IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal
International Research Journal
IJNRD
Research Through Innovation

Crafting Floor Plans: Generating Architectural Layouts from Descriptions using GANs

Balraj Vaidya, Padmakar Pimpale, Abhijeet Sagare

International Institute of Information Technology, Pune
Savitribai Phule University
Pune, India

Abstract: Human beings understand natural language descriptions and can imagine corresponding visuals. Automatic synthesis of real-world images from text descriptions has been explored in computer vision, but there's been a gap in document images like floor plans. Previous studies focused on floor plan synthesis from sketches and data-driven models. This research represents the first attempt to generate building floor plan images directly from textual descriptions. The input consists of a description of the internal structure and furniture arrangements within a house, with the output being a 2D floor plan image. Experimentation was conducted on publicly available benchmark floor plan datasets, resulting in the successful synthesis of realistic floor plan images from English descriptions.

***Index Terms* - Generative Adversarial Networks (GANs), Floor plan generation, Data-driven models, Natural language processing, Text-to-image synthesis, Compute Vision, Document image synthesis.**

1. INTRODUCTION

Drafting floor plans for a construction project is an integral part of its initial design phase, requiring expertise, skill, and time due to its technical complexity. Automatically generating floor plan images from client requirements poses a significant challenge. One motivation for creating floor plans, particularly for existing building exteriors, arises from the fact that procedural building generators often overlook interior details. However, translating client specifications, often expressed in English, necessitates Natural Language Processing (NLP).

Traditionally, NLP-equipped systems analyse and/or generate sentences in a given language, identifying various phrasings for the same command or information. With the emergence of models like Word2Vec and Adversarial Models, interest in synthesizing images from textual descriptions has grown. Despite notable progress in synthesizing natural images, exploration of document images remains limited. While computer graphics efforts have focused on vectorizing scanned documents or converting sketches into digital graphics, the translation of natural language descriptions into graphical documents remains largely unexplored.

Our project represents the inaugural exploration of synthesizing floor plan images from English textual descriptions, leveraging GANs. depict a common scenario where a textual description is transformed into a 2D floor plan image, emphasizing internal spatial arrangement within buildings over their external appearance. The proposed framework caters to various computer graphics applications, including gaming, virtual reality, and business sectors such as real estate. Thus, we present qualitative results instead of quantitative evaluations.

Clearly articulating housing requirements to architects is challenging for laypersons. Therefore, synthesizing a prototype model and iteratively refining it would greatly benefit both parties involved. Consequently, we propose a learning framework to automatically generate building floor plan images visually resembling actual floor plans from English descriptions.

Our project aims to develop an AI framework to aid architects or designers in the early stages of architectural design, leveraging GANs. The architectural design process typically starts with an idea and undergoes multiple cognitive and practical transformations until the final physical infrastructure is realized. However, translating ideas into tangible forms for the early design phase remains challenging. Despite the wider acceptance of semantic building models like Industry Foundation Classes (IFC), their practical implementation remains elusive. Currently, there are insufficient means to utilize such building information models and their contained information to support early architectural design stages..

2. RELATED WORK

The use of automated layout design aids architects during the early stages of design. Interested readers are directed to a comprehensive review paper cited as [1]. Graph-theoretic approaches have gained popularity among researchers in various fields such as GIS, computational geometry, and notably architectural design. In [2], the NP-hardness of finding a minimum-area rectangular layout for a given contact graph was demonstrated. A new graph-theory-based model for solving automatic layout design problems was proposed in [8], featuring a detailed algorithm for generating floor plans meeting specified constraints. However, this model requires some manual input from architects regarding room specifications, adjacencies, and initial layouts. [4] provides a historical review of automated facility layout techniques, focusing on algorithms optimizing single objective functions and their applications to space allocation problems. Ahmady et al. [7] conducted a detailed survey on the Multi Floor facility layout problem, while [6] introduced a novel simulated annealing algorithm based on linguistic patterns and fuzzy theory for facility layout problems. Additionally, [5] proposed an algorithm for design process verification and integration with Building Information Modelling (BIM).

The concept of shape grammar, introduced in [13], was utilized for interactive floor plan design tasks, later extended by [17] for generating building facades, and similarly employed by Whiting et al. [12] for stability analysis of buildings. Various researchers [3], [11], [10], [9] proposed image-based rendering techniques for building layout and external structures. Pottman et al. [16] introduced a novel semi-discrete surface representation linking smooth and discrete surfaces. However, none of these techniques produce internal building layouts from high-level specifications. While there have been limited attempts to address this issue, such as the technique proposed in [15] for generating grid-like internal layouts through random splitting with axis-aligned planes, and the iterative approach proposed in [23] for floor plan generation, these methods were only demonstrated for specific cases. In [14], a method for automated generation of building layouts for computer graphics applications was proposed, closely related to our work. The key difference lies in [14] using fixed-format high-level requirements, while our approach derives requirements from natural language descriptions.

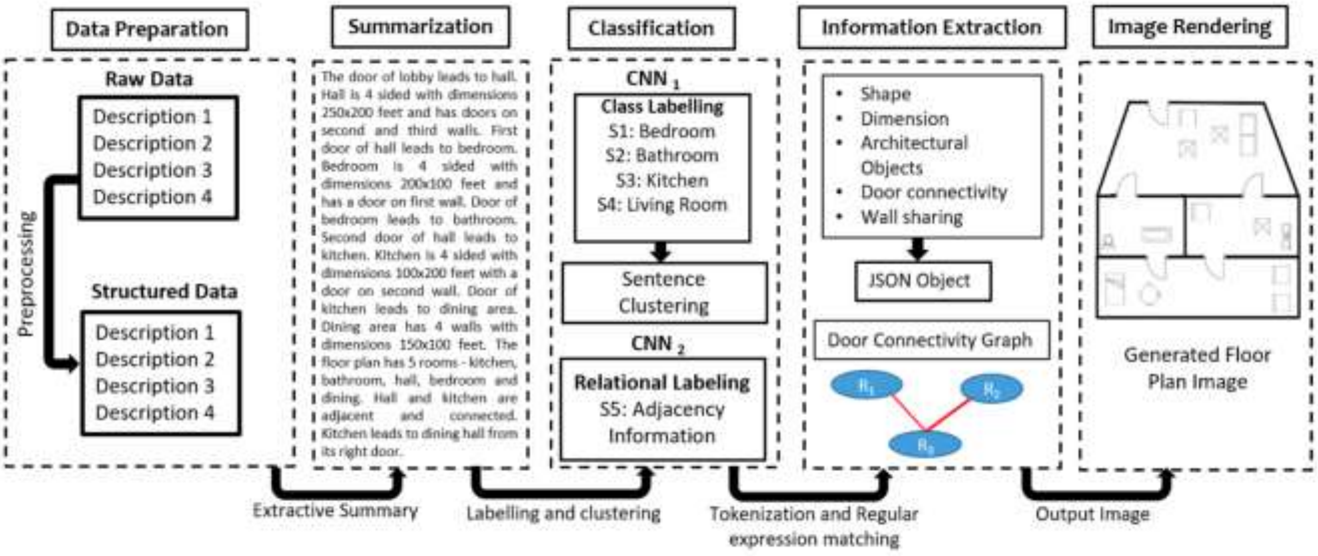
In summary, the current state of scholarship on floor plan image synthesis from sparse requirements is still in its early stages, with considerable potential and numerous practical applications. To our knowledge, no previous work has detailed the generation of building layouts from English textual descriptions. Our approach combines Natural Language Processing, Machine Learning, and Computer Graphics, with applications in computer gaming, robotics, and the real estate industry.

3. METHODOLOGY

Figure 2 illustrates the proposed framework.

A. Comprehension of User Requirements

Understanding user requirements entails preprocessing textual descriptions to extract pertinent information. This involves segmenting large raw texts into sentences to distill meaningful details. Subsequently, room-related information is extracted along with their spatial positions within the floor plan. Sentence tagging assigns semantic labels to facilitate the extraction of adjacency information among rooms and entities. Lastly, an appropriate placement model is determined to accommodate furniture according to user preferences.



The door of lobby leads to hall. Hall is 4 sided with dimensions 250x200 feet and has doors on second and third walls. First door of hall leads to bedroom. Bedroom is 4 sided with dimensions 200x100 feet and has a door on first wall. Door of bedroom leads to bathroom. Second door of hall leads to kitchen. Kitchen is 4 sided with dimensions 100x200 feet with a door on second wall. Door of kitchen leads to dining area. Dining area has 4 walls with dimensions 150x100 feet. The floor plan has 5 rooms - kitchen, bathroom, hall, bedroom and dining. Hall and kitchen are adjacent and connected. Kitchen leads to dining hall from its right door.

Figure 2 represents the flow diagram of the framework.

1.Text Summarization: We adopt an extractive approach to summarize text, wherein significant sentences or keywords are selected statistically and concatenated to form a summary. The proposed model involves preprocessing sentences, constructing an undirected graph to assess sentence similarity, labelling each word with a word class, ranking sentences based on word class similarity, and including top-ranked sentences in the summary. Consider two sentences, D and Q, each composed of a set of n words. Let D = dk, where k = 1, 2, ..., n represents a word in sentence D. The sentences serve as vertices in an undirected graph, with edges between nodes labelled by the similarity score between the corresponding sentences. The similarity score, represented by equation (1), accounts for word occurrence frequency, sentence length, and semantic relevance.

B. Sentence Classification and Clustering:

In this stage, we rearrange the summary and convert words into vectors using word2vec. We train a Binary CNN classifier for each room to label sentences accordingly. Additionally, we cluster sentences based on rooms and train an extra CNN model to identify relational sentences describing room adjacency or door connectivity. The CNN network consists of three convolutional layers with ReLU activation function and a SoftMax layer for output normalization. From the parsed sentences, we extract room labels, furniture details, room relationships, and architectural features, storing them in JSON objects. Furthermore, we create a Door Connectivity Graph based on room connections via doors.

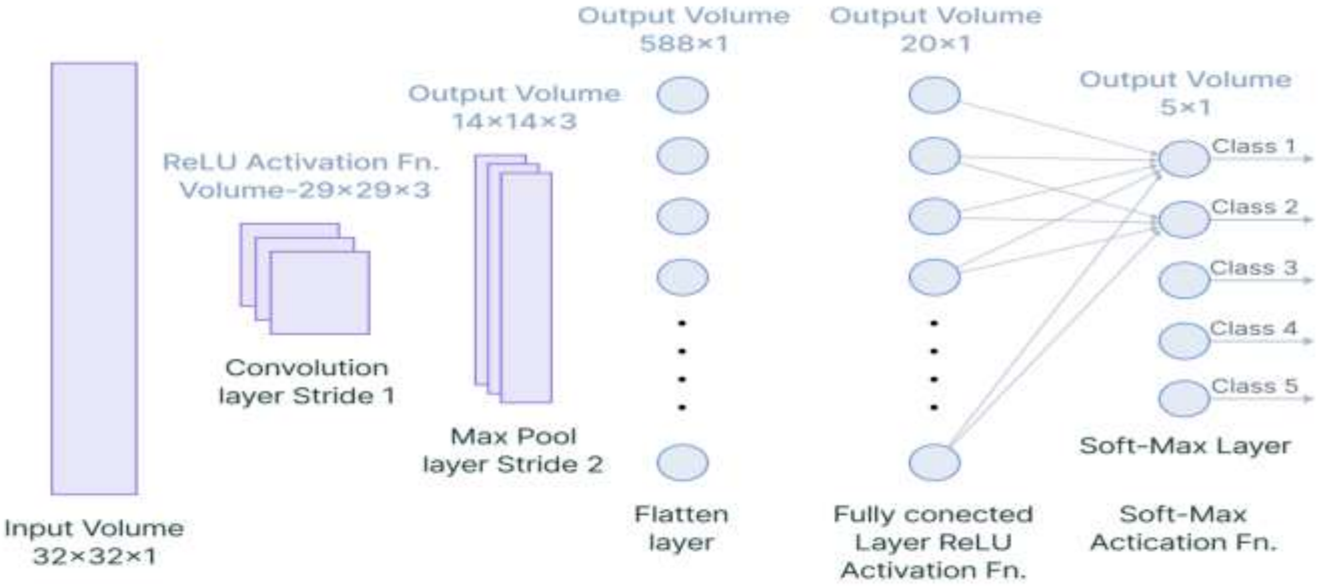


Fig. 3. Convolutional Neural Network layers

1. Information Extraction:

In the information extraction phase of the floor plan generation process, tagged sentences are the primary input. These sentences are labeled with room tags or relation tags, indicating their significance in describing the floor plan layout. For sentences tagged with room identifiers, further processing is conducted to extract crucial details about each room. This includes determining the room's shape, dimensions, architectural elements present within, door connectivity, and sharing of walls with adjacent rooms. To achieve this, custom dictionaries and various techniques such as tokenization and regular expression matching are utilized to accurately identify and extract relevant information from the textual descriptions. The extracted details are then structured into JSON objects for each room, encapsulating comprehensive room specifications like type, shape, dimensions, door placement, and furniture arrangements. Additionally, sentences labeled with relation tags are processed separately to extract relational information, primarily focusing on door connectivity relations between rooms. This information extraction phase ultimately facilitates the creation of a Door Connectivity Graph (DCG), where rooms serve as nodes and edges represent door connections, providing a graphical representation of the floor plan layout's spatial relationships.

2. Floor Plan Rendering:

In the floorplan rendering stage, the extracted information is utilized to generate a visual representation of the floor plan. This involves translating the structured data, including room labels, furniture details, and architectural features, into a comprehensive layout. The process begins by traversing the Door Connectivity Graph, which outlines the connections between rooms via doors. Using a Depth First Search approach, each room is systematically synthesized based on its local coordinates. This ensures that rooms are accurately positioned within the floor plan, taking into account their size, shape, and any specified architectural elements. Once individual rooms are rendered, they are aligned to a global coordinate system, providing a cohesive layout for the entire floor plan. The final result is a detailed and visually appealing representation of the building's interior layout, ready for further analysis or presentation to stakeholders.

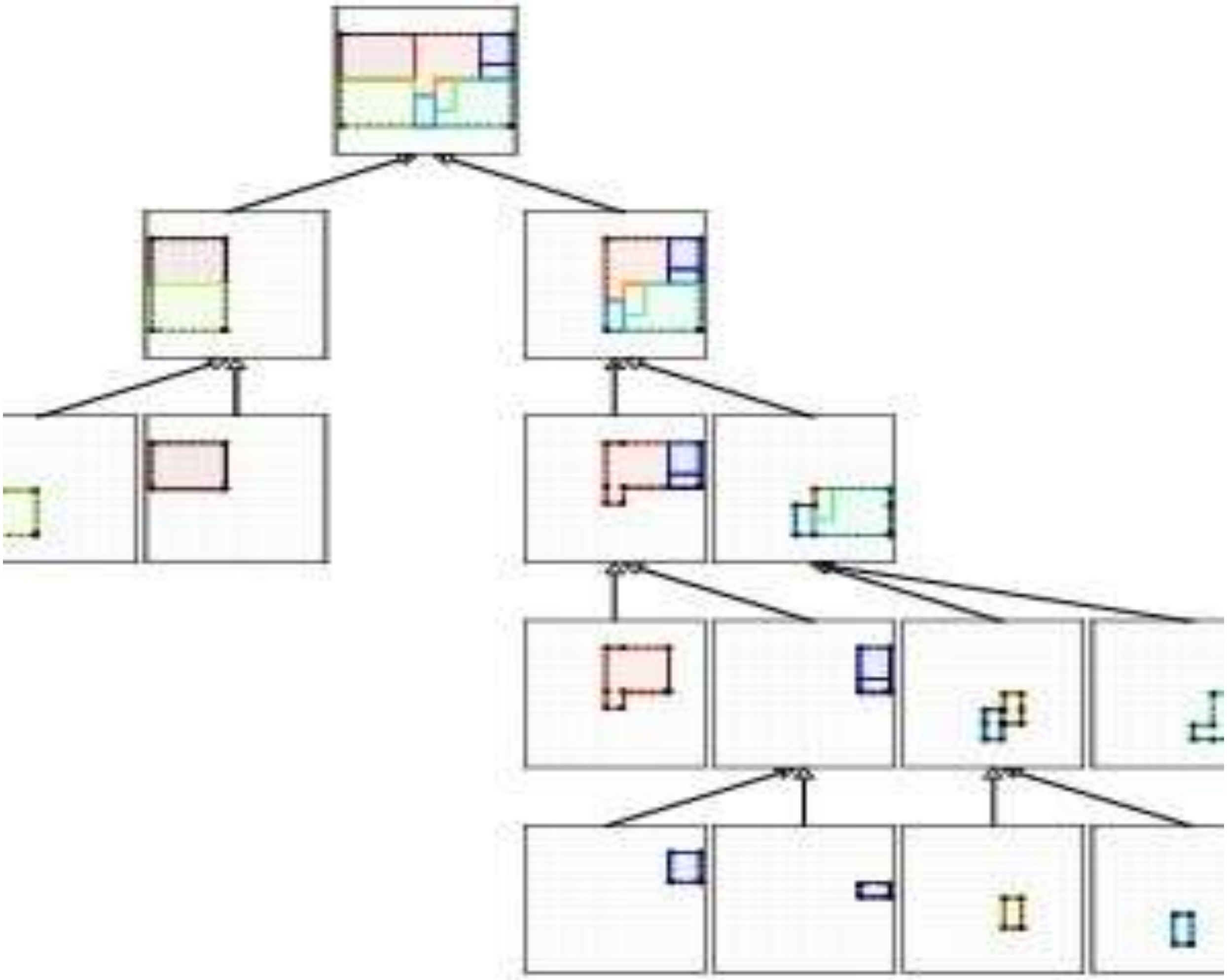


Fig. 4. Utilizing Depth First Search to analyse the building structure and generate a layout for the floor plan.

C. optimization:

Optimization in floor plan generation involves refining the layout to enhance various aspects such as functionality, efficiency, and aesthetics. This process can be guided by user feedback or predefined objectives, ensuring that the resulting floor plan meets specific requirements and preferences. One aspect of optimization is maximizing natural lighting within the building. Algorithms can adjust the placement and size of windows and openings to optimize the entry of natural light into interior spaces. Energy efficiency is another critical consideration in floor plan optimization. The system may employ algorithms to optimize the layout for energy conservation, considering factors such as insulation, building orientation, and HVAC system design. By optimizing the arrangement of rooms and building components, the system can reduce energy consumption and improve overall sustainability. Aesthetic optimization focuses on enhancing the visual appeal of the floor plan. Algorithms may prioritize design principles such as balance, proportion, and symmetry to create harmonious and visually pleasing layouts. Additionally, the system can incorporate design elements that reflect the architectural style or preferences of the user, ensuring that the final floor plan meets their aesthetic expectations. Furthermore, optimization techniques can address functional requirements by optimizing the arrangement of rooms and spaces to improve usability and convenience. This may involve optimizing circulation paths, ensuring efficient access to key areas such as kitchens, bathrooms, and living spaces, and maximizing usable floor area while minimizing wasted space. Overall, optimization techniques play a crucial role in refining floor plans to achieve desired outcomes in terms of functionality, energy efficiency, aesthetics, and user satisfaction.

D. *Finalizations:*

Finalization of the floor plan involves creating a polished and comprehensive document ready for construction or presentation. This stage consolidates all the design decisions, annotations, and specifications into a finalized floor plan. Detailed annotations are added to the floor plan, providing important information such as dimensions, materials, and room labels. These annotations ensure clarity and accuracy during the construction process. Additionally, the finalized floor plan may include supplementary information, such as elevation drawings, section views, and detailed notes, to provide a comprehensive understanding of the building design. The document is reviewed and verified to ensure that it accurately reflects the intended design and meets all regulatory requirements and standards. Any necessary revisions or adjustments are made during this stage to address any discrepancies or inconsistencies. Once the floor plan is finalized, it is ready to be shared with stakeholders, including architects, engineers, contractors, and clients, for further review, approval, and implementation. The finalized floor plan serves as a crucial reference throughout the construction process, guiding the execution of the design and ensuring that the final built structure aligns with the original vision and requirements.

4. RESULTS

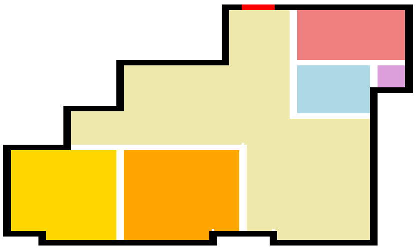
The outcome of the floor plan generation process showcases the effectiveness of the proposed framework in extracting essential details from textual descriptions and synthesizing coherent floor plans.

In the initial stage of text summarization, the framework employs an extractive technique to distil quantitative information about rooms, as well as adjacency and connectivity details, from input descriptions. This summary serves as the foundation for subsequent processing steps.

Moving on to information extraction, tagged sentences are analysed to extract pertinent details such as room shapes, dimensions, architectural features, door connectivity, and furniture arrangements. Custom dictionaries and advanced techniques ensure accurate extraction, culminating in the creation of structured JSON objects for each room. Additionally, relational information, particularly door connectivity between rooms, is extracted to construct a Door Connectivity Graph (DCG) depicting the spatial relationships between rooms.

The final step involves rendering the floor plan image based on the extracted information. Using recursive algorithms, room coordinates are generated, and architectural objects are strategically placed within each room while ensuring they do not obstruct doorways. The resulting floor plan faithfully reflects the specifications outlined in the textual descriptions, demonstrating the framework's capability to generate coherent and detailed floor plans from sparse input.

Overall, the framework successfully bridges the gap between textual descriptions and visual representations of floor plans, offering a valuable tool for architects, designers, and other stakeholders in the construction and real estate industries.



(b) Floor Plan

The bathroom is located on the east side, It is next to living and kitchen, The size of the room is 4 feet width and 5 feet length The common room is located on the south west corner, It is next to living and master , The size of the room is 10 feet width and 10 feet length The kitchen is located on the north east corner, It is next to living and bath, The size of the room is 7 feet width and 8 feet length The living room is located on the north side, It is in front of all other rooms, The size of the room is 12 feet width and 27 feet length The master room is located on the south side, It is next to living and near to common, The size of the room is 10 feet width and 11 feet length The storage room is located on the east side, it is inside southeast corner of kitchen, The size of the room is 2 feet width and 2 feet length

(a) Textual Description

Fig. 5. A demonstration of generating a complete floor plan image based on an English textual description.

5. CONCLUSION AND FUTURE WORK

Conclusion:
In conclusion, our proposed framework demonstrates the feasibility of generating detailed floor plans from textual descriptions. Through the stages of text summarization, information extraction, and image rendering, we have shown the capability to interpret natural language descriptions and translate them into visual representations of floor plans. While the current implementation focuses on basic room layouts and furniture placement, it lays the foundation for more advanced applications in the future.

Future Work:
Moving forward, there are several avenues for enhancing and extending this project. Firstly, incorporating more advanced natural language processing techniques could improve the system's ability to interpret complex descriptions and extract nuanced details. Additionally, integrating optimization algorithms could enable automatic refinement of floor plans based on user preferences and design objectives. Furthermore, expanding the scope to include considerations such as material selection, lighting, and environmental factors would make the generated floor plans more comprehensive and practical for real-world applications. Finally, exploring the integration of augmented reality (AR) or virtual reality (VR) technologies could offer immersive visualization experiences and facilitate better collaboration and communication in architectural design processes.

7. REFERENCES

[1] March, Lionel and Steadman, Philip The geometry of environment: an introduction to spatial organization in design, London: RIBA Publications, 1971

[2] Buchsbaum, Adam L. and Gansner, Emden R. and Procopiuc, Cecilia M. and Venkatasubramanian, Suresh Rectangular Layouts and Contact Graphs, ACM Trans. Algorithms, 4(1), pp. 8:1–8:28, (2008).

[3] Legakis, Justin and Dorsey, Julie and Gortler, Steven Feature-based Cellular Texturing for Architectural Models, Proceedings of the 28th Annual Conference on Computer Graphics and Interactive Techniques, 2001.

[4] Robin S Liggett Automated facilities layout: past, present and future, Automation in Construction, 2000

[5] Vincenzo Donato Towards design process validation integrating graph theory into BIM, Architectural Engineering and Design Management, 13(1), 22-38, 2017.

[6] Jerzy Grobelny and Rafa Michalski A novel version of simulated annealing based on linguistic patterns for solving facility layout problems, DAS, 2010Knowledge-Based Systems, 124, p.p.55-69, (2017).

[7] Abbas Ahmadi, Mir Saman Pishvaee and Mohammad Reza Akbari Jokar A survey on multi-floor facility layout problems, Computers & Industrial Engineering, 107, 158-179, 2017

[11] A. Schwarz and D.M. Berry and E. Shaviv Representing and solving the automated building design problem, 26(9), 689-698, 1994.

[8] Xuejin Chen and Kang, Sing Bing and Xu, Ying-Qing and Julie Dorsey and Heung-Yeung Shum Text information extraction in images and video: a survey, ACM, 27(2), 2008.

[9] Mu¨ller, Pascal and Zeng, Gang and Wonka, Peter and Van Gool, Luc, Image-based Procedural Modeling of Facades, ACM Trans. Graph, 26(3), 2007.

[10] Lefebvre, Sylvain and Hornus, Samuel and Lasram, Anass By-example Synthesis of Architectural Textures, ACM Trans. Graph, 29(4), 2010

[11}Whiting,EmilyandOchsendorf,JohnandDurand,Fre´do,ProceduralModelingofStructurally-soundMasonryBuildings,ACMTrans.Graph.,28(5), 2009.

[12] Harada, Mikako and Witkin, Andrew and Baraff, David Interactive Physically-based Manipulation of Discrete/Continuous Models, Proceedings of the 22Nd Annual Conference on Computer Graphics and Interactive Techniques, p.p.199-208, (1995)

[13] Marcus, Mitchell P and Marcinkiewicz, Mary Ann and Santorini, Beatrice Computer-generated Residential Building Layouts, ACM Trans. Graph, 29(6), (2010).

[14] Hahn, Evan and Bose, Prosenjit and Whitehead, Anthony Persistent Realtime Building Interior Generation, Proceedings of the 2006 ACM SIGGRAPH Symposium on Videogames, 2006

[15] Pottmann, Helmut and Schiftner, Alexander and Bo, Pengbo and Schmiedhofer, Heinz and Wang, Wenping and Baldassini, Niccolo and Wallner, Johannes Freeform Surfaces from Single Curved Panels, ACM Trans. Graph., 27(3), (2008)

[16] Jess Martin Procedural house generation: A method for dynamically generating floor plans, Symposium on Interactive 3D Graphics and Games, 2006.

[17] Delalandre, Mathieu and Valveny, Ernest and Pridmore, Tony and Karatzas, Dimosthenis Generation of synthetic documents for performance evaluation of symbol recognition & spotting systems, IJDAR 13(3) pp. 187-207, (2010).

[18] Legakis, Justin and Dorsey, Julie and Gortler, Steven Feature-based Cellular Texturing for Architectural Models, Proceedings of the 28th Annual Conference on Computer Graphics and Interactive Techniques, 2001.

[19] Robin S Liggett Automated facilities layout: past, present and future, Automation in Construction, 2000.

[20] Vincenzo Donato Towards design process validation integrating graph theory into BIM, Architectural Engineering and Design Management, 13(1), 22-38, 2017.

[21] Jerzy Grobelny and Rafa Michalski A novel version of simulated annealing based on linguistic patterns for solving facility layout problems, DAS, 2010Knowledge-Based Systems, 124, p.p.55-69, (2017).

[22] Abbas Ahmadi, Mir Saman Pishvaee and Mohammad Reza Akbari Jokar A survey on multi-floor facility layout problems, Computers & Industrial Engineering, 107, 158-179, 2017.

[23] A. Schwarz and D.M. Berry and E. Shaviv Representing and solving the automated building design problem, 26(9), 689-698, 1994.

[24] Pottmann, Helmut and Schiftner, Alexander and Bo, Pengbo and Schmiedhofer, Heinz and Wang, Wenping and Baldassini, Niccolo and Wallner, Johannes, Sketching Reality: Realistic Interpretation of Architectural Designs, ACM Trans. Graph. 29(1), 27(3), p.p. 0730-0301, (2008).

[25] Xuejin Chen and Kang, Sing Bing and Xu, Ying-Qing and Julie Dorsey and Heung-Yeung Shum Text information extraction in images and video: a survey, ACM, 27(2), 2008.

[26] Mu¨ller, Pascal and Zeng, Gang and Wonka, Peter and Van Gool, Luc, Image-based Procedural Modeling of Facades, ACM Trans. Graph, 26(3), 2007.