Searchable & Interactive Campus Map

A prototyping project

Construction & Robotics
Yibo Dong

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Contact

Alexianergraben 44, 52062 Aachen.

Contact: yibo.dong@rwth-aachen.de

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1 Introduction

The development of technologies such as digital twins has greatly accelerated digitization and informatization of the construction industry. In addition to the application in new buildings, the digitization of existing buildings and their utilization also has a very good prospect. This report presents a method that uses iTwin Platform [1] to build a searchable and interactive campus map (SIM) system that students and staff in the university can easily access through both PC and mobile device.

You can learn more about iTwin and Bentley in https://developer.bentley.com/itwinplatform/.

[1] Bentley's iTwin platform is an open, scalable cloud platform that provides APIs and services to help developers create digital twin applications for project teams and owner-operators to create, visualize, and analyze digital twins of infrastructure assets. The platform takes care of back-end concerns such as security, infrastructure, and data integration so that developers can focus on building applications and bringing them to market faster ("What is the iTwin Platform?", n.d.).

1.1 Background

A campus map and navigation system can be very important for students' daily activities as well as all kinds of activities involving everyone on campus. By using the campus navigation system, students can navigate to specific buildings or the cafeteria, staff members can navigate to parking spaces or their working place, individuals with disabilities can search for the location of accessible restrooms, and mothers with babies can find the nursing rooms, etc.

However the existing campus navigation system, taking RWTH Aachen University as an example, still has some shortcomings. As a 2D planar map platform, the existing RWTH Navigator [2] can only provide geographic location information at the building level. This appears to be less intuitive when users try to find a specific room rather than a building. Moreover, users can not get the layout information inside the building using a 2D map. In certain instances, determining the floor of a room or identifying the most accessible entrance to a building can be challenging. The task of locating a specific room within an unfamiliar building, especially in structures with intricate internal layouts, may require significant effort.

[2] RWTH Navigator was developed based on Google Maps APIs.

The existing one is also less interactive and less information about the buildings or rooms is provided. Students can not obtain the information about the occupancy of each classroom, nor can they obtain the information about the scheduling of the courses, nor can they obtain specific information about a course in the map system.

To solve all these problems mentioned above and establish a more convenient, useful, and functional campus navigation system for students and staff, SIM was developed with the help of the iTwin platform.

1.2 Introduction of iTwin Platform

1.2.1 What is iTwin?

iTwin is an open platform for infrastructure digital twins introduced by Bentley. According to Bentley, the iTwin platform could handle data integration, visualization, change tracking, security, and other complex challenges. The iTwin platform is built on open APIs and libraries purpose-made for digital twin applications that create, visualize, and analyze digital twins of infrastructure assets.

1.2.2 Why choose iTwin?

The iTwin platform not only has many powerful APIs but also provides many tutorials and learnable sandboxes. In terms of web applications, with the basic iTwin viewer provided by iTwin, it is easier for non-professional programmers to get started. The wide support of data type by the iTwin platform also reduces many potential problems. Taking building models as an example, iModel of iTwin not only supports the DGN format of Bentley's MicroStation but also supports the RVT format of Revit. Moreover, the support of the IFC[3] format expands the possibilities of iTwin.

[3]/IFC which stands for Industry Foundation Classes. According to buildingSMART, IFC is a standardized, digital description of the built environment, including buildings and civil infrastructure. It is an open, international standard, meant to be vendor-neutral, or agnostic, and usable across a wide range of hardware devices, software platforms, and interfaces for many different use cases ("Industry Foundation Classes (IFC) – An Introduction", n.d.).

2 Project Objectives and Scope

The overarching goal of this prototype project is to develop a user-friendly web application that provides seamless accessibility to all members of the campus, whether they are using a PC or a mobile device. SIM is designed to empower students and staff with the ability to effortlessly search for courses, and locate rooms and buildings. A distinctive feature of SIM is the inclusion of detailed 3D models for each building, accessible through the iTwin viewer in IFC format.

Upon selecting and clicking on a particular room, the iTwin viewer's functionality shines, as it not only highlights and zooms in on the chosen space but also furnishes users with comprehensive three-dimensional spatial information. This includes details like the floor, orientation, and spatial relationships with neighboring rooms, enabling users to grasp the physical context effortlessly.

Furthermore, users have the flexibility to filter rooms based on specific criteria, leveraging tags or labels such as classrooms, restrooms, accessible restrooms, nursing rooms, and more. This feature streamlines the search process, ensuring that individuals can swiftly locate spaces that meet their specific needs.

Taking the user experience a step further, clicking on individual classrooms unveils a wealth of information. Users can access the detailed schedule for each classroom from Monday to Friday. Additionally, for each course held in that classroom, users can delve into specific details such as the time range of the course.

3 Methodology

3.1 Create 3D models

The iTwin platform supports a variety of file formats, not only Bentley's proprietary formats like DGN but also a wide range of third-party file formats. Among them, Revit is chosen to build the model and export the file in IFC format.

Revit is software specifically designed for Building Information Modeling(BIM) workflows. It allows users to create, manage, and share architectural and structural models within an integrated environment. This helps in coordinating designs throughout the project life-cycle, reducing errors, and improving overall efficiency.

In general, people can perform 3D reconstruction by utilizing existing architectural information such as existing building blueprints, or by obtaining data and information through on-site surveys. For this prototype, a high-precision 3D model is not necessary. It only requires a simple architectural model that includes the external outline, floor information, room positions, etc. All of these can be easily accomplished using Revit.

An important step during the modeling process is to tag each room; room names can also be added in Revit at the same time[4].

[4]This step can also be deferred and accomplished later by utilizing a JSON file, assigning a name to each room.

To ensure the 3D model includes precise location information, it is essential to define the project address during the modeling process. This can be accomplished through "Manage−>Location−>Project Address" in Revit[5]. Figure 1 shows how to set the project address.

[5]Note that obtaining the precise coordinates and orientation of the building may necessitate a detailed site survey. However, for this prototype, approximate location information is deemed satisfactory.

Once the modeling is complete, the model can be exported as an IFC file. Figure 2 shows a simple model of the Reiff Museum at RWTH

3.2 Upload IFC file to iTwin platform

3.2.1 What's included in the IFC file?

IFC is an open, international standard data model for exchanging and sharing information in construction and infrastructure projects. It provides a universal, neutral data model capable of describing information such as architectural elements, components, spaces, properties, and relationships. This facilitates data exchange between different BIM software.

The flowing code illustrates how an IFC file encapsulates comprehensive information about one of the rooms previously showcased in the Reiff Museum.

```
#124=IFCAXIS2PLACEMENT3D(#3,$,$);
#125=IFCLOCALPLACEMENT($,#124);
```

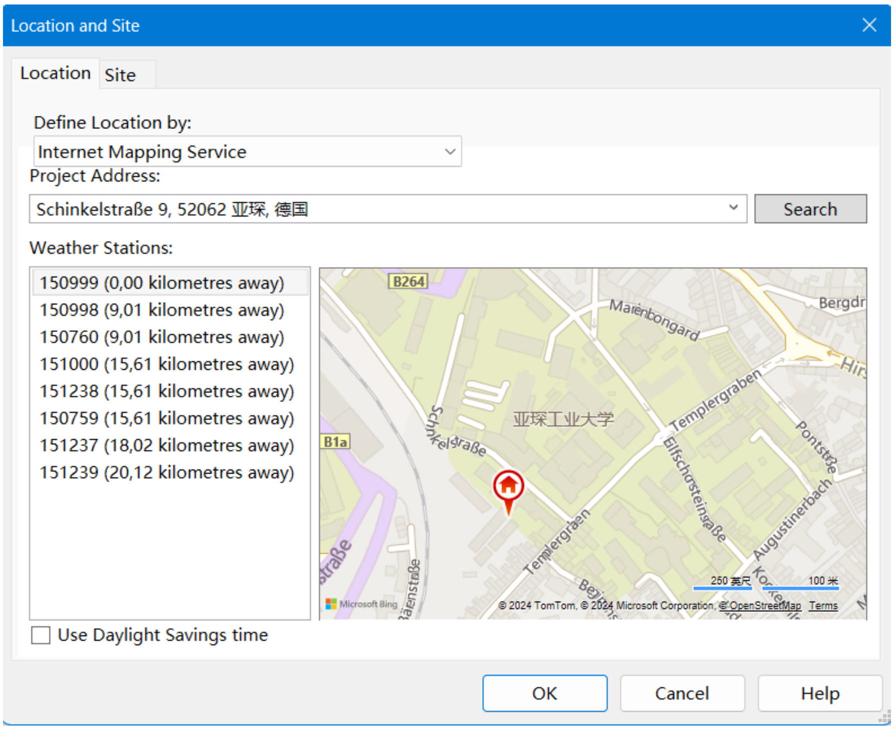

Figure 1: Set Project Address

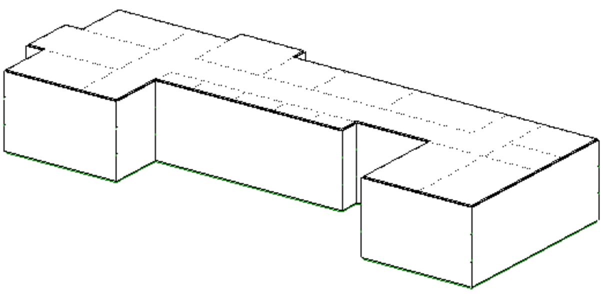

Figure 2: A simple model of Reiff Museum

```
3  #126=IFCSITE('099kwOZCr2O9XG0Gs7L_8n',#18,'Default',$,$,#125,$,$
       ,.ELEMENT.,(50,46,37,6),(6,4,39,0),0.,$,$);
4  #127=IFCAXIS2PLACEMENT3D(#3,$,$);
5  #128=IFCLOCALPLACEMENT(#110,#127);
6  #129=IFCCARTESIANPOINT((-5.773159728050814E-15,4.4408920985006262
       E-16));
7  #130=IFCAXIS2PLACEMENT2D(#129,#11);
8  #131=IFCRECTANGLEPROFILEDEF(.AREA.,$
       ,#130,9.0799999999999947,12.199999999999996);
9  #132=IFCCARTESIANPOINT
       ((-68.412581079798372,36.988755723868437,0.));
10 #133=IFCDIRECTION((-0.70710678118654779,-0.70710678118654735,0.))
       ;
11 #134=IFCAXIS2PLACEMENT3D(#132,#9,#133);
12 #135=IFCEXTRUDEDAREASOLID(#131,#134,#9,2.4384000000000001);
13 #136=IFCSHAPEREPRESENTATION(#100,'Body','SweptSolid',(#135));
14 #137=IFCPRODUCTDEFINITIONSHAPE($,$,(#136));
15 #138=IFCSPACE('2T86EtkzTE$B$aWrqPOkCV',#18,'1',$,$,#128,#137,'
       Room',.ELEMENT.,.INTERNAL.,$);
16 #139=IFCSPACETYPE('2T86EtkzTE$B$aYrqPOkCV',#18,'Room 1:20990',$,$
       ,$,$,'20990',$,.NOTDEFINED.);
17 #140=IFCPROPERTYSINGLEVALUE('Name',$,IFCLABEL('Room'),$);
18 #141=IFCPROPERTYSET('2HDJmr$$QXT1pRJXwc3x$y',#18,'
       Pset_AirSideSystemInformation',$,(#140));
19 #142=IFCPROPERTYSINGLEVALUE('Name',$,IFCLABEL('Room'),$);
20 #143=IFCPROPERTYSET('3NAuonpaEiWDbv4HNxvKKG',#18,'
       Pset_ProductRequirements',$,(#142));
21 #144=IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('Room 1')
       ,$);
22 #145=IFCPROPERTYSET('3hASiw3mdMnwYRihNjucLs',#18,'
       Pset_SpaceCommon',$,(#144));
23 #146=IFCRELDEFINESBYPROPERTIES('0x6Al3M22At1Jug4ICALOu',#18,$,$
       ,(#138),#141);
24 #147=IFCRELDEFINESBYPROPERTIES('0IMpwW08NNJq8TPKv3dka_',#18,$,$
       ,(#138),#143);
25 #148=IFCRELDEFINESBYPROPERTIES('0yI75K2S167iMI$mUiodBe',#18,$,$
       ,(#138),#145);
```

This code includes information about the location, orientation, geometric shape, and type of room space. The 15th line establishes a room space using IFCSPACE. On the 21st line, we can ascertain that the room is named ’Room 1’.

And the flowing line however contains the location information of the entire building. It is not difficult to see that the latitude of this building is 50°46’37"6, and the longitude is 6°4’39"0 [6].

```
#126=IFCSITE('099kwOZCr2O9XG0Gs7L_8n',#18,'Default',$,$,#125,$,$
    ,.ELEMENT.,(50,46,37,6),(6,4,39,0),0.,$,$);
```

[6] The method of obtaining the coordinate information for each building will be discussed in the following sections.

3.2.2 Upload File

After creating the model, the next step is to upload it. Begin by creating a new iTwin followed by generating a blank iModel. In the File Synchronization within iTwin, you can upload your file as an iModel. Once these steps are completed, you will get an iTwin ID and an iModel ID, resembling the example below. These IDs will be used later on, as they serve as the sole and unique identifiers for our model within the iTwin platform.

```
IMJS_ITWIN_ID=c5a76e76-114c-4b01-ac64-386696b5d27f
```

```
IMJS_IMODEL_ID=0a905a1c-67a0-4419-aa9f-90309405e20b
```

3.3 Build the viewer app

Creating a viewer app on the iTwin platform can be a straightforward task. The fundamental application framework encompasses the viewer navigation tools, viewer content tools, viewer status bar, and measurement tools.

Drawing upon these foundations, the scope has been expanded by incorporating additional providers namely the "LearningRoomsProvider", "LecturesProvider", "ClassInfoProvider", "ClassProvider" and "RoomsProvider". In the subsequent sections, a detailed exposition of each of these widgets will be provided, elucidating their functionalities and contributions to the overall system.

3.3.1 Source of Data

3.3.2 Building Data

The modeling process of building models has been introduced in the preceding section. The data for building models can be derived from existing data or on-site surveys, and we will not elaborate on this further here.

3.3.3 Course Data

For the courses, the data is sourced from RWTH’s "carpe diem!"[7]

[7]The planning tool "carpe diem!" is a valuable tool for the scheduling and room planning of more than 3,500 courses and exams. Central planning via "carpe diem!" enables RWTH Aachen University to create a teaching and examination schedule that combines and reconciles constantly increasing student numbers, the best possible utilization of scarce space capacities, and the interconnectedness of courses (“carpe diem!”, n.d.).

The following is an example of course information exported from "carpe diem!".

```
    {
    "Name": "Einfuehrueng in die Programmierung (Tutorien Physik)
        (-112023) (Tutorium (TU)), Standardgruppe - 1. Termin (1
        students)",
    "LvNummer": 12.52945,
    "Start time": "02:15 PM",
    "Duration": 90,
    "#hours": 1,
    "Date": "Thursday, 02:15 PM - 03:15 PM",
    "Rooms": "No room allocated",
    "Buchungstart": "14:30",
    "Buchungend": "16:00"
  }
```

The data includes the course name, course number, start time of the course, duration of the course, course date, classroom assigned for the course, and the scheduled time for occupying the classroom, starting and ending.

The next question is how to determine the coordinates of each building to accurately position the 3D model at the corresponding location on the map. For this issue, a tool called Nominatim is utilized [8]. By invoking the

[8]Nominatim uses OpenStreetMap data to find locations on Earth by name and address (geocoding). It can also do the reverse, find an address for any location on the planet (n.d.).

API of this website, one can obtain the coordinates of a building by using the city's name along with the name of the building.

The following Python code illustrates the process of acquiring the coordinates data.

```
import requests

# List of addresses with associated names
addresses = [
    'Lernraeume Aixtron Kackertstrasse|Kackertstrasse 15, 52072 Aachen',
    # ... (other addresses)
    'Lernraeume Walter-Schottky-Haus|Sommerfeldstrasse 24, 52074 Aachen'
]

# Dictionary to store coordinates with associated names
coordinates = {}

# Loop through each address
for address in addresses:
    # Split the address into name and location
    name, location = address.split("|")

    # Construct the URL for querying coordinates using Nominatim API
    url = f'https://nominatim.openstreetmap.org/search?q={location}+aachen&format=geojson&addressdetails=1'

    # Send a GET request to the Nominatim API
    response = requests.get(url)

    # Check if the request was successful (status code 200)
    if response.status_code == 200:
        # Parse the JSON response
        data = response.json()

        # Extract and store the coordinates in the dictionary
        coordinates[name + "|" + location] = data["features"][0]["geometry"]["coordinates"]

        # Print the current state of the coordinates dictionary
        print(coordinates)
    else:
        # Print an error message if the request is not successful
        print(f"Error: {response.status_code}, {response.text}")

# The coordinates dictionary now contains the latitude and longitude for each address
```

4 Results

4.1 Find the location for specific course

Through the search function, SIM can filter out the specific locations of courses and display the 3D models of the buildings where the courses are located at the corresponding locations on the map.

Figure 3 shows the overview of all the buildings at RWTH Aachen University that have been scheduled with courses in the data exported from "carpe diem!".

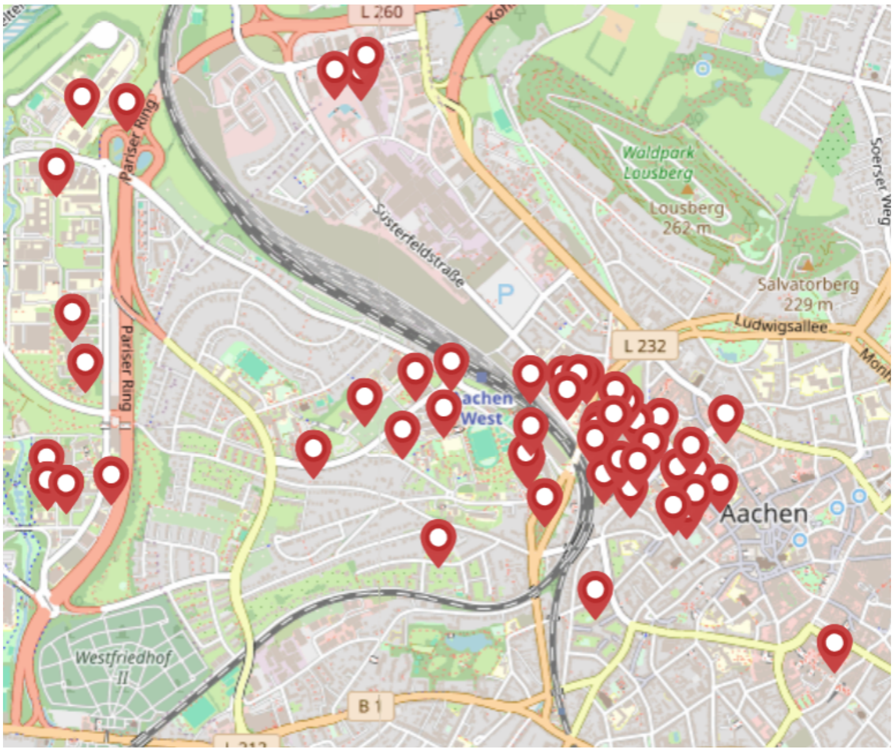

Figure 3: Overview of all builidngs

Users can search based on the course name, course number, classroom number, building name, and other criteria.

Figure 4 is the result when users search for Reiff Museum or any courses and rooms related to Reiff Museum. Compared to traditional 2D maps, 3D models provide a more intuitive understanding of the structure of the building.

This is not the end yet; the next step is to showcase one of the key features of SIM. When searching for a specific course and confirming the designated classroom, the application will highlight the space of this classroom, as previously mentioned, the IFCSPACE, and focus on it.

Figure 5 is an example of how SIM highlights the classroom space.

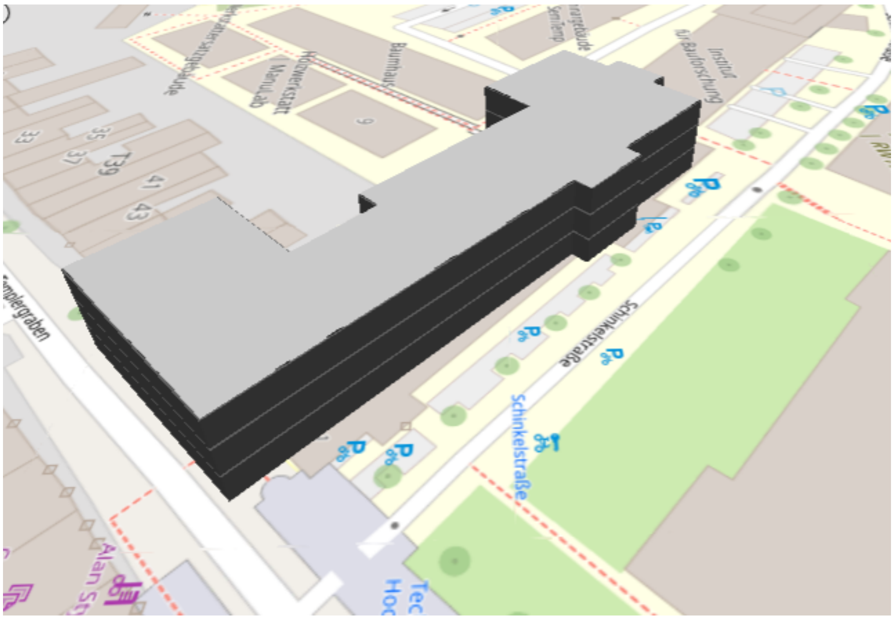

Figure 4: 3D model of Reiff Museum

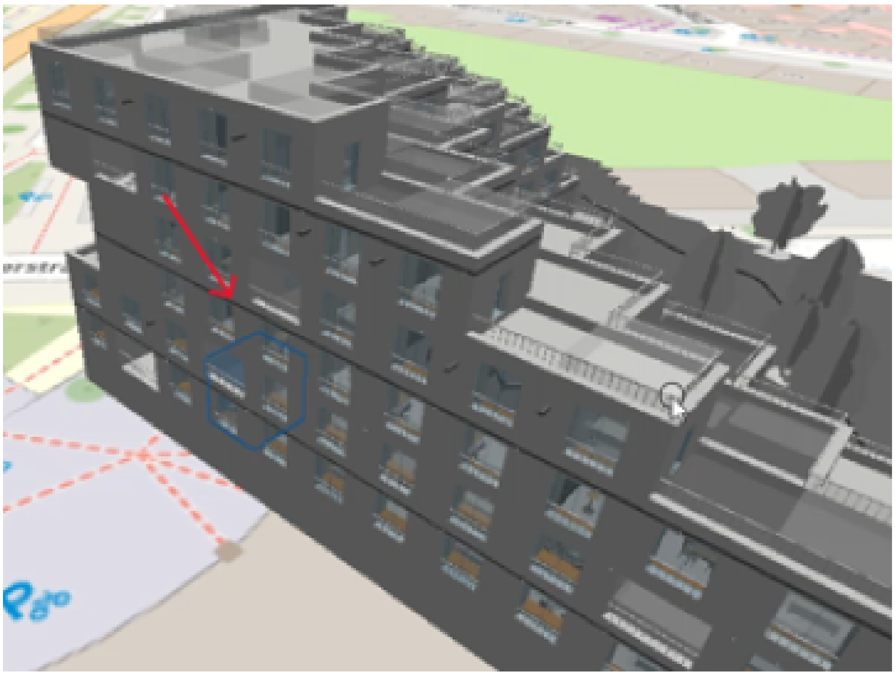

Figure 5: Caption

4.2 Level Clipper

Now, as a newly arrived student or a visitor unfamiliar with a particular building, users are aware of the spatial location of the room they are looking for. The floor on which it is located and the side of the building where the room is situated are known. For those more familiar with three-dimensional space, some may even discern that entering the building through a specific entrance would be more convenient for reaching this room.

What's next?

Understanding the location of a room solely from the interior of a building can be insufficient, especially in structures with complex internal layouts. Navigating intricate corridors without a clear understanding of the internal structure may lead to confusion. To address this challenge, a concept called a "Level Clipper" has been conceived. This approach involves "cutting open" the building to reveal its internal layout, providing a more comprehensive understanding of the spatial organization within complex structures.

Thanks to the detailed building data included in the IFC file. By extracting the floor height and story height [9], it is possible to create a plane located near the ceiling height of the specific room. By cutting away the portion above this plane, the section of the floor where the room is located can be shown.

[9] The specific implementation details will be reflected in the code files.

Figure 6 is an example showing the section of a floor.

4.3 Navigation

Since the coordinates of each building are known, SIM uses these coordinates to realize that when the navigation button is clicked, SIM efficiently redirects to the navigation website, facilitating an automatic transition to the designated location.

4.4 Looking for available classrooms

Another noteworthy feature of SIM is its ability to find available classrooms within a specified time range. Users can seamlessly navigate the system to identify and secure suitable learning spaces, enhancing their overall experience in managing and organizing educational activities.

The implementation of this functionality involves filtering the course information obtained from "carpe diem!", and identifying classrooms that do not have any scheduled courses at a specific day and time (set in SIM to occur every half hour, such as 09:30 or 11:00).

All these vacant classrooms can also be searched by using the above-mentioned search function.

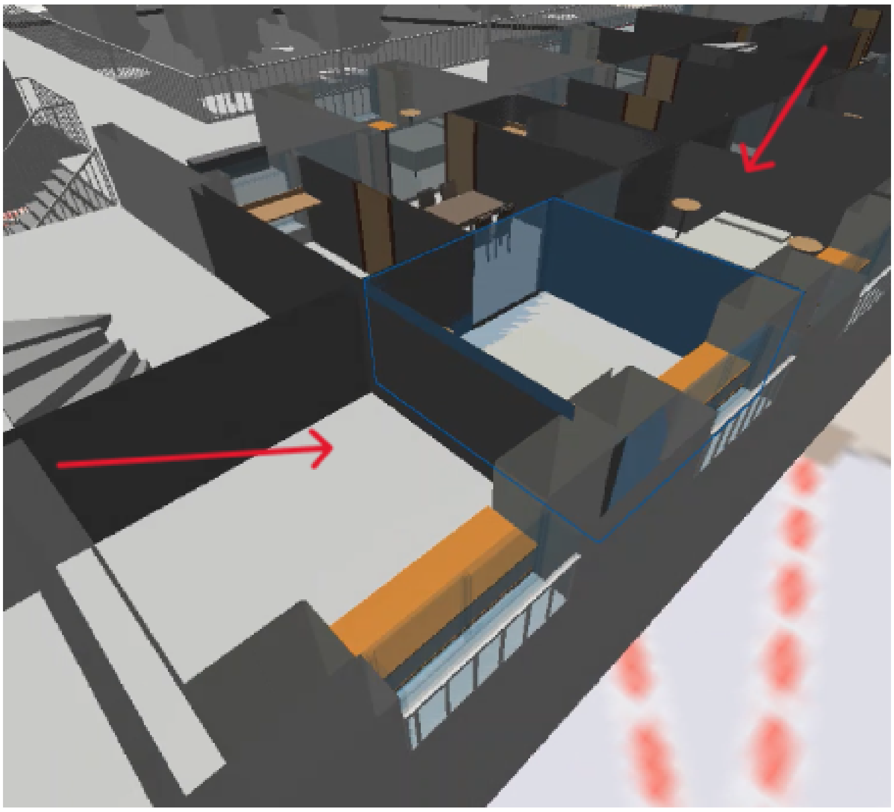

Figure 6: Section of a floor

4.5 Display the schedule and information of the classroom's courses

SIM can automatically generate a class schedule for a specific classroom on a particular day based on the course information provided by "carpe diem!". The schedule is arranged in chronological order and also includes detailed information about each course.

5 Discuss & Conclusion

The functionalities achieved by the project's results are essentially in line with expectations. The advantage of SIM lies not only in the intuitiveness of 3D compared to 2D but also in its independence from complex data sources. This is made possible by its parsing capability for course data from "carpe diem!". With a simple update of course data every semester, SIM can automatically refresh all data, making the process remarkably straightforward and convenient. No additional effort is required for data input, showcasing the simplicity and efficiency of SIM.

To further compare SIM with existing campus navigation systems, a comparative table [10]is presented to illustrate the differences. The table highlights the intuitive nature of SIM and its more advanced search functionalities, providing evidence of its ability to enhance students' daily lives with greater convenience. The user-friendly interface of SIM, coupled with its comprehensive search features, stands out as a testament to its capacity to streamline and improve the overall learning experience for students.

[10]In this table "+" represents the presence of this function, and "-" represents its absence.

Table 1: Comparison of SIM with the Existing Campus Map System

Functionalities	**SIM**	**Existing System**
Search rooms in building level	+	+
Search rooms in room level	+	-
Navigation	+	+
Search for vacant classrooms	+	-
Detailed course information	+	-
3D display of buildings and classrooms	+	-
Floor section	+	-

During the process of development, we encountered some challenges. The lack of data about the architectural details resulted in a lower precision in modeling. Additionally, the absence of accurate geographical information led to a noticeable deviation between the final position of the models and their actual locations. However, these issues can be effectively addressed through professional on-site surveys and precise measurements. Implementing thorough field investigations will not only enhance the accuracy of the models but also ensure a more faithful representation of the real-world locations.

SIM is a platform that can be continuously expanded, incorporating a variety of sensor data in the future, such as carbon dioxide sensors, temperature sensors, and more. Even the data from carbon dioxide sensors can be utilized to predict the number of occupants in a classroom, thereby providing students with better information. As the Internet of Things continues to evolve, an increasing amount of data can be seamlessly integrated into SIM, transforming it into a constantly updated and improved mapping system.

Reference List

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A Appendix Section

The code file can be accessed in this GitHub repository: https://github.com/yibodong2001/SIM_Searchable-Interactive-campus-Map.