A digital twin based on Land Administration

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Who are the 3D LA users and what do they want?

Users are interested in **apartment** building and its surrounding

- Buyers can see the exact location of the apartment building, including surrounding green spaces and the distance to neighboring structures. This easy information access will support buyers' purchasing decisions

- Notaries use 3D models to examine property parcel's boundary and adjacent areas in detail, ensuring the accuracy of legal documents during real estate transactions

- Investors evaluate the potential for property appreciation by analyzing the nearby facilities, influencing their decision to purchase the property

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Digital Twin and 3D Land Administration

Digital twin improves the visualization and understanding of the complexities in 3D Land Administration via 3D models, updated information, decision support…

Missing functionally in earlier reported 3D LA work (next to fine functionality: 3D pan, zoom, rotate, selecting objects, slicing, select floor, underground, query by name,…):

1. Switch on/off physical objects to provide reference for legal spaces in a building (and surrounding buildings in a lower detail, depending on distance)

2. Next to spatial information also core administrative information of selected entities (in form of a LADM instance level diagram/ graph)

3. Support real time changes: directly show updates of administrative information, show daylight situation at different dates and times
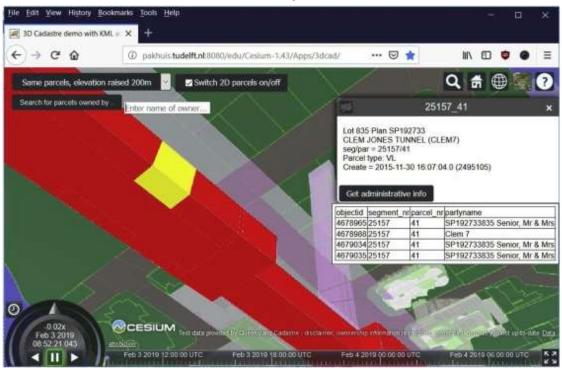
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Related work

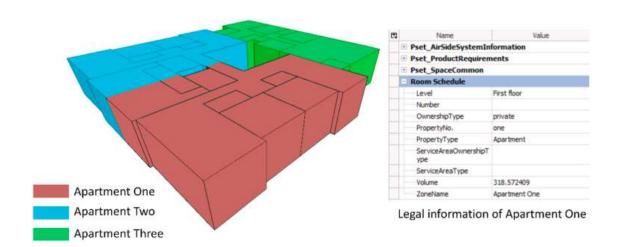3D Land Administration Prototype Brisbane, Queensland

- 3D building data is mainly extracted and constructed from survey plans (in **PDF or TIFF** files) and stored in LADM database

- Legal/ administrative information is presented in **table** form in 3D web user interface

Cemellini, et al. (2020)

Related work

Modelling building ownership boundaries within BIM environment

Legal information of Apartment One

- Apartment One
- Apartment Two
- Apartment Three

- 3D building data is **IFC files**

- Enrich IFC for each building unit with closed space and identifier (user defined properties)

- Converted geometry from IFC into PostgreSQL/LADM database

Alattas, et al. (2021)

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Related work

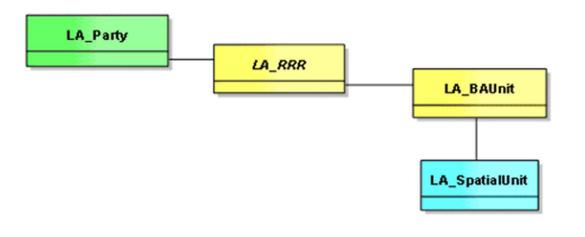BIM Legal Prototype by Dutch Notaries

https://bpd2.ogdb.nl/bpd/project/9531/landgoed-hoevesteijn

- Provide 2 modes, physical space and legal space

- LADM is not considered

- Surrounding information is not considered

Methodology: LADM

Lemmen, C. (2012).

The Land Administration Domain Model (LADM, ISO 19152) is a conceptual model focused on the legal and geographical aspects of land administration

It provides packages that describe the framework of land administration

The three main packages of LADM are the Party Package (green), the Legal/Administrative Package (yellow), and the Spatial Unit Package (blue)

Methodology: Digital Twin

A digital twin is a virtual 3D representation of real-world asset(s) that includes both static and dynamic data

- Dynamically update real-time basic property information and legal information

- Sunlight simulation

- Enhances decision-making processes

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Methodology: Virtual Globes

With the development of 3D web-based applications, virtual globes have emerged as a new medium for visualizing and interacting with geographic data

Several WebGL-based virtual globes have been developed to facilitate cross-platform and cross-browser applications, including Cesium

Cesium is an open-source JavaScript library that enables the creation of 3D virtual globes and 2D maps in web browsers
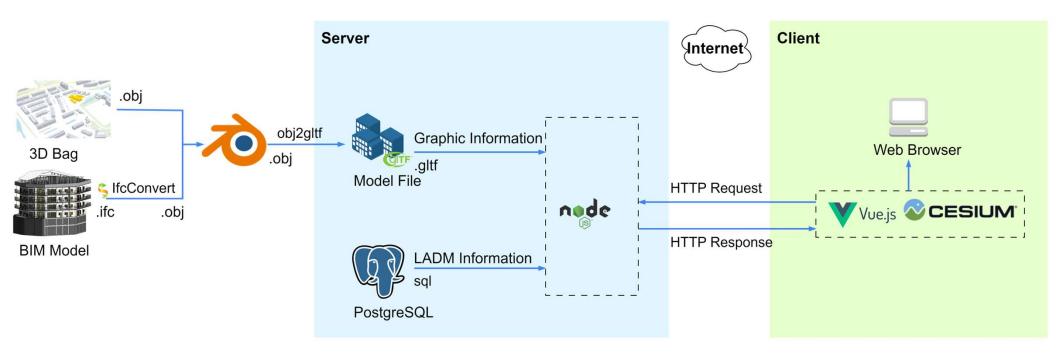
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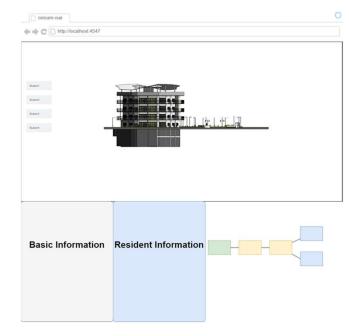
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System Architecture

Prototype Design

Step 1 : LADM Database and Data Preparation

Step 2 : User Interface Development
The user interface was developed using Vue.js and Cesium
to provide an interactive and intuitive experience for users

Step 3 : Webserver Development
The backend of the system was developed using Node.js,
handling data requests and serving as the intermediary
between the frontend and PostgreSQL database and file

Step 4 : Testing

- ✓ Component Verification: Test each system component for correctness and functionality.
- ✓ Meetings to gather feedback and make necessary adjustments to improve usability and functionality.
- ✓ Usability testing: Test if users can complete tasks and evaluate their satisfaction

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Information Flow

Integrate the LADM information from the database with the 3D models

1. Load Models and Set IDs:
assign a unique ID to each 3D model and bind a click event. When the
user clicks on a model, the ID of the selected model can be obtained.

2. Basic information in .json file
Store the basic information of the properties in a JSON file, each
information has a unique ID corresponding to the model ID

3. LADM Info
When loading
access option


```
axios.post("http://localhost:4547/query/queryall", {sql: sqlString.t_apartment}).then(res => {
  if (res.status === 200) {
    this.transformData(res.data.rows).then(res=>{
      let relationship_Building = this.categorizeToNameWithMap(res,"Apartment_id");
      let relationship_Name = this.categorizeToNameWithMap(res,"Party_name");
      // console.log("relationship_Building",relationship_Building)
      // console.log("relationship_Name",relationship_Name)
      this.$bus.emit("graph-data-send-ok", [relationship_Building,relationship_Name]);
      setTimeout(()=>{
        loading.close();
      },3000);
    })
  }
})
```

LA_RRR:right05
LA_RightType:Ownership
share:1/1
beginLifespanVersion:20150219,09:16
endLifespanVersion:99999999,23:59

LA_BAUnit
uID:005
beginLifespanVersion:20150219,09:16
endLifespanVersion:99999999,23:59

LA_SpatialUnit:apartment103
suID:010007
area:111
dimension:3D

LA_Party: Jack
Party_id: 03
LA_PartyType:naturalPerson
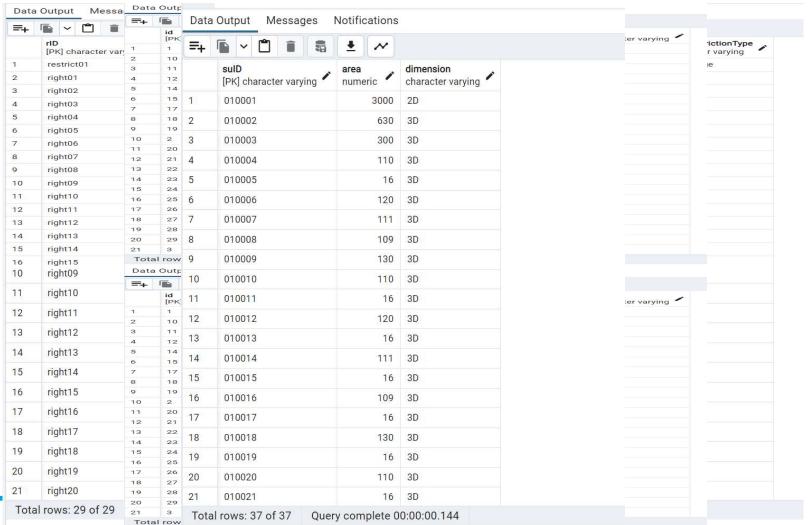
LA_RRR:right06
LA_RightType:Ownership
share:1/1
beginLifespanVersion:20160105,12:41
endLifespanVersion:99999999,23:59

LA_BAUnit
uID:006
beginLifespanVersion:20160105,12:41
endLifespanVersion:99999999,23:59

LA_SpatialUnit:apartment104
suID:010008
area:109
dimension:3D

LA_RRR:right07
LA_RightType:Ownership
share:1/1
beginLifespanVersion:20170415,14:32
endLifespanVersion:99999999,23:59

LA_BAUnit
uID:007
beginLifespanVersion:20170415,14:32
endLifespanVersion:99999999,23:59

LA_SpatialUnit:apartment105
suID:010009
area:130
dimension:3D

LA_Party: Sophia
Party_id: 04
LA_PartyType:naturalPerson

LA_RRR:right08
LA_RightType:Lease
share:1/1
beginLifespanVersion:20170901,09:00
endLifespanVersion:20190901,23:59

LA_Party: Mia
Party_id: 05
LA_PartyType:naturalPerson

LA_RRR:right09
LA_RightType:Lease
share:1/1
beginLifespanVersion:20180601,09:00
endLifespanVersion:20190901,23:59

LA_Party: Ella
Party_id: 05
LA_PartyType:naturalPerson

LA_RRR:right10
LA_RightType:Lease
share:1/1
beginLifespanVersion:20180601,09:00
endLifespanVersion:20190901,23:59

Database

System Functions

3D LAND ADMINISTRATION SYSTEM

Scenario Visualization
- IFC Model Visualization
- Adaptive LOD
- Dynamic Slicing View
- Sunlight Simulation
- Floor Visibility Control
- Basemap Switch

Land Adminstration
- Legal Space Model
- LADM Diagram
- Basic Property Imformation
- Underground Space

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Load BIM Models
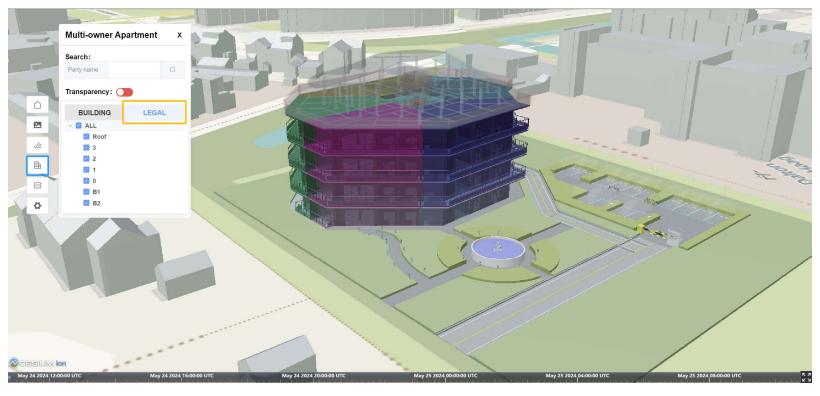
3D Physical Model   Clarify the physical structure of the building

Show legal spaces

3D Legal Model

Clarify property boundaries and apartment rights

3D Surrounding Building Model Switch

This function allows users to control and switch between different Levels of Detail (LOD). Users can toggle the visibility of various LOD models to view the building at different detail levels based on their preferences
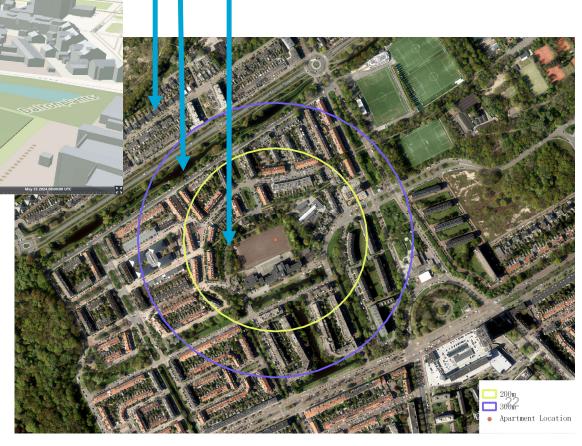
3D Adaptive Building Model Switch

LOD1.2
LOD1.3
LOD2.2

- Within 200 meters: Displays the highest level of detail
- Between 200m and 300m: Displays a moderate level of detail
- Beyond 300m: Uses a simplified model

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200m
300m
Apartment Location

Floor Visibility Control

This function allows users to control the visibility of different floors in a multi-storey building model. Users can toggle between viewing the entire building, specific floors based on their preferences

Sunlight Simulation

Follow system time

This function allows users to dynamically view the effects of sunlight at different times of the day, thereby enhancing decision-making

Sunlight Simulation

User can select time

- It helps architects evaluate overall sunlight exposure and potential shading from surrounding structures to optimize building designs
- It helps potential apartment buyers make purchasing decisions based on property lighting conditions

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Dynamic Slicing View

This function enhances 3D cadastral visualization, allowing users to interactively slice through multi-story buildings and view cross-sections from a vertical perspective

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Dynamic Slicing View

Overlay effect showing selected floor

Visualizing underground space

Turn on the 'transparency' button
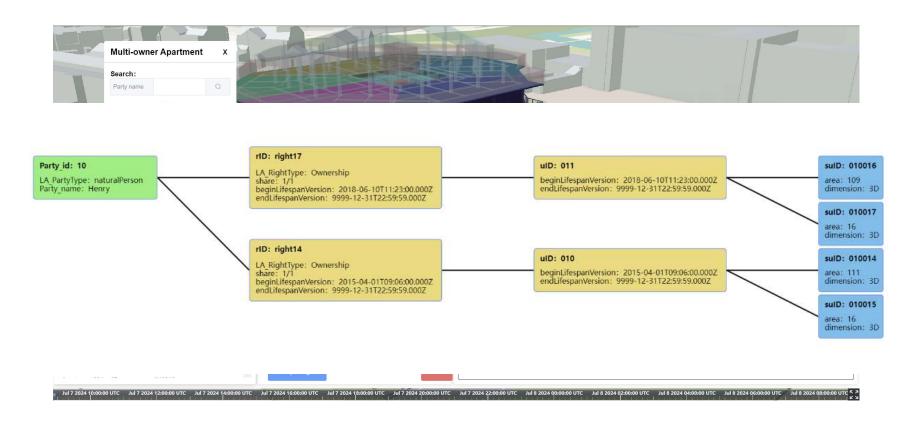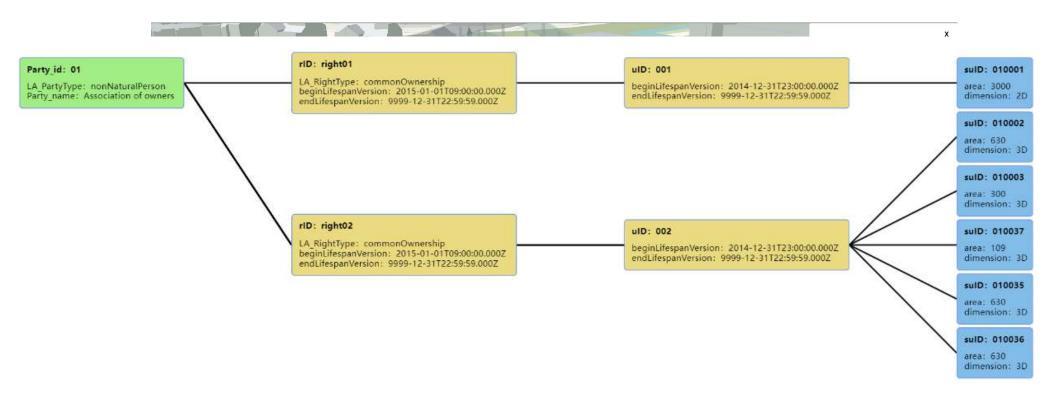
- This feature overcomes the limitation of 2D cadastral maps that hide underground information
- It provides users with a more intuitive and clearer view of underground space, allowing them to view underground garages, utilities, etc.
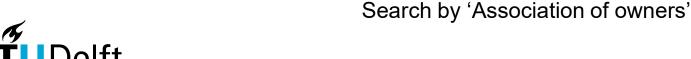
LADM Data Display: Spatial Query by Click on Apartment

LADM Data Display: Textual Query by Party Name

Search by 'Association of owners'

AntV G6 Graph Visualization Engine
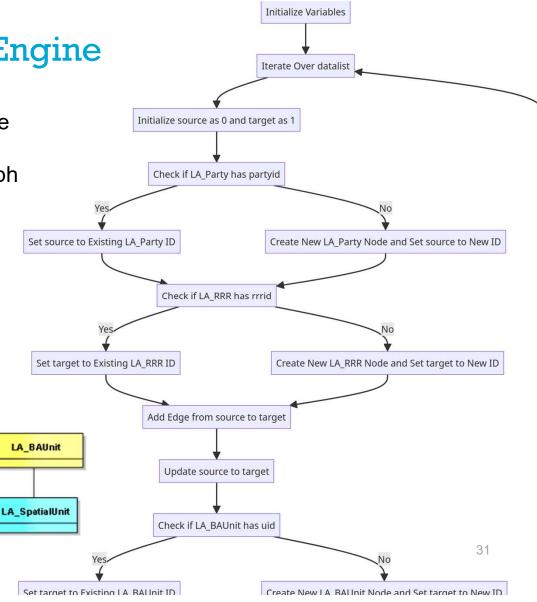
This method is designed to convert the data to the nodes and edges format required by AntV G6, in order to meet the specifications of the LADM graph

- Adds nodes sequentially in the order of LA_Party, LA_RRR, LA_BAUnit, and LA_SpatialUnit based on LADM
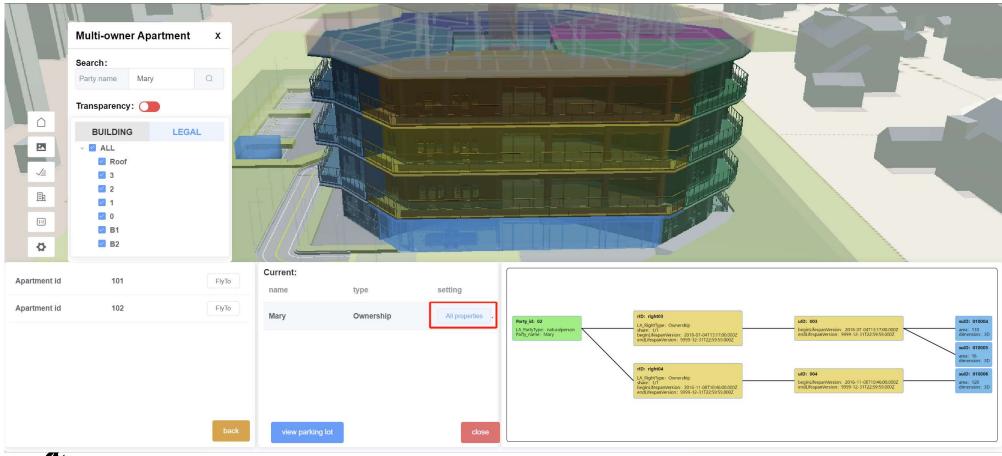
- Add edge: Specifies the source and target for each edge to ensure the correct relationships between nodes

http://g6-v3-2.antv.vision

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Flowchart:
- Initialize Variables
- Iterate Over datalist
- Initialize source as 0 and target as 1
- Check if LA_Party has partyid
  - Yes → Set source to Existing LA_Party ID
  - No → Create New LA_Party Node and Set source to New ID
- Check if LA_RRR has rrrid
  - Yes → Set target to Existing LA_RRR ID
  - No → Create New LA_RRR Node and Set target to New ID
- Add Edge from source to target
- Update source to target
- Check if LA_BAUnit has uid
  - Yes → Set target to Existing LA_BAUnit ID
  - No → Create New LA_BAUnit Node and Set target to New ID

Node diagram:
- LA_Party
- LA_RRR
- LA_BAUnit
- LA_SpatialUnit

Search by Party Name (Result Apartment and Carpark)

Search by Owner Name 'Mary'
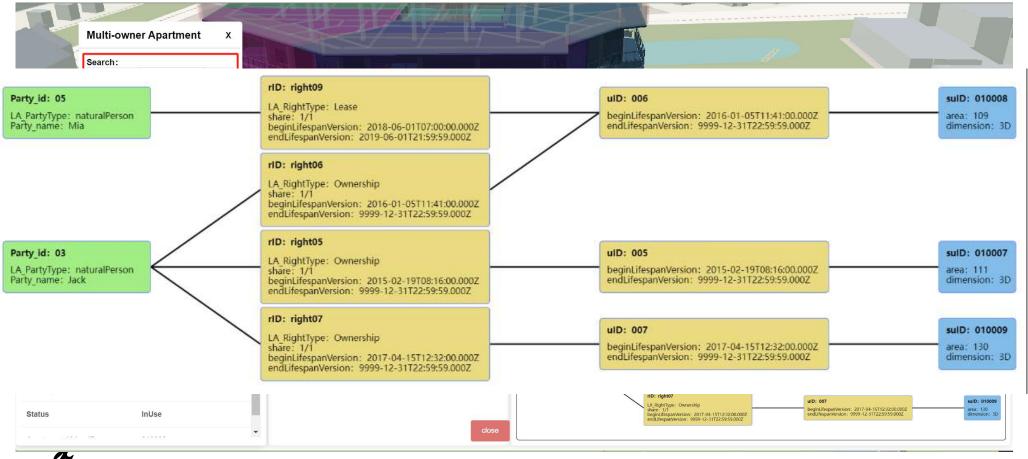
Search Result Multiple Owners

Search by Tenant Name 'Sophia'

Search by Apartment Identification

Search by Apartment ID '303'

Search Showing Both Current And Previous Information

Multi-owner Apartment   X

Search:
[Apartment id] 🔍

Transparency: 🔴⬜

Party_id: 18
LA_PartyType: naturalPerson
Party_name: Jessica

rID: right23
LA_RightType: Ownership
share: 1/1
beginLifespanVersion: 2021-08-01T12:04:00.000Z
endLifespanVersion: 9999-12-31T22:59:59.000Z

uID: 016
beginLifespanVersion: 2021-08-01T12:04:00.000Z
endLifespanVersion: 9999-12-31T22:59:59.000Z

suID: 010024
area: 120
dimension: 3D

Party_id: 17
LA_PartyType: naturalPerson
Party_name: Lucas

rID: right22
LA_RightType: Ownership
share: 1/1
beginLifespanVersion: 2015-04-03T06:29:00.000Z
endLifespanVersion: 2021-08-01T12:04:00.000Z

uID: 015
beginLifespanVersion: 2015-04-03T06:29:00.000Z
endLifespanVersion: 2021-08-01T12:04:00.000Z

suID: 010025
area: 16
dimension: 3D

Area living room	109
SpaceType	Private
Balcony	Yes
Status	InUse

Previous:

name	type	setting
Lucas	Ownership	All properties

[view parking lot]   [close]

Display the previous owner's information

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Content

1. Related Work

2. Prototype Development

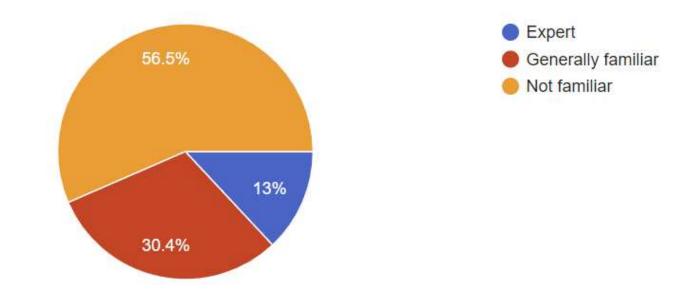3. Functionality Overview

4. **Usability Testing**

5. Conclusion and Future Work
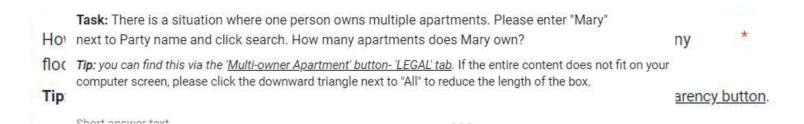
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Usability testing

A total of 23 participants took part in the usability testing after invitation send to the FIG WG LADM and 3D LA members (June 2024)

The results show varying levels of familiarity with the contents of LADM:

Legend:
- Expert
- Generally familiar
- Not familiar

56.5%
30.4%
13%

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Instructions and Responses via Google Form

Task: There is a situation where one person owns multiple apartments. Please enter "Mary"
next to Party name and click search. How many apartments does Mary own?

Tip: you can find this via the 'Multi-owner Apartment' button- 'LEGAL' tab. If the entire content does not fit on your
computer screen, please click the downward triangle next to "All" to reduce the length of the box.

Short answer text

If this digital twin system were to be redesigned, what features would you suggest? Please
provide your suggestions for redesigning or enhancing the system.

Detailed answer text

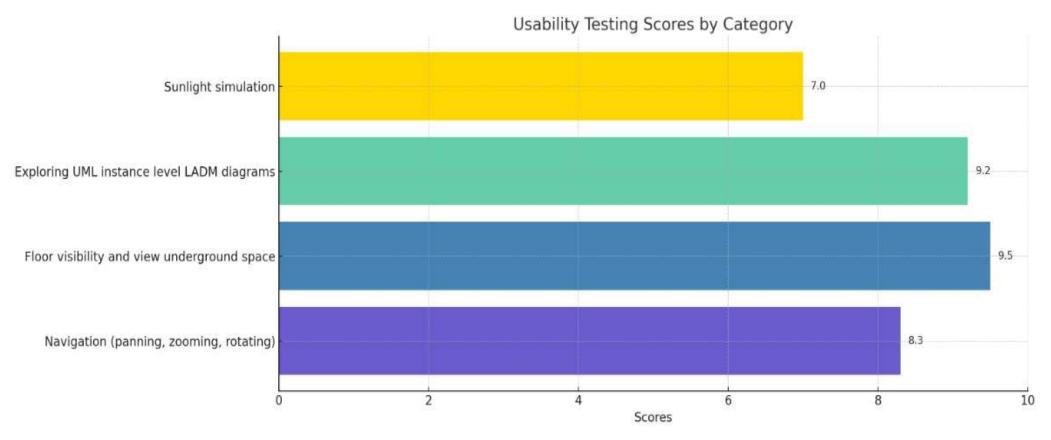**Task:** In which year did Lucas sell his apartment? *

Short answer text

Task: What is the RRR type for a bank? *

Tip: Please search for 'Bank' in the Party name field.

Usability Testing, Functionality Rated by Users

Usability Testing Scores by Category

- Sunlight simulation — 7.0
- Exploring UML instance level LADM diagrams — 9.2
- Floor visibility and view underground space — 9.5
- Navigation (panning, zooming, rotating) — 8.3

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User Feedback and Suggestions

- Timeline:
  Prefer a time slider over a time selector for timeline

- Search Function:
  Enable the Enter key for search functionality in addition to the search icon;
  Add prompts about case sensitivity in searches; A general search bar

- Additional 3D objects with legal spaces:
  Incorporate more types of 3D RRRs, such as: Tunnels, Airspace, Mining rights

- First-person view:
  Add a first-person view to navigate inside buildings

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1. Related Work

2. Prototype Development

3. Functionality Overview

4. Usability Testing

5. **Conclusion and Future Work**

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Conclusion

This study developed a multifunctional 3D Land Administration System

The most significant feature of this system is that it provides UML instance level LADM diagram in a clearer way, and can explore the building and the surroundings with adaptive LoD according to distance

The research utilizes BIM models in IFC format as spatial data input, the LADM data is store in a DBMS and employs Cesium create 3D geospatial application and web-based visualization, allowing for a broader user experience

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view building in 3D

https://www.gdmc.nl/LADM3Dview/

Future Work

1. Address the challenges of complex real-world legal data, beyond the hypothetical data used in this study

2. Explore the inclusion of graphic data directly within the database

3. Explore more 3D legal spaces such as air rights, underground utilities, and mining concessions

4. Extend the system to include valuation and spatial plan

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References

3D sales viewer url: https://bpd2.ogdb.nl/bpd/project/9531/landgoed-hoevesteijn

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Cemellini, B., van Oosterom, P., Thompson, R., & de Vries, M. (2020). Design, development and usability testing of an LADM compliant 3D Cadastral prototype system. Land use policy, 98, 104418.

Stoter, J., Ploeger, H., Roes, R., van der Riet, E., Biljecki, F., Ledoux, H., ... & Kim, S. (2017). Registration of multi-level property rights in 3D in the Netherlands: Two cases and next steps in further implementation. ISPRS International Journal of Geo-Information, 6(6), 158.

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