buildingSMART International (2022)
441-STUDENT Student Research using openBIM

AaDzWONo

Implementing passive RFID technology into BIM models in combining them with open-source software applications

Entrant details

Role or Job Title on the Project	Student
Employer	
University of Applied Sciences TH-Mittelhessen, Germany	
Employer Role	Academic or Research Institution
Are you or your employer a member of buildingSMART?	Yes - Chapter Member

Entry details

Entry Details

By checking this box I understand and acknowledge that this awards program is to assess information about openBIM, and that openBIM is not only about the use of solutions. openBIM is about setting up an environment where every party in a team can work in the optimal way ("how they prefer") without putting limitations on others. It is about freedom to take control over your data and workflows, while keeping that freedom for others as well. Full use of open standards is not mandatory for this mission.	✓

Website	https://opennavibim.herokuapp.com/

Location

Technische Hochschule Mittelhessen (THM)
University of Applied Sciences
Faculty of Civil Engineering
Wiesenstraße 14
35390 Gießen
Germany

Submitting Party and Stakeholder Logos (compiled into one .ppt/pptx file for upload)

PPTX	Logo.pptx (264 KiB download)

Entry Description

The integration and installation of innovative Radio Frequency Identification (RFID) technologies in combination with wireless Internet of Things (IoT) technologies in Building Information Modelling (BIM), assigned building elements, can create connectivity between the physical- and the virtual world.

Beyond the identification of physical objects, further information can be connected, which can be made available to different user groups during the entire life cycle of the building structure. This provides a high level of transparency, in that by scanning the tagged building elements, complete associated information can be accessed and presented to users via applications, in visual and audio form. One use of an RFID and BIM-supported electronic guidance system, namely for the visually impaired, has already been investigated in my bachelor thesis at the University of Applied Sciences (Technische Hochschule Mittelhessen, THM).

This Master's Thesis focuses on the implementation of passive RFID technology into BIM models in combining them with open-source software applications. BIM represents the digital twin of building models in the digital world and can be linked to physical structures (buildings, roads, sewer systems and such others) and building materials (e.g. textiles, mineral and plastic floor coverings, concrete components) by integrating RFID tags.

Connecting the parametric BIM models with the physical building elements by using RFID and wireless IoT technologies in a multi-platform application enables the BIM building models to be actively used throughout the life cycle of a building, not only by the facility management, but also by the public for various use cases.
During the literature review, suitable software and hardware components were selected, and a prototype multi-platform application for a navigation and positioning system was developed as proof of concept for the Industry Foundation Classes (IFC) file. (See Demo Version at https://opennavibim.herokuapp.com/).

The challenge was to read the RFID tags in different installation scenarios. Depending on the installation situations (under, over or in the material), various requirements were specified for RFID tags and readers (RFID, handhold personal digital assistant "PDA"). In this field, further hardware developments are necessary.

What stage of completion is the entry content representing?	Design Development

Stakeholder Statements

Stakeholders are the authorities, public and private institutions for the implementation of barrier-free openBIM based, centimetre accurate indoor and outdoor navigation system

Upload a 2 minute video to show the scope of the entry.

AVI	opennavibim_demo video.av... (43.3 MiB download)

Problem Statement

1.1 Background and Problem Statement

The use of RFID, Sensors and wireless IoT technologies is becoming increasingly significant for the further development of BIM. Today products, such as RFID technologies, sensors and beacons are used in the planning and construction process of construction projects to make the processes and progress on construction sites more effective, and to assign information to the construction objects and to document it.
The research of RFID and wireless IoT technologies and their integration into BIM building models were methodically and practically investigated based on two concrete and the feasible applications using the following questions:

- • What is the current state of the art and research of integrating RFID and IoT technologies in BIM projects?
- • Can we use the model-based data in the operating phase of the structure over its life cycle, and would this provide additional value?
- • Can digital BIM models be linked to the physical structures in real-time using RFID technology as a digital twin, for example setting up a navigation and positioning system?
- • What opportunities are provided by RFID and wireless IoT technologies based on BIM systems for barrier-free mobility and physical infrastructure objects?
- • Which software and hardware components can we use to implement RFID and wireless IoT technologies in BIM building models? With regard to application possibilities the following problems were investigated:

A. Use Case 1 - Centimetre accurate pedestrian guidance system for the blind and people with limited mobility
An essential component for visually impaired people is independent mobility and information acquisition. Orientation is, almost everywhere, prerequisite for independent participation in society. In unfamiliar buildings it is particularly problematic. Tactile guidance systems are increasingly being provided outdoors, but they usually only up to the building entrance. For indoor areas, tactile aids (warnings) are available as knobs and strips made of plastic or stainless steel that can be attached to existing floor coverings. However, these guidance systems have hardly been used so far because they usually interfere with the design concept. Optical guidance systems can help a visually impaired person with orientation, while blind people can use haptic guidance systems. However, these systems do not provide any information about the surroundings, only directional and potentially dangerous information.

B. Use Case 2 - Infrastructure Objects in Urban Water Management
When digitisation began, most construction projects were designed and realised in CAD programmes. The next step was to integrate the data into geographic information systems. This allowed the objects to be registered, managed, analysed and visualised in geodatabases.
The next step was to merge the data into a NIS (Network Information Service) system in order to plan and document data regarding the facilities, from planning to the end of the operation, including the necessary maintenance work. Only a few steps are missing to complete NIS to a full twin with regard to BIM systems. Reliable recognition of the object on site is not always possible. Likewise, in the real world, for example, signage can point to the objects, but does not show them. Also, GPS data often is not accurate, for example in detecting Infrastructure objects. This requires high-resolution GPS instruments, which are also used in Geodesy. The water supplier and wastewater disposal company (MWB) in the city of Giessen uses such systems for the maintenance and servicing of road inlets (water gullies).

The focus of this Master Thesis is the investigation of software and hardware solutions for the integration of RFID and wireless IoT technologies into BIM systems based on the above mentioned use-cases. It aims to deliver a basis for the practical application through the implementation of RFID and wireless IoT technologies into open BIM processes to provide preliminary work for the above defined applications based on BIM systems and soft- and hardware components.

Previous efforts and limitations

The aim was to develop a prototype application as a proof of concept for incorporating RFID and wireless IoT technologies into BIM models by using the Industry Foundation Classes (IFC STEP 21) data exchange format in the building industries for navigation, tracking, and information systems.

Based on the results of my previous studies in the methodological and practical laboratory investigations, this thesis focuses on developing software application frameworks for the integration of RFID and wireless IoT technologies into BIM systems based on the above mentioned use cases.

Solutions for this were sought in order to investigate this for the further use of structures in the operational phase with regard to the integration of RFID transponders (tags) in or under different materials (e.g. textile, mineral and plastic floor coverings, concrete components etc.).

In order to accomplish this, further investigations were carried out to implement the software and hardware solutions into the above-mentioned use cases, and a “Proof of Concept" was designed. With regard to this work, the Use Cases (guidance system for the blind and infrastructure objects with regard to inflow sources by urban water management) have similar interfaces:
• Secure and real-time communication of RFID tags placed in building materials with the help of software tools.
• Development of database and server applications to support model-based data storage and management.
• Development of an App to link the data with peripheral devices (e.g. smartphones, tablets and RFID readers).
• Real-time connection of the virtual world (data, information) with the physical world.
• Connection of the software and hardware components.

Research method

In this study, the Integration of RFID and wireless IoT technologies into BIM models was investigated, and a “Proof of Concept” for software applications and hardware solutions was generated. This was accomplished by developing a web application for the purpose of navigation, location and information systems using openNaviBIM.

In the literature research numerous technologies for the implementation of the software frameworks, which were partly derived during the development phase of the web application in the practical part of the work, were examined. The development of the openNaviBIM web application was based on IfcJS, a JavaScript library for loading, displaying and editing IFC models. The unique feature of IfcJs is the possibility to use IFC models without converting them and to deploy BIM models to the public with an open-source Approach.

By using hybrid applications, the BIM models can constantly be checked by the administrator(s) (facility manager(s)) and, if necessary, updated and made available to the users (Public) according to their requirements. For this purpose, it would have been much more practical if this preliminary work had been done in a desktop application, rather than in a smartphone mobile application.
Furthermore, in practice, the use of open-source web applications is widespread, especially since the deployment of Cloud-based service solutions using the API. In this project, for example, digital the Ocean Service API was used to make the IFC files available in the Cloud and to enable their access by the client in real-time.
In the Web-app openNaviBIM the data will be stored by the client in the MongoDB (a document-oriented database system) using CRUD (Create, Read, Update and Delete) operations. MongoDB is open-source NoSQL based database and is better for big data transactions with faster process.

A detailed literature research and method for the approach can be found in my master thesis in the appendix.

Findings/Validation

The research results show that by integrating RFID tags, as BIM objects, into building elements during the planning phase, the physical objects can be linked to digital BIM models with the help of “RFID tag” component families, using a serial numbers to specific coordinates. The developed application is available for connecting BIM models with RFID technology.

The selected software applications are freely available as an open source for proof of concept and can be freely installed in any platform, such as Microsoft Windows or Mac PC operating systems. First, a complete digital building model was exported into the open source .ifc format. Then the database system (MongoDB) and a JavaScript server (MeteorJS) were set up as a "backend". IFC.js and Three.js, the open-source JavaScript libraries, were used to load, display and edit the IFC models in a browser or an app. With the help of IFC.js the IFC models, including all their information, can be visualised in common browsers and mobile devices.

Connecting the RFID reader to the openNaviBIM app on a smartphone, using the NFC tag, works well. After reading the NFC tag using an Android smartphone, the marked element in the BIM model is highlighted in the app, and the audio message, which is stored in the BIM model, is played.
The use of an RFID reader will work in a similar way. Here, the RFID tags are scanned using an RFID reader, and the reader is linked via the openNaviBIM app using Bluetooth.
At the THM Giessen Campus, RFID tags are already installed in the test site.Therefore, these can readily be used, for example, for the development of the first BIM-supported navigation and positioning system using the openNaviBIM app via Bluetooth.

Conclusion/Contributions/Limitations

RFID technology offers high accuracy in determining the position of objects. In addition, the battery-free tags are largely maintenance-free and have a long service life. In discussions with RFID manufacturers , it was assured that a service life of 20 to 50 years could be assumed for the tags. The passive RFID tags can be easily integrated indoors and outdoors (into all kinds of materials) and linked to

database information. They can be integrated into new buildings in the industrial manufacturing process, as well as into existing infrastructure, so that their integration can offer significant added value.

For the development and practical implementation of the "Implementation of RFID- and Wireless IoT Technologies in BIM", interdisciplinary cooperation, model-oriented planning and model-based communication already play an important role in the planning phase of buildings. This means, for example, that resources over the entire life cycle of a building can not only be tracked, but the product and object data can be made transparently available for further use (e.g. tracking of structure information via RFID tag for the maintenance of the object).

The implementation of RFID and wireless IoT technologies into BIM models creates added value to the interplay of people, tools and processes during the long operation and usage phases of the structures. For the successful implementation of this project, it is necessary to involve qualified personnel. This concerns not only the qualification and willingness of the users to undergo further training, but also the acceptance of digital innovative solutions and tools in practice.

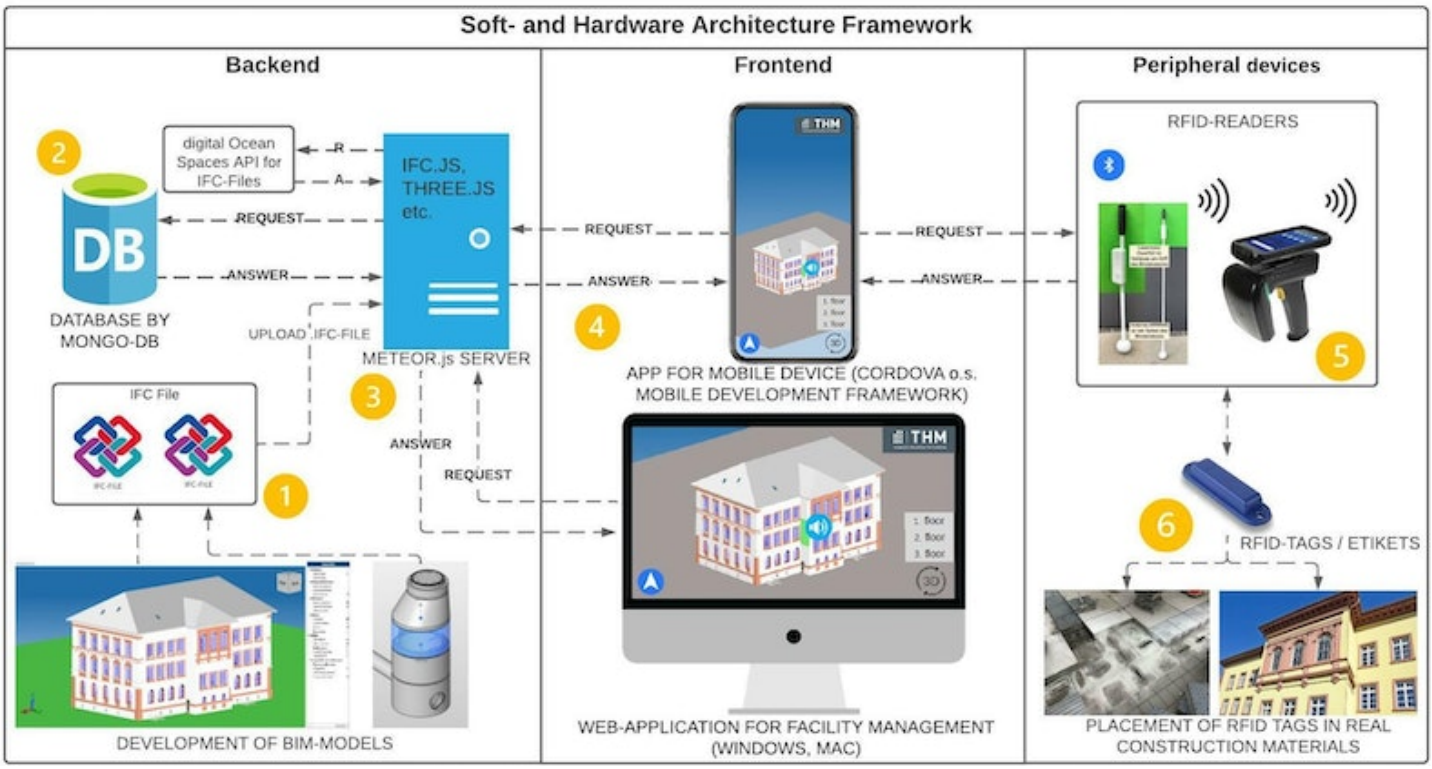
Limitations: The experience with RFID equipment's were to read the RFID tags in different installation situations. Depending on these (under, above or in the material), different requirements for RFID tags and reading devices (RFID, PDA (Personal Digital Assistant)) were necessary and accordingly implemented. Further hardware developments are necessary in this field.

Example Use

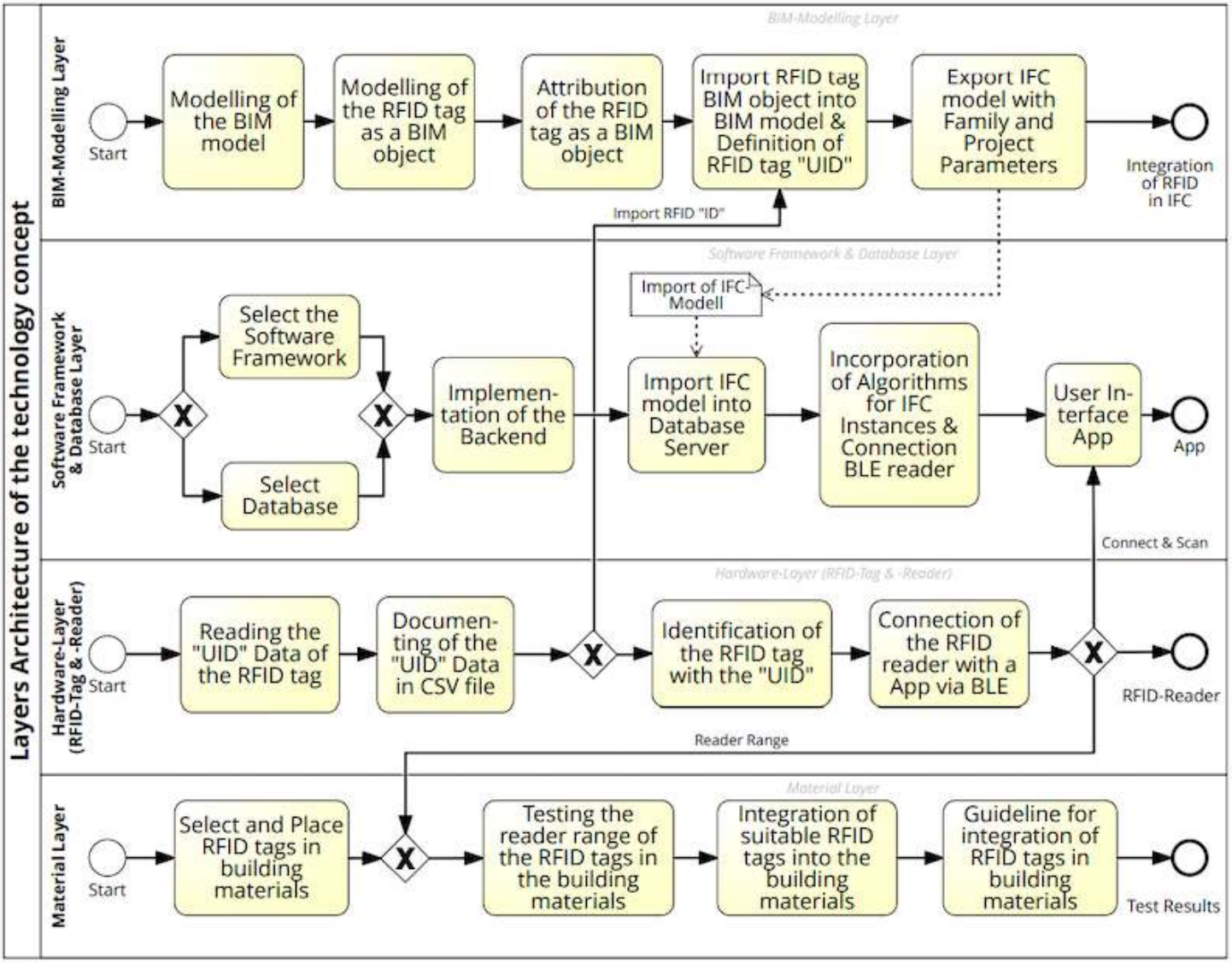
PDF	EN_Presentation.pdf (6.7 MiB download)

openBIM Evidence

Software Ecosystem Map



Process Maps



openBIM Data Metrics Summary

PDF	EN_Presentation.pdf (6.7 MiB download)

Upload .ifc file(s) or other technical files to support validation of the research results.	https://opennavibim.herokuapp.com/

Use Cases

BIM Uses were defined on the project	✓
BIM Uses formed an integral part to how the project was delivered	✓
I agree to be contacted for more information about the project BIM uses outside of this awards program.	✓

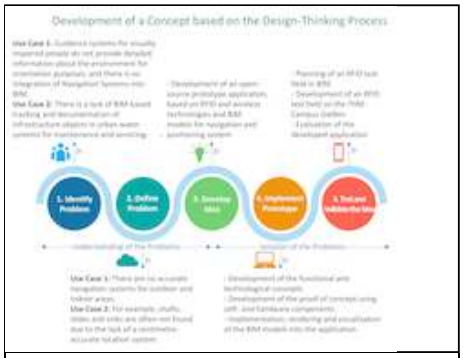
Documentation on use case(s) as a single file upload

PDF	EN_2022-02-18_THESIS_Jura... (11.2 MiB download)

Log in to awards.buildingsmart.org to see complete entry attachments.

Type of attachment
Article

IFCtoApp.png 155 KiB



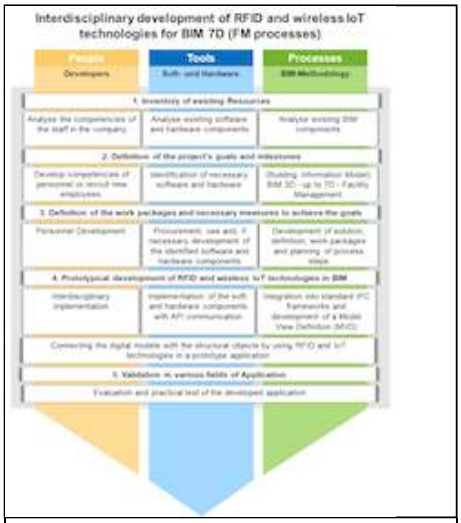
Type of attachment
Image

DT-Prototyp_EN... 648 KiB

PDF

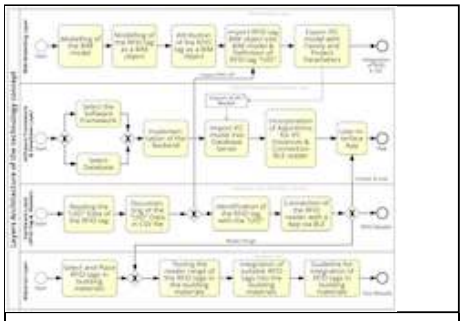
Type of attachment
Presentation

EN_Presentation... 6.7 MiB



Type of attachment
Image

EN_FM_Process... 114 KiB



Type of attachment
Use Case Documentation

Layers_Architect... 358 KiB