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Class project - Creating a GIS system for 2D and 3D visualisation



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Glossary

GIS Geographic Information System

DEM Digital Elevation Model

Orthophotos Aerial photograph or satellite imagery geometrically corrected

WMS Web Mapping Service

WMTS Web Mapping Tiled Service

WFS Web Feature Service

UML Unified Modeling Language

Introduction

The aim of this project is to create a GIS system for 2D and 3D visualisation that can also make simple treatments on geographical data in 4 weeks. To do so, all class members have taken part in this project, and Agile project management has been used to develop and manage our project. The duration of each sprint was only 1 week, because there was no more time to increase this duration. The team is presented in this report.

UML language was used to make the application analysis. It provides a standard way to visualize the design of a system, and all sorts of diagrams can be made to represent database models or the application components for instance.

This project client was Victor COINDET, head of the Teaching Department in Information Systems Technologies at ENSG. He asked the team to work with Lyon's data, a french city located in south-east of France, specifically on the 5th district. It was the team role to download 2D and 3D data of this district. The results presented in this report are issued from this district.

1. Analysis

1.1 Languages

One requirement of the client was to only use C++. To visualise 2D data, external libraries can be used, like Nohlmann JSON library to parse data into JSON, and GDal to display it. To visualise 3D data, OpenGL is used. To avoid too much installations for the client, we decided to use Docker containers to run the PostGIS and 3DCityGML databases. The docker container is created with the application creation, and started each time that the application is opened. This way, the client does not know how the platform interact with the database.

1.2 Functionalities

1.2.1 List of functionalities

The application is a simple Geographical Information System (GIS), so it has to handle simple functionalities, such as:

- **2D Visualisation:**

- Interacting with map (pan, zoom etc.) ;
- Managing layers (choosing which layer to display, change order of layers...) ;
- Display raster and vector layers ;
- Import flow layers from IGN website *Géoservices* ;
- Show entity attributes when clicking on them.

- **3D Visualisation:**

- Controlling camera (pan, zoom, camera rotation etc.) ;
- Managing layers (same as 2D visualisation) ;
- Display raster layers (orthophotos on DEM) and vector layers (3DCityGML file for example) ;

Additionally, basic treatments and operations on layer will be implemented, such as:

- **2D Visualisation:**

- Changing layers styles ;
- Editing vector layers ;
- Calculating basic treatments on vector layers (buffer, intersection, union ...) ;
- Export layers to ShapeFile or other extensions output.

- **3D Visualisation:**

- Calculating indicators on 3D vector layers, such as: max height, height of the lowest point of the roof...

These are not exhaustive functionalities, and they are not ordered by difficulty nor by importance.

1.2.2 Use case diagrams

Use case diagrams can be used to represent interactions between actors and the platform. The figure 1.1 shows the use case diagram of the application.

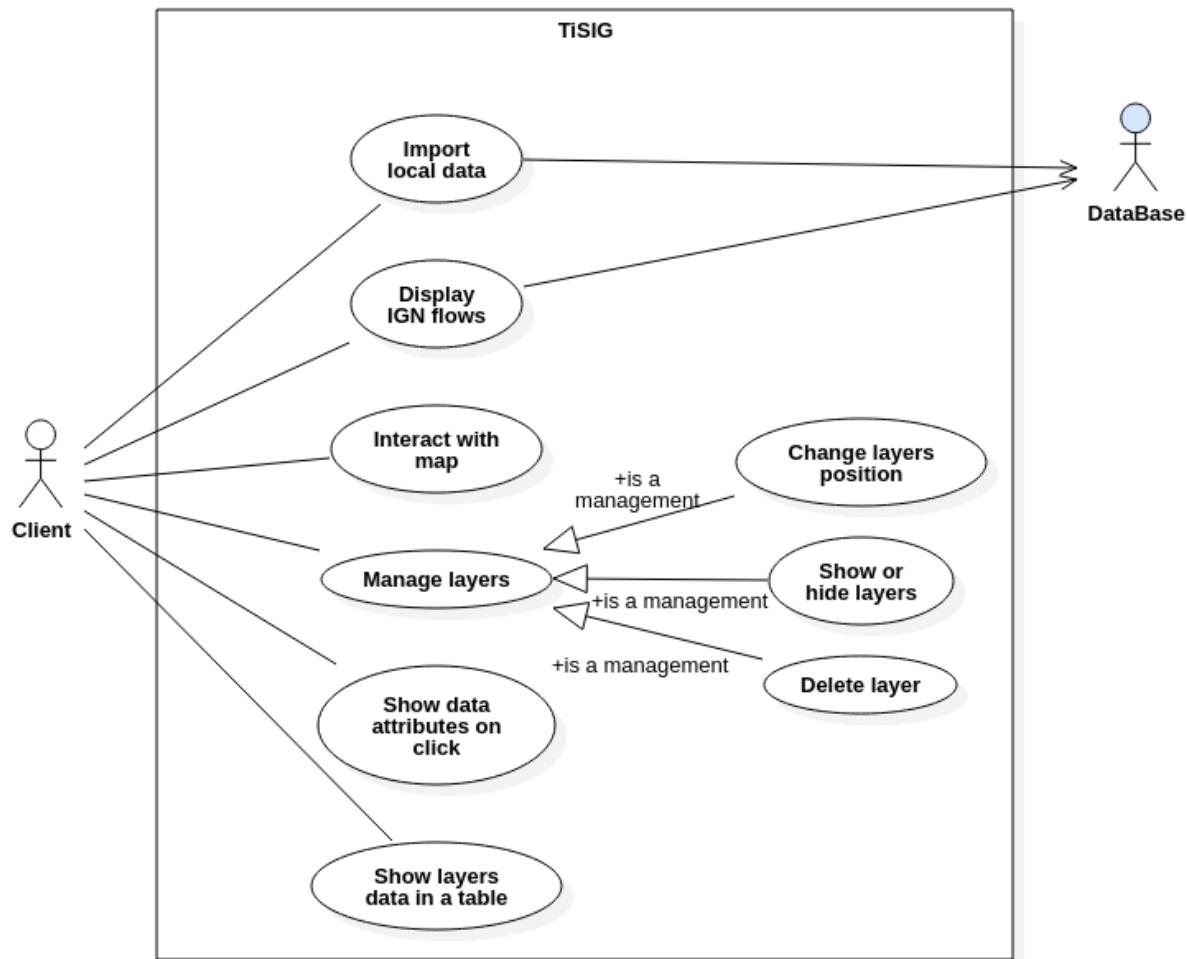


Figure 1.1: Use case Diagram

On this diagram, the client can interact with TiSIG according to the features discussed before. Indeed, the client can interact with the map, manage layers and visualise data informations. Also, he can import data and display IGN flows. For these two actions, data is saved into the system internal database, and then used by TiSIG to be displayed.

Only first needed features has been included in this diagram, but it is possible to include more actions. Even though, actors are the same: the client and the database. When it is about changing data or manipulating data, interacting with the database is necessary. The DBSM (DataBase System Manager) used is PostgreSQL, and PostGIS, a geographic extension of PostgreSQL, is used as well. PostGIS can manage spatial treatments such as intersection or buffer creation. Each time a user wants to manipulate data - which means not only show data and interact with the map -, interactions with the database are performed.

1.3 Application architecture

For the application architecture, the team decided to work with spatial database, such as PostGIS, even though it is not necessary for the beginning of the project. Indeed, some libraries in C++ exist to display ShapeFile for example without external database. However, this decision has been made to implement easily spatial treatments, as PostGIS already implements them. To difference 2D and 3D visualisation, two databases are needed. The 3D database implements 3dcitydb, a database schema that implements CityGML standards. To make the architecture analysis, 3 UML diagrams have been made: a class diagram, a component diagram and a deployment diagram.

1.3.1 Class diagram - Database model

To structure the database, using a class diagram is appropriate. Each class represents a table, and those tables belong to one database (2D or 3D). 3 stereotypes are used in this diagram: *Database*, *Abstract table* and *Table*. An abstract table is a table that gives a table template but can not be instantiated. Database class diagram is represented on figure 1.2.

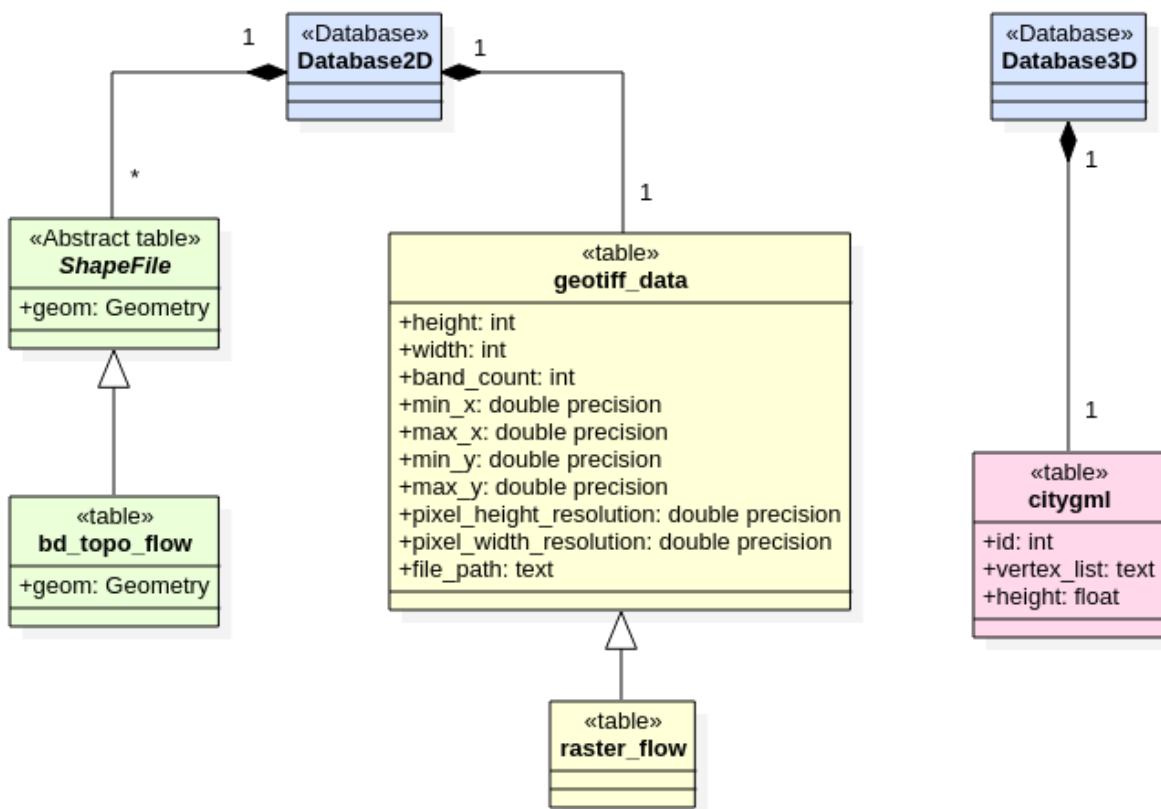


Figure 1.2: Class diagram

The **ShapeFile** table is an abstract table, which means that there are no tables named "ShapeFile" in the database. However, this table gives a template for all shapefiles imported into the database: they all have at least a geometry and an id. Each layer imported in the system is saved into the database in the form of a table. The table name is extracted from the file name, where all conflicts are resolved. For example, the system transforms points and space into underscores. For each vector flows, a table exists too. In this diagram, only Topographic database - *BD TOPO* in french - is represented.

For raster data, it works differently. Only one table - **geotiff_data** - is created, and all information about every raster files will be inserted here. This choice has been made because it is easier to read

directly a geotiff than to parse it into a database and then read information and display it on the application. Metadata about the file, like width, height or band_count is also saved into the database. This way, it is possible to show metadata about this one by doing a request in the database. Like vector flows, raster flows are inherited from the raster table. It allows the platform to request the correct table when displaying flows.

Finally, a different database is used for 3D visualisation. This database is named *CityGML*, and contains a lot of tables, but only the one requested by the application is represented here: **surface_geom** table. Each feature of this table represents a building contained in the 3DCityGML file. A building has an id, a list of vertexes to construct polygon using OpenGL, an height and a category which can take a value, such as "school" or "church" for example. The other tables are not represented here because they are used by the application to treat 3DCityGML file, but they are never requested.

1.3.2 Component diagram

Each database only represents one system component, even though there are more than two components in reality. To show how system components interact with each other, it is possible to use a component diagram. The figure 1.3 represents the system component diagram.

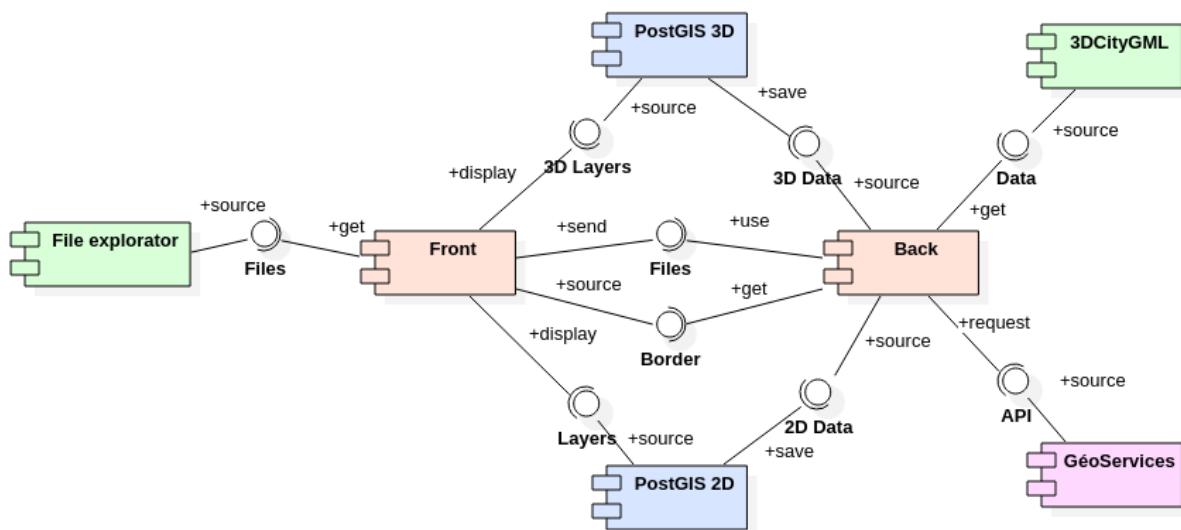


Figure 1.3: Component diagram

One category can be assigned to each component. There are four categories in the system: Database, external services, application and internal files / storage. They are respectively coloured in blue, pink, orange and green. These categories will then be used by the system deployment diagram, represented in figure 1.4. It has been decided to divide the application between front-end and back-end in the component diagram for two reasons. The first reason was for the understanding of the diagram. By dividing front and back, the interactions with other components and between them - *i.e.* interactions inside the application - are more visible. Secondly, this choice has been made to know how to divide work between front and back teams. By dividing them in the analysis, the task planning has been easier to make.

To display 2D or 3D data, the user has to import its own files from the file explorer. Those files are retrieved by the front, and sent to the back-end. Then, treatments on data are made, and then saved into their respective databases: 3dCityGML and DEM into PostGIS 3D; ShapeFiles, GeoTIFF and GeoJSON into PostGIS 2D. Once they are saved, front-end can request these databases to display layers in the application. 2D and 3D data can not be visualised in the same time.

For raster and vector flows, it works differently. First, front-end send the extent of the screen (coordinates in Lambert 93 or WGS 84) to back-end. With borders, it is possible to request Géo-Plateforme's API to get only interesting features to display in the application. Those features are then treated like ShapeFiles or GeoTIFF, saved into the database and displayed after. As long as a flow is displayed on the application, this process is repeated.

1.3.3 Deployment diagram

System components are now known, but it is also important to know on which devices each component will be. To do so, a deployment diagram can be useful. The figure 1.4 represents the system deployment diagram.

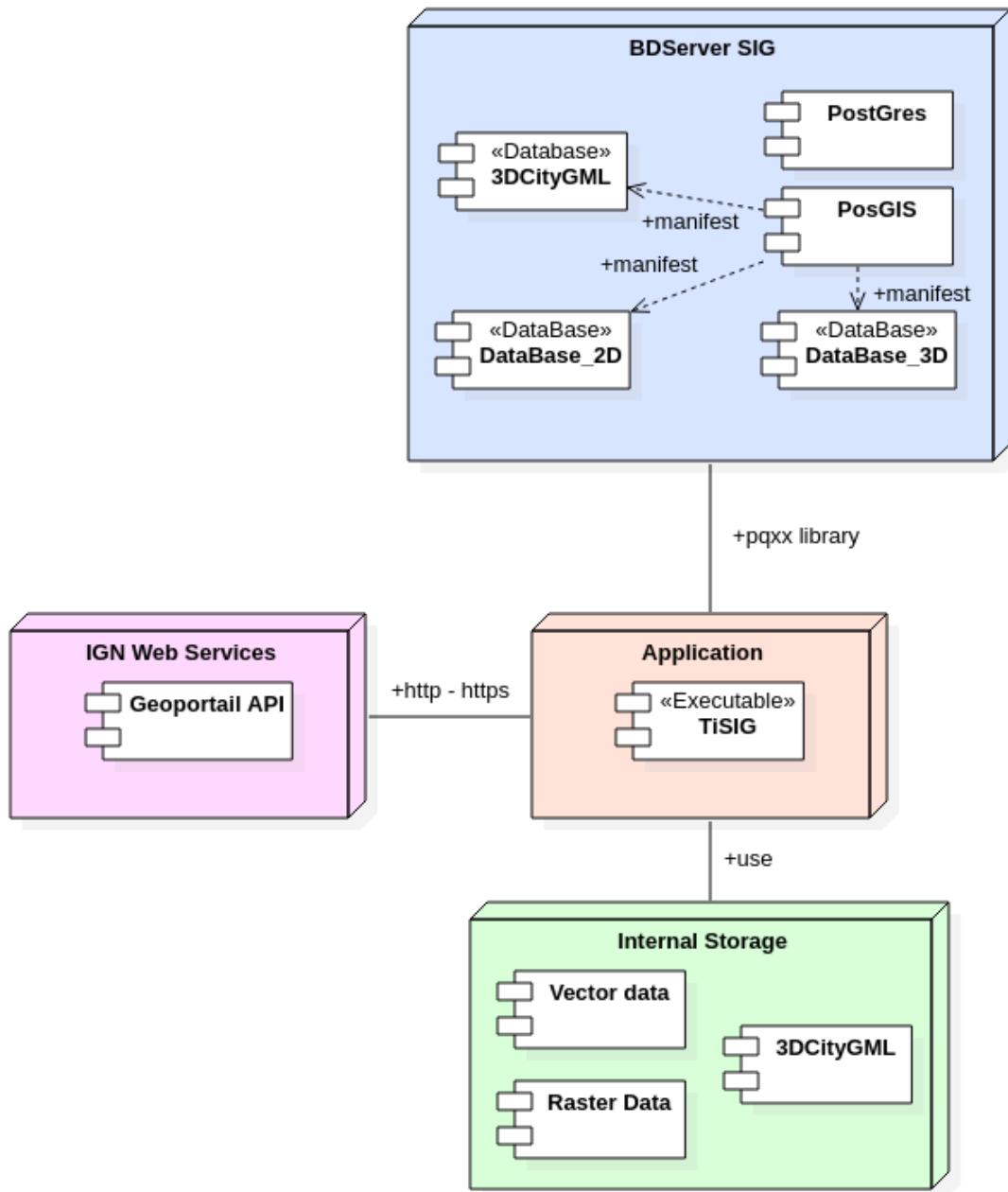


Figure 1.4: Deployment diagram

A deployment diagram represents interactions between devices and protocols they use to communicate. As described in the component diagram, there are 4 devices: Application, Internal Storage,

BDServer GIS and IGN Web services. Names are different, but they represent the same thing than before and same colours have been used. Front-end and back-end have been put into TiSIG application, because dividing them here would not have been useful.

The application use files locally stored to display them. Once they are transformed, they are saved into the database. All interactions between database and the application are made with the pqxx library, a C++ library used to manage PostGreSQL servers. For flows, GéoPlateforme API is called through *http* protocol. As it does with internal files, data is then saved into the database.

It is not represented in the deployment diagram, but a Docker Container, based on a 3dcitydb image, is used to contains both databases. It does not change the interactions between devices, only the real location of the database. By using a docker, the user does not have to launch and install PostGreSQL nor PgAdmin 4, and it ease TiSIG's installation. Except for IGN webservices, all others nodes are in the client's computer.

1.4 TiSIG's sketch

Right after analysing client's needs, our UX Designers, Frederic YE and Lisa ZARATIN, have drawn what they imagined TiSIG would look like. After client's approval, this sketch has been used to develop TiSIG. The sketch is represented on figure 1.5.

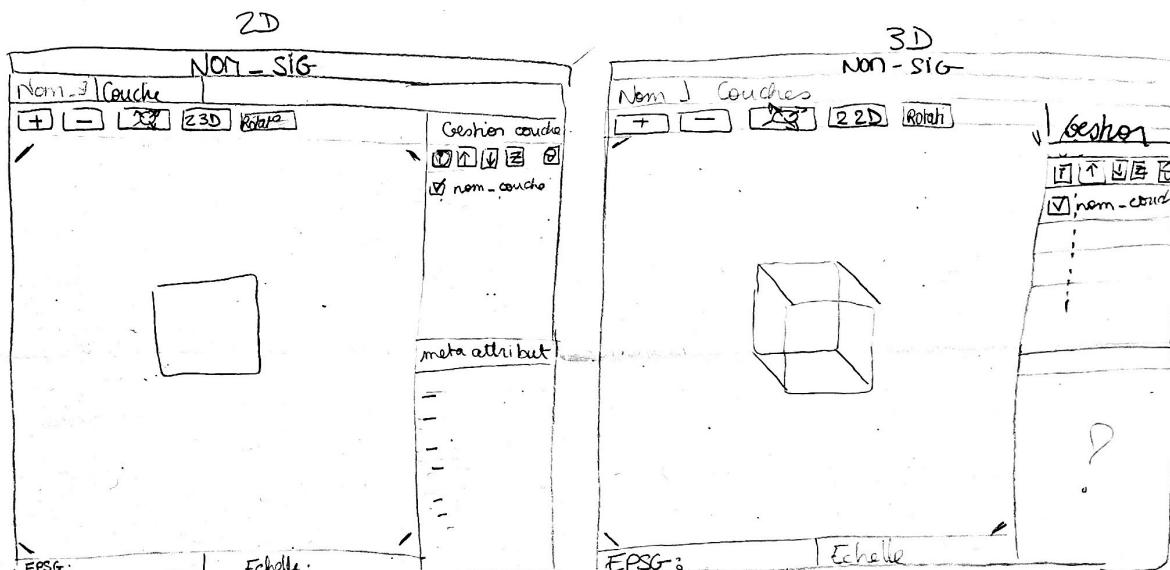


Figure 1.5: TiSIG's sketch

2. Project Management

This project was our first project in a team of 15 using agiles methods. To ensure that everything goes well, different tools have been used.

2.1 Team members and agile roles

The team was composed of 15 students. We divided it in two subteams: one for the front-end (front team) and one for the back-end (back team). This way, it was easy to split the work to do for the project life. As agile methodology was used, a scrum master and a product owner had to be chosen for each team. During the 4 weeks of project, scrum masters did not change, but product owners did sometimes. This decision was made naturally, as we discussed it between us, and let people take the role they wanted simply by saying it. A "Scrum of Scrum", supposed to make scrum masters agree when they were conflicts, was also chosen at project beginning. However, we took the decision to erase this role because it was useless, as the two scrum masters could reach on an agreement when it was necessary.

In the following list, when someone is tagged with Product Owner for one or several weeks, it means that this person was developer for the other weeks. Because it was a small project, scrum masters also were developers. Even though they had to make the product backlog or other things, it let enough time to also develop. It is the same for product owners. The front team was composed of:

- Vittorio TOFFOLUTTI: **Scrum Master**;
- Lisa ZARATIN: **Product Owner from week 2 to 4**;
- Victorien OLLIVER: **Product Owner for week 1**;
- Romain COURET: **Developer**;
- Vincent GIUDICELLI: **Developer**;
- Claire GUERRINI: **Developer**;
- Frédéric YE: **Developer**;

The back team was composed of:

- Mathis ROUILLARD: **Scrum Master**;
- Claire GIRARDIN: **Product Owner from week 3 to 4**;
- Clovis BERGERET: **Product Owner for week 2**;
- Axel DUMONT: **Product Owner for week 1**;
- Hannick ABDUL-KUTHOOS: **Developer**;
- Mathéo MARÉCHAL: **Developer**;
- Hicham OUTMRHOUST: **Developer**;
- Cécile TALEC: **Developer**;

2.2 Agile methodology during the project

During the whole project, as mentioned before, each person had a unique role per week. Additionally, we used Trello, an online project management tool. With Trello, it is possible to create boards. These boards can be used as Product Backlogs, Kanban or for other things too. For example, to easily see who was the product owner of a week or who work on a specific user story, we had a board named *Roles* where each week, for front-end and back-end, agile roles and main user stories were assigned to one person.

2.2.1 Product Backlog and Sprint Backlog

To create the product backlog, we first chose to do a team brainstorming to define what was important for the client. It is important to mention that we did not have a project subject during the first two days, so we had to create user stories without knowing if it would be relevant. Each member had a user story assigned and we decided that everyone had to write their own user stories, and not only scrum masters and product owners. That was probably a good idea because the first week of project was a sprint of barely two days, but every member was involved. We divided them into front and back, and created a product backlog for the two subteams. An example of the front's product backlog is represented on figure 2.1.

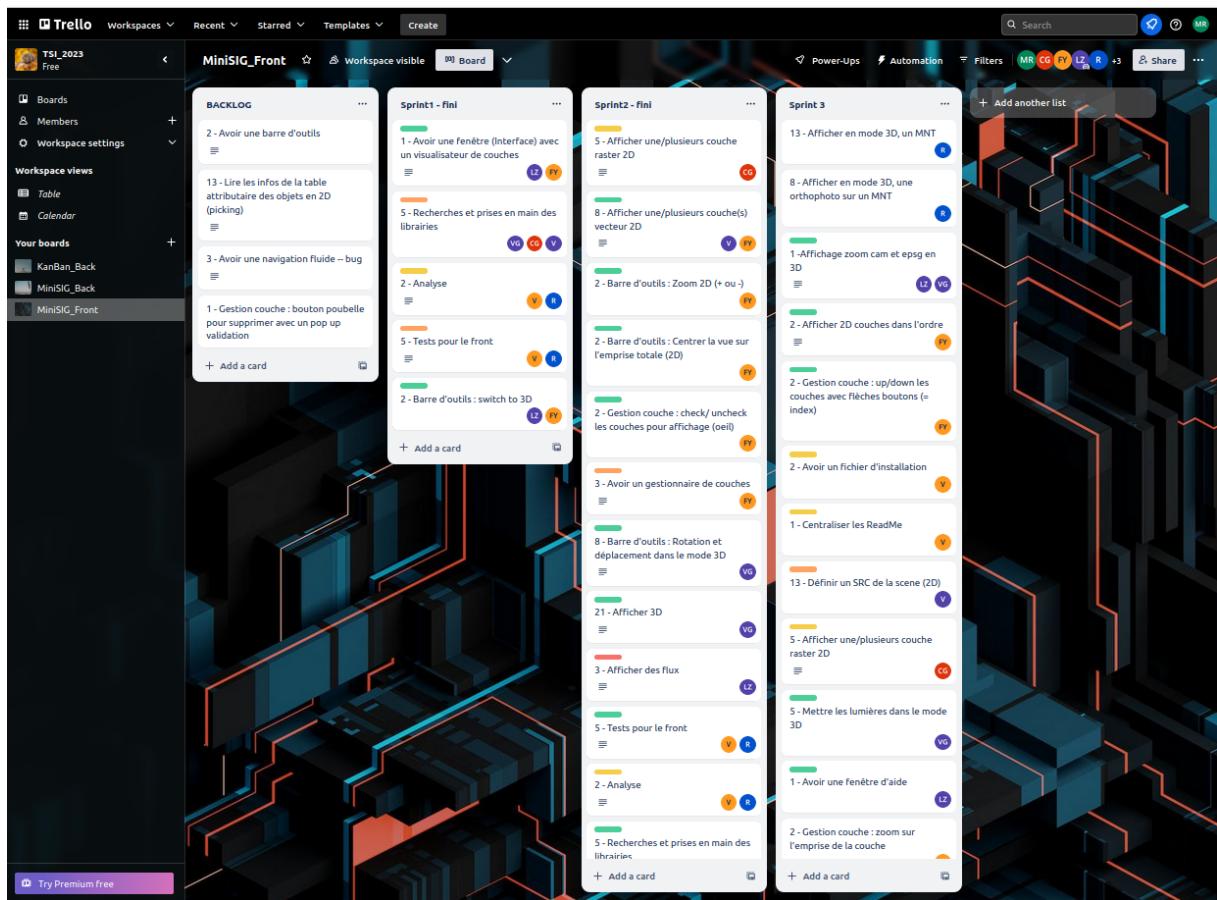


Figure 2.1: Example of the front's product backlog during week 3

Before starting the first sprint, all user stories were written and put in the *BACKLOG* list. Then, the scrum master and product owner of each subteam decided which user stories was going to be developed. The two subteams then communicate to agree on a main functionality to implement. For example, if the back team decides to work on 3D visualisation, it is important that the front team starts to work on that too. The two teams work differently: front team decided to put colour on

2. Project Management

every task to describe their progress - red when it is not started yet, green when it is finished; back team decided to estimate the progress of each user story at the end of the sprint, using Fibonacci sequence - 8 out of 13 means that the task is almost finish.

2.2.2 Meetings with the client

One principle of agile methodology is to interact frequently with the client. To respect this, product owners had weekly meetings with the client. During these meetings, product owners shown the project progress to the client, discussed about the client's needs and talked about encountered obstacles. They took place at each sprint beginning so the team could adapt the sprint depending on client's new needs. It was important to validate application progress, and to prevent misunderstandings.

2.2.3 Daily meetings and Sprint Review

During the whole project, we had two team meetings per day, and at the end of each sprint, a Sprint Review. The first meeting, the **Daily Stand Up**, was at the beginning of the day and its goal was to say what one was planning to do for the day or what one was troubled about. It could be really quick, especially when no user stories were about to be finished. After this meeting, the day could really starts, and everyone knew what others were doing during the day.

At the end of day, an other meeting called **Retrospective** was made. During the retrospective, at the opposite of the daily stand up, one could say what they finally did during the day and if one did not progressed, they could say it out loud. To say out loud the problem encountered during the day is not always easy, but this effort was actually quite efficient, as some problems were solved after this meeting - at least ideas to solve the problem were given. These two meetings structured each day of work and gave a work routine to the team.

At the end of a sprint, we also did a **Sprint Review**. The goal of this review was to see what we succeed to do over the sprint and what we did not. Everyone participated to these meetings, and it was like a longer retrospective.

3. Development and results

3.1 Development

3.1.1 Development retrospective

As agile methodology was used during this project, it is interesting to do a retrospective of development. Mainly, two important things need to be discussed. The first one is about tasks difficulties. Indeed, when the product backlog was created, each user story had to be assigned a grade, using Fibonacci sequence. The team did not have all necessary skills and the insight needed to assign a "correct" grade to all user stories. For example, everyone knew that 3D visualisation would be complicated, so their weight - *i.e.* their grade - was high. However, to display 3D data in front-end, the tasks went quickly - less than three days - even though they had the highest weight of the two sprint backlogs - 21. This is just an example, but it was important to take that into account during the development, because when this case happens, it is easy to have someone without any tasks for the last two days of the sprint for example. The same thing also happened in the opposite side: an easy task turned out to be quite difficult and had to involve several persons instead of one.

The second thing was the separation between front-end and back-end. At the beginning of the project, there were no problems to divide the team between front and back, with one person in the back team that could help the front team if needed. But when main user stories began to be completed one by one, the limit between the two teams get thinner and some people started to switch of teams. They did not literally change of team, but tasks they were doing were sometimes more like tasks of the other team. This can lead to problems because when it starts, it is difficult to know who deals with a specific task. However, it remains useful to be able to switch teams easily when needed. One can take advantage from that by working with someone else that can bring a fresh view of the problem. Most of the time, it solves problems.

3.2 Results

3.2.1 2D visualisation

On figure 3.1, we can see how the superposition of two layers of different types work. We were able to fit both layers accordingly to the coordinates. However, the scale indicator is not working perfectly, and it is not displayed.

On figure 3.2, you can see that buildings that have a specific nature are coloured differently than the rest. For instance, blue buildings represent religious ones. On the bottom right of the window, information displayed about the building right-clicked by the user. In this example, the large green building at the center of the screen is picked.

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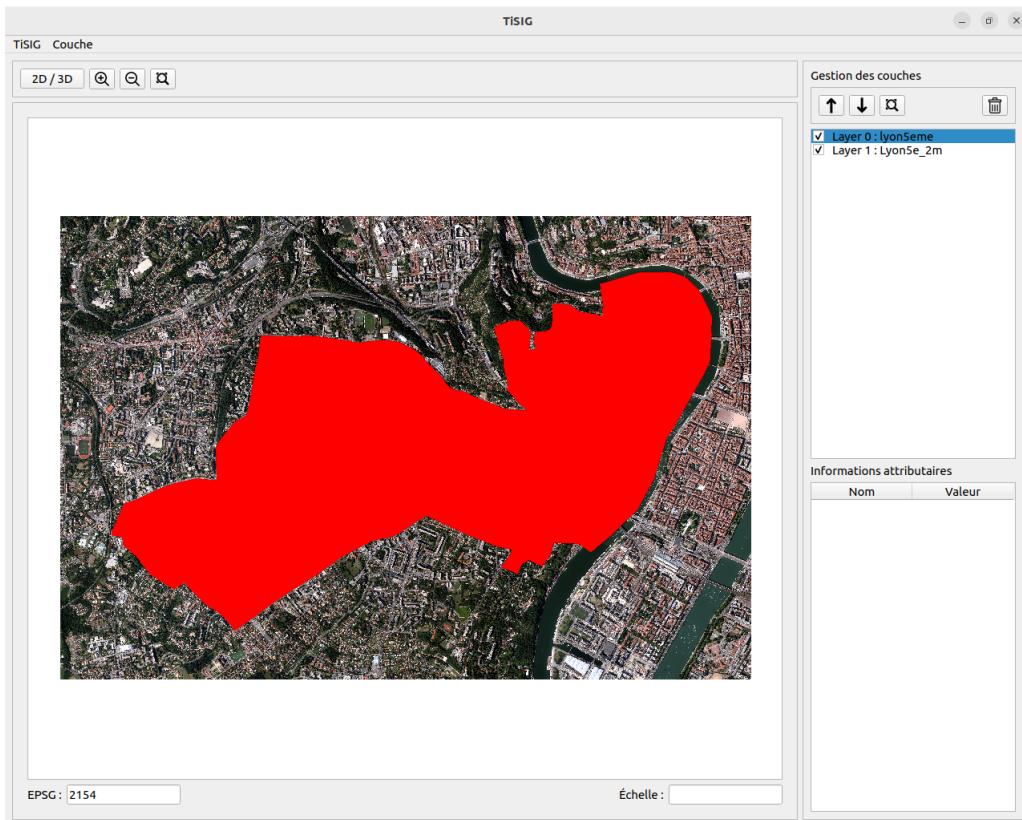


Figure 3.1: Example of raster and vector data displayed in 2D mode

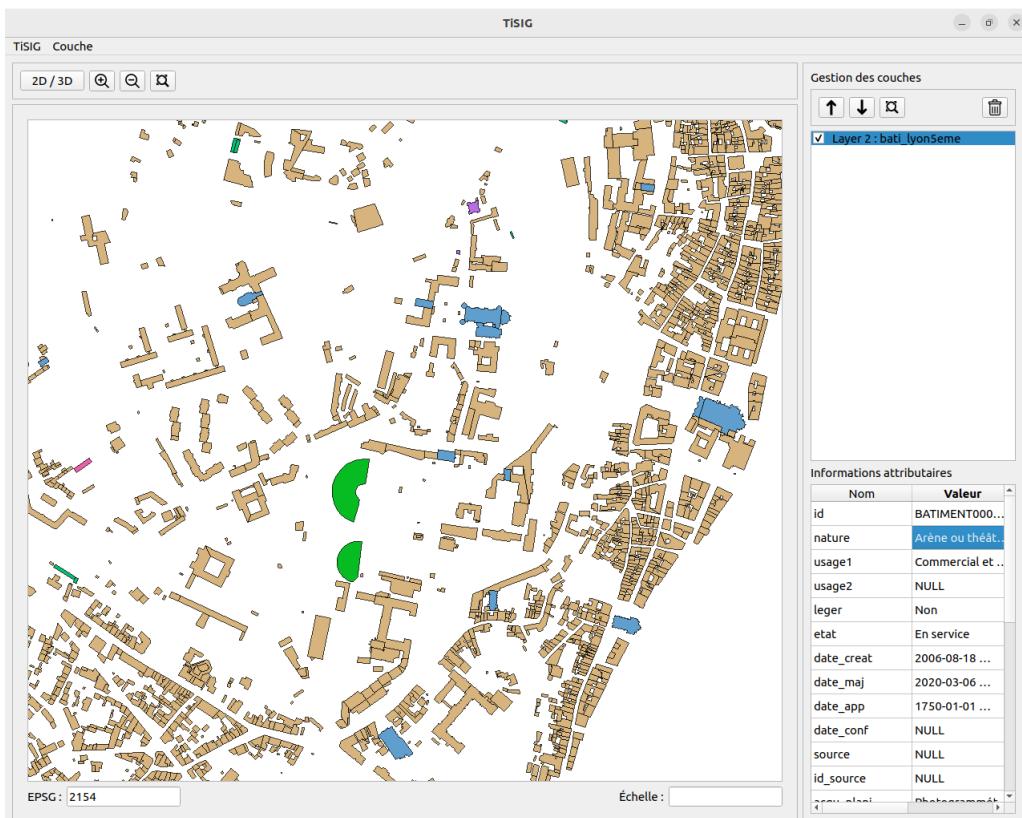


Figure 3.2: Showcase of the picking feature in 2D mode

3.2.2 3D visualisation

On figure 3.3, you can see the display of an orthophoto plastered on a DTM. Since the user can tilt the model, the depth is visible on TiSIG.

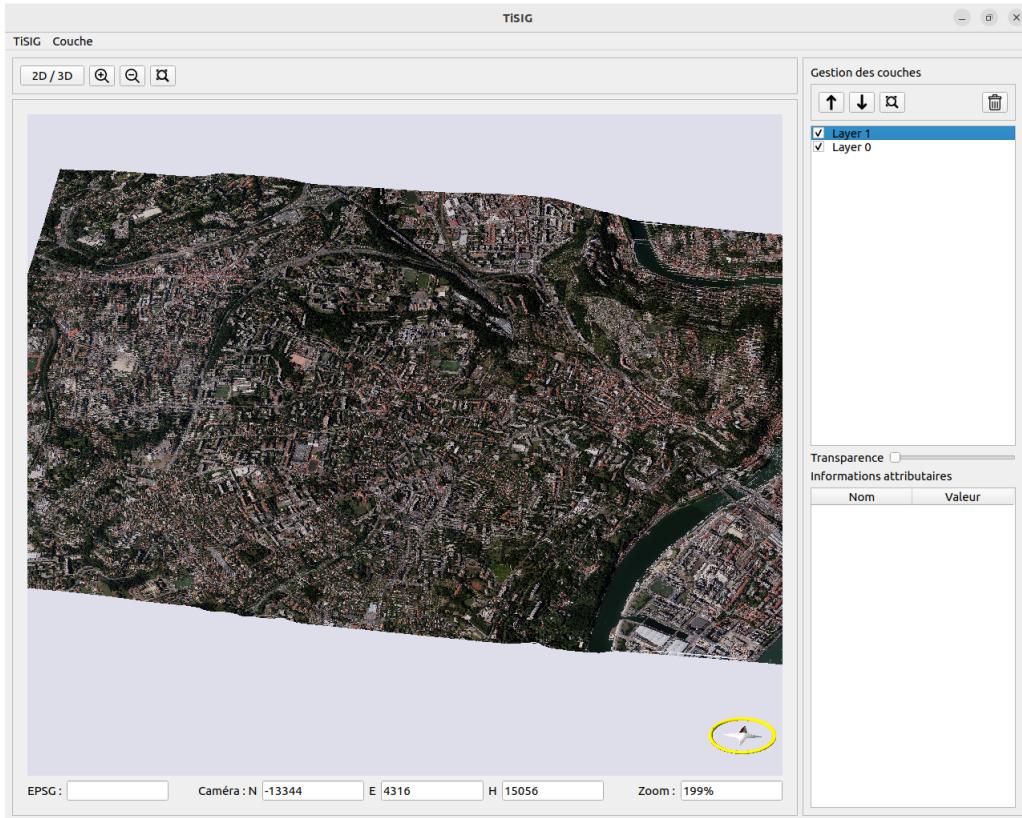


Figure 3.3: Example of an orthophoto plastered on a DTM in 3D mode

On figure 3.4, buildings from CityGML file are displayed. As you can see, the triangulation is not perfect. You can choose to display the nature of the buildings by using the slider on the right side of the window. These natures may vary from the 2D mode, since the source is not the same.

3. Development and results

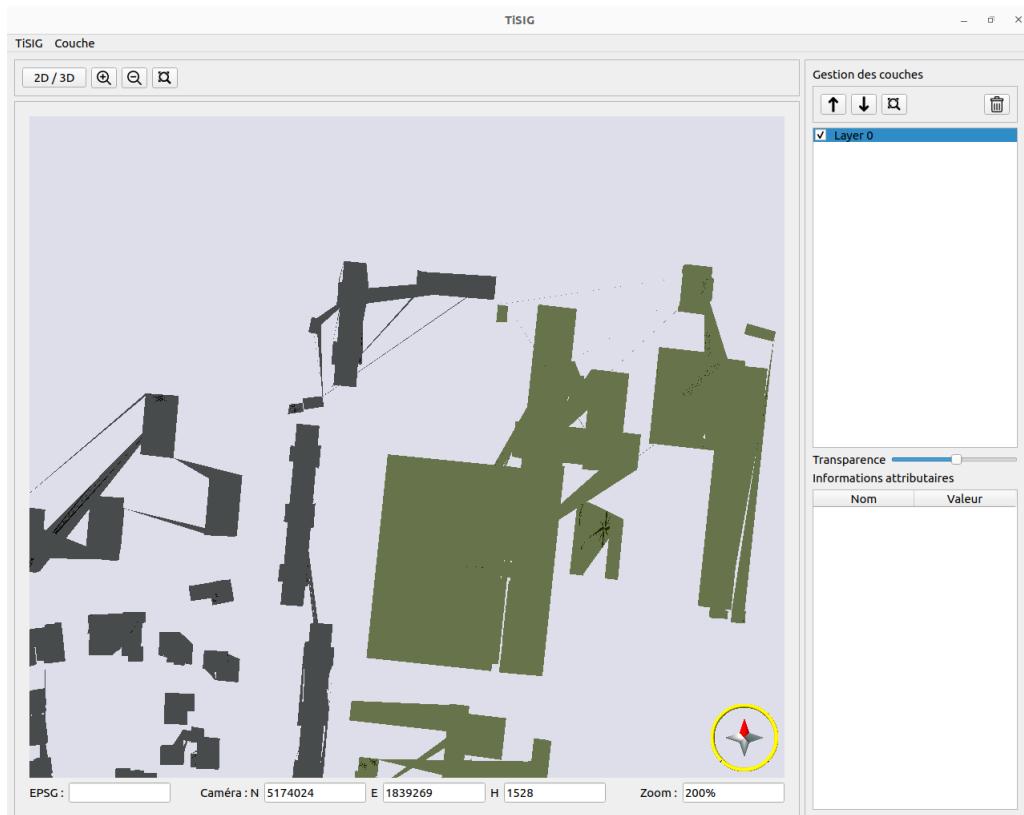


Figure 3.4: Example of the CityGML display feature

4. Personal contribution to the project

In this part, every member of the team will present how their role - in agile methodology - contribute to the project.

- **Hannick ABDUL-KUTHOOS** (Developer): "This project allowed me to work in a team of 15 which helped me improve my communicating skills and it also helped me develop my c++ skills."
- **Clovis BERGERET** (Product Owner for week 2): "I think that working on this GIS project improved our skills as a whole, since we tackled issues together. This is also the first time that we really used AGILE methods and I think it helped a lot."
- **Romain COURET** (Developer): "This project enabled me to increase my skills in C++ and collaborate within a large team (comprising more than 5 individuals). Additionally, I gained knowledge into the functioning of GitHub Actions and acquired the ability to automate workflows."
- **Axel DUMONT** (Product Owner for week 1): "During this project, I was able to develop the import of images from WMS and WMPS raster streams (from creating the request to downloading the images), linking the necessary WMPS images as a grid of image tiles, and tools for converting coordinate projection systems. This project allowed me to leverage my knowledge in C++ and agile methods while enhancing my problem-solving skills."
- **Claire GIRARDIN** (Product Owner from week 3 to 4): "The completion of this project has been a rewarding experience that allowed me to explore and strengthen my skills in C++, a language I approached for the first time this year. Working within a team of 15 people was a captivating challenge. It provided me with a concrete insight into using the AGILE methodology to successfully execute a project of this magnitude."
- **Vincent GIUDICELLI** (Developer): "In this project, I really enjoy working in group, with a motivated team and in a spirit of mutual aid. I rediscovered AGILE methods and increased my skills in GIT and C++."
- **Claire GUERRINI** (Developer): "I learned that good communication and organisation can make possible the achievement of an autonomous 15-students project, even when it is hard at the beginning to have an accurate vision of what could be done."
- **Mathéo MARÉCHAL** (Developer): "I found personal growth in tackling challenging mathematical and computational issues. It truly was a gratifying experience. The collaborative aspect was equally intriguing."
- **Victorien OLLIVER** (Product Owner for week 1): "This project enabled me to develop competences in C++ and to work in bigger team than usual."
- **Hicham OUTMRHOUST** (Developer): "this project allowed me to be comfortable developing in c++ and showed me how powerful the language is even if sometimes it can be quite hard to debug the code, I also learned to cooperate on a dev project inside a relatively big team using the agile method for the project management."

4. Personal contribution to the project

- **Mathis ROUILLARD** (Scrum Master): "During this project, I had the chance to be scrum master and I liked it. Even though I did not have all the needed skills to be Scrum Master, I think that it was an interesting experience that made me see that leading a project could be a good choice."
- **Cécile TALEC** (Developer): "This project taught me how to work simultaneously with 14 other developers, and made me realize the importance of organization and management tools for such project."
- **Vittorio TOFFOLUTTI** (Scrum Master): "As part of the project to develop minisig in C++ with OpenGL on Linux, I contributed to the application testing phases, ensuring that errors were detected and that code continuity was guaranteed. At the same time, I helped the team make the transition from CMake to QMake, optimising the compilation process. Taking responsibility for the installation of the application, I ensured that it was accessible to all, ensuring optimal accessibility for all team members and more. As front-end scrum master, I successfully led the Agile methodology, although the constant management of all the team's activities presented challenges."
- **Frédéric YE** (Developer): "The project taught me how to work in a team. I was able to understand the use of Git, which is really amazing."
- **Lisa ZARATIN** (Product Owner from week 2 to 4): "Before this project, I thought that I wouldn't be able to work in a 5+ people team. I also thought that we would break the dev branch more often."

Conclusion

In only 4 weeks, the team was able to answer the client's needs - adapted during the project - and surpassed the difficulties encountered. Agile methodology has been really useful to develop the application and to be efficient while working under good conditions. The team did its best to apply agile methodology during all the project, even if it was the first time for everyone working in a team of 15 developers. For this reason, this project made every member of the team learn a lot.

Concerning the application, there are a lot of things that could be done in the future if the project had been longer. For example, basic treatments on layers could be implemented for 2D or 3D visualisation. Also, basic changes of layers symbology could be added to the application, especially for 2D visualisation. To conclude, a lot could be add to TiSIG, even if the amount of work enabled its first version to be very respectable.