國 立 交 通 大 學

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碩 士 論 文

以階層式案例推論方法輔助建築平面考試試題設計
A Hierarchical Case-Based Reasoning Approach to Building Schematic Exam Item Design

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摘　要

隨著電腦及網路科技的進步，藉由電腦及網路的學習評量稱為 CBT (Computer-Based Testing)已成為一個趨勢，對美國建築師考試(ARE，Architect Registration Examination)而言，電腦化測驗已普遍應用在考試的各個項目，其中以圖形化(Vignette)測驗佔大多數，目的在藉由圖面的繪製來測驗出知識整合的能力,而在本研究中,我們將專注於建築平面(Schematic Design)設計的項目。在試題的出題設計上因為是測驗高階的設計知識概念，所以在出題上對老師是很困難的。他們通常需要去做複雜且多層次的考量，定義且設計試題，以確保能有效的測驗出學生的能力，所以常常會花很多的時間及成本。我們的目標是建立一個輔助出題系統去協助老師出題且能對之前的考題再利用，讓出題不再是從無到有那麼的困難。目前考題的再利用方面，往往是圖面的蒐集整理，沒有結構化的去對圖面內容做定義，以致於再利用的程度有限。所以如何結構化的描述建築平面設計知識模型是一個很重要的課題,而模型的描述能力、延伸性及操作能力是一個很重要的評估指標。如何清楚的描述知識的特性，我們的概念是藉由專家的角度及電腦科學的技術來設計我們的模型，HCBR(Hierarchical Case-Based Reasoning)的方法是提出一個階層性的概念，來對知識做有層次的分類，以案例為基本單位加以推論及再利用。除此之外，我們提出一個智慧型的搜尋條件產生器(Intelligent Query Generator ，IQG)，IQG 能有效協助老師對系統下搜尋條件，藉由搜尋條件的增減的建議，能找到適合的案例，搜尋條件可當成考題，而搜尋出來的案例可以當成改考卷的參考答案；其中我們所定義的搜尋語言(Query language， QL)是協助 IQG 運作的重要角色，目的在有效描述輸入的條件。最後，我們會提出系統設計上的建議，在實作方面，我們會實作出建築平面比較器，並以問卷的方式，來驗證系統的成效。

關鍵字: 案例式推論、建築平面設計、試題

A Hierarchical CBR Approach to Building Schematic Exam Item Design

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Abstract

With the growth of the computer and the Internet technology, the learning assessment via the computer and the Internet, called Computer-Based Testing (CBT) has become a trend. In the Architect Registration Examination (ARE) the CBT is applied in schematic design test item to assess students planning capability. In this paper we focus on schematic design test item of subject building planning in ARE. However, the design of test item for assessing high level knowledge is difficult for teachers. Since they usually need to concern complex situations to make sure the effectiveness of test, the creation of test item is usually time consuming and costly. Our goal is to construct a system to assist teachers in item generation by reusing desirable cases. However, the database of current design cases usually focuses on documentary collection for layout information and is ill-structure for design knowledge representation. Therefore, how to organize the design knowledge to represent multidiscipline and granularity property of building for reusing is an interesting and important issue. The expressive power, extensibility and manipulation of model are also our issue. To clearly represent the building properties for above issue, our ideal is to organize design attributes form experts' perspective by extending the layout with environmental context information. Accordingly, the Hierarchical Case-Based Reasoning (HCBR) approach is proposed to organize the knowledge granularities by hierarchical relations. Therefore, the Intelligent Query Generator (IQG) is proposed to support the verification of constraint rule during item design by iterative case retrieval process. If the designed constraint rules are too specific which means no case is retrieved, then the IQG will recommend the user release the constraint rules. With the IQG the teacher can easily generate the desirable test item. To evaluate the effectiveness and usability of proposed approach, the prototype system and ten test cases were implemented. The corresponding questionnaire analysis was applied and the result shows that the proposed approach has high satisfaction degree.

Keywords: Case-Based Reasoning, CBR, Schematic Design, Exam Item, Architectural Design

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Chapter 1 Introduction

With the growth of the computer and the Internet technology, the learning assessment via the computer and the Internet, called Computer-Based Testing (CBT) has become a trend. The CBT can be used in assessment of high level knowledge. For example, in the Architect Registration Examination (ARE) the CBT is applied in schematic design test item to assess students planning capability. Thus, the CBT is getting more important.

In ARE, the test of vignette can be divided into three categories which are site planning, building planning and building technology. In this paper, we focus on schematic design test item of subject building planning in ARE. However, the design of test item for assessing high level knowledge is difficult for teachers. Since they usually need to concern complex situations to make sure the effectiveness of test, the creation of test item is usually time consuming and costly.

With our observation, the schematic design exam in building planning usually consists of multidiscipline and different granularity of constraints for building properties. While the experts or senior teachers create the test item, they usually refer to the existing design cases to construct the new one. Thus, our goal is to assist teachers easily creating the item by reusing the cases. However, the database of current design cases focusing on documentary collection for layout information is ill-structured for schematic designing knowledge representation. Therefore, we aim to reorganize the knowledge representation to describe the multidiscipline and several granularity properties of building for schematic designing knowledge reusing. Thus, the expressive power, extensibility and manipulation of knowledge representation model are our issues.

To clearly represent the building properties for above issue, our idea is to organize design attributes form experts' perspective by extending the building layout with more environmental context information. While experts design buildings, they are concerned with the followings: property of zoning and segment, type of building, configuration of rooms. Accordingly, the Hierarchical Case-Based Reasoning approach is proposed to organize the knowledge granularities by hierarchical relations where each layer denotes attributes of different granularties. In addition, the multidiscipline building properties are classified into three types of attributes: usage, topology and constraint rule.

Accordingly, the similarity functions are designed for different attribute types to provide flexible case retrieval service. The Intelligent Query Generator (IQG) is proposed to support the verification of constraint rule during item design in iterative case retrieval process. To assist teachers creating the test item, if the designed constraint rules are too specific to retrieve no cases, then the IQG will recommend the user to release the constraint rules. If the designed constraint rules are too general and too many cases are retrieved, then the IQG will recommend the user to add more constraint rules. With the IQG, the teacher can easily generate the desirable test item.

To evaluate the effectiveness and usability of proposed approach, the prototype system and ten test cases were applied. The corresponding questionnaire analysis was applied and the result shows that the proposed approach is usable for assisting in item designing.

The remainder of the article is organized as follows. In Chapter 2, we introduced some related works about the ARE and CBR. In Chapter 3, we surveyed the schematic design on architectural domain. In Chapter 4, the HCBRSD scheme was introduced. In Chapter 5, the system implementation and experiments were discussed. Finally in Chapter 6, we provided the conclusion and future work for this research issue.

Chapter 2 Preliminaries

In this chapter, Architectural Registration Examination (ARE) and exam item are introduced first. Second, we emphasize upon configuration of architectural space and analyses how the existing papers model architectural plans and where does it apply. Finally, we will introduce Case-Based Reasoning (CBR) to explain how to implement former cases to solve current problems.

2.1 Architectural Exam Item

Architectural Exam Item is a graphic/layout-based subject. Due to complicated derivation and certain conditions constraints, several iterations of inference are needed to produce results in physical layout until the result is satisfied. As teachers normally solve problems based on their past experience, CBR is suitable to be applied.

Nowadays, architectural exam in most of the countries is pen-and-pencil format, except for US, which is the pioneer of computerizing the exam. The exam consists of multiple-choice questions and graphic vignettes two parts and total of 9 business exams are included in contents.

(i) Multiple-choice Questions (MCQ)

MCQ is carried out by using mouse to choose for options, which consists of six subjects : Pre-design, General Structure, Lateral Force, Mechanical and Electrical System, Materials and Method, and Construction Documents and Service.

The number of questions for MCQ is fixed, for example, 90 questions for lateral force subject, while 120 questions for the remaining five subjects. Every test for each subject has different time limit and duration.

(ii) Vignettes

Graphic Divisions consist of three parts, Site Planning, Building Planning and Building Technology. There are 15 steps of vignettes to test the knowledge, skills and architectural ability in different aspects of the exam participants. Examinee are required to answer the questions based on programs and regulations. Belows are the list of vignettes of each graphic division.

Architect Registration Examination (ARE) of America :

Part 1 : Site Planning

Site Design

Side Zooning

Side Grading

Part 2 : Building Planning

Interior Layout

Schematic Design

Part 3 : Building Technology

Building Section

Structural Layout

Accessibility - Ramp

Mechanical & Electrical Plan

Stair Design

Roof Plan

Figure 2.1 The ARE entry window

Schematic Design of Building Planning

In this research, we will focus on the item of **schematic design** which is one of the important subjects for architectural beginner and national exam. The purpose is to test the ability of student on space arrangement and organization, in which the basement analysis, relation of space organization, space volume dimension and the interaction between space and environment are needed to be considered. The key point is to test the ability of student on integrated thinking and problems solving in different point of view.

In Figure 2.2, a screen shot of mock exam provided to exam participants to practice and get familiar with the exam shows the practicing software of schematic design provided by NCARB (National Council of Architectural Registration Boards).

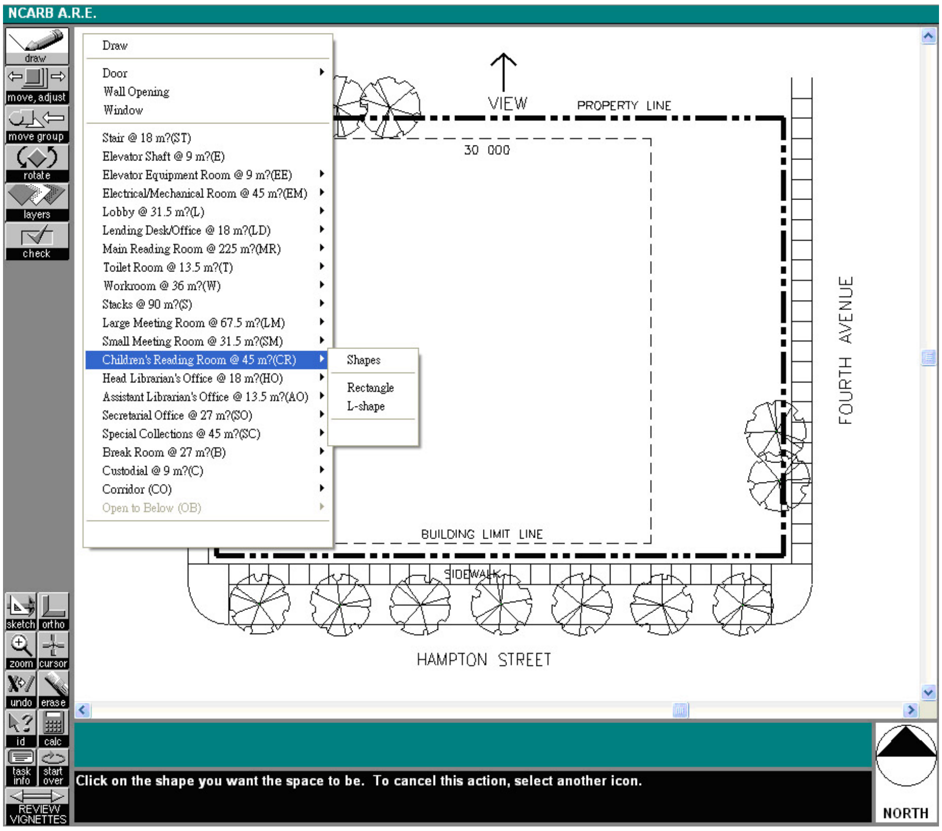


Figure 2.2 The schematic design exam window

2.2 Schematic Design Modeling

We have surveyed several researches about the architectural space modeling as follows.

(1) Small-graph matching and building genotypes [8]: This paper discussed an application on "Building-genotype and similarity" and used bubble diagram to model spaces.

(2) A graph-based algorithm for extracting units and loops from architectural floor plans for a building evacuation model [21]: This paper mainly discussed how to calculate the evacuation directions of exit and also used bubble diagram to model spaces.

(3) Visual knowledge specification for conceptual design [12]: This paper mainly discussed the "Knowledge ontology and design rules" and used UML to model spaces.

(4) A geometric modeling framework for conceptual structural design from early digital architectural models [13]: This paper is mainly an application on "Integrated architectural-structure representation" and used UML to describe spaces.

Through our observation, 2 types of method are often used to model architectural space organization (1) Bubble diagram (2) UML, these methods can only be applied to specific application. Structure of spatial description and extension can only be achieved by UML; therefore, bubble diagram is limited on specific plans. Both of the methods above are not possessed with the ability of inference.

2.3 Case-Based Reasoning (CBR)

Case-Based Reasoning [5] [6] [7] [11] is attempted to solve new problems through revising the solutions of former cases, which is searching similar cases to find solutions of former problems and transform them to become the solutions of new problems. For example, when architects are doing architectural design, they will develop their architectural plan by referring to similar design conditions or trying new designs; if they could produce their plan successfully, then we would memorize the architectural plan and try to solve similar situation by using this design next time. CBR is a concept produced based on this idea; therefore it is a well knowledge management technique that can help us to derive the develop circumstances of new case according to former case experience.

By using Case-Based Reasoning, the first step is to describe a problem (presentation) and retrieve the most similar case from case base (Retrieval). Because the retrieved case will not be totally identical with current case, the adaptation will be applied in light of the case solution to verify the revised solution with user and environment, and the verified case will be added into case-base if required.

Therefore, case-base reasoning is a process that is closer to human decision policy; it can combine new knowledge to current case-base automatically, and create case-base if required.

When case-base reasoning concept is used on architectural exam generation, we can presume new solutions by referring to former solutions.

Chapter 3 Schematic Design of Case Representation

The first of the design process on school is schematic design phase where floor plans, sections, elevations and building systems are created. It is the footprint of the building which in order to house all of the building functions.

3.1 Multi-Layer Schematic Structure

Suitable case can be found immediately and effectively while searching data. Besides, it also can be found by different point of view and skillful inference. Thus, the knowledge of how to design house by expert can be specified as the criteria of three views.

(1) The point of view on location/section, e.g., business section, residential district, etc.

(2) The point of view on building type, e.g., mixture of residence, apartment complex, etc.

(3) The point of view on configuration, e.g., 3* bedroom, 1* living room and 1 * kitchen.

According to our observation, HCBR can be separated into 3 layers.

Layer1 : Site layer

Layer2 : Building layer

Layer3 : Room layer

3.2 Multidiscipline Schematic Attribute

3.2.1 Architectural Language

From theory by Perice and Morris [17], the analysis of symbols structure is to discuss the relations between the elements that construct the symbols. This relation can be divided into three layers based on its properties, which are qualisign, sinsign, and legisign. The study of such relations is syntactics. Language expert from M.I.T., Chomsky, has the most influence on language symbol study. His language structure theory included two layers, deep structure and surface structure. As shown in Figure 3.1, the surface structure is evolved from deep structure through generative rule.

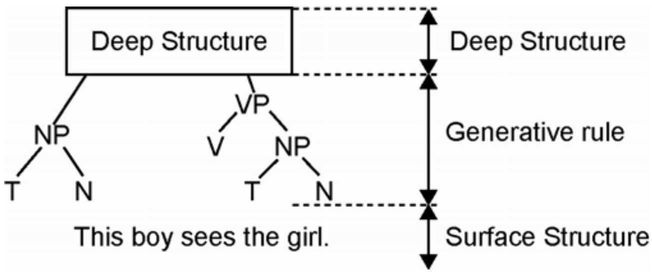


Figure 3.1 The language structure

According to our observation, we can consider architectural as a language [9] that can be divided to Syntactic, Semantic, Pragmatic, as shown in Figure 3.2.

(1) Syntactic: Rules of space topology. For example, the sequence of space is from entrance to living room and from living room to each subsequent room.

(2) Semantic: Meaning of space. For example, in the view of physics theory, entrance is not suitable to be placed opposite of the door of balcony at the back.

(3) Pragmatic: The real meaning of space topology in current situation. For example, small suite is more popular in city but less popular in countryside.

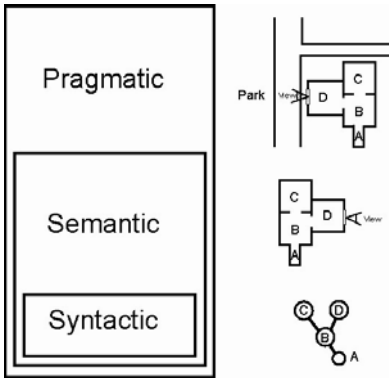


Figure 3.2 The architectural language

3.2.2 Schematic design flow

Architectural plane [2] [3] [10] [20] is a series of space combination. This combination represents the relation and interaction between spaces, and it is called genotype. Space area including external environment (dimension, scale) which affects the location and appearance of the building is called phenotype. Figure 3.3 shows a typical genotype and has different representation on phenotype due to external factors.

(1) Genotype :

Genotype is a general term for all of the genes in human body [15]. It is also termed as inheritage type, is the sequence or combination of human genes, or the inheritage materials in cells.

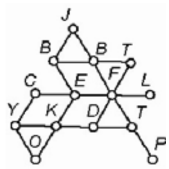


Figure 3.3 The topology of architectural

(2) Phenotype :

Phenotype is the external appearance and behavior of human body. It is also termed as surface type, is the external appearance of inheritage characteristics.

Schematic design process

Through above, we can know that schematic design process is the process transformed from genotype to phenotype. Please refer to Appendix C in details.

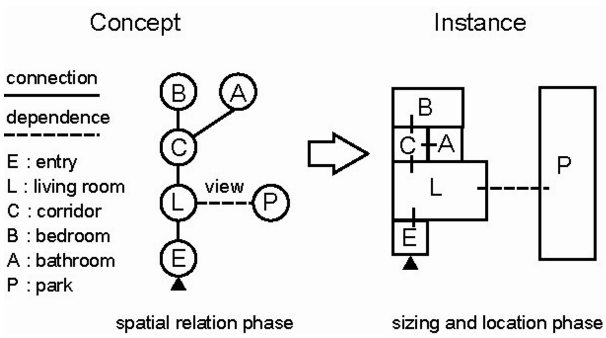


Figure 3.4 The schematic design process

Step1 : Define symbol. Every space has a symbol to express the number and area of the space.

Step2 : Draw bubble diagram. Bubble diagram expresses the relation between spaces. Depending on activities and space topology, it has different combinations.

Step3 : Size the space. Define the dimension of space area, scale relations and fill in the node of bubble diagram.

Step4 : Locate the space. Define the relation between space and external factors. For example, if there is a park outside the building, living room should be opposite of the park.

Step5 : Create space function. Space topology should fulfill its ability on carrying out its function and should satisfy artistic and structural requirements.

According to our observation, we classify the exam item to 4 parts:

(1) Subject

(2) Usage

(3) Topology

(4) Constraint rule

A simple sample of exam item

Based on design process above, we classify the exam item into 4 parts as below.

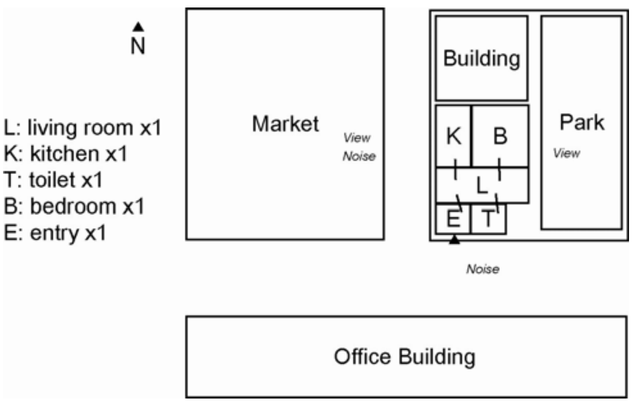


Figure 3.5 The layout of architectural exam item

(1) **Subject** :

(1-1) My single suite.

(2) **Usage**

(2-1) I want a seated north and heading south home.

(2-2) My living room and bed room are possessing good view, and far away from noise.

(2-3) I hope that my bed room may not be smaller than 18 m^2.

(3) **Topology**.

(3-1) My house entry should be away from road.

(3-2) I hope to connect that all spaces through living room.

(3-3) I can see a distant place when I am washing dishes.

(4) **Constraint Rules**

(4-1) On account of the consideration of private authority, I hope that the private level of space from entrance to inner space can be discriminated to semi open, open and private.

3.3 Schematic Attribute Property

The requirement of design can be classified to interior requirement and exterior requirement; for exterior requirement, physical environment (e.g., wind, sun light) and the interaction between space and environment (e.g., view, noise) are needed to consider. For interior requirement, the consideration will change according to different construction types (i.e., the space design of residence house and building are different), we will discuss the requirement of residence in this section.

1. External (environment)

(1) Uniformity : no direct facing can be divided to light and wind (i) Light, i.e., when there is only one window open up inside a room, it will produce glare phenomena (ii) Wind, i.e., Draft occurs when the entry and exit of room (door or window) are aligned.

(2) Orientation : there are absolution and none absolution direction

(i) Absolution direction :

Light, i.e., room with a western exposure.

Wind, i.e., northeasterly season wind.

(ii) None Absolution direction, e.g., **view**, **noise**, etc.

2. Internal (Design required of small house)

(1) The sequence of syntactic, i.e., It is not advisory to have kitchen ahead of bedroom.

(2) Size of entrance. Places after the main entrance must only be vestibule, living room or porch.

(3) Room inside room is prohibited, i.e., Study room in the bedroom.

(4) Not more than one door in a room (closed space).

(5) Toilet should not exist in the kitchen.

(6) Toilet is prohibited to face directly with master bedroom.

(7) Not advisory to place toilet just beside master bedroom door.

(8) Gas stove is placed near window.

(9) Bedroom area can not be larger than living room.

3. Degree of space privacy

Degree of space privacy can be divided into 4 categories

(1) Open, e.g., living room, tunnel, etc.

(2) Semi open, e.g., dining room, kitchen, etc.

(3) Semi private, e.g., intermediate space.

(4) Private, e.g., bed room, study room, toile, etc.

Based on the degree of space privacy, the sequence of space is ***Open area*** > ***semi open*** > ***semi private***> ***private***.

As shown in Figure 3.6, we can use cognitive map [14] to indicate the relation of requirement including limit of design and requirements.

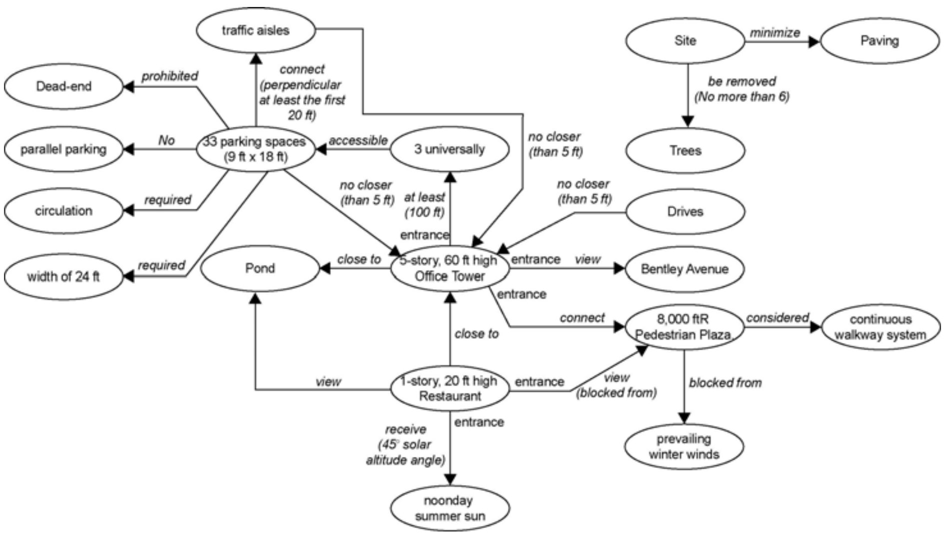


Figure 3.6 The limitation and requirement of design

3.4 Schematic Attribute Property

As mentioned above, we represent case in 3 layers including location/section, building type, configuration, where each layer can be divided to 3 views including usage, topology and constraint rule as shown in Figure 3.7. We focus on schematic design here and only the usage of the design of view of layer1 and layer2 will be discussed.

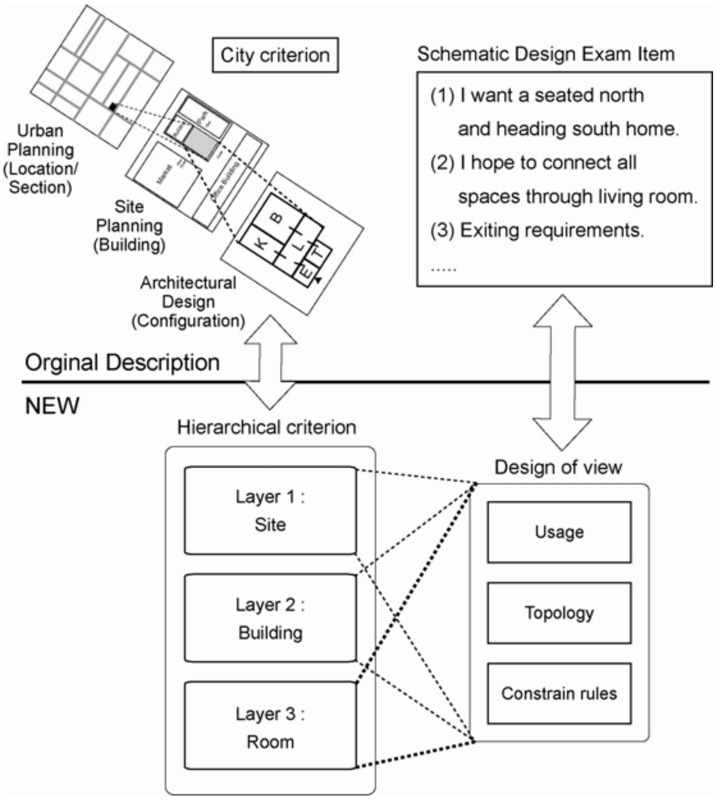


Figure 3.7 The traditional design using our propose model

Definition 3.1 Case in a three-tuple

Hierarchical CBR Structure, HCBR ={L, N, R}, where

1. L = {$layer_1$, $layer_2$, …, $layer_n$} is a point of view.
2. N={$node_1$, $node_2$,…,$node_n$} is a member of layer.
3. R={HP}, HP includes relations “Has-Part”.

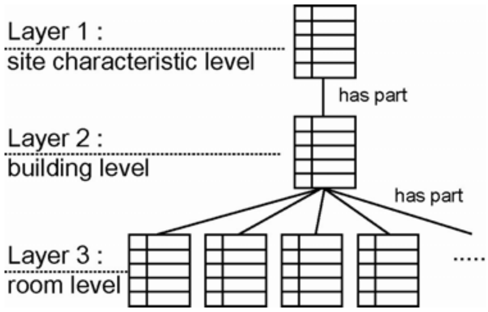


Figure 3.8　A case of HCBR

(1) Layer (L)

Layer 1 : Site characteristic level, i.e., layer1 in Figure 3.7 : location /section which explains the degree of site usage and important information of layer 2 and layer 3 respectively.

Layer 2 : Building level, i.e., layer2 in Figure 3.7 : building type which explains the types of building, containment of space, etc.

Layer 3 : Room level , i.e., layer3 in Figure 3.7 : Configuration which explains the characteristic of each room, e.g., area scale, external requirement.

(2) Node (N)

Each node expressed by frame knowledge is an object coming after instance, based on the consideration of extension; we have ontology to explain category that can produce object. The ontology owns “a-kind-of” and “IS-A” relationships between the classes of comparison in future [1].

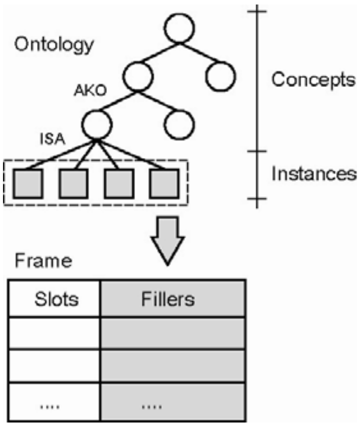
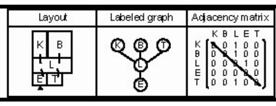


Figure 3.9 The mapping between frame and ontology

Algorithm 3.1 Ontology-to-Frame Algorithm
Input: Input related ontology according to layer.
Output: Frame
Step 1. List the knowledge case set for the ontology, ontology knowledge classes contained classes, and relationship.
Step 2. Choose related attribute according to requirement.
Step 3. Copy attributes to frame slot.
Step 4. Fill in suitable rule to frame.

Table 3.1 The data types of case

Data type	Name	Possible Value	Tag
string	direction	("east","west","south","north")	[D]
	spatial level	("public","semi-public","private")	[SL]
	level	("site","building","room")	[L]
	house type	("apartment complex","studio condominium","apartment")	[HT]
number (category)	coordinates	(x, y)	[C]
number	distance	number	[N]
string (category)	spatial connection	("room_1","room_2")	[SC]
	environment factor	("view","noise","light","wind")	[EF]
matrix	genotype		[M]

(3) Edge (E): Has-part. Currently, we only have one type of relationship between frames.

Detailed explanation for each layer is listed below:

Layer 1 : Site characteristic Layer

The main function of site characteristic layer is to describe the location as shown in Figure 3.10; besides, information of layer2 and layer3 are also included e.g. space arrangement, squire size. Therefore, information can be completely received and compared when searching on first stage, required property of first stage are listed below.

(1) The character of base, e.g., zone.

(2) The intensity of usage, e.g., Building Bulk Ratio, Coverage Ratio, etc.

(3) The construction style, e.g., house, office building, etc.

(4) The space arrangement, e.g., 2 x Bedroom and 1 x Living room,

(5) The square size

(6) The using floor

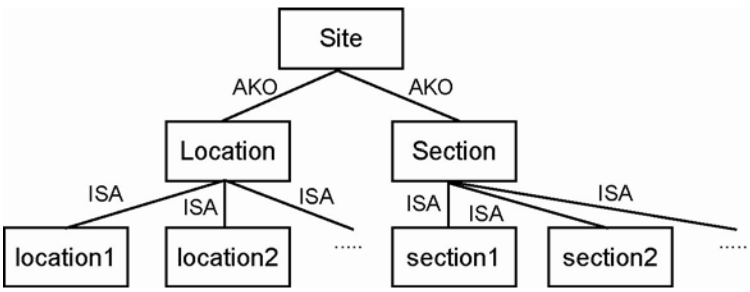


Figure 3.10 The site ontology

Layer 2 : Building Layer

This stage is mainly explaining the classification of architectural building as shown in Figure 3.11, the required property of stage 2 is listed below.

(1) The construction style, e.g., house, office building, etc.

(2) The space arrangement, e.g., 2 x Bedroom and 1 x Living room.

(3) The square size and using floor

(4) The construction character = (E, V, M, R, L, C, P, I, G)

The main explanations of construction character are showed in Table 3.2.

Table 3.2 The construction characteristic of building

Tag	Construction character	Description
E	Elevator	Elevator inside residence, usually for vertical transportation.
V	View	Generally 5 floor above possess enough view.
M	Mixed space used	Application of space function, i.e., living room, dining room, bed room are sharing same space.
R	Complex residence	Numbers of residence family in same story.
L	Low complexity activity	The complexity of people coming in/ going out of residence space.
C	Cross maisonette	Intermediate layer room and floor in the floor, usually for height raising space.
P	Parking	Parking space, usually in basement.
I	Infrastructure	Service type of facility, e.g., swimming pool.
G	Guard	Safety guard.

In Table 3.3, the characteristic of different construction types are explained, i.e., town house contains the characteristic of low complexity activity and infrastructure required.

Table 3.3 The look up Table of building characteristic

Level / Character / Type of house	Level 2 : Building Level								
	elevator	view	mixed space used	complex residence	low complexity activity	cross maisonette	parking	infrastructure	guard
apartment	╳	╳	╳	╳	○	╳	╳	╳	╳
studio condominium	○	○	○	○	╳	○	○	╳	○
apartment complex	○	○	╳	○	△	╳	○	○	○
town house	╳	╳	╳	╳	○	╳	╳	○	╳
mixture of residence and commerce	○	○	╳	○	╳	╳	○	╳	○

Satisfy ○ Partial Satisfy △ Not Satisfy ╳

(5) The view direction

(6) The noise direction

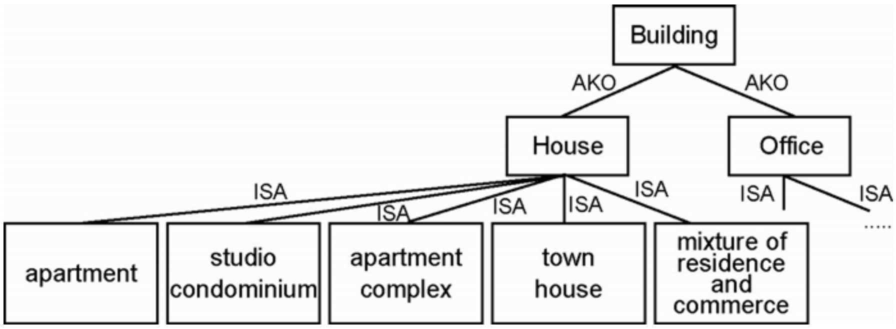


Figure 3.11 The building ontology

Layer 3 : Room Layer

This stage is applied mainly to describe the configuration of space, Figure 3.13, describes the characteristic of each space and the relations of spatial connection. The required property of stage 3 is listed below.

(1) The name of space

(2) The area size

(3) The private level

(4) The space required, e.g., view, wind, etc.

(5) The space refuse, e.g., noise.

(6) The relation type = (C, D, A, P, I), Space connection rule can be divided into different types as below.

Table 3.4 The relation type of space

Tag	Type	Descript
C	Connection	Direct connection characteristic between spaces, i.e., master bed room will connect with a bath room space.
D	Disconnection	Disconnection characteristic between spaces, i.e., dining room will not connect with toilet.
A	Adjacency	Adjacency characteristic, e.g., living room, dining room and kitchen will be adjacent to each others.
P	Dependence	Possess a visible requirement but can not reach directly, i.e., living room needs a view, so it needs to face towards park.
I	Independence	Possess an invisible requirement and also cannot reach directly, i.e., avoid from noise, living room doesn't need to face towards road.

Definition 3.2 Adjacency matrix

The adjacency matrix of a finite directed graph G on n vertices is the n × n matrix where the nondiagonal entry a_{ij} is the number of edges from vertex i to vertex j, and the diagonal entry a_{ii} is either twice the number of loops at vertex i or just the number of loops. There exists a unique adjacency matrix for each graph, and it is not the adjacency matrix of any other graph. In the special case of a finite simple graph, the adjacency matrix is a (0,1)-matrix with zeros on its diagonal. (Reference from WIKI)

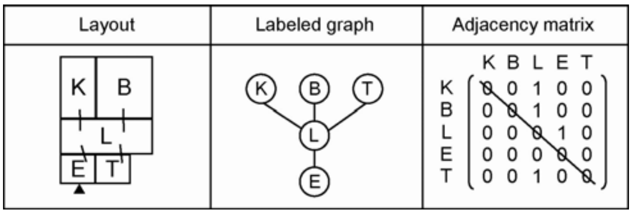


Figure 3.12 An example of label graph and adjacency matrix

(7) The center coordinate

(8) The relative distance to center coordinate of house

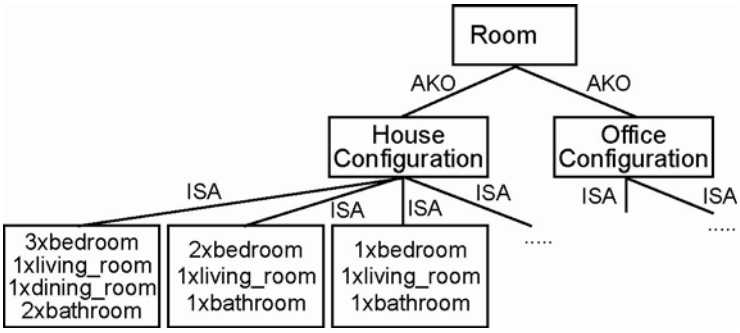


Figure 3.13 The room ontology

Detailed explanation of *node* is listed below:

Frame-Based Knowledge Representation

Frame-Based Knowledge Representation proposed by Mawin Minsky in 1975 is primarily used to develop new specialist system. Frame-Based Knowledge Representation mainly consisting of frame name, relations between frames, slot value, default slot value, slot value area/field, and procedure information (Negnevitsky, 2002) is used to describe our knowledge.

Table 3.5 The components of frame

Component	Description
Frame name	After area knowledge is divided by specialist into each knowledge frame, the knowledge behind each frame will be named and each knowledge frame is representative of the sub-area knowledge consisted in that area.
Relations between frames	Describe the relation between knowledge frames, i.e., inheritage relations between parents & sub-group, and relations between frame of the same level and interaction between knowledge frames based on the relations.
Slot value	Each knowledge frame contains one or more properties, when processing to certain property, data are filled (categorized) to that property. Symbols, numbers and Boolean can be used to represent slot value.
Default slot value	Under start-up condition or default condition of property that yet to be inferred, default slot value is used for operation.
Slot value area	Appropriate /probable area is set based on data properties.
Procedure information	When system is processing inference, it will meet with either of the two cases as below: (i) When changed: Related inference rules will be processed when slot value changes. (ii) When needed: Related inference rules will be processed when certain requirement, conditions and data are needed.

From the Table above, we know that frame name which is the same as category name contains its properties and methods. When inference is processed, knowledge frames will not affect each other but operate independently. From the interaction between frames, information can be transferred between frames are possible, and the description of relations between frames, is similar with interaction among the same level and inheritance relation between different levels. Therefore, we know that frame-based Knowledge Representation has the properties of object encapsulation and inheritance. In AI (Artificial Intelligence) area, this Representative method is also termed as object knowledge representative method. So far both represent the same method.

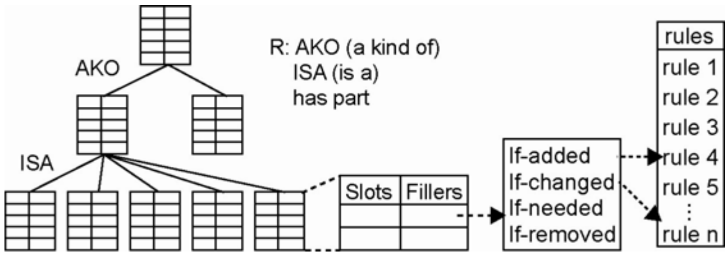


Figure 3.14 The characteristic of frame

Finally, we can use a simple example to explain our mode, as shown in Figure 3.15.

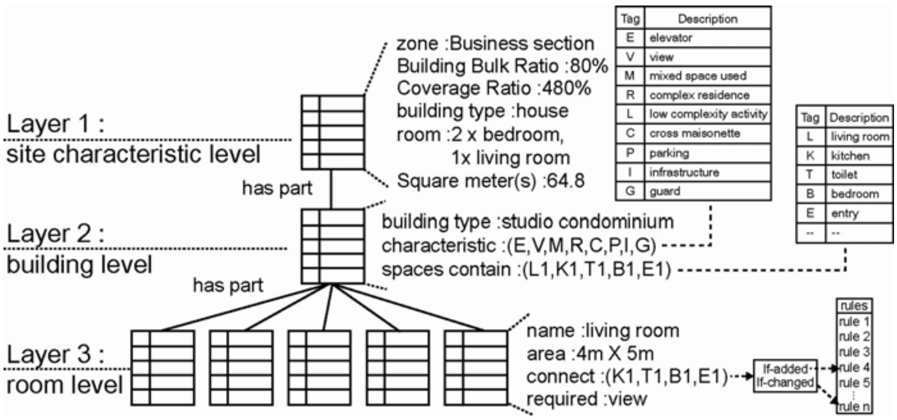


Figure 3.15 An example of HCBR

Evaluation

After modeling the architectural plans knowledge, we can evaluate them in terms of different aspects, which included expressive power, the extensibility and operative. HCBR is a hierarchical CBR framework, which is the method commonly used by expert system, and has good performance on expressive power, as shown in Table 3.6. The performance of extensibility is built up hierarchical; therefore the extension of layer is very flexible and also possess acceptable performance on the extension of frame attribute, as shown in Table 3.7.

Eventually, based on the operative, algorithm and method can be embedded to attribute and infer through trigger due to the inference ability of the frame.

Table 3.6 The expressive Power

Expressive	Our Research	Others
Modeling	Hierarchical CBR	ILL-structure
Genotype	Hierarchical relation	Bubble diagram
Structure	Frame-based	UML
Situation	○	△
Interaction	○ (1)	✕
Relation	○ (2)	△
Spatial private level	○ (3)	✕
Ontology	○ (4)	✕
Design rule	○ (5)	△

Satisfy ○ Partial Satisfy △ Not Satisfy ✕

(1) view,noise,wind,light; (2) connection,disconnection,adjacency,dependent, independent; (3) public,semi-public,private; (4) knowledge embedded; (5) frame-based (when changed, when needed)

Table 3.7 The extensibility

Extensibility	Our Research	Others
Attribute	○ (1)	○
Frame	○ (2)	✕
Layer	○ (3)	✕
Design rule	○ (4)	△
Relation type	○	△

Satisfy ○ Partial Satisfy △ Not Satisfy ✕

(1) like building style,etc.; (2) building type expand; (3) like furniture layer expand (4) algorithm, method

As a comprehensive view, our model is a knowledge model represented by ontology-based method, so that it can have well performance on knowledge description, flexibility of extension and inference.

Chapter 4　Hierarchical CBR Schematic Design (HCBRSD)

4.1 CBR Support Exam Item Design

The Hierarchical CBR Schematic Design is based on CBR framework [4] [18] [19], and the structure of frames is used to express knowledge. This can be a kind of object inheritance, and also can be used for derivation, so it is widely used by experts. From system operation of CBR structure, requirements are first set and relevant floor plans are taken out from data storage. After that, the system will retrieve several of the floor plans, called case retrieval. The user chooses to use tools provided by system to facilitate changes, is called case adaptation (include case reuse and case revise) and finally, adapted file will be set as exam paper and stored in data storage again, which is termed as case retain.

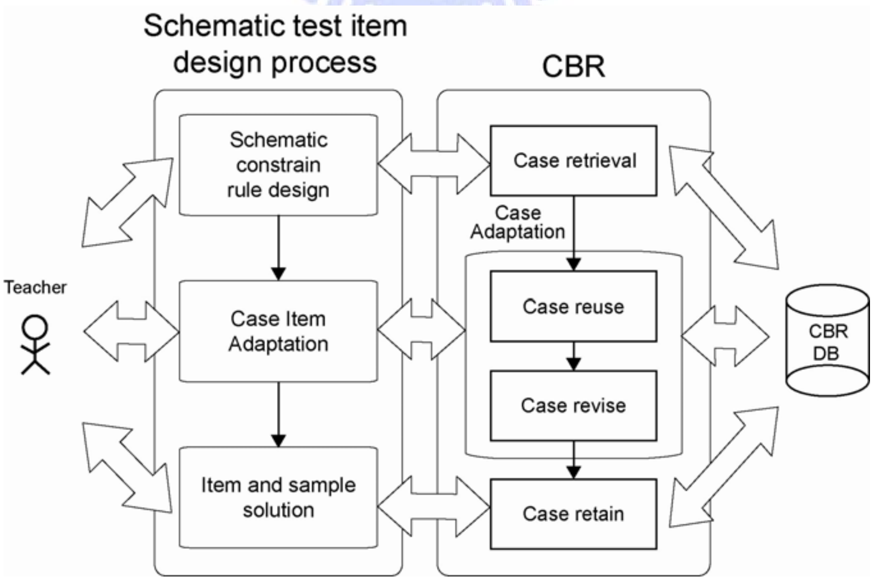


Figure 4.1　The hierarchical CBR schematic design

4.2 Case Retrieval

In the similar appraisal's situation, the system will obtain the preliminary detailed list case that is similar to the new question in the case storehouse. In this detailed list's situation, the arrangement will exist in the range of the similar score. If in the similarity grading past situation's threshold value, this case will be removed from the name list. Then, the system or the user may decide that in this kind of situation, is most similar and the best for further analysis.

Reminder is a key component of analogical reasoning through cases: in other words, a person or computer must be reminded of the appropriate case at the right time (Tsatsoulis and Williams, 2000). Retrieval is an action to recall a case in CBR. By retrieving a case from memory, a CBR system must decide which is the most appropriate case for current status based on the comparison of the degree of similarity. Therefore, the recall cases are dominated by similarity assessment and retrieval will be greatly influenced by the way the case is organized.

4.2.1 Similarity function

Similarity is used when indicating a connection between two objects [16]. Designers always compare the similarity of architectural elements to solve design problem as well as generate ideas during design process. For example, in the case of the Frank House designed by Peter Eisenman, the idea of "layering" comes from the similar form composition of the Schroder House designed by Gerrit Rietveld. So the layer of similarity is important for associating ideas. Each layer contains different data type, user can design the similarity function according to different data type, the mapping Table as shown in Table 4.1.(i) Category-based

Feature Similarity (CBFS) is for attribute comparison, (ii) Coverage Similarity (CS) is for query topology comparison, (iii) Sequence Similarity (SS) is for spatial sequence comparison, (iv) Complete Case Similarity (CCS) is for whole case comparison.

Table 4.1 The mapping Table of data type and similarity function

Similarity Function	Data type
Category-based Feature Similarity (CBFS)	string
	number (category)
	number
Coverage Similarity (CS)	string (category)
Sequence Similarity (SS)	matrix

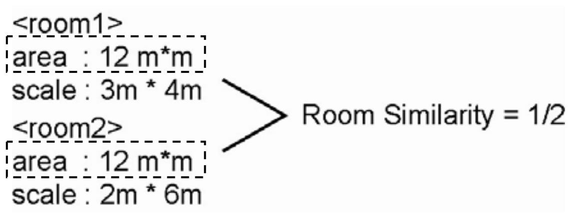
(1) Category-based Feature Similarity (CBFS) (Jaccard similarity coefficient)

Definition 4.1 Category-based Feature Similarity (CBFS)

$$CBFS=\frac{|FV_A \cap FV_{A'}|}{|FV_A \cup FV_{A'}|}$$

FVA is the Feature Value of Feature A in one case and $FV_{A'}$ is the Feature Value of Feature A in the compared case.

Example 4.1



(2) Coverage Similarity (CS)

The case is similar to the composition of the coverage and sequence similarity. Coverage similar to a similar number of genotypes refers to the ideal model case between genotype and genotypes compared to the case library cases, as well as the type of means of sequence similarity between the ideal task for the genotype and genotype compared to the case database case. In order to calculate the topological similarity of the cases, we must work to find a similar comparison of the expectations of the cases, genotype and type of the first, and take them as the same situation, the calculation of similar genotypes. The physical meaning of the scope of coverage is comparing to a number of similar tasks on the total number of tasks required for the tasks or genotype flow (depending on the different circumstances), which is defined as follows:

Definition 4.2 Coverage Similarity

1.CS = NCS * RCS is the coverage similarity between the query desired genotype pattern and the compared genotype, where

NCS is the coverage similarity of node (room).

RCS is the coverage similarity of relation (connection).

2. $$NCS=\frac{NCMatch(Px)}{TNNQ}$$,where

NCMatch() is the node (room) coverage, as shown in Algorithm 4.1.

TNNQ is the total number of nodes in the queried space.

3. $$RCS=\frac{RCMatch(Px)}{TNRQ}$$, where

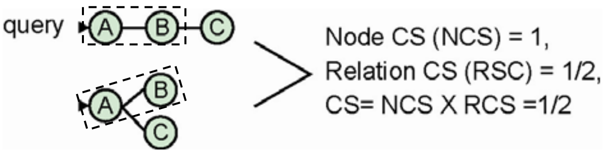
RCMatch() is the relation (connection) coverage, as shown in Algorithm.

TNRQ is the total number of relations in the queried relation.

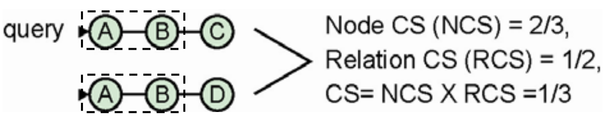
Algorithm 4.1 NCmatch
Input: Px Output: Match Definition of Symbols: CTi: The Compared spatial sequence i in the compared case Step 1. Compare Px with the spatial sequences in the case , if Max(Similarity (Px,CTi)) > threshold, then set (Px, CTm) a case pair and set Match = 1, else Match = 0 Step 2. Return Match

Algorithm 4.2 RCmatch
Input: Px Output: Match Definition of Symbols: CTi: The Compared spatial sequence i in the compared case Step 1. Compare Px with the spatial sequences in the case , if Max(Similarity (Px,CTi)) > threshold, then set (Px, CTm) a case pair and set Match = 1, else Match = 0 Step 2. Return Match

Example 4.2 (a)



Example 4.2 (b)



(3) Sequence Similarity (SS)

For sequence similarity, the main idea is to find similar possible sequence, where the possible sequence is the combination of every two genotypes in case. For example, there are 3 combinational pairs A->B, B->D, and A->D for task flow A->B->D. In order to calculate sequence similarity, first step is to find similar sequence pairs, which means two A->B and A'->B', A->B is in desired task flow and A'->B' is in the compared task flow, where (A, A') and (B, B') are two similar case pairs. The sequence pair similarity is the similarity average of 2 similar cases which is showed in Example 4.3, and the overall sequence similarity for a case is to equalize each similar sequence pair among all possible sequence. The definition is shown as follows:

Definition 4.3 Sequence Similarity

1. SS = NSS * RSS is the sequence similarity between the query desired room private level and the compared genotype, where

NSS is the sequence similarity of node (room).

RSS is the sequence similarity of relation (connection).

2. $$NSS=\frac{NSMatch(Px)}{TNNS}$$,where

NSMatch() is shown in Algorithm 4.3

TNNS is the total number of nodes in all cases.

3. $$RSS=\frac{RSMatch(Px)}{TNNS}$$,where

RSMatch() is shown in Algorithm 4.4

TNRS is the total number of relations in all cases.

Sq = (ST, DT) is the possible sequence generate from the query desired flow

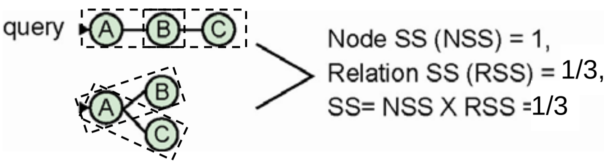
ST ={t_1, t_2,.. t_n} is the source genotype in genotype sequence

DT ={t_1, t_2,.. t_n} is the destination genotype in genotype sequences

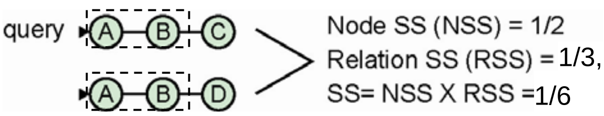
Algorithm 4.3 NSmatch
Input: Sq Output: NSMatch Step 1. Find if there is a matched sequence node in the compared case spatial sequence, if found then go to step 2, else end. Step 2. NSMatch = (TSSimilarity(ST) + TSSimilarity(DT)) / 2 Step 3. Return NSMatch

Algorithm 4.4 RSmatch
Input: Sq Output: RSMatch Step 1. Find if there is a matched sequence relation in the compared case spatial sequence, if found then go to step 2, else end. Step 2. RSMatch = (TSSimilarity(ST)+ TSSimilarity(DT)) / 2 Step 3. Return RSMatch

Example 4.3 (a)



Example 4.3 (b)



(4) Complete Case Similarity (CCS)

In complete case retrieval, a complete case similarity is calculated to retrieve an integral case, which is most similar to, desired case, in which both cases featuring table similarity and case genotype are used. For the case feature Table, it means to find out the average similarity between each feature Table. The complete case similarity is defined as below:

Algorithm 4.5 Similarity comparison process
Input: Case Output: Case Number Step 1. Test if similarity Layer1 of Retrieved Case < threshold. True -> Return NULL Step 2. Test if similarity Layer2 of Retrieved Case < threshold. True -> Return NULL Step 3. Test if similarity Layer3 of Retrieved Case < threshold. True -> Return NULL False -> Return Case Number

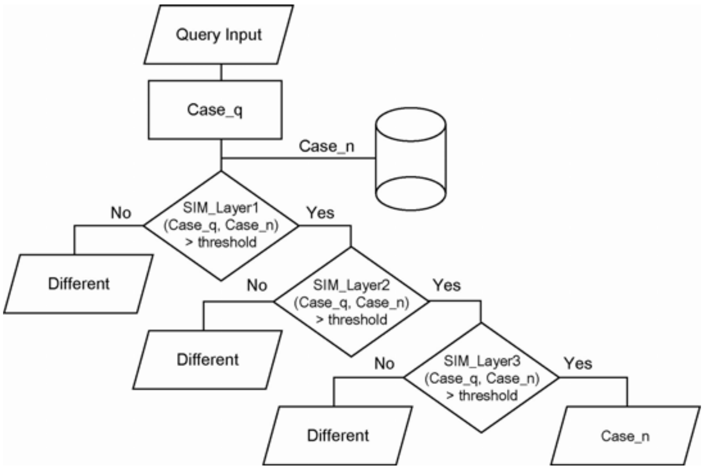


Figure 4.2 The hierarchical query process

(i) SIM_Layer1 (Case_q, Case_n) = ∑CBFSn(Case_q, Case_n)

(ii) SIM_Layer2 (Case_q, Case_n) = ∑CBFSn(Case_q, Case_n)

(iii) $SIM\_Layer3(Case\_q, Case\_n) = \sum\{CBFSn(Case\_q, Case\_n) + CSn(Case\_q, Case\_n) + SSn(Case\_q, Case\_n)\}$

Example 4.4

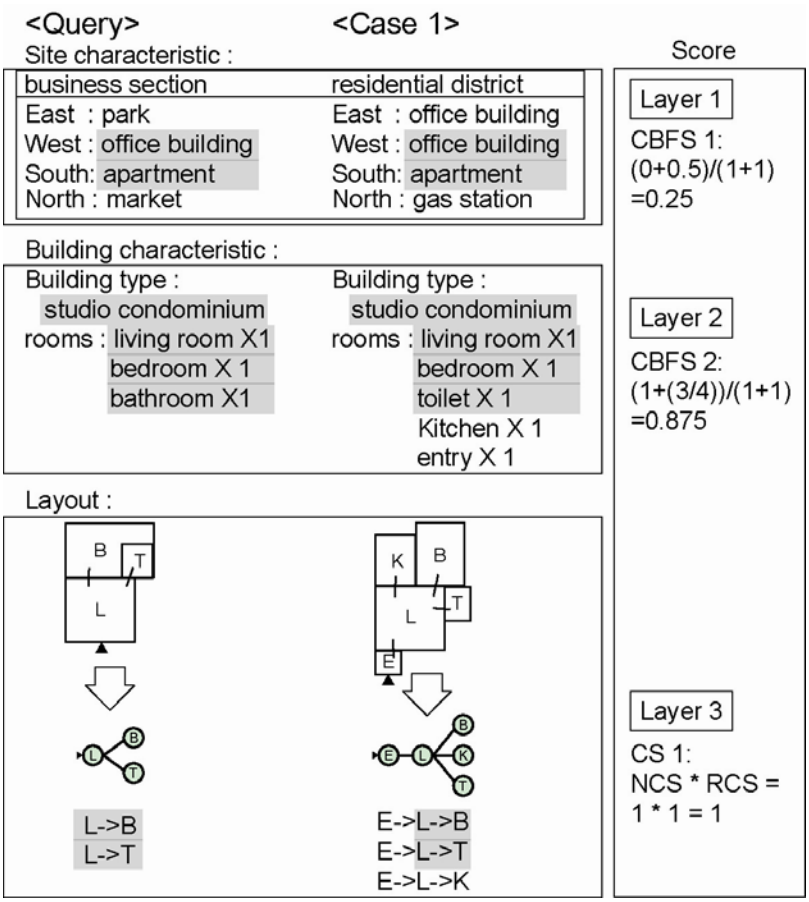


Figure 4.3 An example of similarity calculation

4.3 Query Language and Intelligent Query Generator (IQG)

Query language (QL)

Based on the concept above, we define a set of regular grammar, called the Query Language (QL), where the grammar rule of QL can be used to model the schematic query, the non-terminals of QL represent the query run-time status, and the terminals of QL represent the actions the examinee can perform.

Definition 4.4 Query Language

Query Language is a 5-tuple, QL= (N, ∑, P, S, γ), where

1. N is a finite set of non-terminal, which represents the run-time status of specific query.
2. ∑ is a finite set of terminals, which represents the actions that the query can perform, e.g., attribute select.
3. P is a finite set of production rules, which represents the action performed by the query and the next run-time status of specific query. A production rule needs to satisfy one of the following forms..
4. S is the starting symbol, which represents the initial run-time status.
5. γ is a finite set of action symbols, which is defined on ∑ to trigger corresponding action routine.

Table 4.2 The description of QL symbols

Type	Symbol	Descript
Non-terminal	S	The starting query symbol.
	Q	The query symbol.
Terminal	AND	The Boolean operation symbol.
	OR	The Boolean operation symbol.
	.	The location symbol.
	<LAYER>	The layer of HCBRSD.
	<FRAME>	The frame of HCBRSD.
	<ATTRIBUTE_CONSTRAINT>	The attribute of frame.

The production rule of QL

S -> S | Q

Q -> Q AND Q | Q OR Q

Q -> <LAYER>. < FRAME >. <ATTRIBUTE_CONSTRAINT>

Example 4.5 The QL for User Interface

```
SELECT_WHERE
(   layer1.building_type == "studio condominium" OR
    layer1.building_type == "apartment complex") AND
    layer1.square_meter < 64   AND
    layer1.square_meter > 30   AND
    layer1.space_contain == {L, B, T} AND (
    layer2.characteristic == "mixed space used" OR
    layer2.characteristic == "low complexity activity" OR
    layer2.characteristic == "cross maisonette" OR
    layer2.characteristic == "guard"   )
```

Intelligent Query Generator (IQG)

When there are too many conditions of query, it is difficult to find a suitable case. However, a limited number of conditions will generate a lot of cases, which require filtration of these cases. One needs to accurately specify the conditions to domains to find the most suitable case. Therefore, we propose a set of query language which can convert our query in use to condition-based, for the ease of system operation. After that, the conditions set can be converted to exam questions. The IQG attempts to help a user to retrieve efficiently

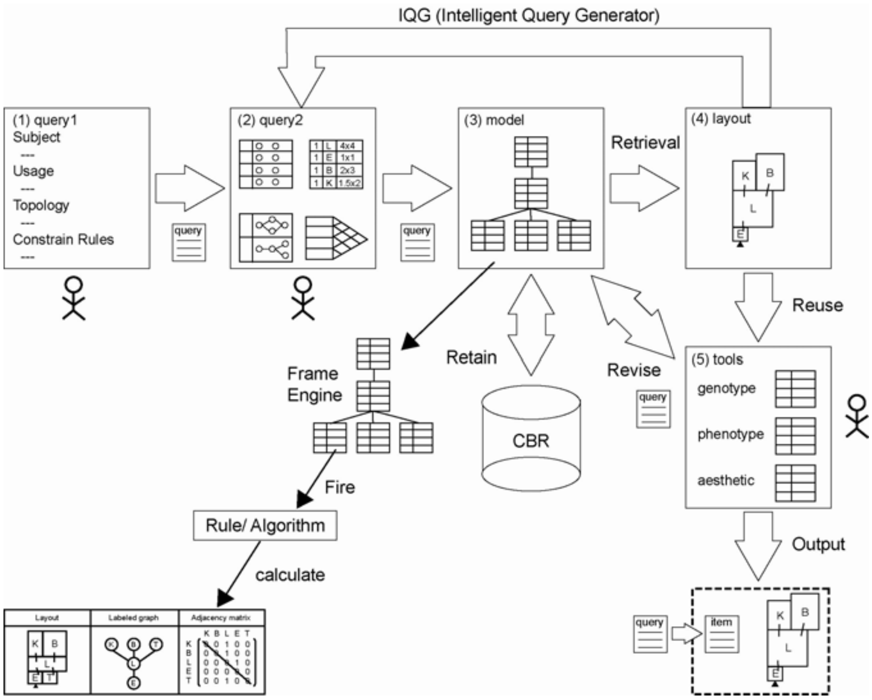


Figure 4.4 The IQG

IQG's physical meaning is assisting in exam item generation, the reasons of using IGQ are (i) Simple query will results in many results. (ii) Complex query results in few results. (iii) Key feature search must be precise on domain. We can improve search results by applying add /remove query constraint. We also can analyze and classify the query and propose the suggestion for next query.

Classification is an arrangement to sort out thing according to actuality or similarity of compare objects into classes or groups. According to association rule, when recalling something in mind there must be something else related to this, therefore we can find out same class or group in accordance with this association relation. Everything possess its own character to show the different between objects which is the foundation of classification, based on this statement, our classification is defined as property classification.

Example 4.6 Query classification (can be found in Table 4.3, Table 4.4)

When user input query, we will analyze query data first and suggest suitable query conditions after checking through Table. So we don't need to know the accurate search conditions for initial query, and the knowledge of saving amended/modified floor plan to models.

```
SELECT_WHERE
  layer2.characteristic == “mixed space used” OR
  layer2.characteristic == “low complexity activity” OR
  layer2.characteristic == “cross maisonette” OR
  layer2.characteristic == “guard”;

Suggestion of query direction :
"studio condominium"
```

4.4 Case Adaptation

Case Adaptation is the process of transforming former case to become new case. Case-Based Reasoning mechanism is basically performed by searching similar case through selecting suitable case, through the methods proposed in our research (1) Configuration process and (2) Self-verify mechanism, the usable structure can be maintained and fit the current needs by modifying space relations and attributes. Self-verify mechanism will help to check the rationality of revise process automatically, to ensure it follows the design rules and allows teachers focusing on design level.

4.4.1 Configuration process

Rapid case adaptation relies on reliable schematic design and knowledge reuse. Configuration process borrows the principles of schematic design and applies them to process schematic design on different view.

(1) **Genotype configuration process** : The process is used to assist teachers in amending/ modifying the characteristic of space relations

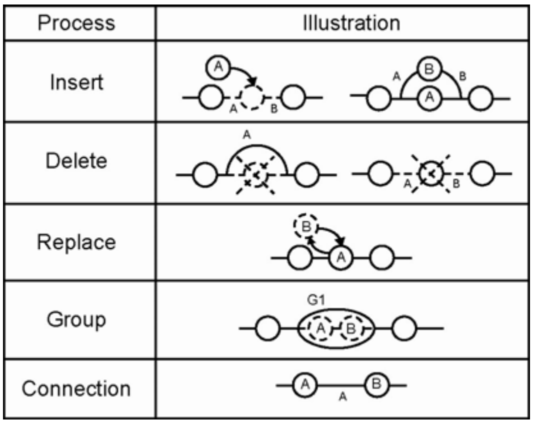


Figure 4.5 The configuration process

(i) Insert process (IR) : The schematic design can be modified with the Insert process while defining the genotype or route during the schematic design.

(ii) Delete process (DR) : This process specifies the cancellation in a route during schematic design : either combines the left and right spaces after removing the middle space or leaving empty (without combination) for the left and right spaces.

(iii) Replace process (RR) : This process determines the replacement or substitution processes in a route and gives an alternate option of identical capability during schematic design.

(iv) Group process (GR) : This process identifies processes utilizing the same resources of node and replaces them with a single process.

(v) Connection process (CR) : This process offers process to connect the nearest node during schematic design.

(2) **Phenotype configuration process** : this process is used to amend/modify based on the real size of space.

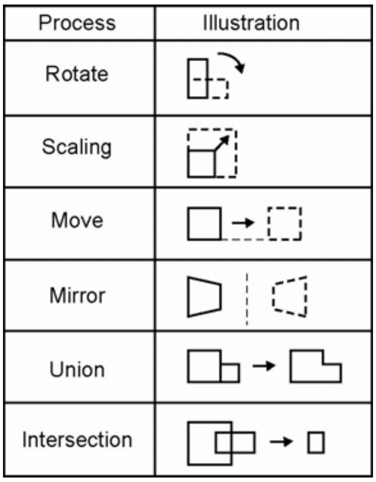


Figure 4.6 The elementary process

(3) **Aesthetic configuration process** : this process is used to amend/modify based on aesthetic point of view.

Process	Example
Continuous	AAAAA...
Gradient	ABCDE...; ZYXW...
Symmetrical	...CBABC...
Contrast	A<-->Z; B<-->Y
Proportion	1:1.618
Balance	ABC | XYZ
Harmonizing	Code Color ; Warm Color
Rhythm	ABB ABB ABB ...
Complete	A~Z
Integrate	Style : Baroque /Rococo

Figure 4.7 The aesthetic process

How to save amended/ modified floor plan to model, when we complete modifying case, system will apply the modified content automatically to corresponding model.

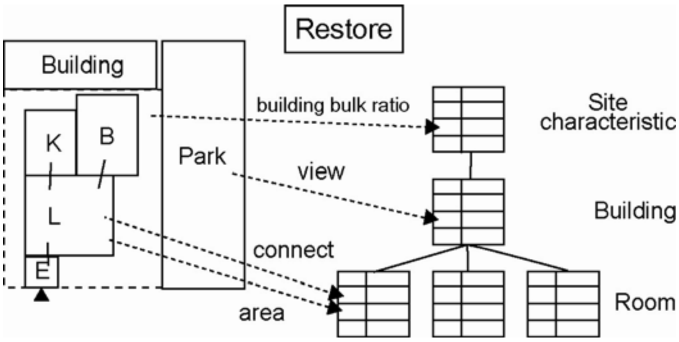


Figure 4.8 The illustration model restoring

4.4.2 Self-Verify mechanism

A method is a procedure associated with a frame attribute that is executed whenever requested. We proposed a method for a specific attribute to determine the attribute's value or execute a series of actions when the attribute's value changes.

Spatial arrangement check

For instance, in a small house we are unlikely to enter kitchen before bedroom, so we will label the level of spaces and check the link connection of each level between spaces.

Method : ***Security Level***

Open area >semi open > semi private > private

Dependent check

Again take small house as our example, the entry front door cannot be directly facing to back door.

Method : ***Block or not ?***

So we will set up a line from front door to back door and check if there is any existing obstruction on this line, no obstruction means the front door is face to back door directly.

Example 4.7 The calculation of space level

On account of the consideration of private authority, we hope that the private level of space from entrance to inner space can be discriminated to semi open, open and private. Here is an example of reasoning by frame.

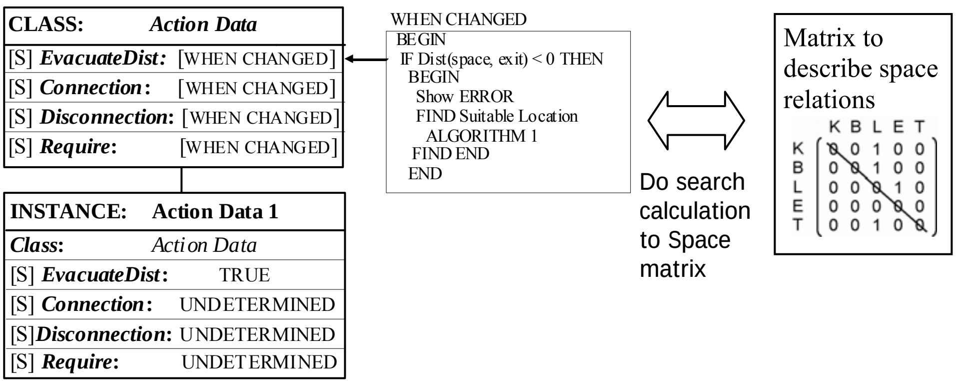


Figure 4.9 An example of space level check

Chapter 5 Implementation and Design

5.1 System Design

This is the recommended system user interface. From interaction with users, it can convert the selected data/information on the screen to query sentence, through query language of query generator. The query sentence can be interpreted for calculation processing. The application is shown below.

Step 1 : Welcome note screen

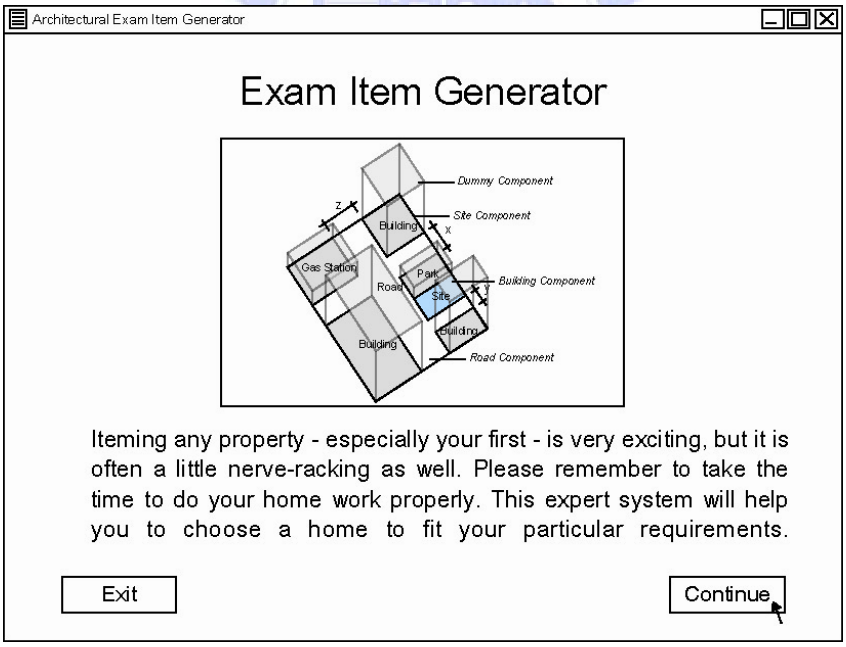


Figure 5.1 The welcome screen

Step2 : Users are required to select city, location, section, zone type, etc. based on their environment conditions and the degree of usage.

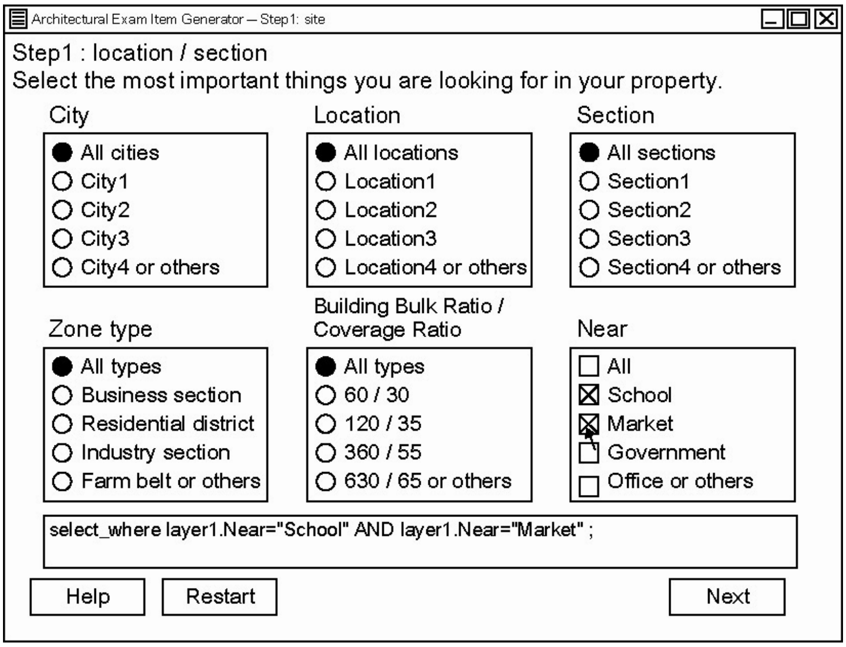


Figure 5.2 The location/section query display

Step 3 : Users are required to select building type, floor, etc. based on the characteristic of the buildings.

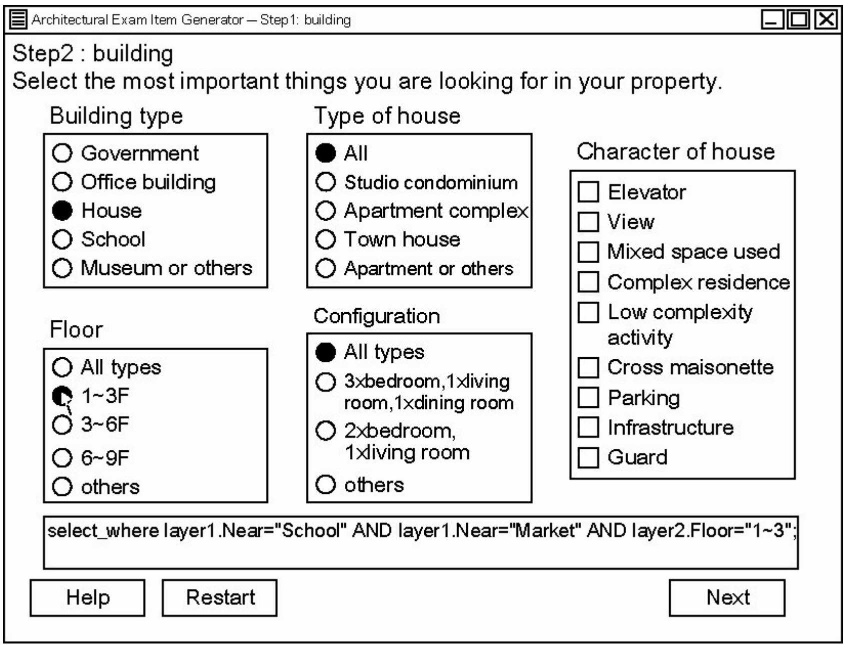


Figure 5.3 The build characteristic query display

Step 4 : Users are required to select based on space arrangement and constraints.

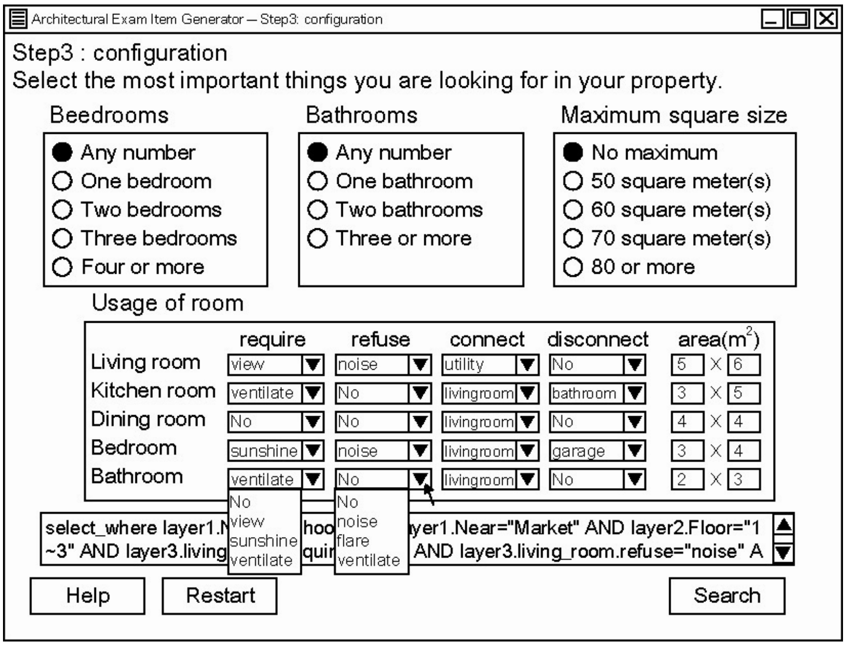


Figure 5.4 The configuration query display

Step 5 : Results and detailed case information are shown.

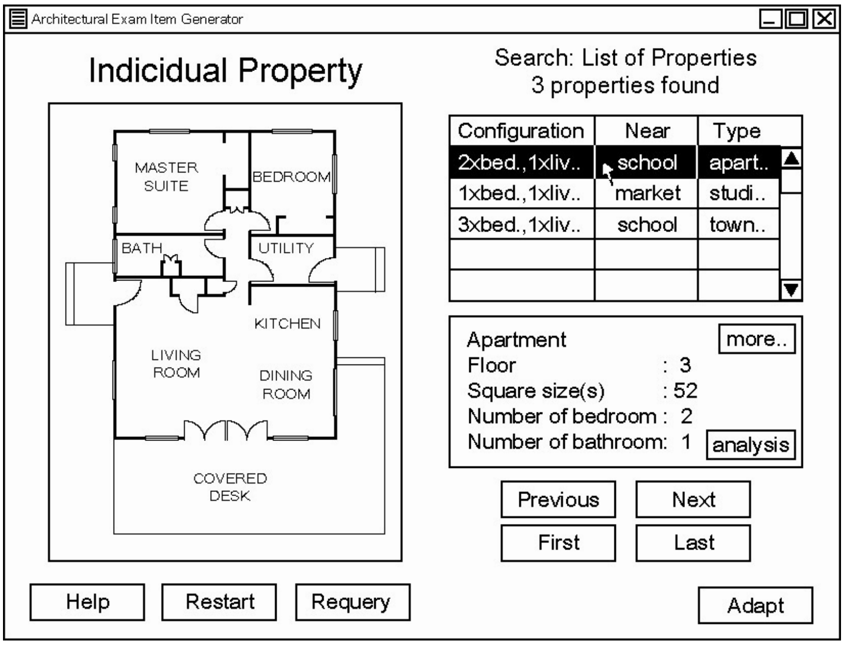


Figure 5.5 The information display

Step 6 : Edit on the selected case.

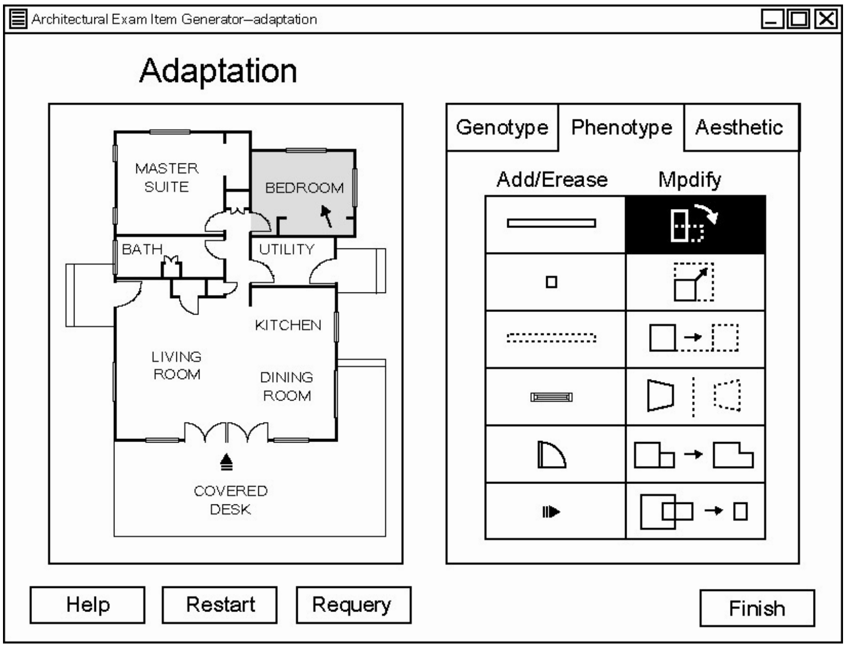


Figure 5.6 The modify tool display

Step 7 : Convert the edited result to an exam question and provide a layout.

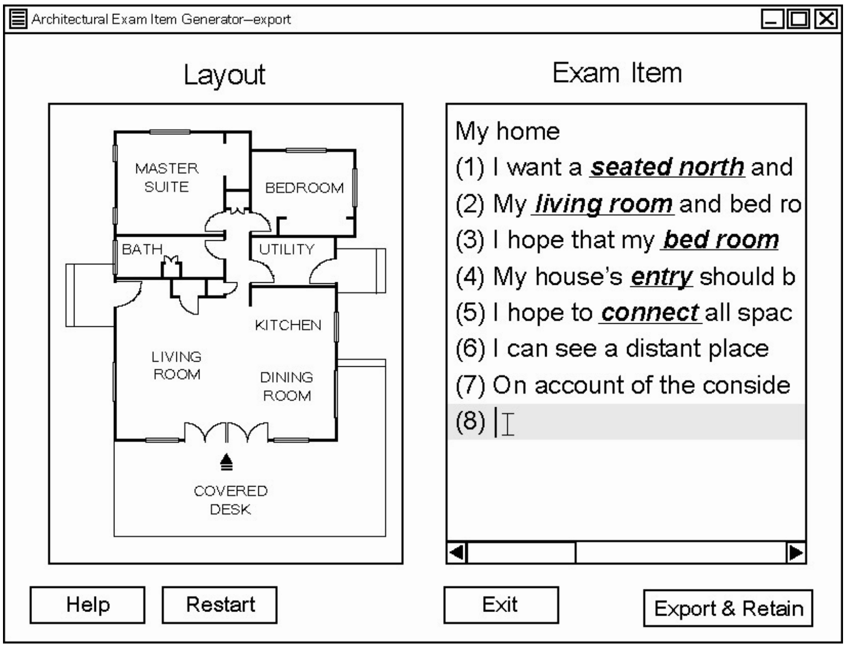
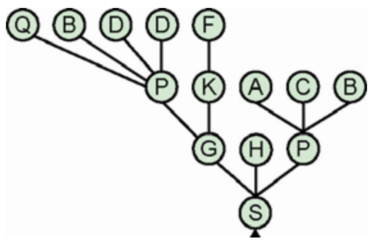


Figure 5.7 The item editing screen

5.2 Topology Similarity Implementation

Based upon HCBR, we have implemented the system for topology retrieve. We use the model operation framework of a compiler to operate our model and using the parser generator tool (Bumble-Bee 2.07) of Lex / Yacc to establish our own complier system. We encode the spatial organization to a formula in which the spatial node is represented by alphabet symbol A, B, etc. The spatial relation (edge) is represented by operator in which operator "*" represents serial connection and operator "+" represents parallel connection.



S*(G*(P*(Q+B+D+D)+K*F)+H+P*(A+C+B))

Figure 5.8 An example of spatial encoding

Step 1 : Interactive UI

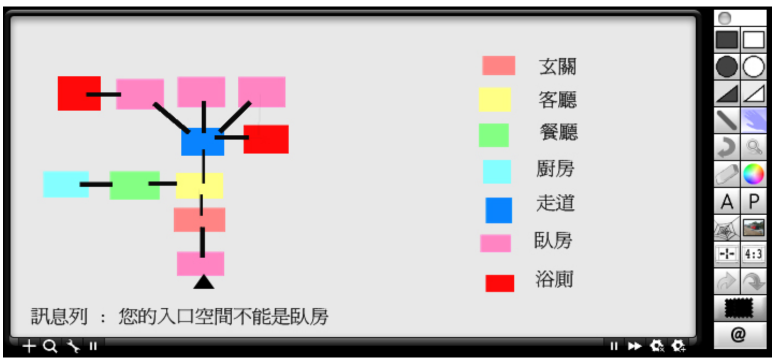


Figure 5.9 The user interface

Step 2 : Encoding

```
drawImage(0, false, "R", "#FF8080", 530, 30, 561, 49);
drawImage(1, false, "R", "#FFFF80", 532, 59, 562, 82);
drawImage(2, false, "R", "#80FF80", 533, 95, 562, 117);
drawImage(3, false, "R", "#80FFFF", 535, 127, 561, 149);
drawImage(4, false, "R", "#0080FF", 537, 158, 562, 182);
drawImage(5, false, "R", "#FF80C0", 537, 192, 566, 209);
drawImage(6, false, "R", "#FF0000", 536, 217, 563, 233);
drawText(0, false, "T", "#FF0000", 577, 28, 617, 49);
setText(0, "?  ?", "#000000", 255, "#E8E8E8", 255, "Courier New Bold", 20, "off", "none", "none", "");
setText(0, "?  ?", "#000000", 255, "#E8E8E8", 255, "Courier New Bold", 16, "off", "none", "none", "");
drawText(1, false, "T", "#FF0000", 584, 59, 613, 76);
setText(1, "擎W輒", "#000000", 255, "#E8E8E8", 255, "Courier New Bold", 16, "off", "none", "none", "");
locateText(1, 577, 73);
eraseText(1);
eraseImage(0);
drawImage(7, false, "R", "#FF8080", 528, 24, 559, 42);
locateImage(7, 528, 36);
locateImage(1, 527, 65);
locateImage(2, 528, 98);
```

Figure 5.10 An example of spatial encoding

Step 3 : Calculation

```
(5*7*11) % (73*5*(7+13)*11)
Input>>Query 0: 5.0
Input>>Query 1: 7.0
1s : a: 5.0, b: 7.0
<<8>>
2s : a: 5.0, b: 7.0
Input>>Query 2: 11.0
1s : a: 35.0, b: 11.0
<<8>>

2.query: ***The same***
1
```

Figure 5.11 The screen of interpreter

5.3 Experiment

5.3.1 Experiment Design

In this section, we found 7 students from NCTU graduate institute of architecture to take part, 4 students (group 1) are graduated from department of architecture and the other 3 students (group2) are not. The questionnaire is designed as Table 5.1, detailed contents of questionnaire can be found out in appendix. According to system, we will input the pattern of building first, and record the results on the output column of questionnaire. Let students do evaluation according to Likert, the degree of Likert is listed on Table 5.2, students are able to choose from five-level Likert degree. The experiment results are shown in Figure 5.12 and Figures 5.13.

Table 5.1 The questionnaire patterns

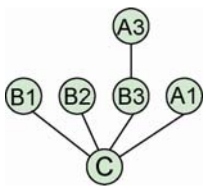
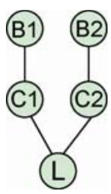
Questionnaire patterns	Description
Q1. 	1. Entry (E) connect to Living room (L) 2. Living room (L) connect to Corridor (C) 3. Corridor (C) connect to Bedroom (B)
Q2. 	1. Entry (E) connect to Dining room (D) 2. Dining room (D) connect to Kitchen (K)
Q3. 	1. Corridor (C) connect to Bedroom1 (B1) 2. Corridor (C) connect to Bedroom2 (B2) 3. Corridor (C) connect to Bedroom3 (B3) 4. Bedroom3 (B3) connect to Bathroom3 (A3) 5. Corridor (C) connect to Bathroom1 (A1)
Q4. 	1. Living room (L) connect to Corridor1 (C1) 2. Corridor1 (C1) connect to Bedroom1 (B1) 3. Living room (L) connect to Corridor2 (C2) 4. Corridor2 (C2) connect to Bedroom2 (B2)

Table 5.2   The format of a typical five-level Likert degree

Degree	Meaning
1	Strongly disagree
2	Disagree
3	Neither agree nor disagree
4	Agree
5	Strongly agree

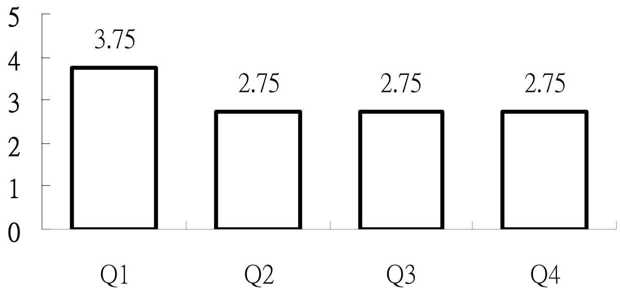


Figure 5.12   The results of case retrieve (group 1)

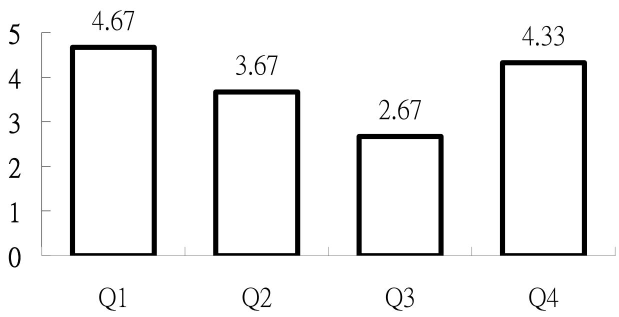


Figure 5.13   The results of case retrieve (group 2)

Through the results, we can know that the performance of students who are not graduated from architecture department (group2) is better. This is because they are the beginner in schematic design. They will be very helpful if there is a system, which can help them to solve the current problem by searching through former cases. And the students from group 1 are not satisfied with the results of this system; one of the students mentioned that, by only discussing case, the good and bad can be discriminated through the function strategy, therefore there is no good or bad for circulation, this indicate that the overall arrangement has no relation with circulation. Therefore, there are many consideration perspectives existing for schematic designs, and for a query system, the way of how to get the suitable viewpoint effectively in short time is very important.

Chapter 6 Conclusion and Future work

In this thesis, we are focusing on schematic design test item of subject building planning in Architect Registration Examination. To clearly represent the building properties for expressive power, extensibility and manipulation, our idea is to organize design attributes form experts' perspective by extending the layout with environmental context information. Accordingly, the Hierarchical Case-Based Reasoning approach was proposed to organize the knowledge granularities by hierarchical relations. In addition, the Intelligent Query Generator was proposed to support the verification of constraint rule during item design by iterative case retrieval process. We discussed about how to model and accumulate the design knowledge cases, and propose similarity function based on the viewpoint of data structure and architectural area. Moreover, the revise process and self-verify mechanism was proposed to support deriving design cases to achieve the new design requirements. Finally, a system interface has been introduced.

Currently, the pilot experiment was applied to prove the concept by retrieving high difficulties pattern to probe into the possibility of computer aided architectural test item generation.

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Appendix A

The Example of Exam Item

The family life center will provide recreational and fellowship facilities for a community church. The site is located on Market Street adjacent to a community church. Parking is available off the site.

(1) The major view is to the north.

(2) The receptionist is to have visual control of the entry to each of the following spaces: the lobby, the game room, and the children's room.

(3) The main entrance door shall face west.

(4) All spaces shall have a 9 ft ceiling height except the multi-purpose room, which shall have an 18 ft ceiling height.

(5) The area of each space shall be within 10 percent of the required program area.

(6) The total corridor area shall not exceed 25 percent of the total program area.

(7) The second floor envelope must be congruent with or wholly contained within the first floor envelope with the exception that doors to the exterior may be recessed for weather protection.

Tag	Name	Area (ft*ft)	Requirements
ST	Stair	800	2 per floor @ 200 ft*ft per stair
E	Elevator Shaft	200	1 per floor @ 100 ft*ft each; Minimum dimension = 7 ft
EE	Elevator Equipment Room	100	
EM	Electrical/Mechanical Room	500	
AO	Assistant Director's Office	200	Exterior window required; Direct access to Secretarial Office
CR	Children's Room	750	Exterior window required; Near Multi-purpose Room
DO	Director's Office	350	Exterior window required; Direct access to Secretarial Office
GR	Game Room	1,350	View—exterior window required
L	Lobby	700	Main Entrance

LM	Large Meeting Room	1,000	Exterior window required
LR	Locker Rooms	200	2 @ 100 ft*ft each; Exterior windows prohibited; Direct access to Multi-purpose Room
MP	Multi-purpose Room	2,600	View—exterior window required; 18 ft ceiling; 2 exits; First floor
R	Receptionist	400	Exterior window required; Near Lobby
SM	Small Meeting Room	750	Exterior window required; Near Large Meeting Room
SO	Secretarial Office	500	Exterior window required; Near Large Meeting Room; Second Floor
SW	Social Worker	500	Exterior window required
TR	Toilet Rooms	800	2 per floor @ 200 ft*ft each
TS	Table/chair Storage	300	Near Multi-purpose Room

Definitions

(1) Means of egress: A continuous and unobstructed path of travel from any point in a building to a public way. A means of egress comprises the vertical and horizontal means of travel to an exit and includes intervening doors, interior wall openings, corridors, circulation areas, and stairs.

(2) Circulation area: A lobby, a vestibule, or a space designated as an "area."

(3) Exit: That portion of a means of egress that provides a protected route of travel to the exit discharge. Exits include both exterior exit doors and exit stairways.

Exiting Requirements

(1) Provide a minimum of two exits from each floor separated by a travel distance equal to not less than 1/2 of the length of the maximum overall diagonal dimension of the floor to be served.

(2) Every room shall connect directly to a corridor or circulation area. Exception: elevator equipment rooms and rooms with an area of 50 ft*ft or less may connect to a corridor or circulation area through an intervening space, but not directly to a stair.

(3) In rooms required to have two exit doors, separate the two exit doors by a distance equal to not less than 1/2 of the length of the maximum overall diagonal dimension of that room. Exit doors may discharge directly to the exterior of the building at grade.

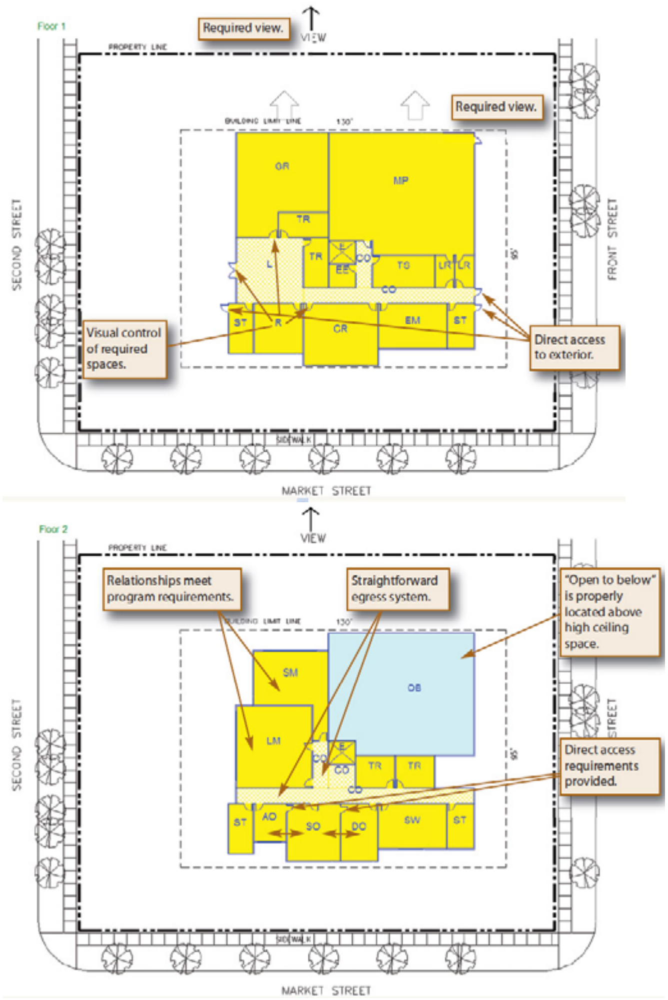
(4) Required exit doors shall swing in the direction of egress travel.

(5) Door swings shall not reduce the minimum clear exit path to less than 3 ft.

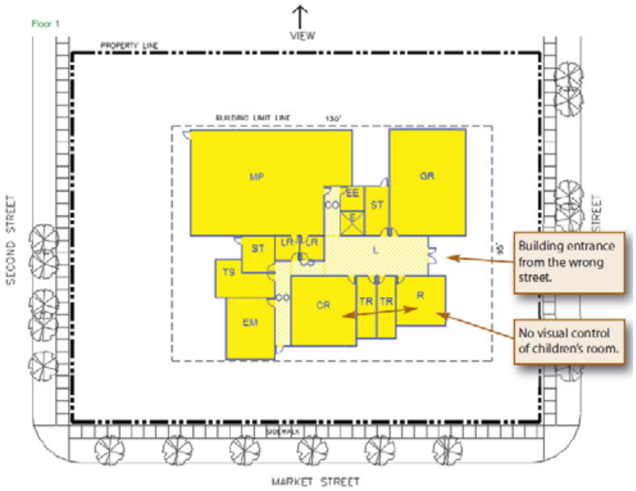
Corridors
(1) Discharge corridors directly to the exterior at grade or through stairs or circulation areas.
(2) Do not interrupt corridors with intervening rooms-circulation areas are not considered to be intervening spaces.
(3) Maximum length of dead-end corridors: 20 ft.
(4) Minimum clear width of corridors: 6 ft.

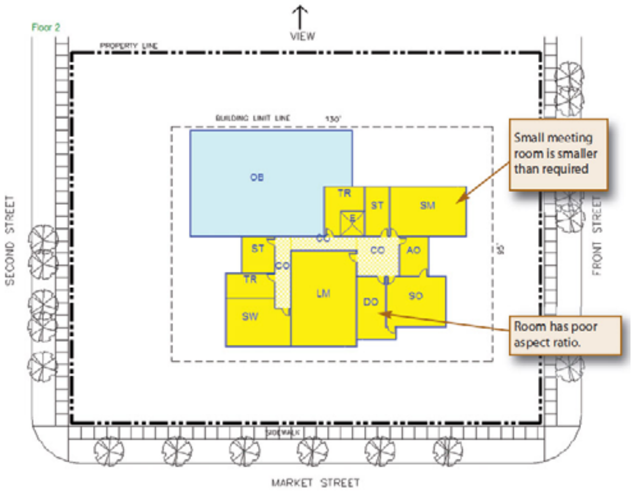
Stairs
(1) Discharge stairs directly to the exterior at grade.
(2) Connect stairs directly to a corridor or circulation area at each floor with exit access doors.
(3) Minimum width of stairs: 4 ft.

Sample passing solution



Sample failing solution





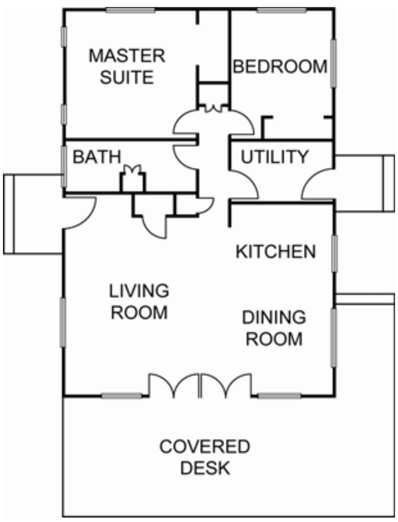
Appendix B

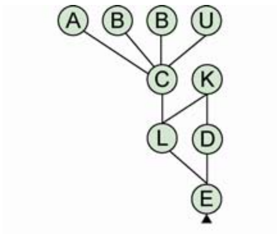
The Questionnaire of Schematic Pattern Retrieve

Symbol Definition

Tag	Description
E	entry
B	bedroom
A	bathroom
N	den
U	utility
D	dining room
L	living room
K	kitchen
G	garage
P	car_port
C	corridor

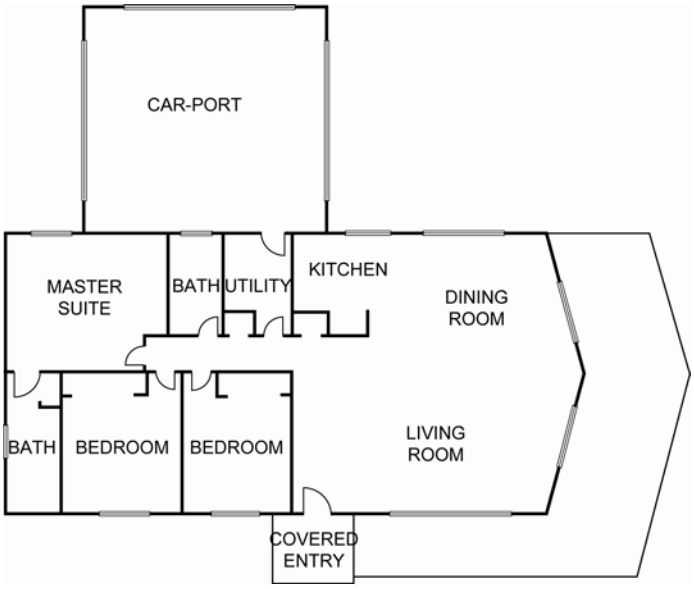
CASE 1

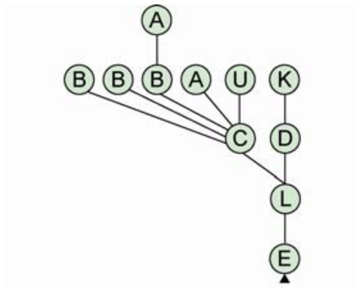




E*(L+(D*K))*C*(A+B+B+U)

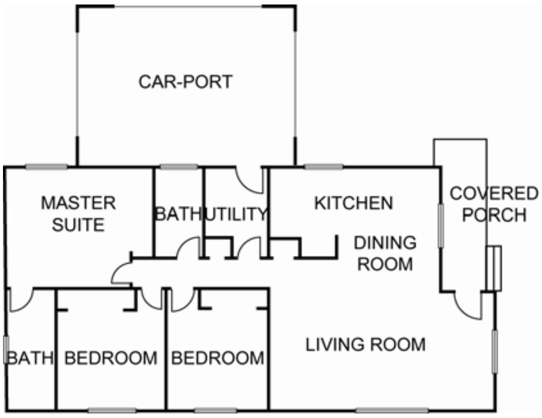
CASE 2

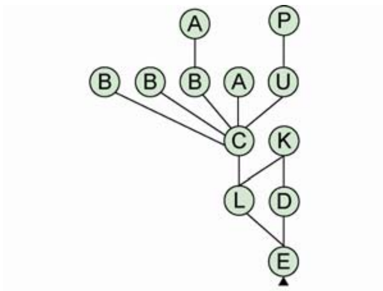




E*L*((D*K)+(C*(B+B+(B*A)+A+U)))

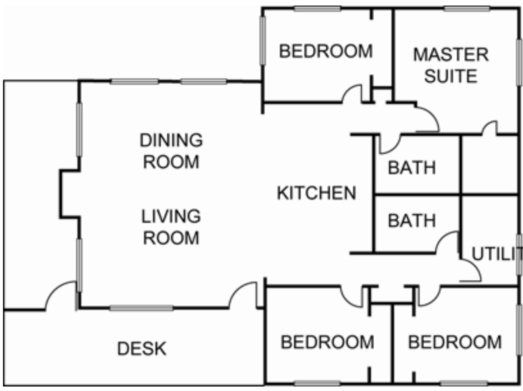
CASE 3

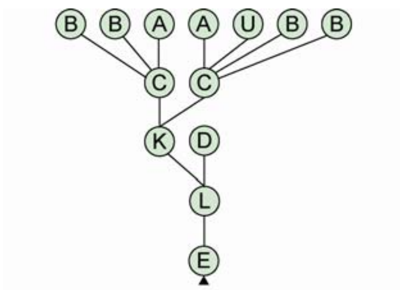




E*(L+(D*K))*C*((U*P)+A+(B*A)+B+B)

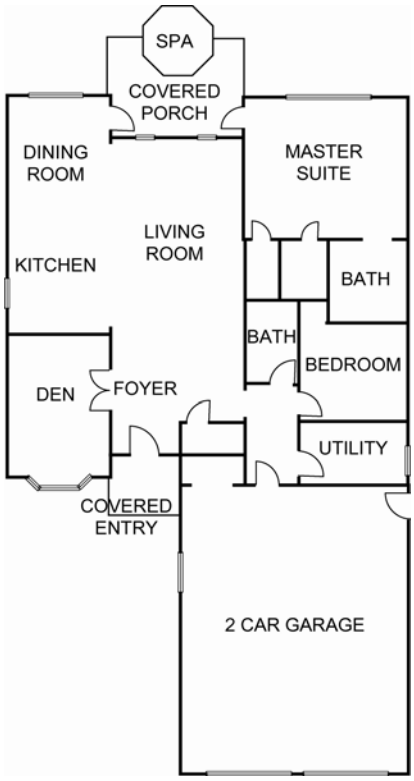
CASE 4

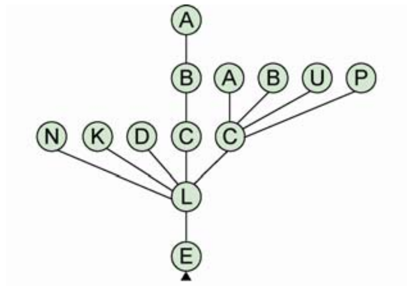




E*L*(K*(C*(A+U+B+B)+C*(B+B+A))+D)

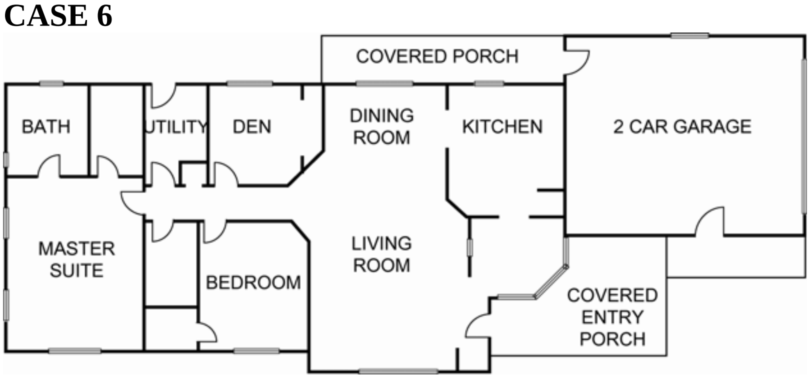
CASE 5

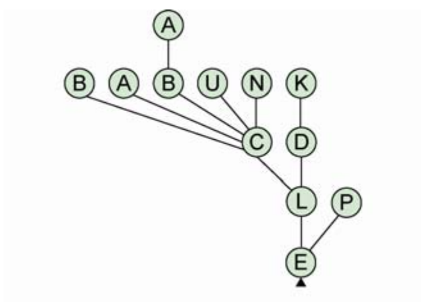




E*L*(N+K+D+(C*B*A)+(C*(A+B+U+P)))

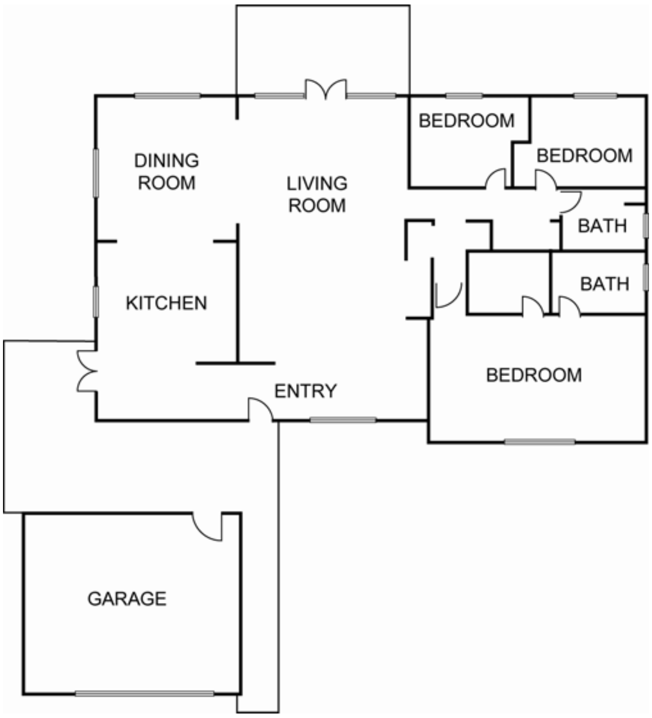
CASE 6

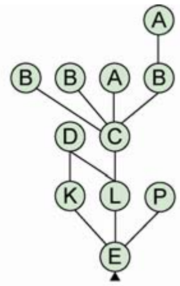




E*((L*((C*(B+A+(B*A)+U+N))+(D*K)))+P)

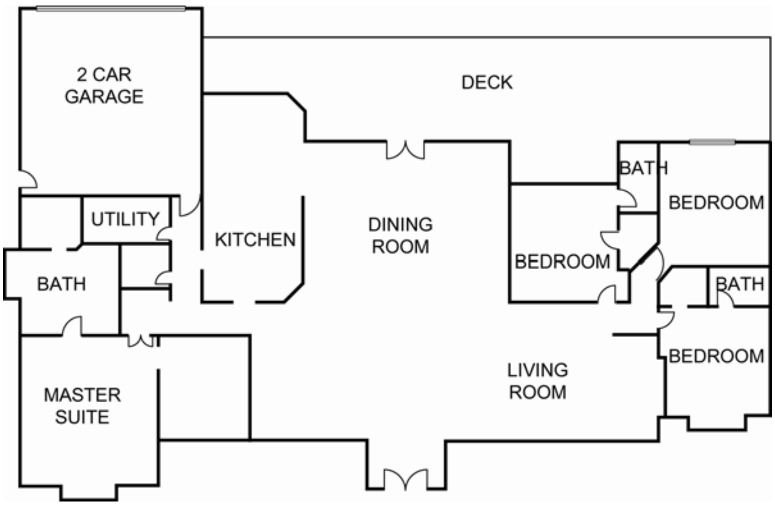
CASE 7

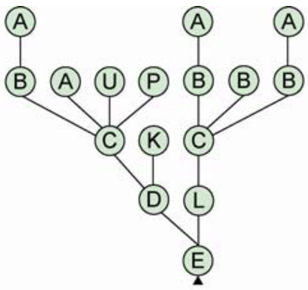




E*((((K*D)+L)*(C*(B+B+A+(B*A))))+P)

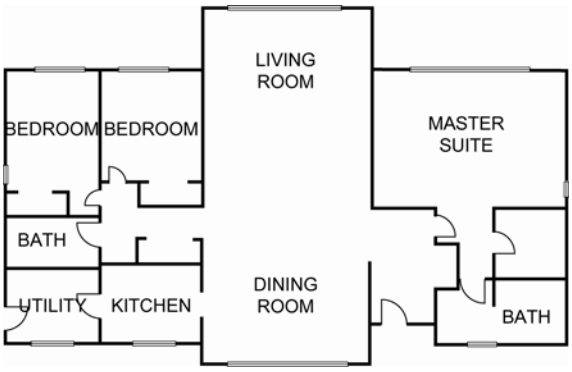
CASE 8

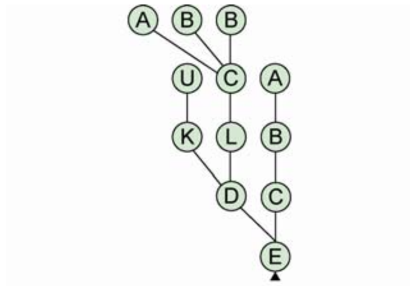




E*((D*((C*((B*A)+A+U+P))+K))+(L*C*((B*A)+B+(B*A))))

CASE 9

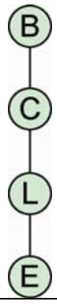




E*((D*((K*U)+(L*C*(A+B+B))))+(C*B*A))

E : entry	**B** : bedroom	**A** : bathroom	**D** : dining room
L : living room	**K** : kitchen	**C** : corridor	

1.



Input : Query Pattern

1. Entry connect to Living room
2. Living room connect to Corridor
3. Corridor connect to Bedroom

System Output :

Case1	***Case5***
Case2	***Case6***
Case3	***Case7***
Case4	***Case8***

5 4 3 2 1
satisfy O O O O O dissatisfy

2.

Input : Query Pattern

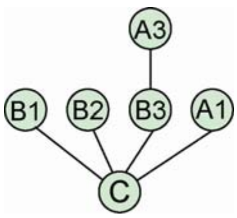
1. Entry connect to Dining room
2. Dining room connect to Kitchen

System Output :

Case1	***Case6***
Case2	***Case8***
Case3	***Case9***

5 4 3 2 1
satisfy O O O O O dissatisfy

3.



Input : Query Pattern

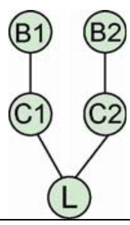
1. Corridor connect to Bedroom1
2. Corridor connect to Bedroom2
3. Corridor connect to Bedroom3
4. Bedroom3 connect to Bathroom3
5. Corridor connect to Bathroom1

System Output :

Case2	***Case7***
Case3	***Case8***

5 4 3 2 1
satisfy O O O O O dissatisfy

4.



Input : Query Pattern

1. Living room connect to Corridor1
2. Corridor1 connect to Bedroom1
3. Living room connect to Corridor2
4. Corridor2 connect to Bedroom2

System Output :

Case4	***Case8***
Case5	

5 4 3 2 1
satisfy O O O O O dissatisfy

Appendix C

The Schematic Design Process

Step 0 :
Symbol definition

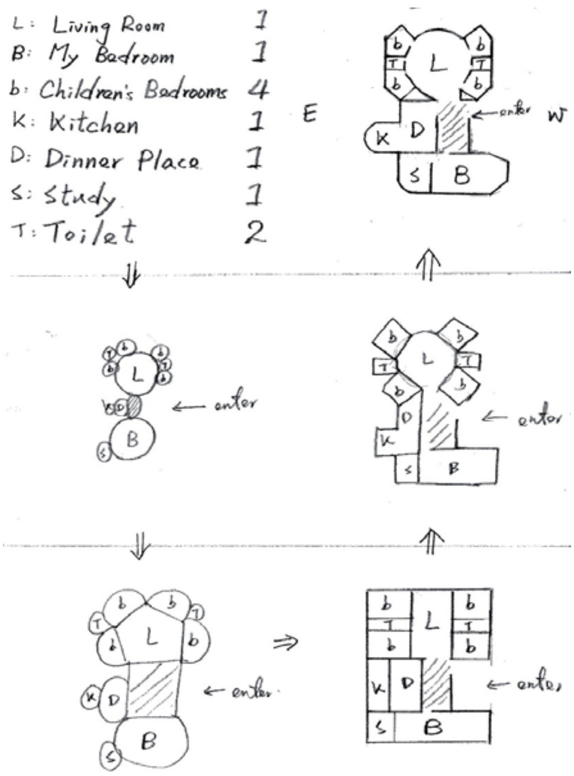
Step 4 :
Creation

Step 1-1 :
Bubble diagram

Step 3 :
Location

Step 1-2 :
Bubble diagram

Step 2 :
Sizing



Convert from genotype to phenotype

這是我理想的家，

(1) 在我的家鄉，在四周都還有稻田的地方，我要有個家，一座平房，座南朝北，符合南台灣的季風氣候。

(2) 我想要有想兩對兒女，所以我需要有四間 children’s bedrooms，而且我希望他們感情會很融洽、很團結，也希望有一個全家人能聚在一起的地方，所以我用一個圓的 living room 把他們結合在一起。

(3) 由於是座北朝南各有兩間，可以看到日出或夕陽，中間夾著兩間 toilets 是專門給小孩子用的。

(4) kitchen 採正方形加個弧邊的設計，讓媽媽使用起來更加方便順手，dining place 就在 kitchen 旁，方便我的 study。

(5) 在臥室內由於我不想要有四四方方的感覺，所以我把兩牆接角的部分改成弧形，把算放上一大片玻璃，讓視野更為開闊，圖書寫作也較為舒適。

(6) 門口開在西側，所以我的 bedroom 較西側小孩子的房間突出，有保護警衛的作用。

Reference:

Center for General Education, National Sun Yat-sen University, Student work.

Appendix D

The Example of HCBR