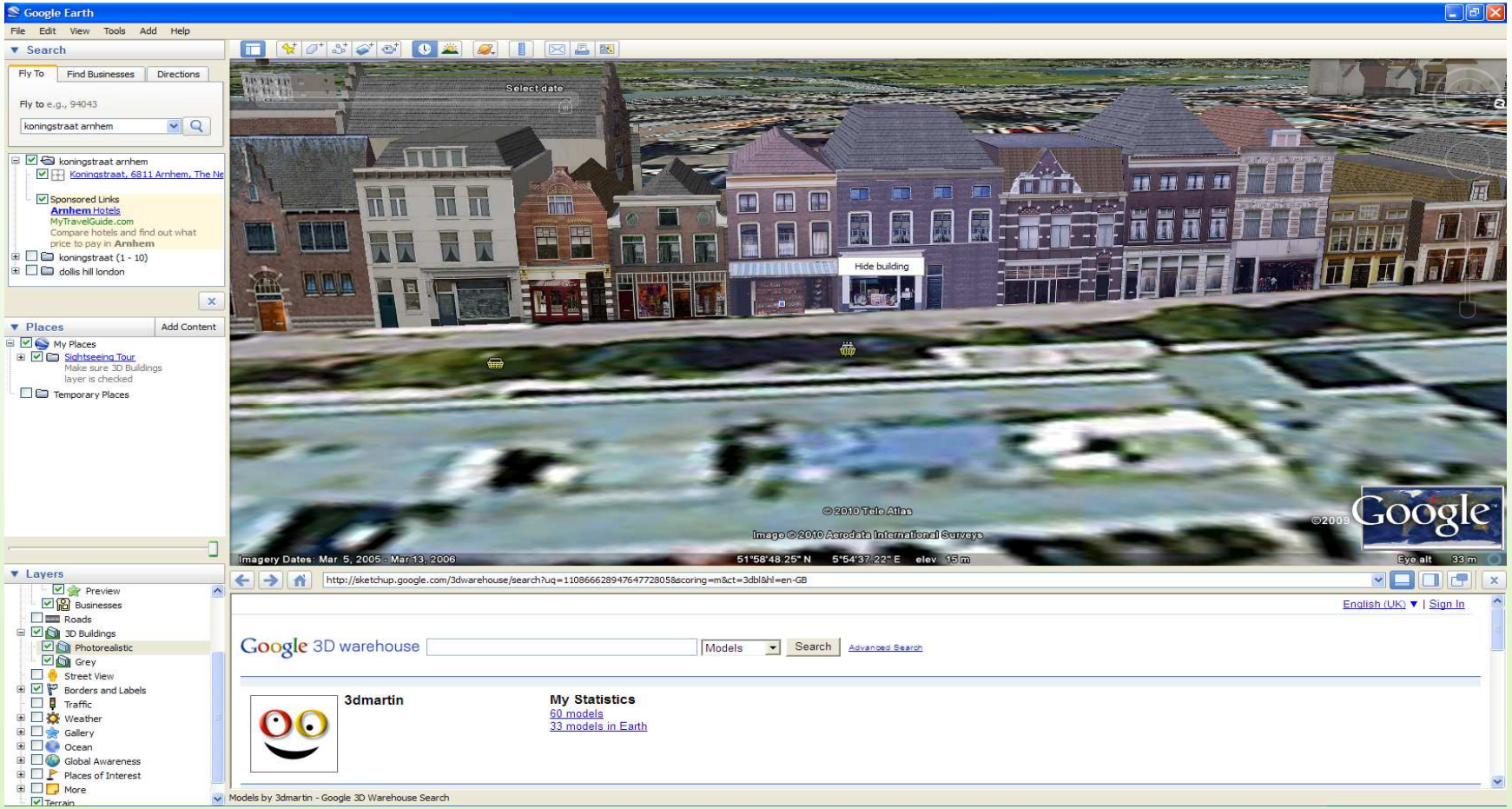
Google Earth



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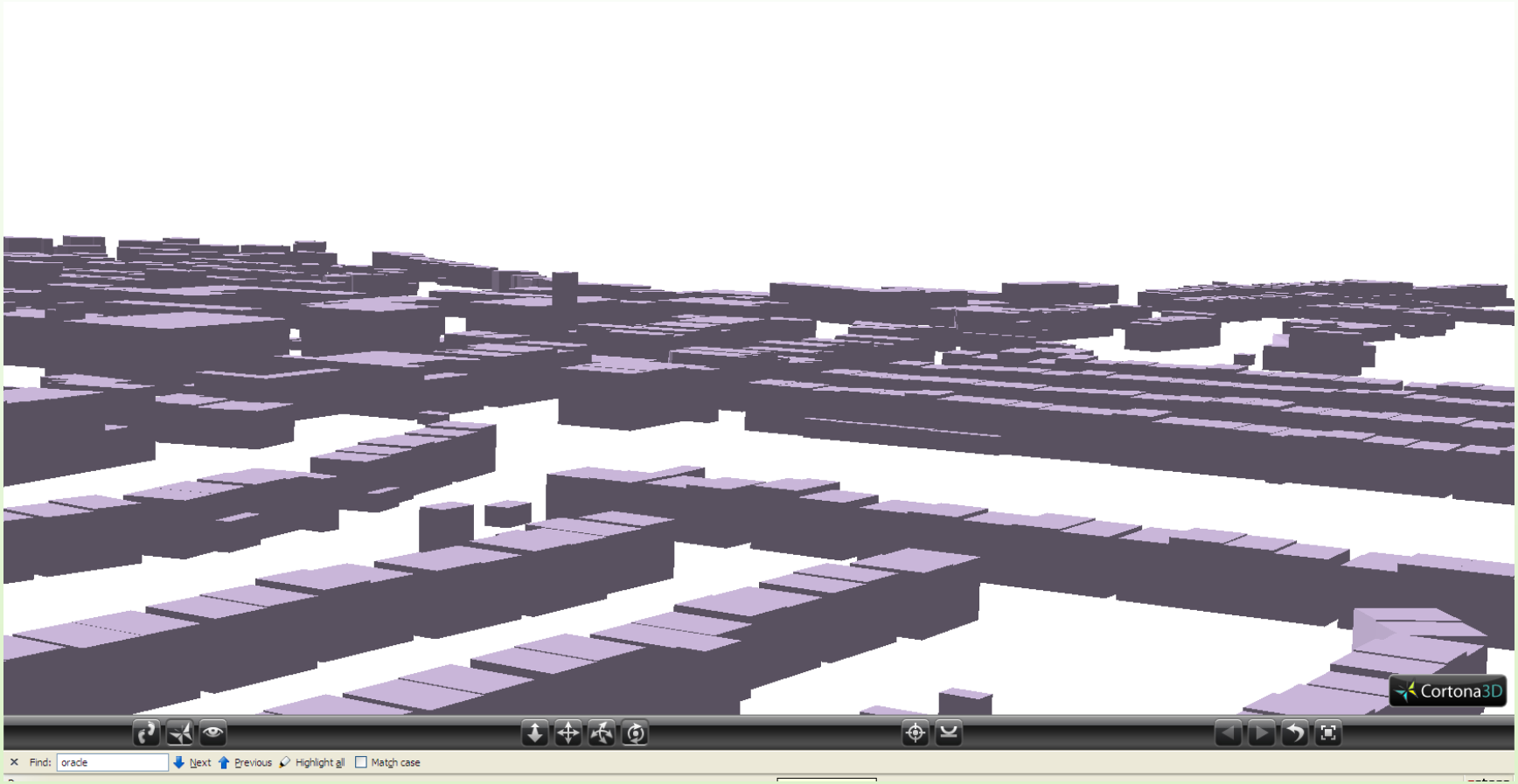
Source: “3D Martin” downloaded from Google Earth, February 2010

Cortona VRML Viewer



Virtual London Data (Ordnance Survey, Infoterra, CASA@UCL)

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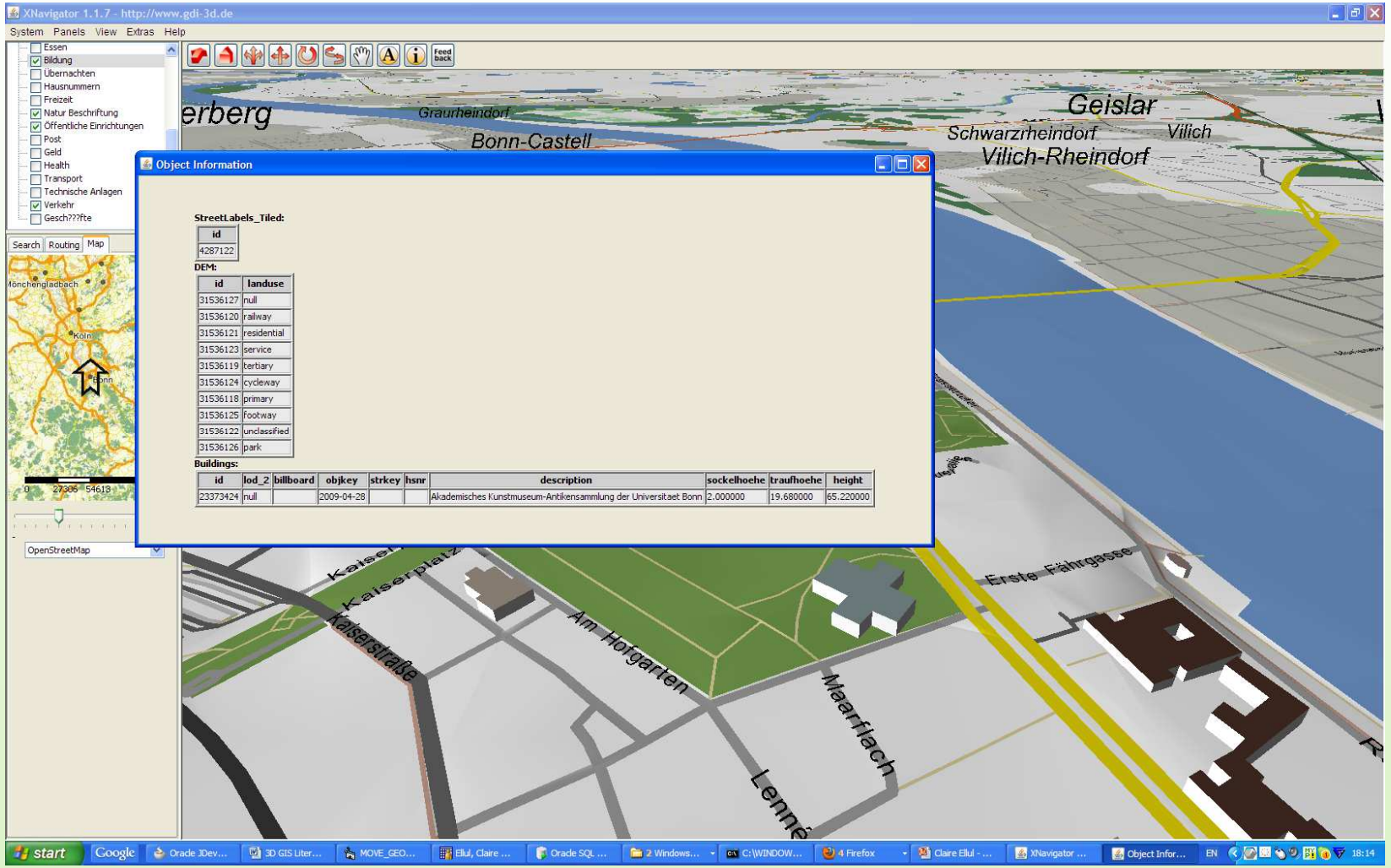
XNavigator for Open Street Map



Source: Alexander Zipf *et al.* , University of Bonn
http://www.giub.uni-bonn.de/karto/xnaviwiki/doku.php?id=download, Accessed 9th March 2010

Presentation – Research

- How to handle the different interaction paradigms:
  - Many 3D viewers have controls such as viewer position and lighting , observer location
  - These derive from 3D visualisation requirements
  - But are not familiar to users of 2D GIS
  - Walking through walls
  - Requirement for Standardised Controls

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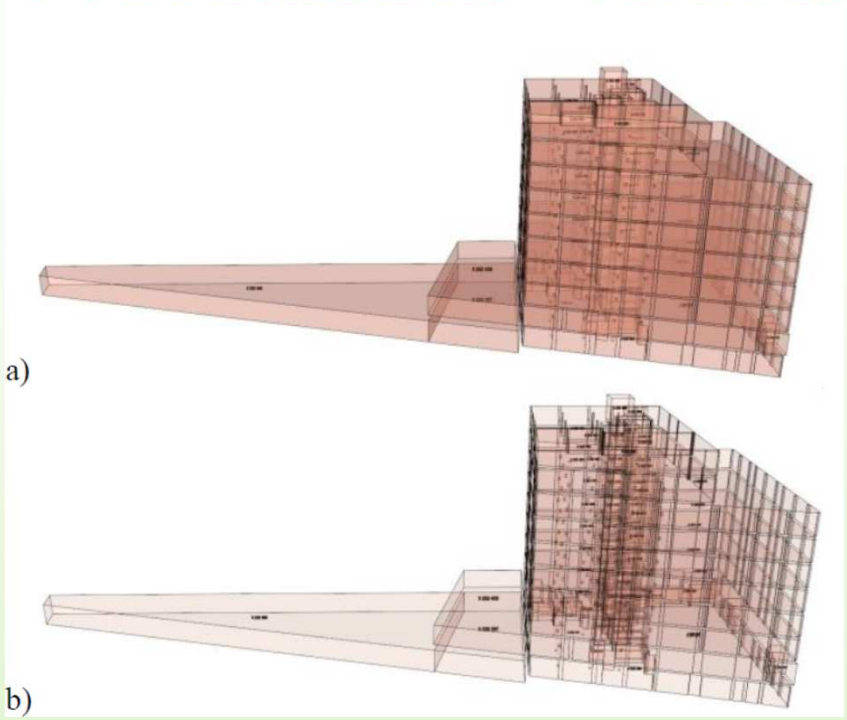
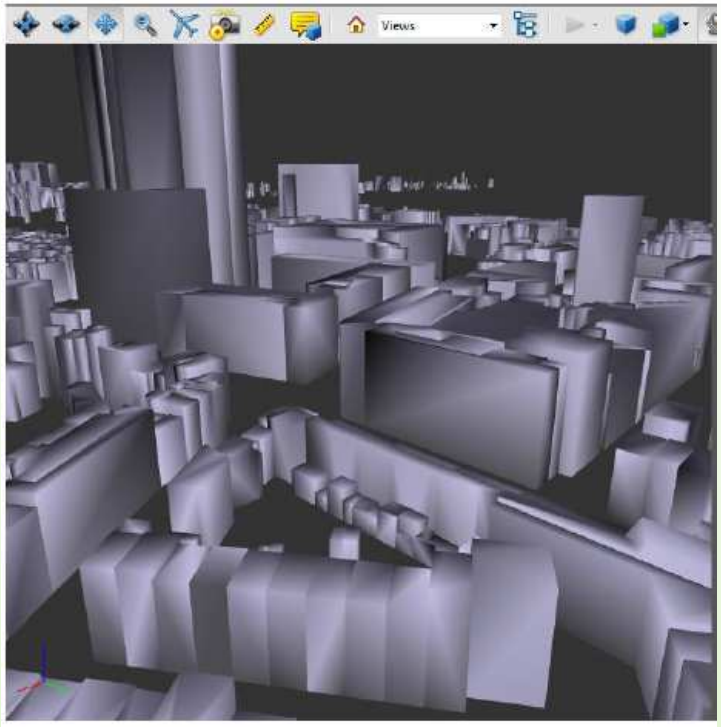
Presentation - Research





- Investigating Usability of 3D Building Models for Notaries @ University of Laval
- Investigating Performance and Usability of 3D PDF @ UCL

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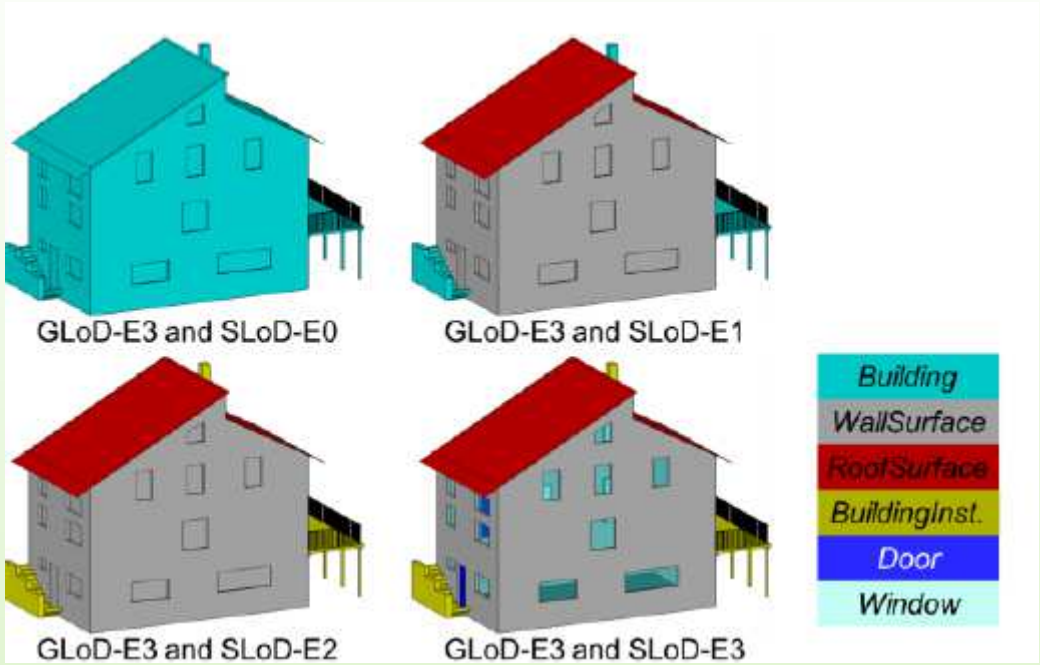
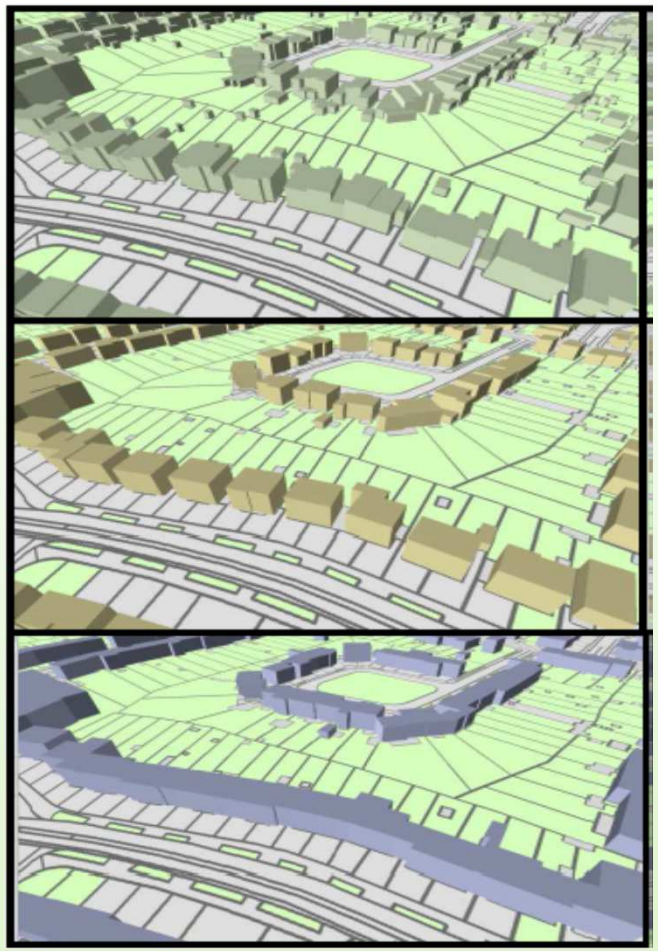
Presentation - Research



More intricate 'Levels of Detail' @ Karlsruhe Institute of Technology, Germany



3D Generalisation and Performance @ UCL

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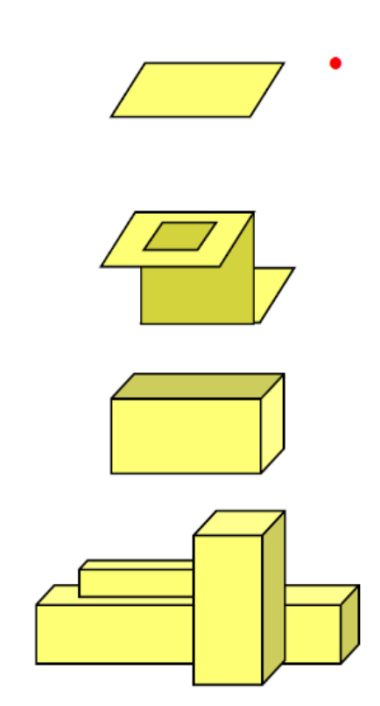
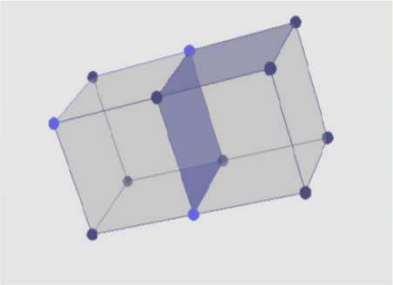
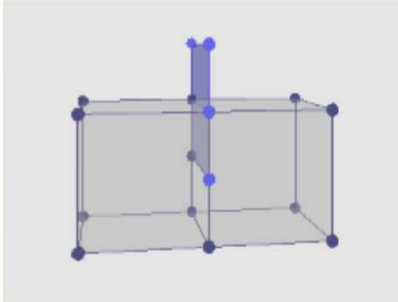
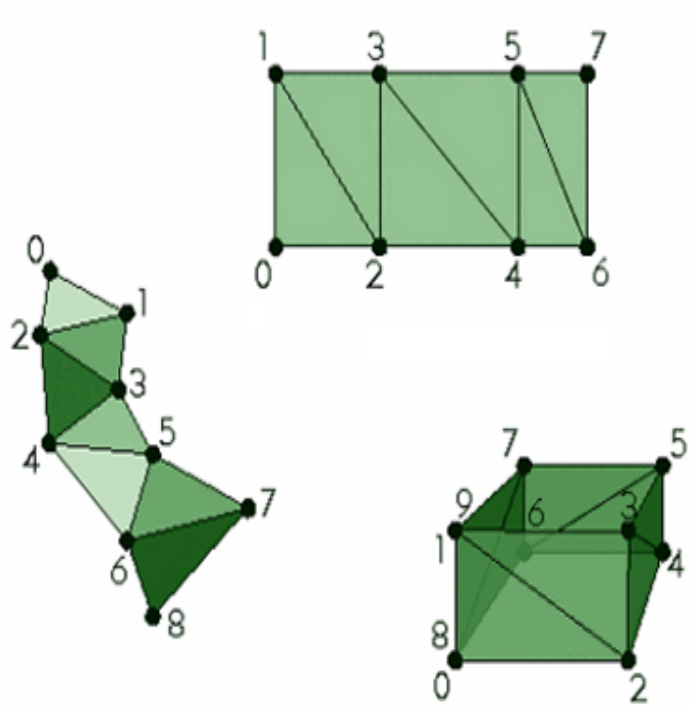
Structuring – Oracle Spatial, PostGIS, ArcGIS

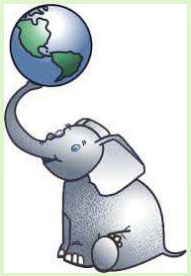








ORACLE



ESRI

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Topological Relationships

- 164 in total

Dimension of Embedding Space	*Dimension of Objects*	*Number of Relationships*
1	Line and Line	8
2	Line and Line	33
3	Surface and Line	31
2	Surface and Surface	8
3	Body and Body	8
3	Surface and Surface	38
3	Body and Line	19
3	Body and Surface	19

Indexing 3D Data

- CREATE INDEX spatial_table_points_gidx
  ON spatial_table_points
  USING GIST(the_geom);

- CREATE INDEX my_nd_index ON my_table USING GIST (geom **gist_geometry_ops_nd**);

- GIST stands for “Generalised Search Tree” which is a basic generic index that can be used for spatial and other data types. PostGIS then uses an R-Tree approach when implementing GIST on spatial datasets

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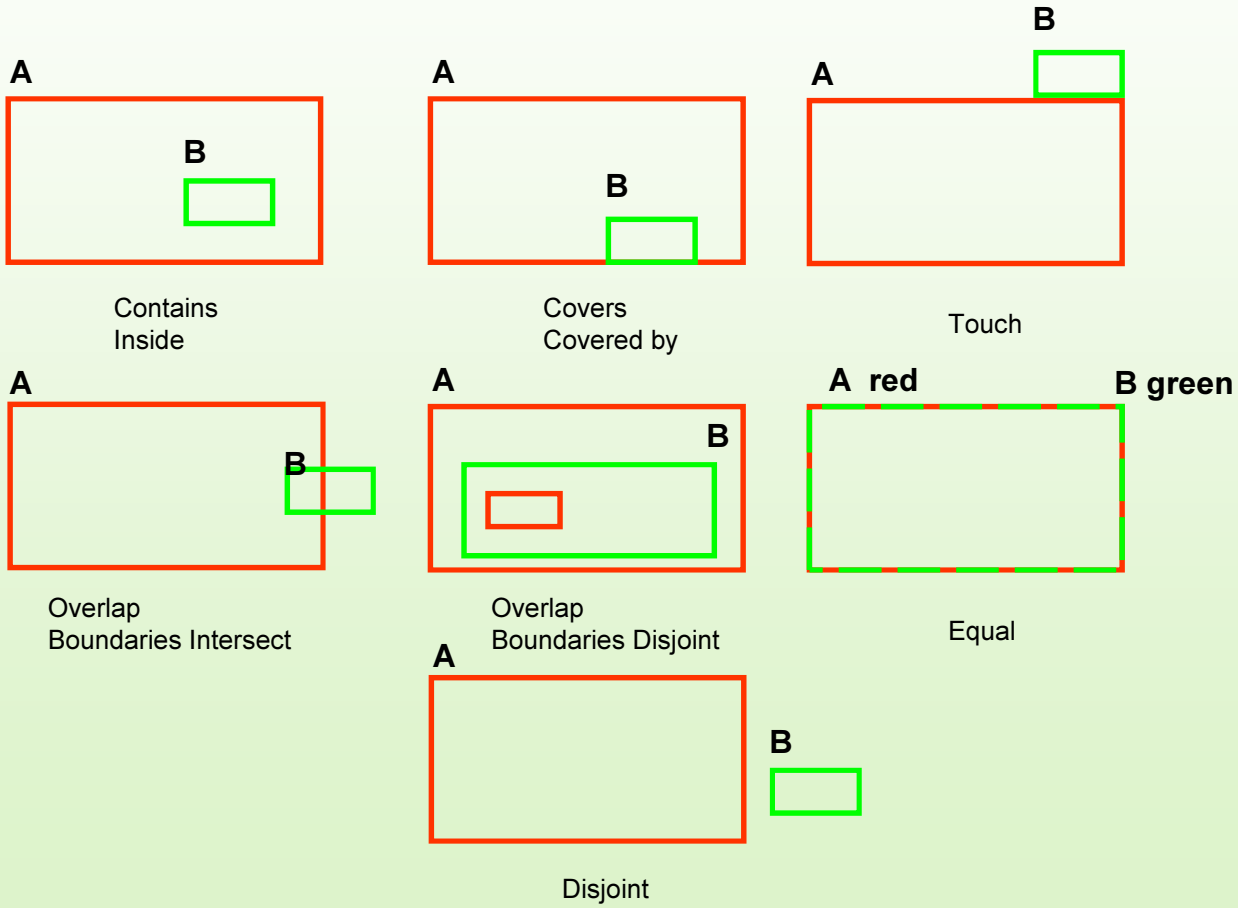
Topological Queries



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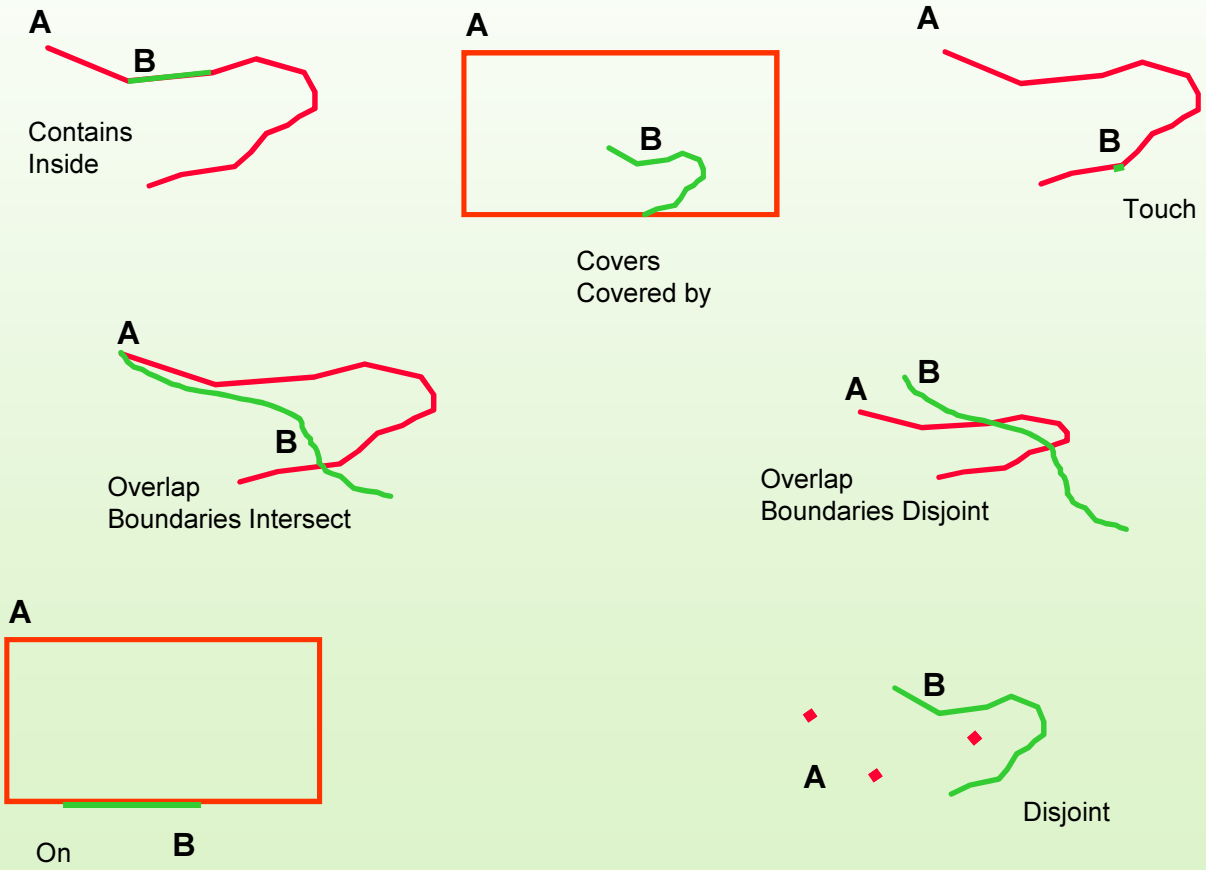
Topological Queries



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