20-osios Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“ teminė konferencija
Proceedings of the 20th Conference for Junior Researchers „Science – Future of Lithuania“

CIVILINĖ INŽINERIJA IR GEODEZIJA / CIVIL ENGINEERING AND GEODESY

2017 m. kovo 24 d. Vilnius, Lietuva
ISBN add publisher
24 March, 2017, Vilnius, Lithuania

eISSN add publisher CD
Article Number: *kk.add publisher*

http://jmk.kk.vgtu.lt./

DEVELOPMENT OF VISUALIZATION AND MANIPULATION METHODS FOR BIM AND DIGITAL CITY MODELS USING WEB GRAPHIC LIBRARY

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Abstract. Easy visualization and processing of the BIM model, sharing and publishing, data analysis, GIS data connection, simulating the existing environment, etc. is possible without any installations of software on computer or a mobile devise due to the employment of the Internet web browser, which has become real having developed a method for using BIM through WebGL. The employment of this tandem allows BIM models to be processed and analyzed in the existing environment like Digital City and real time visualization, which is giving rich future for full BIM software products with all manner of functions and tools that will work through the Internet. The Web based BIM Internet platform is the next step in BIM and another step towards World BIM conformity.

Key words: 3D model, BIM, BIM model, Digital City, Existing environment, GIS, JavaScript, LOD, Uses, Web, WebGL.

1. Introduction

The BIM model publishing for collaboration purposes is one of the most important recent problems. BIM software afford to create, manipulate, render and visualize, export, import and save geometric and attribute information on the objects in proprietary file formats that can be used for all disciplines of the BIM Project and be processed directly in software installed on the computer. Every company has its own viewer that gives the ability to visualize the project out of software such as Bentley Navigator, Tekla BIMsigh, etc. For .rvt file – native format of Autodesk Revit with full graphics and data integrity (www.evolve-consultancy.com/resource/bim-brief/bim-collaboration-formats), the Autodesk Company has developed the Internet service named a360 Viewer (www.a360.autodesk.com/viewer) that gives opportunity to view this type of files through the Internet. However, this service has no tools for manipulating objects. Beyond the Revit suite, there has been currently no software that will present, update, create, render, import or even reference RTV files without computer having software installed on it.

The BIM model can be stored in more common file formats like IFC (Industry Foundation Classes), which is an open standard and text-based format that simplifies proprietary types of the element into the standardized classes (help.autodesk.com/view/RVT/2016/ENU/?guid=GUID-EE6C0CF8-7671-4DCC-B0C7-EEA7513C90A9) of the object. Its main purpose is to provide project teams with the ability to exchange data between CAD tools (www.solibri.com/support/bim-ifc/), cost estimation systems and other construction-related applications; however, this kind of file formats cannot distinguish components providing issues with attribute information and this is the reason why it cannot be used like the main project files.

The BIM model can be converted to other file formats like Wavefront .obj that contains only geometric information and does not conserve any of attribute information (http://www.fileformat.info/format/wavefrontobj/egff.htm). Nevertheless, this file format is extremely popular and wide in use and can be easily visualized in a number of software; thus, it was necessary to develop the way to use it in BIM and make it possible to work with geometric and attribute information. One more common file format that conserves attribute information with geometry is JavaScript (https://developer.mozilla.org/en-US/docs/Web/JavaScript). This file format gives a wide range of opportunities to work with BIM model applications such as Phase planning, Programming, Lighting Analysis, etc. (http://bim.psu.edu/Uses/). All manipulations with objects and their attributes can be done only employing a web browser having dynamic result visualization that allow working in any computer even in a remote mode only through the Internet due to WebGL.

Such problems as access, easy processing, analyzing, visualization, sharing, etc. can be solved by the Web-based BIM Internet platform. Additionally, JavaScript gives the ability to work employing many composite objects at the same time, which is suitable for simulating infrastructure, designing engineering systems and City modeling and allow syndicating the existing environment with the BIM model that gives an additional opportunity to BIM. Thus, the paper considers what WebGL is, how to develop the JavaScript model, how to make a model for the existing environment and how to implement all that in a single project based on the Web browser.

2. What is WebGL

WebGL - (Web Graphics Library) is a JavaScript Application programming interface (API) (http://www.webopedia.com/TERM/A/API.html) for rendering an interactive 3D environment and 2D graphics within any compatible web browser without the use of plug-ins (https://www.khronos.org/registry/webgl/specs/1.0/). This technology is integrated completely into all web browsers that support standards and allow GPU accelerated usage of physics and image processing and acts as a part of the web page canvas. The elements of WebGL can be mixed with other HTML elements and composited with other parts of the page or page background. WebGL programs consist of the control code written in JavaScript and the shader code executed on the Graphics Processing Unit (GPU)

(http://www.webopedia.com/TERM/G/GPU.html) of the computer. This JavaScript API is designed and maintained by the non-profit Khronos Group (https://www.khronos.org/).

The JSConf 2015 (http://2015.jsconf.eu/) in Budapest included a presentation of JavaScript and WebGL shortly describing all main things of working with WebGL. At present, 3 main engines support WebGL: Unity (https://unity3d.com/ru), Unreal Engine (https://www.unrealengine.com) and Three.js. Unity and Unreal Engine are known as game engines having wide developing abilities and Three.js is an engine developed only for WebGL rendering and is free to use. The Three.js engine was chosen to be used in this project because of free license and strong opportunities.

Three.js is a cross-browser JavaScript library/API used for creating and displaying animated 3D computer graphics in a web browser (http://threejs.org/docs/index.html#Manual/Introduction/Creating_a_scene). Three.js supports many file formats with model data such as .obj, .fbx, .js, .json , etc. (http://threejs.org/docs).

WebGL does not support any of the known BIM software proprietary formats, as it only supports simple formats. To make possible to visualize information in the browser, the existing BIM model formats need to be converted into the well-known file formats such as .obj. In the run of the conversion process, a part of the file that contains geometric information is converted into another file, and, at this step, the BIM model can be visualized in WebGL like a simple 3D model. As for conversion, all attribute information on the objects that were stored in the primary BIM file is missing. To link objects and their attributes, the modifications of the WebGL environment and objects have to be applied.

3. Development of Methods Linking BIM Models and Attribute Information in WebGL

To achieve the set objectives, there are two ways of processing the BIM model:

1. Use of file formats that preserve the geometry of the objects and information about them in the file;
2. Use of common file formats, such as Wavefront .obj that store only the geometry of the objects and use an external storage.

In the first case, proprietary formats have to be converted into the formats that are supported by the JavaScript environment; however, no one of BIM software has default tools for making such conversion. Some add-ons that allow doing this kind of manipulation have been developed for Autodesk Revit, and one of these extra tools is RvtVa3c from vA3C (http://va3c.github.io), which allows exporting the BIM model into .JSON file format for the three.js library. In that case, the file contains geometric information and attributive data on the objects.

In the second case, a file format .obj has to be used. The majority of the programs that operate on 3D data support the .obj file format, and therefore its use is important, but, as for the structure of the obj file, only geometry and no attribute information can be saved. To implement the support of the converted BIM model, the structure of the Three.js environment needs to be modified by adding of parsing procedure that will process an additional field containing information that will be included in the .obj file. After conversion is done, the structure of the file needs to be changed adding extra data fields:

- Add the “name” attribute of the objects that will allow indexing geometric shapes in the Three.js environment;
- Add an identifier field in order to implement the ability to associate geometric information from the file and information stored in a database on a remote server.

The result is the modified .obj file that contains geometric information and the ID of objects and the modified Three.js code that is given the opportunity to identify additional fields of information from the loading process. Due to changes, it is possible to process geometric information from a file and link it to an external database that stores data about the objects. This Database can also be stored on the Internet or in any other resources.

Different types of file formats and their processing abilities have been compared and are presented in Table 1 where .obj2 is the obj file with the modified structure and *external ways* - without application of professional BIM software.

Table 1. Format types and their difference

Format	**.rtv***	**.ifc**	**.obj**	**.obj2**	**.js**
Geometric information	+	+	+	+	+
Storing information about geometries in file structure.					
Attribute information	+	-	-	-	+
Storing information about the attributes of objects in file structure.					
BIM processing	+/-	-/-	-/-	-/+	-/+
Processing a model in BIM software / Processing a model in external ways.					
BIM analysis	+/-	-/-	-/-	-/+	-/+
Analyzing a model in BIM software / Analyzing a model in external ways.					
External visualization	-	+	+	+	+
Opportunity to store and visualize a model in additional ways.					
Linking a model with GIS data	-	-	-	+	+
Linking a model and the GIS Database using keys.					

.rtv* - in this case, .rtv presents all proprietary file formats.

4. Creating the WebGL Scene

In order to work with 3D models in the WebGL environment, the scene where objects will be processed and visualized has to be created. Making a suitable scene is an important part of WebBIM development, because it contains all necessary features for data processing and analysis.

WebBIM - is the Web based internet platform that syndicates BIM and GIS and allows loading, processing, manipulating and analyzing the BIM models and Digital City models trough web browsers using JavaScript web graphic library.

The scene having the ability to load both types of BIM models was developed. Positions, sizes and angles, geometric and attribute information can be changed. Also, the ability to load model in layers was developed, which is necessary for dealing with a large number of objects.

The ability to select objects in the scene and display their attributes allows inspecting the scene, detecting issues, clashes and making comments on them (Fig. 1) and has been implemented by JavaScript.

Fig. 1. Inspection of attribute information

Comments can be stored on the server and sent to the BIM manager immediately after their occurrence, which provides a possibility for the BIM manager and the customer of working in real time and allows coordinating the development of the project online. In addition, comments can be divided into groups and send to the person who directly simulated the commented object.

The simulation of the celestial sphere and the Sun, the parameters of its ecliptic, the brightness of light, shadow, etc. were developed in the scene, which makes it possible to carry out many types of model analysis such as Site and Solar analysis (Fig. 2).

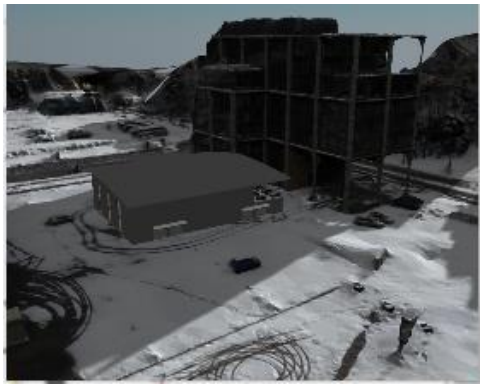

Fig. 2. Site and solar analysis

Levels of detail (LOD) 100 (Fig. 3 a), 200 (Fig. 3 b) and 350 (Fig. 3 c) were created, which provides the opportunity to change the LODs of the model and environment in the settings. On account of this, the models can be used for city conceptualization, architectural designs, visualization, etc.

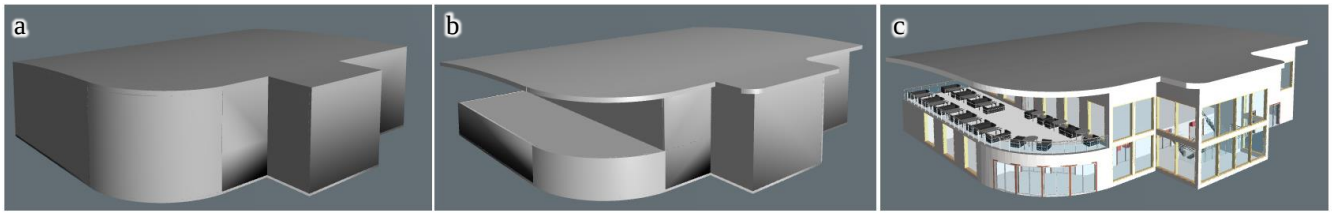

Fig. 3. Detalization of the level of the model: a) 100, b) 200, c) 350

The environment can be loaded in different resolutions to provide a better performance of the scene.

Due to the internal coordinate system and its projections to the existing systems of coordinates, a possibility of accurately determining the location of the objects in the scene and making the Geographic coordinate system to place models in the map using GIS data arises.

Therefore, now, the WebGL environment is ready to process modified objects and manipulate them in the created scene; however, there is a need for a real world environment to provide an explicit analysis of investigated objects. There are several ways to make the existing environment replica to operate it within scene.

5. City Simulation and WebGL

A number of examples of Digital Cities that can be visualized in WebGL using web browsers and giving the opportunity to explore the existing environment such as Essential BIM are available today (http://essentialbim.com/). This type of data visualization suggests a possibility of viewing the map, measuring distances, height and making dot-data. The types of the models that present the cities are different and include point clouds, meshes, planes with models or simply models; every type presents a visual date but cannot be used for work employing attribute data, because they are not able to contain and process any of visual data.

Plenty of ways to make the model of the existing environment exist, and all of them need to be challenged:

- by means of surveying and the subsequent creation of a 3D model. This method is the longest since geodetic filming takes a long time and is the most accurate. Within the process of shooting, any theodolite and the total station can be used.
- by laser scanning that produce point cloud representation as a result. The process also takes a long time, because the device needs to be put on route points, but scanning takes place automatically, which makes this method faster than the previous one.
- using the total station such as Topcon is 301 with photo capturing. As a result of this method, the 3D model with photo textures is obtained. This method of creating the model is much faster than laser scanning but also requires positioning the device point.
- by means of orthophoto photogrammetric transformation, to obtain an orthophoto flight by the aircraft using special equipment. Next, the orthophoto is processed employing such programs as Delta/Digitals. The introduced method of creating 3D models is much faster than others, but also the most expensive.
- By means of photogrammetric works on the pictures taken with the help of a conventional camera; this method has to use a quadcopter.

These images are processed employing photogrammetric programs. The method of creating the 3D model is the quickest and least expensive.

The last taken technique for obtaining the model for the 3D city in this project was photogrammetric software ContextCapture that allowed producing high resolution 3D models from simple photographs, without any human intervention. The principle of the method is to analyze several photographs of a static subject taken from different viewpoints and to automatically detect pixels corresponding to the same physical point. From a number of such correspondences, relative orientations of photos and an accurate 3D shape of the scene can be inferred. The above discussed software solves this problem cutting edge photogrammetry, computer vision and computational geometry algorithms thus fulfilling industrial-quality requirements in terms of precision, scalability, efficiency, usage, robustness and interoperability.

Photogrammetric complexes allow making the textured mesh of the city from photographs and exporting it. There are many choices in the export menu, and one of them is exporting to the web named WebReady. The exporter generates the scene for the object based on the Three.js library converting the 3D model to JavaScript supported format files with different mesh level detalization and creating a folder with the ready project. Unfortunately, there is no opportunity to do analysis of the model and work with it because of one aim of the exporter – only the presentation of the ready result. Data can be converted into simple object formats and imported into the WebGL scene to make it possible to work with data and not only to visualize it.

The unity of the Digital City, the BIM model with attribute data and GIS data gives many abilities to simulate, process and analyze information such as urban heat island (Fig. 4.a), study on changes in climate, the dynamics of urban air flow (Fig. 4.b), heritage preservation, underground space utilization (Fig. 4.c), underground utilities, telecommunication coverage (Fig. 4.d), etc.

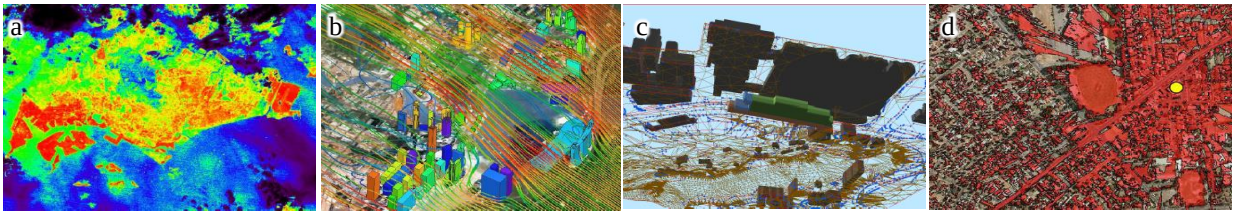

Fig. 4. The examples of using the Digital city, BIM model and GIS unity

6. The cases of Using the Internet Platform of the BIM Model

The best way to describe the main results is to say were and how the developed method can be used. For this purpose, it is necessary to describe uses that can be obtained. The BIM Project Execution Plan is described in a broad sense in BIM ThinkSpace (http://www.bimthinkspace.com/2015/09/episode-24-understanding-model-uses.html), and, according to article conditions, WebBIM has a huge range of opportunities that are given in Table 2.

Table 2. Uses of WebBIM

Name	Description	Status
◦ *General*		
Record Keeping	The generation and maintenance of BIModels as Record Models* *- Using BIM Software Tools for generating an accurate representation of the existing facility, including its spaces, assets, physical condition and the surrounding environment.	implemented
Visual Communication	3D models are generated or enhanced for the purposes of communication, visual, spatial or functional qualities through renderings, fly-throughs, scenography and holography	implemented
Virtual Reality Simulation	The use of the model includes 3D models that are a part of an Immersive Environment where users experience simulated places, objects and processes.	in progress
3D Printing	The use of the model shows how BIModels are applied as a base of generating 3D Prints.	in progress
◦ *Planning and Designing*		
Conceptualization	Initial investigation into design possibilities and spatial requirements. Conceptualization occurs during the sub-phase of the Conceptual Design and may utilize specialized Spatial Analysis Tools	implemented
Selection and Specification	The use of BIModels for elemental/material identification, selection, specification and procurement	implemented
Space Programming	The BIModel is used for investigating spatial client requirements. Space Programming occurs during the sub-phase of Conceptual Design and may utilize specialized Spatial Analysis Tools	implemented
Urban Planning	3D models are used for planning urban spaces, transportation systems and recreational areas. Model-based Urban Planning may integrate data from several databases, including property information, land parcels, zoning and traffic	in progress
◦ *Simulating and Quantifying*		

Accessibility Analysis	BIModel is used for assessing whether a facility allows direct (unassisted) or indirect access for people with disabilities or special needs such as vision, hearing and mobility impairment	in progress
Clash Detection	Using 3D models for coordinating different disciplines (e.g. structural and mechanical), for identifying/resolving possible clashes between virtual elements prior to actual construction or fabrication and for reference to Clash Avoidance	in progress
Safety Analysis	The use of the model shows how 3D models are applied for investigating spaces and simulating actions for the purpose of establishing the safety of workers and lack of health hazards. As an example, a static human figure or an Avatar are used for establishing whether the dimensions of a maintenance pit or a ceiling void are adequate for the safe movement of a maintenance person.	in progress
Security Analysis	The use of the model shows how BIModels are applied for conducting virtual security audits. These may include assessing vulnerability to terrorist attacks, analyzing access points, security signage locations, traffic routes, locking/unlocking systems, and locations/coverage of security cameras	in progress
Site Analysis	The use of the model shows how BIM Software Tools and/or Geographic Information System tools are used for making a decision on on optimal site for a building project and/or an optimal location of the building within a specified site	implemented
Solar Analysis	The use of the model shows how BIModels are applied for conducting shadow studies, simulating solar radiance on building envelops, and analyzing the effect of building location/shape on solar heat loads...	in progress
◦ *Operating and Maintaining*		
Relocation Management	BIModels are used for planning and managing the relocation of movable assets within a facility	implemented
Space Management	The use of the model shows how 3D models are applied for managing occupancy of rooms and spaces within physical assets. Space Management is a subset of Asset Management	in progress
Building Inspection	The BIModel is used as a medium to inspect and report on building condition, completion, and whether it meets applicable codes and standards	in progress
◦ *Monitoring and Controlling*		
Field BIM	The use of the model shows how BIModels are related to databases and accessed in the field (i.e. on the construction site). Through a tablet, laptop, smart phone or wearable equipment, the user would inspect design, send requests for clarifications, mark drawings/models, complete a checklist, etc.	in progress
Real-time Utilization	Using the BIModel for displaying information fed in real-time from sensors distributed around a building or site. Information may include the current occupancy, temperature, humidity, toxicity and energy consumption.	in progress
◦ *Linking and Extending*		
BIM/Spec Linking	The use of the model shows how BIModels are applied for populating and/or integrating the specifications of online products. Such a link between Model Components and product databases may be live, asynchronous, one-way or two-way	in progress
BIM/GIS Overlapping	BIModels are used for populating and/or integrating with Geographic Information Systems	in progress
BIM/Web-services extension	The use of the model shows how BIModels are linked with financial networks, booking systems and a variety of web-based services	in progress

7. Conclusions

The developed method of visualisation and processing the BIM model in the web browser solves such problems as:

1. Easy access;
2. External processing and analysing;
3. Easy sharing and visualization;
4. Linking the 3D model and attribute information;
5. Working with the BIM model and GIS data;
6. Digital City mapping and etc.

There is an opportunity to make BIM and GIS unity not only to combine them in a single project but to make a fully marge environment with difficult associations that extend the capabilities of both. Certainly, the modified types of the .obj file and the JavaScript file are not exactly the same as proprietary file formats hence it cannot give the access to object topology, however it opens new useful ways to publish BIM models and work with BIM uses. The introduced technique can be used as a great new part for BIM execution planning.

Finally, the developed method creates rich future for full BIM software products with all manner of functions and tools that will work through the Internet without installations, distributives, additional programs, etc. WebBIM is the next step in BIM and one more step to World BIM conformity.

8. References

[1] Bourdakis, V. (1997) *Making Sense of the City*, Centre for advanced Studies in Architecture (CASA), University of Bath, UK

[2] Bourdakis, V. and Day, A. (1997) A VRML Model of Bath in R. Coyne, M. Ramsar, J.Lee & K.Zreik (eds) Design and the Net, europIA Productions, pp.13-22

[3] Dodge, M., Doyle. S., Smith. A. & Fleetwood, S. (1998) Towards the Virtual City: VR & Internet GIS for Urban Planning, Birkbeck College, UK.

[4] Institute of Environmental Assessment and The Landscape Institute (IEATLI) (1995). *Guidelines for Landscape and Visual Impact Assessment*. First Edition. London: E&FN SPON, and imprint of Chapman & Hall.

[5] M. Sinning-Meister, A. Gruen, H. Dan (1996). 3D City models for CAAD - supported analysis and design of Urban Areas", Photogrammetry and Remote Sensing, 51, No. 4, August 1996, (196-208)

[6] Soh Kheng Peng, Victor Khoo (2014) Mapping Singapore in 3D, June 2014

[7] The Computer Integrated Construction Research Group, The Pennsylvania State University (2011) BIM Project Execution Planning Guide V2.1 (9-12)

[8] Daniil Shkundalov, Research of tools for storing and analyzing raster geospatial data in an environment object-relational DBMS: master's work, Geographic Information Systems, Ukrainian state University KNUCA, Ukraine, 2015.

[9] Anastasiya Velikorussova, Research of creating three-dimensional models methods according terrestrial laser scanning and terrestrial photogrammetry, Geographic Information Systems, Ukrainian state University KNUCA, Ukraine, 2015.

[10] Draft for public comment, Level of development specification, April 2015

[11] Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston, BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, 2, 2011

[12] Brad Hardin, Dave McCool, BIM and Construction Management: Proven Tools, Methods, and Workflows, 2, 2015

[13] Karen Kensek, Douglas Noble, Building Information Modeling: BIM in Current and Future Practice, 2014

[14] Karen M. Kensek, Building Information Modeling (PocketArchitecture), 2014

[15] Jon Duckett, JavaScript and JQuery: Interactive Front-End Web Development, 1, 2014

[16] Douglas Crockford, JavaScript: The Good Parts, 1, 2008

9. Internet References

[1] WebBIM Project - http://webbim.do.am

[2] Essential BIM - http://essentialbim.com

[3] BIM execution Planning – bim.psu.edu

[4] vA3C - http://va3c.github.io

[5] Solibri support - https://www.solibri.com/support/bim-ifc

[6] BIM collaboration formats - http://www.evolve-consultancy.com/resource/bim-brief/bim-collaboration-formats

[7] Three.js docs - http://threejs.org/docs/index.html#Manual/Introduction/Creating_a_scene

[8] IFC format in BIM - www.solibri.com/support/bim-ifc

[9] GitHub - https://github.com

[10] Stack Overflow - http://ru.stackoverflow.com

[11] BIM ThinkSpace - http://www.bimthinkspace.com