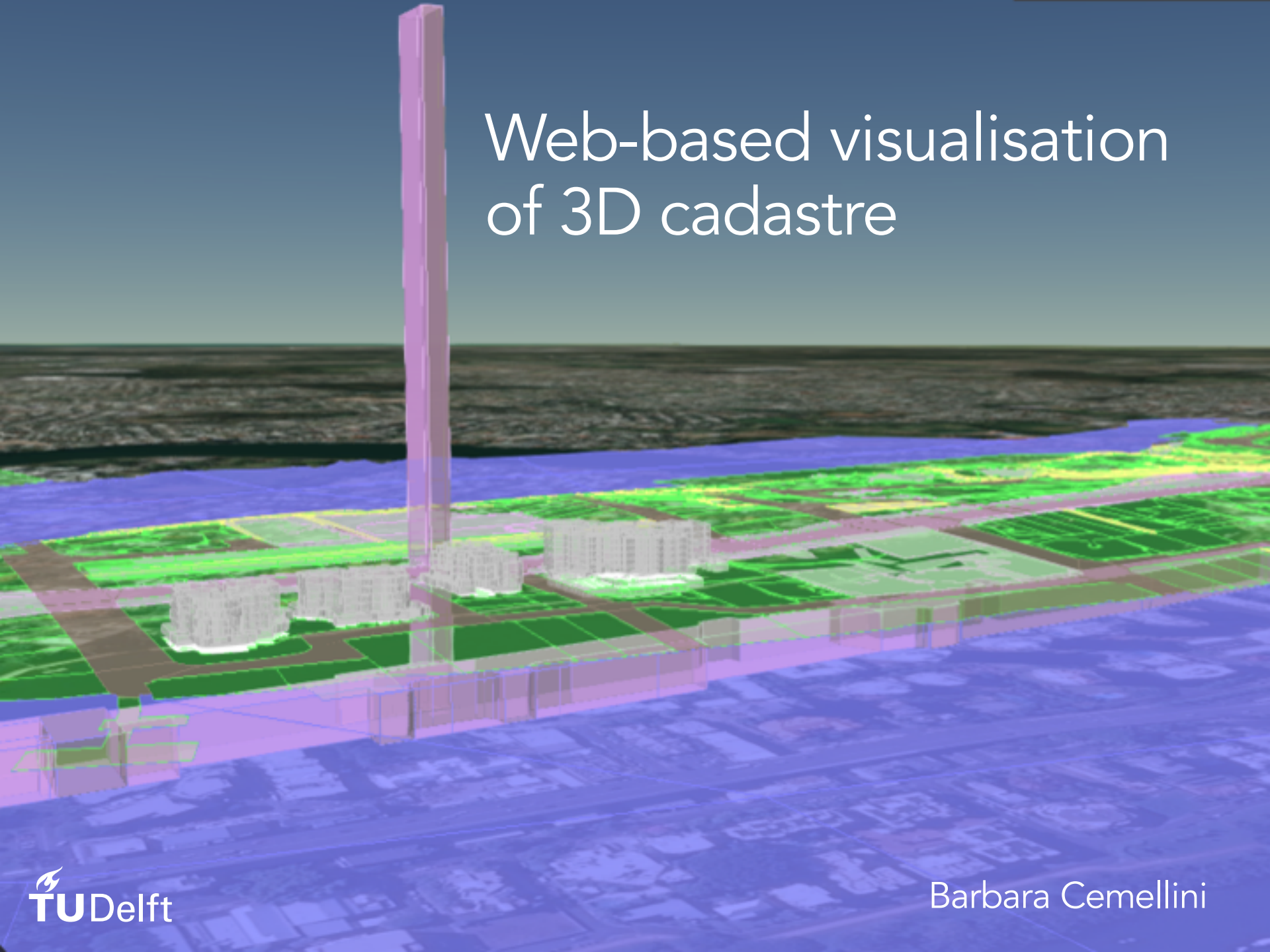
Web-based visualisation of 3D cadastre



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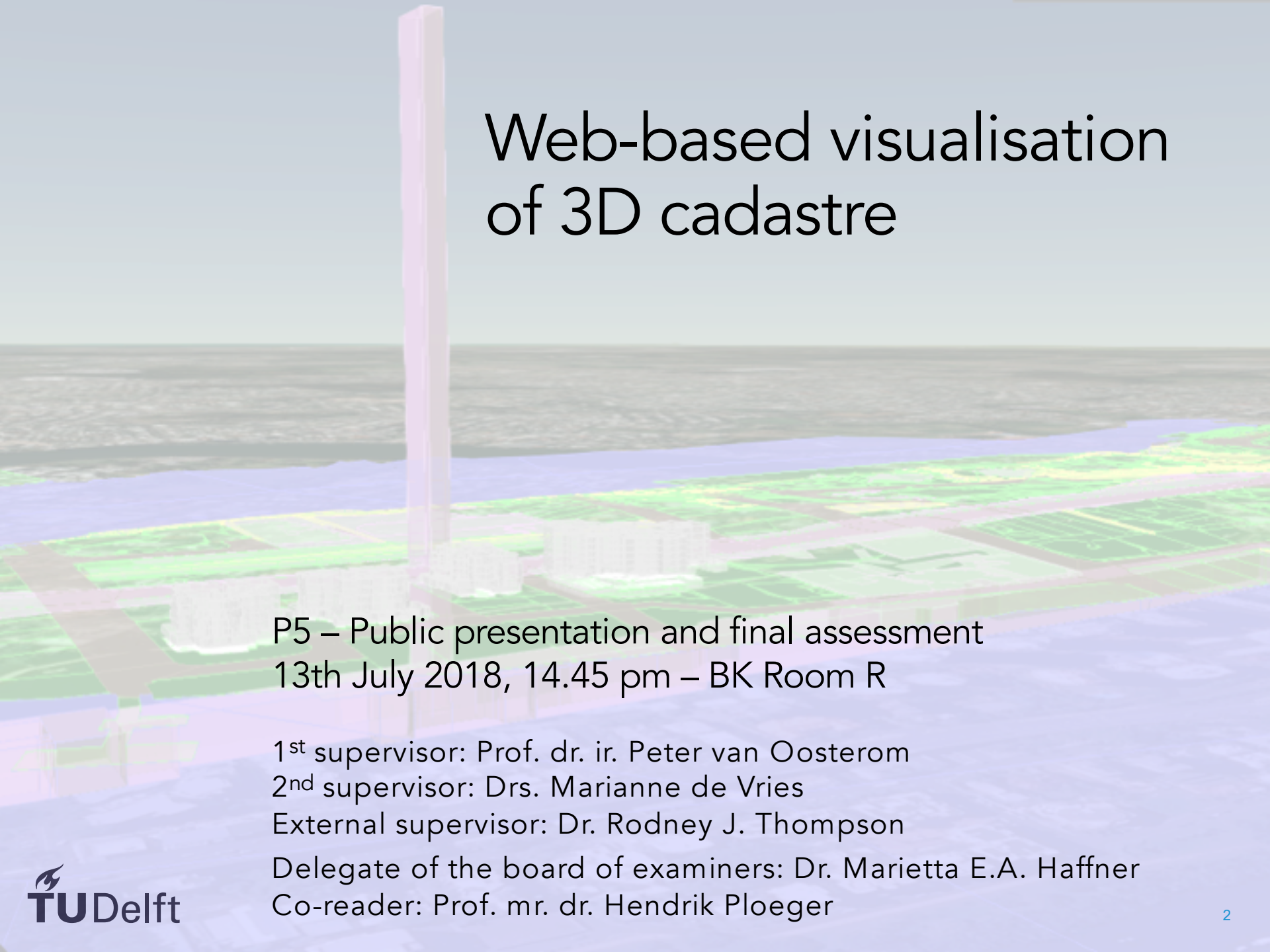
Barbara Cemellini



Web-based visualisation of 3D cadastre

P5 – Public presentation and final assessment
13th July 2018, 14.45 pm – BK Room R

1st supervisor: Prof. dr. ir. Peter van Oosterom
2nd supervisor: Drs. Marianne de Vries
External supervisor: Dr. Rodney J. Thompson
Delegate of the board of examiners: Dr. Marietta E.A. Haffner
Co-reader: Prof. mr. dr. Hendrik Ploeger

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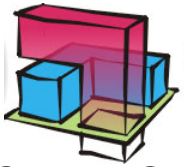
Presentation outline

- Introduction
- Related work
- Scope and research questions
- Methodology
- Tools
- Datasets
- Implementation of the 3D cadastre prototype
- Usability test
- Future work

Introduction



3D CADASTRE

WEB

VISUALIZATION

More and more countries in the world are developing 3D cadastre.

Cadastre is about making information available to the public, therefore visualizing it on the web it is very important to reach the potential users.

...but visualization is still a challenge!

Cadastral parcels are often **invisible**, so *how can we visualize something that is not visible to our eyes?*

The main issues are: **occlusion**, **unbounded volumes**, **ambiguous perception of** position, size and shape of **objects**.

Combining **topography** and **legal boundaries** is good for orientation purposes, but it is a further challenge, because occlusion issues rise with the growing number of objects shown on the viewer.

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Related work

- **3D Cadastre Prototype for the Russian Federation**
- **The Queensland Digital Cadastral Database (DCDB)**
- **The Dutch cadastre**
- **Other solutions found in literature:**
  Many open source and commercial prototypes for 3D cadastral systems both web and desktop based:
  - Prototype of 3D **ePlan** developed by **Land Use Victorian Government**
  - Two 3D cadastre web map prototypes developed in **Indonesia**, based on KML with Google Earth and X3D with ArcGIS online.
  - Desktop based 3D cadastre for the administration of urban land use in **Shenzhen**, China.

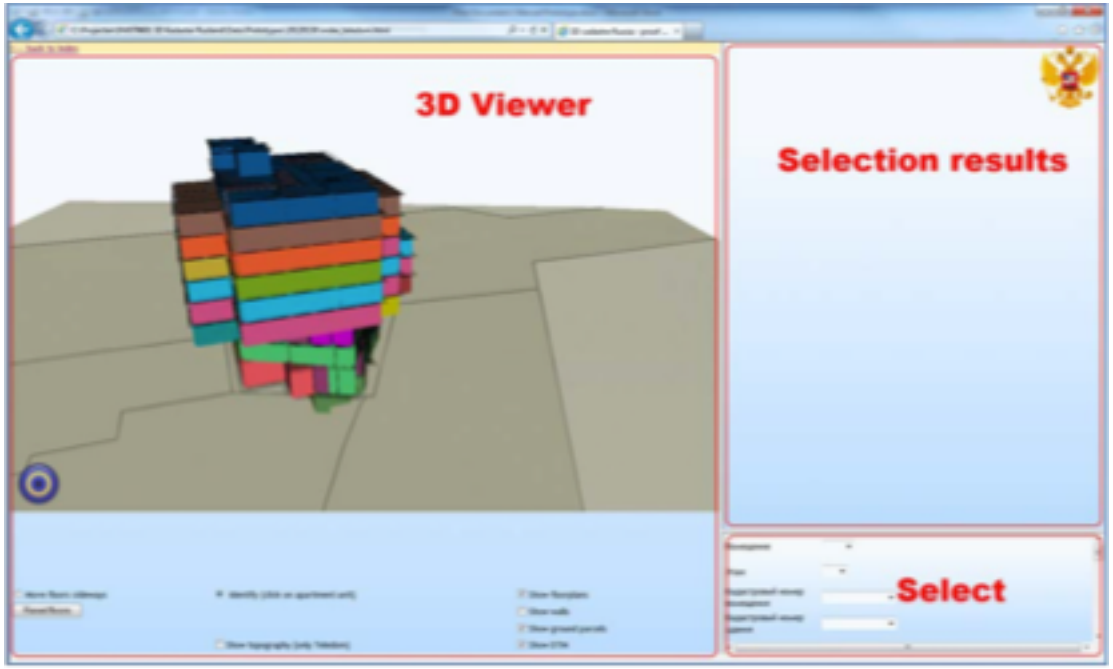
Related work: The Russian Prototype

Aim: display 3D objects and their legal boundaries

- Geometry stored in X3D files.
- Corresponding administrative information stored in XML files.
- Requires the installation of a plug-in in the web browser.

Issues:

- Plug-in installation
- Information not in a unique place (i.e. DBMS)

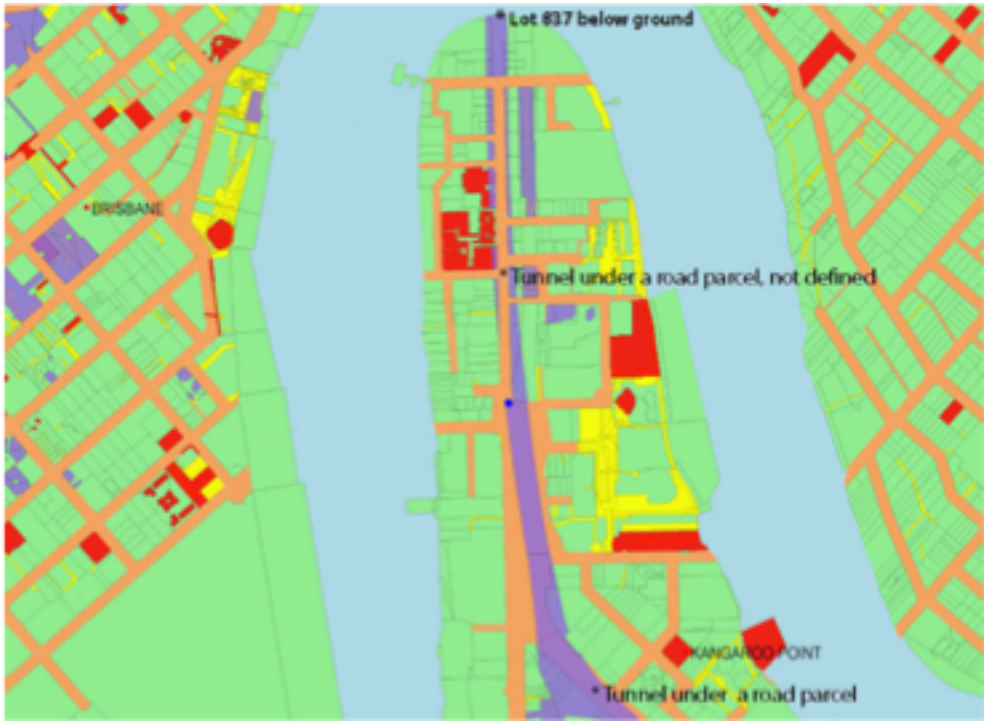


Related work: The Queensland Cadastre

- Since 1997 it is possible to create parcels with 3D geometry.
- The cadastral map only contains the footprints of the 3D parcels.
- The 3D survey plans are stored on paper drawings or on PDF files.

Issues:

- The 3D parcels cannot be interactively visualized
- No spatial validity checks possible
- 3D information is not stored together with 2D cadastral map

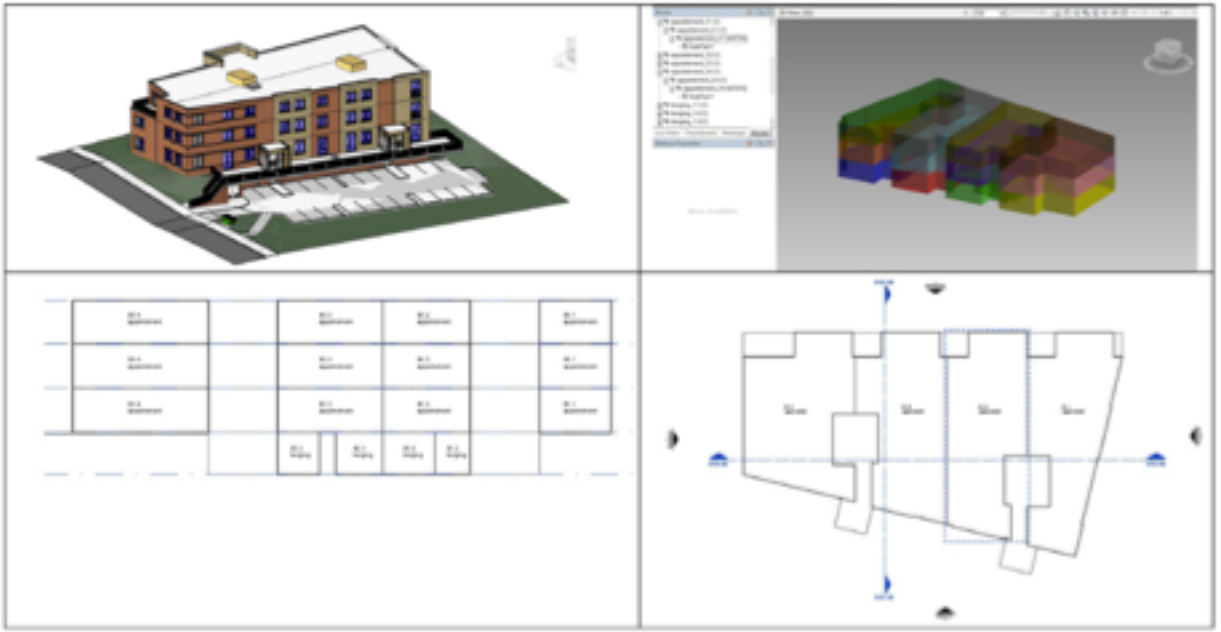


Related work: The Dutch Cadastre

- Uses 3D PDFs to represent the parcels.
- It allows interaction: zooming, rotating, sliding and query data.

Issues:

- Focus is only on visualization, 3D data is not registered
- 3D geometries cannot be topologically validated
- Data cannot be altered easily
- Neighboring parcels cannot be visualized



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Scope and main research question

What is a good system design to obtain a proper, clear and not misleading **VISUALIZATION** of 3D cadastral parcels through a geo-web viewer?

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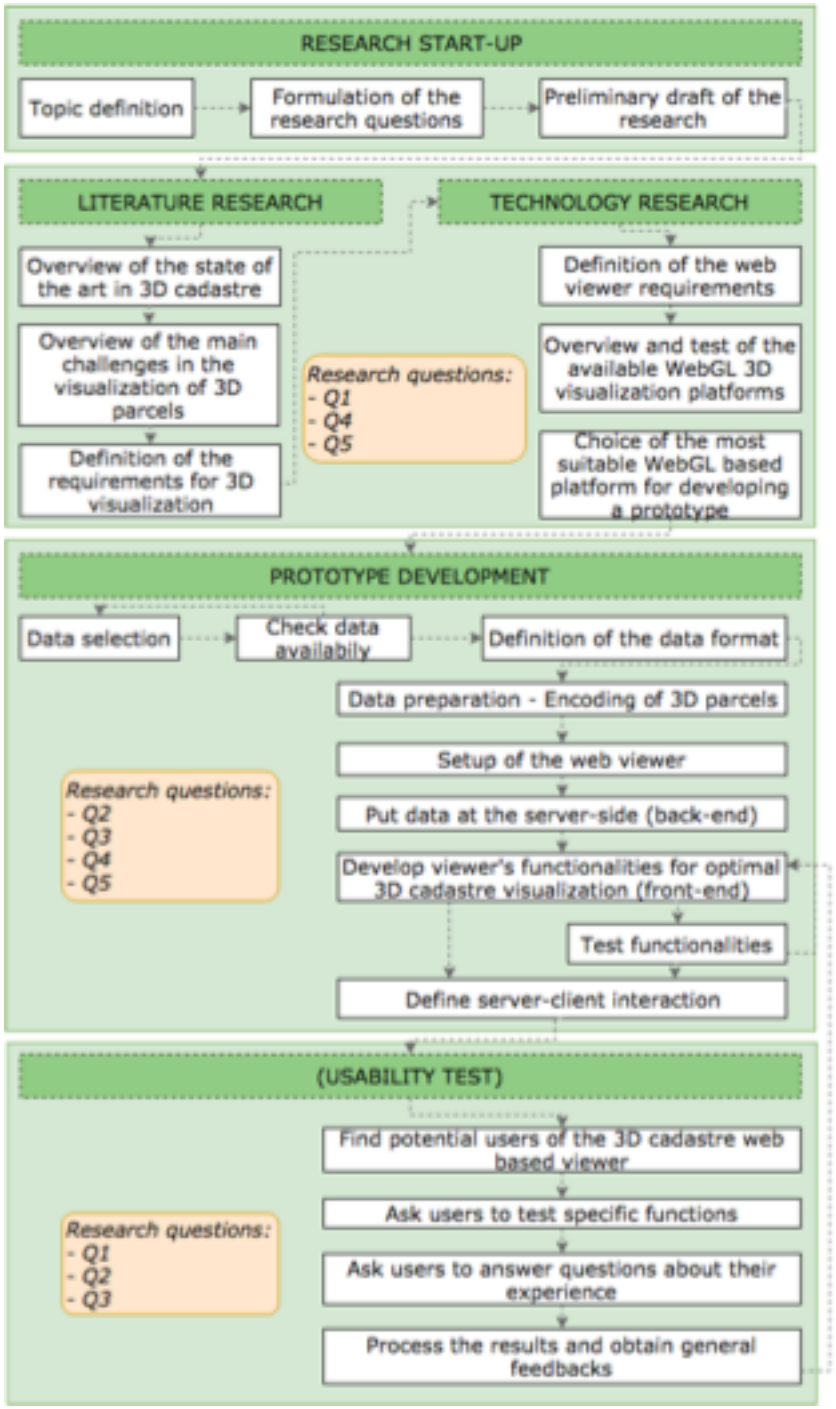
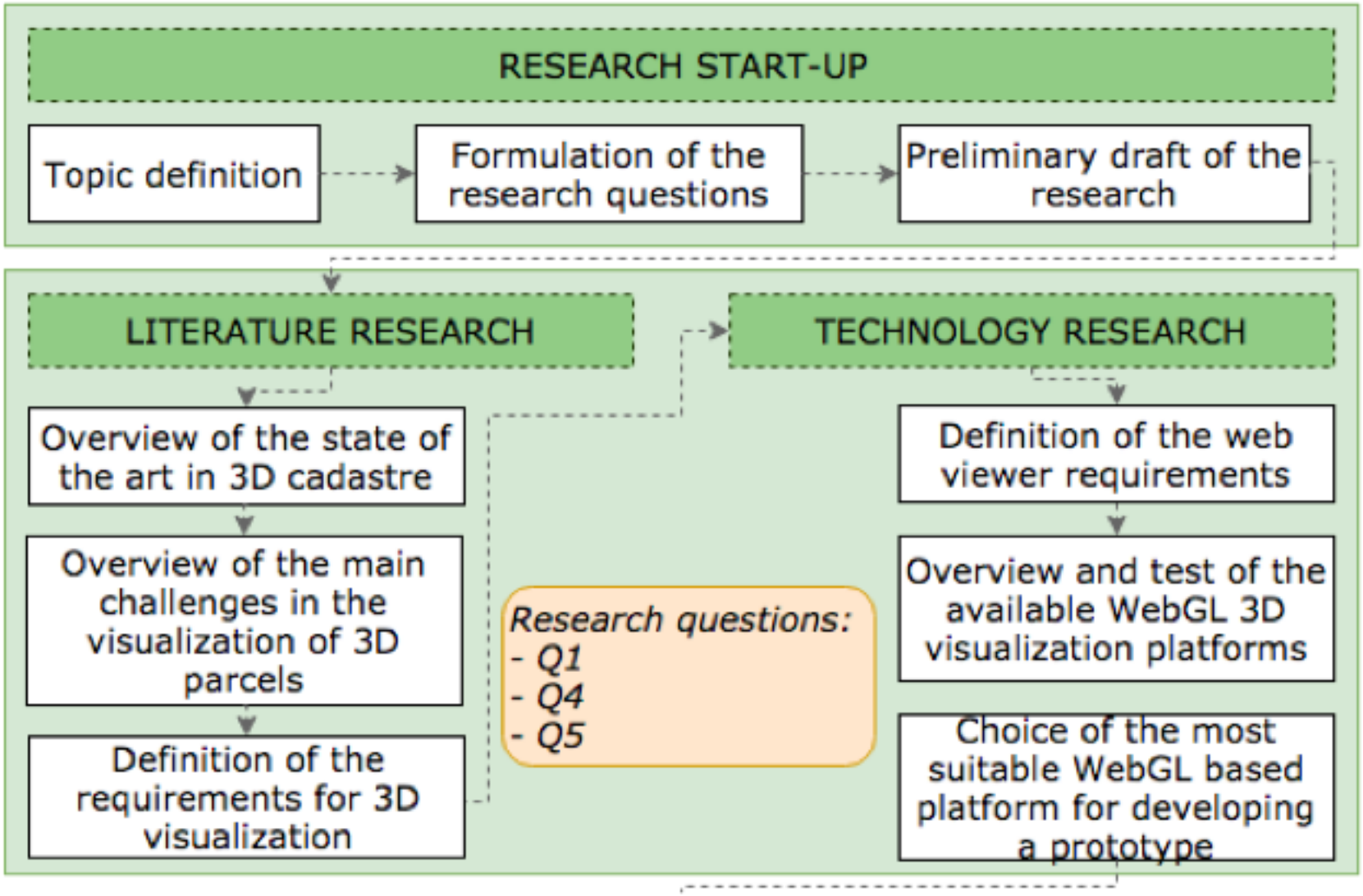
Methodology

Following the '*Design Science Research*' Approach **five** different **phases** have been identified:

- Research start-up
- Literature research
- Technology research
- Prototype development
- (Usability test)

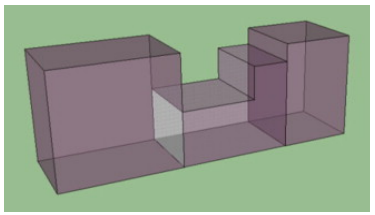
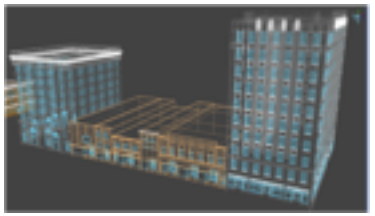
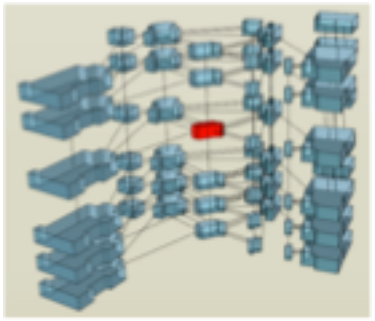
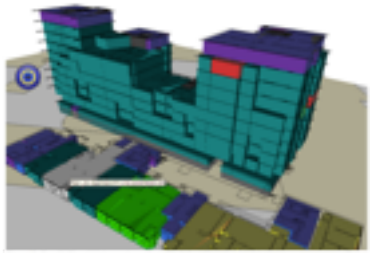
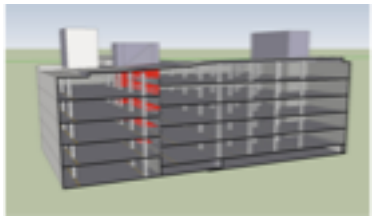
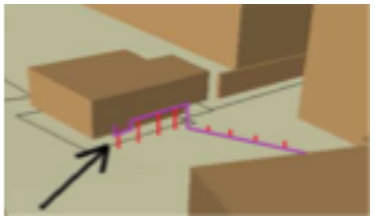
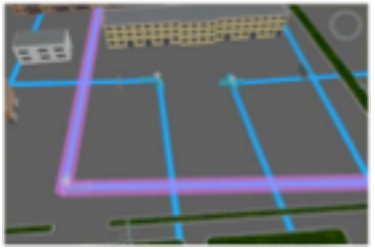


Methodology: research



Requirements for 3D visualization

- Navigation tools and view controls
- Tooltip
- Integrating topography and reference objects
- Transparency
- Object selection
- Object search
- Wireframe display
- Cross-section view
- 3D measurement tools
- Display partly unbounded objects and 'complex' geometries
- Explode view
- Sliding
- Visualization cues
- 3D buffer

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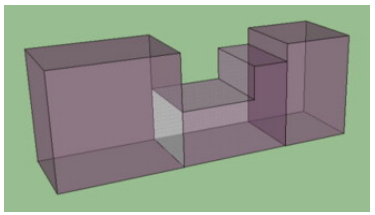
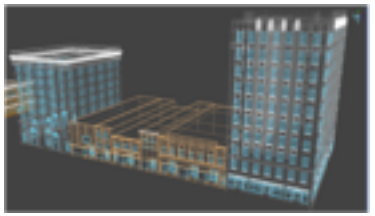
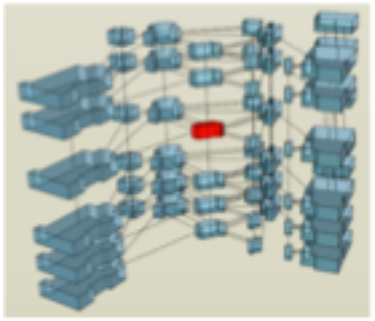
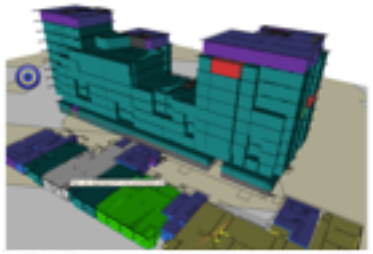
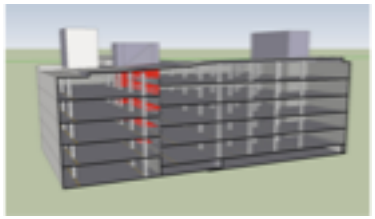
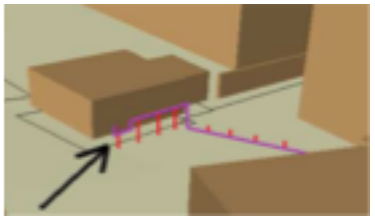
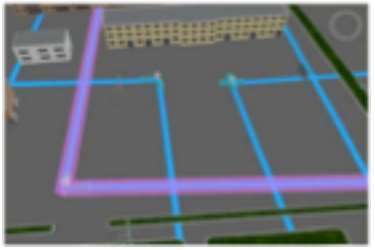

Requirements for the web viewer

- Platform and browser independence
- Layers control
- Support of 3D topographic visualization
- Support for geo-referencing
- Underground View
- Open source platform
- Possibility for the platform to be extended
- Database support
- Support different models (vector/polyhedral, raster/voxel, point clouds)
- 2D overview map (orientation)
- Handling massive data and caching/tiling between server and client
- Ensure spatial validity (3D vector topology)

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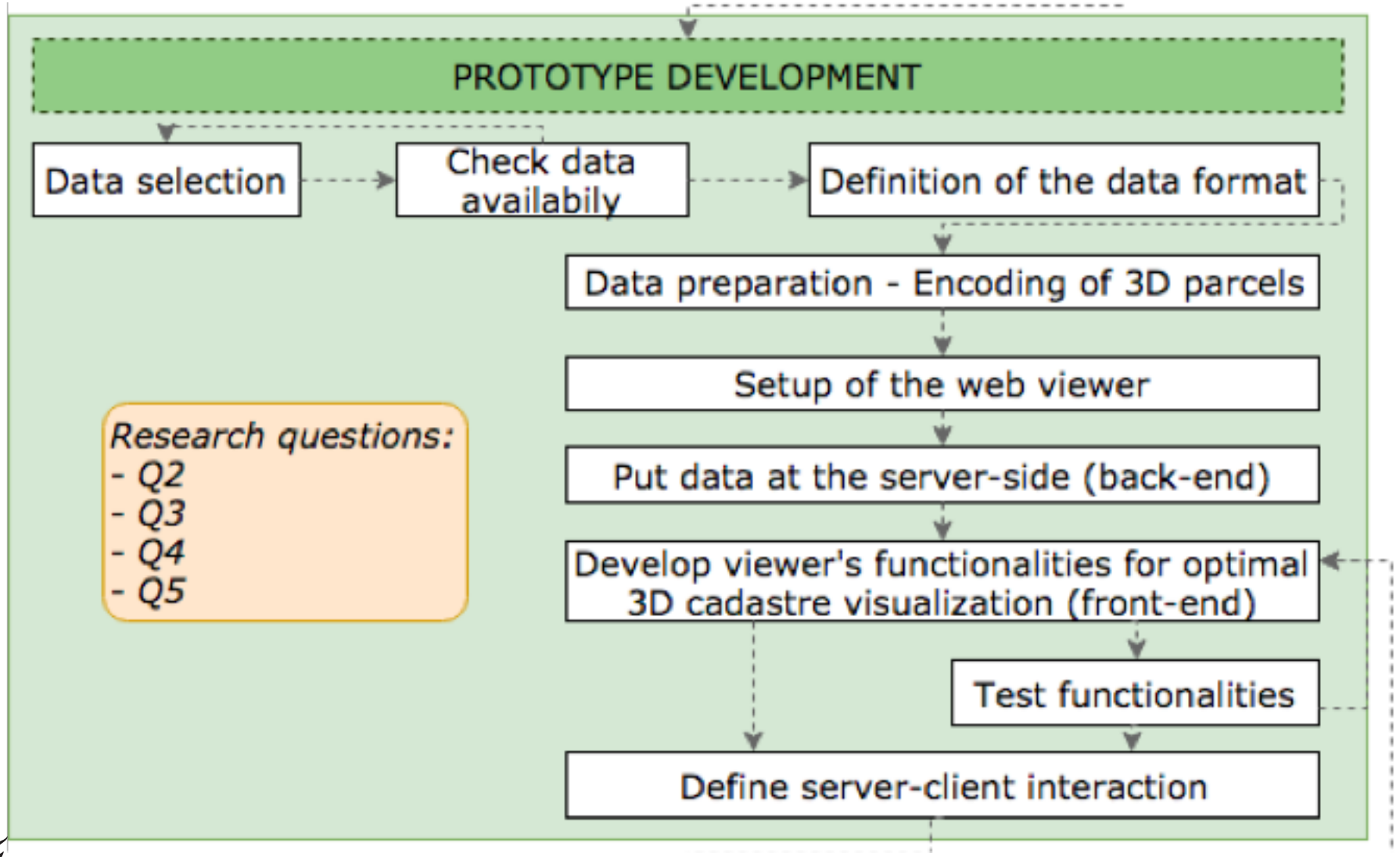
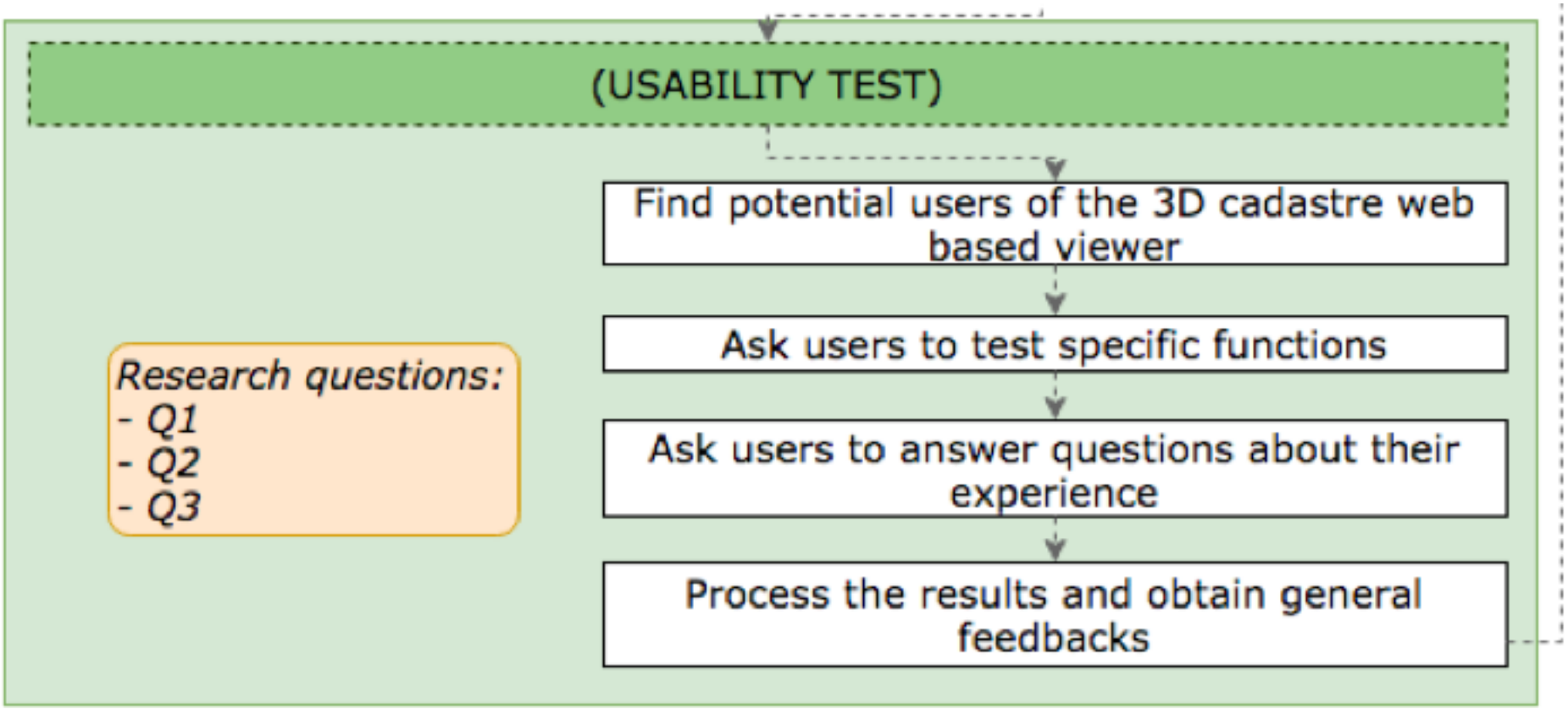
Methodology: prototype development



Methodology: usability test



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Comparison of the WebGL platforms

- **Cross-platform open source** web standard for a low-level **3D graphics API**
- Brings 3D into the web browser **without** the installation of **a plug-in**
- **Supported by all** major **browsers**
- Performs rather well in case of **complex visualizations**

Testing of available WebGL based platforms:

CESIUM

iTowns


CityEngine Web Viewer

OSM Buildings


GeoBrowser 3D

WebGL Earth

Platforms comparison – 3D visualization

Requirements related to 3D visualization in the available WebGL platforms						
Requirements	**iTowns**	**Cesium JS**	**OSM Buildings**	**WebGL Earth**	**GeoBrowser 3D**	**ESRI CityEngine**
Navigation tools and view controls	✔	✔	✔	✔	✔	✔
Tooltip	✔	✔	✔	✔	✔	✗
Integrating topography and reference objects	✔	✔	✔	✔	✔	✔
Transparency	✔	✔	✔	✔	✔	✔
Object selection	?	✔	✔	✔	✔	✔
Object search	?	✔	✔	✔	✔	✔
Wireframe display	✔	✔	?	?	?	✔
Explode view	?	?	?	?	?	?
Sliding	?	?	?	?	?	?
Cross-section view	?	?	?	?	?	✔
Visualization cues	?	?	?	?	?	?
3D measurement tools	✔	✔	?	?	✔	✔ only through program-ming
3D buffer	?	✔	?	?	?	?
Display partly un-bounded objects and 'complex' geometries	?	?	?	?	?	?

Platforms comparison – web viewer

Requirements related to the web viewer in the available WebGL platforms						
Requirements	**iTowns**	**Cesium JS**	**OSM Buildings**	**WebGL Earth**	**GeoBrowser 3D**	**ESRI CityEngine**
Platform and browser independence	✔	✔	✔	✔	✔	✔
Handling massive data and caching/tiling between server and client	✔	✔	✔	✔	✔	? but foresees the possibility of handling massive cadastral data
Layers control	✔	✔	✔	✔	✔	✔
Database support	?	?	?	?	?	✔
Support different models (vector, raster, point clouds)	✔	✔	✗	✗	✔	✔
Support of 3D topographic visualization	✔	✔	✗	✔	✔	✔
Support for georeferencing	✔	✔	✔	✔	✔	✔
Ensure spatial validity (3D vector topology)	?	?	?	?	?	?
Underground View	?	?	?	?	?	✔
Open source platform	✔	✔	✔	✔	✔	✗
Possibility for the platform to be extended	✔	✔	✔	✔	✔	✔ Python scripting interface
2D overview map (orientation)	✔	✔	?	?	?	?

Selection of the most suitable platform

Cesium JS is a WebGL based open-source JavaScript library to create 3D geospatial applications.

Cesium has a forum to help developers on specific issues.

Sandcastle: live code editor and example gallery.

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Area of interest

Close to the city centre of Brisbane, Australia
(near the Story Bridge and the
Kangaroo Point neighborhood).

The **Queensland Digital Cadastral Database (DCDB)** has a long tradition and the biggest amount of data available so far.

The area has been chosen because it combines a **variety of 2D and 3D objects**:

- 3D building format units
- 3D volumetric format units (included the underground tunnel “Clam 7”)
- Land and watercourse 2D spatial untis
- 3D parcels which changed over time

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Data

- **2D cadastral parcels** from Queensland DCDB
- **3D survey plans** from Queensland Cadastre, either in *building format* and in *volumetric format*. The volumes will represent three main categories in the real world: buildings, tunnels and air space.
- **2.5D terrain surface**, i.e. elevation data in the form of a DTM, point cloud or contour lines
- **Reference data**, i.e. topographic objects in 2D or 3D.
- **Rights**, or Registration of Rights, Restrictions and Responsibilities **(RRRs)**, if available
- **Persons/parties**, if available. Otherwise use of a dummy dataset to simulate the real data.

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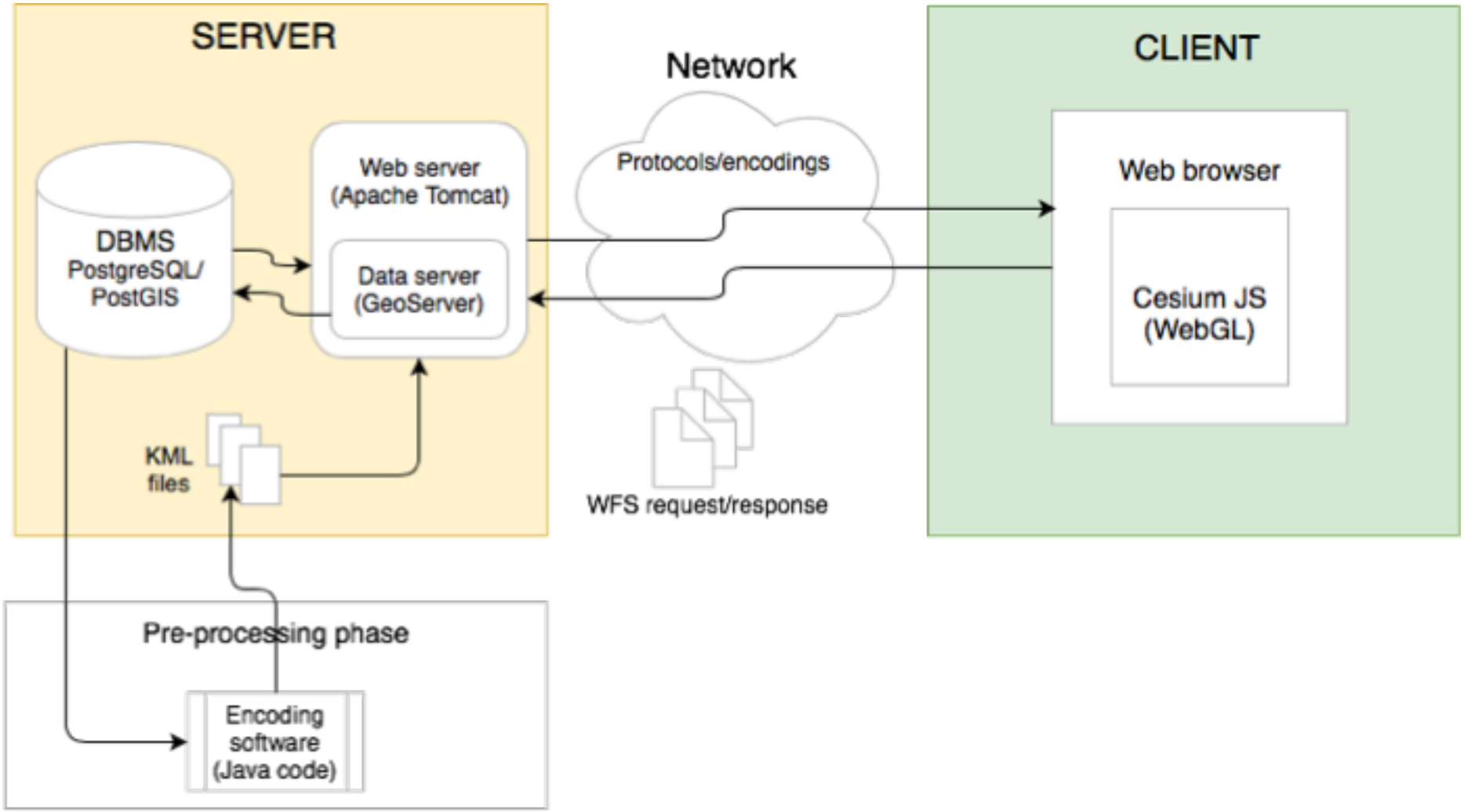
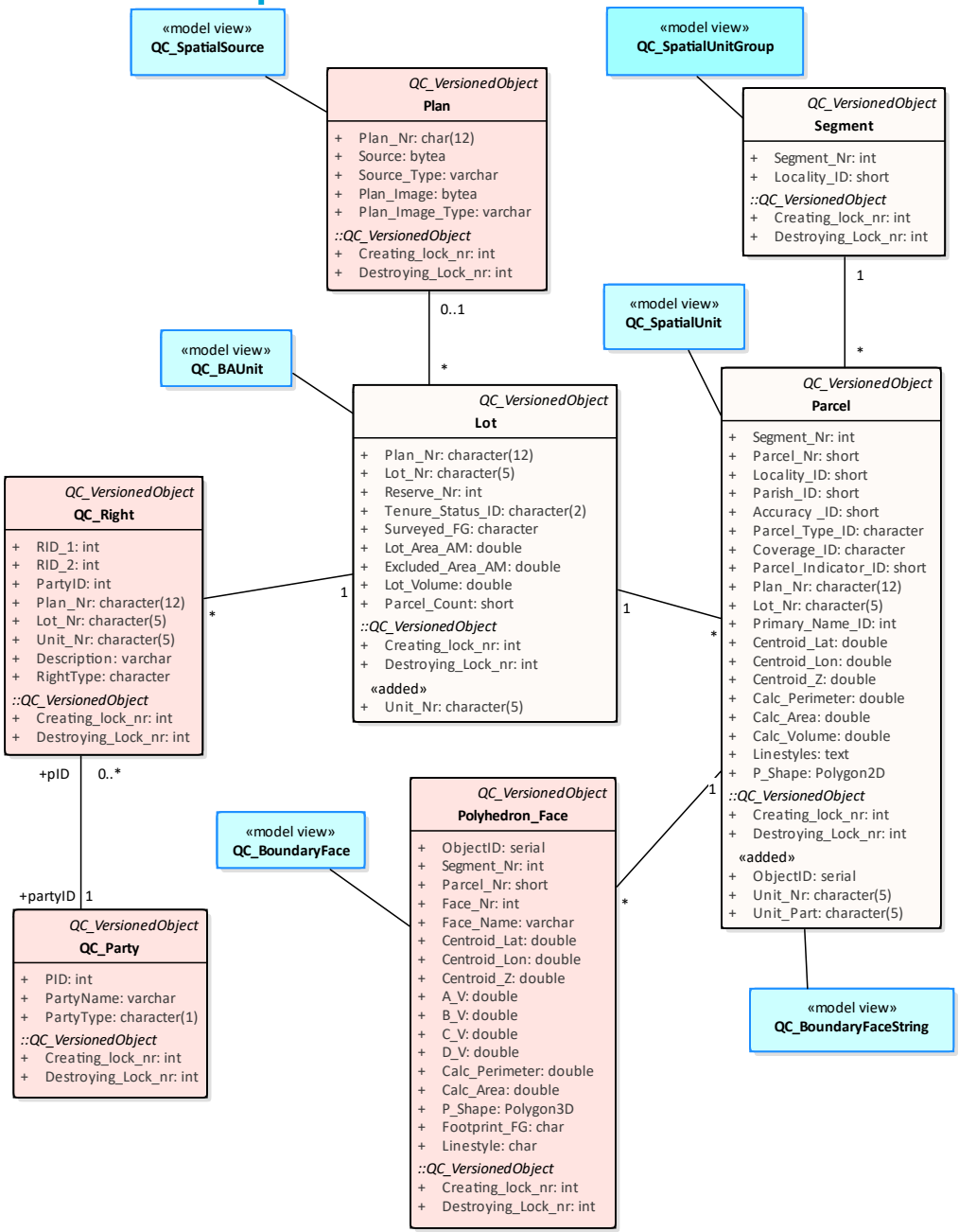
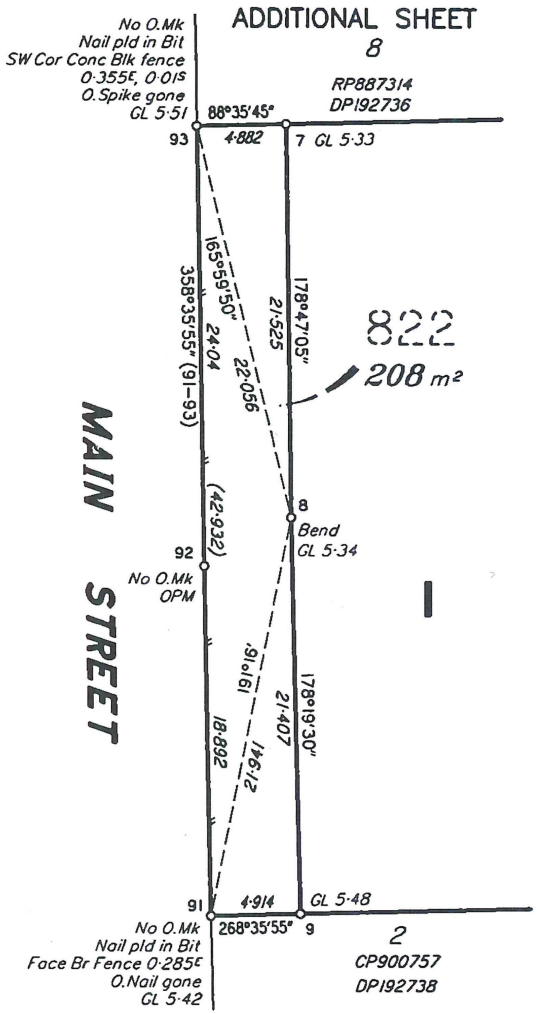
Server-client system architecture

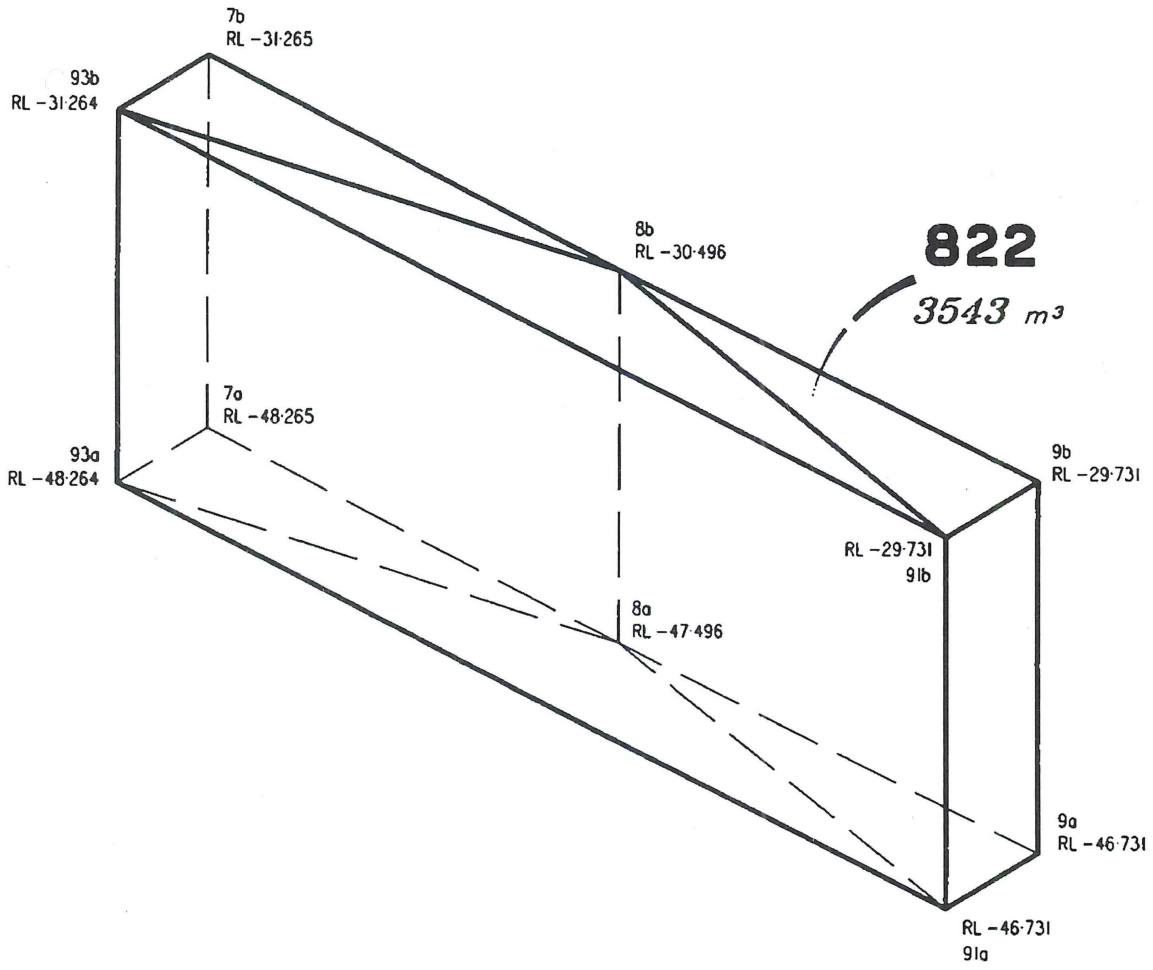


The LADM compliant database schema



Data encoding - 3D volumetric survey plans





Data encoding - 3D volumetric survey plans

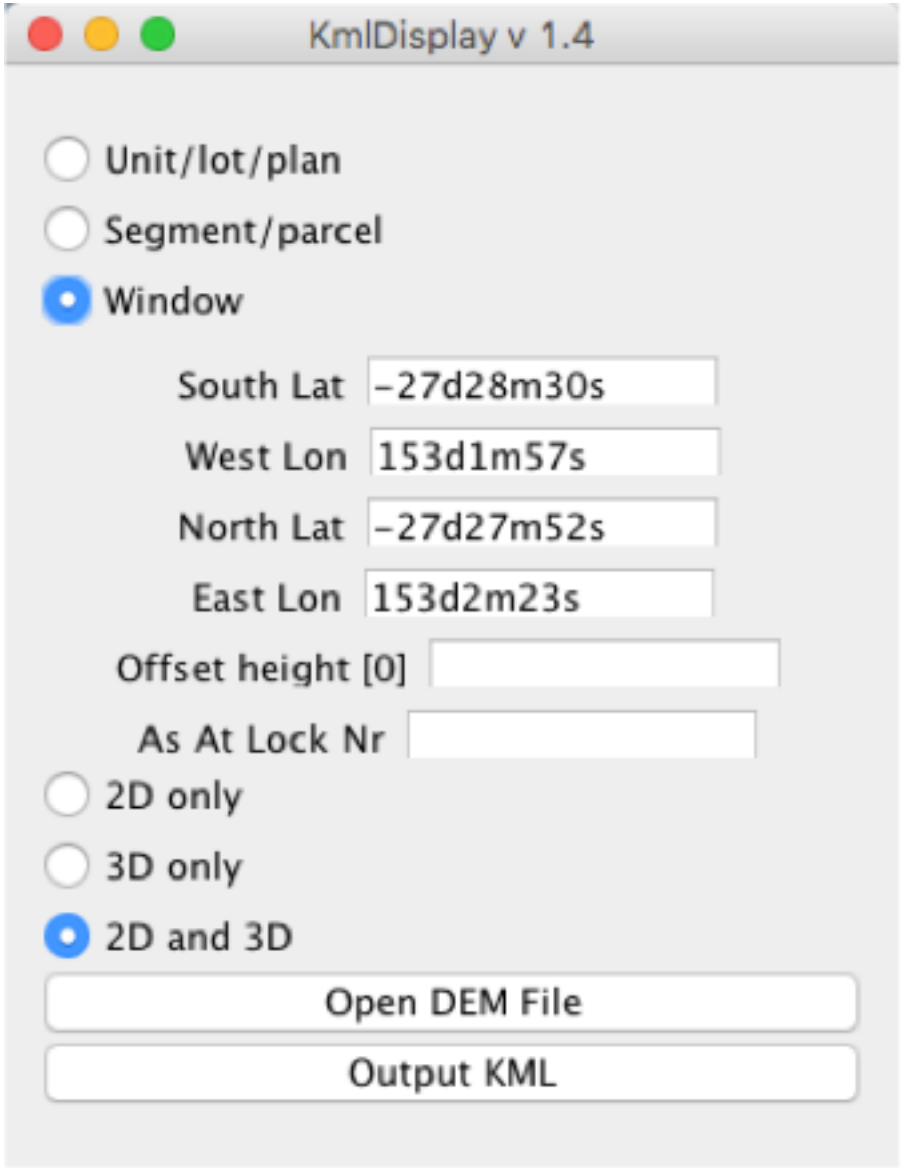
DCDB Parcel 822/SP192737 25159/233	Lon	Lat	Pid	Cnr Nr	X	Y	B and D	Elevations
S SW	153.0354519	-27.466975	-1	91	103	0		
SE E	153.0355025	-27.466974	-1	9	601	12		
	153.0354952	-27.466781	-1	8	530	2156		
N NE	153.0354911	-27.466598	-1	7	489	4181		
NW W	153.0354415	-27.466599	-1	93	0	4170		
	153.0354445	-27.466708	-1	92	30	2961		
****	additional edges if needed							
****	additional elevations if needed							
93 a -48.264 b -31.264								
91 a -46.731 b -29.731								
9 a -46.731 b -29.731								
8 a -47.496 b -30.496								
7 a -48.265 b -31.265								
****	parcels							
Parcels Lot 822 25159/233								
Footprint								
A 93a 7a 8a 9a 91a								
B 93b 91b 9b 8b 7b								
****	Textural data							
Date	06/12/2007							

Data encoding - 3D volumetric survey plans

The user can **extract the KML files from the DB**, choosing the characteristics of the data:

- All the parcels or just a subset
- Offset height
- 2D, 3D or mixed 2D and 3D

The choice of a DTM is also possible.



Selection of the elevation data

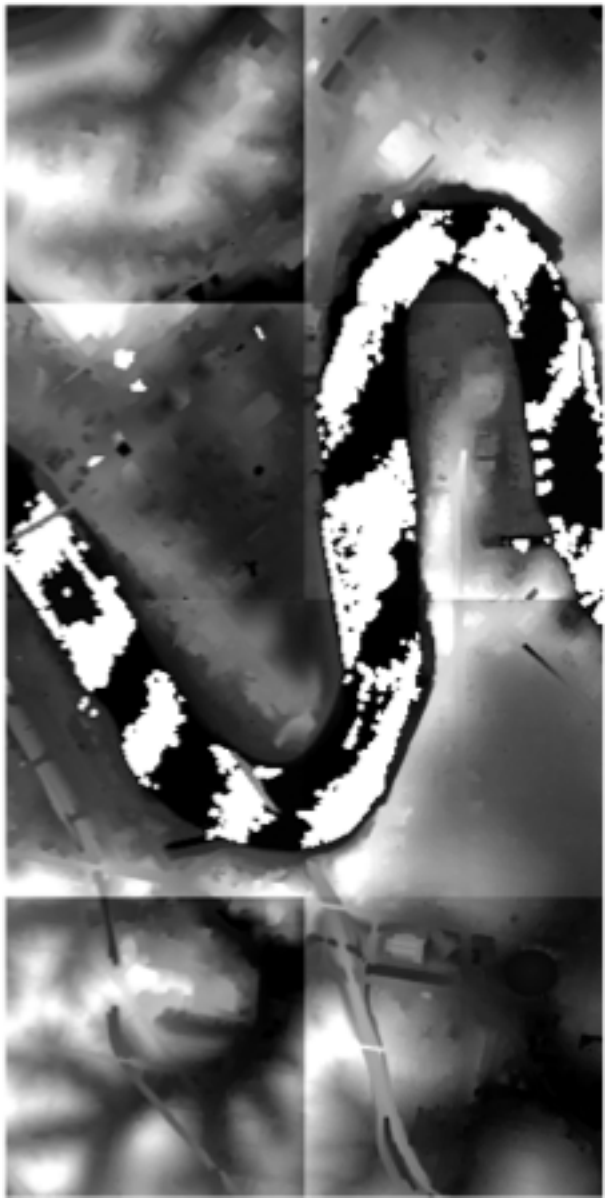
STK world terrain is a worldwide terrain elevation tileset provided by Cesium JS, but it is not accurate enough to place parcels on top of it.

Selection of the elevation data

DTM provided by Fugro as a GeoTIFF file, it has a resolution of 50 centimeters.

GeoTIFF to KML:

1. From (Geo)TIFF to ESRI ASCII grid
2. From *.asc to space/comma delimited *.xyz
3. From ASCII XYZ to KML



Display of 3D objects: Comparing different data formats

Keyhole Markup Language (KML)

- International standard since 2008, maintained by OGC.
- Tag based structure, built on top of XML grammar.
- It is the native format of Google Earth and it is particularly suitable for geodata.
- KML support in Cesium JS is still limited

JavaScript Object Notation (JSON)

- Well supported in Cesium JS.
- Supports 3D data in the form of extruded 2D volumes. No "real" 3D data supported.
- Extruded volumes are not able to represent complex 3D parcels accurately. Not suitable for the purpose of 3D cadastre.

GL Transmission Format (glTF)

- Known as ***the*** 3D model format in Cesium JS and an essential part of 3D tiles.
- Not so straightforward to create this format. Technologically feasible, but too time consuming at this stage of the development.

Batched 3D Model (B3DM)

- It defines each feature by means of its vertices (each of them with unique ID)
- It allows to create groups of features to create caching and tiling mechanisms

Subsurface visualization: What's the best way to visualize underground parcels?

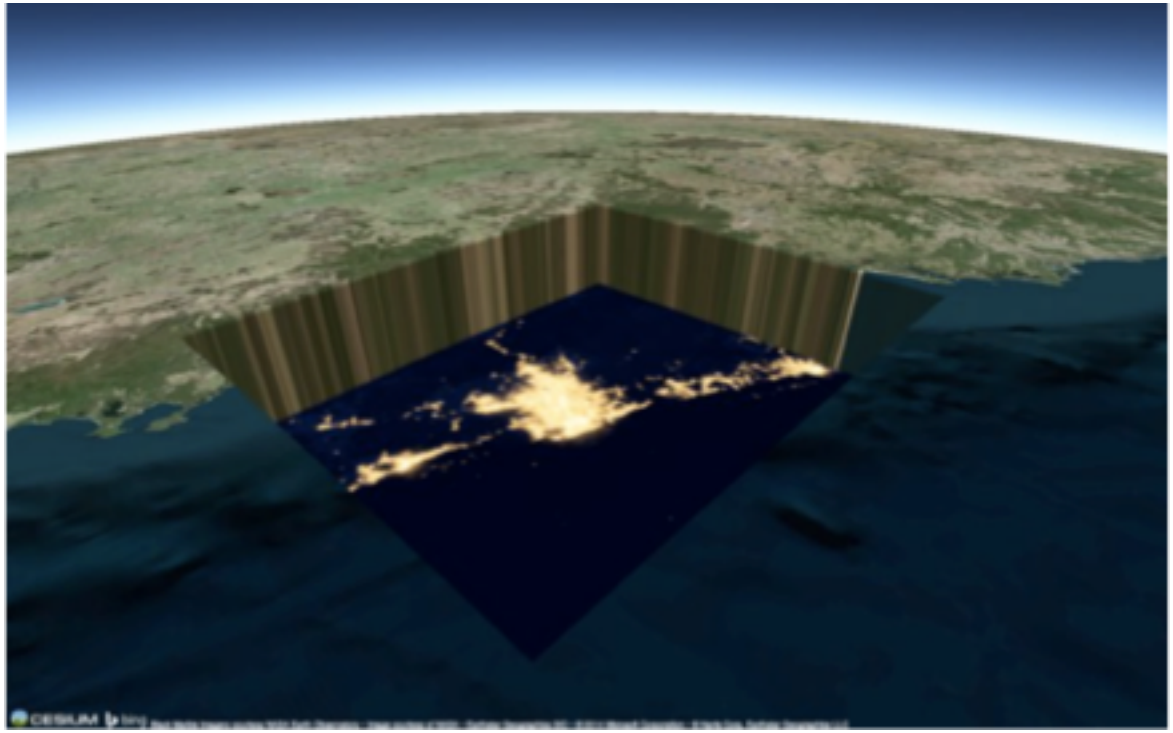
Cesium JS does not support subsurface visualization, because the camera cannot go under the earth surface.

Three possible solutions to overcome this issue:

- **Ground push plug-in**
- **Fake surface**
- **Translucent terrain**

What's the best way to visualize underground parcels?

Ground push plug-in



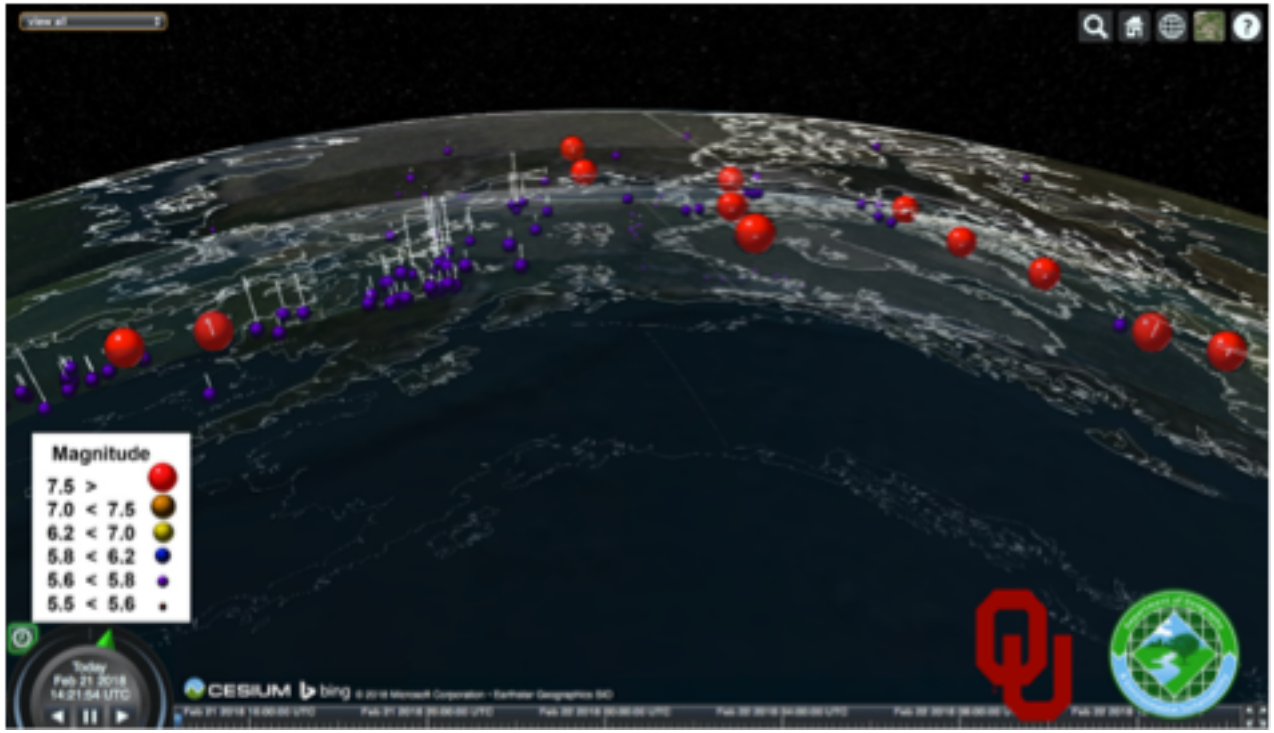
☺ push up and down the surface of a user defined amount.

☹ the shape of the rectangle cannot be changed after it is initialized.

☹ zooming too close makes the rectangle disappear.

What's the best way to visualize underground parcels?

Fake surface

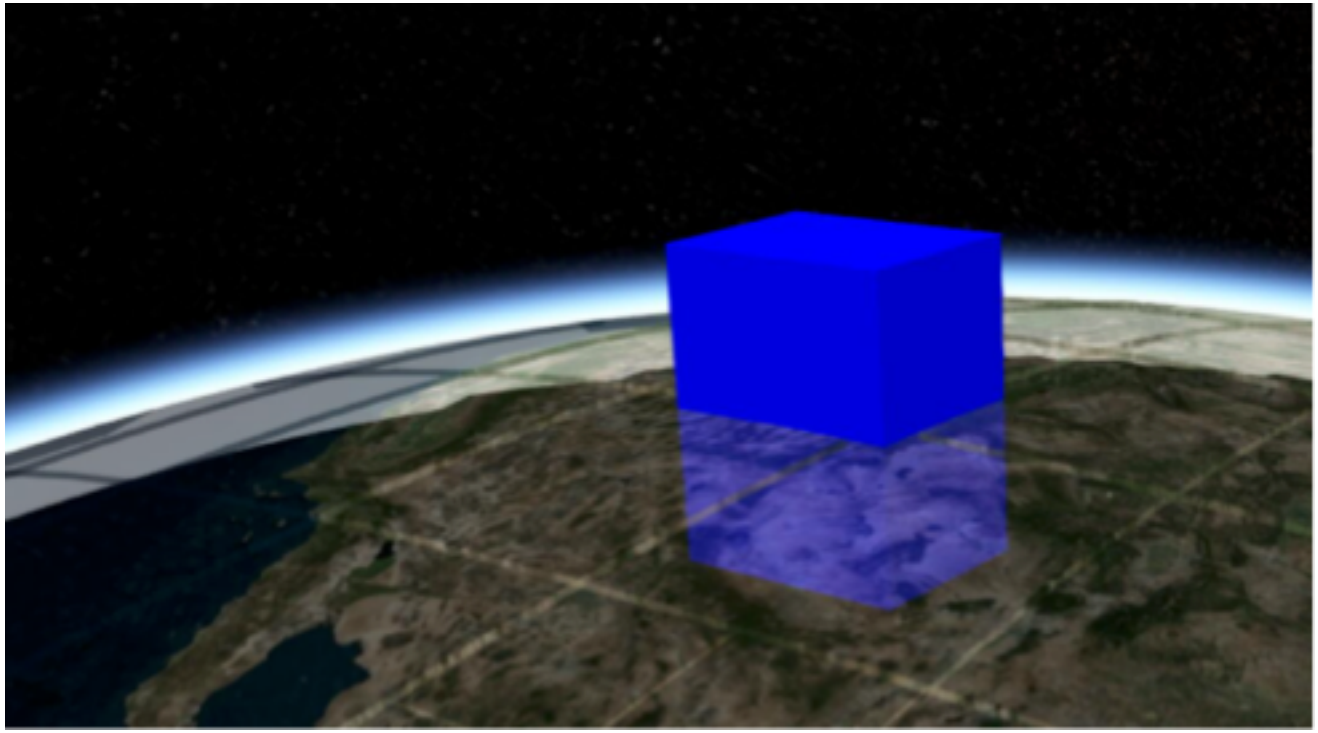


☺ the camera can go under the fake surface

☹ the parcels need to be shifted up of a certain amount to match the surface

What's the best way to visualize underground parcels?

Translucent terrain



☺ the surface does not need to be moved/modified.

☹ the camera cannot go under the surface, the objects can only be seen 'from above'.

The visualization is confusing

What's the best way to visualize underground parcels?

Definition of a new requirement for 3D cadastre visualization: the **dynamic elevation tool**.

Possibility to move the 3D objects up or down of a user defined amount to be able to visualize in detail the underground parcels that are hidden by the earth surface.

The user can navigate to the exact location and have a reality-like visualization. If needed, transformations can be applied to better visualize the hidden parcels.

A new requirement: the dynamic elevation tool

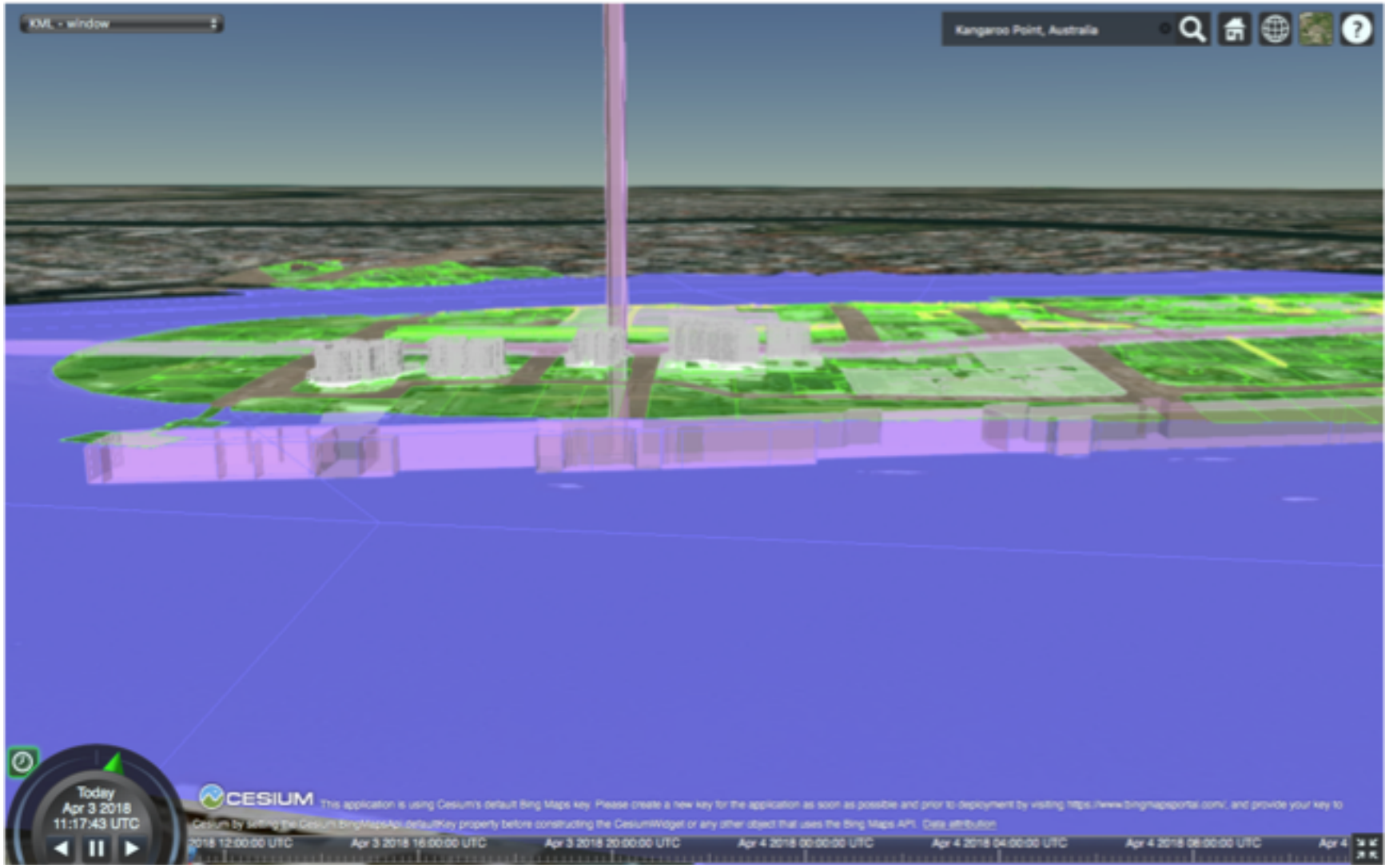
Actual implementation:

A **drop-down menu** which allows the user to choose between two different elevations: ground level or 200 meters above ground.

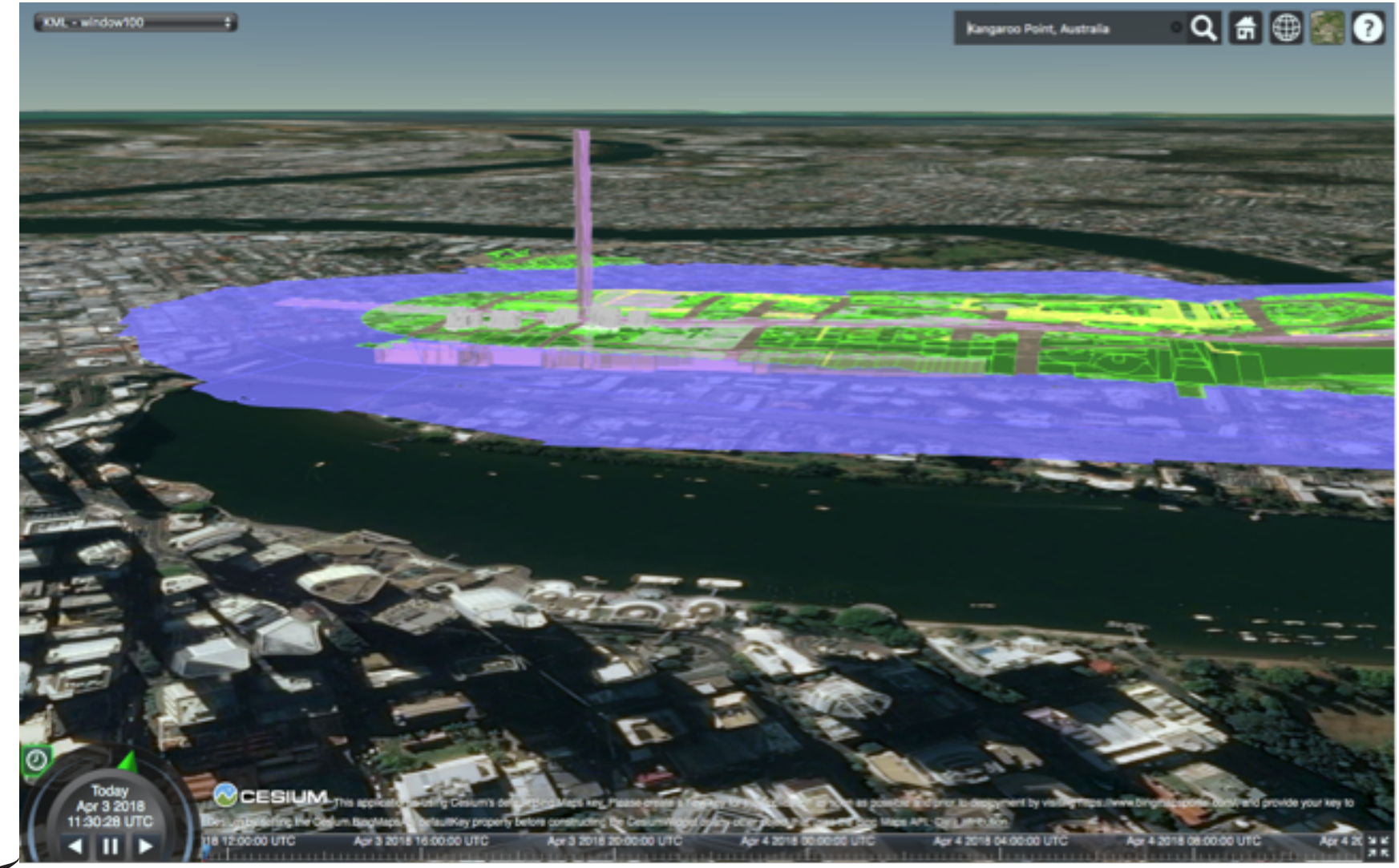
Future implementation:

Changing the drop-down menu into a **slider** or **a tool to manually drag the parcels.** The shift should allow the camera to navigate around the parcels to analyze them from every angle.

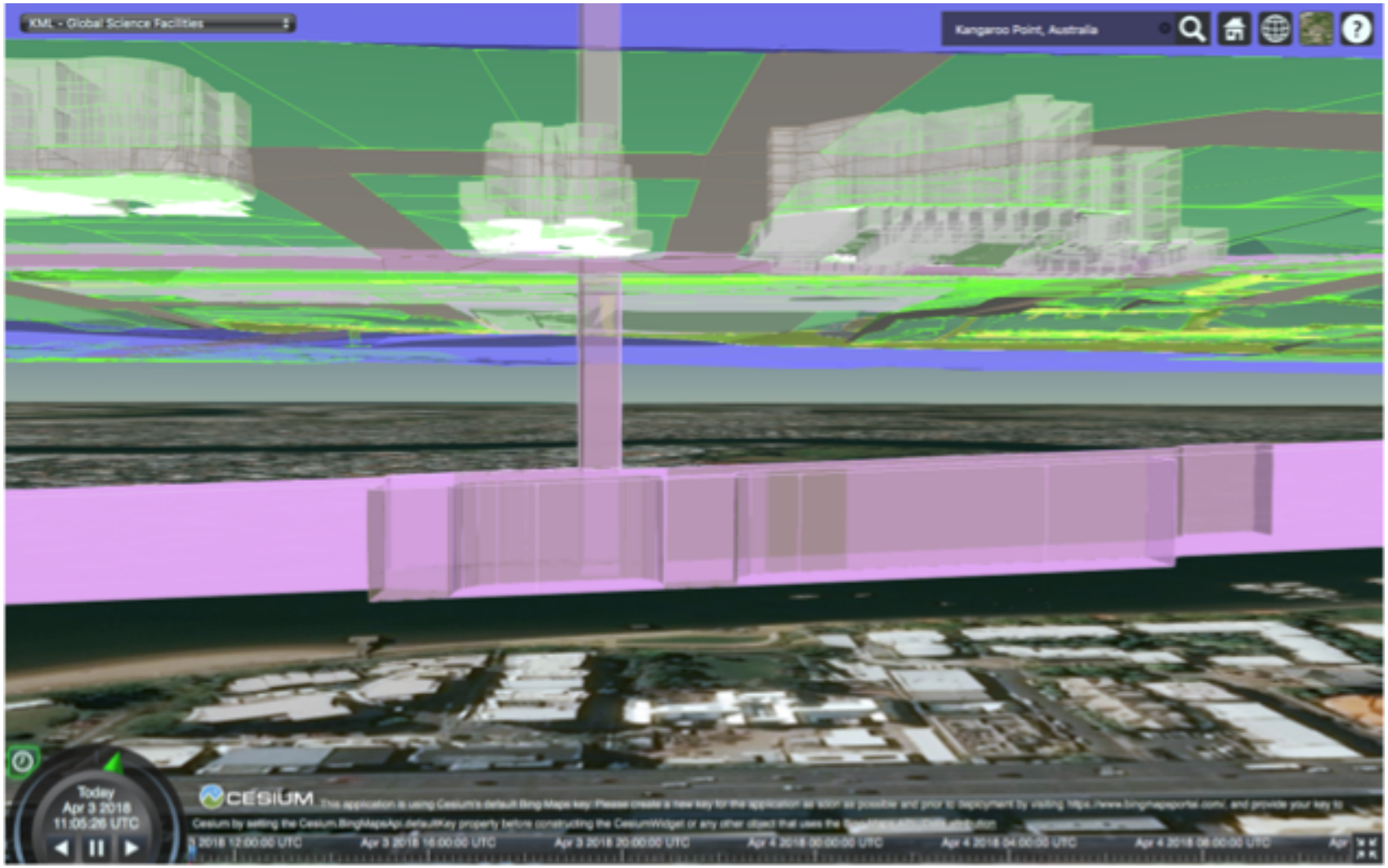
Visualization of the parcels in Cesium JS



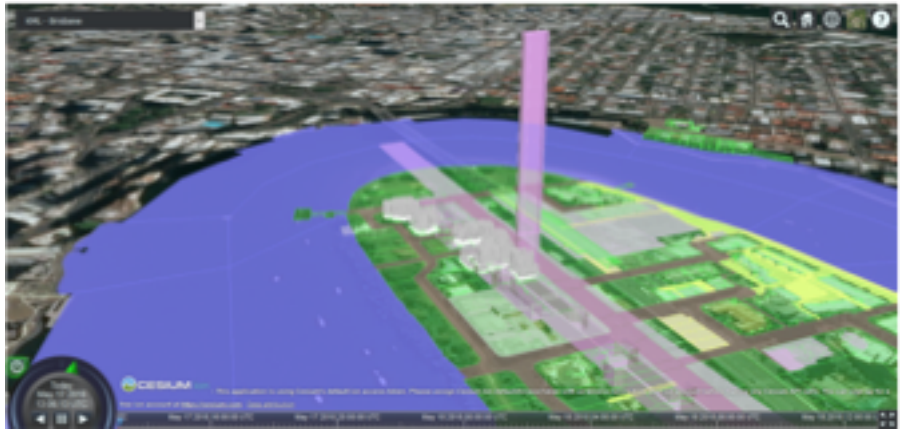
Visualization of the parcels in Cesium JS with interactive elevation

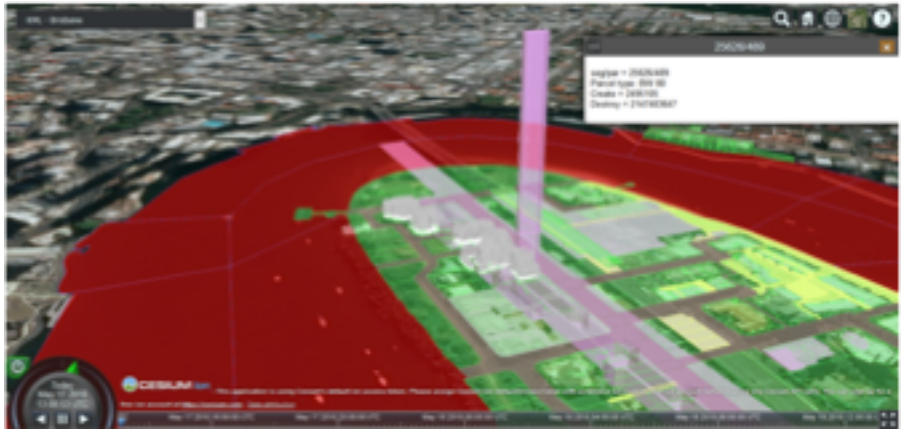


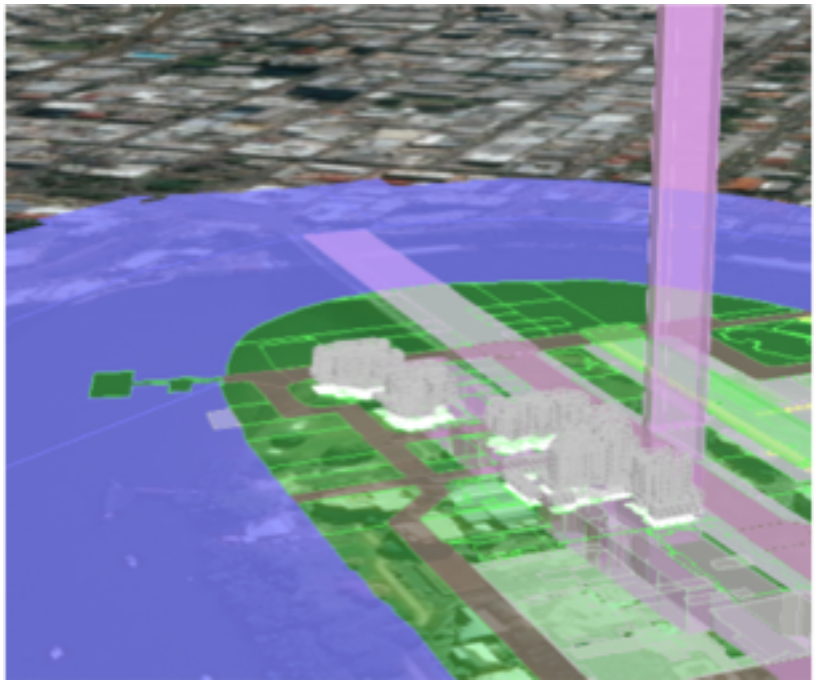
Visualization of the parcels in Cesium JS with interactive elevation

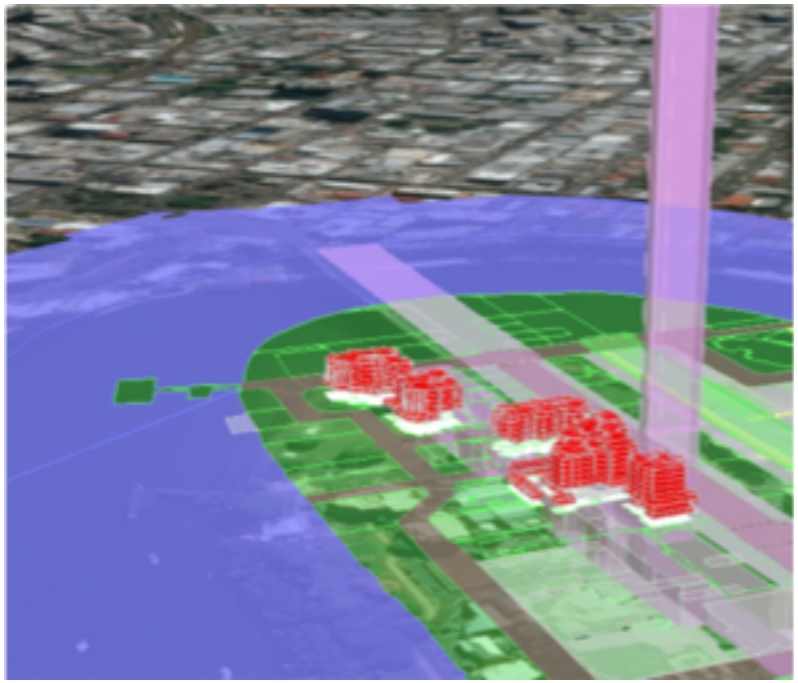


Feature selection (highlight) with KML









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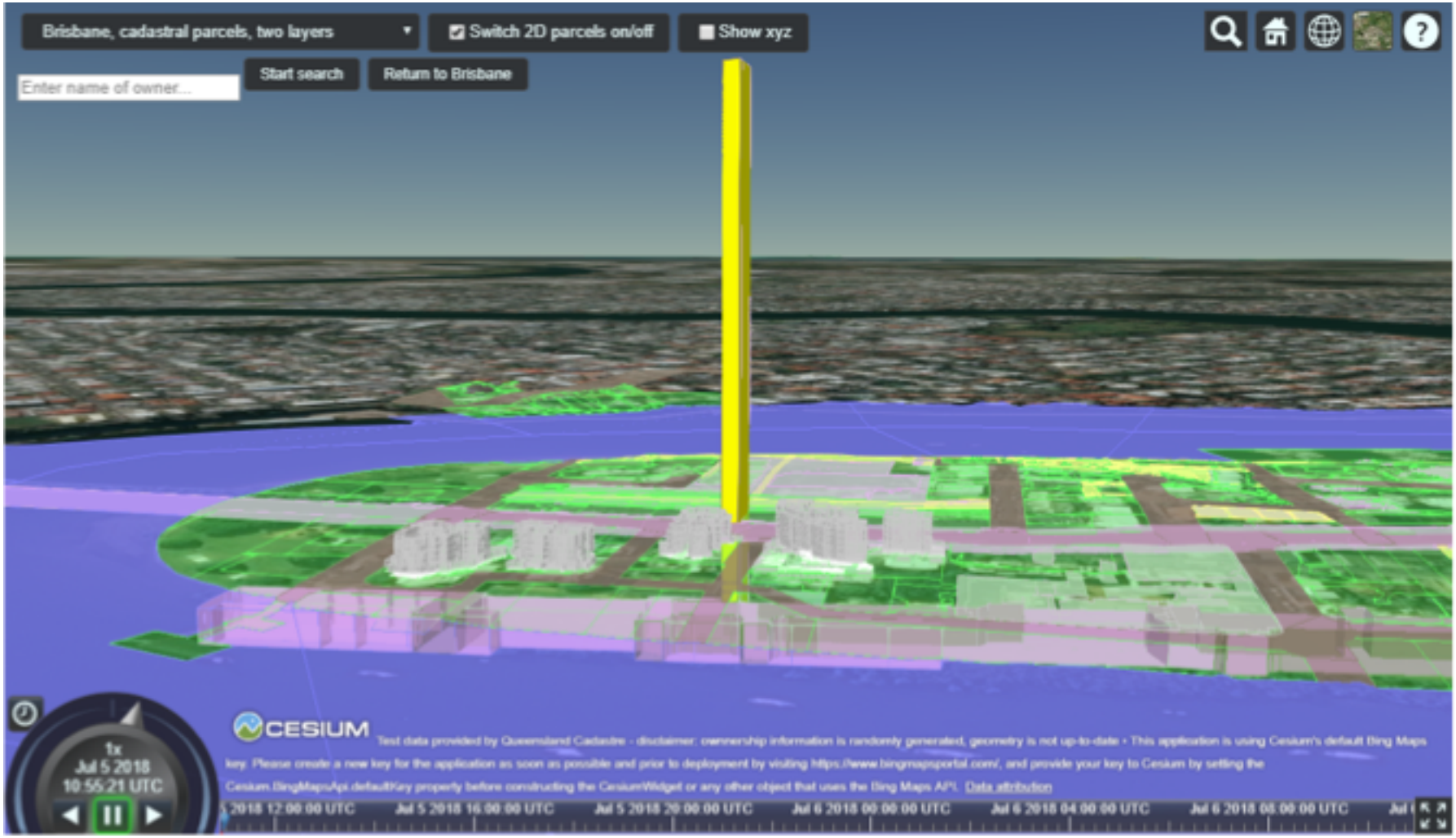
Feature selection (highlight) with KML



Tooltip functionality

1st implementation: a green highlight box indicates the selected feature.

Downsides:

- The shape and size of the highlight box are fixed
- Clicking on a random point of a face, the box always aims at the centre of the face.

Tooltip functionality

2nd implementation:

The selected parcel is highlighted in yellow and a pop-up menu contains the information about the parcel.

Retrieval of administrative information from the DB (RRRs and persons/parties):

The selected parcel is highlighted in yellow and a pop-up menu contains the information about the parcel

Retrieval of administrative data: WFS request/response

http://pakhuis.tudelft.nl:8088/geoserver/geoweb/ows?service=WFS&version=1.1.0&request=GetFeature&outputFormat=application/json&typeName=geoweb:v_owner_of_parcel&cql_filter=segment_nr = 25159 and parcel_nr = 262


```
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        "properties": {
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            "parcel_nr": 262,
            "partyname": "Clem 7",
            "creating_lock_nr": 2495105,
            "destroying_lock_nr": 2147483646
        }
    }],
    "crs": null
}
```
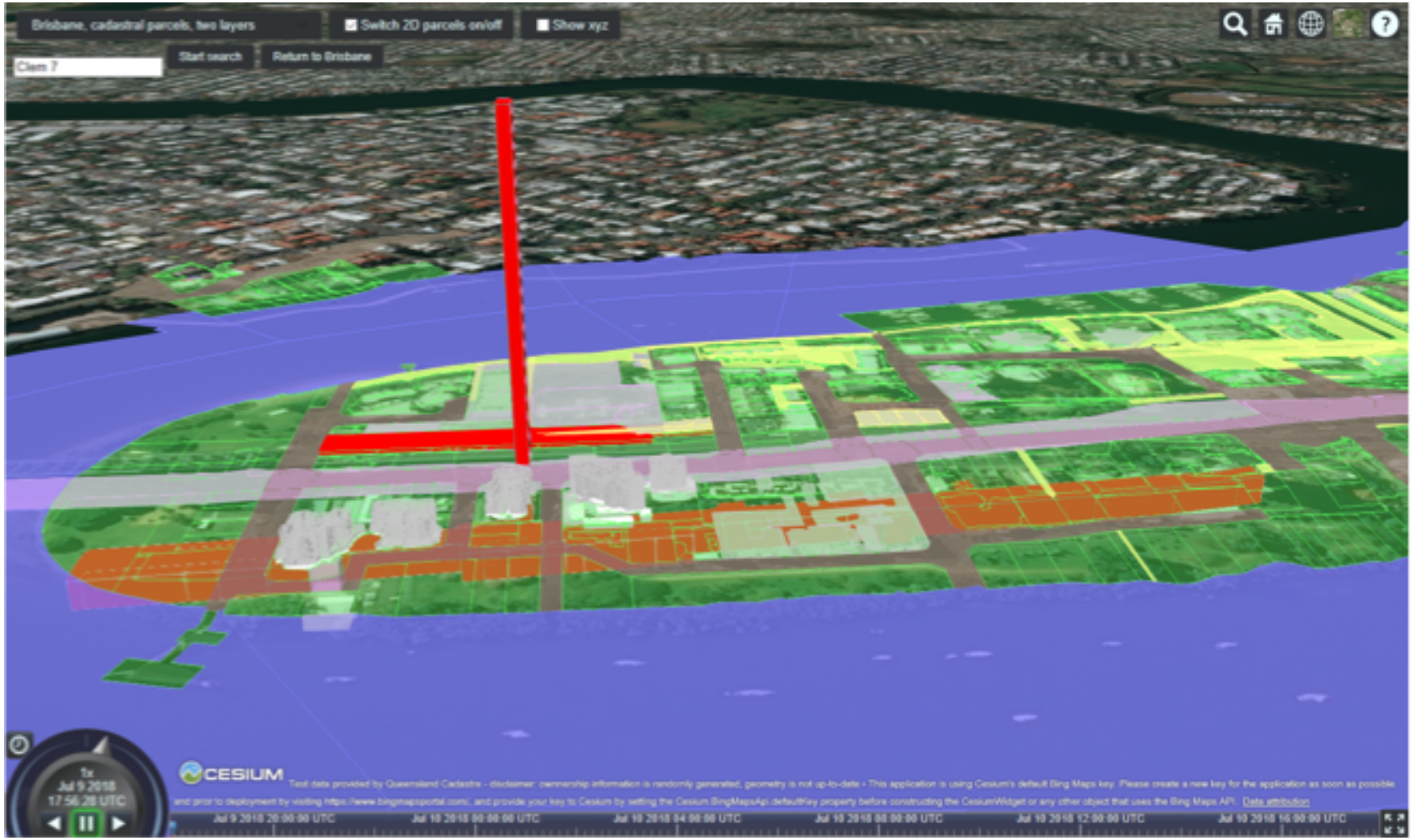

Object search on administrative data



Object search on administrative data: WFS request/response

http://pakhuis.tudelft.nl:8088/geoserver/geoweb/ows?service=WFS&version=1.1.0&request=GetFeature&outputFormat=application/json&typeName=geoweb:v_parcel_owned_by&propertyName=objectid,segment_nr,parcel_nr&cql_filter=partyname like '%Clem 7%'


```
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        }
    },
    ...
    ...
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        "properties": {
            "objectid": 4679900,
            "segment_nr": 25159,
            "parcel_nr": 262
        }
    }],
    "crs": null
}
```

Summary of the requirements included in the prototype – 3D visualization

- *Navigation tools and view controls*
- *Tooltip*
- *Integration of topography* (i.e. a DTM)
- *Transparency*
- *Object selection and highlight*
- Object search, to check which parcels are owned by a certain person.
- ***Dynamic elevation tool,*** to solve the problem of subsurface visualization
- ***Camera start-up position,*** implemented to set the initial position of the camera at the start up of the viewer.

Summary of the requirements included in the prototype – Web viewer

- *Platform and browser independence*, thanks to the WebGL technology
- *Layers control*, although it is not possible for the user to add his own layers and modify the existing ones.
- *Support for topographic visualization*, from a technological point of view
- *Support for geo-referencing*, thanks to the virtual globe technology
- *Underground visualization*, is now possible as a result of the vertical shifting of the parcels
- *Open source platform*
- *Possibility for the platform to be extended*

Presentation outline

- Introduction
- Related work
- Scope and research questions
- Methodology
- Tools
- Datasets
- Implementation of the 3D cadastre prototype
- Usability test
- Future work

Usability testing

Four main phases to carry out the usability test for the 3D cadastre prototype:

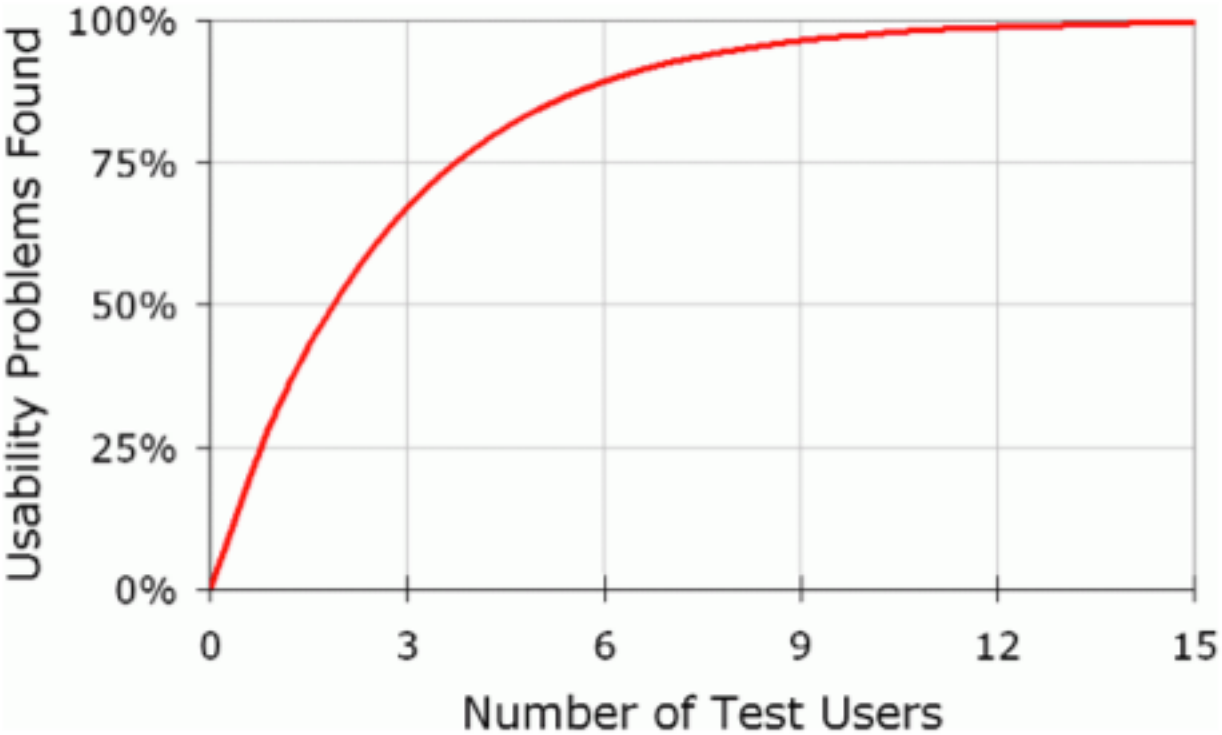
1. Recruiting users
2. Define goals and tasks to be performed
3. Create a questionnaire
4. Process results and obtain feedback

Recruiting users

Possible **user groups** of the 3D cadastre prototype:

- Researchers in the field of 2D and 3D cadastre (including staff of the MSc Geomatics for the Built Environment);
- Students of Geomatics for the Built Environment at TU Delft;
- Professionals using cadastral applications (lawyers, notaries, engineers, architects, land surveyors, building managers etc.);
- Managers in the government and municipal authorities responsible for the maintenance of the land administration system;
- Public and private entities, companies;
- General public, citizens.

Recruiting users



Each additional test person provides a diminishing added value

About 5 users are enough to spot 80% of the issues.

Define goals..

The main **goal** is to ensure the **usability** of the prototype, which means that it *must*:

- be useful to the target users;
- help users to be effective and efficient in performing their tasks;
- be easy (or even satisfying) to learn/use;
- eliminate issues and frustration for the users.

..and tasks to be performed

1. Navigate through the viewer, pan, zoom and rotate view to get familiar with the controls.

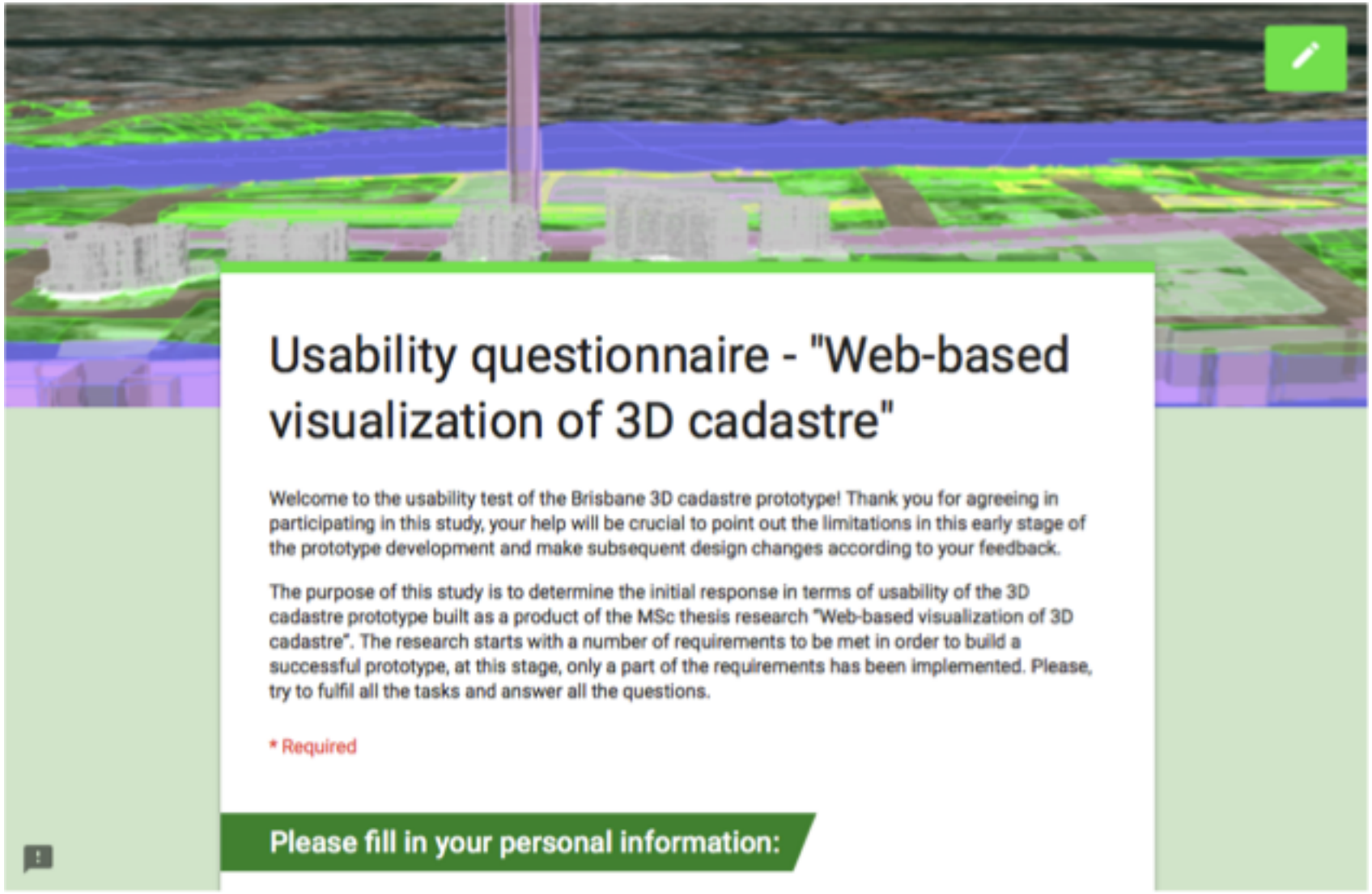
2. Change the visibility of the layers.

3. Visualize an underground parcel, i.e. zoom close enough to see the details and navigate around it to see the boundaries from every angle.

4. Visualize information about a single parcel, i.e. ownership information, and unit/lot/plan number, etc.

5. Search for a single owner and visualize all the parcels owned by that person.

Questionnaire



Usability questionnaire - "Web-based visualization of 3D cadastre"

Welcome to the usability test of the Brisbane 3D cadastre prototype! Thank you for agreeing in participating in this study, your help will be crucial to point out the limitations in this early stage of the prototype development and make subsequent design changes according to your feedback.

The purpose of this study is to determine the initial response in terms of usability of the 3D cadastre prototype built as a product of the MSc thesis research "Web-based visualization of 3D cadastre". The research starts with a number of requirements to be met in order to build a successful prototype, at this stage, only a part of the requirements has been implemented. Please, try to fulfil all the tasks and answer all the questions.

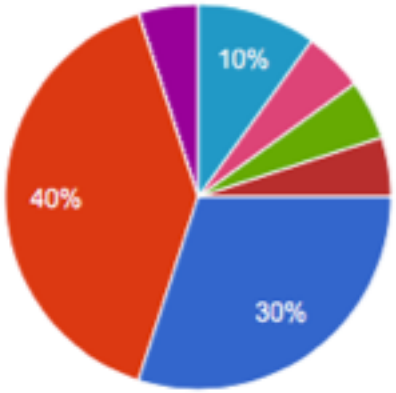
* Required

Please fill in your personal information:

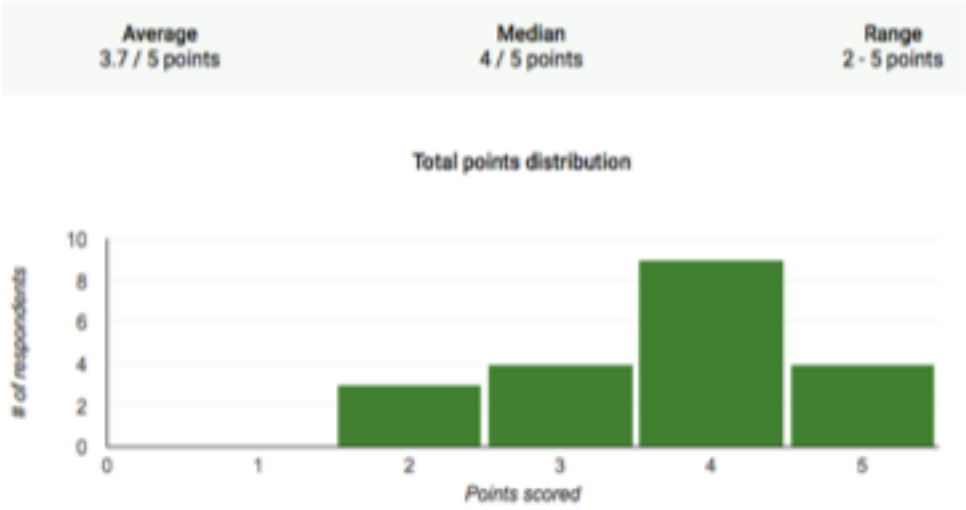
Results of the usability test

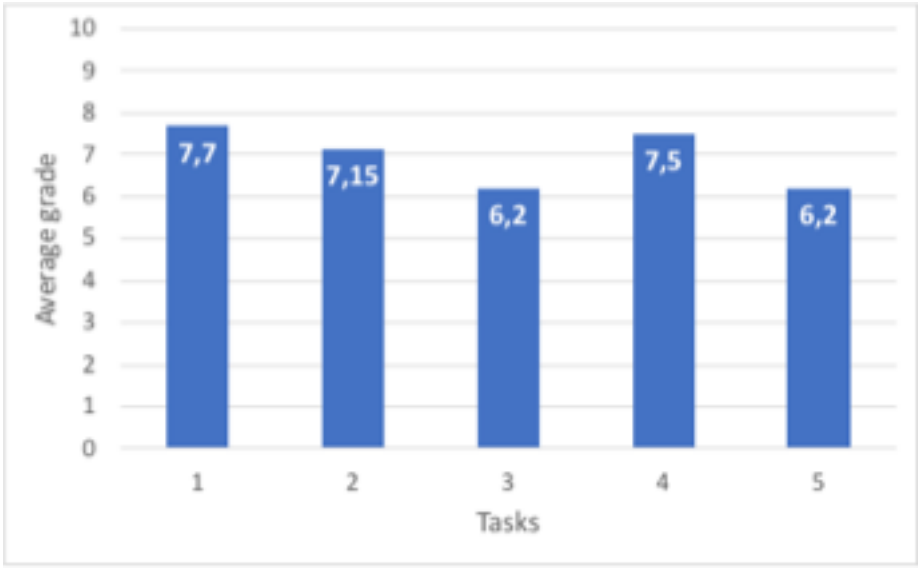
20 test users responded

to the questionnaire!



- Researchers in the field of 2D and 3D cadastre (including staff of the MSc...
- Students of Geomatics for the Built...
- Professionals using cadastral applic...
- Managers in the government and m...
- Public and private entities, compani...
- General public, citizens;
- Student Delft
- PhD student in Information Technol...
- Phd student with geomatic master d...





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Results of the usability test

Criticisms and suggestions for improvement:

1. **Dynamic elevation tool** (the two different layers are confusing and "Show XYZ" button is buggy)
2. **Object search** on administrative data (viewer does not zoom to the selected parcels and two search boxes are confusing)
3. **Speed** (during load and select/highlight)

Most appreciated functionalities:

1. Possibility to **get administrative information** from the parcel selected
2. Possibility to **visualize underground parcels** (although the functionality needs to be improved)
3. **Object search** (although needs to be improved)

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Future work

- Refinement of the **dynamic elevation tool**
- Refinement of the **highlight functionality** (maybe using B3DM)
- Refinement of the **object selection concept: the active set**
- Integration of real **administrative data (RRRs and persons/parties)**
- Towards **XML(KML) structured 3D survey plans**, so it will be possible to skip the encoding process
- Continue with the implementation of the **other requirements** (starting from the ones in the orange list).
- Carry out a **formal usability test**


Thanks for your attention!