BHUMI: Jurnal Agraria dan Pertanahan
Received: November 21, 2018; Reviewed: November 8, 2018; Accepted: December 11, 2018

To cite this article: Sulistyawati, MN, Trias Aditya, Purnama B. Santoso 2018, 'The implementation of LADM versionedobject class for representing spatio-temporal of cadastre 4D objects', *Bhumi, Jurnal Agraria dan Pertanahan*, vol. 4, no. 2, Nov. hlm. 249-265.

DOI: http://dx.doi.org/10.31292/jb.v4i2.281

THE IMPLEMENTATION OF LADM VERSIONED-OBJECT CLASS FOR REPRESENTING SPATIO-TEMPORAL OF CADASTRE 4D OBJECTS

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Abstract: Spatial representations and ownerships of 3D properties change over time. Changes are recorded as historical data of transactions, adding the dimension of 3D spatial data into 4D data, known as Cadastre 4D. Spatial representations of 3D properties are prone to disputes when the shape and dimensions representing ownership changes do not match with the reality. This paper focuses in assessing visualizations of 4D cadastre objects applying Versioned-Object class stated in the International Standard of Land Administration Domain Model (ISO 19152:2012). Based on the analysis on the current strata title ownership registration implemented in Indonesia's land Information System (known as KKP), a model of 4D spatial data that fits to the administration system in Indonesia was developed. Visualization of 4D cadastre objects applied in this research is suited to VersionedObject class LADM and presented on the web to represent changes of 3D geometry boundaries over time.
Keywords: Cadastre 3D and 4D, VersionedObject, LADM, data presentation, land information system

Intisari: Penyajian spasial dan kepemilikan properti 3D mengalami perubahan dari waktu ke waktu. Perubahan dicatat sebagai data historis transaksi, dengan menambahkan dimensi data spasial 3D ke dalam data 4D, yang dikenal sebagai Kadaster 4D. Representasi spasial properti 3D rentan terhadap sengketa ketika bentuk dan dimensi yang mewakili perubahan kepemilikan tidak sesuai dengan kenyataan. Paper ini berfokus pada visualisasi data spasial obyek kadaster 4D dengan menerapkan kelas VersionedObject LADM (ISO 19152:2012). Berdasarkan analisis pada pendaftaran kepemilikan atas satuan rumah susun terkini yang telah diterapkan di Sistem Informasi Tanah Indonesia (dikenal sebagai KKP), telah dikembangkan model data spasial 4D yang sesuai dengan sistem administrasi di Indonesia. Visualisasi objek kadaster 4D yang digunakan dalam penelitian ini sesuai dengan kelas *VersionedObject* LADM dan disajikan di web untuk mewakili perubahan batas geometri 3D dari waktu ke waktu.
Kata Kunci: Kadaster 3D dan 4D, VersionedObject, LADM, penyajian data, sistem informasi pertanahan

A. Introduction

Urbanization and population growth in urban area causes the shift from expanding the city towards developing vertically. Not only apartment developments, the massive developments of constructions and infrastructure above and below the ground as well as the increasing number of cable and pipe infrastructure signify the public awareness regarding rights, restrictions and responsibilities (3R) of 3D property and utility objects. Based on that situation and public awareness of the rights legitimacy for cadastre objects, the 3D cadastre concept has emerged (J E Stoter, Salzmann, & Molen, 2002).

The concept of modern cadastral systems, echoed as Cadastre 2014, is an updated concept of the conventional land registration system where the relationship of rights, restrictions and responsibilities (3R) of cadastre objects becomes structured and more transparent (FIG, 2014). Cadastre 2014 vision realizes the transparency and legality of cadastre objects, both in 2 dimensions, and 3 dimensions. In land information modelling, such relationships can be reached when Land Administration Domain Model (LADM) is applied as the reference in developing a land information system. Cadastre, deals with data and information representing land/space boundaries and its ownerships, becomes crucial to support the development of a reliable land information system. LADM, which comprises of five basic packages of LADM (Oosterom & Lemmen, 2015), is applicable to Indonesian context because the existing land administration system in Indonesia has been differentiated into five main packages (Sucaya, 2009).

All property objects (both in 2D and 3D) could change over the time. The changes including spatial changes, rights changes, ownership changes and so forth. Incomplete representations and their supporting documents of the changes would make the history unclear. The changes regarding spatial representations and ownerships occurs on the 3D cadastre objects should be recorded well to avoid disputes and fraud. The recorded information deals not only with 3D spatial changes (e.g., either splits or merging of 3D property), but also rights and ownership changes (i.e., data versioning on spatial units, rights-restrictions-responsibilities and parties).

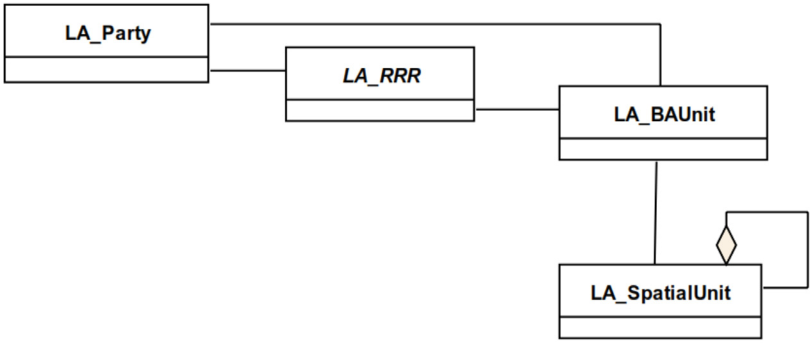
This paper presents the results of a research work dealing with the presentation of 4D cadastre objects. 3D cadastre objects (apartment) are presented in a 3 dimensional model above the earth model. On the model, the spatial changes (shape and position) of 3D cadastre objects can be presented over the time. The research work consists of four research activities. First activity was related to the evaluation of strata title ownership registration (*Hak Milik atas Satuan Rumah Susun – HMSRS*) through the official land information system, called KKP owned by Ministry of ATR / BPN. Secondly, identified and analyzed the implementation of VersionedObject in the LADM reference model. Versioned-object class can be implemented to manage and to present cadastre data history. Thirdly, reviewed the existing 4D cadastre object presentation model. Finally, the research produced a prototype to visualize a model of 4D cadastre object on the web applying LADM and Versioned-object class.

B. LADM dan Versioned-object Class

LADM is a standard model that can be used as a reference for a modern land information system. LADM is accepted as the ISO in 2012, known as ISO:19152. This reference model is built as object-based diagrams, namely UML (Unified Modeling Language). There are five packages on LADM: parties, RRR (Rights, Restriction, Responsibility), spatial units (geometry of cadastre objects), spatial references (surveying) and presentation of cadastre geospatial data. Each of these packages represents an important component of land administration and interconnected activities. The UML of LADM is simplified into 4 classes, namely LA_Party, LA_RRR, LA_Spatial Unit and LA_BA Unit (ISO 19152, 2012). The relationship between the four classes is illustrated in the UML diagram shown in Figure 1. LADM can show the complete legal situation of cadastre objects, including public rights and restrictions. LADM also integrates important data such as owners and spatial units, which are linked to the ownership right of a cadastre object.

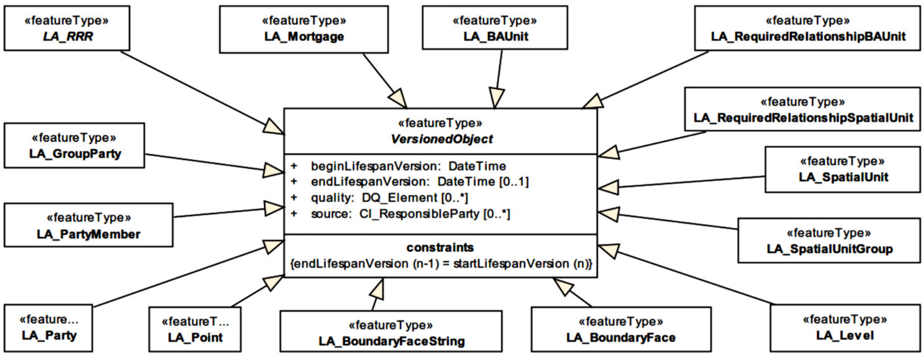
The importance of the temporal dimension is to trace changes of property objects. The element of version or object history in LADM is shown in the VersionedObject class. The VersionedObject class is added to LADM to manage and maintain history data in the database. The VersionedObject class connects with all classes and subclasses in LADM because all classes have a change history. The relation between the VersionedObject class with other classes is depicted in UML in Figure 2.

Figure 1. UML of 4 packages LADM relationship (ISO 19152, 2012)



Source: ISO 19152 2012, *The Land Administration Domain Model*, 2012

Figure 2. UML of relation between class VersionedObject with other classes



Source: ISO 19152 – *the Land Administration Domain Model.* (2012)

C. 4D Cadastre Object

Each cadastre object could experience changes with regard to either spatial or textual data from time to time. Temporal dimension elements should be considered in the representation of cadastre objects (Lemmen, 2012). The changes that occur on the cadastre object are recorded in the history. The awareness on the importance of the data history for 3D property objects raises the concept of 4D Cadastre.

In regard to the importance of 4D Cadastre, as stated in Döner et al (2011) land and property are "always, at least implicitly, related to a certain amount of (3D) space and spans a certain amount of time (3D + time, or 4D)". 4D Cadastre is the concept dealing with the management of 2D and 3D cadastre objects along with its legal data and constraints that are recorded over time. The 4D cadastre rule is both not overlapped and no gaps in the history of cadastre object (Oosterom, Ploeger, Stoter, Thompson, & Lemmen, 2006). If the 4D cadastre rules can be fulfilled then the dispute over the cadastre object can be avoided and the reliability of the data will be increased. The 4D cadastre object consists of 2D and 3D spatial units equipped with their corresponding legal and spatial changes history. The 3D spatial units represent any units within the building complex located above or below a parcel. In the past, this 3D spatial unit can only be owned by a party that has an ownership right. Now, the building can be divided into rights corresponding to rooms or part of rooms, as implemented in the ownership of apartment (i.e., strata title).

In regard to common rights of the building in 3D property registration, there can be several object or things commonly owned by a group of party. There are several things that can be shared on 3D cadastre objects (Jantine Esther Stoter, 2013), including:

1. Common parcel

   The common parcel is a parcel which is used together and not separately on which the building containing apartment is built and is set with specific terms of building permit.

2. Shared parts
   The shared part is unseparated section in the unit intended for shared use between adjoining units. Shared parts include foundations, columns, beams, walls, floors, roofs, guttering, stairs, elevators, corridors, conduits, pipes, power grids, gas and telecommunications.
3. Shared objects
   Shared objects are objects on the apartment that is owned together and is intended for shared usage. Shared objects include meeting rooms, plants, landscaping, social facilities buildings, worship rooms, playgrounds and separated parking spaces or inside the building structure.

Each unit of 3D cadastre objects may have different rights that physically above or below a parcel surface. There can be three approaches to represent the relationship between 3D cadastre objects and their parcel (J E Stoter et al., 2002):

1. Full 3D
   The full 3D approach is a method in presenting 3D cadastre objects physically placed above or below ground as 3D models that uses topographic surface as references to present 3D properties as volumetric data.
2. Hybrid approach
   The hybrid approach is a method in presenting 3D cadastre objects physically placed above or below ground as simple 3D models that uses apartment/2D parcel map as the reference.
3. Link/tag approach
   The link / tag approach is a method in presenting 3D cadastre objects as presentations stored differently than 3D models and not overlaid. These representations of 3D cadastre objects are only connected either via a link or used as an attribute to 2D parcel map.

There can be two types of 3D models or 3D object definitions (Thompson & Oosterom, 2015), including:

1. The construction format (surface): defined entirely by the terms of construction that surrounds it. An example of the type of 3D visualization of the construction format is B-Rep (Boundary Representations).
2. The volume format (solid): defined solid geometrically. In this case, there is no wall construction that occupies the volume. An example could be an extraction of 2D object or the use of CSG (Constructive Solid Geometry).

D. Indonesian Land Information System (Komputerisasi Kantor Pertanahan/KKP)

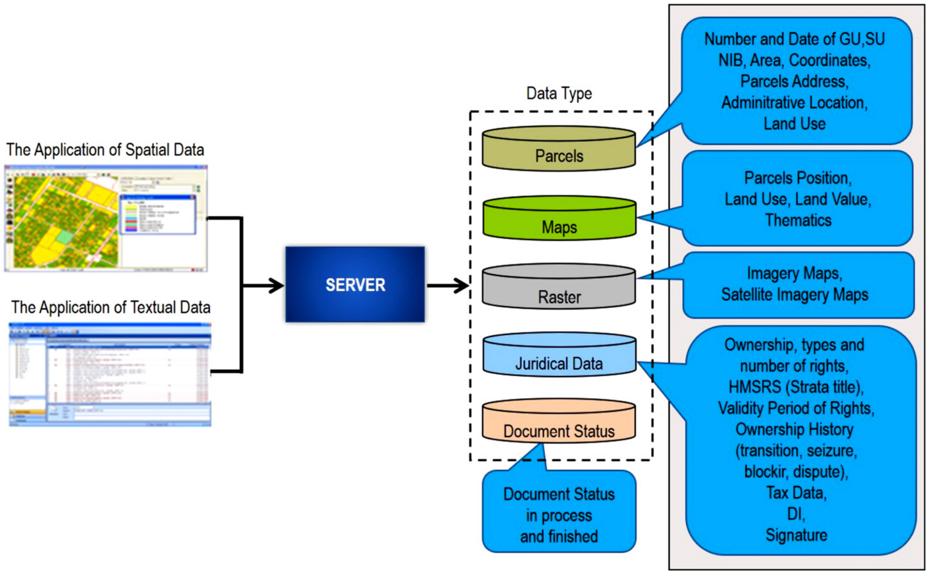
Indonesian Land Information System (Komputerisasi Kantor Pertanahan

KKP) is a desktop web-based information system that manage the land information and land transactions. Application and database of KKP adopt the LADM conceptual model as the core database structure. Figure 3 is presented the diagram of KKP database structure. In Figure 3, it can be seen that the KKP database has implemented 5 basic packages of LADM in managing land information, including the owner's subject; determination, restrictions and reliability of land information; spatial units (parcel geometry) and the spatial reference and presentation of land geospatial data. In addition to that, KKP also stores ownership history that it can be used to track the ownership history when a dispute occurs. This indicates that the KKP has also implemented the LADM Versioned-Object class.

In the data presentation, KKP could present data and information to users in regard to 5 basic packages of LADM. KKP presents information regarding the ownerships, RRR (especially rights). KKP presents the presentation of the spatial unit into a base map utilising a reference system that is called TM3°. Here, the history of spatial changes (2D polygons) and textual changes can be displayed on the KKP. The changes of parcels boundary are presented on the "registration map". Users can see the geometry changes that occur in a parcel. In addition to 2D cadastre object (parcel), KKP is now able to show attributes of 3D cadastre objects.

The application of 4D cadastre object in KKP is still limited due to KKP's constraint to represent 3D legal objects. The 3D cadastre object in the KKP system can only be displayed separately into 2D spatial and textual data. Registration of 3D condominium rights in Indonesia is possible in the current 2D system with the use of a 3D tag presentation method. Spaces, rights and textual data are stored and presented separately, linked only by specific numbers/codes (Aditya et al., 2009). 3D tag option as it is now implemented (based on the Law and Governmental Regulation) will indeed easily be implemented but has drawbacks on its sustainability to represent 3D geometries of 3D objects accurately. This can be important to avoid possible conflicts on the use of space below and over the parcels for apartment and 3D infrastructures. This condition makes it is difficult to present the history of cadastre spatial data. The presentation of historical spatial data is closely related to the presentation of historical textual data, so it will be better to present both data simultaneously.

Figure 3. Diagram of the KKP database structure



Source: Badan Pertanahan Nasional Republik Indonesia 2012, *Layanan Pertanahan,* BPN, Jakarta. (BPN RI, 2012)

In addition to above-mentioned constraints, 3D object components such as common parcel, shared objects, shared parts and private spaces, could not be presented individually on top of the map in the KKP system. The need for 3D spatial representation and history motivates this work to present the methods to store and present 3D and time changes on the map for property registration purposes.

E. 4D Modelling for spatial data presentation

This research aim to produce spatial data presentation of 4D cadastre objects. Modeling process starts with the analysis of the existing information system and literature study that it has been discussed in the preceding sections. Next, based on the results of the analysis of current national land registration system for 3D property, some constraints on 4D cadastre requirements (i.e. visualization of common and private rights including shared objects and shared parts over time) will be addressed by implementing VersionedObject class.

As discussed earlier, 3D Cadastre presentation can be in form of "full", "hybrid", or "link/tag" approach. The hybrid approach is chosen in this research because the availability of the current registration data are only 2D parcels without contour. As also mentioned previously in paper [1], the hybrid approach for 3D cadastre registration in Indonesia can be seen as the most suitable approach. This can be understood as the survey and mapping system of the cadastre system are currently still using 2D coordinate systems. Changes from 2D into volumetric (3D) data management will be burdening Land Office and users in terms of the complexities of data conversion, system migration as well as institutional and legal framework. By this premise, it is better to concentrate on land registration (2D parcels) while integrating 3D property registration in urban environments into the cadastre system. In this research, the construction format is chosen to show 3D objects including private space (i.e. apartment unit) and shared parts as well shared objects to be presented as 4D cadastre objects.

Steps of activities undertaken in this research include:

1. Preparation and collection of data
2. Data processing
3. Data visualization

The steps will be described as follow.

E.1. Preparation and Collection of Data

The case study in this paper is 3D apartment units of Gemawang (known as Rusunawa Gemawang). Rusunawa Gemawang is located in Sleman Regency, Yogyakarta Special Province. The data collected in this work include primary and secondary data. The primary data was the results of field survey of land boundaries and field validation of 3D units. The collection of secondary data include the compilation of floor plan and ownership data obtained from the management unit of Rusunawa Gemawang. Details of the data collected are presented in Table 1.

Table 1. Data used in the research

No.	Data	Data Source	Data Format
1	The map of Rusunawa Gemawang resulted from land survey done in 2015.	The land measurements have been collected by research team of Geodetic Engineering of UGM in 2015 (Heliani & Widjadjanti, 2015)	List of coordinates of building footprints of Rusunawa Gemawang (level 1-4) and sample points of 3D unit (X, Y and Z coordinates)
2	Common parcel (2D land boundary)	National Land Affairs Agency in Sleman District.	Shapefile (SHP)
3	Floor plan of Rusunawa Gemawang	The management of Rusunawa Gemawang	The book of floor plan Rusunawa Gemawang in 2009
4	Table of strata title unit's ownership.	The management of Rusunawa Gemawang	Table of strata title unit's ownership dan its history.

E.2. Data Processing

a. Spatial Data Digitazion

The coordinates of common parcel and building footprints, stored as X, Y, Z format, were plotted into the CAD software. The digitization was done to connect point boundaries of the building to form wall and floor surfaces as it is shown in the floor plan. The attribute entry related to description and strata title's unit ownerships was also done to all 3D units in Rusunawa Gemawang. The digitization was done using the 3D AutoCAD Map software. This CAD software is chosen as the software is commonly used by land surveyors and it has ability to facilitate various data format conversion.

The point and line boundaries form surface boundaries of 3D units. Coordinates are stored using TM 3° coordinate system. As the Rusunawa is located in Sleman Regency, the coordinate system is set to DGN'95 TM 3° zone 49.1. In map canvas in the AutoCAD Map, 2D parcel and 3D units are drawn from this survey coordinates. The concept of boundary representation (B-Rep) for 3D model development is applied here as this approach is suitable to build surface-based 3D models to represent individual apartment units. This surface-based 3D model is representing 2D and 3D spatial units with a reference to the floor plan and strata title description.

Each strata title unit is given with a unique code for easy identification and access. Such unique code is preceded with label C and level number; C2-1 to C2-16 for 2nd floor, C3-1 to C3-16 for 3rd floor and C4-1 to C4-16 for 4th floor. Each apartment unit is stored in a different AutoCAD data layer. In each of these layers, the 3D spatial unit consists of 6 polygons or surfaces. In the subsequent stage, the shape of polygons were converted as geometries in the database following simple feature access – SQL Option (ISO19125-2).

b. Textual Data Entry of Ownership of Apartment Units

Textual data related to ownerships of the units of strata title and their corresponding transfer history were collected from the management unit of apartment. This data can be seen as legal information related to use of apartment units. The owner change history is also important information to show a modified version of 3D property. As the ownership data was given in a printed form, hence the textual data entry was done. For this purposes, strata title information was inputted and stored as MS.Excel format before converted into the database.

c. Design of 4D Cadastre Spatial Database

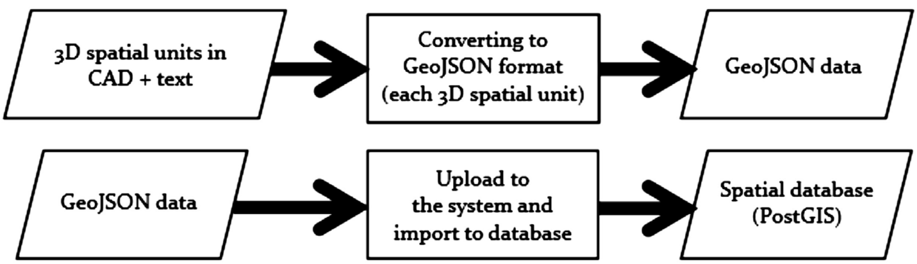
3D spatial units of apartment and their history were stored as tables in PostGIS spatial databases. The tables with geometries were designed in accordance to LADM and VersionedObject class. The data that are stored in PostGIS include:

1. Spatial:
   a. 2D common parcel
   b. 3D spatial units
      i. Spaces faces
      ii. Private unit (strata title)
      iii. Shared parts
      iv. Shared objects
      v. Spaces (combined several faces of the space)

   c. Utility network (optional)
   d. Administrative area (province, city/district, sub district, village)
2. Rights: type of rights, number of rights, book of land, history
3. Parties (owner): number of id card (*nomor KTP*), name, address, phone number, etc)
4. History of spasial and ownership data (versioning data)

Based on the results of the research that has been carried out, in general, the stages of spatial and textual data processing and storage into the database are presented in Figure 4.

Figure 4. The process of spatial and textual data storage in the database



Source: Data Processing, 2018

In regard to spatial data, the collection of 3D surfaces representing 3D spatial units in AutoCAD need to be converted as WKT (Well-Known Text), an SQL option to store 2D/3D spatial data as simple feature specification according to ISO:19125-2. In this work, GeoJSON is chosen as an intermediate format to ease data storage of 3D spatial units of apartment. (Page, 2015) states that GeoJSON is a WKT data format created in Javascript programming environment. Javascript files are known to be small and considerably light for data processing in the browser side. The GeoJSON can increase the effectiveness and efficiency of data storage on the server.

The process of converting CAD data into GeoJSON data was done by using the GDAL ogr2ogr tool. The GDAL ogr2ogr tool can be used to convert various data formats. In the conversion process, the desired data format (GeoJSON) is chosen, with the targeted geometry type is set to Multipolygon 3D and spatial reference system is set to EPSG:4326 (WGS 84). EPSG:4326 is chosen as a spatial reference system because the output data to be visualized in Cesium need to use WGS'84. Examples of the results of GeoJSON data are shown in Figure 5.

Figure 5. Examples of spatial data in GeoJSON format

```
{
"type": "FeatureCollection",
"name": "entities",
"crs": { "type": "name", "properties": { "name":
"urn:ogc:def:crs:OGC:1.3:CRS84" } },
"features": [
{ "type": "Feature", "properties": { "Layer":
"bagian_bersama", "SubClasses":
"AcDbEntity:AcDb3dPolyline", "EntityHandle": "4FF" },
"geometry": { "type": "MultiPolygon", "coordinates": [ [ [
[ 110.36733082946682, -7.755273080064086, 6.0 ], [
110.36733082946682, -7.755273080064086, 3.0 ], [
110.36737349032377, -7.755257756236309, 3.0 ], [
110.36737349032377, -7.755257756236309, 6.0 ], [
110.36733082946682, -7.755273080064086, 6.0 ] ] ] ] } },
{ "type": "Feature", "properties": { "Layer": "c1-01",
"SubClasses": "AcDbEntity:AcDb3dPolyline", "EntityHandle":
"50B" }, "geometry": { "type": "MultiPolygon",
"coordinates": [ [ [ [ 110.36737349032377,
-7.755257756236309, 3.0 ], [ 110.36736058487949,
-7.755222013938578, 3.0 ], [ 110.36736058487949,
-7.755222013938578, 6.0 ], [ 110.36737349032377,
-7.755257756236309, 6.0 ], [ 110.36737349032377,
-7.755257756236309, 3.0 ] ] ] ] } },
```

Source: Data Processing, 2018

Figure 6. SQL syntax for inserting GeoJSON data into the database

```
INSERT INTO
spaces (geom)
VALUES (
    ST_GeomFromGe
oJSON (
        '(
            "   type    "   :
"   MultiPolygon
"   ,
    "   coordinates
"   : [
            [
                [
                    [100,        -
6, 0], [99.8,
-   6.5, 0],
[99.8,          -   6.5,
5], [100,               -   6,
5], [100,               -   6,
```

```
0]
                ]
            ], [
            ...........
            ], [
                [
                    [99.8,          -
6.5, 0], [100,
-   7, 0], [100,
-   7, 5], [99.8,
-   6.5, 5],
[99.8,          -   6.5,
0]
                ]
            ]
        ]
    )'
    )
);
```

Source: Data Processing, 2018.

The SQL function in Ajax PHP will read the uploaded GeoJSON data. For this purpose, the ST_GeomFromGeoJSON function on PostGIS is used. This function can change the geometry data from GeoJSON format into the Well Known Binary (WKB) in order to be read by PostGIS. Subsequently, the data is inputted into the PostGIS database with INSERT function with a formatted syntax shown in Figure 6.

E.3. Data Visualization

After spatial databases of 3D property registration was prepared, the next activity was to design a 4D cadastral information system prototype (3D cadastre + time). The prototype of the 4D cadastral information system (3D cadastre + time) was designed based on the results from studying the National Land Information System (KKP) for handling 3D property registration and based on literature review related to 4D cadastre.

The prototype was designed to implement VersionedObject class of LADM in managing historical data related spatial and textual data of 3D cadastral objects. The prototype was developed as a web application built upon a set of scripts utilizing PHP programming language. PHP scripts functions are used to retrieve data from the databases by queries, populating data template and sending data to be presented on the map canvas.

The presentation of GeoJSON data of 3D spatial units was done by making use of Cesium javascript library. Cesium was chosen as the library for presenting 4D cadastral objects for its high capability to present 3D models and related attributes efficiently. As previously explained, 3D property spatial data in GeoJSON format was stored into the PostGIS as WKB. As Cesium requires text format (e.g. KML/WKT/GeoJSON) for visualizing 3D models, the data queries to transform from WKB to GeoJSON was done at request using ST_asGEOJSON function offered in PostGIS. This function can be accessed with AJAX PHP so that the system automatically changes from WKB to GeoJSON everytime a user send a request to visualize selected 3D spatial units. GeoJSON data production is done with PHP script. GeoJSON is one of many formats that can be presented on top of Cesium browser. The GeoJSON format (Page, 2015) is selected because it is the lightest data format and possible to handle big 3D data using Cesium. The GeoJSON specification does not, by itself, provide any information on how to display the objects encoded in a GeoJSON document (e.g., what color to use for a line). Here, developers can use some styling standards. This work uses CSS styles to represent visual representations of 3D spatial units.

For visualizing temporal information related to 3D spatial unit, a function for displaying 3D version of time property data (4D cadastre) is prepared in the visualization model. When a user requests a history of rights, the prototype would query or search of the corresponding temporal information of rights based upon the returned unique code sent to the server. The system will catch the results of query and then will provide a list of rights relevant to the object requested by the user. The list of rights is a version of the rights requested. The system could then search of corresponding WKB geometry data from the list of rights of 3D property (especially the strata title), if any. When a specific unit is selected, the corresponding WKB geometry is changed to WKT. The WKT data for each version is stored in a different GeoJSON file. Each GeoJSON file stores different versions of 4D cadastral data. Then, each GeoJSON file is presented on the face of a different Cesium map canvas. Each Cesium map canvas has been sorted out starting from the current state of registration until the first registration state. All the states are registered with corresponding registration time. If the version of the right of a specific 3D property has expired, it would automatically trace the order of rights until its first registration to the common parcel.

F. 4D Cadastre model for land administration

4D cadastre objects are presented in a web-based system that can display spatial data, textual data and its history. The apartment are located on a parcel depicted above the globe model, using Cesium library. The spatial data of 4D cadastre objects are queried from PostGIS datastore into GeoJSON format in order to be able to be displayed on top of Cesium.

The presentation of 4D model is equipped with some functions including:

1. The prototype ability to display spatial and textual information of 2D and 3D cadastre objects.
2. The prototype ability to display spatial and temporal changes of 4D cadastre object time by time.

The example of 3D cadastre object presentation is presented in Figure 7. The 3D cadastre object is a apartment, composed of several spaces. Apartments are modeled in a construction format so that the components of 3D cadastre objects including private spaces, shared parts, shared objects and common parcel are presented in different colors. Here, blue colour to present private space/apartment unit, yellow colour to present shared parts and white colour to present a shared object. This different component presentation can show users which parts can be used either privately or together. In addition to indicating the rights of every residents, it can also be used to show restrictions to every resident.

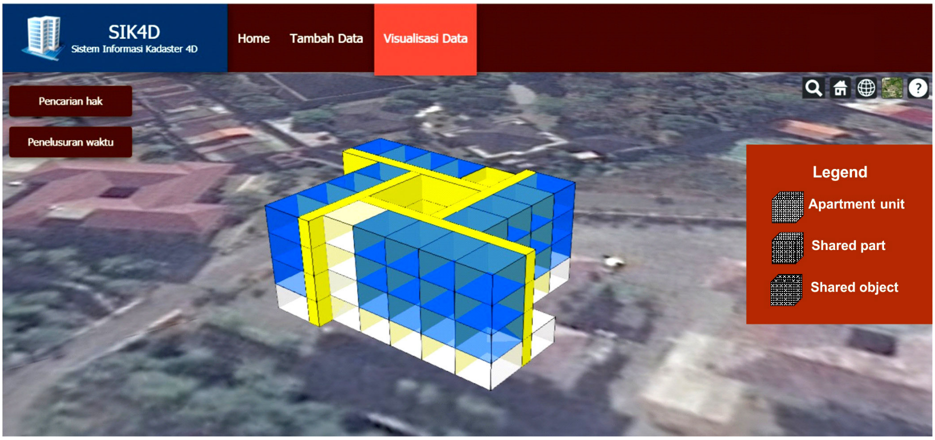
In this research, the cadastre object is presented using a hybrid approach. Spatial and textual data of 4D cadastre objects are presented in a view. The hybrid approach is chosen as a method in presenting 4D cadastral objects that is representative to present the changes of individual object. Users can instantly know the history of changes just in one view. The example of the 4D cadastre object presentation is shown in Figure 8. In Figure 8.a, there is a apartment unit numbered HMSRS.1001 (C2-1415) (colored red). On its description, space is a merger of space C2-14 and C2-

15. The user can browse the history of space changes, as shown in Figure 8.b and Figure 8.c.

As shown on the map (see Figure 8.b) the description of space history of C2-1415, which relates to C2-14 and C2-15, is given. C2-14 space was selected in Figure 8.b (colored in red). In the description of C2-14 space, there is an information that space has been turned off (the right was not activated again) and combined with C2-15 to C2-1415. The history of the cadastre object changes can be verified by looking at the Land Book. Based on the description found in C2-14 space, the space history of C2-1415 is valid. From this illustration, the prototype of 4D cadastre can show the changes both spatial and temporal changes.

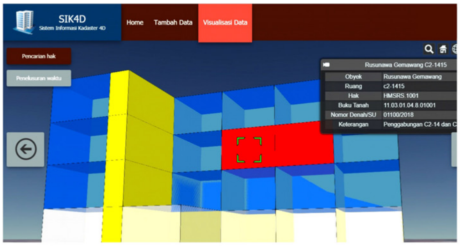
In the prototype, as shown in Figure 8.c., the presentation of spatial data history is not only limited to 3D objects, but also to the 2D cadastre objects (parcels). In Figure 8.c the user searches of the space history of C2-14 (HMSRS.135), so the history of HMSRS.135 is presented. The history of HMSRS.135 turns out to be a 2D cadastre object (parcel) with the rights number HGB.145. That parcel is a common parcel. This indicates that the HMSRS.135 space is the first rights when the apartment is being built.

Figure 7. The presentation of 3D cadastre objects on the system.

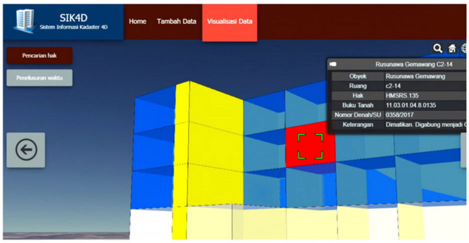


Source: Data Processing, 2018.

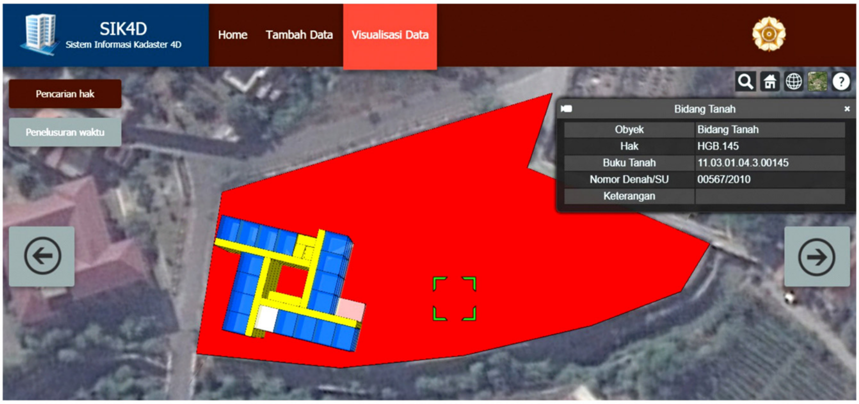
Figure 8. Presentation of 3D cadastral objects over time (4D cadastre).



a. The appearance of space C2-1415 in 2018.



b. The appearance of space C2-14 in 2017.



c. The appearance of the space location (before apartment was built) in 2010

Source: Data Processing, 2018.

The spatial data presentation model of 4D cadastre object has been successfully created. Based on the above discussion, the prototype model has been able to show each component related to 4D object registration so that the rights and restrictions of each spatial unit becomes clearer. Which parts are private parts and which parts are shared are visualized clearly. In addition, the presentation model can show the history of a cadastre object, from private 2D parcel becomes 2D common parcel.

Such capabilities in visualizing 3D+time situation of 3D spatial units would improve the current Land Information System (KKP). The presentation of 3D spatial cadastre object data with a hybrid approach can be added to the current KKP system to accommodate the presentation of registered objects. 3D registered objects becomes more visible on the system because spatial data and their corresponding rights can be seen at the same time. This function has been applied in current KKP system of ATR/BPN to 2D parcels only, but not to 3D cadastre objects. Another function that can be added to the current KKP system based on what has been presented in this paper is a function to trace the history of changes. The information related to the registration process stored on the KKP system (i.e. time of first titling and transfer registration of spatial and juridical data) can be used to trace the version of 2D and 3D cadastre objects.

G. Conclusion

The prototype model of 4D cadastre presentation which is produced in this research is implemented on the web via Cesium as a hybrid 3D cadastre approach. The 3D cadastre objects of apartment units that are presented on top of Cesium are visualized on top of a 2D parcel. The hybrid approach is chosen so that the relationship between 2D cadastre object and 3D cadastre object can be presented together in a single view as seen in Figure 8.c. The construction format is chosen as a presentation format, so that each side of the building structure is clearly visible. The prototype can show the common and private rights of a apartment including strata title, shared objects and shared parts. The differences of right types are represented by different colors, so it is more easily for users to differentiate 3D units.

The important updates that are resulted in this research is the presentation of the 3D cadastre objects with their history as 4D cadastre objects. The presentation of history on the resulted model applied the LADM VersionedObject class. The history of both spatial and textual data changes has been stored in the database and presented according to users' needs. Through the prototype, the users can examine changes of both spatial and ownership data over time. It is expected that the proposed model can be used as inputs to overcome 4D presentations of 3D cadastre objects implemented in the current national land information system.

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