BIM and GIS - Bidirectional Data Exchange for Renewable Energy Planning

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Key words: BIM, GIS, Integration, Link Model, BIMserver

SUMMARY

Building Information Modelling (BIM) is rapidly emerging as the standard for planning, constructing and operating buildings and infrastructure across various industries. Concurrently, there is a political commitment in Germany to significantly expand the use of renewable energies. Given the scale involved, the planning of wind and solar energy parks is primarily carried out in the Geographic Information System (GIS). However, the complexity, multi-layered nature and historically long processes of design, planning, application and construction phases necessitate innovative digital solutions to accelerate these processes. The research project, "BIM and GIS - Bidirectional Data Exchange for Renewable Energy Planning," is actively developing new products and methodologies to facilitate an integrated workflow from design to planning, application and construction of renewable energy installations. The resulting digital data flow at the BIM/GIS interface is designed to be seamless, minimizing disruptions and preventing information loss.

The project's objective is to transfer essential planning data from GIS to BIM, such as georeferencing information for systems, into Autodesk Revit BIM planning software. This ensures that relevant data is instantly accessible to the BIM model planner whenever a spatial modification is made in the specialized GIS model, creating a cohesive and synchronized workflow. Conversely, data like technical specifications of the wind turbine can be automatically incorporated into the GIS software, facilitating distance and yield analyses for wind farms, among other functionalities. To accomplish this, a link model will be implemented to establish a continuous data structure between the BIM and GIS domains, ensuring bidirectional data exchange. This link is established between Autodesk Revit, the BIM authoring software and moGI-Planner, a specialized GIS program developed by the M.O.S.S. Computer Grafik System GmbH. The link model utilizes the open-source software BIMserver and a custom API plug-in (Application Programming Interface) for Autodesk Revit. Additionally, the interface for moGI-Planner is created by using Python modules, enabling the reading of GeoJSON files to enhance compatibility and interoperability.

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1. INTRODUCTION

Germanys political agenda is focused on a substantial expansion of renewable energies, with particular emphasis on wind power generation, which already contributes to about 50% of electricity generated from renewables in 2022 (Bundesministerium für Wirtschaft und Klimaschutz, 2024). As a crucial energy source for the ongoing transition, wind power is put forward for further expansion in the coming years, alongside technologies like photovoltaics. The main objective is to reduce dependency on fossil fuel and heating fuel imports. To achieve this goal, several laws have been enacted, establishing mandatory area targets for onshore wind energy across German federal states and streamlining authorization procedures in designated wind energy zones. The planning of wind and solar energy parks is predominantly GIS-based (Geographical Information System), given the scale involved. However, the BIM (Building Information Modelling) methodology is increasingly becoming the standard for planning, constructing and operating buildings and infrastructure. Presently, there is a deficiency in technologies that can immaculately connect the realms of BIM and GIS. The complex, multi-layered and traditionally time-consuming phases of design, planning, application and construction are executed independently in the specialized domains of BIM and GIS. Unfortunately, planners face challenges in exchanging data and information between BIM and GIS without encountering media discontinuity. This lack of integration hinders the potential synergies that could streamline and optimize the entire process.

The BIM and GIS domains fundamentally differ in their approaches, particularly in the creation of models and data storage, posing challenges for achieving interoperability between the two worlds. The reference to the geographical context is of decisive importance in construction planning, where planners and decision-makers address crucial aspects at various stages:

- **Design Planning:** This phase involves considering how the facility integrates into the broader landscape context.
- **Approval Planning:** Evaluating whether the planning variant aligns with the relevant legal requirements is essential.
- **Implementation Planning:** Determining how construction work can be executed with minimal disruption to local residents is a key consideration.

In practical terms, these questions are typically addressed using geographic information systems. For future integrated planning, establishing a seamless link between data from these two specialized domains without loss is imperative. Additionally, ensuring the consistent and bidirectional interoperability of their software systems is crucial. The main challenges arise from the following differences:

There are notable disparities in the scale and modelling paradigms between GIS and BIM or AEC (Architecture, Engineering and Construction) application domains. BIM models intricately detail specific buildings, including individual components and technical equipment. In contrast, GIS-based 2D/3D models encompass entire continents, cities, or countries, incorporating different thematic elements such as buildings, traffic areas, terrain, bodies of water and vegetation (see Figure 1).

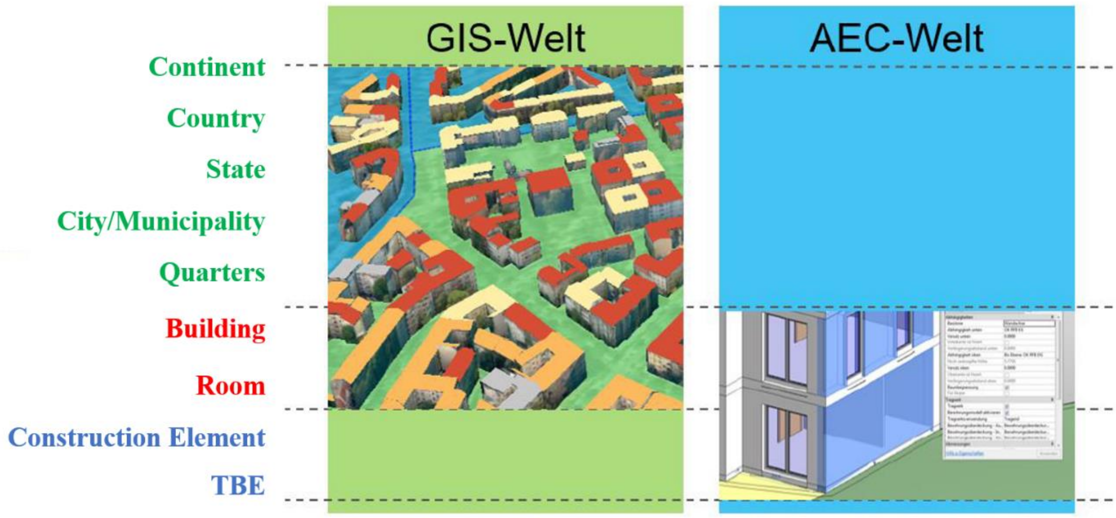

Figure 1- Level of detail and scale ranges for the content of the GIS and BIM specialist domains (Kaden, 2019)

Distinct modelling paradigms exist beyond scale differences. BIM follows a top-down approach, beginning with a conceptualized building idea developed into a model and eventually constructed. The primary goal of a BIM model is an accurate representation of the planned world, focusing on constructive elements and components. Conversely, GIS adopts a bottom-up approach, capturing the existing real world through observation, surveying, or remote sensing and transforming it into a 2D or 3D model. The objective of a GIS-based model is an accurate representation of the real world, typically depicting only visible object surfaces.

The divergent objectives of BIM and GIS applications have led to significant differences in system architectures, data models and exchange formats. These disparities pose challenges for integrated data processing and system linking. The use of different coordinate systems further complicates matters, as geodetic coordinate reference systems in GIS enable clear georeferencing, while BIM relies on local coordinate systems suitable for individual buildings.

The current inability to connect BIM and GIS data and systems within an integrated information management system, results in media discontinuity and information loss. This limitation proves to be problematic in the planning and construction of structures like wind turbines or solar parks. Consequently, critical planning steps are often neglected until late in the process, leading to insufficient consideration due to media discontinuities. Prolonged iterations between stakeholders and costly rescheduling become inevitable, progressively delaying the planning processes. Addressing these challenges is essential for achieving effective integration and streamlining collaborative efforts in the planning and construction phases.

M.O.S.S. Computer Grafik System GmbH and Erfurt University of Applied Sciences have jointly launched the research project "BIM and GIS - Bidirectional Data Exchange for Renewable Energy Planning." The primary objective of this initiative is to establish connectivity between the existing specialist programs moGI-Planner and Autodesk Revit through the implementation of a link model. Developed by M.O.S.S. Computer Grafik System GmbH, the moGI planning software serves as a GIS tool for spatial planning related to wind and solar parks. On the other hand, Autodesk's Revit is a BIM authoring software designed for creating and editing specialized Building Information Modelling models, essential for the design, planning and execution of construction projects. Notably, these two programs lack direct communication capabilities and are unable to exchange data seamlessly. The absence of a direct link arises from differences in file formats and content, making it impractical to exchange files between the two specialist programs without undergoing a conversion process.

To attain this objective, the aim is to close the identified gaps between BIM and GIS without resorting to data conversion, thereby preventing any loss of information. Therefore, it is necessary to maintain the original domains where information is created and stored, preserving the integrity of data. This is achieved by identifying identical elements and linking them through the respective ontologies of the specialized models. The bidirectional data exchange approach establishes a communication pathway between specialist planners in the domains of BIM and GIS, allowing indirect collaboration through a unified software platform. This significantly simplifies the planning, design and realization processes, especially in the context of wind farm planning. The advancements align with the objectives outlined by the Federal Ministry of the Interior, Building and Community (BMI) for 2021, which envisions the gradual and complete implementation of the BIM methodology in federal building construction by 2027 (BMI 2021).The ongoing research project and the associated work-in-progress paper underscore that the BIM methodology can be implemented in a forward-looking and sustainable manner by establishing connections with other specialized domains and information spaces. This approach not only bridges the technological divide between BIM and GIS but also demonstrates the potential for collaborative and future-proof implementation across diverse fields.

2. RELATED WORK

The concept of linking heterogeneous data spaces has been a well-known topic in computer science for some time. Discussions and research on how to link data from diverse information spaces using link models have been ongoing since as early as 1989, with the emphasis on retaining the data within its original data spaces (Berners-Lee et al., 1994). In the specific context of linking BIM and GIS specialized models, several examples demonstrate the feasibility of connecting or integrating domains across disciplines.

Laat and van Berlo (2011) illustrated in their work that information from BIM technical models can be successfully transferred to GIS technical models. This transfer was achieved by assigning information from BIM technical models to defined classes in Industry Foundation Classes (IFC) and then transferring it using the GeoBIM extension. Zhu et al. (2021) developed a method to transform the geometries of BIM models stored in IFC into the shapefile data format commonly used for GIS models. Their focus was on solids within IFC files, such as rectangular, circular and I-profiles. The study also demonstrated the transformation of points from the local coordinate systems of BIM models into geocoordinates of GIS models.

Ding et al. (2020) demonstrated the bidirectional transfer of data between GIS and BIM using text mining methods. The letter trigram-based word hashing method (WHSMM) emerged as superior in terms of performance compared to other linguistically based methods, effectively transforming datasets from IFC to CityGML and semantically mapping the content.

El-Mekawy et al. (2012) showcased the possibility of merging data from GIS and BIM into a Unified Building Model (UBM), combining CityGML and IFC. This integration involved collecting all classes and related concepts from both models, merging overlapping concepts and employing Unified Modeling Language (UML) to represent objects and relationships.

The approach proposed by Schilling et al. (2023) demonstrates the possibility of connecting specialized models of BIM and GIS through a link model using semantic web technologies. In this methodology, domain-specific applications are encapsulated within a Docker container and deployed in a microservices architecture. Communication between these applications occurs through specially developed Application Programming Interfaces (API). The geometries of BIM and GIS are stored in domain-specific databases, namely PostGIS and BIMserver. To facilitate the integration of heterogeneous data, all necessary links are stored in a graph database (GraphDB) using the Resource Description Framework (RDF).

Fuchs (2014) introduced the concept of using the multi-model software M2A2 and multi-model containers to merge different specialist models from the BIM world into a single viewer, allowing for the creation of customized profiles. This approach enables planners to display pertinent information from various specialized models. The development of the multi-model query language MMQL eliminates the need for homogeneous data formats within specialist models, emphasizing the necessity for only homogeneous, generic data access.

Malik et al. (2015) demonstrated that linking data from heterogeneous formats is feasible using the Resource Description Framework (RDF) and the Extensible Markup Language (XML), thereby minimizing data loss.

While existing research indicates the feasibility of connecting GIS and BIM technical models through a link model, the development of a non-commercial system specifically tailored for the planning and realization of wind farms remains an ongoing research focus. M.O.S.S. Computer Grafik System GmbH and Erfurt University of Applied Sciences are actively working to develop their own system for this purpose as part of the research project "BIM and GIS - Bidirectional Data Exchange for Renewable Energy Planning." The project is still in progress and the methods and technologies suitable for the specific use case are being researched and evaluated. Subsequent sections of this work-in-progress paper will elaborate on the chosen approaches, the software structure and the planned steps to realize the link model between moGI Planner and Autodesk Revit.

3. THE eeBIM CONCEPT

3.1 MULTI-MODEL IDEA

The research project "BIM and GIS - Bidirectional Data Exchange for Renewable Energy Planning" is currently in its early stages of development and the individual components are still undergoing finalization. The following concept provides an overview of how the heterogeneous data spaces within the BIM and GIS specialist domains can be successfully interconnected.

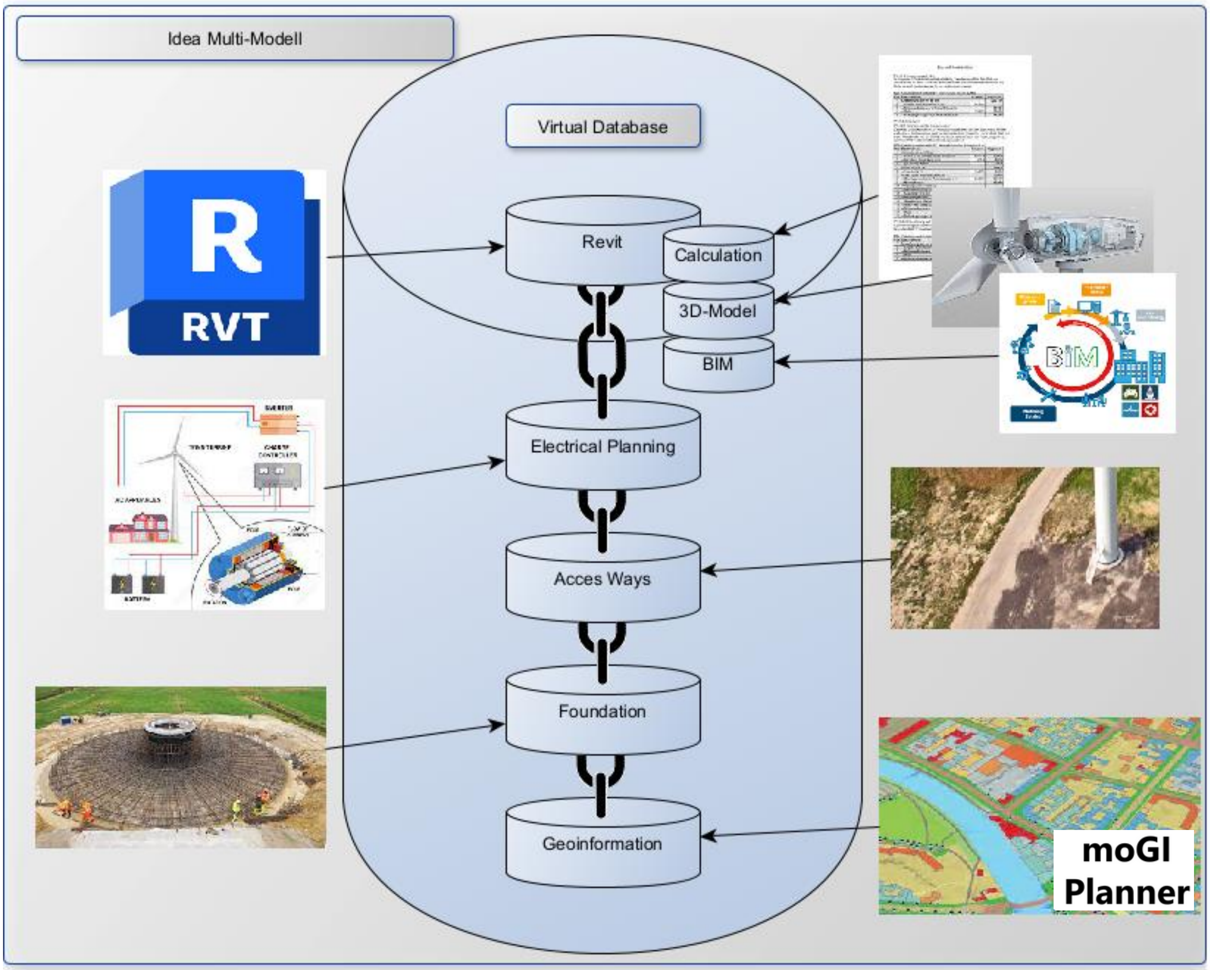

Figure 2-Multi-Model Idea

Figure 2 presents the first idea of the multi-model, which represents the data required for planning a wind farm and links them in a newly created virtual data space. In the context of this concept, the term 'virtual' describes the fact that the created database does not physically exist in reality, but is linked to the original storage location. The connection between the individual databases is symbolized by the chain links. However, thanks to the link model, it behaves like a database from which data and information can be retrieved. The diagram illustrates the various trades and planning services required to design, plan and implement a wind farm. These services are stored in different specialized models and form a heterogeneous data space. The link model brings together all the relevant data for design, planning and implementation and makes it available to all planners in the virtual database created.

In the first step of the project, the BIM authoring software Autodesk Revit and the GIS planning software moGI-Planner will be linked. The software and technologies required to implement the linked model are presented below.

3.2 moGI-PLANNER

The moGI Planner, developed by M.O.S.S. Computer Grafik System GmbH, presents a web-based, modular solution for the planning of wind and solar parks based on a geographic information system (GIS). The central function of the moGI Planner is to provide planners with spatial information, e.g. on properties, nature conservation areas and residential buildings and to plan the land utilisation for wind turbines and the associated infrastructure (e.g. power lines). The planner enables the placement of individual wind turbines within a wind farm, whereby it independently calculates the required clearance areas in the technical and authorisation sense from manufacturer specifications and legal requirements.

Figure 3-UI moGI-Planner (M.O.S.S. Computer Grafik Systeme GmbH, 2024)

The Figure 3 depicts a user interface of the moGI Planner, providing a visual representation of the placement of individual wind turbines on land parcels. The property management function enhances the user experience by automatically displaying ownership structures and existing lease agreements for the respective parcels of land. Furthermore, the moGI-Planner is equipped with interfaces to various specialized programs, enabling variant planning and yield analyses. Integration with Customer Relationship Management (CRM) and Enterprise Resource Planning (ERP) programs is seamlessly incorporated into the system.

In the context of the "BIM and GIS - Bidirectional Data Exchange for Renewable Energy Planning" project, the moGI-Planner facilitates data exchange with other systems through an interface using the GeoJSON format. This interface enables the import and export of data and information between the moGI-Planner and other systems involved in the planning and management of renewable energy projects. The utilization of the GeoJSON format streamlines interoperability and promotes seamless collaboration across different platforms within the project.

The GeoJSON file is parsed using the Python scripting language, as depicted in Figure 4 - CodeGeoJSON. The standard JSON library, specifically provided by Jazzband (2023), is employed for reading the coordinates. The information from the GeoJSON file is then stored in a GeoJSON object. Subsequently, the script accesses the FEATURES of the GeoJSON, extracting individual data such as geometry, which is then read out and stored in a memory variable. At this point, the data is ready for further processing or output as required.

```
import json

# GeoJSON-file-path

geojson_file_path = 'WTG_POSITION_P.geojson'

# load GeoJSON data

with open(geojson_file_path, 'r') as file:

geojson_data = json.load(file)

# Now geojson_data is a Python dictionary that represents the loaded GeoJSON data

# You can access the various properties and geometries just like in a normal dictionary

# Access to features

features = geojson_data['features']

for feature in features:

        # Access to properties

properties = feature['properties']

# Access to geometry

geometry = feature['geometry']

# You can carry out further processing steps for properties and geometries here

# Example of accessing the coordinates of a point geometry

point_coordinates = geometry['coordinates']

print('Punkt-Koordinaten:', point_coordinates)
```

Figure 4-Determine geocoordinates from GeoJSON with Python

3.3 BIMserver

The information is stored in the open-source BIMserver using the Industry Foundation Class (IFC) format (The open-source BIM collective, 2023). BIMserver not only serves as a repository but also facilitates communication between the moGI-Planner GIS software and the Autodesk Revit BIM software. The structure of the link model is depicted in Figure 5, highlighting the BIM server as the central hub for data distribution.

In this model, the moGI-Planner uses the GeoJSON format for its data, whereas the Autodesk Revit BIM software is compatible with both Industry Foundation Class (IFC) and Revit's proprietary RVT format. It's worth noting that IFC, established in the late 1990s, is considered an open format and has played a crucial role in the BIM domain for exchanging specialized models (Borrmann, 2015).

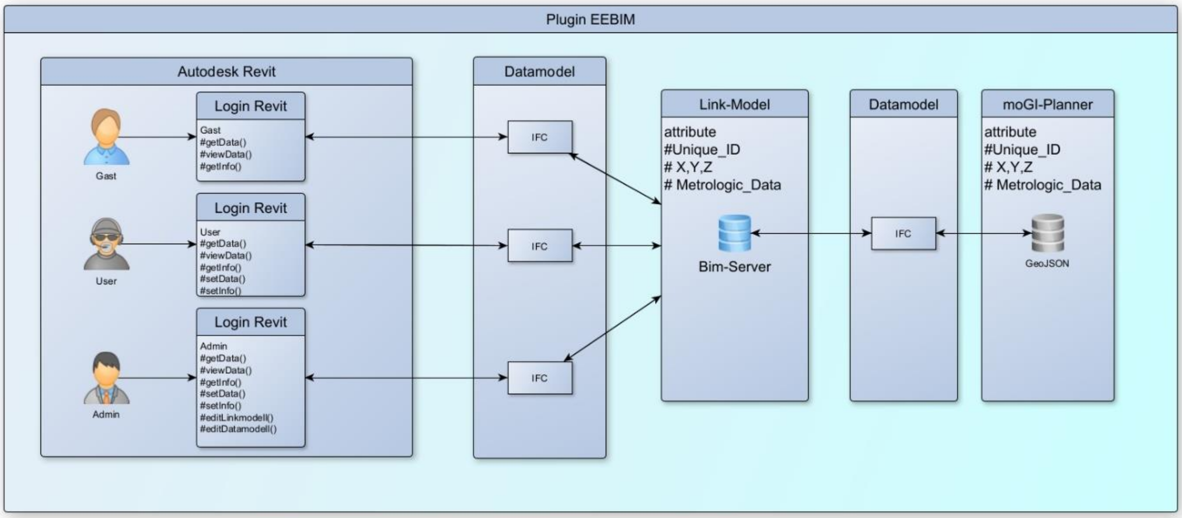

Figure 5-First structure link model

According to Figure 5, data from moGI is transmitted to the BIMServer, which then filters and semantically assigns it. Simultaneously, Revit transfers its data to the BIM server through an API plugin. The server, acting as an intermediary, filters and semantically categorizes this incoming data. It's crucial to note that data storage on the BIM server is temporary. In the event of modifications to the Revit or moGI technical models, the BIMServer conducts checks to determine if the altered data points are part of the multi-model, subsequently updating them as needed.

The information hosted on the BIM server is accessed, transmitted and displayed by the BIM server when a specialized model is opened in Revit or moGI. However, it's important to clarify that permanent data storage persists in the respective specialized models. For instance, when positioning a wind turbine, the planner accomplishes this task in moGI, saving the center point as a geocoordinate in the World Geodetic System 1984 (WGS 84) within the GeoJSON file. This information is then transferred to the BIM server for retrieval, storing the geocoordinate alongside associated details about the Wind Turbine and its center point. Upon opening or updating the specialized model of the wind turbine in Revit, the Revit plugin communicates with the BIM server to query data. The plugin is informed that a geocoordinate for the wind turbine's center point is available and it subsequently transfers this geocoordinate as a project base point into the corresponding Revit file (RVT format) within the BIM model of the wind turbine.

3.4 REVIT-PLUGIN

The mentioned plugin serves as a critical component for the seamless operation of the link model with the Autodesk Revit BIM specialized user software. It facilitates the direct presentation of essential information from the moGI GIS specialist application through the Revit API. Additionally, it provides users with the capability to automatically incorporate modifications made in the BIM model or signal adjustments performed in the moGI project. Detailed representations of these changes are presented to the user, offering the flexibility to apply them immediately or later. Conversely, in the opposite direction, the plugin assumes the responsibility of transmitting pertinent information to the BIM server when it is crucial for the moGI GIS software. This bidirectional communication ensures that both BIM and GIS applications remain synchronized, allowing for efficient collaboration and information exchange between the two specialized domains.

3.5 CONTAINER SOFTWARE

As demonstrated in comparable research, such as the work by Schilling et al. (2023), Docker containers play a pivotal role in the distribution of data within the link model. Docker containers offer a practical solution for bundling code and all necessary dependencies, enabling the efficient and reliable transfer of applications between different computer environments. These containers encapsulate all components essential for running an application, encompassing code, runtime, system tools, system libraries and configurations. This technology empowers the software to operate independently of the underlying infrastructure, enhancing portability and consistency across diverse computing environments (Docker Inc., 2024).

In the context of the research project "BIM and GIS - Bidirectional Data Exchange for Renewable Energy Planning," a Docker container is utilized to transport data and information between specialized programs and the BIM server. This approach ensures a streamlined and consistent deployment of the required components, facilitating effective communication and data exchange within the link model. The utilization of Docker containers contributes to the project's goal of creating a flexible, scalable and interoperable solution for bidirectional data exchange between BIM and GIS domains in the realm of renewable energy planning.

4. CONCULSION AND OUTLOOK

This work-in-progress paper on the research project "BIM and GIS - bidirectional data exchange for renewable energy planning" proves that the connection between the two specialist programs Revit from Autodesk and the moGI planner from M.O.S.S. Computer Grafik System GmbH is possible. The considerations to date show which approach and technologies can be used to accomplish the given task, although the research project is still at a very early stage of technical realization. Most of the mentioned methods and technologies have not yet been fully implemented.

The approach discussed so far for reading GeoJSON files, which are used in the moGI GIS program, proved to be promising. The geocoordinates can be determined using open-source libraries and the scripting language Python. The next step is to transmit these coordinates to the BIM server.

In a previous section of this paper, the concept for the exchange of geocoordinates, in particular for the location of a wind turbine, was discussed. For future applications, it is crucial to be able to transfer geometries such as distance surfaces, foundation diameters and turbulence ellipses of the wind turbine. BIM data formats such as IFC and RVT are able to visualize geometries such as circles and curves (Borrmann et al., 2015, p.34-41). The GeoJSON data format describes geometries such as circles using a large number of points to form a polygon, which corresponds approximately to a circle. Research into approaches for the seamless transfer of these geometries without having to accept data losses due to transformations between a circle and a polygon will be an important part of future research.

To ensure that the link model only transfers the necessary information for planners from one specialized model to the next, a comprehensive analysis of the necessary planning steps is required. This analysis includes all processes and steps carried out by planners in the specialist programs Autodesk Revit and moGI in the context of the design, planning and construction phases of a wind farm. It is planned to conduct user surveys among planning offices to ensure that the software is developed as closely as possible to the real planning process. A master's thesis in 2024 will help to identify and process the necessary information.

The central, as yet unanswered question concerns the storage of data and its semantic meaning. As described in the "Related Work" section, there are already approaches and methods for storing information and semantics in triples. We are convinced that this method is also suitable for our use case and it is planned to use the RDF data model to store the semantic information.

As part of the research project, an innovative method for opening up data spaces was investigated. The automated extraction of information from PDF files and its subsequent semantic categorization has not yet been feasible in existing research work on link models in the field of BIM and GIS (Fuchs, 2014). In the Federal Republic of Germany, certain building regulations, such as the distance rules for wind turbines from residential areas, are subject to the regulations of the respective federal states and municipalities in which the turbines are erected (Wissenschaftliche Dienste, 2021). These regulations are published on the relevant websites of the offices of the federal states.

The use of artificial intelligence (AI) and text recognition aims to integrate these legal texts, which are available in the form of PDF files, into the link model. The first attempts at this have shown promising results. By using the Python scripting language, an AI module was developed that can extract the spacing rules from a PDF file and the content of web pages using keywords. A web scraper is used to determine the distance rules, which vary depending on the federal state and municipality. This extracts the data from current websites. The Python module BeautifulSoup (Wention, 2015) is used to load the content of the website into a memory variable. After loading all the data, the module spaCy (Explosion, 2023) searches the memory variable for keywords such as 'minimum distance'. Subsequently, all numbers close to the keyword are determined and filtered to read out the distance rules. This approach is an experiment to automatically create new interfaces to other data spaces that previously required manual intervention. This is seen as an opportunity to extend the link model to other areas that were previously inaccessible or insufficiently accessible.

ACKNOWLEDGEMENTS

This Project is supported by the Federal Ministry for Economic Affairs and Climate Action (BMWK) on the basis of a decision by the German Bundestag.

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