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Integrating Scan Data to enhance BIM: An Overview of Techniques, Mapping Strategies and Building Life-Cycle Applications

***Abstract**. In the fields of AEC (Architecture, Engineering and Construction), BIM (Building Information Modeling) is developing quickly. Integrating point clouds from 3-D laser scanners with BIM is a potent solution with a range of applications across the building life cycle. This is due to LiDAR technology, which has become a significant component in BIM, obtaining 3D point clouds – a geometric representation of 3D models that is semantically rich. It is essential to understand the current status of 3-D laser scanning and BIM applications as well as their integrated tactics. In this review paper, the first section of the study summarizes the different approaches on Scan to BIM technique. Then, a detailed explanation of the various methods of mapping the scanned data with BIM is given. Proceeded by summarizing the various applications throughout the building life cycle.*

***Streszczenie.** W obszarach AEC (architektura, inżynieria i budownictwo) szybko rozwija się BIM (modelowanie informacji o budynku). Integracja chmur punktów ze skanerów laserowych 3D z BIM to skuteczne rozwiązanie z szeregiem zastosowań w całym cyklu życia budynku. Dzieje się tak dzięki technologii LiDAR, która stała się istotnym elementem BIM, uzyskując chmury punktów 3D – bogatą semantycznie geometryczną reprezentację modeli 3D. Niezbędne jest zrozumienie obecnego stanu zastosowań skanowania laserowego 3D i BIM, a także ich zintegrowanej taktyki. W tym artykule przeglądowym pierwsza część badania podsumowuje różne podejścia do techniki skanowania do BIM. Następnie podano szczegółowe wyjaśnienie różnych metod mapowania zeskanowanych danych za pomocą BIM. Następnie podsumowano różne zastosowania w całym cyklu życia budynku. (**Integracja danych skanowania w celu ulepszenia BIM: przegląd technik, strategii mapowania i aplikacji cyklu życia budynku**)*

Keywords: Building Information Modelling (BIM), Structural Health Monitoring, Building Life-Cycle, 3D scanning, Point-Cloud.
Słowa kluczowe: Modelowanie informacji o budynku (BIM), monitorowanie stanu konstrukcji, cykl życia budynku, skanowanie 3D, chmura punktów.

1. Introduction

The trendy techniques among the Architecture, Engineering and Construction (AEC) sectors during the past few decades has been Building Information Modeling (BIM). The use of BIM is becoming more common in various fields, including economic systems, transportation infrastructures, mechanical, electrical, and plumbing (MEP) fields, 3D city modeling, economic systems, and transportation infrastructures [1], [2]. A few of the advantages that BIM seeks to bring about are easier maintenance, improved customer service, production quality, coordination and collaboration, and cost reduction and control [3]. Despite the advantages, there are still certain difficulties, such as huge data, interoperability, and a lack of automated operations. An effective BIM implementation requires three key elements: high-performing measurement, adequate attribute data, and precise visualizations. Because of advancements in laser scanning, 3D measurement tools in BIM are now more useful and accessible. It's important to effectively process and transmit the large amount of data that 3D-measurement laser scanners produce. "Scan to BIM" refers to the procedure of employing scan data either aerial or ground to capture a physical site or location in order to produce an intelligent 3D model with BIM software [4], [5].

A sufficient number of reviews have been published, with an emphasis on a few applications in the building life cycle. This paper provides an overview of building life cycle applications and looks at trends in the approach to combining 3-D laser scanning with BIM. Also offers in-depth information on point-cloud data processing methods, including open standards utilized in BIM, for sampling, registration, and semantic segmentation.

2. Approaches on Scan to BIM

2.1. 3D Point-Cloud Data

Point clouds are the building blocks used to create 3D models of built environments in the Scan to BIM process. A point cloud is an arrangement of points, each with its own global coordinates as well as, intensity, RGB, and GPS time that together represent the 3D shape or feature of the environment that was recorded. Applications such as environmental monitoring, disaster management, urban planning, and simulation use scan to BIM modeling. By merging various scanning points into one dataset using a general coordinate structure, the geometry of the three-dimensional object is captured.

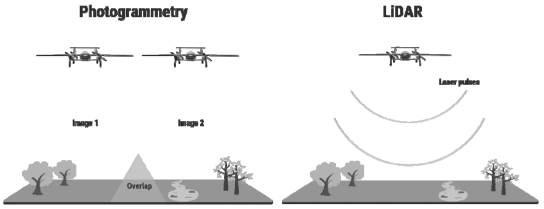

Fig.1. Methods used to create point clouds.

Photogrammetry and LiDAR are the two methods used in remote sensing most frequently to create point clouds (Fig.1). Every technique has a unique set of features depending on the environment that needs to be captured. In a case study from [6], the precision of UAV photogrammetry, mobile-terrestrial LiDAR, and airborne LiDAR data levels were examined and contrasted. They concluded that projects requiring models of paved surfaces, such as roads are better suited for mobile-terrestrial photogrammetry, also known as UAV photogrammetry. Aerial LiDAR is seen to be more appropriate for larger projects, due to its extreme precision, particularly when surveying undeveloped areas.

The main criteria used to evaluate the quality of the point cloud are its precision, point density, accuracy, and resolution. Precision is the degree to which repeated measurements of the same object are precise, while accuracy is the degree to which the measured value is near to the actual value. The 3D spatial coordinate precision can only be estimated because the actual value of these coordinates is unknown [7]. Resolution, relates to the degree of distinguishable details in the scanned point clouds, whereas point density measures the quantity of points per square meter. Varying degrees of accuracy and density of points are required by different instruments. The levels required are mostly determined by the acquisition and processing times.

Processing huge point clouds presents a number of difficulties, including data integration and storage. Processing produces a lot of data in a short period of time. The point clouds fall under the category of "big data" because of the difficulties involved in gathering, storing, and analysing enormous amounts of data [8]. Big data is characterized by five Vs, according to the authors of [9].

2.2. LiDAR Systems

For equations it is recommended to use standard Light Detection and Ranging (LiDAR) based georeferenced data-capture devices have recently gained popularity in the advancement of remote sensing technologies. Early in the 1960s, LiDAR was created for use in meteorological applications. LiDAR is widely used for a various purpose, such as HD mapping, topography, forestry management, asset inventory and 3D modeling analysis since it has the capacity to capture 3-D spatial data accurately and rapidly. LiDAR measures range using two methods: phase shift and time of flight [10].

As of date, the most useful data source for obtaining point clouds has been LiDAR because of its consistency, precision, and low error rate. Various techniques can be used to collect the data, including satellites, aircraft, and ground-based terrestrial or mobile modes. The three primary LiDAR systems are mobile laser scanning (MLS), terrestrial laser scanning (TLS), and aerial laser scanning (ALS) (Fig.2) that serve as the primary technologies providing inputs for Scan to BIM. Laser scanners have several advantages over other LiDAR systems, such as greater measurement ranges, fast acquisition speeds, and high-quality data [11]. Triangular-based LiDAR, on the other hand, is better suited for small objects and has a limited measuring range. A laser scanner's resolution and spatial area are not the same.

Fig.2. Mobile and Terrestrial laser scanners

2.3. Processing of a point-cloud

To process a 3D point cloud data, few techniques involved such as sampling, registration, outlier-removal, and compression in order to facilitate subsequent operations such as segmentation, object recognition, and classification. After data from LiDAR or photogrammetry are gathered, raw point clouds are left over. To align and combine these point clouds into a single coordinate system, a procedure called registration must be performed. In order to minimize the size of the point clouds, sampling or compression techniques are employed, along with outlier-removal techniques to eliminate any noise or outliers from the data.

2.3.1. Down-Sampling

LiDAR produces very large point clouds, making it difficult and time-consuming to perform tasks like registration, segmentation, and 3D reconstruction. Sampling is required in order to reduce the burden. The pre-processing phase for 3D point clouds is typically sampling. The pre-processing stages also take into account additional procedures like filters and outlier removal. The review publication [12] provides further details on point cloud filtering methods. The initial stage of processing point clouds is quick and effective down-sampling. Applications such as CloudCompare, Autodesk, Geomagic Suite, Leica and Z+F Laser Control software are often used when down-sampling 3D point clouds.

Replica points in high density are removed while the points in low density are retained according to Al-Durgham's [13] adaptive down-sampling technique. Since then, numerous studies have embraced this methodology. The planar neighborhood-based technique was expanded by Lin et al. [14] Planar adaptive down-sampling and Gaussian sphere-based down-sampling techniques were included by Al-Rabwabdeh et al. [15] for irregular point clouds. The potential to speed up the performance of this strategy was constrained by the time required to evaluate the local density based on nearby information.

Down-sampling the points in normal spaces is the foundation of the normal-space sampling (NSS) [16] and dual normal-space sampling (DNSS) [17] approaches. DNSS samples point to each of the rotational and translational components throughout the sampling process, whereas NSS samples the points in translational normal spaces. Simple techniques with low computational costs are NSS and DNSS. They do not take into account the spatial distribution of the sample points, therefore they are not appropriate for large-scale point clouds.

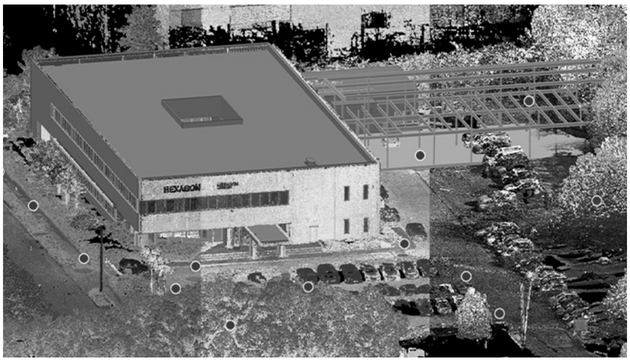

Fig.3. Processing of a point cloud data using different methods.

2.3.2. Registration Methods

Registration is a critical step in the Scan to BIM point cloud processing workflow. By determining the relative location and orientation in a global coordinate system, registration helps to identify the relevant regions between point clouds. Some of them [18], [19] concentrated on conventional registration techniques, while others [20], [21] discussed deep learning techniques. These investigations show how current registration techniques are still inadequate for massive datasets.

2.4. Semantic Segmentation

One of the most important steps in the Scan to BIM process is semantic segmentation, which separates an image or point cloud into a semantic level of meaningful sections and labels each of these components into one of the specified classes semantically [22]. In the past, point cloud segmentation was usually done using heuristic methods before deep learning methods were developed. The point-cloud segmentation (PCS) and point-cloud semantic segmentation (PCSS) techniques were thoroughly examined by the authors in [23]. While PCS attempts to create homogeneous regions by assembling points with comparable attributes by relying solely on physical characteristics and ignoring semantic information, PCSS employs supervised learning techniques to classify and label data points into a single predefined class using semantic information [24]. On the other hand, statistical contextual models and independent PCSS are the two main categories of supervised machine-learning approaches that underpin semantic segmentation.

The techniques most commonly used for semantic segmentation are RANSAC, conditional random field, Hough-transform, and support vector machine (SVM). To classify BIM elements for IFC, for example, Koo and others [25] used SVM. Edge-detection and Hough transforms were studied by ZHU and Brilikas [26] in order to classify a building's concrete elements. In terms of BIM reconstruction, Vo et al. [27] used an octree-based region-growing technique along with a conditional random field technique. Tarsha Kurdi and colleagues [28] used the Hough-transform and RANSAC. 3D roof planes were automatically identified from LiDAR data. With remarkable success, traditional methods have been applied to large point clouds. Processing point clouds with a lot of data, however, needs.

2.5. BIM Interoperability and BIM Standardization

A range of software and operations are used in the BIM process, instead of being a solitary piece of software. The construction process involves a variety of organizations, each of which uses a unique piece of software and can require a unique kind of data [29]. To effectively handle the interoperability concerns, it is necessary to have a standardized interchangeable data format that minimizes data loss during the storage and transmission of information between various parties. This is where the standards of BIM are relevant.

Many organizations use interchange protocols and guiding concepts to develop BIM standards. Various open BIM standards have been developed by buildingSMART and the Open Geospatial Consortium (OGC) like IFC, MVD, IDM, gbXML, and LandXML. Open BIM standards have already been reviewed and were published in [30]. The authors discussed various open BIM standards and interoperability-enhancing software technologies. The poll did not, however, pay attention to standards like gbXML and LandInfra. The first international standard, IS0 19650, was issued by the International Organization for Standardization (ISO) to aid in information management in BIM throughout an asset's lifespan.

3. Methods of Mapping the scanned data with BIM

3.1. BIM Modelling from the data pulled by Point Cloud

This is the primary step for fusing BIM with 3-D laser scanning technology. This procedure is required for these applications that ask for BIM. Original BIM data is generated by use of 3D laser scanning technology. At this stage, some researchers concentrate on different data acquisition platforms and scan planning in order to accomplish different goals. By means of several suitable experiments, Thomson et al [31], analyze indoor MLS as a means of gathering data for developing BIM models instead of using TLS. Chen et al. [32] use the scan-planning methodology. After obtaining the target building's point cloud, modeling was completed. Three different types of procedures are examined based on the level of automation – Automatic, Semi-automatic and Manual modelling.

Typical features such as facades, MEP (mechanical, electrical, and plumbing) components, and interior structural elements are often automatically modelled. The entire point cloud is initially divided up into numerous components (such as planes and columns). Methods including model fitting-based methods [33], feature clustering-based methods [34], and region-growing-based methods [35], [36] are frequently used in this process. Then, using rule-based approaches [37]–[39], machine learning approaches [40], [41], or deep learning approaches [42], [43], these elements are classified. When modeling an individual item, like precast concrete pieces, the previously indicated procedures are not required [44]. The model parameters for the items that were found are then estimated. After data translation, the whole BIM model is built using parametric models.

Semi-automatic modeling techniques are typically used when larger scenes are being built [45], [46] or when more intricate models are being created [47]. The regular elements' model parameters are automatically determined in semi-automatic modeling techniques. These model parameters must be imported into the software due to modeling-specific requirements. Then a manual process using software is carried out.

Heritage buildings [48]–[50], which have heterogeneous, complicated, and irregular components, usually use the manual modeling method. The parametric design of the components of heritage buildings is not currently supported by automated software processes. Even with commercial software, the manual method is still time-consuming.

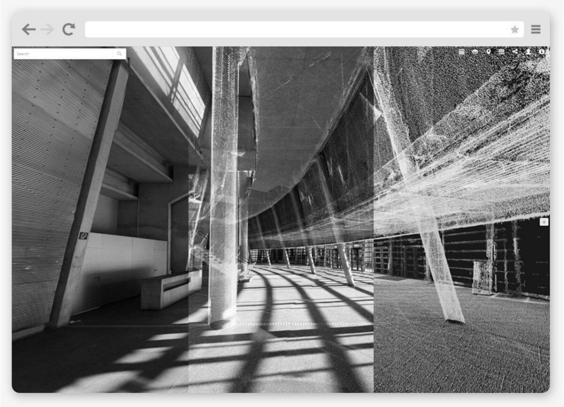

Fig.4. Mapping the scanned data with BIM using different methods.

3.2. Contrasting the Point cloud data and the BIM Model

The as-build point cloud from a 3-D laser scanner is typically compared to the as-design BIM model in a number of applications during the life cycle of a building such as SHM, building component quality monitoring, and construction progress tracking. In this progression, the subsequent three comparisons are employed: In first workflow, there are the differences between as-build and as-design point clouds; In second workflow, there are as-build and as-design meshes; and in third workflow, there are as-build and as-design BIM models.

As-built and as-designed BIM model point clouds are compared in Workflow 1. First step is to align the point cloud from the 3-D laser scanner with the BIM model. Next, the point cloud as-design is obtained at the same resolution as the point cloud as-build (as-damaged). The full extraction process is described in [51]. Down-sampling of the two-point clouds is done to produce a voxel grid with a defined resolution by evaluating the properties of each voxel in the two-point clouds to determine if it is "occupied" or "unoccupied". Afterward, depending on the voxel's state, each point can be categorized as belonging to the proper building component.

Workflow 2 compares the mesh from the as-designed BIM model with the as-built point cloud. Aligning the point cloud from the 3-D laser scanner with the BIM model is the first step. Then, by evaluating the relationship between a point and a mesh, the individual point from the as-built point cloud is mapped with a component of a building. To assess whether the point is a part of the intended object, various criteria must be met. It comprises, among other things, the angle between the normal of the point cloud and the surface [52], the distance between points that are orthogonal to the surfaces of the target construction components [53], and more.

The technique of matching points with objects in 3D models is a fundamental yet undervalued phase in workflows 1 and 2's overall process. The matching process can use a local shape descriptor. It creates a feature vector using the geometric data of the immediate area surrounding the chosen point. The matching method is more resistant to noise and occlusion when local shape descriptors are used. The performance of the SHOT [54], RoPS [55], QLCI [56], and BSC [57] descriptors is good. These applications' accuracy is increased by the matching process using local shape descriptors.

Workflow 3 compares the BIM models as-built and as-designed. By extracting the model's geometry or doing other types of commercial software analysis, this workflow carries out the objectives of quality assurance, structural health monitoring, and progress tracking using the current as-built BIM model.

4. Applications of BIM in the Building Life-cycle

4.1. Applications in the Construction Period

4.1.1. Construction Progress monitoring

Conventional progress tracking methods are labor-intensive, error-prone, and need a large number of workers. More focus has been placed on automating this procedure over time using cutting-edge computer technologies. Through the use of 3-D laser scanning and BIM, automated construction progress tracking is able to achieve deviation by comparing the as-built building point cloud or model with the as-plan model. The study of construction progress tracking is now using two different sorts of techniques.

The first automated construction progress tracking system was introduced by Turkan et al. [58] and blends 3D object recognition algorithms with 4D BIM. Only in structural situations, it achieves a good progress tracking performance due to the employment of surface-based object identification techniques. For the purpose of tracking the progress of MEP components, Bosch et al. 's scan vs. BIM processing system [59] featured a few upgrades from earlier research. The work being presented develops a new method for completing additional unstructured building components' progress control. The circular cross-section detection technique based on the Hough transform was then combined with Bosché et al. To support their methodology, they used scan vs. BIM object recognition and identification framework [53]. Assumptions about an element's geometry and point cloud density are required by all of the aforementioned techniques of approach.

By contrasting the contractive 3-D model's face count with that of the original 3-D model, Zhang et al. [52] calculated the completion rate. The distance between each point and the face affects how each point behaves. By calculating the surface covering of building components, Rebolj et al. [60] were able to ascertain the building components' current state. Points close to the surface of the building components are orthogonally rasterized onto three planes. The outcomes of all three projections were then combined to archive coverage of the element. A technique for automated deviation detection using point-to-point comparison was put forth by Chen et al. [51]. First, a uniform sampling of points from the mesh model was used to transform the BIM model into an as-plan point cloud format.

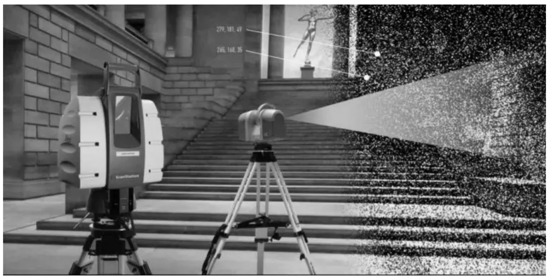

Fig.5. 3D laser scanning is used in the application of construction progress tracking and in quality control phase.

4.1.2. Quality Control in Construction phase

In order to avoid having to redo any work, quality monitoring of the building components is crucial. To achieve this, a variety of tools are still commonly used, including more advanced equipment like a total station and hand-held laser rangefinder in addition to more conventional ones like plumb and gauges. These new measurement techniques yield better precision than conventional methods. However, they still take a lot of time and are boring. The reason is that sampling strategies greatly affect their operational efficiency.

A procedure that blends TLS and BIM was presented by Bosché et al. [61] in order to significantly automate floor level control. Instead of relying on BIM, the proposed solution depends on the scan and applies specific dimensional control processes to the floor data [59]. Guo et al [62] introduced a method for automated quality control inspection of MEP modules housed in steel frames. The method describes how to register a point cloud with a BIM model by first matching steel frames with one other and using a shape-fitting algorithm to detect different element types (such as cable tray, ventilation duct, and pipe). The disadvantage of this approach is the need for manual determination of various form fitting algorithm parameters. A technique for assessing the side surfaces of precast concrete pieces' dimensional quality was reported by Wang et al [63]. The boundary of the precast concrete element is utilized to match the point cloud of the precast concrete element with the BIM model. It stores the variance in dimension and finds the shear critical sites. Kim and colleagues suggested comparable processing techniques to evaluate the quality of precast concrete components. [64], [65]. Unlike the methods previously mentioned, Precast elements' geometries were removed from the model of precast concrete elements using the Wang et al. [44] approach, and their quality was evaluated.

4.1.3. Safety on Construction Site

Safety on construction sites continues to be a major concern for the building industry. Between 2010 and 2017, 600 Chinese construction workers perished annually. Providing personal protective equipment and safety training, as well as giving priority to workplace safety, are all important. Lowering worker fatalities can be greatly aided by construction safety studies that make use of BIM and 3-D laser scanning.

A system that can recognize falls and caverns at building sites and offer the necessary fall protection equipment was presented by Wang et al [66]. The BIM model displays the necessary protective safety equipment and excavation pits as required by current occupational safety and health requirements. Through the presentation of an example, Teizer et al. [67] gave a summary of the sensing technologies that are available for tracking temporary resources on building sites and by presenting exemplary cases, illustrated the current state of research applications. Extracting resource tracking data from sensors automatically could provide an additional layer of safety protection for construction workers.

4.2. Utilizations during the Maintenance phase

4.2.1. Structural Health Monitoring

Over the duration of the structure's service life, SHM is to monitor, evaluate, and identify target structure loads and structural reactions. In order to help the owners make decisions regarding structural management and maintenance, it aims to evaluate its safety status. An essential metric for assessing structure state is displacement. A wide range of highly accurate structural displacement measurement is challenging to perform. Dense and precise measurements can be made with 3-D laser scanning without requiring a lot of time or human contact. Some articles use point clouds directly created by laser scanners for SHM. For the purpose of evaluating the structure's safety, others used the BIM model's geometries that were obtained via laser scanning.

Through the incorporation of BIM and cutting-edge sensor technology, Chan et al. [68] outlined a theoretical framework with the aim of improving bridge asset management methods' dependability and efficiency. For the Yongxin Floodgate Pumping Station Project in China, the use of 3-D laser scanning technology was able to save costs by 40% and increase efficiency by 50% when compared to the traditional method. A structural safety diagnosis technique using 3-D laser scanning and BIM was presented by Ham et al. [69]. The case study compared and analyzed the point cloud and the BIM model to determine the degree of pipe rack deformation. By contrasting point clouds and BIM, the aforementioned methods achieve the SHM objective.

The development of a historical bridge model can be made simpler by using a new technique that Banfi et al. [70] presented. This methodology also allows for the sharing of relevant multimedia material into a database for SHM. Regarding finite-element analysis (FEA) of historical structures, Rolin et al, in [71], a comprehensive geometric modeling technique was introduced. The Senlis cathedral in France's spire's structural performance was investigated using this methodology. Patil et al [72], presented a method that combines 3-D laser scanning, BIM, and FEA for evaluating a curtain wall's structural soundness. The article [73] proposes a similar procedure. In all of the aforementioned articles, it is essential to model existing buildings. The distinction between their frameworks is that FEA software was utilized to investigate structural problems in [71] and [70]. For continual inspections, the FEA can offer extra information. In [72], there is a greater emphasis on the sharing and presentation of SHM data.

4.2.2. Recovery After the Disaster

The location of the building and the extent of the damage it endured after collapse are unclear. It must be identified for search and rescue personnel to perform an effective recovery from a disaster. For gathering data on earthquake-affected areas, the best technology is remote sensing. It is feasible to determine the position and damage characteristics of each building by comparing the data gathered following the earthquake with the scan data from the building that was intact prior to the earthquake.

Bloch et al.'s way of presenting comprehensive information regarding the destroyed building was effective [74]. The technique uses a collapse simulation engine and potential damage patterns for the structure using the pre-event building's BIM. Following the earthquake, a point cloud with the same damage is captured using 3-D laser scanning technology. The point cloud marked as damaged is then compared with each possible damage pattern that was found in the database. As an example, consider RC frames with masonry infill walls, Zeibak-Shini et al. [75] devised and tested an algorithm-based technique that was previously reported by Bloch et al. [74]. The as-built BIM's RC frames are recognized by the algorithm. Based on the outcome of the preceding phase, it then obtains a rough approximation of the orientations and locations of the structural frame elements as they are damaged in the point cloud. The aforementioned techniques first generate potential building damage patterns and compare them to as-damaged laser scanning data. Make sure there are a sufficient number of building damage patterns in the database if you want to achieve decent results. The previously mentioned models state that Ma et al. [76] presents a laser scanning emulator and explains how to edit BIM models that have been damaged to create point clouds that are similar to those created by a real laser scanning on site. The lack of data from actual earthquake damaged buildings is filled up by the precise data obtained via synthesizing technology.

4.2.3. Energy Management and Modeling

An enormous amount of information is needed for building energy efficiency assessment and repair. The conventional CAD software-created architectural model is only partially detailed. That means a large amount of manual data entry is required in order to measure a building's energy efficiency. As a result, it is challenging to change the initial architectural design because the analysis of building energy use frequently complies with the architectural layout. Even if the design is optimized based on the findings of the analysis, the process is still difficult, time-consuming, and ineffective. BIM offers a design model that contains extraordinarily comprehensive design data. Buildings can be designed and repaired to use less energy if the model includes the required credible information.

An approach to producing textured as-built models automatically was put out by Lagüela et al. [77]. Data processing for geometric and thermographic data follows data acquisition. A point cloud is utilized in conjunction with an automated registration technique to create RGB and thermographic images to automatically produce textured 3-D models. For the benefit of energy specialists, Otero et al. [78] created a semi-automatic method for determining a building's indoor 3-D geometry. An automated process that produces as-built models with shade surfaces for use in solar analysis that is useful was described by Vilarin et al. [79]. It significantly reduces the building's energy use. An integrated method for building energy inspection was created by Celis et al. [80]. It will encourage efficient restoration efforts aimed at reducing CO2 emissions and turn buildings with a high potential for energy savings into zero-consumption structures. Marzouk et al. [81] devised a method that employs BIM and 3-D laser scanning to collect data on equipment maintenance for water treatment plants.

4.2.4. Modelling for Existing Building

Demand for as-build models for existing buildings is rising as more BIM tools are used in the construction process. In conventional methods, building BIM models are usually created using commercial software like CAD, Revit, and 3-Ds Max. A CAD base map must also be created using 2-D discrete point data that was collected with a device similar to a total station in the absence of CAD data, which is laborious and time-consuming. Using data from 3-D laser scanning, automated BIM model creation for existing buildings has been the focus of many studies. Railroad components, historical structures, and indoor modeling are covered in the papers under consideration.

Indoor structure modeling focuses primarily on geometric modeling for indoor structures. Plane segmentation, categorization of building components, data conversion and border detection are typically included in this progression in the work under review. The works of Thomson et al. [82], Wang et al. [83], and Jung et al. [45] all present rule-based methods for classifying building components. Their approaches to modeling indoor structures differ in how automated the data conversion phase is. An improved semi-automated process for producing as-built BIMs in large indoor spaces was put forth by Jung et al. [45]. While automatic methodologies presented by Thomson et al. [82] and Wang et al. [83] are not appropriate for huge scenes. The method given by Xiong et al. [84] differs from that in the studies mentioned above. To automatically categorize architectural elements like walls, ceilings, or floors, he employed a machine learning technique. In this field, deep learning technology is being embraced gradually. Chen et al. [42] proposed a data-driven deep learning approach to automatically identify and categorize building materials from a laser-scanned point cloud image.

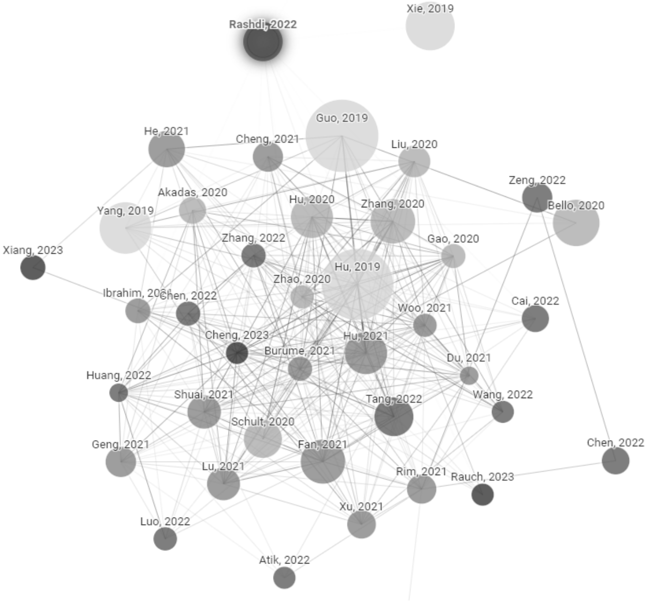

Fig.6. A graphical representation of interconnected articles.

5. Conclusion

BIM is growing in popularity, but there are still some issues with the Scan to BIM technique. Since laser scanners are the main source of data in BIM, processing large amounts of unstructured point clouds of data can be challenging. A good digital BIM representation requires analyzing and understanding each stage of the process, from gathering 3D point clouds to generating digital 3D models that are well-structured and semantically improved. With the advancement of technology, researchers have developed automatic techniques for BIM reconstruction. Recent experiments demonstrate how poorly these approaches identify complex structural features; they still require human verification to increase their efficacy in a complex setting. Thus, it is still difficult to extract semantics from the raw BIM data using a completely automated technique. This review article goes into great detail on the Scan to BIM approach, including scanning technology, 3D point-cloud processing techniques, and BIM interoperability standards. Also, summarizes methods of mapping the scanned data with BIM and applications based on construction and maintenance period in the life cycle of building. 84 related papers which are published in the last ten years are reviewed in total. Out of that, the top few papers that connects to the subject very well with good citations and more references has been graphically plotted and shown in Fig.6.

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