3D Cadastre Web Map: Prospects and Developments

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Key words: 3D Cadastre Web Map, 3D Data Processing, CAD, KML, X3D, PostGIS

SUMMARY

Although 3D cadastre web map offer benefits to, among others, planning and disaster management application domains, they pose some technical constraints to be implemented using current web technologies. Some technical constraints may include field data processing, data compatibility and browser limitations. One of technical solutions in support of 3D data processing is the use of OpenGIS standard i.e. KML in streamlining 3D measurements into the existing cadastre geodatabase. Further, another standard that is useful is X3D. X3D stores and visualizes 3D objects above or below land parcels. Some prospects of the use of those open standards will be illustrated through case studies. First case study is the use of KML as an intermediate format to bridge between CAD with PostgreSQL PostGIS for mapping space-related rights. Second case study is the use of cadastre and environment-related data in X3D format in support of rapid mapping for Mt. Merapi post disaster assessments. From those two case studies, technical specifications for developing a solution of a 3D web map suitable for a proposed hybrid cadastre, will be discussed.

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1. INTRODUCTION

Urban growth stimulates rapid developments of multilevel structural constructions above and below land parcels which is in turn causing growing interest for improved parcel and space use and ownership management. 3D cadastre has been introduced as a conceptual approach to seamlessly manage parcel and space geometries and their associated rights, restrictions and responsibilities. Regardless legal and institutional settings, seamless data storage and visualization of accurate yet efficient 3D cadastre has been challenges to many cadastral offices in the world.

Data acquisition of 3D cadastre data will include cadastral surveys of 2D parcels and 3D objects with legal spaces. 3D cadastral surveys is an important prerequisite for 3D data modeling where survey methods may include terrestrial survey (e.g. GPS survey, terrestrial survey with Total Station and Distometer) and photogrammetry (e.g. terrestrial laser scanning and image matching methods). Once field data have been acquired, 3D data modeling will take part to draw and store 3D objects and 2D parcel boundaries. A popular approach to store 2D and 3D cadastral measurements for cadastral offices is the use of CAD software such as AutoCAD or Bentley MicroStation. At some extent, 3D cadastral measurements that were stored in CAD system are then converted into 3D geometries stored in cadastral spatial databases.

For planning and disaster management applications, online access and visualization of (geometric) 3D cadastral data are often required in order to support data sharing and data communication. For example, 3D representation of parcels and buildings needs to be visualized on top of the terrain and flood hazard map of the area as a 3D view in order to provide convincing perspectives for community and decision makers during rehabilitation and reconstruction activities in post lahar flood disaster responses. For this purpose, CAD data of 3D representations of terrain, parcels, buildings, predicted hazard prone areas have to be converted into spatial databases or data model (e.g. CityGML, GML, KML, etc.) that are accessible via internet. Many projects and initiatives have been launched to support such needs including developments of GML and X3D standards.

This paper is aimed to provide showcases on the utilization of cadastral data and 3D model in support of needs for data sharing and visualization through internet. In so doing, the paper will discuss the prospects that 3D data visualization especially through web can provide more opportunities for optimal use of 3D cadastre data and information. Two case studies will be presented to explore the needs and challenges for the use of 3D data in land administration-spatial planning including space management, and disaster management application domains.

2. MOTIVATION

CAD and GIS data that are produced from survey and mapping activities of 3D physical objects tend to increase, thus provide challenges not only in terms of the storage but also of their utilization. From GIS perspectives, possibilities for 3D CAD/GIS data generation have been increasing but there are still limitations and difficulties in developing applications that facilitate seamless 3D CAD/GIS data representation, analysis, and visualization. For example, as will be described in this paper, failures and inconsistencies in visualizing a combined 2D and 3D geometries that were generated from CAD using X3D format are common problems in 3D browsers. Yet another example, 3D data type available in open source solution (e.g. PostGIS) does not match with requirements to seamlessly visualize the model in X3D.

Despite the complexity in dealing with 3D cadastral data representation and visualization, cadastral offices around the world show a growing interest in adaptation and adoption of 3D Cadastre concept. Furthermore, emerging technologies for 3D visualization and interactive augmented reality highlight potential uses of 3D cadastral data as a fundamental layer to support other application domains dealing with places and spaces such as planning and disaster management. In this respect, web solutions for data access and visualization of 3D cadastral data offer advantages in terms of accessibility and efficient software investment as distributed users can have access to the data through the browsers. Such advantage does matter for some application domains like planning and disaster response activities.

The data flow for online 3D cadastral data access and visualization covers two simplified phases: from surveying to modeling phase and from modeling to rendering/visualization phase. For the first phase, current survey and photogrammetry technologies offer full support to generate 3D data model in the format of CAD drawings. In order to convert CAD drawings into spatial databases, most CAD software have been providing choices of database interfaces (e.g. using ADO) that enable 2D geometries to be stored in various spatial databases. Unfortunately, the support for storing 3D geometries is still limited. For the second phase, the challenges are much complicated than the first phase. The data model that support visualization include KML and X3D. 3D KML data can be visualized using Google Earth application or through a browser with GE plug-in is installed. X3D is still limited for browsers with X3D plug-ins for web VRML browsers.

3. 3D CADASTRE WEB MAP: TECHNICAL OVERVIEW

3D web map in this paper is meant that web technology is used either as a solution for data management that includes data updating, query and visualization or simply as a visualization tool. The first case requires a geospatial DBMS that is able to store CAD data and to access geospatial DBMS through web technology (Stoter and Oosterom 2004). In relation to the first case, most of existing approaches are still in development and not yet implemented by cadastral offices.

For example in the case of Indonesian cadastre situation where two case studies will be presented, the geospatial DBMS is currently only available to support land and apartment registration (i.e. 2D legal parcels and apartment units). For 2D land parcels, their geometries and their corresponding rights and restrictions have been successfully modeled and implemented. Each parcel polygon has a unique relationship to its right registration and its corresponding 2D legal parcel measurements. For apartment units, the current solution is that a property registration (i.e. apartment unit) is done to its space right but the geometry is only related to the common land parcel whereas the corresponding legal drawing plan of the registered apartment unit has not been stored individually. This first case study aims to show a possible solution in integrating 2D parcels and 3D geometries gathered from field cadastral survey into an integrated geo databases for CAD data storage and 3D geometries' query and visualization through web browsers.

In order to integrate 3D geometries and their associated space rights and legal documents, a possible hybrid solution (preserving 2D parcels and rights) is proposed as presented in Figure 1.

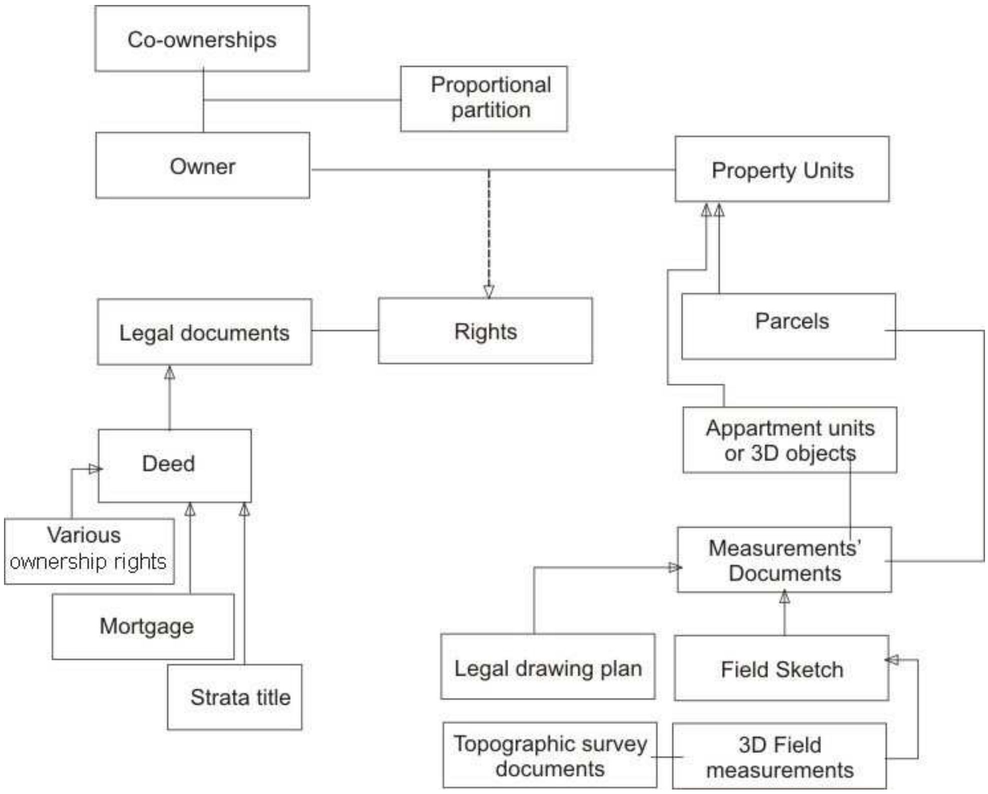

Figure 1. A possible updates for existing 2D cadastre geo DBMS of National Land Agency that accommodates needs to integrate 3D measurements into 2D cadastral data

Figure 1 depicts a bigger picture of current 2D cadastre data management that covers data storage of CAD data measurements, 2D geometries and attributes of rights and corresponding legal documents. An extension to 3D measurements require 3D data modeling and 3D data storage of 3D objects and its links to field measurements or field verification of individual space-related physical object. Further the definition of space geometries is also specified for corresponding proportional partitions and their rights and restrictions.

The proposed solution is a hypothetical approach that partly has been implemented in the forthcoming first case study. The building blocks that were modeled include geometries of 3D property units and attributes of owner and rights. For this purpose, CAD software chosen is AutoCAD Map 3D whereas geospatial DBMS chosen is PostgreSQL, PostGIS and the browser used is Mozilla Firefox with Google Earth plug-in. The web implementation is done through AJAX-based application.

The second case in relation to the use of Web technology as a visualization tool will be illustrated through the second case study. The second case study aims to illustrate potentials of the use of a combination of aerial photographs, digital terrain model, cadastral parcels, and buildings and hazard map for disseminating hazard information and for communicating reconstruction needs in 3D perspective. For this approach, GIS technologies include the use of conversion tools to convert CAD into 3D GIS data (i.e. Accutrans 3D or 3D Object Converter) and the use of open source 3D web browsers and ArcGIS Explorer to visualize the results.

4. CASE STUDIES: 3D CADASTRE WEB MAP FOR SPACE MANAGEMENT AND DISASTER MANAGEMENT ACTIVITIES

4.1. Case Study 1: 3D Cadastre Web Map for Space Management

Background

In order to examine the feasibility for extending the existing 2D geo DBMS implemented, a prototype was built to integrate CAD data gathered from field measurements with attributes about ownerships and rights. In current property registration for apartment unit, field measurements were done to check the existing 2D situation of the 3D unit against the drawing plan. 3D geometries gathered from field measurements were neither required to be stored as CAD drawings nor as geo DBMS. In this case study, the object that was surveyed and mapped was a multi-storey campus building, i.e. The Graduate School Building (Aditya, Subaryono et al. 2009). The case study was not just intended to handle space registration but can only be used to support space management as the attributes data available in the campus can be linked to provide query and analysis of space occupation and utilization.

Field measurements were done to collect data on reference points (using GPS), parcel boundaries surrounding the building, building outlines (using Total Station), and verification of drawing plan (using distometer). 3D measurements were done through drawing plan verification. The field notes were created by doing measurements to horizontal distances for each individual unit and by attaching height and space diagonal measurements into the drawing plan.

Methods

From field survey activities done, field measurements then were represented as CAD data using AutoCAD Map 3D software. Subsequently, the conversion was done in order to store CAD data into SQL geometries. PostgreSQL PostGIS was selected as the targeted geospatial databases for that project. Unfortunately, as there is no suitable 3D data connection from

AutoCADMap 3D into PostGIS or straightforward conversion available from AutoCAD Map, KML was chosen as an intermediate format to enable system to store 3D geometries into PostGIS. Ideally, 3D geometries should be stored as Polyhedron (volume bound by flat surfaces) (Vandysheva, Tikhonov et al. 2011). However, due to limitation of PostGIS support for 3D data types, 3D geometries were converted as polyhedral surface through a web interface utilizing PHP XML DOM. For visualization process and query, geometries were formatted as KML out of PostGIS to be displayed into browser with a GoogleEarth plug-in. The conversion of the data format is illustrated in Figure 2.

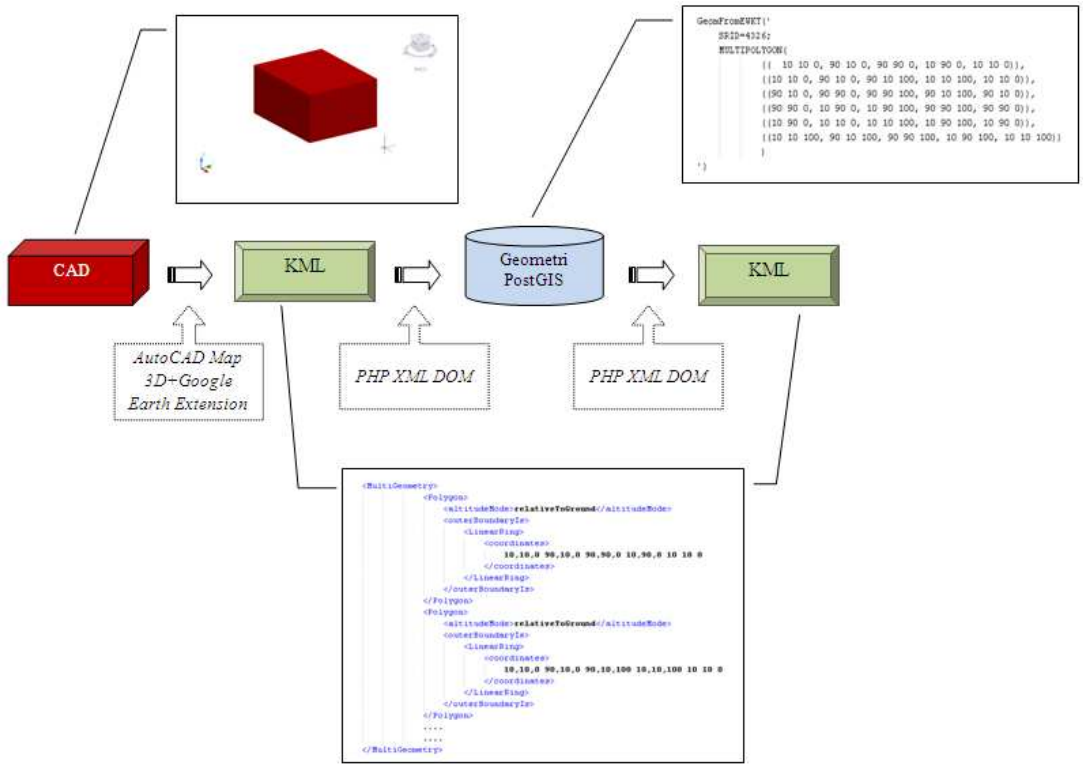

Figure 2. The data conversion process from field measurements (drawn as CAD) into geo DBMS via KML format

With polyhedral surface (known as MULTI POLYGON in PostGIS) as the data type, a 3D object or volume space was modeled as a collection of surfaces that were made of point coordinates (x,y,z). Using MULTI POLYGON, as a consequence topological relationships and queries can not be easily implemented into the built databases. Typical 3D CAD objects that can be stored using MULTI POLYGON data type are presented in Figure 3.

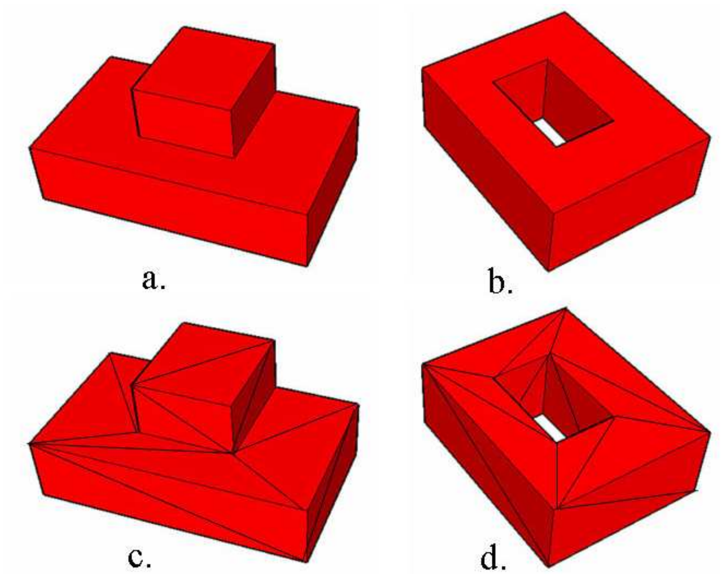

Figure 3. Complex 3D objects that can be stored in the case study

Figure 3 (a) is a 3D object that has different heights for its roofs. Such object can be created as a solid object in AutoCAD Map utilizing UNION function. Figure 3 (b) is a 3D object that has an empty cubic space in the middle of the object. Such object can be created by taking off one solid object from another solid object by utilizing SUBSTRACT function. In principal, typical CSG (Constructive Solid Geometry) can be implemented when modeling 3D objects in AutoCAD Map. As mentioned previously, KML was used as an intermediate format. For this purpose, AutoCAD Map was equipped with GoogleEarth extension that is capable for exporting selected data into KML format. In this respect, GoogleEarth extension converted solid CAD objects into *triangulated polyhedral surface* type in KML. This *triangulated polyhedral surface* geometry type defines surfaces of corresponding 3D object as 3D triangulated surfaces consisting 3D TIN points. As the result, MULTI POLYGON data type stores an individual 3D surface as a collection of triangulated polygon. Thus, Figure 3 (a) and (b) in AutoCAD Map will be stored in PostGIS as corresponding geometries seen in Figure 3 (c) and (d).

Results

Once geometries of physical objects were stored in geo DBMS, registration of 3D unit can be done. In this case study, a scenario has been built that administrator of cadastre office or municipal office will do registration after survey and verification activities have been completed. In order to support this need, a web application was built. The web application offers possibilities for administrator to establish a relationship between owner and corresponding right for a specific unit (Figure 4) and to manage the geo DBMS (to do data editing, insertion and deletion). In addition to that, users (not necessarily administrator) will have opportunities to query and visualize the units (Figure 5 and Figure 6).

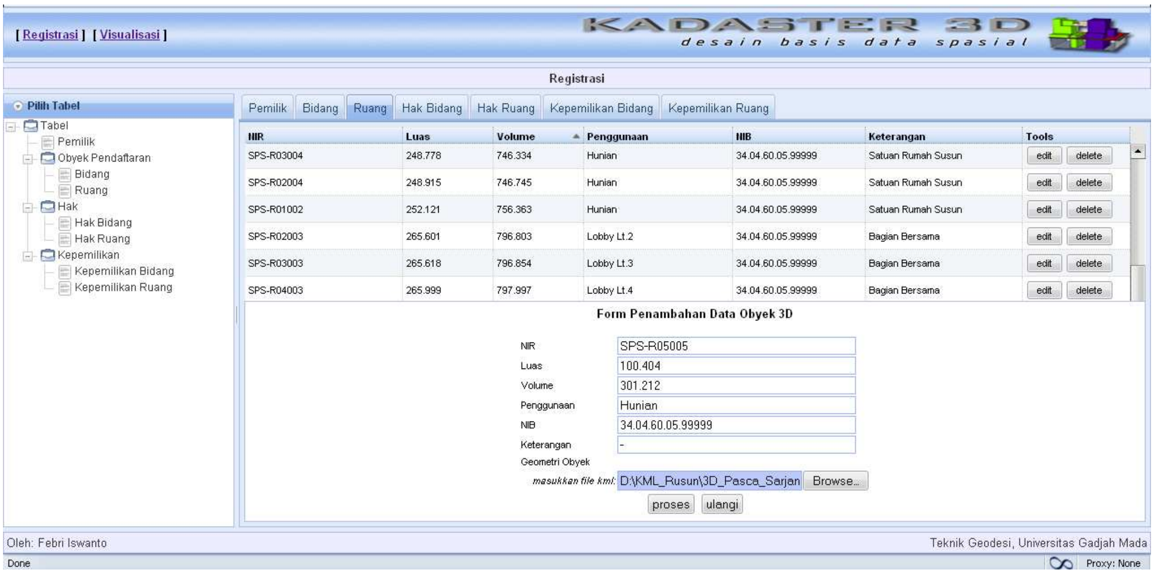

Figure 4. A registration page is offered to manage right and owner

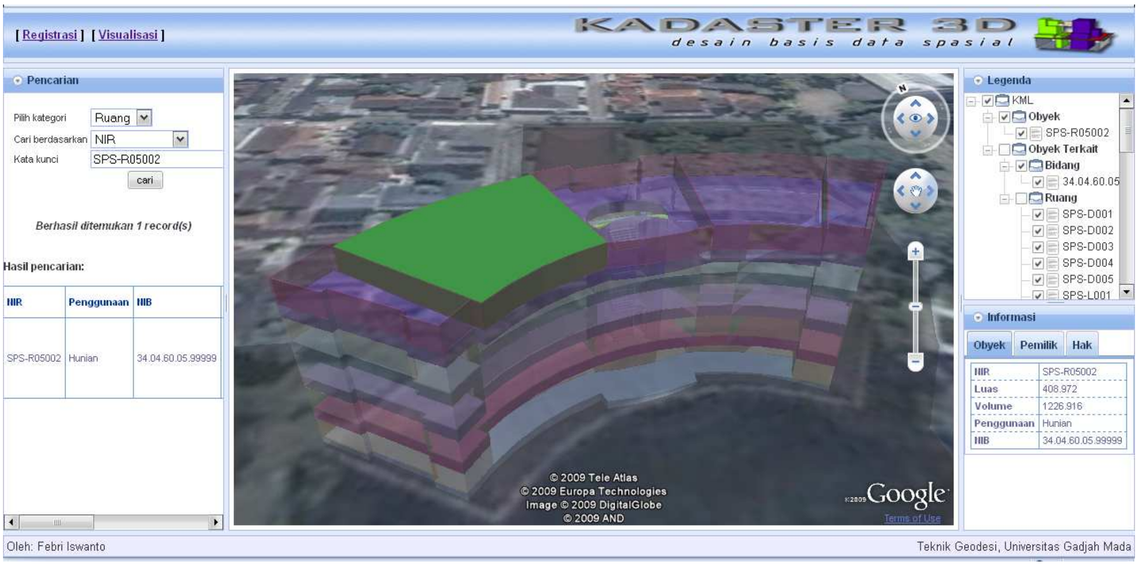

Figure 5. The visualization page : the main panel is for mapping 3D objects and for displaying search result, the left panel is for query interface and the right panel is for property browsing and exploration

The web was developed as an interactive 3D web utilizing PostGIS as the geo DBMS and an internet browser with Google Earth plug-in installed as the visualization interface. Server side script was written using PHP while client-side scripting was done using Dojo Framework[1] in order to provide usable AJAX application. For dynamic data conversion PHP XML DOM was used as a parsing tool to convert KML into SQL geometries stored in PostGIS and vice versa from PostGIS into KML format for visualization purpose.

[1] www.dojotoolkit.org/

Figure 6. Search result and its corresponding pop up window is displayed orthogonally

4.2 Case Study 2: 3D visualization of affected land parcels of flood hazard post Mt. Merapi eruption

The second case study discusses a different aspect of the use of web for 3D Cadastre. Whereas the first case study demonstrates the use of web technology as a data management solution, the second case study will focus on the use of web as a visualization tool.

Background

Code River is located in urbanized area of Yogyakarta city with its stream originated in Mt. Merapi, in the northern part of Yogyakarta city. The latest eruption of Mt. Merapi in 2010 produced thick layer of ashes in which, caused by heavy rainfalls, turns into a deadly lahar that flows through the rivers to the urbanized area below. The lahar flow, especially in Code River, caused major damages in heavily populated area in the city of Yogyakarta. As Mt. Merapi's eruption is usually a recurring event of once in 4 years, the residential area around Code River tends to have a high level of vulnerability to another forthcoming lahar event. Thus, disaster mitigation and preparedness including either relocation or reconstruction of residential areas around Code River should be done.

In order to support both relocation and reconstruction activities, one of the important steps is to identify the affected land parcels in the area. The identification process is conducted by overlaying cadastre data and hazard zone map in around Code River. Flood hazard zone map is acquired by analyzing the 100-year-flood from hydrological and topographical parameters. As most of natural and man-made objects are three dimensional, 3D visualization is quite important to aid decision making processes. This is more to explore in the case of disaster response. For example, in the case of flood, lower land parcels will be more vulnerable than the upper ones. The visualization then developed in 3D web cadastre map to achieve active interactivity and participation as well as broader response from public and stakeholders.

Methods

Topographic data of the latest condition of Code River post Mt. Merapi's eruption is acquired using Small Format Aerial Photography (SFAP) via Unmanned Aerial Vehicle (UAV). Three dimensional terrain model of Code River then built from the aerial photos. The terrain and hydrological data then used to build flood case scenario using HEC-GeoRAS[2] in ArcGIS. Flood case scenario of 100-year period is chosen to represent lahar flood in Code River post Mt. Merapi's eruption in 2010.

Small Format Aerial Photogrammetric (SFAP) is used to acquire the latest post-eruption topographic condition of Code River. The method is chosen to meet the need of fast and accurate geometric data of the river. Available topographic data in Code River are highly inadequate to provide a terrain model to be used as geometric data for the flood modeling using HEC-RAS. Thus, SFAP is considered as a suitable solution to provide topographic condition (surface terrain) for a post-disaster rapid mapping in Code River (Aditya, Rokhmana et al. 2011). Figure 7 presents an overview of the result of aerial photography of the study area .

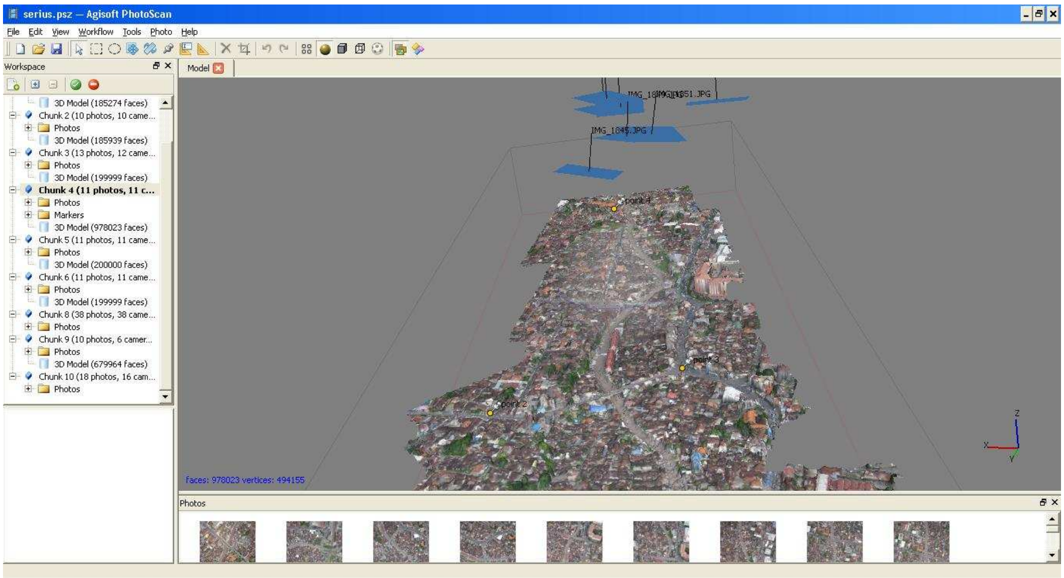

Figure 7. 3D terrain generation from aerial photography

Flood hazard model which shows the extent of 100-year flood post Mt. Merapi’s eruption is generated from a statistical analysis of 17 years maximum flood of Code River data. Log-Pearson type-III distribution is chosen to determine a flood with return period of 100 year or 1% probability. The Log-Pearson type-III distribution is chosen based on previous study in Code River. A discharge of 142.281 m^3/s is calculated as a 100-year flood from statistical analysis of hydrological data in Code River. The flood extent based on this value, i.e. the 100-year flood, is generated using combination of HEC-RAS with HEC-GeoRAS in ArcGIS. Figure 8 below shows an overlay of flood extent or flood hazard model with three dimensional surface generated from SFAP.

[2] http://www.hec.usace.army.mil/software/hec-ras/

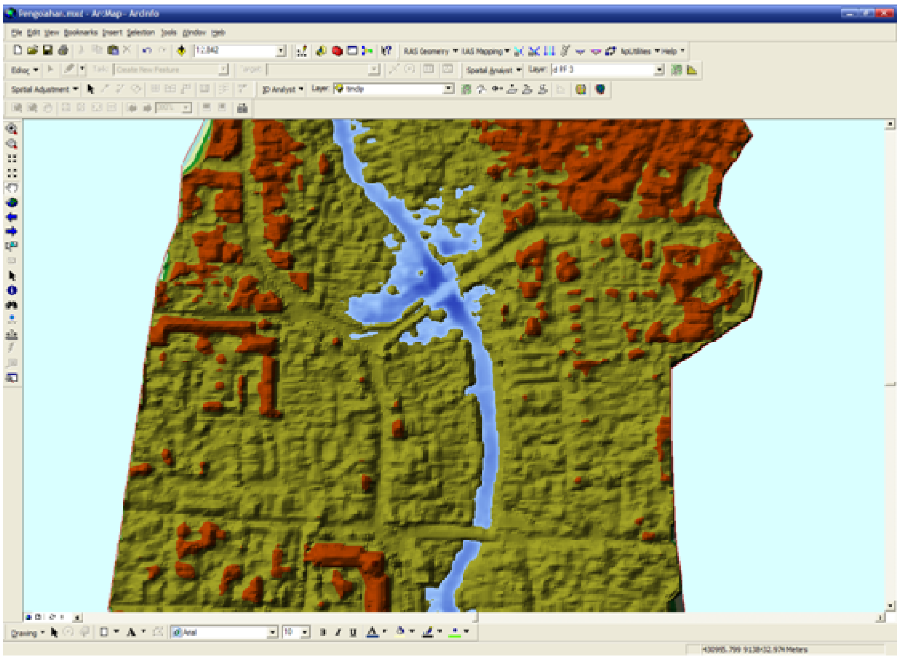

Figure 8. 100-year flood extent in Code River based on statistical analysis

To identify which parcels are affected to the flood, GIS analysis is conducted using cadastral data of land parcels around Code River and the flood extent from hydrological modeling. X3D format of the terrain, flood extent, and land parcels are achieved through some conversion processes. This process mainly deals with conversion from 3D CAD or shapefile data in ArcGIS to VRML/X3D formats. The resulted terrain and flood extent then converted to X3D to visualize it as web content (Figure 9). For this case study, AccuTrans 3D[3] was used to convert CAD data (with .DXF format) into X3D or VRML (.WRL) formats, meanwhile 3D Object Converter[4] was used to convert 3D shapefile into X3D or VRML formats.

The web visualization is aimed to enable an integrated view on the terrain, flood hazard map, affected houses and parcels for targeted stakeholders. The visualization was done using three ways: firstly, with a plug in that attached to a web browser, secondly with an independent X3D players, such as Instant Player[5] or Octaga Player[6], and thirdly with using ArcGIS Explorer. A typical flow process in creating an integrated 3D model of terrain, flood hazard, affected houses and parcels is presented in Figure 10. Three dimensional visualization using X3D is also compared to that of VRML, especially with the case of surface modeling. The visualization of affected land parcels in X3D then compared with the visualization using ArcGIS online accessible through ArcGIS Explorer. In this respect, a typical flow for data processing in ArcGIS is presented in Figure 11.

[3] http://www.micromouse.ca/
[4] http://3d-object-converter.en.softonic.com/
[5] http://instantreality.org/
[6] http://octaga-player.software.informer.com/

Figure 9. Topographic data acquired from aerial photography converted to X3D format

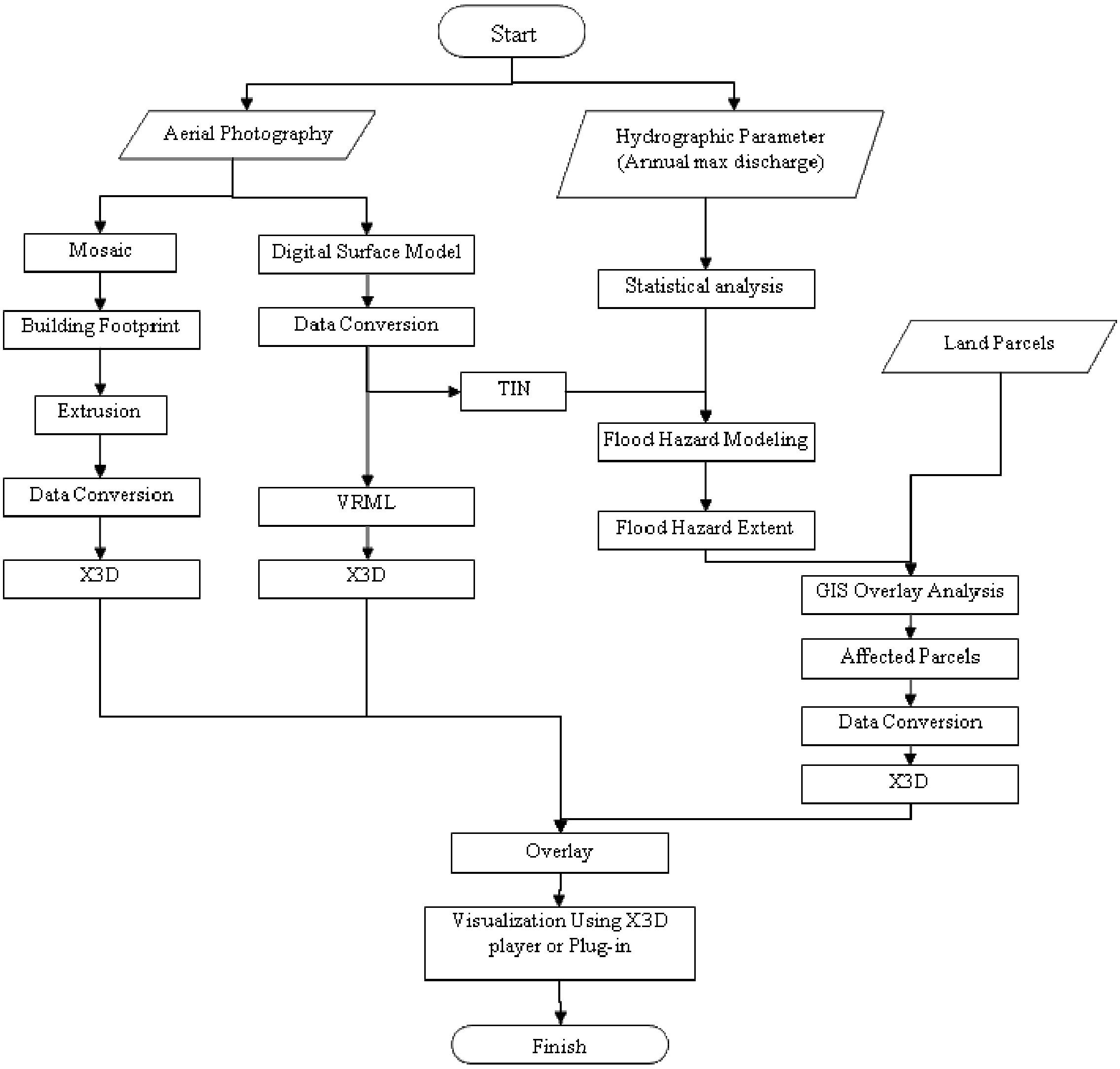

Figure 10. Data processing flow for generating X3D (as well as VRML) formats of the terrain, land parcels and 3D objects of the case study

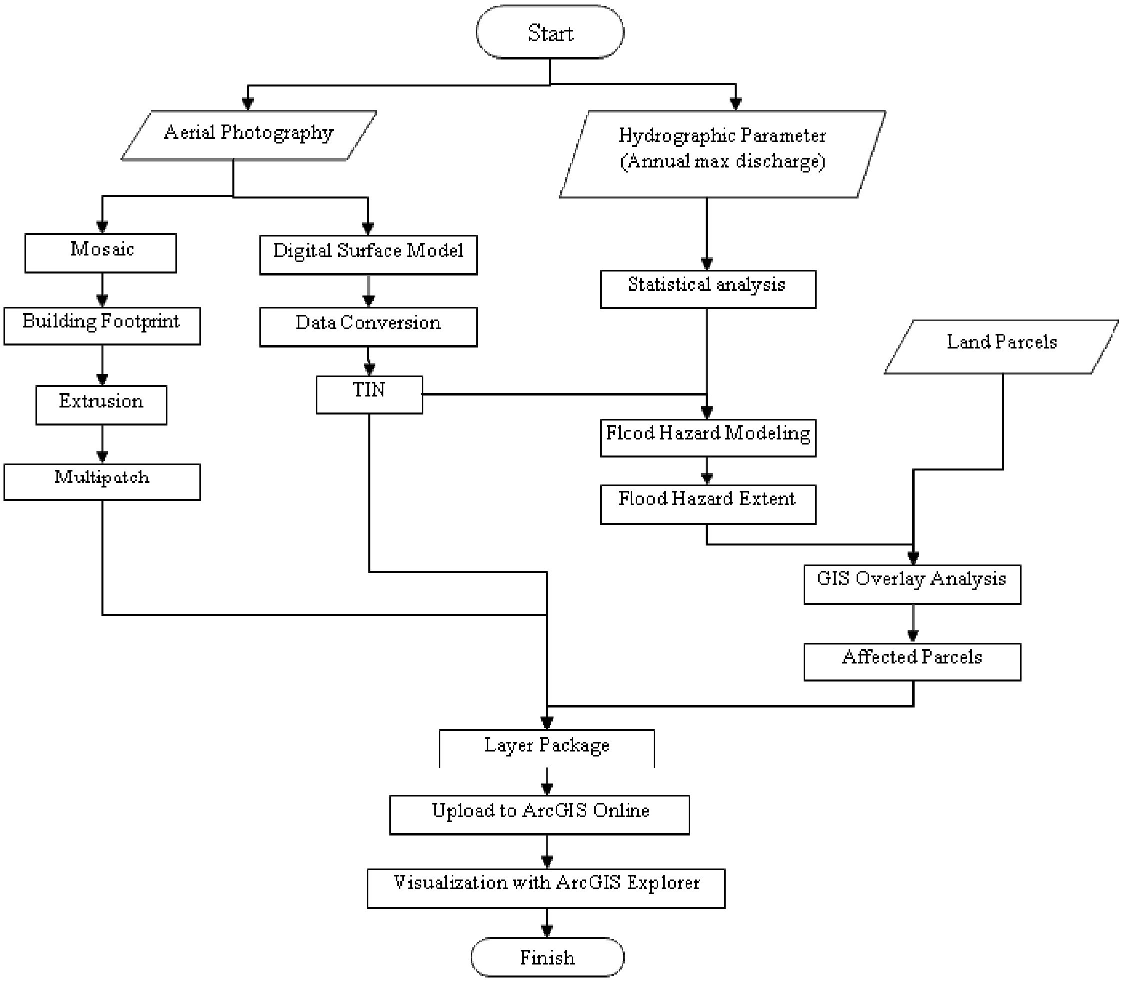

Figure 11. Data processing flow for generating 3D representation of terrain, land parcels and 3D objects of the case study accessible through ArcGIS online

Results

Three means of data conversion i.e. X3D and VRML that correspond to Figure 10 as well as ArcGIS Multipatch that corresponds to Figure 11 have been done successfully. Current conversion tools provide promising opportunities in creating standardized format of X3D. However, some problems have arised in the visualization process. Using some conversion tools, some digital surface data, which is originally in *.WRL format, appears to be corrupt in its converted X3D visualization (Figure 12). In some cases, texture mapping of the digital surface are finished successfully, while some others failed to draw the terrain and texture. Another problem is that converted 3D polygon of land parcels seemed to be corrupt, while the case didn't seem to be happened in its VRML format (Figure 13).

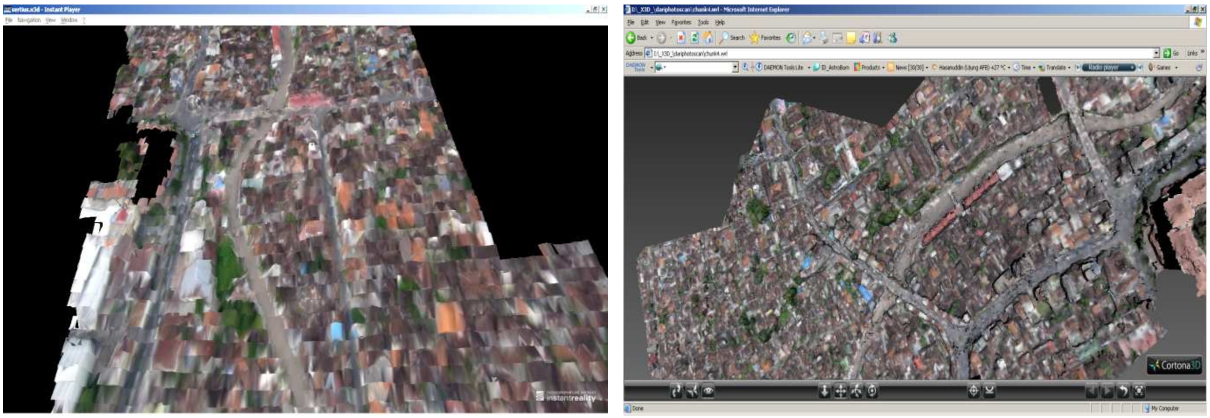

Figure 12. Jaggy surface of Code River in X3D Format (left), compared with the same area in VRML (right)

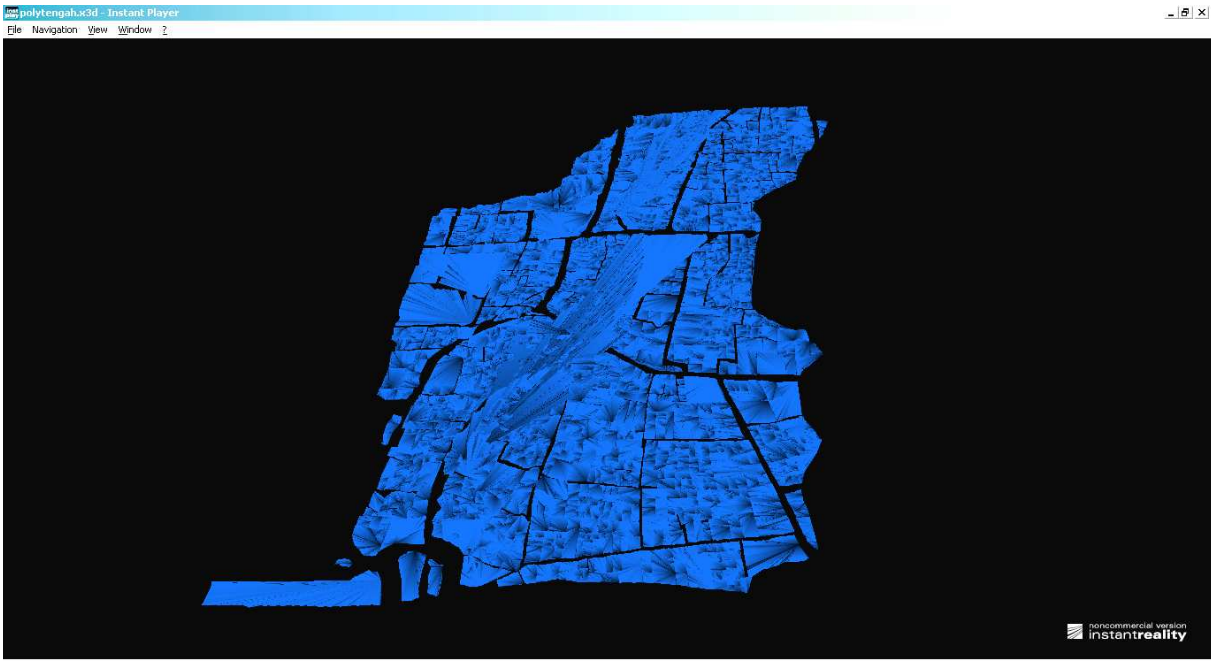

Figure 13. Converted 3D polygon of Land parcels in X3D format

ArcGIS Explorer is a non-commercial GIS data viewer to explore, visualize and share GIS information. The land parcel and other data are uploaded to ArcGIS server, and then the data is downloaded and visualized online using ArcGIS Explorer (Figure 14). A complete solution for 3D GIS analysis of affected land parcels in this case study is so far achieved by using this solution. ArcGIS Explorer offers sufficient support to maintain 3D visualization and analysis of GIS data. But it has an essential limitation in data interoperability. ArcGIS Explorer only support file formats that are generally supported by ArcGIS and another ESRI products. Besides, compared to X3D and VRML, more hardware resource is needed in order to visualize the GIS data trough ArcGIS Explorer.

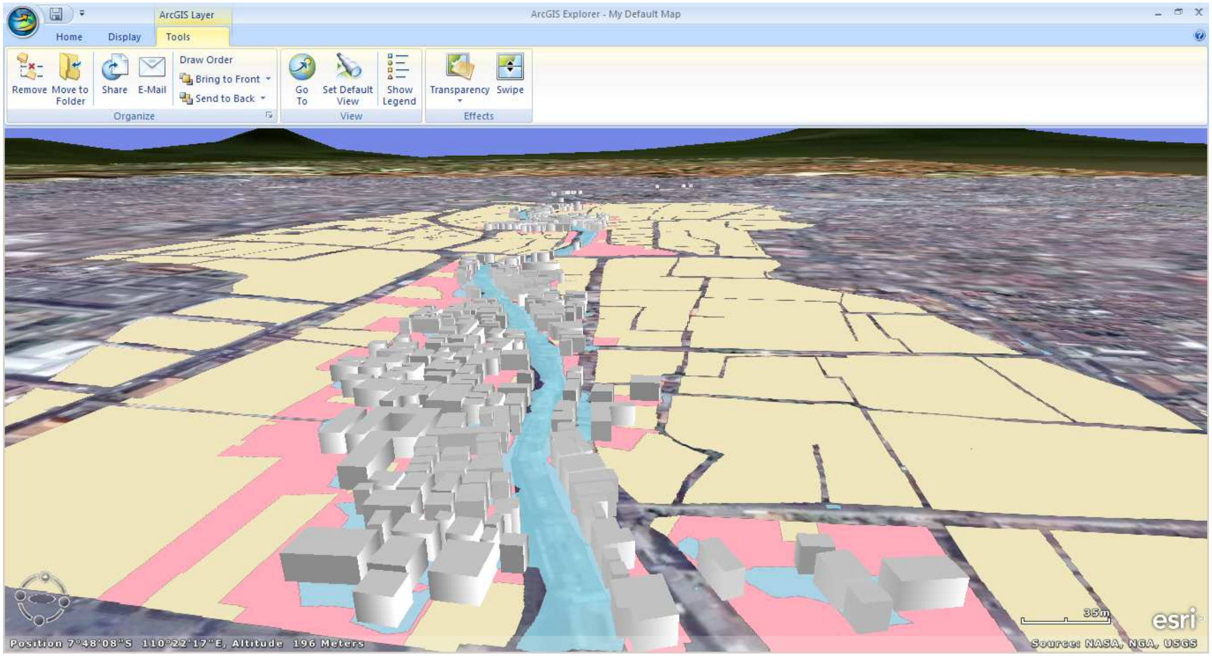

Figure 14. Visualization of affected land parcels and buildings with ArcGIS Explorer

5. LESSONS-LEARNT ON CURRENT 3D CADASTRE WEB MAP DEVELOPMENTS

From case studies presented, it is clear that 3D cadastre web solution is possible to be developed in order to support data management and data visualization. For data management purposes, as seen from the first case study, it can be concluded that utilizing current web database and web graphics components, it is possible to provide an integrated data query involving visualization of 3D objects and presentation of space attributes. Unfortunately, it seems that a seamless integration between web database and 3D visualization components that are available in the market is still far from complete. For example, the developed prototype of space management proves to be misleading in returning the results when a user selects a specific unit from a perspective view instead of planar view (Figure 15). In this respect, multi level units will be very difficult to be browsed and selected using a planar view only.

From the second case study presented, the advantages for visualization of 3D data on multi themes could potentially help stakeholders' cognition in understanding the potential flood hazard and the needs for disaster mitigation and responses. Disaster mapping that requires rapid data collection and processing and reliable dissemination will be one of the promising field for the use of X3D. In case of flood hazard, three dimensional cadastre data that are readily available online will help the victims and the residents to identify which land parcels are vulnerable to the flood and which are not. Further, predicted losses and damages can be calculated in order to provide necessary measures during rehabilitation and reconstruction phases.

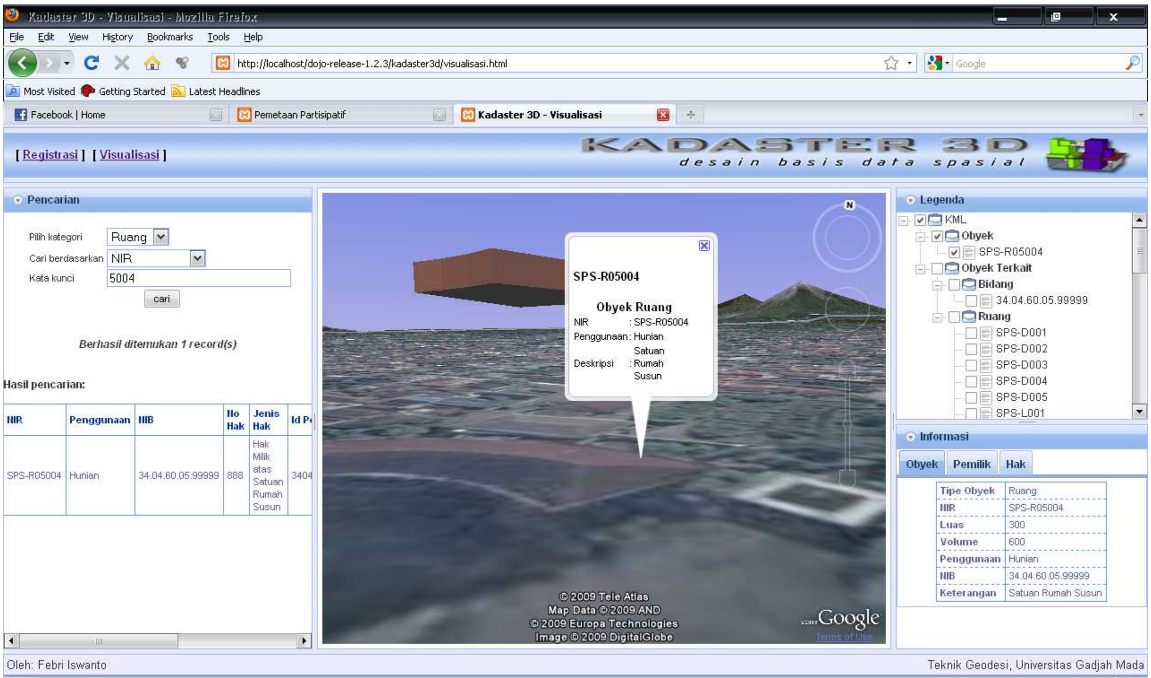

Figure 15. Despite possibilities to present an integrated visualization of 3D geometries and attributes, a user selection with perspective view can be misleading

As to the use of X3D, the web application can also be developed to present 3D objects with its associated attributes. Terrain and buildings can be integrated and then be related to their corresponding attributes for web visualization (with X3D plug-in) using e.g. AJAX application framework (Figure 16). However this web application tends to produce inefficient data access. Possible solution for improving data access and unnecessary X3D plug-in installation on the browser is with the use of X3DOM. X3DOM[7] is an open source framework and runtime to integrate HTML and declarative 3D content. Unfortunately, the 3D geo web application shown in Figure 16 was not able to be presented utilizing X3DOM as X3DOM at the moment does not support geospatial coordinates.

One of the advantages of using X3D data format is that the format is supported by a broad kind of platforms. Many software now support the conversion to and from X3D format. Moreover, with the rapid development and open access to 3D GIS data, it's expected that X3D will be one of the important standard in web 3D information in a not too distant future.

Some notes in relation to the implementation of 3D cadastre web map either using VRML/X3D or ArcGIS online or GoogleEarth interfaces can be given as follows:

- Web browsers with GoogleEarth plug-in is capable in presenting 3D objects visualization generated from PostGIS along with their associated space-related attributes. As far as terrain and 3D objects are concerned, visualization through web browsers either with Google Earth plug-in or with VRML browser (Uchoa, Cardeles et al. 2007) can be achieved. However, some inconsistencies and misleading mouse events can still be found. In addition, efficient topological query seems problematic as the available data type for storing 3D objects is just MULTI POLYGON. As the

[7] http://www.x3dom.org/docs/latest/

result, the processing time would take little longer (Stoter and Oosterom 2004). For this respect, best option for 3D Cadastre (Vandysheva, Tikhonov et al. 2011) must be matched with capabilities of computer graphics of the plug-in browsers for 3D visualization and interaction purposes.

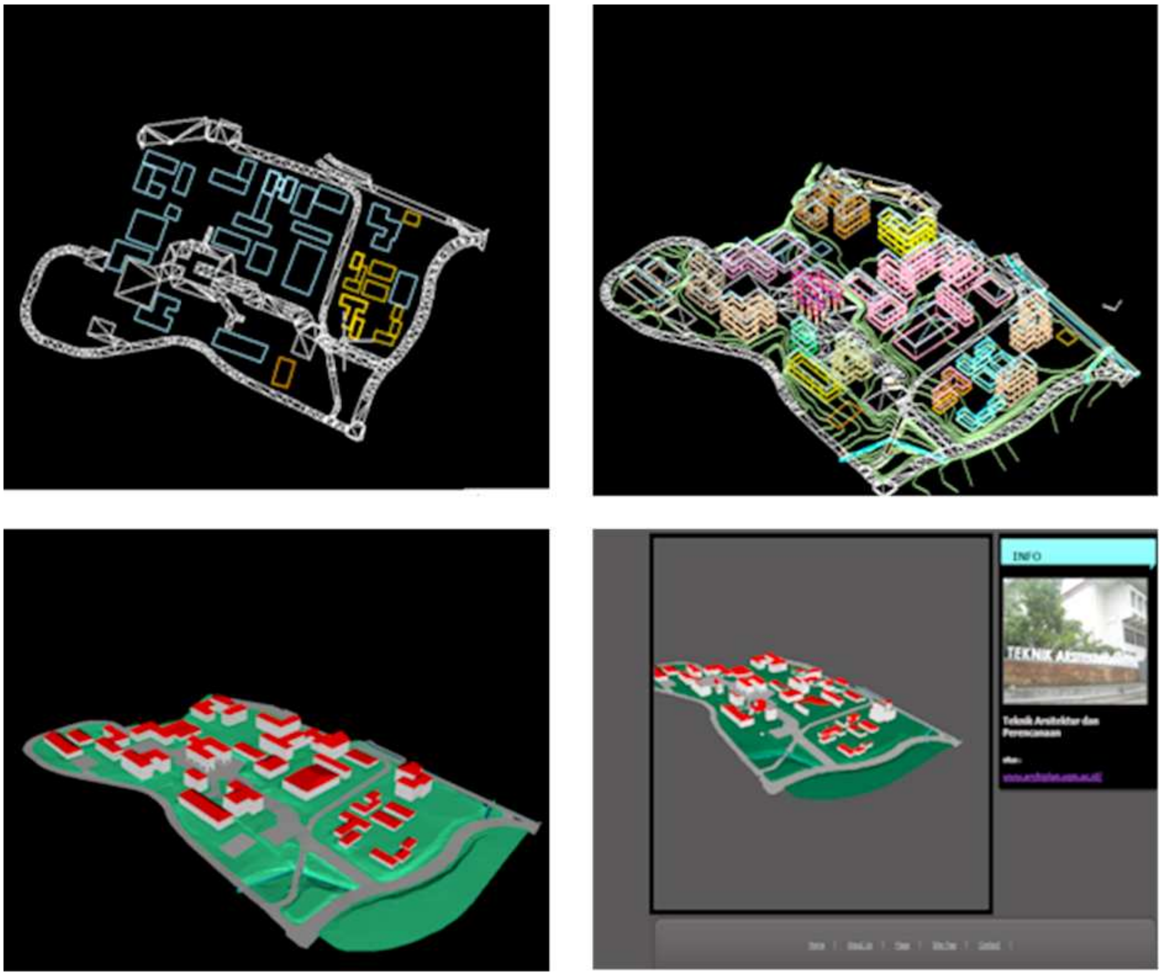

Figure 16. Possible integrated visualization of X3D objects and attributes through web browsers utilizing X3D plug-in

- From the development of X3D web as shown in Figure 16 and from the second case study, it can be stated that X3D format still has difficulties in dealing with parcels (especially parcels constructed from polylines) and 3D surfaces. Thus, 3D visualization options using open source 3D formats and browsers are still limited. In this respect, from the implementation of data processing in the second case study, it can be learnt that geometries must be set using IndexFaceSet element. As a consequence, the texture mapping of images into terrain surfaces or into 3D objects was considered not succeeded. In contrary, tightly-coupled 3D modeling and visualization using ArcGIS or Bentley Microstation (Frédéricque, Raymond et al. 2011) software package provides high-quality 3D visualization results but it requires more hardware resources than using open source format and 3D browsers. Additionally, possibilities for a full data interoperability are limited.

6. CONCLUSIONS

3D cadastre web map can be seen as a forthcoming cadastre information system that is essential in order to support many urgent applications such as space management and disaster mapping. With broad possibilities in 3D data acquisition, 3D data processing requires flexibilities to meet requirements in data storage and data visualization. For possible data integration and visualization, open source standards play important roles to facilitate data exchange. KML is capable to be used as an intermediate format for converting CAD data into spatial database. Regardless the limitation of the existing geo DBMS in storing 3D geometries, the presented solution that proposes the use of KML and PostGIS is considered to be sufficient to extend 2D cadastre geodatabase into 3D hybrid cadastre geodatabase. In this respect, hybrid cadastre refers to a solution that integrate 2D geometries of land parcels and 3D geometries of the property units (Stoter and Oosterom 2004).

The use of X3D in web cadastre has a promising future to present 3D cadastre data along with the earth's terrain surface, yet some obstacles and constraints must firstly be considered. So far, X3D has been proven as a lightweight medium to present three dimensional model on the web. Further development is awaited in order to make X3D as a GIS-ready platform to visualize and also analyze geospatial features via the internet. Some constraints that need to be improved include: inconsistent visualization of 3D objects and terrain data between one 3D graphics browser to other browser. Current open source software development and computer graphics technologies can be considered far from sufficient in enabling optimal online 3D data sharing and visualization. Challenges include insufficient support for spatial data types in spatial databases, immature 3D representation and data modeling of terrain surfaces and 3D space or volumetric geometries, inconsistent 3D representation detail and accuracy across 3D browsers.

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LIST OF ACCRONYMS

ADO	: ActiveX Data Objects
AJAX	: Asynchronous Javascript and XML
CityGML	: City Geography Markup Language
CAD	: Computer Aided Drawing
DBMS	: Database Management System
GML	: Geography Markup Language
KML	: Keyhole Markup Language
PHP	: Hypertext Preprocessor
SQL	: Structured Query Language
VRML	: Virtual Reality Markup Language
X3D	: the ISO standard XML-based format for representing 3D computer graphics
XML	: eXtensible Markup Language

BIOGRAPHICAL NOTES

Trias Aditya is currently the Head of Research Center for Spatial Data Infrastructure Development of UGM. He is Assistant Professor at: the Department of Geodetic Engineering, Gadjah Mada Univeristy (UGM), Indonesia. He completed his MSc and PhD degrees in Geoinformatics from ITC, the Netherlands. His research interests include interoperable LIS/GIS and Geovisualization and his latest research projects are 3D Cadastre, Collaborative Spatial Data Infrastructure and Public Participation in Urban Disaster Risk Reduction.

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