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GENERATING MASS HOUSING PLANS THROUGH GANS - A CASE IN TOKI, TURKEY

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Abstract

Nowadays, Machine Learning (ML) is frequently used in almost all disciplines having an intersection with technology. Recently, architects are using existing plan data sets in architecture through Deep Learning (DL) algorithms of big data to achieve generative and non-existent plan models by using ML. Especially, Generative Adversarial Neural Networks (GANs), one of the deep learning algorithms, have been in use in the creation of generative models for architectural studies. Within the scope of this paper, architectural drawings were generated by using GANs. This generation method allows for the training of spatial layout planning to networks and for the generation of plans that do not exist in the dataset. Architectural drawings of TOKI (Housing Development Administration of the Republic of Türkiye) mass housing projects were used as datasets. In line with studies already carried out, this study attempts to create a method for further processing of the research. In this study, the differences between the plan typologies generated with raster images and the reality relations in visual productions between graph-based plan layout productions were evaluated. In this context, 157 plan datasets were obtained by multiplying plans which were spatially correlated with the RGB settings of 21 plan typologies. As a result of this research, it has been determined that the spatial layout planning of the HouseGAN algorithm provides TOKİ's current plan typologies of generation together with bubble diagrams. HouseGAN was trained using its dataset and the outputs obtained were realistic background images.

Keywords

Machine Learning, Generating Architectural Drawings, GANs

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ABSTRACT

Nowadays, Machine Learning (ML) is frequently used in almost all disciplines having an intersection with technology. Recently, architects are using existing plan data sets in architecture through Deep Learning (DL) algorithms of big data to achieve generative and non-existent plan models by using ML. Especially, Generative Adversarial Neural Networks (GANs), one of the deep learning algorithms, have been in use in the creation of generative models for architectural studies. Within the scope of this paper, architectural drawings were generated by using GANs. This generation method allows for the training of spatial layout planning to networks and for the generation of plans that do not exist in the dataset. Architectural drawings of TOKI (Housing Development Administration of the Republic of Türkiye) mass housing projects were used as datasets. In line with studies already carried out, this study attempts to create a method for further processing of the research. In this study, the differences between the plan typologies generated with raster images and the reality relations in visual productions between graph-based plan layout productions were evaluated. In this context, 157 plan datasets were obtained by multiplying plans which were spatially correlated with the RGB settings of 21 plan typologies. As a result of this research, it has been determined that the spatial layout planning of the HouseGAN algorithm provides TOKİ's current plan typologies of generation together with bubble diagrams. HouseGAN was trained using its dataset and the outputs obtained were realistic background images.

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ملخص

في الوقت الحاضر، يتم استخدام التعلم الآلي بشكل متكرر في جميع التخصصات تقريبًا التي لها تقاطع مع التكنولوجيا. في الآونة الأخيرة، يستخدم المعماريون مجموعات البيانات للمساقط الأفقية في مجال العمارة من خلال خوارزميات التعلم العميق للبيانات الضخمة لتحقيق نماذج لمخططات غير موجودة باستخدام التعلم الآلى. على وجه الخصوص، تم استخدام الشبكات العصبية التوليدية (GANs)، وهي إحدى خوارزميات التعلم العميق، في إنشاء نماذج توليدية للدراسات المعمارية. في نطاق هذه الورقة، تم إنشاء الرسومات المعمارية باستخدام شبكات GAN. تسمح طريقة التوليد هذه بالتدريب على التخطيط الفراغى المكاني للشبكات ولإنشاء مساقط غير موجودة في مجموعة البيانات. تم استخدام الرسومات المعمارية لمشاريع الإسكان الجماعي TOKI (إدارة تطوير الإسكان في جمهورية تركيا) كمصدر لمجموعات البيانات. تمشيا مع الدراسات التي أجريت بالفعل، تحاول هذه الدراسة إنشاء طريقة لمزيد من معالجة البحث. في هذه الدراسة، تم تقييم الفروق بين أنماط المساقط الأفقية التي تم إنشاؤها باستخدام الصور النقطية وعلاقات الواقع في الإنتاج المرئي بين إنتاجات التخطيط القائمة على الرسم البياني. في هذا السياق، تم الحصول على ١٥٧ مجموعة بيانات للمساقط عن طريق مضاعفة المساقط التي ارتبطت مكانيًا بإعدادات RGB لـ٢١ نموذجًا للمسقط. نتيجة لهذا البحث، تم تحديد أن تخطيط المساقط المكاني لخوارزمية HouseGAN يوفر نماذج مساقط TOKİ الحالية للتوليد جنبًا إلى جنب مع المخططات الفقاعية. تم تدريب HouseGAN باستخدام مجموعة البيانات الخاصة به وكانت المخرجات التي تم الحصول عليها عبارة عن صور خلفية واقعية.

الكلمات المفتاحية: التعلم الآلى، توليد رسومات معمارية، شبكات عصبية توليدية.

1. INTRODUCTION

Plan layout generation methods have gained a different dimension thanks to machine learning. In addition to computational design techniques, by utilizing artificial intelligence algorithms, existing plans are used as a data set, processed, and tested with different algorithms for regeneration (Özerol and Selçuk, 2022). Some researchers trying to create an interface for users, also trying to use different algorithms and turn to the question of which of the plan layout generation methods provides clearer and more accurate generation (Chaillou, 2019; Nauata, 2020).

Plan generation methods are used together with algorithms developed according to the data sets used. Algorithms such as Pix2Pix (cGAN) are used to prepare the semantic segmentation and masking of a data set consisting of raster images. However, it is possible to see that in DCGAN algorithms used with the simplest architecture of GAN networks, data sets are used for training the network without pre-processing. These generation methods can give different results depending on the amount of the data set and its correct processing.

Architectural plan generation techniques have been developed from the past to the present by adding Graph Theory (March *et al.,* 2020). The mathematical basis of the algorithms used, turning them into rules and constraints in creating the plan layout, has been an essential point for processing the generation into computer-based information systems (Gross,1994). As a result, the reason why all the works are done is associated with Graph Layout Presentation plays a significant role in helping them to determine the proximity relations between the spaces and whether there are transitions between each other and to position them according to the north, south, east, and west orientations. While the room values are considered 'nodes,' the distance relations between them or the 'yes' or 'no' relations between them are either determined by the matrix values, or the values are determined according to the side lengths and accessibility of the rooms. Positioning can be achieved by assigning these values to the 'edge' edges that provide the 'nodes' relations (March 1971; Gross, 1995).

When the previous studies we have carried out are evaluated, the realism of the results obtained when GANs algorithms trained with datasets converted from raster images to vector images are tested and the usability of the results by architects should be questioned and other GAN algorithms should be trained and compared in this context. In this process of the study, plan layout studies are generated with raster image data sets (DCGAN, Pix2Pix) and graph-based plan layout models containing GNN algorithms such as HouseGAN trained within the scope of the study. Testing and generation of different algorithms in these two different generation models resulted in the generation of a realistic and usable plan layout in plan generations.

2. CURRENT RESEARCH STUDIES

A lot of work has been done at the intersection of architecture and machine learning, but recently GANs have emerged as the most used algorithm in plan generation methods or 3D model generation methods (Özerol and Selçuk, 2022). In addition to these studies, different algorithms (Wu *et al.,* 2019; Hu *et al.,* 2020). have been started to be developed in the preparation of plan layouts as data sets.

2.1. Plan Layouts Generation by Processing Raster Images

Liu *et al.* (2017) in their study (raster) first created the junctions from the intersections of the walls. The locations of doors and windows are determined. Afterward, post-processing, which creates a vector format, was obtained with the CNN algorithm. The important part of this process is the processing of the data from a raster image to a vector format.

Zeng *et al.* (2019) used the R2V dataset and the R3V dataset in their study. In this study, it is observed that an input consisting of coloured, black, and white drawings is segmented according to the size and location of the rooms with the estimation of the network. This segmentation process has been tested and compared on more than one algorithm, including the algorithm in the previous study. Thanks to the open-source code in this study, the segmentation of our dataset was tried over Google Colab and the similarities were compared.

These stages carry out the plan layout generation, segmentation, and estimation processes tried with the CNN algorithm. However, many plan layout processes that provide a generation with GANs networks go through these processes, especially if they are carried out with data sets obtained from raster images. Because by determining the (boundary, edge) parts of the data sets, the proximity of the rooms with each other and their size relations enable the network to establish the plan layout hierarchically by detecting neighbourhood relations.

Chaillou, (2019, 2020) provided the segmentation of plan layouts over raster images by using the NVIDIA Pix2pix algorithm in their work, and both provided the generation of plan layouts and generated them together with parcels on an urban scale. However, in this study, like the training model of other raster images, the networks are trained on a pixel basis. In this way, different combinations in both the walls and the interior are regenerated.

Table1: Recent Studies on Raster Image Generation

Authors	**Dataset**	**Algorithm**
Chaillou, 2019	LIFULL HOMES	ArchiGAN
Zeng et. al. (2019)	R2V	DeepLabV3+ PSPNet
Liu et. al (2017)	LIFULL HOMES	CNN

While examining the data sets, all the researchers try semantic segmentation methods if they are going to proceed over raster images. Although most of these methods are processed on ready-made data sets, different results can be developed in segmentation processes depending on the algorithm. The semantic segmentation methods obtained so far are listed as follows.

The pooling process is created by reducing the resolution pixels of an image to a smaller capacity (Akhtar & Ragavendran, 2020). In this different mapping process, the pooling phase may vary according to the maximum and average values. U-net; Its architecture is built for the segmentation of biomedical studies. However, it has been determined that the resolution of the result outputs is better than the old methods (Ronneberger, Fischer, & Brox, 2015). Resnet; Thanks to the multi-layer convolutional networks realized in its architecture, partitions such as U-net can be obtained (He, Zhang, Ren, & Sun, 2016). In recent studies, researchers have tried more than one c-GAN algorithm with their own data sets and compared them according to their production values, durations and Fréchet inception distance (FID) values (Rodrigues & Duarte 2022).

2.2. Current Studies of Machine Learning Algorithms Generated Using Graph Layout Generation of Plans

Graph Theory is a method used by mathematicians, physicists, chemists, electricians, computer engineers, architects, and planners for a very long time. One of the critical factors in using this method in all these scientific and professional groups is developing a more abstract linear expression method with systems, particles, and spaces that can establish close (binary) relations. According to the graph theory explained by the critical mathematical theorist Harary (1969), the matrix system also provided significant benefits in detecting and determining the variability of the states of the points and the edges connecting these points. While the relations between nodes can be directly or indirectly related, the closeness of these relations can be expressed with the adjacency matrix system, making it easier to change the length and weight of the connection edges (Harary, 1969). Architects first realize their way of thinking with various diagrams such as design sketches and bubble diagrams. Grason (1971) developed a graphical expression method according to the program infrastructures of spatial planning in the architectural design method. This expression method places spatial layout paradigms in the north, south, east, and west planes. A graphics-based presentation technique is developed that is positioned together with spatial orientations. March (1971) made his analysis based on the graph theory of the Swiss mathematician Euler[1] (1707-1782). March *et al.* (1971) analysed the transfer of the transition state and proximity relations between spaces. He discussed these transitions and neighbourhood relations together with the matrix system and the graphic plan layout expression method. It has been observed that the points placed in the rooms form a network pattern in line with the spatial relations, distance, and proximity relations. Considering the rooms as a zone, these proximity states can be connected to stripes according to the links of their dimensions and openings with each other.

Baybars (1982) developed a different perspective on the connections between plan and graph theory. The contribution of functions such as inner courtyard and circulation to the spatial, graphic plan layout change has been shown as a difference in the graph mapping technique of the spaces in the discussed plans through neighbourhood relations. This change has been possible by establishing a connection between the rooms through the relationship between 'there' and 'no.'

Liao *et al.* (2015) developed software called VEGGIE (a Visual Environment of Graph Grammar Induction Engineering) to consider the semantic relations of shape grammars and spaces together in their study. They tried to create spatial, graphic grammar traditionally (Liao, de Vries, Kong & Zhang, 2015). Along with these semantic approaches, settlement studies on topography have also been developed. Ślusarczyk (2018) approached the graph presentation layout system from a hierarchical point of view and created the "hierarchical layout hypergraphs (HL-graphs)" method with the software he developed for local architectural plan layout. After these studies, many researchers deemed RFP (Rectangular Floor Plan). layout formations from the block plan layout system are more appropriate for creating a productive plan model. Progress was made in this regard. Shekhawat (2018) continued to work on RFP. They tried to combine various theorems with RFP, combined them with graph layout systems, and followed a comparative method.

It has been determined that Graph Presentation of Plan Layout methods provide benefits both in the use of the network and in the realistic plan generation systems produced for the users, in the process of producing the plans (Nauata, Chang, Cheng, Mori, & Furukawa, 2020; Shekhawat, Upasani, Bisht, & Jain, 2020) studies with the GAN networks. It has been evaluated that both the realistic plan generation systems produced for the users are beneficial. However, the diversity of recent studies proves that Graph Layout Generation of Plans algorithms is more diversified. Recently, the most used algorithms of machine learning in plan generation techniques have been GANs and CNN algorithms, respectively (Özerol & Arslan Selçuk, 2022). These algorithms have been tried to be used in the most accurate way to shape the spatial layout planning process.

In Table 2, the data sets used in recent studies and the algorithms they used are included. It is understood that, while developing these algorithms, researchers tried more than one algorithm and discovered their own algorithms. Shekhawat *et al.* (2020) dealt with this situation by associating the RFP layout plan generation methods with the graph layout system with the minimum and maximum values that the rooms can take, giving quantitative weight to the lines between the points. Hu *et al.*, (2020) used the RPLAN dataset while developing the Graph2Plan algorithm in their study. Afterward, they created the user interface with the graph plan layout combination of this data set, which they processed by combining them with the GNN algorithm in Phycharm.

[1] In particular, the theorist expressed the Köningborg bridge problem graphically by creating edges between points and places that are connected to each other. Strings are not added in the graphical expression between areas that are not directly related to each other; that is, there are no bridges (Biggs, Lloyd, & Wilson, 1986).

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Table 2: Recent Studies on Graph Based Plan Layout Generation

Authors	Dataset	Algorithm
Nauata *et al.*, (2020)	LIFULL HOMES	HouseGAN
Hu *et al.*, (2020)	RPLAN	Graph2Plan
Shekhawat *et al.* (2020)	-	GPLAN

Nauata *et al.* (2020) used the LIFULL HOMES DATASET in the HouseGAN study. First, boundary detections were created on the floor plan images, which are raster images obtained here, and then Conv-MPN and GCN algorithms were tried with Graph Layout Based generation and correct models were tried to be revealed by comparing these algorithms.

Pixels gain importance as both masking and segmentation are done in raster image data sets. Recently, separating these images with clearer lines has enabled the results to obtain more realistic and clearer images. Therefore, boundary detection parts also gain importance in new algorithms developed for segmentation. When this segmentation process is supported with the Graph neural network in plan layout generations, the neighborhood relations of the room volumes with each other and their alignment to each other's borders are provided more clearly.

3. METHODOLOGY

Considering literature review we concluded that the generation methods of the Architectural Plan Layouts, which are with the raster image-based data set (Uzun et. al,2020), and the methods that change according to their pre-processing datasets status. The generation methods of the Architectural Plan Layouts, in which dual working algorithms (such as GNN and GPN) are used with the support of the graph layout presentation method (Nauata et. al,2020). It is important that these GANs algorithms, which are one of the fast generation methods, produce results that are realistic and close to the given input values (Figure 3.1).

Fig.1: Methodology

The creation and use of the dataset during the final implementation depends on whether the network is working with the Unsupervised Learning method, or the Supervised method developed by Lee *et al.*, (2019) (Figure 3.2). While DCGAN, one of the methods used, works with the unsupervised learning method, HouseGAN works with the supervised learning method.

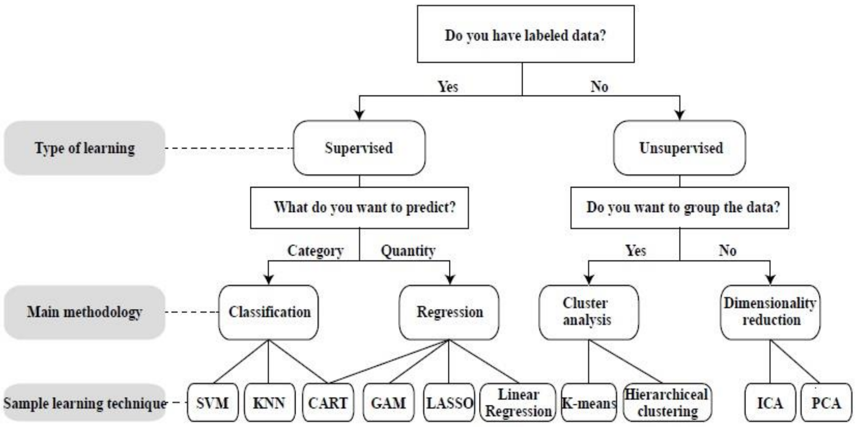

Fig.2: The Elements of Statistical Learning (Lee et al., 2019)

4. IMPLEMENTATIONS WITH GANS

DCGAN

This algorithm is provided by establishing a TensorFlow link (URL-1) Relu activation function is used and the Convolutional 2D padding method is used (URL-1). These operations have two modules that distinguish GAN algorithms from other deep neural networks, discriminator, and generator. The generator replicates the dataset after training the network, while the discriminator detects the difference in the replicated dataset. These detection values are important. The training cycle of this basic algorithm was formulated by Goodfellow in 2014(1).

$$\text{“}\min_G \max_D V(D, G) = E_{x\sim p_{data}(x)} [\log D(x)] + E_{z\sim p_z(z)} [\log(1 - D(G(z)))] \quad \text{(Goodfellow et al., 2014)”} \qquad (1)$$

TOKİ Plan typologies have been prepared by giving different colors to each room by using the Numpy Array Anaconda-Jupyter Notebook. Then, this smallest dataset, consisting of 21 typologies, was replicated to 157 plan datasets by rotating and mirroring with the data augmentation method. These generated data sets were tested for high epoch values by retraining the network (Figure 4.1).

However, results up to an epoch value of 500 could not make the images generated can detect real or fake. Because the raster image images of the generated plan layout images were blurred noise images.

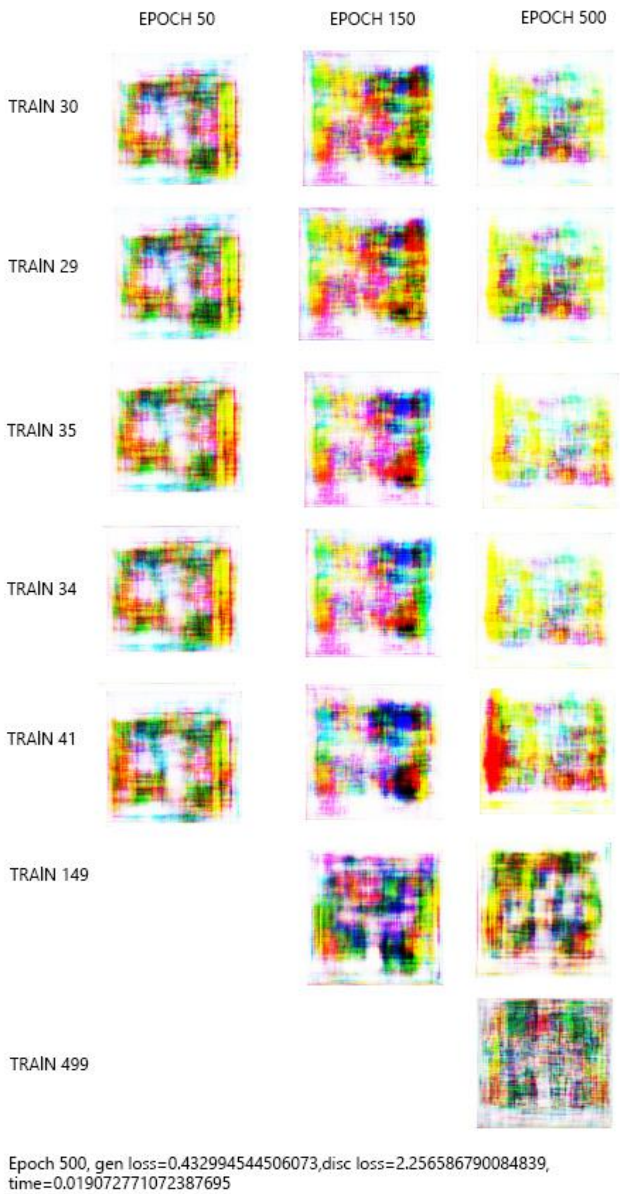

Fig.3: Images obtained in line with the epoch cycles tried with the augmented data set

HOUSEGAN

Considering the data determined later and in parallel with a recent study suitable for spatial settlement planning, the data and open-source licensed codes were used with the HouseGAN algorithm. The code, obtained via Github open-source code sharing, was cloned, and pulled from Google Colab. Major problems were encountered in the Windows operating system and Phyton coding platforms such as Pycharm and Jupyter. The dataset was then changed, and the initial dataset was tried, but positive results could not be obtained. Using 117,587 plan datasets, this algorithm worked in conjunction with graphical diagrams. In addition to the generated plans by the authors, simultaneous graphical charts were generated (Figure 4.2). This pilot study provides an essential method for the further process of the study. The graphical user interface makes it possible to create a plan generation interface that can give easy generation to users or architects. This algorithm was implemented via Google Colab using open-source code shared by Nauata et. al., (2020). Its own dataset, Lifefull Home, defined by the code, is used.

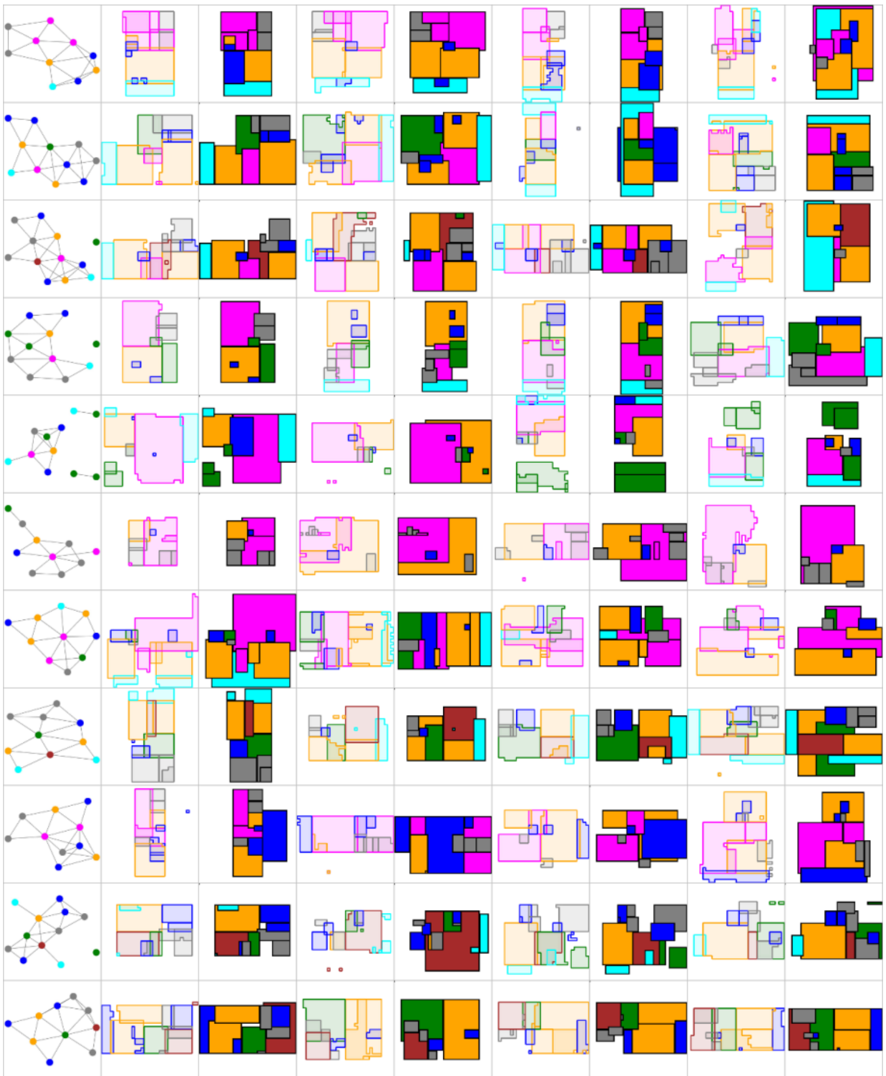

Fig.4: HouseGAN with LIFULL HOMES Datasets, images generated by authors

5. CONCLUSIONS

In the first study, the plans created with the DCGAN algorithm were created with our own data set (TOKI plan typologies). However, in raster image-based generation, the resolution quality, and numbers of datasets images gain importance as well as the algorithms used. The HouseGAN algorithm was used with its own dataset, the LIFEFULL dataset. Considering these methods carried out within the scope of this paper, despite the multiplication of TOKI plan data sets, raster image data sets with colored rooms used for training the DCGAN network could not provide generation close to the given input values of the network. The reason for this is thought to be due to the insufficient number of data sets and the incomplete handling of the data set (supervised learning) in the working logic of the algorithm (supervised learning).

Secondly, the HouseGAN algorithm has been tried by using its LIFULL dataset. In addition to Conv-MPN and GCN and CNN algorithms, which are used in addition to the working process of the supervised learning algorithm in the working logic of the network, different Architectural Plan Layouts generated by the method in which they create their own GAN algorithms by using them together can be given with Graph-Based Plan Layouts.

It is concluded that the generated plans can be used more realistically and, in a way, that architects can use them systematically and more functionally. In the further process of the study, comparisons can be made with our own data set according to FID values by using the techniques and pix2pix algorithms. In addition, Graph based plan layout generation algorithms can also be tested within themselves and all these values can be compared.

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