Integrating 3D into an OpenLayers based online GIS application

MSc Geomatics graduation plan

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1 Introduction

Geo-information has many applications in various different sectors and is used by public agencies as well as the private sector. One important way to share geo-information is through the web. With web GIS applications it is easy to share maps and make them accessible to anyone. The users can view the geo-information without the need of file transfers and specific software. Web GIS applications have been predominantly focused on 2D geo-information.

The interest in 3D geo-information has grown a lot over the last few years. More and more use-cases and applications are being developed. It has become clear that 3D geo-information is becoming important tool in many fields of study and private sector developments. Research by EuroSDR has shown that the use of 3D geo-information can be economically viable (Coote et al., 2017), and a continuation on this study has shown it creates public value (Ho, Crompvoets, & Stoter, 2018).

There are some examples of 3D web GIS, such as Kilden Nibio (Nibio, 2023), the BRO 3D I3S webservices by TNO (TNO, 2023), and the 3DBAG viewer (tudelft3d & 3DGI, 2023). However, the existing examples are mostly made by experts in the field of GIS or they are not based on open source software.

Openlayers is an open source library that allows publishing 2D geo-information on a web page (OSGeo, 2023b). There are existing tools based on Openlayers which allow non-experts to publish 2D datasets easily, such as Tailormap (B3Partners, 2024). However, there are no such tools to easily publish 3D datasets.

1.1 Problem statement

Although the interest in 3D geo-information has grown, it is not yet clear which use cases of 3D geo-information can benefit from sharing the datasets through on online GIS web application. There is also not yet an open source tool based on Openlayers that allows the publication of 3D geo-information on the web without too much expert knowledge. If the ability to publish 3D geo-information can be added to an existing Openlayers based application this would make sharing 3D easier, and it can help to gain more knowledge about which use cases of 3D geo-information this would be useful for.

1.2 Graduation plan

This document is the proposed graduation plan for this thesis. section 2 summarises the initial results of the literature study. In section 3 the research question is stated, along with the scope of the project. section 4 explains the methodology that will be used to answer the research question. Finally, section 5 provides a planning of the project, and section 6 states the tools and datasets that will be used.

2 Related work

In order to be able to make the eventual solution useful and easy to use, it is necessary to understand the relevance of 3D geo-information on the web and to identify important users and use-cases of 3D geo-information on the web. The relevance of 3D geo-information is discussed below in subsection 2.1, after which potential use cases are considered in subsection 2.2. Lastly, in subsection 2.3 three existing 3D web GIS applications are analysed.

2.1 Value of 3D geo-information

Between 2015 and 2017 a EuroSDR project analysed the costs and benefit of 3D geo-information for public mapping agencies (Coote et al., 2017). Two case studies were used to do this: Flood management and urban planning. They found that "The cost-benefit analysis demonstrated in both of the selected use cases that benefits outstrip costs by a multiple of between two and three times even when considering each use cases in isolation." (Coote et al., 2017). The project shows that, for these two use cases, investing in 3D geo-information is economically beneficial for public mapping agencies. Further research was done, using the data gathered by the EuroSDR project, by Ho et al. (2018). They looked beyond economic value and analysed the public value created by 3D geo-information, which includes more general benefits for society. They concluded that investment in 3D geo-information can generate public value in many different ways, such as quality of life, safety, and transparency of public organisations (Ho et al., 2018). This further encourages investment in 3D geo-information and infrastructure for 3D geo-information.

2.2 Users and use cases of 3D geo-information

In the EuroSDR project a value chain analysis was also done for six use cases: Forest management, flood management, 3D Cadastre and Valuation, Resilience (civil contingency), Asset management, and urban planning (Coote et al., 2017). One part of this value chain analysis were the users of 3D geo-information. Many end users were identified for all use cases. Some of these users and use cases that are potentially relevant for 3D geo-information of the web will be highlighted here. (Coote et al., 2017) (The users were identified by the EuroSDR project, the reasoning why these might be relevant for 3D on the web is done by the author of this thesis proposal.)

In asset management, specifically management of utilities, an important benefit of 3D data is reduced utilities strikes. 3D data about of locations of cables and other utilities would reduce damage and danger caused by excavators hitting these utilities (Coote et al., 2017). Sharing this data via a web application could be a good solution. This way, up-to-date quality data would be available at building sites, and anyone on the sites can access this information without the need of GIS software.

In flood management, 3D geo-information can be used by municipalities to visualise flood risks. With this they can inform decision makers in government as well as citizens (Coote et al., 2017). Online 3D GIS could be good way to share these visualisations, since most citizens and decision makers do not have GIS software and knowledge.

In the case of 3D cadastre and valuation, the most important identified benefit is "Allowing citizens to review and contribute to the data held by the tax authorities about their property creates a crowd-sourcing production efficiency for tax authorities as well as improving citizen trust in the authority's data holdings." (Coote et al., 2017 (Coote et al., 2017)). A practical solution to accomplish this could include the use of a 3D web GIS application. The tax authorities could use this to share the data with citizens. The citizens could view the data and perhaps contribute using this web application.

In the urban planning use case, informing the citizens is again one of the most important benefits of 3D geo-information. (Local) governments can use it to visualise plans and development to better show citizens the results and impacts (Coote et al., 2017). They could share these visualisation with citizens with the use of a 3D web GIS application.

2.3 Examples of 3D geo-information on the web

Kilden Nibio

Kilden is an online resource made by research institute Nibio in Norway. It has a function to switch to a 3D view. This function then shows a terrain model of Norway, with the the option to display many different maps draped over the it. The terrain model is a 2.5D dataset. To display the data in 3D, Cesium (Cesium GS, 2023) was used. The application sends terrain to the client based on the zoom level. This means actual terrain data is streamed to the client, but not the whole model with the full detail and full extents that is stored on the server. When zooming or panning, the client requests a new terrain model from the server. (Cesium GS, 2023) (Nibio, 2023)

BRO 3D I3S webservices

The BRO 3D I3S webservices are made by research institute TNO in the Netherlands. The service allow users to view soil models of the Netherlands online in 3D. The web viewers are made using ArcGIS Scene Viewer (Esri, 2024), and they use the Indexed 3D Scene Layers (I3S) standard. They have two different types of data sets: GeoTOP, which is a voxel model, and REGIS II, which consists of 100x100 meter blocks that have layers of different sizes. For the voxel dataset, the entire model is sent to the client when opening the web viewer. For the REGIS II dataset only a part of the model is sent to the client, and new requests are sent when zooming or panning. (TNO, 2023)

3DBAG viewer

3DBAG is an automatically generated 3D dataset of buildings in the Netherlands. An online 3D viewer was created to show this dataset. The viewer displays the 3D model along with a background map from a different source which is obtained via a WMTS. The 3D model itself is streamed to the client using a batched 3D model. Only a part of the model is send to the client based on the position of the camera, and new requests are sent when zooming or panning. (tudelft3d & 3DGI, 2023)

3 Research questions

3.1 Research questions

To solve the problem statement written in subsection 1.1 this thesis will answer the main research question:

How can 3D functionality be integrated into an existing Openlayers based GIS web application in a useful and easy to use way?

To answer this research question, some sub-questions need to be answered.

1. What kind of 3D datasets are available and what are the useful use cases of 3D online GIS?
2. How can you make it easy to publish 3D datasets without too much expert knowledge?
3. How can 3D functionality be integrated into an Openlayers application?
4. What should the data flow look like?
   a) How and where is the data stored?
   b) What should be done server-side and client-side?

3.2 Scope of the project

To answer these questions, research will done by means of literature study and interviews. This will be further elaborated on in subsection 4.1. Additionally, a proof of concept will be made. This will be an application with which 3D datasets can be published on a web page. The application will be an extension of the existing Openlayers based Tailormap application (B3Partners, 2024). To define the scope of this proof of concept, requirements are listed below using the MoSCoW method (Miranda, 2022). The must requirements are necessary for a successful completion of this thesis. The should requirements will be worked on and the aim is to complete these. The could requirements are possible additions that could be added if they proof to be important based on the research explained in section 4. A more detailed explanation of the proof of concept is given in subsection 4.2.

The proof of concept:

Must

- Allow publication of 3D datasets on the web for viewing
- Handle 3D vector data
- Allow basic styling
- Handle datasets up to 2 GB

Should

- Use 3D Tiles to stream the 3D data
- Have an option to show semantic information (such as)
- Have an option to allow clipping of the data

- Handle datasets bigger than 2 GB

Could

- Handle terrain models
- Handle voxel models
- Handle point clouds
- Have an option to allow filtering of the data
- Have an option to allow editing of the data from the client side

Will not

- Be an entirely new application to publish data on the web

4 Methodology

This section proposes the methodology that will be used to answer the research questions stated in section 3. The methodology has been split in two parts: user and applications research to answer sub-questions 1 and 2 and a technical methodology to answer sub-questions 3 and 4. These parts are not separate, they will be done simultaneously and their results will feed into the other part.

4.1 User and applications research

To answer sub-questions 1 and 2, research will be done into potential users and use-cases of 3D online GIS. To answer these questions it is necessary to find use-cases of use-cases of 3D online GIS and discuss them with parties that will potentially publish 3D datasets on the web. Publication options (sub-question 2) also need to be discussed with them. This part of the research will be done in four steps.

1. Literature study

First, a literature study is conducted to find already identified use cases in other studies. Some existing examples are also identified. In these use cases and examples the following things will be identified:

- Types of 3D data (point cloud, boundary representation, voxels, terrain model, etc.)
- Who is publishing the 3D data on the web?
- Who is the target audience for the published data?
- What options could be needed for this application? (viewing, editing, styling, clipping, filtering, etc.)

2. Interviews

Interviews will be conducted to obtain more detailed information about the needs of parties that might publish 3D data on the web. The interviews will be held with parties that have a potential interest in publishing 3D data on the web. The interviewed parties will be different types of organisations, such as municipalities, Kadaster, private companies, and safety regions. They will be asked (among other questions) about the following things:

- What 3D datasets do they have and what 3D datasets do they plan on obtaining in the future?
- What do they plan to use the 3D datasets for, and with what type of people do they want to share the data?
- Can an online web application be a good solution to share the 3D datasets?
- Who would need to be able to publish or edit the online 3D GIS application, and how much knowledge do they have of GIS?
- What options (viewing, editing, styling, clipping, filtering, etc.) would they need for in the online 3D GIS application?

3. Testing

A proof of concept will be built as will be explained in subsection 4.2. When a first version of this is done and ready to use, it can be tested by the parties that were interviewed, or other parties that could potentially use it to publish 3D geo-information on the web. This testing is mainly done to better answer sub-question 2, but it can also help to answer the other sub-questions.

4. Feedback

After testing, feedback will be obtained from the people who tested the proof of concept. This feedback will be integrated into the conclusions drawn for the sub-questions and the main research question. The feedback will also be used to improve the proof of concept as far as possible.

4.2 Technical methodology

To answer sub-questions 3 and 4, a proof of concept will be made. This will be an application with which one can publish a 3D geo-information dataset on the web. This application will be made within an existing Openlayers based application which is used to publish 2D geo-information on the web. This existing application is Tailormap made by B3Partners (B3Partners, 2024). Tailormap uses Openlayers to display 2D maps. To be able to also display 3D data, Cesium will most likely be integrated into the application. Cesium would be used within the Openlayers application to display a 3D dataset along with a 2D map. However, if this does not give the desired results, other options to display 3D data can be explored as well.

Type of data

The proof of concept will not be made to be able to handle all kinds of 3D geo-information (voxels, terrain models, point clouds). The focus will be on 3D vector data. This means it will be able to handle file formats such as a .obj file or a CityGML file. This choice was made based on the initial research that has been done. However, if the further research explained in subsection 4.1 shows that another type of 3D geo-information is as important and has immediate use cases, this type of data can be integrated into the proof of concept as well.

Data flow

The amount of data in a 3D geo-information dataset is generally larger than a 2D dataset of the same area. In a web application the amount of data that can transferred is limited. This means the data flow has to be carefully designed. There are different ways do deal with this: The web application could keep all the 3D data on the server side and only send images to the client. This means requests are send every time the user moves the 'camera', and a new image is generated on the server and send to the client. The second option is to send the entire 3D dataset to the client when the website is loaded. The client then generates the images when moving the camera. The third option is to send part of the 3D data to the client based on the position of the camera. The client then generates the images based on the smaller dataset. When rotating or when zooming or panning a small amount, no new request needs to be send to the server. When zooming or panning more a new request is send to the server for a new part of the 3D model.
The second option is discarded, because it is not viable for large datasets, and because most identified potential use cases involve sharing the data with large amounts of people that might not have a powerful computer. The aim will be to implement the third option, since this allows

for smooth movement when viewing, without having to transfer the entire dataset. It is also the method used by the three existing examples discussed in subsection 2.3. However, if this strategy does not give the desired result the first option will also be tested. For the second option the data flow is illustrated in Figure 1 (the JavaScript package is send to the client when loading the web page).

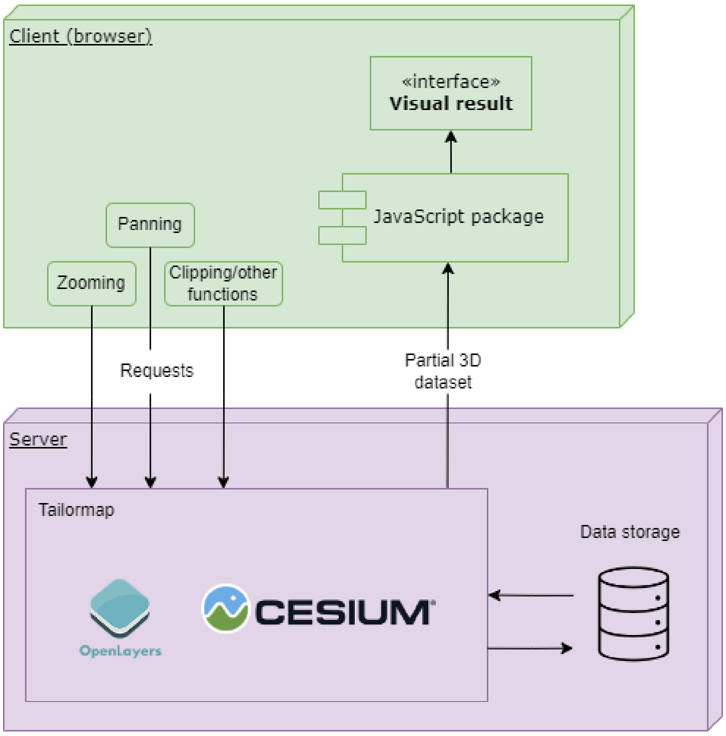

Figure 1: Data flow (OSGeo, 2023b) (Cesium GS, 2023)

To be able to create the partial 3D datasets to stream to the client, the OGC standard 3D Tiles will be used (OGC, 2023). More specifically, the data will be stored as a batched 3D model according to the 3D tiles specification. This means a function will be added that converts the input dataset to a batched 3D model when a web page (with 3D dataset) is created using Tailormap.

5 Time planning

The planning for this thesis is visualised in Figure 2. An overview of the deadlines can be found in Table 1.

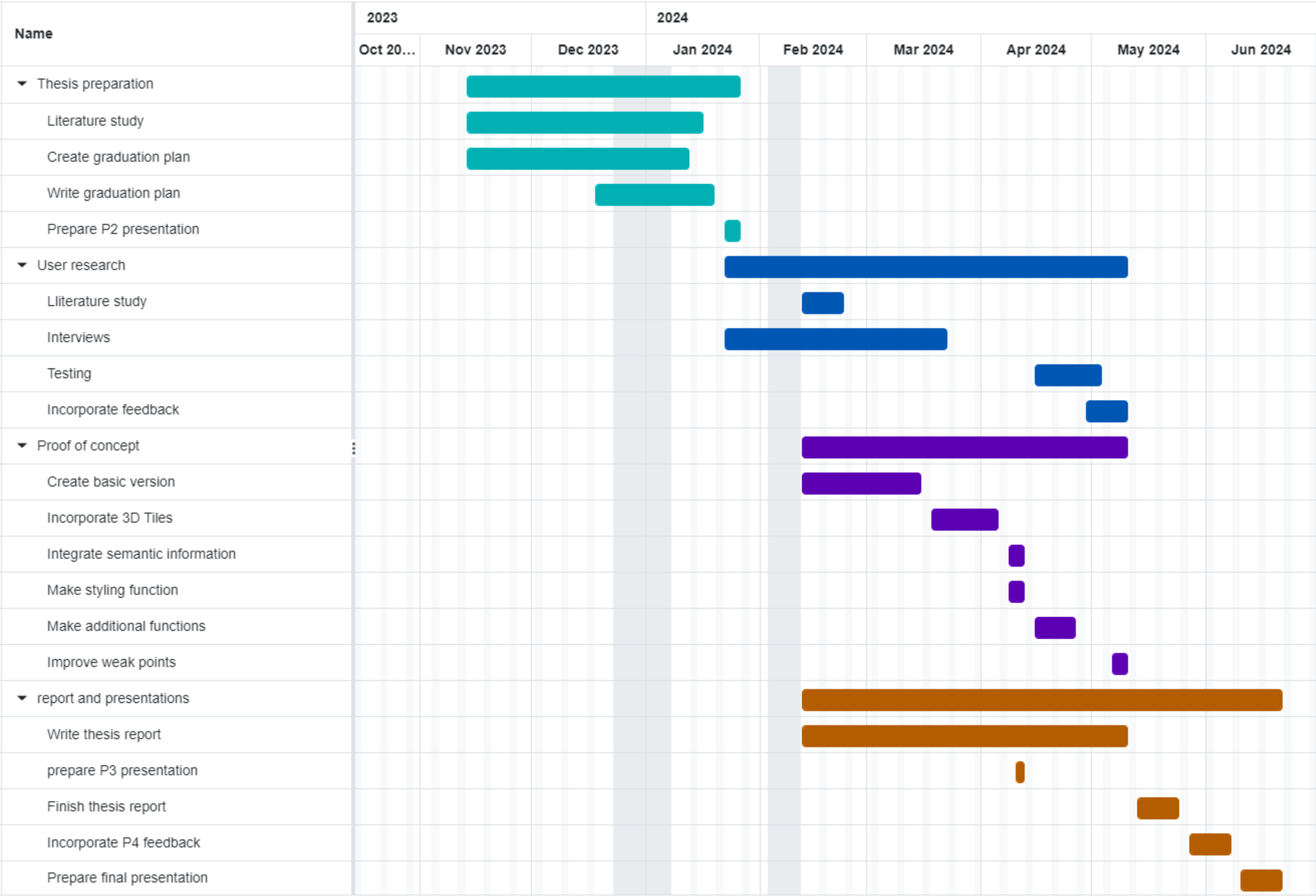

Figure 2: Gantt chart

Table 1: Deadlines and presentations

Event	Date
P1	17/11/2023
P2 Report	19/01/2024
P2 Presentation	26/01/2024
P3	TBD
P4	Between 13/05/2024 and 31/05/2024
P5 Report	Between 10/06/2024 and 28/06/2024
P5 Presentation	Between 17/06/2024 and 05/07/2024

6 Tools and datasets used

6.1 Tools

The proof of concept will be made using the existing web GIS application Tailormap, made by B3Partners. This is an Openlayers based application written in TypeScript. The proof of concept will also be written in TypeScript. The open libraries that will be used are Openlayers (OSGeo, 2023b), Cesium (Cesium GS, 2023), and possibly Ol-Cesium (OSGeo, 2023a).
To run and test the proof of concept developments the application Docker Desktop will be used.

6.2 Data

To test the proof of concept developments some data sets will be required. These data sets will be obtained from the interviewed GIS users or from other clients of B3Partners. Some openly available 3D datasets from the TU Delft or other organisation can also be used.

References

B3Partners. (2024). *Tailormap.* Retrieved from https://www.tailormap.nl/

Cesium GS. (2023, 12). *Cesium.* Retrieved from https://cesium.com/

Coote, A., Knight, P., Colding, T. S., Home, R., Fröjdenlund, J., Lysell, G., ... Stoter, J. (2017). *Official publication n o 68 european spatial data research.*

Esri. (2024). *Scene viewer.* Retrieved from https://www.arcgis.com/home/webscene/viewer.html

Ho, S., Crompvoets, J., & Stoter, J. (2018, 6). 3d geo-information innovation in europe's public mapping agencies: A public value perspective. *Land*, *7*. doi: 10.3390/land7020061

Miranda, E. (2022). Moscow rules: A quantitative exposé. In V. Stray, K.-J. Stol, M. Paasivaara, & P. Kruchten (Eds.), *Agile processes in software engineering and extreme programming* (pp. 19–34). Cham: Springer International Publishing.

Nibio. (2023). *Kilden nibio.* Retrieved from https://kilden.nibio.no/

OGC. (2023). *Ogc ® document: 22-025r4 3d tiles specification community standard approved.* Retrieved from https://www.ogc.org/standard/3dtiles/

OSGeo. (2023a, 8). *Ol-cesium.* Retrieved from https://openlayers.org/ol-cesium/

OSGeo. (2023b). *Openlayers.* Retrieved from https://openlayers.org/

TNO. (2023, 10). *Bro 3d i3s webservices.* Retrieved from https://3d-bro-webservices-esrinl-content.hub.arcgis.com/

tudelft3d, & 3DGI. (2023). *3dbag viewer.* Retrieved from https://3dbag.nl/en/viewer