RECOGNIZING ARCHITECTURAL OBJECTS IN FLOOR-PLAN DRAWINGS USING DEEP-LEARNING STYLE-TRANSFER ALGORITHMS

DAHNGYU CHO[1], JINSUNG KIM[2], EUNSEO SHIN[3],
JUNGSIK CHOI[4] and JIN-KOOK LEE[5]
[1,2,3,5]*Department of Interior Architecture and Built Environment, Yonsei University, Seoul, Republic of Korea*
[1,2,3]*{wheks822|wlstjd1320|silverw0721}@gmail.com*
[5]*leejinkook@yonsei.ac.kr*
[4]*Major in Architecture IT Convergence Engineering, Division of Smart Convergence Engineering, Hanyang University ERICA, Gyeonggi, Republic of Korea*
[4]*jungsikchoi@hanyang.ac.kr*

Abstract. This paper describes an approach of recognizing floor plans by assorting essential objects of the plan using deep-learning based style transfer algorithms. Previously, the recognition of floor plans in the design and remodeling phase was labor-intensive, requiring expert-dependent and manual interpretation. For a computer to take in the imaged architectural plan information, the symbols in the plan must be understood. However, the computer has difficulty in extracting information directly from the preexisting plans due to the different conditions of the plans. The goal is to change the preexisting plans to an integrated format to improve the readability by transferring their style into a comprehensible way using Conditional Generative Adversarial Networks (cGAN). About 100-floor plans were used for the dataset which was previously constructed by the Ministry of Land, Infrastructure, and Transport of Korea. The proposed approach has such two steps: (1) to define the important objects contained in the floor plan which needs to be extracted and (2) to use the defined objects as training input data for the cGAN style transfer model. In this paper, wall, door, and window objects were selected as the target for extraction. The preexisting floor plans would be segmented into each part, altered into a consistent format which would then contribute to automatically extracting information for further utilization.

Keywords. Architectural objects; floor plan recognition; deep-learning; style-transfer.

1. Introduction

Architectural drawing is the set of meaningful information needed for designing, narrating, and executing a construction project. Recognizing the information contained in the traditional drawings, which exists as forms of papers, CAD files,

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etc., will help future architects for better designs. The work is time-consuming and labor-intensive, making it more efficient if the computer, not a human, can automatically interpret the drawings. Traditional drawings, however, are in a form that only humans can understand, and thus, there must be some tasks preceded for the computer to understand. To figure out the preceding work, architectural drawings were manually analyzed, and this led to the conclusion that the main reason the computer could not understand the drawings was due to the difficulty of recognizing the various symbols corresponding to one represented object in the drawing. For example, wall objects mainly consist of a pair of lines, but in some drawings, they may be represented in a color-filled form. Therefore, in this paper, a new strategy will be suggested to integrate the various styles of drawings by unifying the symbols that represent a single object for the better understanding of architectural drawings by the computer.

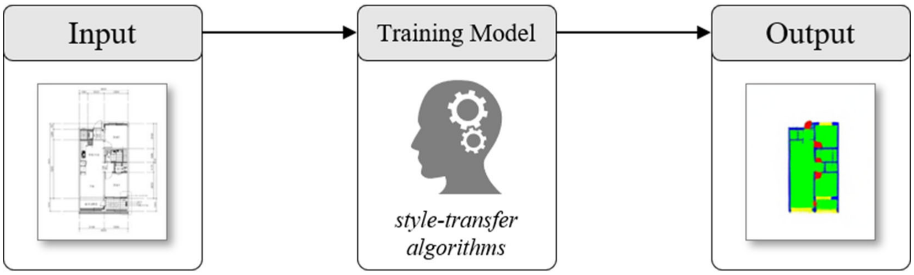

Figure 1. Outline of the study.

2. Background

2.1. ARCHITECTURAL DRAWINGS

Architectural drawings have been a symbolic language to communicate building design for a long time. They have standard representations for the building objects and design descriptions, which allow the integrating focus of the building process today. However, the problem of these architectural drawings is that the standard representation is only human-readable. The contents are conventionally ‘semantic’ which makes it only understandable by designers. Humans may find similar expressions between different drawings, but from a computer’s point of view, difficulties exist to recognize the same symbols with slightly different expressions because the symbols are not identical.

There are several reasons for the different representations of the drawings, depending on the 1) type of drawings, 2) design phase, 3) designer’s intention. Types of drawings include a floor plan showing an orthographic top-down view, an elevation and cross-section plan showing longitudinal views, reflective ceiling plans, etc. Since these drawings show different views, the representation of one object is inevitably distinct. Also, the level of detail of the drawings varies depending on the design phase of the drawing. The most complex drawing is the construction structure drawing (CSD). It is detailed enough to show internal steel bars and concrete structures since it is intended for design engineers and construction managers to use. The detail included in the drawings would differ when comparing CSDs and drawings from the preliminary design phase. Lastly, according to the intention of the designer, the emphasized object would differ, making a change in the representation.

This paper focuses on the use of floor plans in all design phases to develop a method for the computer to recognize different representations. The expression methods of different types of drawings differ so greatly, making it a challenge to use them uniformly, but the drawings according to all the design phases can all be utilized because they differ only in the degree of detail, which could be accepted.

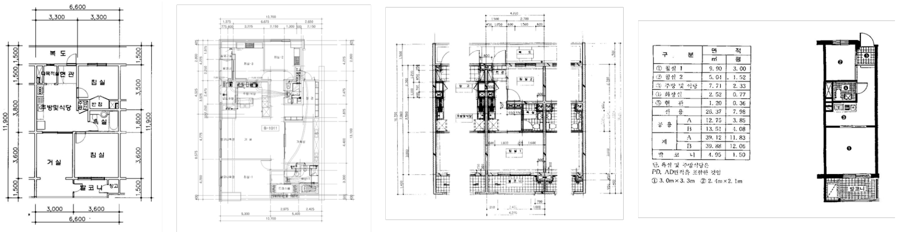

Figure 2. Various formats of floor plans: format with simplified walls, format with electronic wirings, format which includes other residences, format with large drawing tables .

2.2. OBJECTS REPRESENTED IN FLOOR PLANS

Floor plans contain a lot of information in various forms such as letters, numbers, lines, symbols, etc. The question of which information to use is one of the main points in floor plan analysis. Many of the literature have classified the information by texts and graphics, and only applied graphics in their work. However, the graphics recognized by the algorithm-based method might have unnecessary pixels, making segmentation difficult between noise and useful pixels. There is a need, thus, for a standard and a technique that can select and read only the necessary pixels instead of all the pixels.

In this paper, we suggest a standard for classifying information as design data and annotation data. Design data consists of structural and functional objects which have a contribution to the actual building. For instance, walls, doors, windows, floors, columns, beams, etc. On the other hand, annotation data consists of data that is needed for precisional comprehension of the floor plan. Annotation leading lines, dimension lines, hatchings, drawing tables, hardware symbols, etc. are included here. Annotation data is regarded as unnecessary information in the recognition of a computer because it mainly exists for the human understanding of plans. Thus, design data should be considered to a great extent in segmentation, which is a more computer-friendly data to recognize.

The scope of this paper focuses on recognizing several selected objects of the design data. The object-oriented recognition is based on objects that are important in the traditional construction industry and are likely to be used in BIM. The importance of an object in the traditional construction industry is determined by how it affects the construction of a building or the occupants of a building. On the other hand, the availability of the object in the BIM authoring tool is determined by how much it can contribute to modeling a building.

Annotation Data	Design Data
• Texts	• Wall
• Annotation leading lines	• Door ***Target Objects***
• Dimension lines	• Window
• Hatchings	• Floor
• Drawing tables	• Column
• Hardware symbols	• Beam
• …	• …

Figure 3. Scope of research.

2.3. AUTOMATING FLOOR PLAN RECOGNITION

Research on automating the recognition of floor plans has been going on for quite some time. Previous studies have been performed for the applications of recognized floor plans such as re-utilization of preexisting designs, 3D modeling, generation of new designs, etc. In these studies, for recognition, objects were defined mathematically in an algorithm-based method, which made the problem of considering all unnecessary pixels. Due to this reason, preliminary work, such as noise removal and text extraction, were needed to remove the elements that interfered with the objects. These tasks were error-prone and took a long time, which led to more efficient methods for dealing with floor plans.

Subsequent machine-learning-based recognition shows how preliminary works can be omitted by transferring the style of the format. The domain of image style transfer has enhanced by the growth of generative network models. Huang and Zheng introduced a way of implementing Generative Adversarial Network (GAN) in the field for the recognition and generation of floor plans. They parsed floor plans by segmenting areas with different functions to design by data. S. Kim et al. proposed a method to convert diverse floor plans into an integrated format also based on GAN in the vectorization process.

3. Classification of Objects for Automating Floor Plan Recognition

3.1. WALL OBJECTS

Wall objects are physical structures that define the space by surrounding a building. It is a continuous structure that divides the space into different areas. Recognition of the main walls gives an overview of the entire building structure and limits the location of the doors and windows. In designing, the preexistence of the wall is necessary, since the alteration of the wall's location will affect the overall structure, appearance and functional aspects of the building. Even within BIM, other objects such as doors, windows, openings, etc. can exist only if the wall is modeled before, making wall objects worth being selected as a target object for this research.

3.2. DOOR AND WINDOW OBJECTS

Doors and windows are objects located between walls. They have limited location since they cannot exist without walls and work mutually with the walls. Door objects are openable boundaries that give access to the building and rooms inside it. They play a role of breaking through the blocked walls and enable movement between spaces, which greatly affects the movement of people. For this reason, door objects are closely related to circulation analysis areas making it likely to be utilized in BIM.

Window objects are openings in buildings for the ingress of light, air, sound, etc. They work as an object to split walls like door objects but differ with the fact that both the appearance and functional aspects are important in window objects. Environmental factors such as visual comfort due to light, thermal comfort due to ventilation and temperature have significant effects on the human body. In addition, unlike the door objects, the window objects are located on the outside of the building, affecting the appearance of the building a lot. Therefore, window objects are likely to be used in fields such as energy analysis of façade design in BIM.

4. Recognizing Objects Using Machine Learning

In this research, the integration progress for floor plan recognition was conducted based on the recognition of the segmented target objects. The whole process of training was carried out by conditional GAN (cGAN) in Colaboratory. Before training the model, pre-tasks are necessary.

4.1. DATA PREPARATION AND PRE-PROCESSING

The training data consists of a pair of input and output data. About 100 existing floor plans were used as the input data, provided by the Ministry of Land, Infrastructure, and Transport of Korea. They show typical Korean residence and have relatively few obstacles hindering the representation of target objects. As output data, the integrated version of the floor plan was used. The integrated floor plans are color-coded with the target objects having different RGB values. RGB values of only 0 or 255 were used for labeling the objects to differentiate the objects as far as possible.

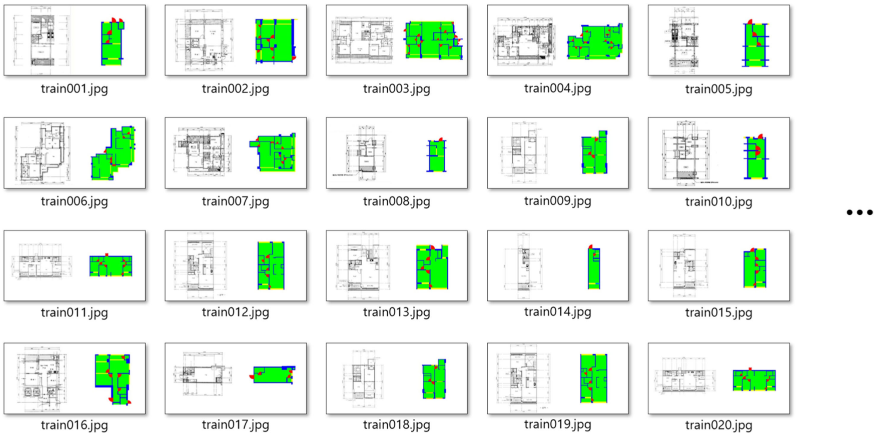

Figure 4. Samples of training data.

4.2. TRAINING AND EVALUATING STYLE TRANSFER MODEL

Conditional GAN (cGAN) proposed by Isola et. al is a powerful network that transfers style preserving the main features. This type of network was chosen for the need to maintain the underlying structure and represented objects in the floor plan. Other types of style transfer algorithms were tried, like CNN, but has failed to keep the structures in a floor plan style. For the utilization of cGAN in this process, some of the structure of the network and parameters were altered.

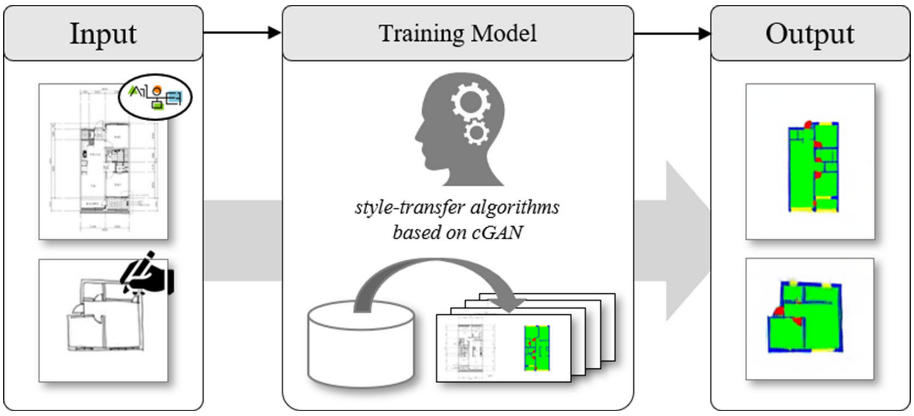

Figure 5. Training style transfer model.

Fig.5 shows the process of the style transfer model. The training model is given a dataset that consists of a pair of original datasets and an integrated version of it. The model is trained in a way to take in a preexisting floor plan and recognize it by producing an integrated format map with colors that represent the different objects.

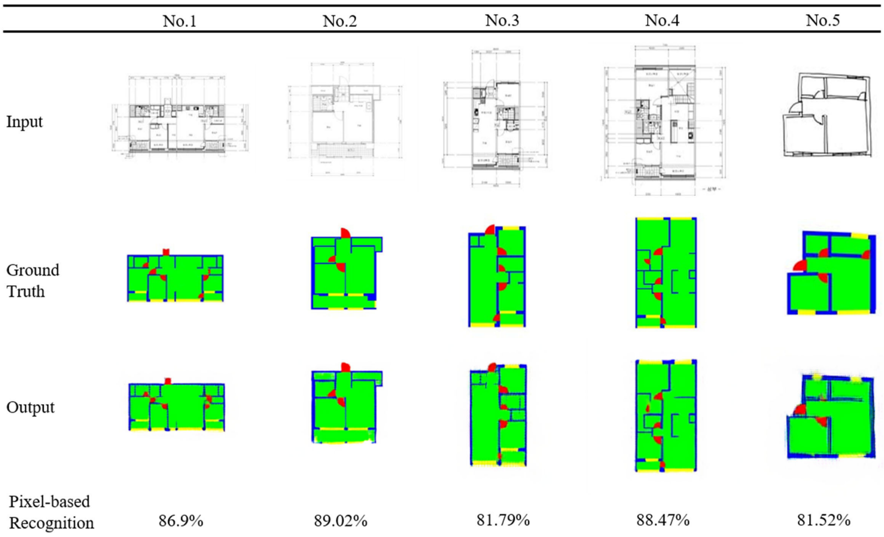

Figure 6. Results of style transfer model.

Figure 6 shows some of the selected results from the testing set. Wall and floor objects are relatively well recognized. Wall objects usually consist of two lines, making them easier to recognize, and floor objects may have high recognition accuracy because of the obvious boundaries of wall objects. In the case of window objects, the recognition rate is quite high because it also has an exact boundary because it always exists between walls. In the case of door objects, it was often only recognized for their location, which may be because they were indistinguishable from other objects that are not the target ones. In the case of No.5, it’s a hand-drawn floor plan which is recognized quite well, thereby increasing the possibility of future use of such a training model.

The evaluation of the recognized figures was made in a way that compares each pixel of the ground truth and the predicted output. Similar to object detection, the segmentation process contains a ‘Ground Truth’ which has labels that indicate the physical location of the object. In object detection, for region representing a particular object in the predicted output, and for the zone corresponding object in the ground truth, the intersection over union (IOU) can be used to assess how much the two overlap each other. Unlike object detection, the evaluation method for segmentation is different in that the classification progress is required for all pixels, and that the overall level of performance is relatively lower than that of other problems. For the recognition of objects in the floor plan, this model was used because it is most important to obtain the results of accurate recognition of the position of the objects. In PASCAL VOC Challenge, the threshold for the IOU is set as 0.5. This means that only when the ratio of overlapping areas between the ground truth and the predicted output exceeds 50% will the reliability score be evaluated for the predicted output. As shown in Figure 6, the recognition rate of the style transfer model used in this study is generally over 80%, showing relatively high accuracy in the domain.

5. Conclusion

This study focuses on a method of transforming various types of drawings into one unified form using a style-transfer model and shows that the computer can automatically and classify the target objects. Through the automatic drawing recognition, the method and applicability of the deep-learning technology, which has been used in various fields, can be applied to the architectural design field. Subsequent research is required to improve the recognition rate and accuracy, and the research on the application of the drawings in the integrated style with a clear standard for the target object that needs recognition. This study is the basis for future automation related applications such as automatic BIM modeling, circulation analysis, spatial relationship analysis, etc. from existing drawings. In future studies, you can just select only the objects you need from an integrated drawing to extract the information and then proceed to the study. This approach to drawings is expected to help with the use of many existing drawings that are currently difficult to utilize as BIM data.

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