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SPACE SUBDIVISION FOR INDOOR NAVIGATION: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Along with the increasing demand for indoor navigation, many attempts were made to improve indoor navigation performance. Information about the room becomes important, because one of the characteristics of indoor navigation is the dynamic indoor conditions. Space subdivision is an effort made to make indoor navigation even more accurate. The purpose of this study is to create a systematic literature review (SLR) regarding the topic of space subdivision for indoor navigation which is based on a SLR method, previously defined research question. This study examines several previous works specifically in the field of space subdivision for indoor navigation with the SLR. This research is expected to be the basis for further research to improve the quality of indoor navigation based on space subdivision.

Keywords: *Space Subdivision, Indoor Navigation, IndoorGML, Subspacing, Navigation Path*

1. INTRODUCTION

Most of individuals spent their time in everyday life inside, either consume their time in the workplace, campus, shopping centre, airport, and residence. Some research also establishes people's time spent their time inside is around 90 percent for time and contingents [1]. According to the Environmental Protection Agency (EPA), the average Americans spend 93 percent of their life indoor, and only 7% of their time is spent outdoors, which is only half of a day per week outside. Navigation has become an inseparable part of our life. GPS (Global Positioning Technology) is a technology that is very inherent and familiar since we use it in our daily life. Within benefits when we are outside becomes useless when we are in a building. Lack of signal is the main reason why GPS cannot be used inside the room. Navigation and tracking systems turned into a traditional tool for transferring items like vehicles and pedestrians of route advice and placement determination. As stated in [2], the position methods like Global Positioning Systems (GPS) and map information about navigation distance are all key elements in those kinds of systems.

In recent years, indoor navigation has gained a lot of attention. Along with the increasingly intense uses of indoor navigation, the demand for space information is increasing as indoor area becomes wider and more complicated. The search for routes in the room becomes an increasingly important factor in daily life because buildings become more complex and extensive. But unlike outdoor navigation, indoor navigation has its own challenges, such as the presence of objects, could be an obstacle, in the room that change frequently. This has an impact on indoor maps that require the ability to be able to change dynamically.

An accurate building map which allow us to carry out a potential network analysis, is required to support indoor navigation application, especially for example in the case of a first responder trying to rescue a large building when a disaster occurs [3]. Effectiveness of emergency management depends on the data coming from various resources and format such as building layout and accessibility[4]. Hence, it becomes apparent an integral requirement of indoor paths is the way to correctly reflect the constraints and structures in indoor area [5]. Research on indoor models, such as semantic, geometric and topology is still very fragmented and application-oriented. Therefore, our current research pays more attention to this a specific and challenging topic. But on the other hand research about positioning

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and tracking is being conducted by researchers [6].

According to [6] a unified approach is expected within indoor modelling to have the ability to automatically identify and distribute geometry semantics and topology of indoor space because models and maps are made for specific buildings, consumer types or applications. Spatial applications develop into indoor spaces, along with easier access to spatial data [7]. At present, several data models that are frequently used are IFC (Industry Foundation Classes), CityGML, and IndoorGML. However, according to [8], IFC and OGC CityGML are all suitable for purpose in a vast selection of applications. Further, they are deficient in terms of the goal of indoor navigation, navigation of mobile robots as a result of absence of topological constructs. Meanwhile, still according to [8], OGC IndoorGML establishes a spatial knowledge framework in the room from building components and network versions for topological connections, such as proximity and connectivity, in indoor navigation.

The indoor navigation system has to be assembled based on logical, physical, and functional constraints for indoor area. In order to achieve those goals, subspacing or subdivision methods are required to partition big and complicated indoor area into proper form of subspace [9]. The simple space subdivision that produces reasonable navigation system for fine-grained navigation stays challenging [10]. Indoor space subdivision is also an important part of indoor investigation that offers information for programs path preparation and navigation [11]. In order to have the ability to do the right navigation, many components must be available: (3D) localization in a room, a model in 3D representing space subdivision, 3D algorithm for route calculation (to topology or system power version), guidance, guide (visualization) of the path and finally tracking / correction (if the route is not followed) [12]. Indoor navigation depends on the availability of free space and whether the empty space can be entered by moving objects or not [13]. Public buildings like hospitals, rail stations and airports, which are assumed to shield number of individuals and services that are unique, they are large in scale and complex. Thus, it becomes an attempt to get the best way despite of signs set to provide help, to some components of interest in buildings [13]. Nonetheless, the spatial description is not easily satisfactory to indoor navigation that is fine-grained, and also the indoor spaces in these versions initially correspond to the layout supplied by the structural components. This means that a space is delineated by the walls, ceiling, and floor enclosing it [13]. Nevertheless, no clear definition has been provided in the features of these subdivision procedure in the standard [14].

2. METHODOLOGY

Systematic literature review (SLR) was employed as a predefined study plan for executing research methodology. It is predicted that research studies which lead to reviews derived from studies can be produced by the literature review that employs SLR after considering that the SLR is exactly identifying, assessing, and distributing all studies based on intriguing happening research questions, or subject area study. SLR is a procedure which classifies, selects, and critically appraises the most question that is formulated to be answered by the prior studies. Before the inspection, the protocol or program is specified back in SLR process. SLR is an organized and transparent process through which the effort that is searching is conducted over several databases and also a similar procedure can be replicated and replicated by other investigators.

2.1 The Review Protocol

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is utilized as a guide in directing a systematic review. Literature review was completed in three stages: first, the authors searched and collected related files by using specific searching terms and keywords. Second, the authors designed an inclusion and exclusion criteria to identify the most relevant citations for the purpose of the review. Third, each document was reviewed by them from the gathered bibliography focusing on identifying information which was required to answer the research questions. As we can see at figure 1, 461 articles were identified through database searching, and, after redundancy and irrelevant data had been removed, they were 70 articles were considered for the screening process. Finally, 43 articles were selected for full-text extraction.

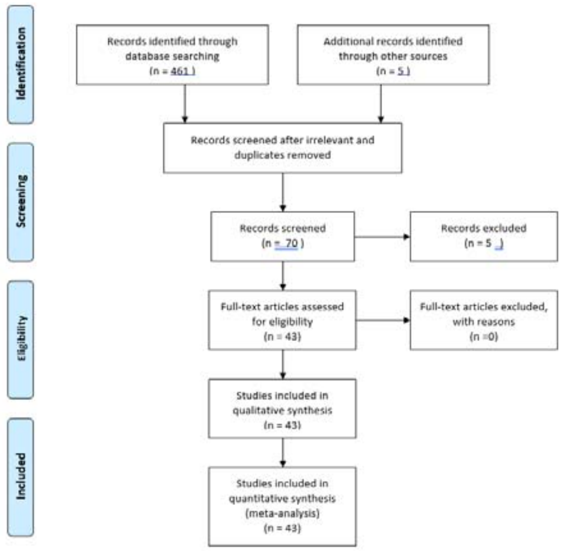

Figure 1 : PRISMA Diagram of This Research

2.2 Formulating of Research Question

The research question is currently running for the research which related to space subdivision for indoor navigation between year 2015 - 2020. The research questions are described in the following table (Table 1).

Table 1. Research Questions

RQ	Research Questions	Motivation
RQ 1	What is the trend of research related to space subdivision in indoor navigation carried out between 2015 – 2020?	Identify the trend of the related research in space subdivision for indoor navigation area
RQ2	What methods are often used in space subdivision for indoor navigation?	Identify the mostly used methods in space subdivision for indoor navigation
RQ3	What are the main challenges within the space subdivision for indoor navigation field?	To recognize the open research challenges in this area

2.3 Systematic Searching Strategies

To conduct the systematic literature review, the following database and digital libraries have been chosen that consist of:

- Scopus
- Web of Science
- Google Scholar
- IEEE Explorer

The search keywords that were used to find related studies include "space subdivision" OR "spatial subdivision" OR "indoor subdivision" OR "space subspacing" OR "spatial subspacing" OR "indoor subspacing". There is a preliminary step necessary to remove redundant papers.

The searching results are in the form of numerous reputable journals and conference proceedings covering issues from the application demand engineering defect administration. So As to get as many citations as needed, the authors also used library centers in order to get full text content to non-subscribed databases like Springer. Upon the conclusion of the searching process, the data were filtered in to more narrow data related to the research questions. The following phase of review was predicated on the references of relevant documents to this study questions and the filtered papers were added into the last listing for more research.

2.3.1 Screening

The selection criteria are derived form the study question as indicated by Kitchenham and Charters (2007). Based on this, the timeline between 2015 to 2020 was chosen among the inclusion criteria so as to make sure the standard of inspection posts with information and printed in a journal and conference proceedings are contained.

Table 2: The Inclusion and Exclusion Criteria.

Criteria	Inclusion	Exclusion
Timeline	2015-2020	<2010
Document Type	Article Journal, Conference Proceeding, Article Review	Book series
Language	English	Non English

3. RESEARCH RESULT AND DISCUSSION

In this section, depending on the SLR execution procedure, the present study defined 43 research studies that discuss about space subdivision for indoor navigation. The research documents will be categorized depending on the publication from selected research index database and classified according to years of publication between 2015 - 2020 before the research studies is compiling to answer the research questions.

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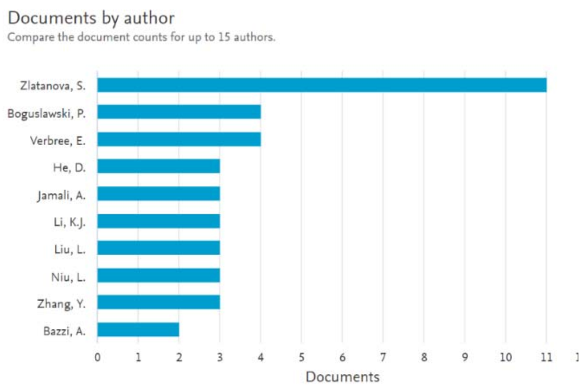

Figure 2: Document by Author

The distribution of research document by author shown in figure 2. Sisi Zlatanova became the most productive researcher in this field, with 11 studies (within search criteria).

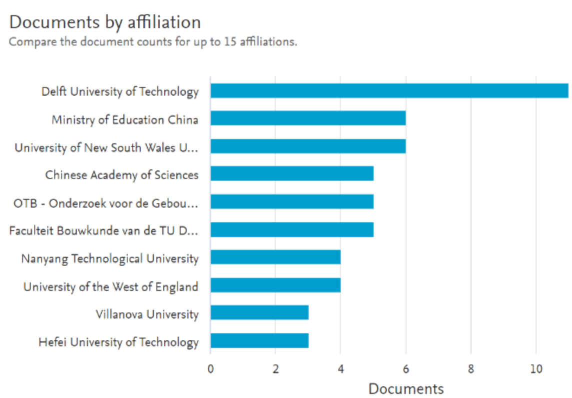

Figure 3: Document by Affiliation

Meanwhile, in terms of an affiliation perspective, Delft University of Technology is the biggest contributor in this field, as can be seen in Figure 3.

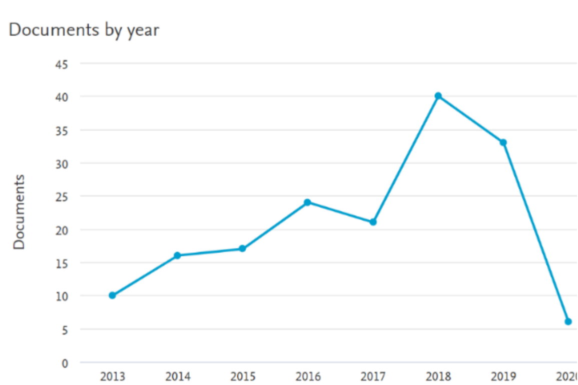

Figure 4: Document by Year

Research in this area tends to increase every year, with 2018 is being the most productive year. This fact can be seen in Figure 4. Vosviewer is used to conduct analysis and visualization of data from search results. Title and abstract subjects of each and every included publication analyzed and were extracted via VOSviewer to identify recurring terms using comparative citation scores. Two duration maps were produced for publications over the study period to exemplify the level of co-occurrence, and terms impact was evaluated primarily based on their citation scores.

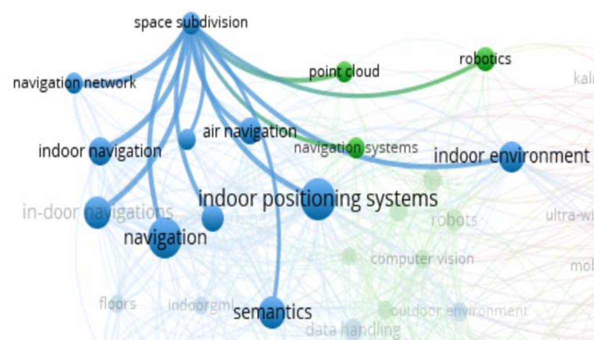

Figure 5: Keyword Visualizations of Space Subdivision

As shown in Figure 5, the topic of subdivision space correlates with other topics or keywords such as network navigation, indoor navigation, indoor positioning systems, semantics and several other keywords. In some studies, such as [15], [16], [10], the topic of subdivision space is closely related to semantic.

If we see semantics as the center as shown in the Figure 6, we can see that semantic topics in the context of space subdivision have close relations with other topics such as navigation, network navigation, indoor graphics, geometry, topology, trajectory, point cloud, navigation system and several other topics.

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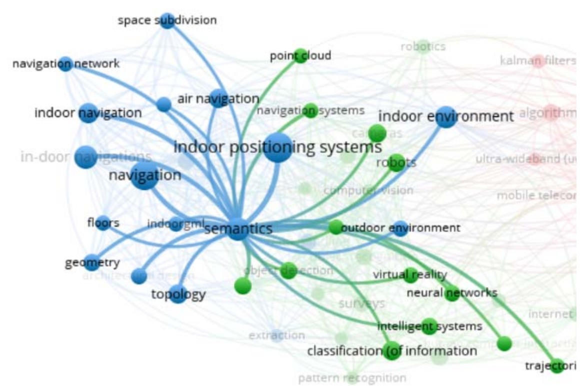

Figure 6: Visualization Related to Semantic

There are several methods that can be used to create an indoor navigation model. However, whatever method is selected, in the GIS-domain, it will be end up with a generalized model of the construction at the conclusion of the procedures [17].

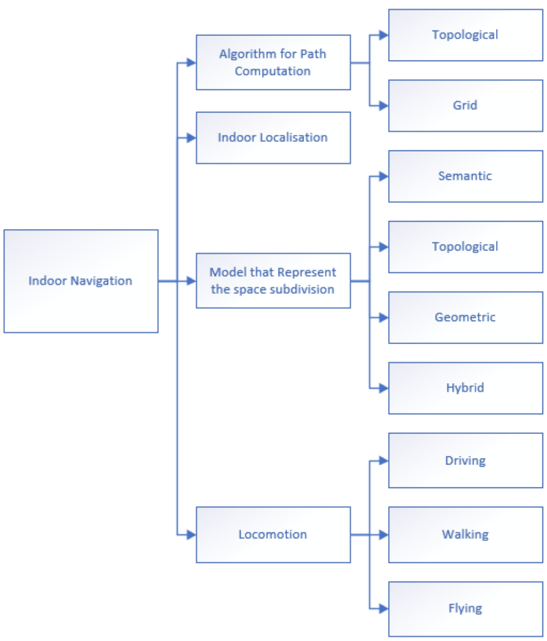

Figure 7: Taxonomy of Indoor Navigation

There are several things related to indoor navigation, including indoor localization, an algorithm for path computation and also a model that represents space subdivision [12]. Locomotion is also an important thing in indoor navigation, as reviewed by [18]. The author summarizes it into a taxonomy which can be seen in Figure 7.

Another thing that is important in the indoor navigation model is the indoor spatial model. [19] makes a taxonomy about it which can be seen in Figure 8.

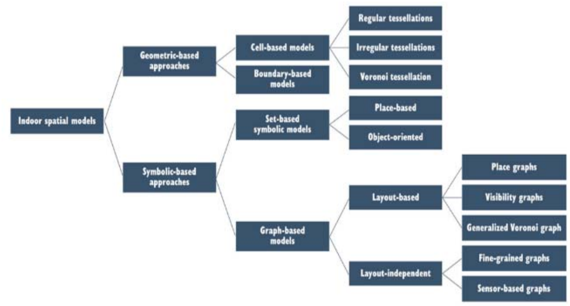

Figure 8: Taxonomy of Indoor Spatial Model ([17] *after* [19]*)*

[20] defined that the indoor subspace as some other decomposition of this indoor space into smaller sections that may be totally or partially surrounded by virtual bounds. Those subspaces might or couldn't have semantic data, and they are not overlapping and participate with a single neighboring element. Based on the use of this subspace, it might be navigable or not navigable. The navigable spaces could be utilized to accomplish actions, while, no activities can be achieved in the non-navigable spaces. There are many approaches for space subdivision that makes classification based on various criteria: the size of the geometric model such as 2D, 2.5D or 3D and depending on the semantic elaboration of the room including geometric, topological, semantic versions or a mix of them [6]. Semantics is expected to subjectively increase the calculated path. Indoor routing can be further adjusted to the drive mode and user task by utilizing semantic annotations.

In [13], they gives Flexible Space Subdivision (FSS), a programmed spatial partitioning stage that totally accepts the unpredictability of the indoor environments. It adds to 3D subspaces allowing to perceive both the free and non free indoor spaces, just as the activities they have. The structure is adaptable enough to consider the alterations of nature other than this static. The FSS framework can also fit in data model such as IndoorGML. The FSS framework can easily fit in existing data models like IndoorGML Figure 9 that is taken from [13] to delineate the UML chart that consolidates the subspaces coming from the framework to existing classes of IndoorGML.

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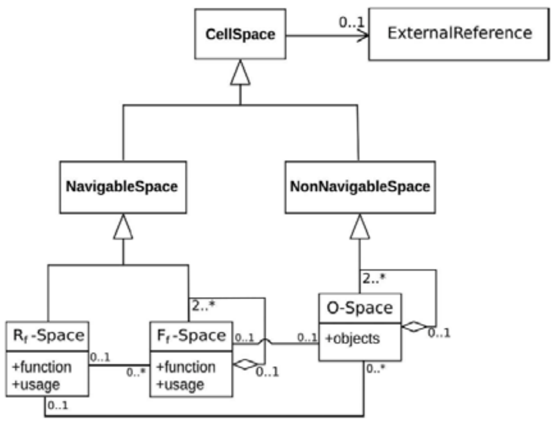

Figure 9: UML Diagram FSS Integrated to IndoorGML (from [13]*)*

It's imperative to split space so as to build network when constructing a spatial information based IndoorGML. [16] suggested the area subdivision algorithm when constructing indoor information to take into account the connectivity. As IndoorGML defines a minimal data version for area, more efforts will be needed to detect its facets, which are not explicitly explained in the standard document. [21] investigate the implications and aspects of IndoorGML and its concept of the mobile space model and discuss the implementation problems of IndoorGML. Since OGC established IndoorGML, subspacing to partition the space to building logical network is introduced. About subspacing for network, transition distance like halls or corridors need to be considered, and [22] demonstrates the procedure for developing an indoor network. Moreover, categorization of transition distance is performed and subspacing of this space is considered.

Several studies of subdivision spaces have been conducted with respect to support indoor navigation. In general, from some of these studies, they use definitions in buildings, such as rooms and corridors, also build connectivity between spaces using a semantic approach, and apply the Poincare Duality concept to obtain navigable networks, for example as conducted by [23], [24].

Addressing the challenges of developing in door navigation solutions, [13] present the Flexible Space Subdivision (FSS) frameworks that clarifies a realistic, non-abstractive 3D indoor space with lively scene changes and automatic identification of suitable navigational spaces, especially the 3D version is in the form of graph, as the indoor navigation system is generated by linking graphed benchmarks by way of a Delaunay triangulation as dual nodes.

In contrast, the Indoor Emergency Spatial Model [25] comprises 3D indoor architectural and semantic advice for innovative situational awareness. Following a more abstract solution, [26] reveal an automated method for 3D modeling of indoor navigation organized in cells without any openings between them. It relies only on geometrical and topological relationships, without semantics. To be able to represent the situation into a rendering of the space as one single indivisible object, maximum extent is not enough because representation is very abstract and this could make the navigation difficult and may result into wasteful route planning. So as to provide a smooth navigation route, the existence of people's natural movement of individuals and indoor environment ought to be taken to consideration [20]. According to [27], studies depend on the geometry and topology of spaces don't sufficiently account for the decision and key nodes of human wayfinding, that is because pedestrians about the corridor route structure's perception is not taken into consideration. Therefore, [27] propose that the indoor visibility map (IVM) to calculate the presence of corridor area, and examine the association between different types of corridors and qualitative presence parameters of IVM.

Entity model extracting approaches provide benefits concerning accuracy for building spaces, even as compared with network and grid design methods, and the extraction results could be converted into a grid or network model [28]. In the study, such complex indoor environments are analyzed in details along with a new strategy for extracting structures' space information is suggested. Further, they also have a method depending on indoor space boundary calculation, the distinction for relationship reconstruction, single-floor space extraction, and cross-floor space extraction. That research is useful to provide a better understanding of the complexity of theoretical indoor space extraction.

The indoor space subdivision that produces reasonable navigation system for fine-grained navigation remains challenging, and

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within they paper, [10] propose SSFGiNav, a method of indoor area subdivision depending on the mix of semantic and geometric information, especially doorway semantics for indoor fine-grained navigation. In the research [10], indoor area is subdivided based on its own structure at first and then navigable/non-navigable and other semantics is used to subdivide the subspaces and also the navigation network consequently created dependent on the development on physical structure level is absence of semantic data inside the room.. Meanwhile, indoor corridor area is subdivided through the engineered corridor semantic partitioning (CSP) algorithm by the places of the doorways.

[6] Propose the framework based on six general concepts: Space, Partition, Agent, Activity, Modifier and Resource. The Supreme goal of that framework is to enable generation of a community and subdivision of indoor space. Thus, it concentrates on profession and physical subdivisions of area which affirms navigation and localization. Besides, in this framework, users and the environment are also included as factors for making flexible context that aware of path-planning.

Several studies have used point clouds as a source of data for indoor navigation, including in determining optimal routing. As [3], [11], [29], [30] and [31] have done. [11] presents innovative techniques to effectively extract the place of openings (e.g. Doors and windows) and also to subdivide area by assessing scanlines. In that study, an opening discovery system is revealed that diagnoses the geometric regularity to enhance the opening that was expressed, and a space subdivision system based upon the method trajectory along with the openings is clarified. Further, [11] also stated that space subdivision results and the opening detection are stored as point cloud labels which can be used for further investigations.

Meanwhile, [32] explores the opportunities for utilizing 3D point clouds to establish a platform for 3D Cadastre research in indoor environments. They investigate the changes in the geometry of the construction that may be automatically found from point clouds, and how they may be linked with a Land Administration Model (LADM) and within a 3D spatial database to enhanced the 3D indoor Cadastre. In addition, the permanent changes (e.g. walls, rooms) are automatically famed from dynamic changes (e.g., human, furniture) and are linked to the space subdivisions. The spaces that have been altered and identified during the procedure will be further analyzed to extract spatial characteristics, such as volume, area, and boundary.

[33] present a whole workflow which allows to create 3D models from point clouds of both buildings and extract indoor navigation systems to encourage path planning of distinct sorts of brokers. The process extracts structural components of structures such as walls, slabs, ceiling and openings, and reconstruct their shapes. [33] tries to make optimal routing based on data from point clouds to support disaster management, for example when a fire occurs in a building. Other studies relating to disaster management include [34], [35],[4].

There are several issues when implementing indoor navigation compared to outdoor navigation. One interesting issue is that indoor navigation requires higher amount of details to process enclosing region around surfing subject or object, consideration of the context of navigation so as to cope with unconstrained indoor area to get accurate outcomes [18]. In addition, [18] also asserted that due to these complex issues, the majority of the frameworks for indoor navigation support only one single sort of locomotion, for example either walking, driving, or flying.

The locomotion types performing unique functions in various operating environments remain as focus of research in fields. In indoor navigation, the majority of the indoor navigation frameworks have focus on one type of locomotion e.g. driving.

This decision of selection of the sort of locomotion has important effect on the space representation [18]. Some research focus on room segmentation of data generated by point clouds without involving trajectories [36]. The proposed segmentation method's most important idea according to [36], is based on the assumption that each room is bound by a vertical wall, then the main concept of the segmentation method is proposed, where the main concept is to project a 3d point cloud onto a 2d binary map and also to close openings to other rooms. By creating a

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preliminary segment map, this will be achieved, also by creating a wall frame around the segment, and iteratively connecting the closest pixel between walls.

[37] proposes an approach uses 2.5D maps that is composed of three major steps: thing footprint conclusion, footprint classification, and distance creation. The approach is demonstrated by two use cases enclosing spaces opens a new study direction toward providing navigation. The intention of the research is to resolve three issues: consideration of vertical constraints in navigation, addition of spaces in navigation to support realistic crossing behavior, and also the agents' use of specific spaces.

Research conducted by [3] leads a new approach for distance subdivision without the need of using perspectives or laser scanner positions. Unlike 2D cell decomposition or even a binary space partitioning, this function introduces a distance enclosure method to take care of 3D space extraction and non-Manhattan World architecture. The results show more than 90 percent of areas are extracted. The method is tested on several buildings and relies on the latest advances in indoor navigation.

[15]s' study suggests a multi-floor adjacency cell and semantic-based index (MACSI). By incorporating the mobile space, the MACSI maximizes the distances between cells dependent on the metabolic cost which extends floor area to three area and subdivides cells. The MACSI includes expansion capacity that generates outcomes with higher semantic query and upgrades efficiencies; also supports complex queries. Furthermore, based on the needs of semantic query, that study determines trajectories and also suggests a multi-granularity indoor semantic hierarchy tree.

[12] has introduced a framework for formal descriptions of all components that affect the division of space. These are spaces (navigable and non-navigable), representatives, resources, activities and modifiers. Based on these theories, research has identified 11 cases of navigation and information management requirements. These requirements determine which properties are topological, geometric and also sematic must be readily designed for almost all cases of indoor navigation [12]. In correlation with sub division, [12] further adds that the purpose of sub division is to ensure the start and end location of resource or whether agent can be accurately identified. The majority of the navigation methods aim at computing system instead of identifying spaces and space subdivision/aggregation, meanwhile space subdivision has been mentioned only in approaches founded on Poincare Duality.

Space subdivision points was likewise talked about in an investigation looking into LADM (Land Administration Domain Model). For instance, [37] think about the various standards of IndoorGML and LADM, investigate the ways to deal with characterize territories and recommend alternatives of spaces into the connecting of the 2 distinct sorts. The examination likewise stresses that LADM space development on Cornerstone of assets and privileges of utilization might be used to indicate semantical and Geometrical spaces that are accessible and available that add to improve the IndoorGML idea. LADM makes it conceivable to set up a connection between inward space and clients by characterizing client types in internal space. A portion of the primary contributions of [37] are: giving answer for the joint utilization of IndoorGML-LADM model, giving an applied improvement of LADM by the refinement of their LA_Party bundle with specialization to get student and staff, assessing the rendition by exchanging test information in to the variant, and directing real access-rights navigation awareness based on the populated adaptation.

Obstacles become an interesting topic in indoor navigation, many studies focus on obstacles as the focus of research in indoor navigation. [38] concentrate on navigation considering challenges. They present a distance subdivision centered on a floor to simplify the navigation system. Considering the famous path-finding approaches predicated on Medial Axis Transform (MAT) or Visibility Graph (VG), the approach from [38] gives a quick sub division of space and also paths which can be harmonious with the link between VG. The experiments reveal that people can navigate round the barriers employing the system that is projected.

In research conducted by [39], the trajectory was found useful to be utilized in conjunction with the purpose cloud to subdivide the indoor space. The scanner trajectory is used as a dataset to separate the exact stories and also to identify the staircases. Additionally, the operator processes only the intriguing areas of the point cloud with the assistance of the trajectory identifying the doors which are daunted by the operator throughout the scanning. Information like different space tags is assigned to the trajectory centered on the doors that were detected. In the end, the cloud idea is semantically enriched by shifting labels from the annotated trajectory to the point cloud that was full [39].

Existing path planning approaches are based on 2D plans pay more attention to the geometric arrangement of indoor space but often ignore rich semantic information of construction components. To overcome this, [40] uses BIM (IFC) as the input and specializes in indoor navigation considering challenges in the multi-floor buildings. After geometric and semantic data are extracted, 2D and 3D space subdivision methods are adopted to realize and also to construct the indoor navigation system whose path planning is to avoid obstacles. Accordingly, the 3D space subdivision is based on triangular prism.

Indoor spaces utilizing fine geometric whose portrayals can offer a decent base for arranged indoor applications, however it is difficult to extensively separate for nothing out of pocket multi-floor indoor spaces out of cutting edge three-dimensional development variants, for example, those depicted utilizing CityGML LoD4, with existing techniques for the region or extraction of indoor spaces dependent on vector topology processing. [41] expounds another voxel-based methodology for extricating free multi floor spaces by 3D development models. It changes the vector preparing undertakings to voxelization with quick enlargement a raster procedure which comprises of three stages arrangement, and limit extraction. The investigation shows that the proposed method could precisely and effectively separate totally free multi-floor indoor spaces, for example, two sorts of spaces, to be specific, staircases and lobbies.

A network qualitatively represents abstract connections between indoor spaces and it may be used for path computation. [42] focus on the network that will not need ideas for metrics. Instead, it relies on possessions and the semantics of indoor spaces. On that research, an navigation path could be calculated by deriving parameters in routing calculations, and minimizing them. [42] provide a mechanism that is based on a distance classification and a pair of routing criteria, and also provide an execution for several buildings to demonstrate that the efficacy of this type of routing. This method's principal benefit is that it will not require information to calculate a path. Thus, the logical system can be generated using verbal descriptions only. Further, this system can be also implemented to spaces.

In the field of indoor mapping, the issue of matching indoor positions with the situation is actually interesting. Sub dividing the floor plan develops several types of locations for matching the position data to your real-world location. [43] have indicated that a high-level degree is possible for locations which are within the high-resolution assortment of the recipient. The performance at the smallest subspaces can only be achieved by having a compact supply of recipients.

Convex hulls are foundational to tools utilized in many of calculations. [44] presents an easy to execute and powerful Smart Convex Hull (S-CH) algorithm for calculating the convex hull of a pair of things from e 3. This algorithm is predicated on "round" space subdivision. The notion of this algorithm that is S-CH would be to expel as much enter signals as possible. The results prove that a few of things are all traditionally used for its convex hull calculation.

Another challenge of indoor navigation is the changing function of a room. For example, the existence of a merger of the room into one, or vice versa from one room into several new rooms. Tracking those changes can possibly be hard as soon as the construction geometry can shift as an instance from administrative to utilization of this distance, without upgrading the function or combining two spaces at the construction. To capture the changes, there is a frequent practice to make use of 2D plans for subdivisions and also to assign responsibilities, restrictions, and rights to your fluctuations in a construction by using the progress of 3D data acquisition methods. Meanwhile, research on the superiority of 3D models in various forms is being studied. [45] investigate the chances of employing the idea of clouds to set 3D Cadastre in indoor and in connection between cerebral modifications. They explore the changes within the years happening at the geometry of this construction whose finding is to upgrade the indoor 3D cadastre. The last changes are mechanically characterized by life changes and certainly, you can be connected with the distance sub divisions.

Many spaces in the environment aren't only indoor or outdoor spaces and are thus seen additional restricting navigation options. To overcome these shortcomings, [46] a brand-new space definition frame in which the entire constructed environment is categorized into indoor, outdoor, semi-indoor, and semi-outdoor spaces. In that research, they supply definitions for the four space categories. Their framework makes it possible for exact the navigation network extraction procedures to be used. This enables path computation for unmarried or combinations of locomotion manners.

In research conducted by [47], the radial basis function (RBF) is used. RBF approximation is a highly effective procedure for dispersed scalar and vector information fields. Its software is quite hard in the case of scattered data. RBF approximation is presented by this paper along with space subdivision technique for big vector fields. The large data sets that were scattered are often overlapped with 3D cells that are utilized by a distance subdivision procedure. Mixing of 3D cells is used to receive continuity and smoothness. In other research, [48] introduces a pedestrian tracking approach that utilizes environment constraints in the kind of a more grid-based indoor design to improve the localization of an WiFi-based system. The area is subdivided into grid cells with a specific size and corresponding semantics, and then the algorithm computes the location probability more than these cells depending on magnetometer measurements and the model on a cell phone. Route navigation is being expanded to cover the entire geographic space. In this situation, outdoor navigation is emerging as a concept from indoor navigation. For building navigation routes, automatic methods do not fully meet all requirements. Traditional approaches rely on calculations for creating Triangulated Irregular Networks (TINs) by Delaunay triangulation or calculations for generating Thiessen polygons called Voronoi diagrams (VDs). The solution involves a modified approach to the segmentation of corridor space. In [49], both algorithms were used in the segmentation process.

One of the applications of indoor navigation is in the case of emergencies, for example a fire in a building. [50] 3D visualization of indoor routing services using extensive and high-quality geographic data sources is essential for spatial analysis in emergency responses. In order to facilitate emergency response simulations, a combination of geometrical, graphical and semantic information is essential. Successful and efficient emergency evacuation responses is facilitated by the availability of both digital static and dynamic information of the incident site.

CONCLUSION

This paper has shown the results of SLR regarding space subdivision for indoor navigation. Research on space subdivision continues to grow from year to year. New methods and data input have been developed, point clouds for example. Research in this field is still challenging, because among other things the development of 3D technology and computing capabilities are constantly evolving.

In addition, standardization and data integration are still interesting thing to the study. The ability of space subdivision to support indoor navigation can be applied to several things, for example for emergencies since in an emergency situation, a lot of changes occur in the interior of a building and also involve several parties, for example from the perspective of the first responder and from the perspective of the victim. This research is expected to be the basis for research on space subdivision in the future.

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