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INTERSECTION OF AN IFC MODEL WITH INFORMATION FROM TRACKED MOTION PATHS IN A BUILDING

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Abstract

This paper describes the enrichment of a building information model (BIM) with information from a building inspection or a motion path and the characteristics taken up thereby, for example pictures, comments or similar. The data from the motion path is generated with an autonomous Indoor Position System (IPS) and superimposed with an Industrial Foundation Classes (IFC) model. This approach focused the application of solutions for longer distances. The presented solution offers an open BIM approach for a robust and efficient data overlay.

Introduction

Motivation

The indoor positioning of pedestrian and Points of Information (POI) in a building is getting more and more important for a lot of applications. While outdoor positioning and localization are well established caused by Global Navigation Satellite System (GNSS), the tracking inside a building is not possible because of the isolation of the signal from the satellite (Real Ehrlich, Blankenbach, 2019). The applications for Indoor Position System (IPS) on a construction site are ranged from tool-, material-, labor tracking to robot tracking and some applications in the field of facility management. A typical use case for IPS in construction management is the documentation process of construction activities and anomalies.

The scope of this work is the information enrichment of a IFC Model by information like images and comments. These information are recorded in a building walkthrough with an IPS. Currently, this information is often located manually by note room numbers or scanning reference sources such as QR codes. Even for the site engineer's it is hard to describe the orientation of the information in the building. Especially in the shell construction state there are few orientation points to reference the information of an inspection. There are some well-known software solutions that solve this challenge of information tracking with augmented reality, but this seems not to be a robust and cheap solution for the mass market. Another quite new solution is the involvement of robots (Fabian Kurmann, 2021) to ensure an automatically documentation process during the construction phase. Such robots walk through a specified path and scan the area with 360° images, points clouds or similar. The recorded anomalies must be evaluated by the site engineer afterwards. The method introduced in this paper is aimed at all parties involved in the construction process who need to locate information in a building. This paper shows a solution to make this documentation process cost-effective, robust, as well as easy to use. This is important to make the application useable for small and middle-sized enterprises (SME) and raie the awareness of its useability for building inspection, an acceptance report or another use cases in the Architectural, Engineering and Construction (AEC) industry.

State of the art in IPS

For the development of IPS in the recent years a number of research reviews and summaries have been published that represent the current state of the art very well (Kunhoth et al., 2020) (Sakpere et al., 2017) (Brand et al. 2017). In (Li et al., 2020) it is well described that currently, there is still no single perfect system that can achieve indoor positioning. This paper is not primarily concerned with a contribution of improving indoor mapping, but rather with its application in an AEC use case. In the following section, a common overview of the current state of the art is shown.

Indoor positioning systems are based on different signaling technologies, for example, radio frequency identification (RFID), radio-based wireless local area networks (WLAN), ultra-wideband (UWB), infrared (IR), ultrasound, mechanical systems as used in this paper or images recognition (vision-based systems).

Modern stationary laser scanners are equipped with corresponding Simultaneous Localization and Mapping (SLAM) features and automate the localization of the scanned point clouds (Biasion et al 2019). Because of multiple sensors, this total station has a very high accuracy in indoor navigation. At present, the accuracy for wearable IPS is in the range of a few meters (1-3 m), so that accurate room navigation is possible. A robust and reliable IPS consists of a fusion of different technologies (Hybrid IPS technologies). These hybrid IPS combines two or more systems to improve the performance of each system.

For this paper used technology

The autonomous system used in this paper is developed by *inertial elements*[1]. The choice of tracking technology was primarily based on applicability, cost, and usability. The motion sensor consists of a shoe mounted inertial measurement unit (IMU) and a pedestrian dead reckoning (PDR) system for real-time indoor localization in an environment without GPS reception. The IMU shoe mount was also supplied by GT Silicon Pvt Ltd. Displacement and direction of the IMU is transmitted to a smartphone application and transmits data from sensors including i.e. accelerometers and gyroscopes in step frequency, which is typically 1 Hz for normal walking. Therefore, the low frequency PDR data (typically a few dozen bytes per second) also reduces the probability of transmission loss. This also relieves the computational load on the application platform.

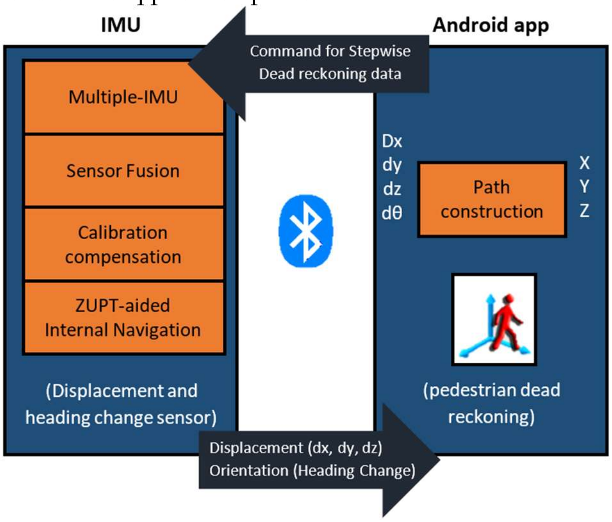

Figure 1: Conceptual approach

The IMU sensor used is the Osmium MIMU22BLP in combination with the Android application DaReX as the interface, as shown in Figure 1. The Figure 2 illustrates how DaReX detects the steps of its wearer and sets displacement and direction of each detected step in relation to the previous step and transmits the information as tracking points through the Bluetooth interface. The IMU can also be controlled via an application programming interface (API).

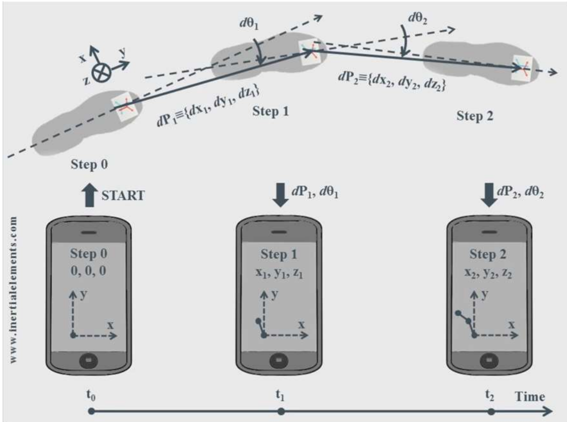

Figure 2: Conceptual approach

The findings in this area of research shows that a lot of resources are being invested in the development of IPS with smartphones. Focused is the development of a standard that does not require any additional sensors or stational hardware except of the smartphone. The interest is an robust and affordable IPS for the mass market (Nguyen et al., 2021). In recent years, many research papers have been published that permanently improve the accuracy and simplicity of IPS. The technology has various application fields, from construction process to operation and maintenance in smart building. The improvement of a smartphone based autonomous IPS that uses machine learning to minimize their measurement errors has the potential to become a standard in the coming years (Chen et al. (2020).

Concept

This approach build up on the approach of (Kreyenschmidt et. al., 2021). The concept of this paper is the superimposition of information such as images or tags to the related rooms using an IFC space model. Theoretically, superimposing with any volume space model would also be possible.

Figure 3 shows a schematic of the whole process, form motion path creation, information recording, information transfer and the superimposition with the IFC space model. After recording the motion path and the related tags, the information will be transferred to a database. This is done as an export or by synchronization from a cloud. From the database, the tracked motion path will be imported into an IFC viewer. Afterwards the recorded tags and the related motion path will be superimposed with the IFC space model to enrich the model information. The superimposition between the information and the IFC space model is done after the test walk.

[1] https://inertialelements.com/

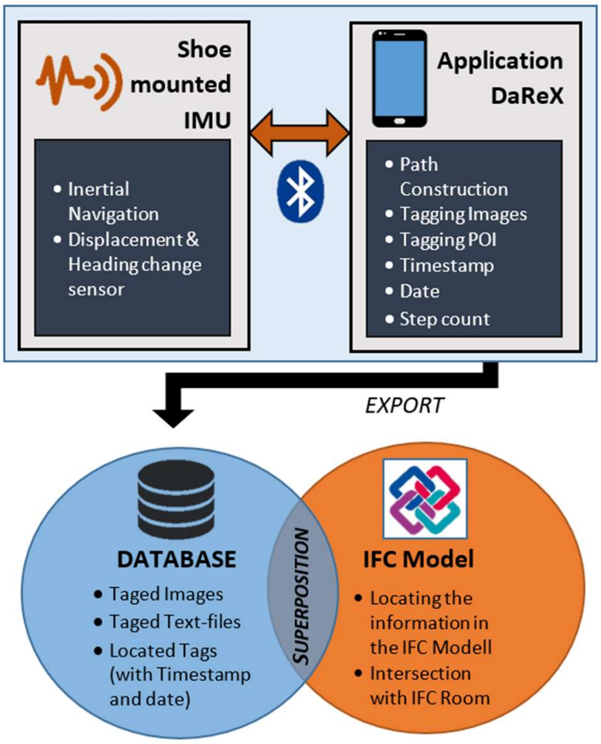

Figure 3: Conceptual approach

Figure 4: Foot mounted IMU

The application on the mobile device generates a text-based log file from the walk-through. This was synchronized with a cloud database. An example of the data file is shown in Table 1. The first table column lists a timestamp indicating the exact time per detected step, which is recorded in the second column.

Table 1: Example of the imported data structure

TIME STAMP	STEP COUNT	X	Y	Z	Dis-tance	degree	Tag-Name
13:57:27.894	0	0,77	1,02	0	1,28	192	Ref. 0
13:57:27.903	1	0,77	1,02	0	1,28	192	
13:57:31.854	2	0,78	0,85	0	1,46	266	
13:57:39.814	3	0,12	-0,37	0	2,93	36	
13:57:41.160	4	0,95	-0,78	0	3,86	264	
13:57:42.395	5	1,97	-1,74	0	5,26	313	
13:57:43.728	6	2,49	-3,12	0	6,73	42	
13:57:45.177	7	2,79	-3,56	0	7,26	74	
13:57:46.610	8	1,86	-2,5	0	8,68	137	PoI.1
13:57:47.679	9	2,32	-2,4	0	9,15	5	
13:57:49.080	10	2,78	-3,61	0	10,44	95	
13:57:52.822	11	2,07	-3,91	0	11,22	90	
13:57:54.096	12	0,61	-4,58	0	12,82	88	

The columns X, Y, Z, distance and degree describe the motion path and the measurement of the walk. This can also be viewed directly in the application. The last column shows the so-called TagName. Here, the point of information (POI) is marked, which means notes of individual measuring points are listed. The application of the mobile device allows directly taken photos, a text input, or a voice message of a specific POI. Afterwards, the POI is listed in the dataset with time, and location from the starting point. Each time a new inspection is recorded, a new log file is created.

Methodology

Tracking with the IPS

The experiment where made in the main building of the Jade University of Applied Sciences in Oldenburg. The mounted system is shown in Figure 4. Every time the device is activated it needs to be calibrated. For the calibration the device needs to be moved in the figure of an eight several times[2]. The coupling of the navigation with the smartphone allows the recording of image and alphanumeric data in tags. By starting the record every motion is tracked. However, the tracking itself is not free of errors and you should avoid unnecessary rotations or abrupt motions. In the experiment described here we had some trouble with the drift of the system, this will be discussed in the next section. For the workflow and the later superimposition of tracked motion path with the IFC model, a reference point is necessary to align the IFC model and the tracked path.

[2] https://inertialelements.com/support.html

IPS accuracy for long motion path tracking

In (Kreyenschmidt et. al., 2021) the experiments were made with tracks with a distance than less than 200m. During the 6 test tracks with longer distances, some bigger deviations where measured. The tracks 5 and 6 are recorded with 2 times 360° (720°) rotations resulted in deviations of less than 2.0m. But constant rotations due to staircases led into a directional drift. The longer test motion path's (1-3) were over two floors (Δz=8.13m) and in this course the IPS was rotated 6 times by 360° (2.160°). The results of the measurement gap are shown in Table 2.

Table 2: Measurement gap of longer motion path tracking[3]

Tracknumber	Δx [m]	Δy [m]	Δz [m]	distance [m]	Δabsolut [m]
1. LOG_FILE_145833	-18,82	-14,51	-0,03	284,13	23,76
2. LOG_FILE_150723	-18,57	-12,75	-0,06	282,41	22,53
3. LOG_FILE_151551	-17,45	-8,18	-0,02	281,83	19,27
4. LOG_FILE_151246	-27,35	-5,73	-0,03	404,34	27,94
5. LOG_FILE_105405	-1,03	4,35	-0,08	272,52	4,47
6. LOG_FILE_110013	-1,24	-1,28	0,71	231,28	1,92

The distance of 404m, track 4 in table 1, refers to a track with complete 8 rotations by 360° (2,880°). The results in Figure 5 shows the accuracy is decreasing with more rotation. The introduction of more measuring points or reference points could probably reduce the drift.

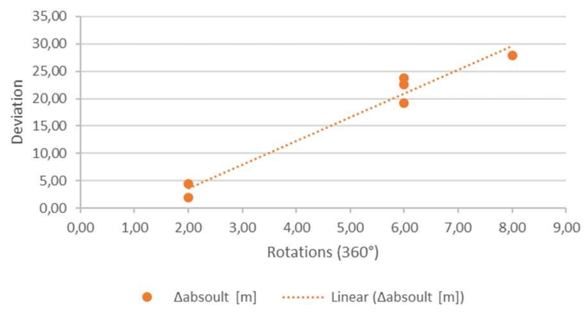

Figure 5: Ratio of drift and rotation

To avoid these deviations the longer test tracks were divided into small sections from one reference point to the next. Therefore, the different sub-sections could rotate to the correct position as shown in the test in Figure 7. To build the subsections of the track several predefined reference points where needed. The reference points where installed in some preselected doors as named in Table 3. The reference points where tabbed with a cross on the floor ground. This process is easy to apply and could also be foreseen in shell constructions.

As shown in Figure 6 the reference points were recorded while holding the tracker on the cross. This process is done for all 8 Reference points to build subsections, align the model and import the track in the IFC model in the next step.

Figure 6: Record of the reference points

Table 3: Reference points

Reference point	distance [m]	Position
Ref.0	0	Start at the door in the 2nd floor
Ref.1	93	At the door of a classroom II21 in the 2nd floor
Ref.2	162	Door Westside at Staircase North 2nd floor
Ref.3	183	Door Eastside at Staircase North first floor
Ref.4	286	Main entrance East ground floor
Ref.5	342	Door Northside at Staircase West ground floor
Ref.6	385	Door Northside at Staircase South first floor
Ref.7	491	End at the door in the 2nd floor (same as Ref.0)

Import and align the model

In the first approach the alignment and the import were made in IFC Viewer Desite md[4]. For more details see (Kreyenschmidt et. al., 2021).

In this approach the alignment of the track is made in a separated JavaScript (ecma2009)[5]. In the separated script, a loop is calculating the array of points. At each point a check is made to see if a reference point exists. If a reference point is found, it is set as the starting point for the section to be optimized and a reference point is selected to align the sub-section. On the basis of the georeferenced model coordinates a translation of the partial distance takes place. With the coordinates of start point, reference point and the end point of the section the rotation angle is calculated as shown in formula 1. All points of the sub-section container are rotated around this angle. The calculated coordinates of the sub-section are stored temporarily in an array and the reference point of the previous section is defined as the new start point for the next sub-section. This process is repeated until the end of the file is reached.

$$\cos^{-1}\frac{P_{reference\,x}\times P_{import\,x}+P_{referemce\,y}\times P_{import\,y}}{\sqrt{P_{reference\,x^2}+P_{referemce\,y^2}}\times\sqrt{P_{import\,x^2}+P_{import\,y^2}}} \quad (1)$$

[3] https://github.com/hobbie-jade-hs/desite-indoor-navigation

[4] https://thinkproject.com/products/desite-bim/

[5] https://www.ecma-international.org/publications-and-standards/standards/ecma-262/

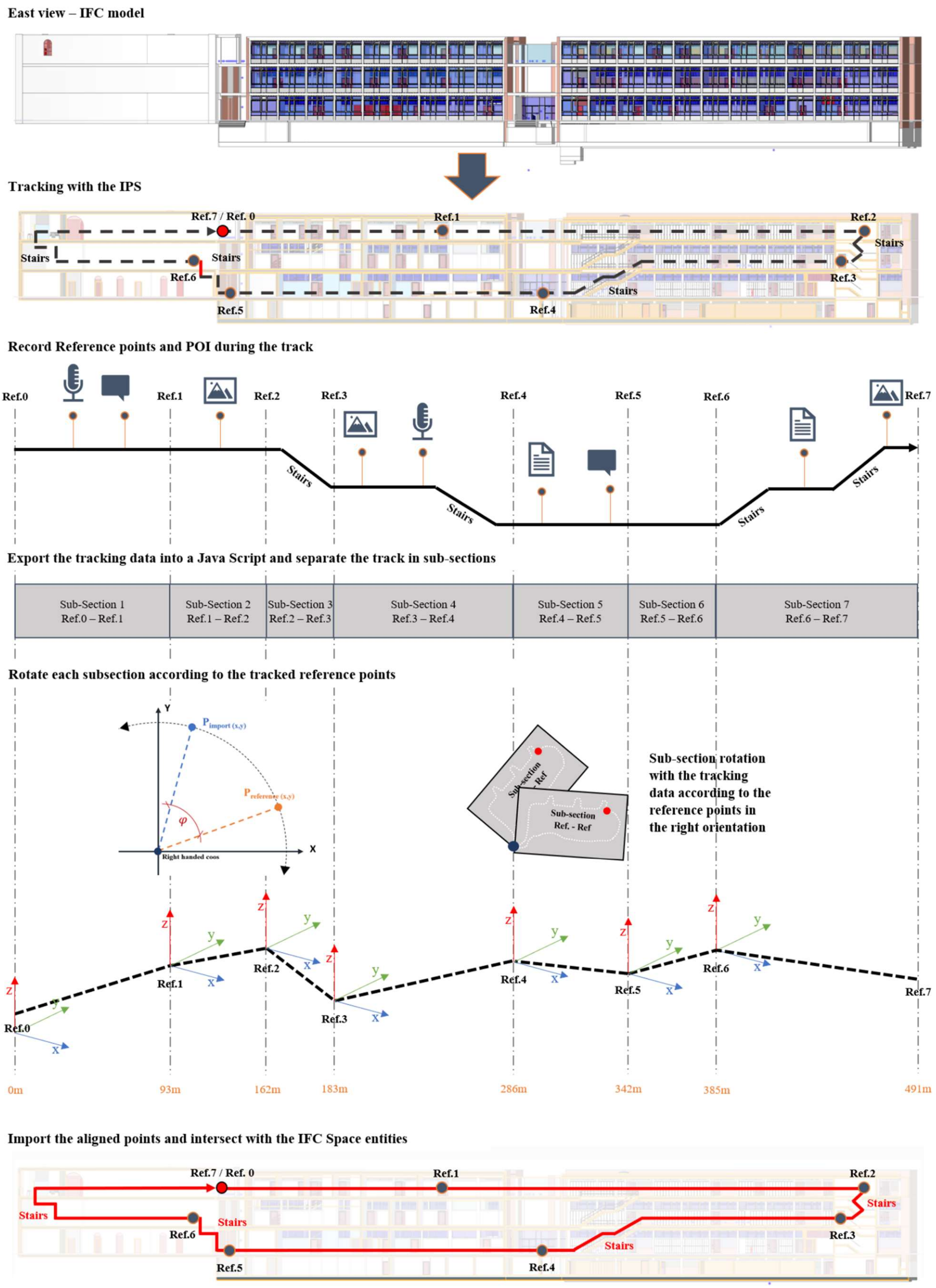

Figure 7: Alignment process of the track

The array of points is written to a text file and which is imported into the IFC Viewer Desite md[6]. The viewer does not have the direct possibility to import the tracked data from the log file into the program. The points were loaded into the project by accessing the application programming interface (API). For this purpose, an algorithm was created in JavaScript (ecma2009)[7], which loads the points to an information container that was created in the project of the IFC viewer. All points are contained within one container. This allows translations and rotations of the objects in a related set.

Each of the 382 tracking points are included as objects, which allows the attribution of each object. That allows further information enrichment in the model. The full process including the script has been published in a Github repository[8].

Superimpose Information and IFC Model

After the tracked points are imported into the IFC viewer, the tags must be superimposed onto the IFC model. The IFC Viewer offers the possibility to superimpose objects with other objects by collision detection. We use this functionality to assign the information of the corresponding room number/-name (see Figure 8). Another possibility is to superimpose between the TimeStamp of the track and the external information such as images and comments. Now, the information or the tag is extended by the attribute of the room name/ room number.

Name	cp:ID	cp:Name	TimeStamp	TagN	Room [-]
> Default (1)	02.11.2020_Hau...	Default			
TrackingPoint-11	c9802d08-6abf-...	TrackingPoint-11	12:11:29.824		II41
TrackingPoint-12	7277d236-a50b-...	TrackingPoint-12	12:11:31.037		II41
TrackingPoint-13	5bd57bb1-b759...	TrackingPoint-13	12:11:32.262		II41
TrackingPoint-14	3495086c-fae2-...	TrackingPoint-14	12:11:33.583		II41
TrackingPoint-15	75731f47-580d-...	TrackingPoint-15	12:11:34.792		II6
TrackingPoint-16	c40162c4-f35e-...	TrackingPoint-16	12:11:35.723		II6
TrackingPoint-17	36146343-a417-...	TrackingPoint-17	12:11:38.795		II6
TrackingPoint-18	13bb0ad1-ef4c-...	TrackingPoint-18	12:11:41.529		II6

Figure 8: Extend the tracking points with Room names

The superimposition is based on the IFC Space entities of IFC, therefore it is unnecessary to have a complete building-model. Rooms and individual reference points are sufficient for superimposition. That means, this application use case could be transferred to the field of existing buildings or heritage BIM, whereas known IFC models are not so common. Moreover, this application use case can be taking place in the field of facility management.

Discussion and future work

Discussion of the accuracy

The aimed accuracy of this approach was the allocation of the tracking point to the specific room from the IFC-space-entity. To archive that the accuracy needs a range of less than 2meter. Because the subsections do not exceed the length of 100m we do not recognize deviations of more than 2m. But even this small deviation can lead to mismatching between room name and tracking points. Especially when the tracked person is documenting Points of information close to a wall, that means closed to another room. A solution therefore is the possibility to integrate a logical algorithm that is based on probability to allocate the specific points to the right room. This is to specify in further research.

Outsourcing of the intersection process

To fulfill the claim of open BIM the next step is in the development is the outsourcing of the intersection process from the IFC Viewer.

There are some open-source projects that would be suitable for this. IFC.js (https://ifcjs.github.io/info/) is particularly interesting. This is a JavaScript library that is designed for the display and processing of IFC models. This would make it possible to outsource the process to the browser and apply the described method in a platform-independent way.

Conclusion

The approach is based on the approach of (Kreyenschmidt et. al., 2021) and presented the further integration of longer distance tracking.

Even if localization methods are described as autonomous and accurate today, the handling and setup of a corresponding workflow is not easy enough to establish them in the mass market. The challenge to the robustness of such a system is currently not given to generate a plug and play solution. The potentials and requirements presented in this paper illustrate how an IPS can make the construction and inspection process more transparent and leaner, with structured Points of Information that are located with an IPS. The wide range of development makes it difficult to predict which method will become widely accepted, or whether there will be a variety of best practice methods in the market.

The IMU sensor in combination with DaReX is confirmed to be useful for tracking applications in the AEC industry. The improvement of Indoor positioning systems is to expect. Nevertheless, it is necessary to increase the robustness of the solution presented here and to take up the discussed approaches in future research to produce more reliable tracking data for longer distances. A robust IPS with information transfer to open standards such as IFC will lead to more efficiency in the construction and operation of buildings.

[6] https://thinkproject.com/products/desite-bim/

[7] https://www.ecma-international.org/publications-and-standards/standards/ecma-262/

[8] https://github.com/hobbie-jade-hs/desite-indoor-navigation

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