List of Figures

Figure	*Title*	*Page*
1.1	Illustration of various subareas of document image analysis (DIA) on a sample scanned document [Sharma *et al.*, 2017].	2
1.2	An illustration of a basic Content Based Image Retrieval system.	3
1.3	Illustration of various query modes along with their corresponding retrieval results	4
1.4	Motivation of the problem.	5
1.5	Floor plans, showing 2D cross sections of buildings and displaying heterogeneity in design.	6
1.6	Retrieval in floor plans by extracting meaningful content and looking for similarity across floor plan databases.	7
1.7	Analysing floor plans for novel content aimed at retrieving similar layouts from a large repository.	8
3.1	Framework diagram for our structural retrieval based on topology	22
3.2	Various stages of structural and semantic analysis on an image from SESYD dataset [Delalandre *et al.*, 2010a]: (a) unsegmented layout, results of (b) morphological operation and wall, boundary extraction, (c) Detection of doors and windows (d) Closing gaps in walls and (e) labelling and segmenting the room structure	24
3.3	Detecting doors and windows using Harris corner detector	25
3.4	Topological graph for the segmented room layout	26
3.5	Example showing how a sink symbol in the furniture set is assigned a unique signature.	27
3.6	Room layout and corresponding graph consisting of both room adjacencies as well as room decor representation	28
3.7	Embedding features from the topological graphs into spectral space. Adjacency matrices with varying sizes are reduced to fixed length vectors in the pattern space. Kindly note, in the right hand side, similar vectors are clustered closely in the feature space.	29
3.8	Topological feature extraction from a room layout in a floor plan	30
3.9	Framework for Room Decor Matching	32
3.10	Top 5 retrieved results corresponding to a query from the SESYD dataset.	32
3.11	Retrieval results for two different query architectural floor plans taken from the SESYD dataset. The top row shows the query image, the corresponding room layout and the semantic graph generated from the floor plan image. For the given query images only the top six retrieval results are shown.	33
3.12	Retrieval results for two different query architectural floor plans taken from the SESYD dataset and the ROBIN dataset. 1. (a) and (b) correspond to the query given from SESYD dataset and the subsequent rank-ordered results. 2. (a) and (b) correspond to the query given from ROBIN dataset	34
3.13	Quantitative result comparing the RLM and the RDM approach on the ROBIN dataset	34
3.14	Plot of intra-class and inter-class distances between layouts using our feature matching technique on the SESYD datset.	36
3.15	Layout matching from floor plans taken from SESYD dataset. Two such results from Category 8 and 4 are highlighted with a red bounding box.	37
3.16	Execution time for the intermediate stages of processing of the framework for different categories of floor plans on the SESYD dataset. Values shown in the bar chart denote the ratio of time taken in seconds for each step to the total time taken for execution.	38

3.17 Execution time for the intermediate stages of processing of the framework averaged over all 51 categories of floor plans in the ROBIN dataset. Values shown in the bar chart denote the time taken in seconds. 38
3.18 Segmentation results on two images from CVC-FP [de las Heras *et al.*, 2015] dataset (a) Input floor plan, (b) Technique proposed in [de las Heras *et al.*, 2014], (c) Our approach 39

4.1 Deep Learning Model based Framework for Floor Plan Retrieval 42
4.2 Architecture of feed-forward neural network, with the input layer, a hidden layer and the output layer 44
4.3 Architecture of a Convolutional Neural Network Model for classification of an image [LeCun *et al.*, 2015] 45
4.4 Example of how convolution operation is performed on an image matrix. 45
4.5 Example of how a ReLU Operation works. 46
4.6 Example of how a Max-Pooling Operation behaves on an image matrix. 47
4.7 Sequence of layers in AlexNet Framework [Krizhevsky *et al.*, 2012a] 48
4.8 Architecture of the Convolutional Neural Network (CNN) model used for feature extraction from the floor plan images. 49
4.9 Rank ordered retrieval result of the proposed framework for five different query floor plans from the ROBIN dataset. Here, top five rank ordered floor plans are shown for each query. 51
4.10 Mean Average Precision values, comparing result of the framework on ROBIN dataset, using features from all the hidden layers of the CNN. 53
4.11 Precision and Recall (PR) plot, comparing state-of-art methods with the proposed framework on ROBIN dataset. 54

5.1 Q depicts the query floor plan and D1 depicts a resultant retrieved floor plan from the database of floor plans. The objects enclosed in red boxes in D1 are furniture components with similar shape as the components in Q, but different types. 57
5.2 Basic framework depicting extraction of high-level semantic features and weighted fusion for retrieval of floor plans. 59
5.3 Room level segmentation results on a pair of floor plan images from ROBIN dataset. 60
5.4 Figure depicting the ordered labeling of rooms after segmentation. (a) Distance is calculated from a leftmost origin point up to all room centroids. Room with the lowest distance from the origin is ordered number 1 and the other rooms are labeled in similar fashion. (b) Subsequent room ordering results. 61
5.5 Example of Room Adjacency String (RAS) feature: (a) Segmented rooms (b) Topological Graph (c) Adjacency matrix (Adjacency string corresponding to Room 2 is highlighted). 62
5.6 Carpet Area Ratio (CAR) feature: (a), (c) Segmented, ordered layout, while (b), (d) CAR feature corresponding to Example 1 and 2 respectively. 63
5.7 Furniture detection and categorization in each room. 63
5.8 Furniture detection and categorization in each room. Illustration underneath each room gives the array $\mathscr{T}$ containing the type of furniture in each room. 65
5.9 Distance score corresponding to each room of the query layout (Q) and the database layouts (S_1 and S_2). Attributed to the difference in features, lower the score, more similar the floor plans are. Hance, finally the score is subtracted from 1 to make the final greater Matching score to represent the floor plans that match more. Color codes are used to highlight the room correspondence. 68
5.10 Retrieval results for four different query architectural floor plans taken from the *ROBIN* dataset. Note that the floor plans highlighted in red are incorrectly retrieved as global layout shape differs from query. 69
5.11 Precision and Recall (PR) plot corresponding to a) Cumulative sum of all the features with equal weights b) Preferring one feature more than the others while retrieval. 70

6.1 Flowchart comparing the different sub-components in two approaches for sketch based retrieval. (a) Approach 1: Basic framework using cyclic GAN for domain mapping and sketch based retrieval (b) Approach 2: An improved unified framework using cyclic GAN and autoencoders in conjunction for floor plan retrieval. 77
6.2 Framework for sketch based retrieval of floor plans. Domain adaptation is facilitated by a Cyclic GAN. 78
6.3 Comparing the original sketches/images with outputs generated from Cyclic GAN. (a) Original floor image from ROBIN dataset. (b) Generated floor plan image using Cyclic GAN. (c) Original floor plan sketch from S-ROBIN dataset. (d) Generated floor plan sketch using Cyclic GAN. Kindly note the quality of generated sketches is better than that of generated images. 79
6.4 Cyclic GAN framework, corresponding to the proposed approach with converting the sketches from the S-ROBIN dataset into GAN generated images (constituting GI-ROBIN dataset) closely similar in features to the to-be retrieved images and images from the ROBIN dataset to sketches (constituting GS-ROBIN dataset). 79
6.5 Network architecture for the Cyclic GAN framework, representing the inputs from ROBIN and S-ROBIN dataset. The outputs being generated constitute the GS-ROBIN dataset. 80
6.6 Schematic structure of the Cyclic GAN network used in the proposed framework for image floor plan to synthesized sketched floor plan mapping, and vice-versa. 81
6.7 Unified framework for multimodal retrieval. 84
6.8 Layerwise depiction of the Convolutional Neural Network (CNN) for query classification 85
6.9 Layerwise depiction of the autoencoder network. 86
6.10 A diagram depicting stages of sketch synthesis from an image through our Cyclic GAN framework. Note how, the discriminator and generator improve with increasing the number of training iterations. 90
6.11 Top five rank ordered retrieval results for the two proposed approaches for three different hand-drawn query floor plans. 92
6.12 Top five rank ordered retrieval result of proposed framework for three different query floor plan images using Approach 2 proposed in the Chapter. 93
6.13 Two examples showing results for querying the system for partial matches. (a) Query Sketch, (b),(c),(d) Retrieved results. Colour Coding establishes room correspondence between the query and the results. 94
6.14 (a) Effect of converting query sketch into image through Cyclic GAN and performing retrieval (CNN A (trained on ROBIN) and CNN B (trained on S-ROBIN)) as opposed to converting the retrieval database into sketches (CNN C). (b) Effect of training CNNs on ROBIN (CNN_1), S-ROBIN (CNN_2) and GS-ROBIN dataset (CNN_3) 95
6.15 Precision and Recall (PR) plot, comparing result of the framework, using all the hidden layers CNN features. 96
6.16 Precision and Recall (PR) plot, comparing result of this framework on autoencoder trained with ROBIN dataset (N1) and S-ROBIN dataset (N2). 96
6.17 PR plot, comparing the two approaches. Approach 1 extracts features and performs retrieval taking minimum of the precision values obtained by each layer (Approach 1 (min)) and taking the best layer (normalization 1 layer) giving the highest MAP value (Approach 1 (norm1)). Whereas, Approach 2 has two autoencoder networks, N1 trained on ROBIN and GI-ROBIN and N2 trained on S-ROBIN and GS-ROBIN. 97
6.18 PR plot, comparing the best of the proposed two approaches (Approach 1 (norm1)) and (Approach 2 (N2)) with SOA techniques. 98

7.1 Comparison of MAP values obtained by techniques mentioned in Chapters $3, 4, 5$ and 6. 103

A.1 Symbol set used as furniture in ROBIN and S-ROBIN dataset. 105
A.2 3-Room layouts in the ROBIN and S-ROBIN dataset. 106

A.3 4-Room layouts in the ROBIN and S-ROBIN dataset. 107
A.4 5-Room layouts in the ROBIN and S-ROBIN dataset. 108

B.1 Architecture of the developed software for floor plan retrieval. 112
B.2 Sequence diagram depicting the overall flow of the software. 113
B.3 Screen prompting the user to select a floor plan of his/her choice. 113
B.4 Segmentation of the selected plan into labeled rooms 114
B.5 Graph embedding of the room level structure of the floor plan. 114
B.6 Selecting how many results to be displayed while retrieval. 115
B.7 User's required floor plans on display as per their similarity from the query floor plan. 116